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Effect of Season on Crop Growth, Flowering, Synchronization Pattern and Seed Yield in the Parental Lines of Maize (*Zea mays* L.) Hybrids

SUDIPTA BASU BHAUMIK, S.P. SHARMA AND M. DADLANI

Division of Seed Science and Technology, Indian Agricultural Research Institute, New Delhi 110 012

sudipta_basu@yahoo.com

ABSTRACT Performance of parental line seeds of maize hybrids viz. Ganga-5, Ganga-11, Ganga Safed-2, PHM-1 and PHM-2 was studied in monsoon, winter and spring-summer season (1996-98) for field emergence, vegetative growth, flowering behaviour, synchronization pattern and seed yield. The results indicated that weather conditions, especially temperature and rainfall influenced field emergence and seedling growth in all the seasons. A temperature of 10°C was found critical for seedling growth and development of maize under sub-optimum conditions prevalent in winter and spring-summer seasons. Vegetative growth, flowering behaviour [days to flowering, duration of flowering, anthesis silking interval (ASI)], synchronisation pattern and seed yield was highly influenced by season, while number of leaves and duration of tasselling remained stable over the seasons. The results revealed the feasibility of seed production of hybrids; PHM-1 and PHM-2 in all the seasons and of Ganga5, Ganga11 and Ganga Safed2 only in monsoon season and with adoption of flowering manipulation practices in winter and spring-summer seasons under North Indian conditions.

Key words : Maize, parental lines, seasons, seed production, synchronization

Maize occupies a pride position among coarse cereals in India due to its high yield potential, wide adaptability and utilization in food and processing industries. The crop has a productivity potential of 3-4 t/ha and 8-10 t/ha in monsoon and winter season respectively but the average productivity in India is only 1.7 t/ha. One of the, reason being that the major maize growing areas of India i.e. North-West and Northeastern states (covering 72 per cent of the total maize area) primarily cultivate local cultivars and only 8-15 per cent of the area is under hybrids [1]. Contrastingly, in the southern states (covering 25 per cent of area) where hybrid seed production of maize is undertaken, 85-90 per cent of the maize area is under hybrids favouring a high productivity (2.7t/ha). Localisation of seed production areas in these states ensures timely availability of quality seeds at an affordable cost. Thus, ensuring availability of hybrid seed with adoption of hybrid cultivars offers a great potential for increasing production and productivity of North and East Indian plains.

Seed production of hybrid maize in the southern states is undertaken during winter season (December-April) due to favourable weather conditions, higher yields and comparative advantage of maintaining isolation. But concentration of maize seed production areas in southern India makes the crop vulnerable to disease outbreaks and possibilities of genetic shift in the parents of hybrids which are released for cultivation in North India. Thus, there is a need for diversification of seed production seasons and areas. Maize is primarily grown as a monsoon crop (June-October) in North India, hence its seed production in this season poses a problem of maintaining isolation from commercial crop, besides chances of obtaining poor seed quality due

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to occurrence of biotic stresses. Seed production in winter (October-April) and spring-summer (February-May) seasons is another possibility. But sub-optimum temperatures during sowing in above seasons (November-February) hamper the field emergence and early crop growth. Besides, high temperature (>40°C) and hot dry winds during flowering (April-May) in spring-summer season may also result in poor seed set, forced ripening or low seed yield and quality.

Thus, the present study was undertaken to examine the feasibility of producing breeder and foundation seed of the parental lines of maize hybrids under North Indian conditions in different seasons.

MATERIALS AND METHODS

The study was conducted at IARI, New Delhi during monsoon, winter and spring-summer seasons (1996-98) with parental lines of five popular commercial hybrids viz. Ganga 5 [(CM 202 x CM 111) x (CM 500)], Ganga 11[(CM 202 x CM 111) x (CM 501)], Ganga Safed 2[(CM 400 x CM 300) x (CM 600)], PHM 1(CM135 x CM 136) and PHM 2 (CM 137 x CM 138). Parental lines were sown on 1 November 1996 (winter), 3 February 1997 (spring-summer) and 10 July 1997 (monsoon) in randomized block design with 3 replications in plots of 5 x 3 m size (four rows) with a spacing of 75 x 25 cm. Sowings in winter and spring-summer season was done on southern slope of East-West ridges for direct exposure of sunrays as suggested by Khehra *et al.* [2] to alleviate the effect of sub-optimum temperature. Field emergence was recorded after 7 and 14 days in monsoon; 7, 14 and 21 days in winter and 21, 28 and 35 days after sowing (DAS) in spring-summer seasons. Field emergence was recorded 21DAS in spring-summer season due to low post sowing ambient temperature (5-20°C) as compared to winter (17-20°C) and monsoon (26-40°C) season. Field emergence (%) was computed as

$$\frac{\text{Number of seedlings emerged in 4 rows}}{\text{Total number of seeds sown}} \times 100$$

After final emergence, five normal seedlings from each plot were picked randomly, oven dried (80°C + 1°C/24 hr) and weighed for seedling dry weight. Vegetative growth characters i.e. plant height (cm), number of leaves per plant, duration of flowering (days) and anthesis silking interval (ASI) in days were recorded at peak flowering on 10 randomly selected plants in each plot. ASI was measured as difference between initiation of anthesis in tassel and emergence of first silk from the cob. Number of days between opening of first to last spikelet in tassel and emergence of first silk to total drying of silk in a cob was recorded for measuring the duration of tasselling and silking, respectively. Random samples of 100 seeds were drawn from plot yield for measuring 100 seed weight. Weather data for the period of experiment was obtained from the Meteorological Observatory, Indian Agricultural Research Institute, New Delhi.

RESULTS AND DISCUSSION

Field emergence

Seedling emergence, establishment and growth of maize are highly influenced by climate, soil and management factors and low soil and ambient temperatures (below 10°C) affect field emergence and plant stand [3, 4, 5]. In the study, low ambient temperature in winter and spring-summer seasons (10°C and 8°C respectively: minimum) had immense influence on field emergence (initial and final) irrespective of genotypes but the effect of sub-optimum temperature was pronounced on initial field emergence than final emergence (Table 1). Seedling emergence took fourteen, twenty-one and thirty five days in monsoon, winter and spring-summer seasons respectively corresponding to the prevalent ambient temperatures (26-40°C, 10-31°C and 8-28°C respectively) and R.H. (65-80%, 24-83% and 28-75% respectively) in these seasons (Table 1). A rainfall of 27mm after sowing in monsoon season favoured better field emergence and seedling growth. Kaur *et al.* [6] also reported a positive correlation between temperature and number of days for germination and seedling growth of maize. The genotypic performance for field emergence revealed that initial germination and vigour of seed is an important factor for attaining satisfactory field stand especially under sub-optimum conditions. The inbred lines, CM300 and CM202 with low germination (84% and 82% respectively) and vigour exhibited poor field

Table 1. Field emergence (%) of maize genotypes in different seasons

Genotype/season	Monsoon		Winter		Spring-Summer	
	7 DAS*	14 DAS**	7 DAS*	21 DAS**	21 DAS*	35 DAS**
'CM 300'	67.5 (55.2)	7.18 (57.9)	58.5 (49.9)	69.9 (56.8)	52.0 (46.1)	59.9 (50.7)
'CM 400'	81.0 (64.2)	84.9 (67.2)	63.5 (52.9)	83.3 (65.9)	63.5 (52.8)	70.4 (57.0)
'CM 600'	81.2 (64.3)	85.2 (67.4)	68.7 (56.6)	83.5 (66.0)	75.4 (60.2)	82.2 (65.1)
'CM400' x 'CM 300'	87.0 (68.9)	91.4 (73.1)	70.8 (57.3)	86.0 (68.0)	78.1 (62.1)	85.2 (67.4)
'CM 202'	79.2 (63.0)	83.9 (66.4)	26.7 (31.3)	51.5 (45.7)	20.0 (26.8)	34.5 (36.0)
'CM 111'	79.5 (63.1)	82.9 (65.6)	60.2 (50.9)	78.7 (62.5)	47.0 (43.3)	62.5 (52.2)
'CM 500'	89.3 (71.0)	92.9 (74.6)	66.6 (54.7)	84.5 (66.9)	66.6 (54.7)	80.8 (64.0)
'CM 501'	85.8 (67.9)	89.1 (70.8)	66.4 (54.6)	85.4 (67.5)	67.7 (55.3)	79.1 (62.8)
'CM202' x 'CM 111'	81.2 (64.4)	84.5 (66.9)	7.18 (57.9)	84.1 (66.6)	72.5 (58.3)	80.6 (63.8)
'CM 135'	89.5 (71.2)	92.2 (73.9)	82.0 (64.9)	87.9 (69.6)	79.1 (62.8)	85.2 (67.4)
'CM 136'	89.1 (70.9)	93.1 (74.8)	79.7 (63.3)	87.0 (68.9)	76.8 (61.2)	85.0 (67.2)
'CM 137'	86.6 (68.6)	90.0 (71.7)	79.5 (63.1)	86.0 (68.0)	77.2 (61.6)	84.5 (66.9)
'CM 138'	87.2 (69.1)	91.4 (73.0)	80.4 (63.7)	87.0 (67.9)	78.7 (62.5)	85.0 (67.2)
Mean	83.4 (66.3)	87.2 (69.5)	67.3 (55.4)	81.0 (64.6)	65.8 (54.5)	75.0 (60.6)
C.D.(0.05)	(3.59)	(3.88)	(3.44)	(2.40)	(2.24)	(2.39)

Values in parenthesis indicate transformed arc value; *First count, **Final count

emergence especially in winter and spring-summer seasons when the soil and ambient temperature was low whereas the vigorous inbreds; CM 135, CM 136, CM 137 and CM 138 (seed germination : above 95%) performed well under these seasons. Previous studies have revealed that pre-sowing seed hydration (invigouration) significantly improved field emergence, its rate and seedling growth under low temperature conditions [3, 7, 8]. Thus, pre-sowing seed hydration could be adopted for improving field emergence and plant stand in winter and spring-summer seasons.

Vegetative growth

Seedling and early vegetative growth of maize are critical for final yield and seed quality and a warm weather favoured better seedling development and crop growth. In the study, conducive ambient temperatures (26-40°C) and rainfall (27mm) in monsoon season favoured better seedling growth (Table 2) as compared to winter and spring-summer seasons wherein the prevailing low temperatures restricted the vegetative growth(resulting in shorter plant height) and prolonged the crop duration. Single crosses exhibited hybrid vigour for seedling growth and inbreds CM300 and CM202 had poor growth as evident by their low seedling dry weight (Table 2). Seedling and vegetative growth of maize is reported to be restricted at temperatures below 10°C [9] and optimum at a temperature between 28-32°C [10].

The length of vegetative phase in maize is closely related to daily average temperatures during crop growth [11]. In this study, the magnitude of increase in plant height was slow upto 40 and 70 DAS in spring-summer and winter season respectively as the minimum temperature was below 10°C, which restricted the vegetative growth (plant height) and photosynthetic activity of the crop. But when the minimum temperature raised above 10°C, a significant increase in plant height was observed in these seasons (Fig. 1). In monsoon season, a plant height of 150 cm was attained in 75 days, which took 100 and 165 days respectively in spring-summer and winter season. Thus, a temperature of 10°C was found to be critical for growth and development of maize.

Hollinger [12] reported that temperature regimes control number and rate of appearance of leaves in maize. In this study, the number of leaves per plant was marginally more in winter and spring-summer season (Table 2) but was a fairly stable character with the genotypic effect being predominant over environment. Number of leaves per plant and plant height was more in single crosses and inbred CM202 had poor vegetative growth in all the seasons.

Flowering behaviour

Environment has a significant effect on flowering behaviour of maize wherein development of silk

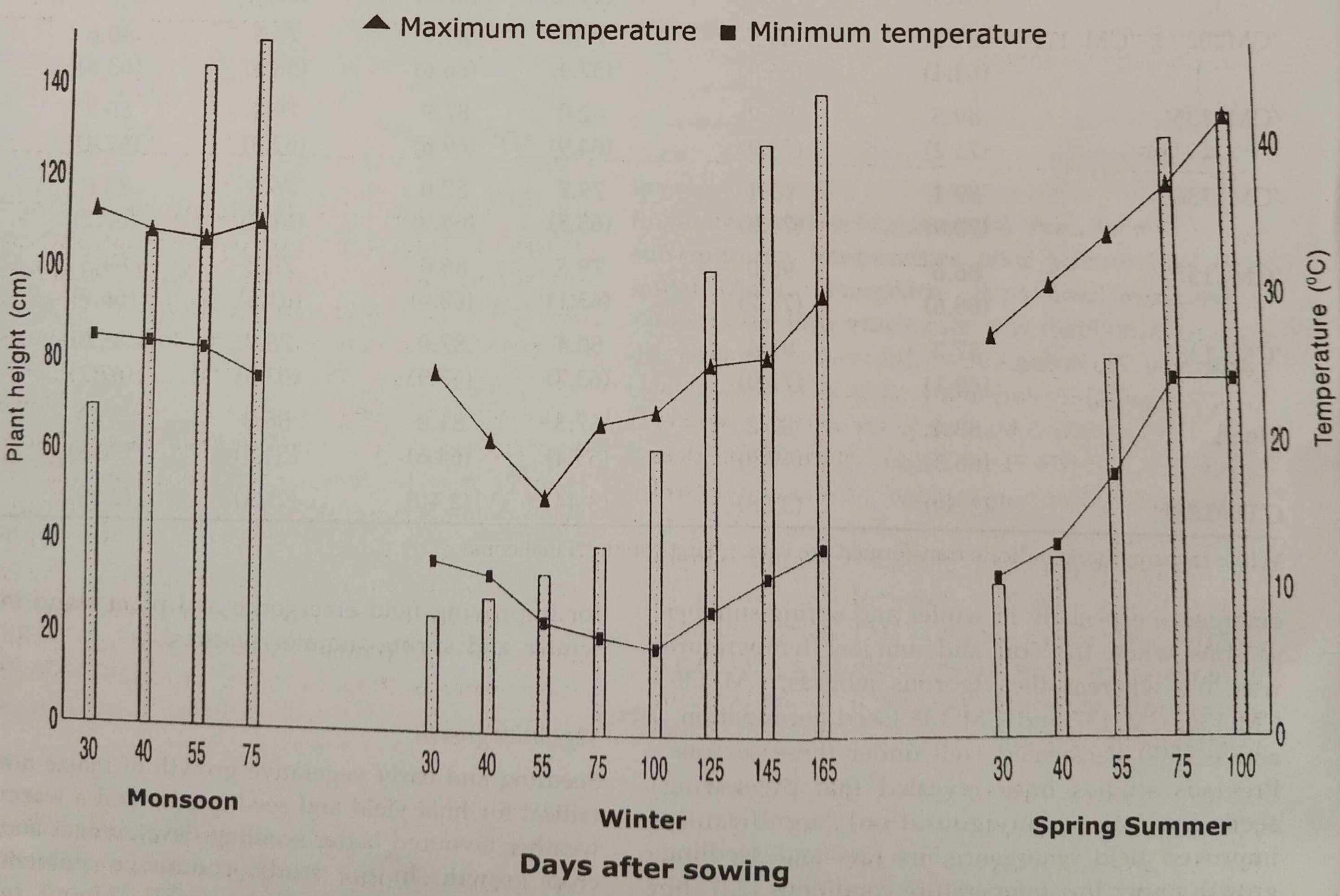

Fig. 1. Increase in plant height of maize genotypes in different seasons

Table 2. **Vegetative characters of maize parental lines in different seasons**

Genotype/season	Seedling dry weight(g)			Leaves/plant			Plant height(cm)		
	Monsoon	Winter	Spring-summer	Monsoon	Winter	Spring-summer	Monsoon	Winter	Spring-summer
'CM 300'	6.40	3.08	2.88	10.6	11.8	12.4	130.5	116.0	129.9
'CM 400'	7.72	3.33	3.30	11.7	12.2	13.4	135.9	126.2	140.7
'CM 600'	7.85	3.41	3.54	12.6	12.4	12.6	143.1	131.7	145.8
'CM 400' x 'CM 300'	8.30	4.07	4.20	14.0	14.2	14.6	177.8	172.0	165.6
'CM 202'	6.11	3.61	3.08	10.9	11.5	9.9	137.9	129.2	108.8
'CM 111'	7.55	4.49	3.32	11.7	12.6	13.2	143.1	133.4	148.6
'CM 500'	7.74	4.54	4.04	10.7	13.1	11.6	150.3	143.7	160.2
'CM 501'	8.10	4.89	3.75	11.2	13.4	11.3	154.3	144.3	157.2
'CM 202' x 'CM 111'	8.37	4.99	4.68	13.6	14.0	13.8	179.3	174.2	166.5
'CM 135'	8.38	3.81	3.43	11.6	12.4	11.2	155.0	132.8	142.6
'CM 136'	8.45	3.80	3.41	11.6	12.0	11.4	155.4	136.3	142.5
'CM 137'	8.52	3.59	3.40	11.6	12.1	11.1	155.5	136.3	144.8
'CM 138'	8.51	3.98'	3.50	11.6	12.3	11.2	154.8	133.1	143.2
Mean	7.84	3.97	3.58	11.8	12.6	12.1	151.7	139.2	145.9
C.D. (P=0.05) Genotype :		0.36			1.32			3.10	
Season:		1.41			NS			5.31	
Interaction:		NS			NS			NS	

and air temperature followed a sigmoid curve and days to flowering had a negative correlation with temperature [13]. In this study, environment had significant effect on flowering behaviour of genotypes. Flower initiation in the genotypes (days to 50% tasselling and silking) was the earliest in monsoon, followed by spring-summer and winter season respectively (Table 3). Genotypic differences were significant and predominant over environment effect for days to flowering which was earliest in CM 600 and parents of PHM 1, PHM 2 and inbreds CM 300 and CM 202 flowered the last in all seasons. Duburcq *et al.* [14] also reported differences for days taken to flowering in maize genotypes wherein genotypic effect being predominant over environment.

In the study, although marginal difference was noted among genotypes for duration of anthesis but ASI and silk receptivity was longest in winter season (Table 3). Genotypic differences were significant for all the flowering traits. Single crosses had longest duration of flowering (anthesis and silking) while the inbred CM 202 exhibited late flowering, shorter silk receptivity (7-12 days) and prolonged duration of ASI (5-9 days) (Table 3) among genotypes. Presolska [15] observed that maize silks remained receptive for seven to eleven days after emergence under favourable conditions, whereas, adverse environmental conditions like hot, dry winds hastened silk drying affecting the seed set. Prolonged duration of ASI could be a major bottleneck for nucleus seed production during winter season where selfing is practiced. Thus, for maintenance of parental lines sib-mating in winter season and selfing in other seasons could be practiced.

Synchronization behaviour

Synchronization of anthesis in male and silking in female parental lines is a prerequisite for

Table 3. Flowering behaviour of maize parental lines in different seasons

Genotype/season	Days to 50% anthesis			Days to 50% silking			ASI (days)			Duration of anthesis (days)			Duration of silking (days)		
	M	W	SS	M	W	SS	M	W	SS	M	W	SS	M	W	SS
'CM 300'	62.0	160.3	95.6	65.0	165.3	99.6	3.0	5.0	4.0	8.7	7.2	7.8	8.5	12.5	10.2
'CM 400'	57.3	159.0	93.6	59.6	163.3	97.0	2.3	4.3	3.3	7.0	6.7	8.1	12.2	12.4	10.3
'CM 600'	51.6	142.3	86.3	53.6	145.0	89.3	2.0	2.6	3.0	6.8	6.9	8.5	12.9	12.8	10.4
'CM400' x 'CM300'	54.3	148.3	90.6	56.3	152.0	93.0	2.0	3.6	2.3	7.8	7.8	8.7	11.4	13.6	11.1
'CM 202'	67.0	158.3	102.6	72.0	167.3	107.6	5.0	9.0	5.0	6.3	5.6	6.0	7.6	12.3	7.6
'CM 111'	57.0	149.0	93.6	60.6	155.6	96.6	3.6	6.6	3.0	7.6	8.4	8.4	8.0	12.1	8.6
'CM 500'	53.6	143.3	82.6	56.0	146.3	85.3	2.3	3.0	2.6	6.1	6.9	7.8	8.3	13.8	11.1
'CM 501'	56.0	145.0	84.6	58.6	148.0	87.6	2.6	3.0	2.3	10.7	10.2	9.8	12.3	15.7	12.3
'CM202' x 'CM111'	56.6	149.6	91.6	59.3	152.67	94.0	2.6	3.0	2.3	10.7	10.2	9.8	12.3	15.7	12.3
'CM 135'	53.0	141.0	83.6	55.0	144.0	86.8	2.0	3.0	3.0	6.5	8.3	7.3	11.4	13.2	11.1
'CM 136'	53.0	142.0	84.6	55.3	144.0	87.3	2.3	2.0	2.6	5.8	8.3	7.0	11.4	13.0	11.4
'CM 137'	54.3	142.6	84.3	57.3	145.3	87.3	3.0	2.6	3.0	6.0	7.9	7.4	11.3	13.2	11.2
'CM 138'	53.6	141.0	83.3	56.3	145.3	86.0	2.6	2.3	2.6	5.8	7.9	7.2	11.6	13.0	11.1
Mean	56.1	147.8	89.0	58.8	151.7	92.1	2.7	3.8	3.0	7.0	7.6	7.8	10.4	13.2	10.6
C.D.(P=0.05) Genotype		2.18			2.58			0.28			0.81			1.02	
Season		28.1			29.1			0.29			NS			1.10	
Interaction		31.1			32.3			1.53			NS			2.01	

M: Monsoon; W: Winter; SS: Spring-Summer

successful hybrid seed production. In the present study, non-synchronization of flowering in parental lines was more in winter season and least in monsoon season (Table 4). Parental lines of CM 202 x CM 111 exhibited maximum non-synchrony, parents of PHM 2 and CM 400 x CM 300 the least and parents of PHM 1 nicked well in all the seasons (Table 4).

Thus, seed production of PHM 1, PHM 2 and CM 400 x CM 300 can be undertaken in all the seasons and of hybrids Ganga 11 and Ganga Safed 2 only in monsoon season, as the non synchronisation of flowering was least in this season (3-4 days) (Table 4). In the present study, all genotypes exhibited long duration of flowering (tasselling: 6-10 days; silking: 7-14 days) in different seasons with abundant pollen production, thus, non synchrony by 3-4 days in flowering is not expected to have significant bearing on seed setting and yield of hybrid seed. Non-synchronization of flowering upto 4 days between parents can be bridged easily by nutrient management and agronomic practices [16] . Seed production of other hybrids would require staggered sowing along with adoption of flowering manipulation practices. Our earlier studies on transplanting of maize in spring-summer season indicated a preponement of flowering by four to six days in transplanted crop as compared to direct sown crop [8]. Thus, transplanting of seedling of the late parent could also be practiced in winter and spring-summer seasons for attaining synchrony among parents for hybrid seed production.

Table 4. Synchronization pattern among parental lines of hybrids in different seasons

Hybrid	Monsoon				Winter				Spring-summer			
	F	M	D	Remarks	F	M	D	Remarks	F	M	D	Remarks
CM202 x CM111	72	57	15	SS	167	149	18	SS	108	94	14	SS
Ganga5 'CM202 x CM111' x 'CM500'	59	54	6	T,NM	153	143	10	SS	94	83	11	SS
Ganga11 'CM202 x CM 111' x 'CM501'	59	56	3	NM	153	145	8	SS	94	85	9	SS
'CM400 x CM300'	60	62	2	-	163	160	3	NM	97	96	1	-
Ganga Safed-2	56	52	4	NM	152	142	10	SS	93	86	7	T
PHM1 'CM 135 x CM 136'	55	53	2	-	144	142	2	-	87	85	2	-
PHM2 'CM137 x CM138'	57	54	3	-	145	141	4	NM	87	83	4	NM

F: Female; M: Male; D: Difference in days to flowering (Days to 50% anthesis and silking respectively in male and female parent); SS: Staggered sowing, T: Transplanting of seedlings, NM: Nutrient management

Table 5. Seed yield and 100 seed weight of maize parental lines in different seasons

Genotype/season	Seed yield(g/cob)			100 seed weight(g)		
	Monsoon	Winter	Spring-summer	Monsoon	Winter	Spring-summer
'CM 300'	24.2	25.8	22.1	15.5	20.7	18.4
'CM 400'	28.0	32.7	30.3	17.6	24.0	19.6
'CM 600'	27.0	37.4	29.8	17.9	23.7	19.6
'CM400' x 'CM300'	34.2	65.2	39.7	21.0	26.7	24.3
'CM 202'	10.2	19.8	11.6	8.9	14.8	8.6
'CM 111'	28.6	32.4	30.2	13.1	20.3	16.3
'CM 500'	33.3	44.6	35.1	14.5	22.9	21.9
'CM 501'	31.7	46.3	34.4	15.0	23.4	22.6
'CM202' x 'CM111'	36.5	56.7	43.6	19.4	25.0	23.8
'CM 135'	31.9	47.3	33.8	19.0	17.7	15.9
'CM 136'	32.7	44.6	34.7	18.5	16.4	16.6
'CM 137'	33.3	49.7	34.9	18.7	17.8	16.0
'CM 138'	33.0	47.2	35.1	18.5	17.0	16.0
Mean	29.6	42.3	31.9	16.7	20.8	18.4
C.D.(P=0.05) Genotype :	2.4				0.6	
Season:	2.2				2.0	
Interaction:	4.1				NS	

Seed yield and 100 seed weight

Seed yield and test weight was highest in winter (Table 5) which could be attributed to favourable and mild temperatures during flowering (15-32°C) and maturity (14-36°C) resulting in prolonged silk receptivity (Table 3) and duration of grain filling (60-75 days). Higher yield in winter season-can also be attributed to higher interception of photo energy and low night temperatures favouring higher production of photosynthetates and lower photo respiration. Adverse weather conditions during flowering in spring-summer crop though had marginal effect on the duration of flowering but significantly affected the seed set and yield. Low seed yield in monsoon season as compared to winter season could be due to shorter duration of crop growth and grain filling (40-50 days). Tollenaar and Daynard [17] and George *et al.* [18] reported that seed yield in maize depends on the rate and duration of grain filling from anthesis to maturity and is correlated with duration of flowering. In this study, seed yield had positive correlation with number of leaves per plant, duration of flowering, plant height and 100 seed weight in winter and spring-summer season. Our results confirms the reports of Mahajan *et al.* [19].

The study concluded that the environmental conditions especially temperature, R.H., rainfall and initial quality of genotypes are the most important factors affecting field emergence and seedling growth of maize. A temperature of 10°C was found critical for growth and development of maize. Number of leaves being a stable character could be used as a diagnostic character in seed certification programmes. Parental lines of single cross hybrids PHM 1 and PHM 2 had good field emergence, vigorous growth and least problem of synchronization of flowering with high seed yield and quality as compared to traditional inbreds; CM 300 and CM 202. Thus, the study highlighted the immense potential of breeder and foundation seed production of these hybrids in North India without adoption of flowering manipulation practices.

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