GENETIC DIVERGENCE STUDIES IN MAIZE (Zea mays L.) ACCESSIONS

S. H. Palkar¹, S. U. Charjan², S. R. Patil³, V. T. Chavan⁴ and P. B. Chavan⁵

ABSTRACT

Eighty eight genotypes of maize (Zea mays L.) were evaluated for genetic divergence to identify potential parents for hybridization programme in kharif 2018 at College of Agriculture, Nagpur. Mahalanobis D² statistics for nine characters viz., days to 50% tasseling, days to 50% silking, days to maturity, plant height, cob length, cob girth, number of grains cob⁻¹, 100 grain weight and grain yield plant⁻¹ were used in this study for computing genetic divergence. The eighty eight genotypes were grouped into twenty clusters by usingTocher's method. The maximum inter-cluster distance was recorded between cluster IV and cluster XX (D = 28.41) whereas, minimum inter-cluster distance was found between cluster VI and cluster VIII (D = 1.82). The canonical analysis and cluster means study revealed the importance of days to 50% tasseling, number of grains cob⁻¹, plant height, grain yield plant⁻¹ and cob length were considered as criteria for selecting potential parents for hybridization programme and according to this criteria 28 genotypes viz., 52202, 52623, 52025, 52201, 52014, 52291, 52087, 52115, 52196, 52020, 52140, 52327, 52285, 52180, 52497, 52552, 52347, 52045, 52597, 52353, 52095, 52081, 52065, 52219, 52263, 52250, 52603 and 52040 were identified to be used as parents for hybridization programme, which were suggested to be crossed in diallel fashion to obtain superior cross combinations. PKVM-Shatak as it is in separate cluster and distant from other clusters can be further improved to produce new hybrid by crossing with parents 52250, 52020, 52087, 52025, 52014, 52040, 52623, 52201, 52180, 52552, 52115 and 52202.

(Key words : Maize, genetic divergence, D² statistics, selection)

INTRODUCTION

Maize (Zea mays L.) is the world's important cereal crop after wheat and rice. Maize is known as queen of cereals because it has great yield potential, wider adaptability and attained the leading position among cereals in term of production as well as productivity. Maize can be grown in a wide range of climates, which is used as a food for human consumption and feed for cattle. It belongs to family Poaceae also called as Gramineae and subfamily Panicoideae. It is one of the first plant species identified to photosynthesize by C4 pathway with high yield potential. Maize seed oil is also low in linolenic acid (0.7%) and contains a high level of flavour Rahangdale et al., (2019) Maize provides many of the B vitamins and essential minerals along with fiber, but lacks some other nutrients, such as vitamin B12 and vitamin C, and is, in general, a poor source of calcium, folate and iron. Silage is prepared from green maize plants. Maize is not only used as food, feed and fodder but also used for some industrial purposes for manufacturing viz. starch, alcohol, acetic acid, glucose, paper, furfural, rayon, dyes, synthetic rubber and resin etc. (Pandit et al., 2019).

Assessment of genetic diversity is an essential pre-requisite for identifying potential parents for hybridization. Diverse parents are expected to yield higher frequency of heterotic hybrids in addition to generating a broad spectrum of variability in segregating generations. D^2 statistic was one of the methods used to study the genetic divergence and it was first time developed by Mahalanobis in 1936. Maize breeders are consistently emphasizing on the importance of diversity among parental genotypes as a significant factor contributing to heterotic hybrids. D^2 analysis is a useful tool for quantifying the degree of divergence between biological population at genotypic level and in assessing relative contribution of different components to the total divergence both at intra and intercluster level (Murty and Arunachalam, 1966).

MATERIALS AND METHODS

The experimental material comprised of eighty eight germplasm obtained from principle scientist and I/C winter nursery centre/ICAR-IIMR/ Rajendranagar Hyderabad-30 and one check *viz*. PKVM-Shatak. These eighty eight genotypes were grown in Randomized Block Design in three

 ^{4 &}amp; 5. P.G. Students, Agril. Botany Section, College of Agriculture, Nagpur, India
 Asstt. Professor, Agril. Botany Section, College of Agriculture, Nagpur, India

^{3.} Professor (CAS), Agril. Botany Section, College of Agriculture, Nagpur, India

Professor (CAS), Agrin. Botany Section, Conege of Agriculture, Nagpur

replications with the spacing of 60 cm×20 cm accommodating 15 plants in each row for the estimation of genetic divergence analysis in kharif 2018-19. Eighty seven parents and one check viz. PKVM-Shatak was also raised in three replications adjacent to the parents for the estimation of genetic divergence. Recommended package of practices were followed to raise a good crop. The data were recorded on five randomly selected plants from each genotype on following six characters except days to 50% tasseling, days to 50% silking and days to maturity which were recorded on plot basis. The data recorded were subjected to D² statistics to know the genetic diversity among the germplasm as suggested by Mahalanobis (1936). Grouping of genotypes into clusters was done as per the method described by Rao (1952) and identifying the superior genotypes was as per the method described by Bhatt (1970).

RESULTS AND DISCUSSION

The analysis of variance for nine characters revealed highly significant differences among the genotypes for all the nine characters indicating presence of substantial genetic variability for the characters studied (Table 1). Based on the magnitude of D² values, 88 genotypes were grouped into 20 clusters (Table 2). Cluster I was the largest comprising of 65 genotypes. The next largest cluster was cluster IX which included 5 genotypes, cluster II, III, IV, V, VI, VII, VIII, X, XI, XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XX included only one genotype each. Average intra and inter-cluster D² values were presented in table 3. The intra-cluster variation ranged from 0.00 to 5.46. Cluster IX possessed highest intracluster distance (D = 5.46) followed by cluster I (D = 4.96). The average inter-cluster distance was maximum between cluster IV and cluster XX (D = 28.41) followed by cluster XI and cluster XX (D = 26.12), cluster II and cluster XIX (D =25.72), cluster XV and cluster XX (D = 25.56), cluster V and cluster XIX (D = 25.06), cluster IV and cluster XIX (D =23.26) and cluster XVII and cluster XIX (D = 23.24). This suggests more variability in genetic makeup of genotypes included in these clusters. The inter-cluster distance was found to be minimum between cluster VI and cluster VIII (D =1.82).

The per cent contribution of nine characters towards total genetic divergence (Table 4) showed that the per cent contribution of days to 50% tasseling to the total divergence was maximum (18.34%) followed by 100 grain weight (17.08%), plant height (14.47%), grain yield plant⁻¹ (13.19%), cob girth (13.09%), days to maturity (11.05%), cob length (6.64%) and number of grains cob⁻¹ (4.05%). Relatively days to 50% silking (2.09%) contributed less towards genetic divergence.Varaprasad and Shivani (2017) also in agreement with high contribution of number of kernels row⁻¹ (22.56%), 100 kernel weight (20.19%), days to 50% tasseling (11.84%) and grain yield plant⁻¹ (10.30%).

The value of first five canonical vectors and canonical roots are presented in table 5 and in table 6

respectively. The first three canonical roots accounted for 54.03% of the observed variability in material ($\lambda_1 = 25.93\%$, $\lambda_1 = 15.11\%$ and $\lambda_3 = 12.99\%$). The overall contribution of the five canonical roots to total variability among 88 genotypes was 75.60% suggesting the completion of major portion of differentiation in first five phases. This indicated that differentiation for nine characters among 88 genotypes was nearly completed in five phases. Further the coefficients in the first five canonical vectors indicate that out of nine quantitative characters grain yield plant¹, number of grains cob⁻¹, cob length, plant height, cob girth and 100 grain weight were important characters in the first vector which was major access of differentiation accounting for 25.93% of total variation. Days to 50% tasseling and cob length were important characters in secondary access of differentiation which accounted for 15.11% of total variation. Important characters in vector III were days to maturity, number of grains cob⁻¹ and days to 50% silking accounting to 12.99% of variation. Plant height and cob girth were important characters in vector IV which accounted for 11.08% and days to 50% tasseling, days to maturity, 100 grain weight, plant height and cob girth were important source of variation in vector V accounting to 10.49% of variation. This suggested that parents selected on the basis of characters like days to 50% tasseling, number of grains cob⁻¹, plant height, cob girth and cob length may be expected to be genetically diverse. Akhi et al. (2017) and Varaprasad and Shivani (2017) also carried out the canonical analysis in maize and reported that days to 50% silking, plant height, cob length (cm), number of rows cob⁻¹, number of grains cob⁻¹ for both the vectors I and II were positive and these are indication of the important components of genetic divergence.

Data regarding cluster means for all the nine characters are presented in table 7. The genotypes from cluster XII possessed the highest cluster mean for plant height, 100 grain weight and cob girth. Cluster XIX showed maximum mean for number of grains cob⁻¹ and grain yield plant⁻¹. Cluster VII showed maximum mean for days to 50% tasseling and days to 50% silking. Cluster VIII showed maximum mean for cob length and cluster XIII for days to maturity, the genotypes with high mean values may be used as parents in future hybridization programme.

According to Bhatt (1970) the mean statistical distance may be considered arbitrarily as a guide line and crosses between parents belonging to different clusters having same or higher inter-cluster distance than the mean statistical distance may be attempted. The crosses should be chosen from widely distinct clusters. But, it is observed in the present study that there might be several genotypes included in such widely separated clusters. Then the question arise which of the genotypes from these more diverse clusters may be used for crossing. In that case preference for those genotypes which perform better for the characters (days to 50% tasseling, number of grains cob⁻¹, plant height, grain yield plant⁻¹ and cob length) which contributed much towards divergence should be given. In

						W	ean squares				
Sr. No.	Source of varience	d.f.	Days to 50% tasseling	Days to 50% silking	Days to maturity	Plant height (cm)	Cob length (cm)	Cob girth (cm)	Number of grains cob ⁻¹	100 grain weight (g)	Grain yield plant ⁻¹ (g)
1. 3. 3.	Replication Genotypes Error	2 87 174	0.03 8.97** 2.44	2.40 7.78** 2.46	4.10 10.63** 3.15	543.40 750.02** 196.88	2.94 8.47** 2.65	$\begin{array}{c} 0.11 \\ 2.74^{**} \\ 0.68 \end{array}$	2796.20 5913.20** 1746.20	5.55 9.73** 2.06	35.87 413.45** 62.87
** Si	gnificant at 1% I	evel									
Tabl	e 2. Grouping (of 88 genot	types of maiz	ze in differe	ent clusters						
Clust	er Total nui	mber of ger	notypes					Genotypes			
	65				520 523 523 522 522 522 520 520 520 520 520 520 520	42, 52377, 52 40, 52274, 52 42, 52329, 52 59, 52631, 52 57, 52633, 52 17, 52638, 52 95, 52459, 52	070, 52483, 536, 52383, 536, 52383, 266, 52310, 2066, 52332, 208, 52332, 208, 52353, 507, 52081, 5	52549, 52340 52058, 52361 52409, 52597 52317, 52205 52041, 52268 52065, DMR	0. 52399, 521 1. 52185, 520 7. 52185, 520 7. 52349, 520 5. 52060, 525 8. 52461, 521 8. 52461, 521 E 63, 52102,	49, 52068, 52 77, 52370, 52 99, 52389, 52 99, 52389, 52 45, 52615, 52 84, 52278, 52 84, 52123, 5221	(098, 52262, (019, 52292, (048, 52556, (031, 52214, (049, 52169, 9, 52263
III								5202 5229	25 01		
2 > 5								5220 5201	2 4		
								5228 5214 5232			
XIXX	v						52180,	52497, 5255 5262 5262	(2, 52347, 52) 23 6)45	
								5219 5219 5204-SH 5202 5220 5220 52208 5223 5223 5223	6 2 3 3 3 3 3 3 3 3 3 3 5 5 5 3 3 3 5 5 5 3 3 3 5 5 5 1 1 1 1		

Table 1.Analysis of variance for various characters

Tocher's method
ce by
distan
cluster
inter-
ıand
eintra
Average
Table 3.

	,	;			;				;										
Cluster	-	╡	∃	1	>	11	٨II	XI IIIV	×	X	X IIX			X V	X IV			XIX	XX
Ι	4.96	6.69	6.56	6.94	9.16	8.32	7.55	8.30 7.66	7.70	6.71	7.56 6	.84	7.55	7.81 6	86.	8.77	9.20 1	3.57	16.35
II		0.00	8.53	2.13	8.76	17.52	10.55	18.19 10.83	5.75	6.39	14.47 7	4.	4.79 8	3.91 6	9 62.	5.25	9.08 2	5.72	20.31
III			0.00	7.38	12.84	66.T	12.27	10.37 11.99	13.59	8.40	10.66 3	.43	6.85 ∠	00	1.74 8	3.31	11.15 1	1.13	23.48
N				0.00	12.81	14.20	11.25	15.56 12.51	10.84	4.48	11.50 6	.72	8.57	.01 10	0.47	5.95	10.09 2	3.26	28.41
Λ					0.00	17.89	4.14	12.48 11.39	9.46	19.31	14.44 14	1 .83	11.31 1	6.22 10	0.41 1	1.18	19.82 2	5.06	11.57
И						0.00	13.79	1.82 7.40	14.90	10.42	6.09 7	.71	15.57 1	0.90 10	5.60 1	2.92	10.56 5	.94	18.35
ΝII							0.00	9.10 10.81	12.21	14.82	6.90 17	7.50	12.51 1	0.92 7	.64	4.92	15.03 20	00.0	15.98
VIII								0.00 7.95	14.87	13.56	4.94 1().85	18.39 1	4.56 10	5.04 1	3.27	14.69 8	.80	16.22
IX								5.46	8.58	12.18	11.60 9	.76	8.83 1	2.07 9	.63 1	0.89	9.27 1	5.56	10.72
X									0.00	8.01	12.19 10	.81	8.54 1	5.84 7	.83	0.06	7.72 1	8.09	8.00
XI										0.00	7.24 6	.78	10.73 8	3.74 9	.04	1.13	5.88 1	3.67	26.12
XII											0.00 14	1.25	18.34 1	1.81	1.51 1	8.24	8.79 8	69.	21.30
XIII											0	00.	7.17 8	3.60 1	2.65 5	5.30	12.40 1	3.68	22.52
XIV													0.00	5.00 5	89.	3.97	9.86 21	0.72	15.86
XV													0	.00 10	0.28 1	2.50	9.81 1	4.03	25.56
XVI														0	.00	6.16	9.19 2	1.51	17.58
ПЛХ															0	00.	16.06 2	3.24	18.62
XVIII																	0.00 1	5.22	18.14
XIX																	0	00.	22.06
XX																		-	0.00

Sr.No.	Source		Time ranked	1 st Per	· cent contributio	_			
;	Days to 50% tasseli	ng	702		18.34				
c'i	Days to 50% silking		80		2.09				
÷.	Days to maturity		423		11.05				
4.	Plant height (cm)		554		14.47				
<u>ب</u>	Cob length (cm)		254		6.64				
ý.	Cob girth (cm)		501		13.09				
7.	Number of grains co	b ⁻¹	155		4.05				
×.	100 grain weight (g)		654		17.08				
.6	Grain yield plant ⁻¹ (g	~	505		13.19				
	Total		3828		100				
Table	5. The value of ca	monical vec	tors						
Vector	r Days to 50%	Days to 50%	Days to Maturity	Plant Height	Cob Length	Cob Girth	Number of prains cob ⁻¹	100 grains weight (g)	Grain yield nlant ⁻¹ (g)
	tasseling	silking		(cm)	(cm)	(cm)			
	-0.076	-0.329	-0.045	0.289	0.456	0.180	0.510	0.104	0.538
Π	0.574	-0.227	-0.178	0.061	0.163	-0.662	0.033	-0.342	0.012
III	-0.104	0.145	0.619	0.096	-0.102	0.035	0.350	-0.662	-0.053
\geq	-0.018	-0.278	-0.416	0.608	-0.399	0.302	-0.078	-0.310	-0.162
>	0.631	-0.053	0.505	0.340	-0.046	0.248	-0.117	0.377	-0.089
Table	6. Value of five ca	monical root	t and their co	ntribution	expressed as l	per cent of 1	the total variatic	uc	
	Root			Value			Contribut	tion (%)	
	ë			2.334			25	.93	
	່:ຕ໌			1.360			15.	.11	
	ຳຕົ			1.169			12	66.	
	ָ :ס			0.997			11.	.08	
	່ະບັ			0.944			10	.49	
	Total			6.804			75	.60	
Sur	n of all canonical ro	ot		9.000					
	Residual			2.196			24	.40	

character to divergence
of individual
Contribution
Table 4.

Cluster	Days to	Days to	Days to	Plant	Cob	Cob	Number of	100 grains	Grain yield
	50%	50%	Maturity	Height	Length	Girth	grains cob ⁻¹	weight (g)	plant ⁻¹ (g)
	tasseling	silking		(cm)	(cm)	(cm)			
I	54.46	57.72	86.12	149.32	13.30	10.74	280.79	18.68	51.44
Π	52.67	56.33	86.00	136.87	11.98	10.35	202.93	17.31	27.49
III	54.00	57.00	88.67	115.80	14.15	11.32	332.27	20.99	57.85
N	52.33	56.67	86.33	148.00	13.06	11.64	222.73	19.19	40.85
v	57.33	60.33	88.00	138.73	14.33	9.31	186.20	18.05	31.75
VI	55.00	58.33	87.33	168.40	16.98	12.44	403.90	19.11	77.11
ΝI	59.00	62.33	85.67	156.67	13.61	10.73	240.00	19.87	46.03
ΙΠΛ	56.00	59.33	87.67	177.67	17.42	11.72	367.20	20.02	73.63
IX	55.93	59.07	87.33	161.93	13.71	10.80	309.11	15.48	49.02
X	52.67	55.67	82.33	152.87	14.04	9.83	258.07	15.29	35.63
XI	50.67	54.33	82.67	161.27	13.09	11.74	301.67	19.29	56.79
ХП	55.67	58.67	82.67	182.13	16.87	12.87	341.70	21.26	69.63
XIII	51.00	54.33	89.33	131.13	13.44	10.52	296.50	18.49	55.16
XIV	55.33	58.33	87.67	109.53	9.53	9.69	253.60	15.76	34.56
XV	56.67	60.33	86.67	116.27	11.63	11.96	304.80	19.16	55.85
ΙΛΧ	55.67	57.67	85.33	148.33	8.98	9.73	234.87	17.57	37.48
IIVX	51.33	56.33	89.00	133.27	13.86	9.37	287.67	18.09	41.69
IIIAX	54.33	57.00	82.67	162.40	14.61	12.82	370.60	16.83	47.54
XIX	55.00	57.67	83.00	144.60	17.07	12.33	414.30	20.03	89.69
XX	57.67	60.33	84.33	146.60	15.50	90.6	316.40	12.97	38.77
S. D.	2.29	2.06	2.29	19.70	2.27	1.21	63.61	2.09	16.47
Variance	5.24	4.23	5.26	387.97	5.17	1.47	4045.73	4.37	271.13

Table 7. Cluster means for nine characters in maize

combination inter-cluster distance 1 IV × XX 28.41 5202 × 52250 Cob length 2 X × XX 20.12 5202 × 52250 Cob length 3 II × XIX 25.72 5202 × 5203 Grain yield plant ⁺¹ 4 XV × XX 25.66 5201 × 5203 Grain yield plant ⁺¹ 6 III × XX 23.46 5220 × 5203 Grain yield plant ⁺¹ 6 III × XX 23.26 5220 × 5203 Grain yield plant ⁺¹ 7 IV × XIX 23.26 5203 × 52230 Cob length 10 XIX × XX 21.51 52115 × 5203 Cob length 11 XVI × XIX 21.30 52196 × 52230 Cob length 12 XI × XX 21.30 52196 × 5220 Cob ingth 13 XIV × XIX 20.31 5202 × 5220 Cob ingth 14 II × XX 20.31 5202 × 5220 Grain yield plant ⁺¹ 15 VII × XIX 20.31 520	Sr.No.	Cluster	Average	Cross Combination	Traits
INV=XX 28.41 52202×52250 Number of grains cob ¹ 2 X=XX 26.12 5263×52250 Cob length 3 II=XIX 25.72 52025×5203 Grain yield plant ⁻¹ 4 XV=XX 25.56 5201+5203 Grain yield plant ⁻¹ 5 V=XIX 25.66 5201+5203 Grain yield plant ⁻¹ 6 III=XX 23.48 5201+5203 Grain yield plant ⁻¹ 7 IV=XIX 23.48 5201+5203 Grain yield plant ⁻¹ 9 XII=XX 22.26 5200×5203 Grain yield plant ⁻¹ 10 XIX=XX 22.06 5203×5220 Cob grath 11 XXI=XX 20.01 5204×5203 Grain yield plant ⁻¹ 12 XI=XX 20.01 5204×5220 Cob grath 11 XVI=XIX 20.02 5203 Gob grath 12 XI=XX 20.31 5202+5220 Cob grath 13 XIV=XIX 20.31 5202+5220 Cob grath		combination	inter-cluster distance		
1 1 1 2223 × 2220 Cob length 3 II × XX 26.12 5222 × 5220 Grain yield plant ¹ 4 XV × XX 25.66 5201 × 5220 Number of grains cob ¹ 5 V × XX 25.66 5201 × 5220 Number of grains cob ¹ 6 III × XX 23.48 52201 × 5220 100 grain weight 7 IV × XX 23.26 5202 × 52603 Grain yield plant ¹ 8 XVII × XIX 23.26 5200 × 5250 Cob length 10 XIX × XX 23.66 52603 × 52250 Cob length 11 XVI × XIX 23.15 52060 × 52500 Go length 12 XI × XX 23.00 520603 Grain yield plant ¹ 12 XI × XX 20.31 5202 × 52250 Cob girth 13 VI × XIX 20.01 5204 × 5220 Grain yield plant ¹ 14 II × XIX 20.31 5204 × 5220 Cob girth 15 VII × XIX 20.320 × 5220 Grain yiel	1	IV × XX	28.41	52202 × 52250	Number of grains cob-1
2 If N XIX 25.22 S2225 × S203 Grain yield plant ⁻¹ 4 XV × XX 25.56 S201 × S2250 Number of grains cob ⁻¹ 5 V × XIX 25.66 S201 × S2250 100 grain weight 6 III × XX 23.48 S2201 × S2250 100 grain weight 7 IV × XIX 23.26 S2202 × S2033 Grain yield plant ⁻¹ 8 XVII × XIX 23.26 S2202 × S2033 Grain yield plant ⁻¹ 9 XII × XX 23.25 PKVM-Shatak × 52250 Cob length 11 XVI × XX 21.51 S2118 × S2603 Grain yield plant ⁻¹ 12 XI × XX 21.30 S2196 × S2250 Cob length 13 XIV × XX 20.31 S2014 × S2063 Grain yield plant ⁻¹ 14 II × XX 20.31 S2014 × S2063 Grain yield plant ⁻¹ 14 II × XX 20.31 S2014 × S2063 Grain yield plant ⁻¹ 15 VII × XX 18.62 S2014 × S2063 Grain yield plant ⁻¹ 16 </td <td>2</td> <td>$X \times XX$</td> <td>26.12</td> <td>52623 × 52250</td> <td>Cob length</td>	2	$X \times XX$	26.12	52623 × 52250	Cob length
4 XV × XX 25.6 5201 × 2250 Number of grains cob ⁻¹ 5 V × XIX 25.66 5201 × 52603 Grain yield plant ⁻¹ 6 III × XX 23.48 52291 × 52203 Grain yield plant ⁻¹ 7 IV × XIX 23.26 5202 × 52603 Grain yield plant ⁻¹ 9 XII × XX 23.24 5202 × 52603 Grain yield plant ⁻¹ 10 XIX × XX 22.06 52603 × 52250 Cob length 11 XIX × XX 21.51 52115 × 52603 Grain yield plant ⁻¹ 12 XI × XX 21.30 52109 × 52250 Cob length 13 XIV × XIX 21.51 52020 × 52030 Grain yield plant ⁻¹ 14 II × XX 20.00 5214 × 52250 Cob grain 15 VII × XIX 20.00 5214 × 52250 Number of grains cob ⁻¹ 16 V × XII 19.31 5204 × 52250 Number of grains cob ⁻¹ 17 V × XI 18.862 5237 × 52020 Cob length 20 VI × XX 18.35 5227 × 5203 Grain yield plant ⁻¹	3	$\Pi \times XIX$	25.72	52025 × 52603	Grain vield plant ⁻¹
5 V × XIX 2506 52014 × 22603 Grain yield plant ⁻¹ 6 III × XX 23.48 52201 × 5220 100 grain weight 7 IV × XIX 23.26 52202 × 52603 Grain yield plant ⁻¹ 8 XVII × XIX 23.24 52087 × 52603 Grain yield plant ⁻¹ 9 XII × XX 22.52 PKVM-Shatak × 52250 Cob length 10 XIX × XX 22.06 52603 × 52250 Cob length 11 XVI × XX 21.03 52196 × 52250 Cob length 12 XI × XX 20.31 52024 × 52603 Grain yield plant ⁻¹ 13 XIV × XIX 20.03 5203 Grain yield plant ⁻¹ 14 IF × XX 20.31 5204 × 52160 Cob girth 15 VII × XIX 18.62 52087 × 52200 Number of grains cob ⁻¹ 17 V × XI 19.31 52014 × 52200 Number of grains cob ⁻¹ 18 VVII × XIX 18.35 52285 × 52250 Number of grains cob ⁻¹ 211 × XIV	4	XV×XX	25.72	52201 × 52250	Number of grains cob ⁻¹
5 11 kX 23.48 52.291 x 52.250 100 grain weight 7 IV × XIX 23.26 52.202 x 52.603 Grain yield plant ⁻¹ 9 XII x XX 23.24 52.003 Grain yield plant ⁻¹ 9 XII x XX 22.06 52.603 x 52.50 Cob length 10 XIX x XX 21.51 52.115 x 52.603 Grain yield plant ⁻¹ 12 XI x XX 21.30 52.004 x 52.50 Cob length 13 XIV x XIX 21.51 52.003 Grain yield plant ⁻¹ 14 II x XX 20.00 52.140 x 52.603 Grain yield plant ⁻¹ 14 II x XIX 20.00 52.140 x 52.604 Cob girth 15 VII x XIX 10.92 52.014 x 52.20 Number of grains cob ⁻¹ 16 V x XI 19.92 52.014 x 52.20 Number of grains cob ⁻¹ 17 V x XI 18.92 52.27 x 52.00 Grain yield plant ⁻¹ 18 VIII x XX 18.42 PKVM-Shatak x 52.00 Ino grain weight 21	5	V×XIX	25.06	52201×52250	Grain vield plant ⁻¹
5 INVAIX 23.26 5220 × 32.603 Grain yield plant ¹ 8 XVII × XIX 23.24 5200 × 52.603 Grain yield plant ¹ 9 XII × XX 22.52 PKVM-Shatak × 52.20 Cob jerth 10 XIX × XX 22.65 PKVM-Shatak × 52.20 Cob length 11 XIX × XX 21.03 52195 × 52603 Grain yield plant ¹ 12 XI × XX 21.30 52195 × 52603 Grain yield plant ¹ 13 XIV × XIX 20.7 52020 × 52603 Grain yield plant ¹ 14 II × XX 20.31 5202 × 5250 Cob jerth 15 VII × XIX 20.00 52140 × 52603 Grain yield plant ¹ 16 V × XII 19.31 52014 × 5220 Number of grains cob ¹ 17 V × XI 18.35 5228 × 5220 Cob length 20 VI × XX 18.35 5228 × 5220 Cob length 21 XII × XIV 18.34 PKVM-Shatak × 5200 100 grain weight 21 XII × XIV 18.24 PKVM-Shatak × 52087 Cob jerth 23	6	III × XX	23.00	52291 × 52250	100 grain weight
A NULL XIX 2.2.0 2.2.0 Constraint Chain yield plant 9 XII × XX 2.52 PKVM-Shatak × 52603 Grain yield plant 10 XIX × XX 2.52 PKVM-Shatak × 52603 Grain yield plant 11 XVI × XX 21.51 52115 × 52603 Grain yield plant 12 XI × XX 21.30 52196 × 5250 Cob length 13 XI × XX 20.30 S2603 Grain yield plant 14 II × XX 20.31 52025 × 52603 Grain yield plant 15 VI × XIX 20.31 52063 Grain yield plant 16 V × XII 19.31 52014 × 5250 Cob girth 17 V × XI 19.31 52014 × 5220 Number of grains cob ⁻¹ 18 VII × XX 18.32 5225 × 5200 Cob length 20 VI × XX 18.35 5225 × 5200 Grain yield plant ⁴ 21 XII × XVI 18.34 PKVM-Shatak × 5200 100 grain weight 21 XII × XVI 18.34 9223 × 52603 Grain yield plant ⁴ 22 <td>7</td> <td>$III \times XIX$ $IV \times XIX$</td> <td>23.40</td> <td>52202 × 52603</td> <td>Grain vield plant⁻¹</td>	7	$III \times XIX$ $IV \times XIX$	23.40	52202 × 52603	Grain vield plant ⁻¹
5 NILXXX 22.52 PKVM-Shatak × 522.50 Cob length 10 XIX×XX 22.65 52603 × 522.50 Cob length 11 XIX×XX 21.61 5215 × 52603 Grain yield plant ⁻¹ 12 XI×XX 21.30 52196 × 52250 Cob length 13 XIV×XIX 20.72 52020 × 52603 Grain yield plant ⁻¹ 14 II×XX 20.31 52025 × 52250 Cob girth 15 VII×XIX 20.00 52144 × 5296 Cob girth 16 V×XVIII 19.82 52014 × 52234 Number of grains cob ⁻¹ 17 V×XI 18.62 52087 × 52250 Number of grains cob ⁻¹ 18 XVII×XX 18.62 52087 × 52200 Cob length 20 VI×XX 18.35 52285 × 52200 Cob length 21 XII×XVII 18.34 PKVM-Shatak × 52020 100 grain weight 22 XII×XVII 18.24 PKVM-Shatak × 5203 Grain yield plant ⁻¹ 23 II×XVII 18.24 PKVM-Shatak × 5203 Grain yield plant ⁻¹ 24 XVII<	8		23.20	52202×52603	Grain yield plant ⁻¹
Matrix	9		23.24	$PKVM-Shatak \times 52250$	Cob girth
10 XIX XIX 2.151 S2115 × S2603 Grain yield plant ⁻¹ 12 XI × XX 21.51 S2115 × S2603 Grain yield plant ⁻¹ 12 XI × XX 20.72 S2020 × S2503 Grain yield plant ⁻¹ 14 II × XX 20.72 S2020 × S2503 Grain yield plant ⁻¹ 14 II × XX 20.31 S2025 × S2503 Grain yield plant ⁻¹ 15 VII × XIX 20.00 S2140 × S2044 Number of grains cob ⁻¹ 16 V × XVIII 19.82 S2014 × S214 Number of grains cob ⁻¹ 17 V × XI 19.31 S2014 × S214 Number of grains cob ⁻¹ 18 XVII × XX 18.35 S2285 × S2250 Grain yield plant ⁻¹ 20 VI × XX 18.35 S2285 × S2250 Number of grains cob ⁻¹ 21 XII × XVI 18.34 PKVM-Shatak × S2087 Cob length 21 XII × XVI 18.34 S225 × S237 Cob length 23 II × VII 17.82 S2204 Number of grains cob ⁻¹ 24 XVII × XXI 17.89 S2014 × S285 Grain yield p	10	XIX × XX	22.52	52603 × 52250	Cob length
11 XIVX 12 2014 S2205 Cob length 13 XIVX XIX 20.00 52140×52603 Grain yield plant ⁴ 1 15 VIIXXIX 20.00 52140×52234 Number of grains cob ⁴ 1 16 V×XVII 19.31 52014×52196 Cob girth 1 1 18 XVII×XX 18.36 52285×5250 Grain yield plant ⁴ 1 1 21 XII×XVI 18.34 PKVM-Shatak×52020 100 grain weight 1 2 XII×XVI 18.14 52234×5250 Number of grains cob ⁴ 1 2 23 I×XIX 18.14 52234×52250 Number of grains cob ⁴ 1 1 1 1 1 1 1 1 1 1 1 <	10		21.51	52115 × 52603	Grain vield plant ⁻¹
International state Substrate Substrate Substrate 13 XIV × XIX 2072 S2020 × S2603 Grain yield plant ⁻¹ 14 II × XIX 2031 S2025 × S2250 Cob grin 16 VI × XIX 2000 S2140 × S2603 Grain yield plant ⁻¹ 16 V × XVII 19.31 S2014 × S2234 Number of grains cob ⁻¹ 17 V × XI 19.31 S2014 × S2234 Number of grains cob ⁻¹ 18 XVII × XX 18.62 S2087 × S2250 Number of grains cob ⁻¹ 20 VI × XX 18.35 S2285 × S2250 Cob length 21 XII × XIV 18.34 PKVM-Shatak × S2020 100 grain weight 22 XII × XVI 18.34 PKVM-Shatak × S2027 Cob length 23 II × VII 18.34 PKVM-Shatak × S2027 Cob length 24 XVIII × XX 18.44 S224 × S2250 Number of grains cob ⁻¹ 25 X × XIX 18.09 S2623 × S2033 Grain yield plant ⁻¹ 25 X × XIX 17.58 S2115 × S2250 100 grain weight	12	XIXXX	21.31	52115 × 52005	Cob length
Int XIX 20.72 Solds A S225 Color grains (1) plant 14 II × XX 20.31 50025 × 52250 C ob girth 15 VII × XIX 20.00 52140 × 52603 Grain yield plant ⁻¹ 16 V × XI 19.82 52014 × 52196 C ob girth 17 V × XI 19.31 52014 × 52250 Number of grains cob ⁻¹ 18 XVII × XX 18.62 52087 × 52250 Number of grains cob ⁻¹ 20 VI × XX 18.35 52285 × 52250 Grain yield plant ⁻¹ 21 XII × XIV 18.34 PKVM-Shatak × 52087 C ob length 22 XII × XVI 18.44 52235 × 5237 C ob length 23 II × VIII 18.19 52025 × 5237 C ob length 24 XVII × XX 18.14 52285 × 5203 Grain yield plant ⁻¹ 25 X × XIX 18.14 52285 ⊂ Grain yield plant ⁻¹ 26 V × VI 17.89 52115 × 52250 100 grain weight 27 XVI × XX 17.58 52140 × 52040 Number of grains cob ⁻¹ 28 II × XI	12	$XIV \times XIX$	20.72	52020 × 52603	Grain vield plant ⁻¹
INTERATION Description Constraint 15 VII × XIX 2000 52140 × 52603 Grain yield plant ⁻¹ 16 V × XVII 19.31 52014 × 52196 Cob girth 17 V × XI 19.31 52014 × 52250 Number of grains cob ⁻¹ 18 XVII × XX 18.62 52087 × 52250 Grain yield plant ⁻¹ 19 VII × XX 18.35 52285 × 52250 Grain yield plant ⁻¹ 21 XII × XIV 18.34 PKVM-Shatak × 52020 100 grain weight 22 XII × XVI 18.34 PKVM-Shatak × 52020 100 grain weight 23 II × VII 18.19 52234 × 52250 Number of grains cob ⁻¹ 24 XVIII × XX 18.14 52234 × 5203 Grain yield plant ⁻¹ 25 X × XIX 18.14 52234 × 52250 100 grain weight 26 V × VI 17.89 52014 × 52285 Grain yield plant ⁻¹ 26 V × VI 17.52 52291 × 52285 Grain yield plant ⁻¹ 27 VI × XVI 16.60 52285 × 5215 Number of grains cob ⁻¹ 21	13	$\Pi \times XX$	20.72	52025 × 52250	Cob girth
12 V X XVIII 10.82 52.16 × 52234 Number of grains cob ⁻¹ 16 V × XVIII 19.82 52014 × 52234 Number of grains cob ⁻¹ 17 V XII 19.31 52014 × 52230 Cob girth 18 XVII × XX 18.62 52087 × 52250 Cob length 19 VIII × XIV 18.35 52285 × 52250 Grain yield plant -1 20 VI × XX 18.35 52285 × 52250 Grain yield plant -1 21 XII × XVI 18.24 PK/VM-Shatak × 52020 100 grain weight 23 II × VII 18.19 52025 × 5237 Cob length 24 XVIII × XX 18.14 52234 × 52250 Number of grains cob ⁻¹ 25 X × XIX 18.09 52623 × 5203 Grain yield plant -1 26 V × VI 17.58 52115 × 52250 100 grain weight 28 II × VI 17.50 52140 × 52040 Number of grains cob -1 27 VII × XII 16.60 52285 × 52115 Number of grains cob -1 30 VI × XVI 16.60 52285 × 52250 Cob length	15		20.00	52140 × 52603	Grain vield plant ⁻¹
In 1.02 2.014 × 52196 Cob girth IV VXI 19.31 52014 × 52196 Cob girth 18 XVII × XX 18.62 52087 × 52250 Number of grains cob ⁻¹ 19 VIII × XIV 18.39 52327 × 52020 Cob length 20 VI × XX 18.35 52285 × 52250 Grain yield plant ⁻¹ 21 XII × XVII 18.34 PKVM-Shatak × 52020 100 grain weight 22 XII × VVII 18.24 PKVM-Shatak × 52087 Cob length 23 II × VVII 18.14 52234 × 52250 Number of grains cob ⁻¹ 24 XVIII × XX 18.14 52234 × 52250 Grain yield plant ⁻¹ 25 X × XIX 18.09 52613 × 522603 Grain yield plant ⁻¹ 26 V × VI 17.89 52014 × 52285 Grain yield plant ⁻¹ 26 V × VI 17.88 52115 × 52250 100 grain weight 28 III × VI 17.52 52291 × 52285 Grain yield plant ⁻¹ 29 VII × XII 16.60 52857 52081 52081 30	15	VXXIII	19.82	52014 × 52234	Number of grains cob ⁻¹
1 X XI 12.1 20.07 × 52250 Number of grains cob ⁻¹ 18 XVII × XX 18.39 52337 × 52200 Cob length 20 VI× XX 18.35 52285 × 52250 Grain yield plant ⁻¹ 21 XII × XVI 18.34 PKVM-Shatak × 52020 100 grain weight 22 XII × XVII 18.24 PKVM-Shatak × 52020 100 grain weight 23 II × VIII 18.19 52025 × 52250 Number of grains cob ⁻¹ 24 XVIII × XX 18.14 52234 × 52250 Number of grains cob ⁻¹ 25 X × XIX 18.14 52234 × 52250 Number of grains cob ⁻¹ 25 X × XIX 18.19 520214 × 52285 Grain yield plant ⁻¹ 26 V × VI 17.58 52145 × 52250 100 grain weight 28 II × VI 17.50 52140 × 52040 Number of grains cob ⁻¹ 29 VII × XII 16.60 52285 × 52115 Number of grains cob ⁻¹ 30 V × XVI 16.65 52552 5253 52597 52196 52291 x 52250 Cob length 5204	10	V×XI	19.32	52014 × 52196	Cob girth
Intervention Function	18	XVII × XX	18.62	52014×52150	Number of grains cob ⁻¹
Def Number of grain yield plant ⁻¹ South State S	10	VIII×XIV	18 39	52307 × 52250	Cob length
21 XII × XIV 18.33 PEVM-Shatak × 52020 100 grain weight 22 XII × XVI 18.24 PKVM-Shatak × 52087 Cob length 23 II × VIII 18.19 52025 × 52327 Cob length 24 XVII × XIX 18.19 52025 × 52327 Cob length 25 X × XIX 18.19 52023 × 52603 Grain yield plant ⁻¹ 26 V × VI 17.89 52014 × 52285 Grain yield plant ⁻¹ 26 V × VI 17.58 52140 × 52250 100 grain weight 27 XVI × XX 17.58 52140 × 52250 100 grain weight 28 III × VI 17.50 52140 × 52040 Number of grains cob ⁻¹ 29 VII × XII 16.60 52285 × 52115 Number of grains cob ⁻¹ 30 VI × XVI 16.65 52552 -x 52603 Grain yield plant ⁻¹ 31 IX × XIX 16.56 52552 -x 5250 Number of grains cob ⁻¹ 31 IX × XIX 16.25 52095 -x 52250 Cob length 32 VIII × XX 16.22 52327 × 52250 <td>20</td> <td>VI×XX</td> <td>18.35</td> <td>52285 × 52250</td> <td>Grain vield plant⁻¹</td>	20	VI×XX	18.35	52285 × 52250	Grain vield plant ⁻¹
21 MIX XVII 1823 PKVM-Shatak × 52087 Cob girth 23 II × VII 18.19 52025 × 52327 Cob length 24 XVIII × XX 18.14 5203 × 52603 Grain yield plant ¹ 25 X × XIX 18.09 52623 × 52603 Grain yield plant ¹ 26 V × VI 17.89 52014 × 52285 Grain yield plant ¹ 27 XVI × XX 17.58 52115 × 52250 100 grain weight 28 III × VI 17.52 52291 × 52285 Grain yield plant ¹ 29 VI × XII 16.60 52285 × 52115 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 5215 Number of grains cob ⁻¹ 31 IX × XIX 16.56 52577 5235 52095 52219 - x 52250 Number of grains cob ⁻¹ 32 I × XX 16.35 52095 52219 - x 52250 Number of grains cob ⁻¹ 33 VIII × XX 16.22 5237 × 52250 Cob length 34 XVIII × XX 16.22 5224 × 52603 Number of grains cob ⁻¹ 35 V × XV 16.22	20	XII × XIV	18 34	PKVM-Shatak × 52020	100 grain weight
2 II × VIII 18.19 52025 × 52327 Cob length 24 XVIII × XX 18.14 52025 × 52327 Cob length 25 X × XIX 18.09 52023 × 52603 Grain yield plant ⁻¹ 26 V × VI 17.89 52014 × 52285 Grain yield plant ⁻¹ 26 V × VI 17.89 52014 × 52285 Grain yield plant ⁻¹ 27 XVI × XX 17.58 52115 × 52250 100 grain weight 28 III × VI 17.52 52291 × 52285 Grain yield plant ⁻¹ 29 VII × XIII 17.50 52140 × 52040 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52552 ± 52115 Number of grains cob ⁻¹ 31 IX × XIX 16.56 52552 ± 52347 ± 5250 Grain yield plant ⁻¹ 52196 52219 - x 52603 Grain scob ⁻¹ 32 I × XX 16.35 52095 ± 52081 - x 52250 Number of grains cob ⁻¹ 33 VIII × XX 16.22 52234 × 5203 Number of grains cob ⁻¹ 34 XVIII × XIX 16.62 52237 × 52250 Cob length <td>21</td> <td>XII×XVII</td> <td>18.24</td> <td>PKVM-Shatak \times 52020</td> <td>Cob girth</td>	21	XII×XVII	18.24	PKVM-Shatak \times 52020	Cob girth
24 XVIII × XX 18.09 52234 × 52250 Number of grains cob ⁻¹ 25 X × XIX 18.09 52234 × 52250 Number of grains cob ⁻¹ 26 V × VI 17.89 52014 × 52285 Grain yield plant ⁻¹ 27 XVI × XX 17.58 52115 × 52250 100 grain weight 28 III × VI 17.52 522140 × 52240 Number of grains cob ⁻¹ 29 VII × XIII 17.50 52140 × 52040 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 52115 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 5215 Number of grains cob ⁻¹ 31 IX × XIX 16.56 52552 × 5215 Sumber of grains cob ⁻¹ 32 I × XX 16.35 52095 × 5219 -x 52250 Cob length 33 VIII × XX 16.22 5237 × 52250 Cob length 34 XVIII × XX 16.22 5224 × 5203 Number of grains cob ⁻¹ 35 V × XV 16.22 5224 × 5203 Number of grains cob ⁻¹ 36 X × XV 16.16 52115 × 5208	23	П×VШ	18.19	52025 × 52327	Cob length
25 X × XIX 1800 52623 × 52603 Grain yield plant ⁻¹ 26 V × VI 17.89 52014 × 52285 Grain yield plant ⁻¹ 27 XVI × XX 17.58 52115 × 52250 100 grain weight 28 III × VI 17.52 52291 × 52285 Grain yield plant ⁻¹ 29 VII × XII 17.50 52140 × 52040 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 52115 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 52115 Number of grains cob ⁻¹ 31 IX × XIX 16.56 52552 × 5215 Number of grains cob ⁻¹ 32 I × XX 16.35 52097 × 5250 Gob length 32 VIII × XX 16.35 52095 × 5219 × 5250 Cob length 33 VIII × XX 16.22 52237 × 52250 Cob length 34 XVIII × XX 16.22 52247 × 52250 Cob length 34 XVIII × XX 16.16 52115 × 52087 Cob ginth 35 V × XV 16.22 52014 × 5201 100 grain weight <td>24</td> <td>XVIII×XX</td> <td>18.14</td> <td>52234 × 52250</td> <td>Number of grains cob⁻¹</td>	24	XVIII×XX	18.14	52234 × 52250	Number of grains cob ⁻¹
26 V×VI 17.89 52014×52285 Grain yield plant ⁻¹ 27 XVI×XX 17.58 52115×52250 100 grain weight 28 III×VI 17.52 52291×52285 Grain yield plant ⁻¹ 29 VII×XII 17.50 52140×52040 Number of grains cob ⁻¹ 30 VI×XVI 16.60 52285×52115 Number of grains cob ⁻¹ 31 IX×XIX 16.56 52552 state state 32 I×XX 16.35 52095 x 52603 Grain yield plant ⁻¹ 32 I×XX 16.35 52057 state state 52196 52097 52337 x 52250 Number of grains cob ⁻¹ 33 VIII×XX 16.35 52095 x 52250 Cob length 34 XVIII×XX 16.22 52237×52250 Cob length 34 XVIII×XXI 16.16 52115×52087 Cob girth 37 XVII×XVII 16.16 52115×52087 Cob girth 38 VIII×XXII 16.06 52087×52234 Number of grains cob ⁻¹	25	X × XIX	18.09	52623 × 52603	Grain vield plant ¹
27 XVI×XX 17.58 52115×52250 100 grain weight 28 III×VI 17.52 52291×52285 Grain yield plant ⁻¹ 29 VII×XIII 17.50 52140×52040 Number of grains cob ⁻¹ 30 VI×XVI 16.60 52285×52115 Number of grains cob ⁻¹ 31 IX×XIX 16.56 52552 52347 52045 -x 52603 Grain yield plant ⁻¹ 32 I×XX 16.35 52095 -x 52045 - x 52200 Number of grains cob ⁻¹ 32 I×XX 16.35 52095 -x 52250 52095 - x 52205 Cob length 33 VIII×XX 16.22 52234×5200 Number of grains cob ⁻¹ 52081 52095 - x 52250 Cob length 34 XVIII×XXIX 16.22 5224×52003 Number of grains cob ⁻¹ 35 V×XV 16.22 52087 Cob girth 36 XVII×XVII 16.16 52115×52087 Cob girth <tr< td=""><td>26</td><td>V×VI</td><td>17.89</td><td>52014 × 52285</td><td>Grain vield plant⁻¹</td></tr<>	26	V×VI	17.89	52014 × 52285	Grain vield plant ⁻¹
28 III × VI 17.52 52291 × 52285 Grain yield plant ⁻¹ 29 VII × XIII 17.52 52291 × 52285 Grain yield plant ⁻¹ 30 VI × XVI 16.60 52285 × 52115 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 52115 Number of grains cob ⁻¹ 31 IX × XIX 16.56 52552 52597 52353 - x 52603 Grain yield plant ⁻¹ 32 I × XX 16.35 52095 52091 52095 - x 52250 Number of grains cob ⁻¹ 33 VIII × XX 16.32 52297 × 52250 Cob length 34 XVIII × XX 16.22 52237 × 52250 Cob length 34 XVIII × XIX 16.22 5224 × 52603 Number of grains cob ⁻¹ 35 V × XV 16.22 52087 Cob length 36 XVII × XIX 16.22 52087 Cob grain weight 36 XVII × XVII 16.16 52115 × 52087 Cob girth 37 XVII × XVIII 16.06 52087 × 52234 Number of grains cob ⁻¹ 38 VIII × XX 15.86 52040 ×	20	XVI×XX	17.59	52115 × 52250	100 grain weight
29 VII × XII 17.50 52140 × 52040 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 52115 Number of grains cob ⁻¹ 31 IX × XIX 16.56 52552 - x 52603 Grain yield plant ⁻¹ 32 I × XX 16.56 52552 - x 52603 Grain yield plant ⁻¹ 32 I × XX 16.35 52095 - x 52250 Number of grains cob ⁻¹ 33 VII × XX 16.35 52095 - x 52250 Cob length 34 XVIII × XX 16.22 52327 × 52250 Cob length 34 XVIII × XIX 16.22 52219	28	Ш×VI	17.50	52291 × 52285	Grain vield plant ⁻¹
25 VI × XVI 16.50 52285 × 52115 Number of grains cob ⁻¹ 30 VI × XVI 16.60 52285 × 52115 Number of grains cob ⁻¹ 31 IX × XIX 16.56 52552 $x 52603$ Grain yield plant ⁻¹ 32 I × XX 16.35 52095 $x 522045$ $x 5220045$ $x 5220045$ 32 I × XX 16.35 52095 $x 52250$ Number of grains cob ⁻¹ 33 VIII × XX 16.35 52095 $x 52250$ Cob length 34 XVIII × XX 16.22 52237 × 52250 Cob length 34 XVIII × XIX 16.22 52234 × 52003 Number of grains cob ⁻¹ 35 V × XV 16.22 52014 × 52201 100 grain weight 36 XVI × XVII 16.16 52115 × 52087 Cob grith 37 XVII × XVII 16.06 52087 × 52234 Number of grains cob ⁻¹ 38 VIII × XXI 15.86 52040 × 52250 Number of grains cob ⁻¹ 38 VIII × XXI 15.86 52040 × 52250 Number of grains cob ⁻¹ 39	29	VII×XIII	17.50	52140×52040	Number of grains cob ⁻¹
21 XXX 16.56 52180 52497 52347 52045 x 52603 Grain yield plant ⁻¹ 31 IX × XIX 16.56 525525234752045 - x 52603 Grain yield plant ⁻¹ 32 I × XX 16.35 52095520955209552095 - x 52250 Number of grains cob ⁻¹ 33 VIII × XX 16.35 $520955209552199 - x 52250 Cob length 34 XVIII × XIX 16.22 5234 \times 52603 Number of grains cob-1 35 V × XV 16.22 52014 \times 52201 100 grain weight 36 XVI × XVII 16.16 52115 \times 52087 Cob girth 37 XVII × XVII 16.06 52087 \times 52234 Number of grains cob-1 38 VIII × XXI 15.86 52040 \times 52250 Number of grains cob-1 39 XIII × XX 15.84 52623 \times 52201 Grain yield plant-1$	30	VI×XVI	16.60	52285 × 52115	Number of grains cob ⁻¹
31 IX × XIX 16.56 52497 52552 52347 $52045 x 52603 Grain yield plant-1 32 I × XX 16.35 521965259752353 -x 52250 Number of grains cob-1 32 I × XX 16.35 520955208152065 -x 52250 Number of grains cob-1 33 VIII × XX 16.22 52327 \times 52250 Cob length 34 XVIII × XIX 16.22 52327 \times 52250 Cob length 35 V × XV 16.22 52044 \times 52201 100 grain weight 36 XVI × XVII 16.16 52115 \times 52087 Cob girth 37 XVII × XVII 16.06 5227 \times 52234 Number of grains cob-1 38 VIII × XX 15.86 52040 \times 52250 Number of grains cob-1 39 XIII × XX 15.86 52040 \times 52250 Number of grains cob-1 40 X × XV 15.84 52623 \times 52201 Grain yield plant-1 $	50		10.00	52180	
31 IX × XIX 16.56 52552 $-x 52603$ Grain yield plant ⁻¹ 32 I × XX 16.35 52196 52597 52353 $-x 52250$ Number of grains cob ⁻¹ 32 I × XX 16.35 52095 $-x 52250$ Number of grains cob ⁻¹ 33 VIII × XX 16.35 52095 $-x 52250$ Cob length 34 XVIII × XIX 16.22 52234×52603 Number of grains cob ⁻¹ 35 V × XV 16.22 52014×52201 100 grain weight 36 XVI × XVII 16.16 52115×52087 Cob girth 37 XVII × XVIII 16.06 5227×52250 Number of grains cob ⁻¹ 38 VIII × XVI 16.04 5227×52234 Number of grains cob ⁻¹ 39 XIII × XX 15.86 52040×52250 Number of grains cob ⁻¹ 40 X × XV 15.84 52623×52201 Grain yield plant ⁻¹				52497	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	31	IX×XIX	16.56	52552 — x 52603	Grain yield plant ⁻¹
$52045 \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \ \$				52347	
32 $I \times XX$ 16.35 $\begin{array}{c} 52196\\ 52597\\ 52353\\ 52095\\ 52081\\ 52065\\ 52219\\ 52220\\ 100 \text{ grain s cob}^{-1}$ 33VIII $\times XX$ 16.22 52327×52250 Cob length34XVII $\times XVII$ 16.16 52115×52087 Cob girth35V $\times XV$ 16.22 52087×52234 Number of grains cob^{-1}36XVI $\times XVII$ 16.06 52087×52234 Number of grains cob^{-1}38VIII $\times XVII$ 16.04 52327×52115 Cob girth39XIII $\times XX$ 15.86 52040×52250 Number of grains cob^{-1}40 $X \times XV$ 15.84 52623×52201 Grain yield plant^1				52045	
32 $I \times XX$ 16.35 52097 $523535209552081520655221952219-x 52250Number of grains cob-133VIII \times XX16.2252327 \times 52250Cob length34XVIII \times XIX16.2252327 \times 52250Cob length35V \times XV16.2252014 \times 52201100 grain weight36XVI \times XVII16.1652115 \times 52087Cob girth37XVII \times XVII16.0652087 \times 52234Number of grains cob-138VIII \times XVI16.0452327 \times 52115Cob girth39XIII \times XX15.8652040 \times 52250Number of grains cob-140X \times XV15.8452623 \times 52201Grain yield plant-1$				52196	
32I \times XX16.3552353 52095 52081 52065 52219 52219-x 52250Number of grains cob ⁻¹ 33VIII \times XX16.2252327 \times 52250Cob length34XVIII \times XIX16.2252327 \times 522603Number of grains cob ⁻¹ 35V \times XV16.2252014 \times 52001100 grain weight36XVI \times XVII16.1652115 \times 52087Cob girth37XVII \times XVII16.0652087 \times 52234Number of grains cob ⁻¹ 38VIII \times XVI16.0452327 \times 52115Cob girth39XIII \times XX15.8652040 \times 52250Number of grains cob ⁻¹ 40X \times XV15.8452623 \times 52201Grain yield plant ⁻¹				52597	
32 I × XX16.35 52095 52081 52065 52219 52219 -x 52250Number of grains cob ⁻¹ 33 VIII × XX16.22 52327×52250 Cob length 34 XVIII × XIX16.22 52234×52603 Number of grains cob ⁻¹ 35 V × XV16.22 52014×52201 100 grain weight 36 XVI × XVIII16.16 52115×52087 Cob girth 37 XVII × XVIII16.06 52087×52234 Number of grains cob ⁻¹ 38 VIII × XVI16.04 52327×52115 Cob girth 39 XIII × XX15.86 52040×52250 Number of grains cob ⁻¹ 40 X × XV15.84 52623×52201 Grain yield plant ⁻¹				52353	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$	32	$I \times XX$	16.35	52095 —x 52250	Number of grains cob ⁻¹
$ \begin{array}{c ccccccccccccccccccccccccccccccccccc$				52081	
$\begin{array}{c ccccccccccccccccccccccccccccccccccc$				52065	
522195221933VIII × XX16.2252327 × 52250Cob length34XVIII × XIX16.2252234 × 52603Number of grains cob^{-1} 35V × XV16.2252014 × 52201100 grain weight36XVI × XVII16.1652115 × 52087Cob girth37XVII × XVIII16.0652087 × 52234Number of grains cob^{-1} 38VIII × XVI16.0452327 × 52115Cob girth39XIII × XX15.8652040 × 52250Number of grains cob^{-1} 40X × XV15.8452623 × 52201Grain yield plant ⁻¹				52219	
33VIII × XX16.22 52327×52250 Cob length34XVIII × XIX16.22 52234×52603 Number of grains cob ⁻¹ 35V × XV16.22 52014×52201 100 grain weight36XVI × XVII16.16 52115×52087 Cob girth37XVII × XVIII16.06 52087×52234 Number of grains cob ⁻¹ 38VIII × XVI16.04 52327×52115 Cob girth39XIII × XX15.86 52040×52250 Number of grains cob ⁻¹ 40X × XV15.84 52623×52201 Grain yield plant ⁻¹				52219	
34 XVIII × XIX 16.22 52234×52603 Number of grains cob ⁻¹ 35 V × XV 16.22 52014×52201 100 grain weight 36 XVI × XVII 16.16 52115×52087 Cob girth 37 XVII × XVIII 16.06 52087×52234 Number of grains cob ⁻¹ 38 VIII × XVI 16.04 52327×52115 Cob girth 39 XIII × XX 15.86 52040×52250 Number of grains cob ⁻¹ 40 X × XV 15.84 52623×52201 Grain yield plant ⁻¹	33	VIII×XX	16.22	52327×52250	Cob length
35 $V \times XV$ 16.22 52014×52201 100 grain weight 36 $XVI \times XVII$ 16.16 52115×52087 Cob girth 37 $XVII \times XVII$ 16.06 52087×52234 Number of grains cob ⁻¹ 38 $VIII \times XVI$ 16.04 52327×52115 Cob girth 39 $XIII \times XX$ 15.86 52040×52250 Number of grains cob ⁻¹ 40 $X \times XV$ 15.84 52623×52201 Grain yield plant ⁻¹	34	XVIII×XIX	16.22	52234×52603	Number of grains cob ⁻¹
36 XVI×XVII 16.16 52115×52087 Cob girth 37 XVII×XVIII 16.06 52087×52234 Number of grains cob ⁻¹ 38 VIII×XVI 16.04 52327×52115 Cob girth 39 XIII×XX 15.86 52040×52250 Number of grains cob ⁻¹ 40 X×XV 15.84 52623×52201 Grain yield plant ⁻¹	35	V×XV	16.22	52014×52201	100 grain weight
37 XVII \times XVIII 16.06 52087 \times 52234 Number of grains cob ⁻¹ 38 VIII \times XVI 16.04 52327 \times 52115 Cob girth 39 XIII \times XX 15.86 52040 \times 52250 Number of grains cob ⁻¹ 40 X \times XV 15.84 52623 \times 52201 Grain yield plant ⁻¹	36	XVI×XVII	16.16	52115×52087	Cob girth
38 VIII × XVI 16.04 52327×52115 Cob girth 39 XIII × XX 15.86 52040×52250 Number of grains cob ⁻¹ 40 X × XV 15.84 52623×52201 Grain yield plant ⁻¹	37	XVII×XVIII	16.06	52087×52234	Number of grains cob ⁻¹
39XIII \times XX15.8652040 \times 52250Number of grains cob ⁻¹ 40X \times XV15.8452623 \times 52201Grain yield plant ⁻¹	38	VIII×XVI	16.04	52327×52115	Cob girth
40 $X \times XV$ 15.8452623 × 52201Grain yield plant ⁻¹	39	XIII×XX	15.86	52040×52250	Number of grains cob ⁻¹
	40	X×XV	15.84	52623×52201	Grain yield plant ⁻¹

Table 8. Selection of cluster combinations, potential parents and cross combination on the basis of genetic diversity

			326	
41	VI×XIV	15.57	52285×52020	Grain yield plant ⁻¹
42	IV×VIII	15.56	52202×52327	Cob length
43	VII×XVIII	15.03	52140 × 52234	Number of grains cob^{-1}
15		1/1 92	52140×52087	100 grain weight
 //5		14.00	52285 × 52623	Cob girth
45		14.90	52265 × 52025	Cooling and a least
40		14.87	52527 × 52625	Grain yield plant
4/	V×XIII	14.83	52014×52040	Grain yield plant
48	VII×XI	14.82	52140×52196	Cob girth
49	VIII×XVIII	14.69	52327×52234	Number of grains cob ⁻¹
50	VIII×XV	14.56	52327×52201	Grain yield plant ⁻¹
51	II×XII	14.47	52025 × PKVM-Shatak	Cob girth
52	V×XII	14.44	52014×PKVM-Shatak	Cob girth
53	$XII \times XIII$	14.25	PKVM-Shatak × 52040	Cob girth
54	IV×VI	14.20	52202×52285	Number of grains cob ⁻¹
55	XV×XIX	14.03	52201 × 52603	Grain vield plant ⁻¹
55 56	VI×VII	13.79	52285 × 52140	Cob length
50 57		13.69	52265×52140	Grain viold plant ⁻¹
50	$\mathbf{A}\mathbf{I}\mathbf{I}\mathbf{I}\wedge\mathbf{A}\mathbf{I}\mathbf{A}$ $\mathbf{V}\mathbf{I}\mathbf{V}\mathbf{I}\mathbf{V}\mathbf{I}\mathbf{V}$	12.00	52106 × 52003	
38 50		13.07	52190 × 52003	Grain yield plant
59	$III \times X$	13.59	52291×52623	Cob girth
			52196	
			52597	
			52353	
60	$I \times XIX$	13.57	52095 — x 52603	Grain yield plant ⁻¹
			52081	
			52065	
			52219	
			52263	
61	VIII×XI	13.56	52327 × 52196	100 grain weight
6		13.50	52327×52190	Cob girth
62		13.27	52327 × 52087	Number of croins och-
00		12.92	52265 × 52067	Number of grains cod
64	$\mathbf{III} \times \mathbf{V}$	12.84	52291×52014	Cob girth
65	$IV \times V$	12.81	52202×52014	Number of grains cob ⁻¹
66	XIII×XVI	12.65	52040×52115	Number of grains cob ⁻¹
67	VII×XIV	12.51	52140×52020	Grain yield plant ⁻¹
			52180	
			52497	
68	IX×IV	12.51	52552 x 52202	Number of grains cob ⁻¹
			52347	C
			52045	
69	XV×XVII	12 50	52201 × 52087	Grain vield plant ⁻¹
70	V×VIII	12.50	52017×52307	Cob girth
70		12.40	52014×52527	Number of grains coh-
/1 70		12.40	52040×52254	Coh longth
12		12.27	52291 × 52140	
13	VII×X	12.21	52140×52623	Grain yield plant ¹
74	X×XII	12.19	52623 × PKVM-Shatak	Cob girth
			52180	
			52497	
75	$IX \times XI$	12.18	52552 × 52196	Number of grains cob ⁻¹
			52347	
			52045 <u> </u>	
			52180	
			52497	
76	$IX \times XV$	12.07	52552×52201	Number of grains cob-1
10		12.07	52352 × 52201	runnoer of grands coo
			52045	
			52190 -	
			52180	
		11.00	5249/	a
77	IX×III	11.99	52552 -× 52291	Grain yield plant ⁻¹
			52347	
			52045 _	

			327	
78	XII×XV	11.81	PKVM-Shatak × 52201	Cob girth
79	$III \times XVI$	11.74	52291×52115	Grain yield plant ⁻¹
			52180	
			52497	
80	$IX \times XII$	11.60	52552 $\rightarrow \times \text{PKVM-Shatak}$	Grain yield plant ⁻¹
			52347	
			52045 -	
81	V×XX	11.57	552014×52250	Grain yield plant ⁻¹
82	XII×XVI	11.51	PKVM-Shatak × 52115	Cob girth
83	IV×XII	11.50	52202 × PKVM-Shatak	Cob girth
			52180	
04	11 7 1 7	11.20	52497	
84	$\mathbf{IX} \times \mathbf{V}$	11.39	52552 - x 52014	Number of grains cob ⁻¹
			52347	
05		11.21	$52045 \rightarrow$	Crain wield alout a
ແ		11.51	52014 × 52020	Grain yield plant
80 07		11.25	52202 × 52140	Number of croins ach-
0/		11.10	52014 × 52087	Number of grains cob ⁻¹
00 90	$\mathbf{III} \times \mathbf{A} \mathbf{V} \mathbf{III}$ $\mathbf{III} \times \mathbf{V} \mathbf{IV}$	11.13	52291 × 52254	Grain viald plant ⁻¹
07	$\mathbf{M} \times \mathbf{A} \mathbf{A}$ $\mathbf{V} \times \mathbf{V} \mathbf{M}$	11.13	52106 × 52005	100 grain weight
50 01		10.02	52170 × 52087	Cob girth
00	VI ~ XV	10.92	52285 × 52201	Number of grains cob ⁻¹
92	VIAAV	10.90	52180 7	Number of grains coo
			52497	
93	IX×XVII	10.89	52552 - x 52087	Grain vield plant ⁻¹
			52347	J F
			52045	
94	VIII×XIII	10.85	52327×52040	Cob length
95	IV×X	10.84	52202×52623	Cob length
			52180	C
			52497	
96	$IX \times II$	10.83	52552 — x 52025	100 grain weight
			52347	
			52045 _	
97	$X \times XIII$	10.81	52623×52040	Number of grains cob ⁻¹
			52180	
			52497	
98	IX×VII	10.81	52552 - x 52140	Grain yield plant ⁻¹
			52347	
			52045	
99	XI×XIV	10.73	52196×52020	Number of grains cob ⁻¹
			52180	
100		10.72	52497 52552 - 52250	Grain viold alont-
100	ΙΛΧΛΛ	10.72	52332 $- x 52230$	Grain yield plant.
			52045	
			J20 1 J 	

the present study all possible combinations beyond the mean inter-cluster distance (D = 10.70) formed from different clusters have been arranged in descending order of magnitude of genetic distance and promising hundred cluster combinations are presented in table 8. Other practical considerations like grain yield plant⁻¹, days to 50% tasseling, number of grains cob⁻¹, plant height and cob length were also taken into account while choosing the genotypes from the selected cluster combinations, which can be crossed in diallel fashion to obtain superior cross combinations.

Based on the above mentioned criteria 28 genotypes *viz.*, 52202, 52623, 52025, 52201, 52014, 52291, 52087, 52115, 52196, 52020, 52140, 52327, 52285, 52180, 52497, 52552, 52347, 52045, 52597, 52353, 52095, 52081, 52065, 52219, 52263, 52250, 52603 and 52040 were identified to be used as parents for hybridization programme, which were suggested to be crossed in diallel fashion to obtain superior cross combinations. PKVM-Shatak as it is in separate cluster and distant from other clusters can be further improved to produce new hybrid by crossing with parents 52250, 52020, 52087, 52025, 52014, 52040, 52623, 52201, 52180, 52552, 52115 and 52202.

REFERENCES

- Akhi, A.H., S. Ahmed, A.N.M.S. Karim, F. Begum and M.M. Rohman, 2017. Genetic divergence of exotic inbred lines of maize (*Zea mays L.*). Bangladesh J. Agril. Res. 42(4) : 665-671.
- Bhatt, G.M. 1970. Multivariate analysis approach to selection of parents for hybridization aiming at in the improvement in self pollinated crop. Aust. J. agric. Res. 21 : 1-7.
- Mahalanobis, P.C. 1936. On the generalized distance in statistics. Proc. Nat. Inst. Sci. India, **12** : 49-55.
- Murty, B.R. and V. Arunachalam. 1966. The nature of divergence in relation to breeding system in some crop plants. Indian J. Genet. **26** : 188-198.
- Pandit, M.B., S.U. Charjan, S.R. Kamdi, S.R. Patil, P.Z. Rahangdale, M. K. Moon and D.Y. Upadhyay, 2019. Performance of double cross hybrids in maize (*Zea mays L.*) J. Soils and Crops, **29** (1): 146-151
- Rahangdale, P.Z., S.R. Kamdi, S.R. Patil, R.D. Deotale, M.B. Pandel,
 D.Y. Upadhyay and G.A. Kankal, 2019. Generation mean analysis in maize (*Zea mays L.*) J. Soils and crops 29(1) : 126:130
- Rao, C.R. 1952. Advanced statistical methods in biometric research. End. L, John Wiley and Sons, Inc. New York.
- Varaprasad, B.V. and D. Shivani, 2017. Genotype clustering of maize (Zea mays L.) germplasm using Mahalanobis D²satistic. J. Global Biosci. 6(2) : 4776-4783.

Rec. on 20.08.2019 & Acc. on 28.08.2019