

Response of tropical maize inbred lines to high plant density stress in terms of grain yield and disease attributes

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Abstract: The significantly lower maize productivity in tropical countries in comparison on temperate zones has always been an area of high concern. The increase in the number of plants per unit area, through the adoption of high plant density (HPD), has been extensively used in temperate maize but this strategy has not been well exploited in tropical maize. The proposed study is to identify HPD adept donor inbreds to generate commercial hybrids to achieve high productivity in tropical/ subtropical maize. A set of 20 inbred lines, selected from diverse origin of tropical maize germplasm pool, was screened under normal plant density (NPD) and high plant density to assess their tolerance to crowding stress in terms of grain yield and prevalent diseases during *Kharif* season. The present study indicated that maize inbred lines PML 387, PML 503 and PML 892 with good seed yield potential and disease resistance may serve as potential donors to generate crowding stress tolerant hybrids for commercial hybrid breeding programme. With systematic evaluation of HPD amenable parents and hence, generated hybrids, there is a feasibility to enhance the maize productivity on commercial scale with new agronomic intervention of altered plant to plant spacing.

Keywords: Banded leaf and sheath blight · Grain yield · High plant density · Maize · Maydis leaf blight

Introduction

Maize has the highest potential for grain yield among all other crops of the grass family. Though the introduction of single-cross hybrids led to an improvement in maize yields significantly, genetic gains are still low particularly under marginal environments in the developing world (Chakradhar *et al.*, 2017). Globally, the USA is the highest producer of maize followed by China, Brazil, the European Union, Ukraine, Argentina, India and Mexico (Anonymous, 2019). In the USA, since the 1930s, the drastic increase in maize grain yield per unit land area has been attributed to an increase in plant density per unit area. Many studies have suggested that yield potential has not been changed in terms of yield per plant rather stress tolerance in plants has been increased for obtaining high yield potential under a wider range of environmental conditions (Tokatlidis and Koutroubas, 2004). Increasing plant density includes lodging resistance, reduced angle of leaf, reduced anthesis to silking interval and smaller architecture of tassel (Leivar *et al.*, 2012). Lower height of plant and ear and a strong stem can reduce lodging and is favourable for high plant density. Upright leaf allows the plant to intercept light more efficiently in its entire canopy thus increasing the photosynthetic efficiency. The small and less leafy plant reduces the level of competition over the other plants (Sangoi and Salvador, 1998). Sass and Loeffel (1959) had implied that the primary cause of barrenness is the lengthening of anthesis to the silking interval. Therefore, shorter anthesis-silking interval is one of major attributes for proper seed setting.

High-plant density has its limitations as well. Planting at high density increases interplant competition for resources and negatively affects final yield. This might be

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due to apical dominance, barrenness, reduced number of ears per plant and reduced kernels set per ear (Sangoi and Salvador, 1998). Earlier studies in this domain indicated that crowding stress reduced the ability of plants to use soil N prominently during the post-silking period (Yan *et al.*, 2017). The increased incidence of biotic stresses has also been indicated (Yu *et al.*, 2017). They reported that high plant density corresponds to reduced distance between individual maize plants and adversely affect the ventilation and light conditions of maize canopies, which facilitate the transmission of spores of pathogens. In addition, the ability of maize roots to absorb nutrients is reduced under high plant density; limited nutrient uptake decreases the soluble sugar content and physiological activity of stalk, thereby reducing the resistance of stalk to pathogens (Anderson and White, 1994; Xue *et al.*, 2016). In short, regardless of whether maize varieties are resistant or susceptible to disease, high plant density increases the mortality and degree of stem rot and sheath blight (Thomison *et al.*, 2011). Despite all the constraints, it is expected that high density apposite inbred lines would generate high-density responsive hybrids. Al- Naggar and Atta (2017) emphasized that hybrids developed under low plant population do not perform well under higher plant

population. The present study was aimed at the identification of efficient inbred lines that harbour the ability to tolerate crowding stress in terms of grain yield and prevalent leaf blights of *Kharif* season.

Materials and methods

A set of diverse 20 inbred lines (Table 1), were planted in randomized block design with three replications in two environments: normal plant density (NPD) comprising 33,333 plants/acre (at a recommended row to row and plant to plant spacing of 60 cm and 20 cm, respectively) and high-plant density (HPD) comprising 43,333 plants/acre (at row to row and plant to plant spacing of 60 cm and 15 cm, respectively). The experiment was carried out at Field Experimental Area, Department of Plant Breeding and Genetics, PAU, Ludhiana across two years during *Kharif* 2019 and 2020. The lines were screened against maydis leaf blight (MLB) and banded leaf and sheath blight (BLSB) under natural conditions. Standard disease rating scale (1-9) was followed for recording the severity of maydis leaf blight and banded leaf and sheath blight under two planting regimes and the genotypes screened were grouped into four categories *viz.*, resistant, moderately

Table 1. List of test maize inbreds with pedigree used for assessing yield performance under different planting regimes

S.No.	Entry	Pedigree
1	LM 6	MS Pool C ₂ IC ₂ -5-1-2-1-1-2-1-1---f
2	LM 13	JCY 3-7-1-1-1---f
3	LM 14	CA 00 310-1-1-1
4	LM 21	LM21-6-3-1-2-1--f
5	LM 25	SE 563
6	PML 41	(Tux C ₂ IC ₂ -5...x Pop24)-10-2-1-1-4-1-1-1-1-1-1-1-1-1-1
7	PML 243	HS-2785-5-1-(2)-4-#-1- --f
8	PML 333	CM 122-1-1-1
9	PML 368	LM 13 Selection N/G -4-1-1-1-1
10	PML 387	[{Tux 162xLM 5-6-1....x LM 5.Pop 24-4-4..}x LM 13]BC 2-1- 3-#-1
11	PML 503	(SE 563 x LM 13)-1-1-1-2-4--f
12	PML 892	900 MG-x-x-1-2-3-1---f
13	PML 920	NSX082012-x-1-1-2-4-2--f
14	PML 1012	LM6-BC ₃ waxy S 5-182-3-3--1-1--f
15	PML 1224	WNC DMR 10R YFWS 1206
16	PML 1225	WNC-DMR 10R YFWS 8337-1-1-2-11-f
17	PML 1229	WNC DMR 10R YFWS 8344-2-2-1-1--f
18	PML 1230	SW 93-D-313-23 Pop 49-2-1-1-3-3 f
19	PML 1231	SMH 3900-#-1-2-3-2-1----f
20	CML 451	((NPH-28-1/G25)/NPH-28-1)-1-2-1-1-3-1-B

resistant, moderately susceptible and susceptible based on their disease reaction (Hooda *et al.*, 2018). Yield per plot (Y/plot; in kilogram) was recorded in terms of ear weight per plot (also called field weight per plot) immediately after crop harvest. Ear weight per plot was converted into grain yield after accounting for grain moisture content (to be recorded in the field) and shelling percentage. Statistical analysis of phenotypic data was conducted using SAS software (SAS Institute 2011).

Results and discussion

Response in maize inbreds to grain yield under different planting regimes

The characterization of maize inbred lines for grain yield over years under different planting regimes is depicted in

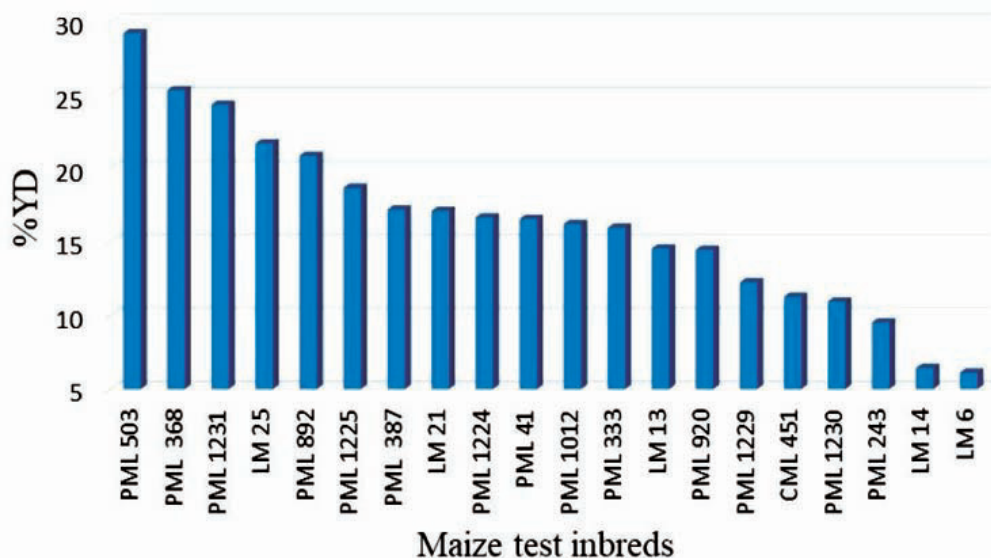
Table 2. In 2019, mean grain yield was 6.70 and 7.49 under NPD and HPD, respectively whereas in 2020, the mean grain yield was 6.64 under NPD and enhanced to 8.03 under HPD, leading to per cent average increase of 11.63 per cent in 2019 and 20.95 per cent in 2020. The overall yield performance across years and planting regimes have identified five top performing maize inbreds viz., PML 1224, PML 1012, PML 1225, PML 387 and PML 1231 (> 7.8 q/acre grain yield) which can be utilized as parents with high seed potential. The grain yield of these identified parental lines was > 8.5 quintal per acre under HPD with the highest grain yield of 9.15 q/acre in PML 1224. The mean per cent yield increment (YD %) across years ranged from 6.13 (LM 6) to 29.22 (PML 503) as depicted in Table 2. Five inbred lines (PML 368, PML 503, PML 892, PML 1231 and LM 25) exhibited more than 20 per cent increase in yield under HPD when

Table 2. Profiling of maize inbred lines for mean grain yield under normal plant density (NPD) and high plant density (HPD) during *Kharif* 2019 and 2020 and per cent increase in yield (YD %) under HPD

Inbred	Grain yield (q/acre)				
	<i>Kharif</i> 2019		<i>Kharif</i> 2020		YD % under HPD across years
	NPD	HPD	NPD	HPD	
LM 6	5.8	6.2	5.6	5.9	6.13
LM 13	6	6.6	6.8	8.1	14.56
LM 14	7.5	7.5	7	7.9	6.43
LM 21	5.9	6.7	5.8	7	17.12
LM 25	6.4	7.5	6.1	7.7	21.71
PML 41	7	7.9	6.9	8.3	16.57
PML 243	6.4	6.6	6.9	8	9.53
PML 333	6	6.9	5.9	6.9	15.97
PML 368	6.2	7.7	6.8	8.6	25.33
PML 387	7.7	8.2	6.8	8.7	17.22
PML 503	6.2	8	6.8	8.8	29.22
PML 892	7.2	8.3	6.8	8.6	20.87
PML 920	5.8	6.2	6.8	8.3	14.48
PML 1012	8	9.3	7.4	8.6	16.23
PML 1224	8.9	9.2	7	9.1	16.69
PML 1225	7.6	8.9	6.9	8.3	18.70
PML 1229	5.9	6.3	6.2	7.3	12.26
PML 1230	6	6.4	5.9	6.8	10.96
PML 1231	6.8	8.1	7.1	9.2	24.35
CML 451	6.8	7.2	7.2	8.4	11.27
Mean	6.70	7.49	6.64	8.03	
SE	0.45	0.66	0.50	0.78	
CD (1%)	1.22	1.78	1.35	2.11	
CD (5%)	0.91	1.33	1.01	1.57	
CV (%)	8.21	10.72	9.21	11.86	

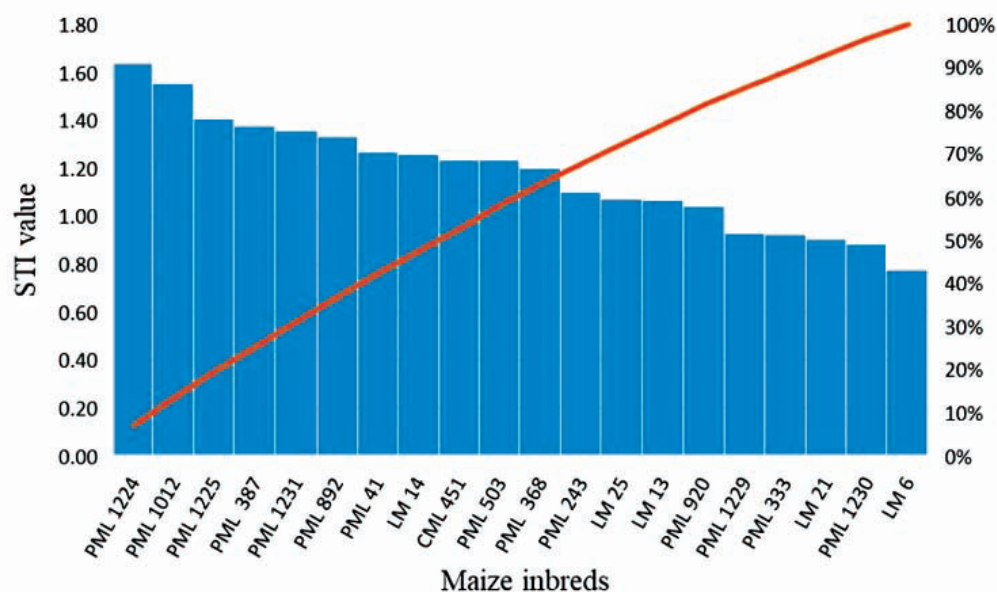
compared to NPD. Figure 1 depicted the average per cent increase in yield across years under HPD. A wide variability in YD % indicated the wide scope of selection of inbred lines to develop hybrids amenable to HPD. Lower plant density delay canopy closure and decrease light interception, which leads to higher yield per plant but lower yield per unit area (Andrade *et al.*, 1999) while, high plant density enhances interplant competition for water, nutrients and assimilates (Edmeades *et al.*, 2000). High plant density also increases the anthesis-silking interval (ASI) and stimulates barrenness (Sangoi, 2001), which leads to reduced kernel number per unit area, the main maize-yield component.

Figure 1. Percent yield increase (%YD) under high plant density



As the increase in number of plants per unit area imposes crowding stress on inbreds, grain yield based stress tolerance index (STI) has been worked out. The Figure 2 depicted the variability in response of test inbreds to STI ranging 0.78 to 1.64. Amongst the top 15 lines which showed more than 15 YD %, 13 lines were having STI more than 1.10, inferring STI served as a good indicator to characterize lines for crowding stress tolerance. Inbred lines viz., PML 387, PML 892, PML 1012, PML 1224, PML 1225 and PML 1231 were showing maximum value of STI, thereby exhibiting good level of plant density tolerance as compared to other test inbred lines.

Figure 2. Profiling of maize inbreds for grain yield stress tolerance index (STI)



Response in maize inbreds to disease attributes under different planting regimes

Maydis leaf blight

Data in Table 3 showed that under NPD, 14 maize lines with disease rating scale ranging from 2.5-3.0 showed resistant reaction and 5 lines with 3.5-4.0 disease rating scale gave moderately resistant reaction to maydis leaf blight. Only one line PML 1224 having 5.5 severity scale was found moderately susceptible. On comparing MLB severity in two planting regimes, maize lines showed comparatively higher disease incidence in HPD than under NPD. Under HPD, 7 and 10 genotypes gave resistant and moderately resistant reaction, respectively (Figure 3). However, two genotypes-PML 333 and PML 1232 gave moderately susceptible and one genotype- PML 1224 showed susceptible reaction. Out of these 20 lines, 4 lines- LM 21, LM 13, LM 14 and PML 41 did not show any increase in MLB severity under HPD condition. Four inbreds viz. LM 25, PML 368, PML 387 and PML 243 gave ≤ 20 per cent increase in MLB severity under HPD condition.

Banded leaf and sheath blight

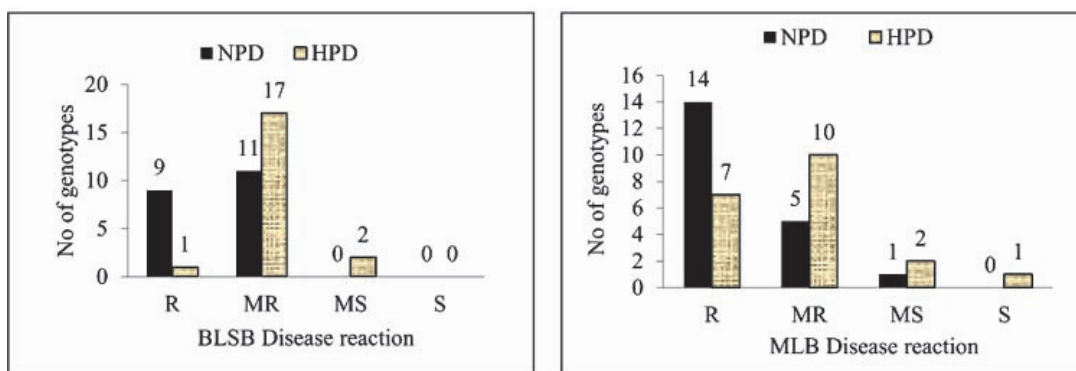
Data in Table 3 showed that under HPD, only one line – PML 1229 gave resistant reaction; however, under NPD, nine lines gave resistant reaction to BLSB of maize. Large proportion fall in moderately resistant group with 17 and 11 lines under HPD and NPD conditions, respectively. Two lines- PML 1224 and CML 451 gave moderately susceptible reaction with severity scale of 5.2 under HPD conditions (Figure 3). There was increase in severity of BLSB in all maize lines when planted under high plant density conditions. Six lines viz. LM 6, PML 1224, PML 503, LM 14, PML 892 and PML 1229 gave ≤ 20 per cent severity increase in BLSB severity under HPD conditions (Table 3). Maize crop is subjected to extensive yield losses due to biotic stresses at different growth stages during monsoon season. To compensate the yield loss, high plant density is a good strategy to meet the current and future food necessities of high population and their rising dietary needs. Though previous studies have shown that densification may lead to increase in disease incidence.

Table 3. Per cent increase in disease severity of maydis leaf blight and banded leaf and sheath blight in maize inbreds under normal (NPD) and high plant density (HPD) during *Kharif* season

S.No.	Entry	Maydis leaf blight severity			Banded leaf and sheath blight severity		
		NPD (1–9)*	HPD (1–9)	Percent increase	NPD (1–9)	HPD (1–9)	Percent increase
1	LM 6	2.5	3.5	40.0	3.0	3.5	16.7
2	LM 13	2.5	2.5	0.0	3.0	4.0	33.3
3	LM 14	2.5	2.5	0.0	4.5	5.0	11.1
4	LM 21	2.5	2.5	0.0	3.2	4.5	40.6
5	LM 25	3.0	3.5	16.7	3.5	4.5	28.6
6	PML 41	3.5	3.5	0.0	3.5	4.5	28.6
7	PML 243	2.5	3.0	20.0	3.5	4.5	28.6
8	PML 333	4.0	6.0	50.0	2.5	4.0	60.0
9	PML 368	3.0	3.5	16.7	3.5	4.5	28.6
10	PML 387	2.5	3.0	20.0	3.0	4.0	33.3
11	PML 503	2.0	3.0	50.0	3.0	3.5	16.7
12	PML 892	2.5	3.5	40.0	3.0	3.5	16.7
13	PML 920	4.0	5.0	25.0	3.3	4.5	38.5
14	PML 1012	3.5	4.5	28.6	2.5	4.0	60.0
15	PML 1224	5.5	7.5	36.4	4.5	5.2	15.6
16	PML 1225	3.0	4.0	33.3	3.0	5.0	66.7
17	PML 1229	2.5	4.5	80.0	2.5	3.0	20.0
18	PML 1230	2.5	2.5	0.0	3.5	4.5	28.6
19	PML 1231	4.0	5.5	37.5	3.5	4.5	28.6
20	CML 451	3.0	4.5	50.0	3.5	5.2	48.6

*1–3.0: Resistant; 3.1–5.0: Moderately resistant; 5.1–7.0: Moderately susceptible; 7.1–9.0: Susceptible

Figure 3. Disease reaction of maize inbreds to (a) banded leaf and sheath blight and (b) maydis leaf blight under normal plant density (NPD) and high plant density (HPD) conditions during *kharif* season



In our study, most of the maize inbreds tested have shown comparatively higher disease under HPD than NPD regime. Further, preliminary results reported three lines viz. PML 387, PML 503 and PML 892 giving moderately resistant reaction to maydis leaf blight and banded leaf and sheath blight under HPD but need further confirmation under artificial screening too. These parental lines with multiple resistance can be well utilized to generate desired resistant commercial hybrids.

Hence, this study indicated that prior selection of parental lines and their evaluation under HPD is a prerequisite for the development of hybrids for HPD. On the basis of seed yield performance and response against MLB and BLSB, maize inbreds PML 387, PML 503 and PML 892 were suggested as potential donors to generate HPD amenable hybrids. However, the significant increase in productivity of inbreds needs to be validated with multi-site screening and nutrient management for commercial level utilization. PML 1229 exhibiting resistant reaction for BLSB under HPD may serve as good genetic resource after confirmation through artificial screening.

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