Journal of Cereal Research
Volume 14 (2): 189-197
Homepage: http://epubs.icar.org.in/ejournal/index.php/JWR
Research Article

Combining ability study on yield and its contributing traits in maize (*Zea mays* L.)

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Article history:
Received: 27 Apr., 2022
Revised: 16 Sept., 2022
Accepted: 09 Oct., 2022

Citation:
Sharma P and U Chandel. 2022. Combining ability study on yield and its contributing traits in maize (*Zea mays* L.). *Journal of Cereal Research* ***14 (2):*** *189-197. http://doi.org/10.25174/2582-2675/2022/131247*

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Abstract

Experimental material consisted of 25 lines, 2 testers and their 50 crosses along with standard checks *viz.,* Palam Sankar Makka-2 and PSCL 4640 were evaluated using Randomized Block Design with two replication during *Kharif* 2020. Genotype mean square was significant for days to 50% tasseling, days to 50% silking, days to 75% brown husk, ear height (cm), plant height (cm), ear length (cm), ear circumference (cm), kernel rows/cob, kernels/row, 1000-kernel weight (g), shelling (%) and grain yield (q/ha) which indicated the presence of sufficient genetic variability in the material studied. Also the ratio of GCA variance to SCA variance was less than unity for all traits indicated preponderance of non-additive gene action. Among lines, KI-3 exhibited higher grain yield followed by KI-7 and CML 140. These lines also exhibited highest significant GCA effect for grain yield and were identified as promising parents. KI-7 × LM 13, CML 140 × LM 13, CML 139 × LM 13, CML 162 × LM 13 and KI-3 × LM 14 exhibited maximum SCA effect for most of traits. These promising cross combinations need to be evaluated in multi-location trials over the years to assess their suitability in different agro-climatic zones of the State.

Keywords: Maize, GCA, SCA, Combining ability, gene action

1. Introduction

Maize (*Zea mays* L.) is the world's third largest grain crop after wheat and rice mainly grown in temperate highlands, tropical as well as in sub-tropical regions. Maize (2n=20) is a C_4 plant which belongs to tribe *Maydae* of family *Poaceae.* It is a highly cross pollinated crop due to which special efforts are required to maintain its genetic purity. It is a tall, monoecious, short day plant having determinate type of growth habit. Development of hybrids in maize includes various steps that starts with development of inbred lines, their evaluation, crossing selected inbred lines and hybrid production. Selection of right inbred line will lead to production of superior hybrids. For this detailed evaluation of existing germplasm/newly developed elite lines for their potential use in future breeding programmes is required. Combining ability is the measure of the genotype values based on their progeny performance in a definite mating system (Allard, 1960). Combining ability analysis help in selection of most promising parents which can produce superior hybrids when a number of lines are involved. It helps in understanding the nature and magnitude of gene action involved. The nature of gene action involved may be additive and additive × additive which is due to general combining ability or it may be non-additive which is due to specific combining ability. The nature of gene action is important factor in determining effective breeding programme. The presence of non-additive gene action is pre requisite for hybrid development programme. Various statistical tools are available to estimate combining ability. Line × Tester analysis method as developed by Kempthorne in 1957, is used in most breeding programmes as it allows estimation of combining ability, gene effect studies and selection of desirable parents and crosses. Since there is no information available on combining ability and gene action of the newly developed maize inbreds, therefore the present investigation was undertaken involving 25 lines, 2 testers and their 50 crosses along with 2 standard checks to estimate combining ability and gene action involved.

2. Material And Methods

Experimental material consisted of 25 lines, two testers and their 50 hybrids along with two standard checks *viz.,* Palam Sankar Makka-2 and PSCL 4640 were evaluated in a Randomized Block Design during *Kharif* 2020 with an objective to understand the nature of gene actions involved in inheritance of different traits and estimate combining ability effects for yield and its contributing traits. List of inbred lines, testers and standard checks used is presented in Table 1. The genotypes were evaluated at Experiment Farm, Shivalik Agriculture Research and Extension Centre, Kangra for various maturity, physiological, yield and its contributing characters. Observations were recorded based upon the performance of 10 competitive plants and average was worked out except for days to 50% tasseling, days to 50% silking and days to 75% brown husk, observations were recorded on plot basis. Standard package of practices were followed and plant protection measures were taken whenever required. The results obtained were subjected to statistical analysis as per method suggested by Kempthorne, 1957 and Panse and Sukhatme, 1984.

Table 1: Details of inbred lines and testers used as parents along with checks

Symbol/Code	Inbred line	Source/Pedigree
	A) Lines	
L_1	CML 33	ICAR-IIMR, WNC, Hyderabad
L_2	CML 117	--do--
L_3	CML 138	--do--
L_4	CML 139	--do--
L_5	CML 140	--do--
L_6	CML 162	--do--
L_7	CML 163	--do--
L_8	CML 292	--do--
L_9	CML 295	--do--
L_{10}	CML 338	--do--
L_{11}	CML 411	--do--
L_{12}	CML 426	--do--
L_{13}	CML 439	--do--
L_{14}	CML 451	--do--
L_{15}	CML 452	--do--
L_{16}	CML 494	--do--
L_{17}	CM 212	VPKAS, Almora
L_{18}	V 335	--do--
L_{19}	V 340	--do--
L_{20}	V 405	--do--

L_{21}	HKI-1040	ICAR-IIMR, Karnal
L_{22}	HKI-1105	--do--
L_{23}	CM 502	--do--
L_{24}	KI-3	CML161/CML165-B-B-B-4-B-B
L_{25}	KI-7	CML165-B-B-B-1-B-B
	B) Testers	
T_1	LM 13	PAU, Ludhiana
T_2	LM 14	--do--
	C) Checks	
C_1	Palam Sankar Makka-2	CSKHPKV, Palampur
C_2	PSCL 4640	Bayers

3. Result and Discussions

The analysis of variance for twelve characters of twenty five lines, two testers and their fifty crosses under study is presented in Table 4.1. Genotype mean square was significant for all traits which indicated presence of sufficient amount of genetic variability among genotypes. Similar results were also obtained earlier by Petrovic et al. (1998); Alam et al. (2008); Patil et al. (2012). Mean squares was further partitioned into crosses mean square, parent mean square and crosses vs parent mean square.

Crosses mean square was significant for most characters under study except shelling (%) indicated wider difference among crosses and hence possibility of selection for identification of desired crosses. Among parents, mean square due to lines was found to be significant for all traits except for shelling (%), whereas, mean square due to testers was found to be significant for most characters except for days to 50% silking, days to 50% tasseling, shelling (%) and days to 75% brown husk indicated presence of sufficient genetic variability among parents. Similar results were reported by Ram *et al.* (2015); Patil *et al.* (2012); Negi *et al.* (2018); Chandel *et al.* (2019).

Analysis of Variance for combining ability revealed that variance due to lines was greater than variance due to testers for kernel rows/cob, days to 50% tasseling, days to 50% silking, days to 75% brown husk, shelling (%) and grain yield. This indicated greater contribution of lines towards GCA. Whereas, variance due to testers was found greater than variance due to lines for ear height, plant height, ear length, ear circumference, kernels/row and 1000-kernel weight indicated greater contribution of testers towards GCA. Also GCA variance to SCA variance ratio was less than unity for all traits expressing greater importance of non-additive gene effects. This also highlighted the utilization of hybrid breeding scheme for enhancing productivity.

Estimates of GCA effect revealed that none of the lines and testers had proved significant for all traits studied. L_5, L_{24}, L_{25} were overall good general combiners ability for most characters studied. L_5 exhibited highest GCA effect for ear circumference, kernel rows/cob, kernels/row, 1000-kernel weight and grain yield. Also, lines *viz.,* L_6 and L_3 had highest GCA effect for days to 50% tasseling and days to 50% silking. L_{25} exhibited highest GCA effect for ear height, plant height and ear length. L_{24} exhibited significant GCA effects for all characters studied except ear height and plant height. Among testers, T_1 was good general combiner for ear length, kernel rows/cob, ear circumference, 1000-kernel weight, grain yield and kernels/row, whereas, T_2 was good general combiner for plant height, ear height. Iqbal *et al.* (2007); Reddy *et al.* (2011); Patil *et al.* (2012); Chaurasia *et al.* (2020) had also reported good general combiners for similar traits.

Studies on specific combining ability indicated that none of the crosses had proved significant for all traits. Possible combinations of parental GCA effect such as "high × high", "high × low", "average × low", "low × low" and "low × high" were involved in crosses with high SCA effect. This indicated presence of non-additive gene effect, especially in "high × low", "average × low" and "low × low" cross combinations. Studies on specific combining ability indicated that $L_{25} \times T_1$ exhibited highest combining ability for grain yield (high × high) and ear circumference (high × high), $L_{24} \times T_2$ exhibited highest combining ability

Table 2: Analysis of variance for yield and its contributing traits (maturity, physiological, yield and its contributing traits)

Characters	Replication	Genotypes	Cross	Line	Tester	Line × tester	Parents	Crosses v Parent	Error
Degree of freedom	1	76	49	24	1	24	26	1	76
Days to 50% tasseling	30.02	15.99**	9.81**	17.54**	0.36	2.48**	17.99**	266.53**	1.11
Days to 50% silking	30.91	16.71**	10.59**	18.27**	0.49	3.34**	16.97**	315.35**	1.59
Days to 75% brown husk	43.66	27.33**	24.04**	41.70**	4.84	7.17**	19.09**	403.05**	1.66
Ear height (cm)	0.52	644.78**	67.53**	57.03**	252.81**	70.31**	403.39**	35205.94**	16.90
Plant height (cm)	27.43	2437.07**	236.77**	210.06**	948.64**	233.82**	1470.38**	135386.11**	44.07
Ear length (cm)	1.14	24.83**	2.91**	2.80**	10.11**	2.73**	7.78**	1541.65**	0.16
Ear circumference (cm)	0.24	4.70**	1.09**	1.12**	2.99**	0.98**	1.46**	266.00**	0.03
Kernel rows per cob	0.18	9.17**	1.81**	2.12**	3.02**	1.46**	2.44**	544.84**	0.08
Kernels per row	2.67	71.25**	34.04**	33.13**	88.54**	32.68**	22.86**	3152.55**	0.31
1000-kernel weight (g)	68.88	5989.69**	865.57**	875.09**	1883.56**	813.64**	1830.20**	365218.39**	20.21
Shelling (%)	30.91	28.22**	12.76	16.89	4.36	8.98	28.74**	772.52**	11.24
Yield (q/ha)	14.61	1275.20**	136.90**	151.75**	387.53**	111.61**	365.00**	80717.22**	2.62

* significant at 5% level; ** significant at 1% level

Table 3: Analysis of variance for combining ability (maturity, physiological, yield and its contributing traits)

Source of Variation	Days to 50% tasseling	Days to 50% silking	Days to 75% brown husk	Ear height (cm)	Plant height (cm)	Ear length (cm)	Ear circum-ference (cm)	Kernel rows/ cob	Kernels/ row	1000-kernel weight	Shelling (%)	Grain Yield (q/ha)
σ^2l	3.76	3.73	8.63	-3.31	-5.94	0.01	0.03	0.16	0.11	15.36	1.97	10.03
σ^2 t	-0.04	-0.05	-0.04	3.65	14.29	0.14	0.04	0.03	1.11	21.38	-0.09	5.51
σ^2 gca	0.09	0.09	0.22	-0.03	0.04	0.00	0.00	0.00	0.01	0.69	0.05	0.34
σ^2 sca	0.60	0.81	2.68	27.18	95.64	1.28	0.47	0.68	16.21	395.52	3.20	53.95
σ^2 gca/ σ^2 sca	0.162	0.119	0.084	-0.001	0.000	0.002	0.003	0.007	0.001	0.002	0.016	0.006

Table 4: Estimates of general combining ability (maturity, physiological, yield and its contributing traits)

	Days to 50% tasseling	Days to 50% silking	Days to 75% brown husk	Ear height (cm)	Plant height (cm)	Ear length (cm)	Ear circum-ference (cm)	Kernel rows /cob	Kernels/ row	1000-kernel weight (g)	Shelling (%)	Grain yield (q/ ha)
Lines												
L_1	1.47 *	1.61 *	3.02 **	-3.89	-6.85 *	-0.49 *	0.35 **	0.66 **	0.83 **	13.24 **	-1.18	3.38 **
L_2	1.22 *	1.36 *	1.52 *	-6.39 **	-12.10 **	0.01	0.26 **	0.46 **	1.01 **	6.99 **	-0.08	2.58 **
L_3	-3.78 **	-3.64 **	-4.98 **	-3.14	-5.10	0.54 *	0.68 **	0.71 **	3.38 **	16.49 **	2.95 **	5.98 **
L_4	-0.28	-0.64	-1.98 **	-2.39	-6.85 *	0.89 **	0.78 **	1.11 **	4.13 **	18.74 **	-1.78 *	8.83 **
L_5	-0.28	-0.39	-0.98	0.36	2.15	1.34 **	1.00 **	1.46 **	5.48 **	24.99 **	-1.00	11.16 **
L_6	-3.78 **	-3.64 **	-6.98 **	2.61	6.65 *	0.96 **	0.63 **	0.51 **	3.91 **	10.99 **	1.07	6.44 **
L_7	-3.03 **	-3.64 **	-5.98 **	1.86	1.90	-0.41 *	-0.10	0.46 **	0.61 *	6.99 **	2.50 **	1.96 *
L_8	-3.03 **	-2.89 **	-2.98 **	-0.14	3.90	-0.74 **	-0.25 *	-0.24	-1.09 **	-5.76 *	0.35	-2.29 *
L_9	-0.03	-0.14	1.02	0.36	-2.10	-0.01	0.16	0.06	0.43	5.49 *	-2.15 **	1.44
L_{10}	0.72	0.36	1.02	-7.39 **	-14.10 **	-0.46 *	-0.57 **	-0.74 **	-2.42 **	-14.76 **	-0.40	-5.55 **
L_{11}	3.47 **	3.61 **	5.02 **	-5.14 *	-9.10 **	-0.06	-0.07	-0.29	-1.24 **	-3.01	1.00	-2.42 *
L_{12}	0.97	0.86	1.02	1.61	6.40	-0.44 *	-0.12	-0.24	-1.27 **	-3.01	0.10	-2.80 **
L_{13}	3.97 **	4.36 **	6.02 **	-5.89 **	-9.85 **	-0.76 **	-0.52 **	-0.64 **	-1.79 **	-13.51 **	1.90 *	-6.20 **
L_{14}	1.47 *	1.36 *	2.02 **	2.61	0.15	-0.39	-0.30 **	-0.24	-1.39 **	-2.26	2.92 **	-2.93 **
L_{15}	-0.78	-0.89	0.02	3.36	7.15 *	-0.91 **	-0.27 **	-0.44 **	-1.59 **	-10.51 **	-1.23	-3.17 **
L_{16}	-0.28	-0.64	-1.98 **	0.86	0.15	-0.84 **	-0.12	-0.49 **	-1.72 **	-10.01 **	1.92 *	-2.81 **
L_{17}	-0.03	-0.14	1.02	0.36	-0.10	1.04 **	0.31 **	-0.04	1.88 **	10.99 **	0.62	3.13 **
L_{18}	0.72	1.11	3.02 **	2.86	4.65	-0.56 **	-0.15	0.16	-1.39 **	-4.51	-3.90 **	-2.22 *
L_{20}	-0.28	-0.14	0.02	4.11 *	8.40 *	-0.39	-0.54 **	-0.84 **	-3.42 **	-18.51 **	-1.43	-5.74 **
L_{21}	-1.53 **	-1.14	-1.98 **	-0.64	0.15	-0.46 *	-0.62 **	-0.89 **	-3.57 **	-20.26 **	2.22 **	-7.69 **
L_{22}	0.72	0.61	2.02 **	2.61	6.40	-0.94 **	-0.90 **	-1.14 **	-3.84 **	-22.26 **	-3.43 **	-9.89 **
L_{23}	3.22 **	3.36 **	2.02 **	5.86 **	10.90 **	-0.34	-0.67 **	-0.94 **	-3.72 **	-21.01 **	-3.75 **	-7.90 **
L_{24}	-2.03 **	-1.89 **	-3.98 **	-0.39	-2.60	1.66 **	0.70 **	1.06 **	4.88 **	23.99 **	2.22 **	11.14 **

L_{25}	-0.78	-0.39	1.02	7.36 **	13.40 **	1.96 **	0.71 **	1.01 **	3.93 **	20.24 **	1.50	9.32 **
						Testers						
T_1	0.06	0.07	0.22	1.59 **	3.08 **	0.32 **	0.17 **	0.17 **	0.94 **	4.34 **	0.21	1.97 **
T_2	-0.06	-0.07	-0.22	-1.59 **	-3.08 **	-0.32 **	-0.17 **	-0.17 **	-0.94 **	-4.34 **	-0.21	-1.97 **

Table 5: Estimates of specific combining ability (maturity, physiological, yield and its contributing traits)

Crosses	**Days to 50% tasseling**	**Days to 50% silking**	**Days to 75% brown husk**	**Ear height (cm)**	**Plant height (cm)**	**Ear length (cm)**	**Ear circumferance (cm)**	**Kernel rows per cob**	**Kernels per row**	**1000-kernel weight**	**Shelling (%)**	**Yield (q/ha)**
$L_1 \times T_1$	1.19 ns	1.43 ns	0.78 ns	-1.09 ns	-0.33 ns	-0.34 ns	-0.17 ns	-0.02 ns	-0.87 *	-1.84 ns	0.92 ns	-1.62 ns
$L_1 \times T_2$	-1.19 ns	-1.43 ns	-0.78 ns	1.09 ns	0.33 ns	0.34 ns	0.17 ns	0.02 ns	0.87 *	1.84 ns	-0.92 ns	1.62 ns
$L_2 \times T_1$	-0.56 ns	-0.32 ns	-0.72 ns	-1.09 ns	-2.08 ns	0.21 ns	0.18 ns	0.38 ns	1.51 **	11.91 **	-0.98 ns	2.07 ns
$L_2 \times T_2$	0.56 ns	0.32 ns	0.72 ns	1.09 ns	2.08 ns	-0.21 ns	-0.18 ns	-0.38 ns	-1.51 **	-11.91 **	0.98 ns	-2.07 ns
$L_3 \times T_1$	0.94 ns	1.18 ns	2.78 **	2.16 ns	2.42 ns	0.83 **	0.45 **	0.43 ns	3.08 **	11.41 **	1.24 ns	3.61 *
$L_3 \times T_2$	-0.94 ns	-1.18 ns	-2.78 **	-2.16 ns	-2.42 ns	-0.83 **	-0.45 **	-0.43 ns	-3.08 **	-11.41 **	-1.24 ns	-3.61 *
$L_4 \times T_1$	-1.56 ns	-1.82 ns	-2.22 *	-4.59 ns	-9.83 *	1.68 **	0.50 **	0.63 **	3.73 **	12.66 **	0.52 ns	6.13 **
$L_4 \times T_2$	1.56 ns	1.82 ns	2.22 *	4.59 ns	9.83 *	-1.68 **	-0.50 **	-0.63 **	-3.73 **	-12.66 **	-0.52 ns	-6.13 **
$L_5 \times T_1$	0.44 ns	0.93 ns	0.78 ns	2.16 ns	3.67 ns	1.33 **	0.38 **	0.08 ns	2.63 **	1.41 ns	1.74 ns	4.51 **
$L_5 \times T_2$	-0.44 ns	-0.93 ns	-0.78 ns	-2.16 ns	-3.67 ns	-1.33 **	-0.38 **	-0.08 ns	-2.63 **	-1.41 ns	-1.74 ns	-4.51 **
$L_6 \times T_1$	-0.06 ns	0.18 ns	0.78 ns	0.91 ns	0.17 ns	1.11 **	0.70 **	0.83 **	4.66 **	21.91 **	-1.48 ns	7.44 **
$L_6 \times T_2$	0.06 ns	-0.18 ns	-0.78 ns	-0.91 ns	-0.17 ns	-1.11 **	-0.70 **	-0.83 **	-4.66 **	-21.91 **	1.48 ns	-7.44 **
$L_7 \times T_1$	-1.31 ns	-1.32 ns	-2.22 *	4.16 ns	8.42 ns	0.03 ns	0.38 **	0.38 ns	0.11 ns	6.91 *	-0.16 ns	1.21 ns
$L_7 \times T_2$	1.31 ns	1.32 ns	2.22 *	-4.16 ns	-8.42 ns	-0.03 ns	-0.38 **	-0.38 ns	-0.11 ns	-6.91 *	0.16 ns	-1.21 ns
$L_8 \times T_1$	0.69 ns	1.43 ns	0.78 ns	7.66 **	10.42 *	0.16 ns	0.23 ns	0.48 *	1.21 **	8.66 *	-0.71 ns	2.36 ns
$L_8 \times T_2$	-0.69 ns	-1.43 ns	-0.78 ns	-7.66 **	-10.42 *	-0.16 ns	-0.23 ns	-0.48 *	-1.21 **	-8.66 *	0.71 ns	-2.36 ns

$L_9 \times T_1$	-0.31 ns	-0.32 ns	-1.22 ns	4.16 ns	10.42 *	-0.87 **	-0.67 **	-0.62 **	-3.92 **	-21.09 **	0.69 ns	-7.19 **
$L_9 \times T_2$	0.31 ns	0.32 ns	1.22 ns	-4.16 ns	-10.42 *	0.87 **	0.67 **	0.62 **	3.92 **	21.09 **	-0.69 ns	7.19 **
$L_{10} \times T_1$	0.44 ns	0.68 ns	0.78 ns	-2.59 ns	-6.08 ns	-0.37 ns	0.00 ns	0.18 ns	-0.37 ns	0.66 ns	-2.36 *	0.03 ns
$L_{10} \times T_2$	-0.44 ns	-0.68 ns	-0.78 ns	2.59 ns	6.08 ns	0.37 ns	-0.00 ns	-0.18 ns	0.37 ns	-0.66 ns	2.36 *	-0.03 ns
$L_{11} \times T_1$	-0.81 ns	-1.07 ns	-1.22 ns	-2.34 ns	-5.08 ns	-0.12 ns	0.40 **	0.63 **	1.36 **	14.41 **	0.64 ns	4.35 **
$L_{11} \times T_2$	0.81 ns	1.07 ns	1.22 ns	2.34 ns	5.08 ns	0.12 ns	-0.40 **	-0.63 **	-1.36 **	-14.41 **	-0.64 ns	-4.35 **
$L_{12} \times T_1$	0.69 ns	0.68 ns	0.78 ns	3.41 ns	6.42 ns	-0.49 ns	-0.75 **	-1.02 **	-3.32 **	-23.09 **	-1.06 ns	-8.47 **
$L_{12} \times T_2$	-0.69 ns	-0.68 ns	-0.78 ns	-3.41 ns	-6.42 ns	0.49 ns	0.75 **	1.02 **	3.32 **	23.09 **	1.06 ns	8.47 **
$L_{13} \times T_1$	-0.31 ns	-0.32 ns	-0.22 ns	-3.09 ns	-3.33 ns	-0.42 ns	0.15 ns	0.28 ns	1.21 **	5.41 ns	-0.21 ns	3.30 *
$L_{13} \times T_2$	0.31 ns	0.32 ns	0.22 ns	3.09 ns	3.33 ns	0.42 ns	-0.15 ns	-0.28 ns	-1.21 **	-5.41 ns	0.21 ns	-3.30 *
$L_{14} \times T_1$	-0.31 ns	-0.32 ns	-0.22 ns	0.41 ns	7.17 ns	-0.69 *	-0.77 **	-1.22 **	-3.39 **	-23.84 **	-0.23 ns	-8.93 **
$L_{14} \times T_2$	0.31 ns	0.32 ns	0.22 ns	-0.41 ns	-7.17 ns	0.69 *	0.77 **	1.22 **	3.39 **	23.84 **	0.23 ns	8.93 **
$L_{15} \times T_1$	0.44 ns	-0.07 ns	-0.22 ns	-3.34 ns	-8.83 ns	-0.27 ns	-0.40 **	-0.62 **	-2.94 **	-12.09 **	-0.18 ns	-4.84 **
$L_{15} \times T_2$	-0.44 ns	0.07 ns	0.22 ns	3.34 ns	8.83 ns	0.27 ns	0.40 **	0.62 **	2.94 **	12.09 **	0.18 ns	4.84 **
$L_{16} \times T_1$	-1.56 ns	-1.32 ns	-2.22 *	-8.84 **	-16.33 **	-0.84 **	-0.55 **	-0.57 *	-2.77 **	-13.09 **	0.27 ns	-5.13 **
$L_{16} \times T_2$	1.56 ns	1.32 ns	2.22 *	8.84 **	16.33 **	0.84 **	0.55 **	0.57 *	2.77 **	13.09 **	-0.27 ns	5.13 **
$L_{17} \times T_1$	0.69 ns	0.68 ns	0.78 ns	7.16 *	12.42 **	1.33 **	0.78 **	0.88 **	4.38 **	25.91 **	1.17 ns	7.92 **
$L_{17} \times T_2$	-0.69 ns	-0.68 ns	-0.78 ns	-7.16 *	-12.42 **	-1.33 **	-0.78 **	-0.88 **	-4.38 **	-25.91 **	-1.17 ns	-7.92 **
$L_{18} \times T_1$	-0.06 ns	-0.57 ns	-1.22 ns	-3.84 ns	-6.83 ns	-0.67 *	-0.67 **	-1.02 **	-3.14 **	-20.09 **	0.54 ns	-7.44 **
$L_{18} \times T_2$	0.06 ns	0.57 ns	1.22 ns	3.84 ns	6.83 ns	0.67 *	0.67 **	1.02 **	3.14 **	20.09 **	-0.54 ns	7.44 **
$L_{19} \times T_1$	-0.31 ns	-0.57 ns	-0.22 ns	-1.59 ns	-2.58 ns	0.13 ns	0.33 *	0.43 ns	0.78 *	7.16 *	3.07 **	3.13 *
$L_{19} \times T_2$	0.31 ns	0.57 ns	0.22 ns	1.59 ns	2.58 ns	-0.13 ns	-0.33 *	-0.43 ns	-0.78 *	-7.16 *	-3.07 **	-3.13 *
$L_{20} \times T_1$	1.44 ns	1.68 ns	1.78 ns	-0.09 ns	-0.08 ns	-0.24 ns	-0.12 ns	-0.12 ns	-0.87 *	-3.59 ns	-2.58 *	-1.25 ns
$L_{20} \times T_2$	-1.44 ns	-1.68 ns	-1.78 ns	0.09 ns	0.08 ns	0.24 ns	0.12 ns	0.12 ns	0.87 *	3.59 ns	2.58 *	1.25 ns

$L_{21} \times T_1$	0.19 ns	0.18 ns	1.78 ns	0.66 ns	0.67 ns	-0.42 ns	-0.25 ns	-0.17 ns	-0.92 **	-3.84 ns	-2.48 *	-1.28 ns
$L_{21} \times T_2$	-0.19 ns	-0.18 ns	-1.78 ns	-0.66 ns	-0.67 ns	0.42 ns	0.25 ns	0.17 ns	0.92 **	3.84 ns	2.48 *	1.28 ns
$L_{22} \times T_1$	0.44 ns	-0.07 ns	-0.22 ns	-4.09 ns	-7.58 ns	-0.19 ns	-0.22 ns	-0.22 ns	-0.94 **	-3.84 ns	1.17 ns	-2.07 ns
$L_{22} \times T_2$	-0.44 ns	0.07 ns	0.22 ns	4.09 ns	7.58 ns	0.19 ns	0.22 ns	0.22 ns	0.94 **	3.84 ns	-1.17 ns	2.07 ns
$L_{23} \times T_1$	-0.06 ns	-0.32 ns	1.78 ns	-4.84 ns	-7.08 ns	-0.24 ns	-0.20 ns	-0.22 ns	-0.82 *	-4.09 ns	1.99 ns	-2.15 ns
$L_{23} \times T_2$	0.06 ns	0.32 ns	-1.78 ns	4.84 ns	7.08 ns	0.24 ns	0.20 ns	0.22 ns	0.82 *	4.09 ns	-1.99 ns	2.15 ns
$L_{24} \times T_1$	0.19 ns	-0.07 ns	-0.22 ns	7.91 **	12.92 **	-1.79 **	-0.52 **	-0.42 ns	-5.17 **	-15.59 **	-2.53 *	-4.83 **
$L_{24} \times T_2$	-0.19 ns	0.07 ns	0.22 ns	-7.91 **	-12.92 **	1.79 **	0.52 **	0.42 ns	5.17 **	15.59 **	2.53 *	4.83 **
$L_{25} \times T_1$	-0.56 ns	-0.57 ns	-1.22 ns	0.66 ns	0.92 ns	1.16 **	0.83 **	0.73 **	4.73 **	17.66 **	1.04 ns	9.13 **
$L_{25} \times T_2$	0.56 ns	0.57 ns	1.22 ns	-0.66 ns	-0.92 ns	-1.16 **	-0.83 **	-0.73 **	-4.73 **	-17.66 **	-1.04 ns	-9.13 **

for ear length (high × low) and kernels/row (high × low). Similarly, $L_3 \times T_2$ (high × low) for days to 75% brown husk, $L_4 \times T_1$ for days to 50% tasseling (average × low) and days to 50% silking (average × low), $L_{16} \times T_2$ for plant height (low × high) and ear height (low × high), $L_{16} \times T_1$ (average × low) for days to 50% tasseling, $L_{14} \times T_2$ (low × low) for kernel rows/cob, $L_{17} \times T_1$ (high × high) for 1000-kernel weight and $L_{19} \times T_1$ (low × low) for shelling (%). Similar results were also reported earlier by Petrovic et al. (1998); Uddin et al. (2008); Niyonzima et al. (2015).

Author's contribution

Conceptualization of research (PS); Designing of the experiments (PS and UC); Contribution of experimental materials (PS and UC); Execution of field/lab experiments and data collection (PS and UC); Analysis of data and interpretation (PS and UC); Preparation of the manuscript (PS and UC).

Conflict of Interest

Author declares that they have no conflict of interest

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