International Journal of Bio-resource and Stress Management

https://ojs.pphouse.org/index.php/IJBSM

Crossref

IJBSM September 2026, 17(9): 01-11

Article AR7151a

Research Article

Natural Resource Management

DOI: HTTPS://DOI.ORG/10.23910/1.2026.7151a

Study of General and Specific Combining Ability in *Kharif* Maize (*Zea mays* L.)

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ABSTRACT

The present investigation was carried during *kharif* (July–October) 2024 at college farm Bihar Agricultural University, Sabour, Bihar, India utilizing twelve lines and two testers along with twenty four crosses to analyse general and specific combining ability. The experimental material comprised twelve lines and two testers, which were crossed in a Line×Tester mating design to generate twenty-four single-cross hybrids. The resulting twenty-four hybrids, along with fourteen parents and two standard checks, were evaluated in a Randomized Block Design (RBD) with three replications. Analysis of variance for combining ability revealed that SCA variance was higher than GCA variance for grain yield and most of the yield-contributing traits, indicating the predominance of non-additive gene action in the inheritance of these characters. Significant variation among the genotypes was observed for grain yield and its associated traits. Among the parental lines, SML 131, SML 45, SML 189, SML 66, SML 65, SML 4 and HK 1209 exhibited significant positive GCA effects in the desirable direction, identifying them as promising parents for developing high-yielding hybrids. Seven cross combinations, namely SML 131×LM 13, SML 45×LM 13, SML 36×LM 13, HK 1209×LM 13, SML 189×LM 14, CLO 2450×LM 14 and CLRCQY 44×LM 14, recorded significant positive SCA effects for grain yield and important agronomic traits, indicating their superior hybrid performance. Among these, SML 131×LM 13, SML 4×LM 13 and SML 189×LM 14 outperformed the standard check for grain yield. These hybrids possess considerable potential for exploitation in hybrid breeding programmes and should be evaluated through multilocation trials for their possible release as high-yielding single-cross maize hybrids to enhance *kharif* maize productivity in Bihar.

KEYWORDS: Additive variance, combining ability, dominance variance, lines, tester

***Citation* (VANCOUVER):** Raj et al., Study of General and Specific Combining Ability in *Kharif* Maize (*Zea mays* L.). *International Journal of Bio-resource and Stress Management,* 2026; 17(9), 01-11. HTTPS://DOI.ORG/10.23910/1.2026.7151a.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, author have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The author has declared that no conflict of interest exists.

RECEIVED on 24th April 2026 RECEIVED in revised form on 19th August 2026 ACCEPTED in final form on 04th September 2026 PUBLISHED on 14th September 2026

1. INTRODUCTION

Maize (*Zea mays* L.) is the third most widely cultivated cereal crop in the world and belongs to the family Poaceae. It is believed to have originated in Central Mexico and is commonly known as corn. Owing to its remarkable genetic diversity, high yield potential, and wide adaptability to diverse agro-climatic conditions, maize is often referred to as the "Queen of Cereals" (Azad et al., 2012). Globally, maize is cultivated over approximately 205 mha, with an annual production of about 1.22 billion tones and an average productivity of 6.2 t ha^{-1} (Anonymous, 2023a). In India, maize occupies about 11.24 mha with a production of 37.67 mt and an average productivity of 3,351 kg ha^{-1} (Anonymous, 2023b). The major maize-producing states are Karnataka, Madhya Pradesh, Maharashtra, Bihar and Uttar Pradesh. Bihar ranks among the leading maize-producing states, cultivating approximately 9.55 lakh hectares with a production of 57.09 lakh tonnes and an average productivity of 5,975 kg ha^{-1}, primarily due to the favourable conditions prevailing during the rabi season. In India, maize serves multiple purposes, including poultry feed (47%), food and livestock feed (13%), industrial applications (12%), starch production (14%), processed food (7%) and exports and other miscellaneous uses (6%). However, kharif maize cultivation in Bihar is constrained by several abiotic and biotic factors, including poorly drained soils, erratic rainfall, waterlogging, a high water table, and reduced pollen shedding, all of which contribute to lower productivity and a reduction in cultivated area (Prasanna et al., 2021). Moreover, there is a shortage of high-yielding hybrids possessing tolerance to moisture stress, diseases and insect pests that are well adapted to the agro-climatic conditions of Bihar.

Hybrid breeding has emerged as one of the most effective approaches for enhancing maize productivity and ensuring food security (Karim et al., 2018). The success of hybrid breeding largely depends on the identification of superior parental inbred lines and an understanding of the genetic mechanisms governing economically important traits. Combining ability analysis is a valuable breeding tool for identifying superior parents and promising hybrid combinations (Belay Nigus, 2022). The concept of general combining ability (GCA) and specific combining ability (SCA), first proposed by Sprague and Tatum (1942), provides insights into the relative importance of additive and non-additive gene effects controlling quantitative traits (El Ghonemy et al., 2023). This information facilitates the selection of suitable parents and cross combinations for hybrid development (Kumar et al., 2018). General combining ability reflects the average performance of a genotype in hybrid combinations and is primarily associated with additive gene action (Sharma et al., 2013). Parents exhibiting high GCA effects are considered desirable because they possess superior breeding value, wider adaptability and relatively stable performance across environments (Fasahat et al., 2016; Chavan et al., 2022). In contrast, specific combining ability represents the performance of a particular cross and is mainly attributed to dominance and epistatic (non-additive) gene effects (Zhang et al., 2015; Begna, 2021). Identification of hybrids with high SCA effects is essential for exploiting heterosis and developing superior commercial hybrids (Mishra et al., 2024). Furthermore, the relative magnitude of GCA and SCA variances provides valuable information on the nature of gene action governing different traits, thereby guiding the choice of appropriate breeding strategies. Keeping these considerations in view, the present investigation was undertaken to estimate the general and specific combining abilities of selected maize inbred lines using a line×tester mating design, with the objective of identifying superior parents and promising hybrid combinations for the development of high-yielding maize hybrids suitable for *kharif* cultivation in Bihar.

2. MATERIALS AND METHODS

The present investigation was carried during *kharif* (July–October) 2024 at college farm Bihar Agricultural College Sabour to estimate the GCA and SCA utilizing 12 lines and 2 tester which was crossed in line×tester mating design. The experimental material consisted of 12 maize inbred lines and 2 testers LM-13 and LM-14 which were obtained from IIMR (Indian Institute of Maize Research), Ludhiana (Table 1 and Table 2). 12 lines and 2 testers were crossed in line×tester mating design during *rabi* 2023–24. Twenty four crosses along with fourteen parents and two checks (Bio 9544 and DKC 7074) were evaluated in RBD design with three replication.

Observations were recorded from five randomly selected plants in each plot for plant height (cm), ear height (cm), cob length (cm), 1000 grain weight (g) and grain yield (kg ha^{-1}). Days to 50% tasseling, days to 50% silking and days to 75% brown husk were recorded on a population basis. The plants were selected from the middle rows to minimize error due to the border effect (Sree et al., 2024). The analysis of variance for each traits was carried out as per standard statistical procedure described by Panse and Sukhatme (1985) to check the differences between the genotypes for all the traits. Data were subjected to analysis combining ability as per the method suggested by Kempthorne (1957).

3. RESULTS AND DISCUSSION

3.1. Analysis of variance

The analysis of variance for combining ability revealed significant differences among the general combining ability (GCA) and specific combining ability (SCA) effects for

Table 1: List of parents and their source

Lines	Genotype Name	Source
L_1	SML 131	BAU, Sabour
L_2	SML 45	BAU, Sabour
L_3	SML 189	BAU, Sabour
L_4	SML 36	BAU, Sabour
L_5	SML 66	BAU, Sabour
L_6	SML 65	BAU, Sabour
L_7	SML 4	BAU, Sabour
L_8	HK 1209	Hyderabad
L_9	BML 7	Hyderabad
L_{10}	CML 451	CIMMYT
L_{11}	CLO 2450	CIMMYT
L_{12}	CLRCQY 44	CIMMYT
Testers		
T_1	LM 13	Punjab
T_2	LM 14	Punjab
Checks		
C_1	Bio 9544	Bio seed
C_2	DKC 7074	Bayer

Table 2: List of crosses

Sl. No.	Line×tester	Name of crosses
1.	$L_1 \times T_1$	SML 131×LM 13
2.	$L_2 \times T_1$	SML 45×LM 13
3.	$L_3 \times T_1$	SML 189×LM 13
4.	$L_4 \times T_1$	SML 36×LM 13
5.	$L_5 \times T_1$	SML 66×LM 13
6.	$L_6 \times T_1$	SML 65×LM 13
7.	$L_7 \times T_1$	SML 4×LM 13
8.	$L_8 \times T_1$	HK 1209×LM 13
9.	$L_9 \times T_1$	BML 7×LM 13
10.	$L_{10} \times T_1$	CML 451×LM 13
11.	$L_{11} \times T_1$	CLO 2450×LM 13
12.	$L_{12} \times T_1$	CLRCQY 44×LM 13
13.	$L_1 \times T_2$	SML 131×LM 14
14.	$L_2 \times T_2$	SML 45×LM 14
15.	$L_3 \times T_2$	SML 189×LM 14
16.	$L_4 \times T_2$	SML 36×LM 14
17.	$L_5 \times T_2$	SML 66×LM 14
18.	$L_6 \times T_2$	SML 65×LM 14
19.	$L_7 \times T_2$	SML 4×LM 14
20.	$L_8 \times T_2$	HK 1209×LM 14
21.	$L_9 \times T_2$	BML 7×LM 14
22.	$L_{10} \times T_2$	CML 451×LM 14
23.	$L_{11} \times T_2$	CLO 2450×LM 14
24.	$L_{12} \times T_2$	CLRCQY 44×LM 14

all the traits studied (Table 3), indicating the existence of substantial genetic variability among the parental lines and their hybrids. Such variability is a prerequisite for effective selection and hybrid breeding, as it provides ample scope for the identification of superior parents and promising cross combinations. The mean sum of squares due to lines was significant for plant height, 1000-grain weight and grain yield, suggesting that these traits were largely influenced by the additive genetic effects contributed by the female parents. Similarly, the testers exhibited significant mean squares for 1000-grain weight and grain yield, indicating that the male parents also contributed significantly to the inheritance of these economically important traits. The significant differences among the parental lines and testers emphasize the presence of diverse genetic backgrounds, which is essential for obtaining superior hybrid combinations. The mean squares due to line × tester interactions were highly

Table 3: Analysis of variance due to combining ability from different crosses

Source of variations	df	DFS	DTS	PH	EH	DTBH	CL	1000 GW	GY
Replication	2	4.91	1.48	528.64	77.59	14.58	1.31	56.36	181319.62
Crosses	23	6.59**	5.98**	940.37**	150.92**	14.98**	10.59**	6885.95**	5441529.10**
Line effect	11	4.35	4.48	1497.69*	172.92	13.75	16.15	7388.63*	3758570.04*
Tester effect	1	0.00	0.50	1153.60	480.50	0.22	0.79	5178.91*	107176.06*
Line×tester effect	11	9.42**	7.96*	363.66**	98.96**	17.56**	5.92**	6538.47**	7609429.35**
Error	46	1.62	2.01	70.30	20.81	1.83	0.57	107.98	248976.61
Total	71	18.33	22.94	3093.58	912.63	8.17	8.79	3630.69	6818995.91

*; ** significant at p=0.05 and p=0.01 level; respectively; df: Degrees of freedom; DFS: Days to 50% tasseling; DTS: Days to 50% silking; PH: Plant height; EH: Ear height; DTBH: Days to 75% brown husk; CL: Cob length; 1000 GW: 1000 grain weight; GY: Grain yield

significant for all the studied traits, including days to 50% tasseling, days to 50% silking, plant height, ear height, days to 75% brown husk, cob length, 1000-grain weight and grain yield. The significant interaction effects indicate that the performance of hybrids depended not only on the individual combining abilities of the parents but also on the specific parental combinations, highlighting the importance of non-additive gene interactions. Similar observations have been reported by Elmyhun et al. (2020), Chavan et al. (2022), El Ghonemy et al. (2023), and Lal et al. (2023). The estimates of variance components further revealed that the SCA variance exceeded the corresponding GCA variance for all the characters studied. This indicates the predominance of non-additive gene action, including dominance and epistatic effects, in the inheritance of these traits. The higher contribution of SCA variance suggests that hybrid performance was mainly governed by specific parental interactions rather than by the average performance of individual parents. Such results are consistent with the findings of Sharma et al. (2019) and Hombaradi et al. (2021).

3.2. Mean values of traits

The mean performance of the twenty-four maize hybrids for eight agronomic and yield-related traits is presented in Table 4. Considerable variation was observed among the hybrids for all the characters studied, indicating the presence of substantial genetic diversity and providing opportunities for identifying superior hybrid combinations. The days to 50% tasseling among the hybrids ranged from 52 days (L_{10}×T_1, L_{12}×T_1, and L_1×T_2) to 57 days (L_{11}×T_1). The hybrids L_{10}×T_1, L_{12}×T_1 and L_1×T_2 were at par with the standard check Bio 9544 (C_1), indicating their potential for early flowering. Similarly, days to 50% silking ranged from 55 to 60 days, with hybrids L_1×T_1 (56 days), L_{12}×T_1 (55 days) and L_1×T_2 (56 days) exhibiting earlier silking than the standard check. Early flowering and silking are desirable traits in *kharif* maize, as they facilitate escape from terminal moisture stress, reduce the risk of lodging due to prolonged monsoon conditions, and allow timely harvesting.

Plant height among the hybrids varied from 167.33 cm (L_4×T_2) to 246.67 cm (L_1×T_1). The hybrid L_4×T_2 was statistically at par with the standard check Bio 9544 (176 cm), indicating its suitability for developing relatively shorter hybrids. Moderate plant height is generally preferred because it improves lodging resistance, enhances standability and facilitates efficient crop management under rainfed conditions. Ear height ranged from 86.78 cm (L_4×T_2) to 119.49 cm (L_1×T_1). Four hybrids, namely L_4×T_1 (93.96 cm), L_8×T_1 (94.56 cm), L_{11}×T_1 (92.91 cm) and L_4×T_2 (86.78 cm), recorded significantly lower ear placement than the standard check. Lower ear height is considered a desirable trait as it lowers the centre of gravity of the plant, thereby improving resistance to lodging and enabling easier harvesting, particularly under high wind and rainfall conditions commonly experienced during the *kharif* season. Days to 75% brown husk, an important indicator of physiological maturity, ranged from 82 days (L_5×T_2) to 90 days (L_{10}×T_2 and L_{12}×T_2). Fourteen hybrids matured significantly earlier than the standard check Bio 9544 (89 days), demonstrating their suitability for early maturity. Early-maturing hybrids are advantageous because they allow timely sowing of subsequent crops, reduce exposure to terminal drought and disease pressure, and fit well into multiple cropping systems. Cob length varied from 13.37 cm (L_{12}×T_1) to 20.28 cm (L_1×T_1). Longer cobs generally contribute to a greater number of kernels per cob and consequently higher grain yield. The superior cob length observed in L_1×T_1 reflects its greater sink capacity and yield potential. The 1000-grain weight among the hybrids ranged from 206.48 g (L8×T1) to 375.97 g (L_1×T_1). Four hybrids, namely L_1×T_1 (375.97 g), L_2×T_1 (327.11 g), L_4×T_1 (326.00 g) and L_7×T_1 (371.95 g), significantly outperformed the standard check Bio 9544 (298.72 g). Since 1000-grain weight is a major component of grain yield, higher values indicate superior grain filling, better translocation of photosynthates and enhanced assimilate partitioning to the developing kernels.

Grain yield, the ultimate economic trait, exhibited wide variation among the hybrids, ranging from 2934.75 kg ha^{-1} (L_3×T_1) to 8192.88 kg ha^{-1} (L_1×T_1). Three hybrids, namely L_1×T_1 (8192.88 kg ha^{-1}), L_7×T_1 (7945.59 kg ha^{-1}) and L_3×T_2 (7969.82 kg ha^{-1}), significantly surpassed the standard check Bio 9544 (7075.47 kg ha^{-1}). The superior performance of these hybrids may be attributed to favourable interactions among yield-contributing traits, including early flowering, desirable plant architecture, greater cob length, and higher kernel weight, resulting in enhanced productivity. The wide range of variation observed among the hybrids demonstrates the effectiveness of the selected parental lines in generating diverse and productive hybrid combinations. The superior performance of certain hybrids also indicates the presence of favourable allelic interactions and the successful exploitation of heterosis for grain yield and associated traits. Such variability provides ample opportunity for selecting hybrids with desirable combinations of earliness, plant architecture, grain weight and yield. Among all the hybrids evaluated, L_1×T_1, L_7×T_1 and L_3×T_2 consistently exhibited superior mean performance for most of the agronomic and yield-related traits while significantly outperforming the standard check for grain yield. The findings of the present investigation are in close agreement with those reported by Assefa et al. (2017), Ibrahim et al. (2021), Abdel-Moneam et al. (2024), Mitiku et al. (2024), Mosa et al. (2024), Sree et al. (2024), and Bhatla et al. (2025), who also observed

Table 4: Mean performance of hybrids maize for yield and yield contributing characters

Sl. No.	Crosses	DFS	DTS	PH (cm)	EH (cm)	DTBH	CL (cm)	1000 GW (g)	GY (kg ha^{-1})
1.	L_1×T_1	52	56	246.67	119.49	87	20.28	375.97	8192.88
2.	L_2×T_1	55	59	230.00	100.95	89	18.17	327.11	7543.20
3.	L_3×T_1	53	57	217.67	106.73	88	16.60	215.12	2934.75
4.	L_4×T_1	56	60	185.67	93.96	89	18.53	326.00	7772.27
5.	L_5×T_1	55	59	191.00	101.98	90	15.27	302.49	5242.92
6.	L_6×T_1	52	57	201.33	102.88	87	14.73	275.29	5575.45
7.	L_7×T_1	54	58	201.33	99.36	85	20.07	371.95	7945.59
8.	L_8×T_1	53	57	178.33	94.56	86	17.30	206.48	6435.17
9.	L_9×T_1	54	58	179.33	96.52	87	16.70	253.69	5975.01
10.	L_{10}×T_1	52	56	187.33	98.32	83	17.83	259.03	6366.97
11.	L_{11}×T_1	57	60	179.00	92.91	89	15.33	229.04	5291.95
12.	L_{12}×T_1	52	55	188.00	95.44	84	13.37	257.96	5039.85
13.	L_1×T_2	52	56	194.00	103.83	87	15.60	220.34	6910.03
14.	L_2×T_2	55	59	188.00	99.13	86	15.23	254.95	6012.30
15.	L_3×T_2	55	60	197.33	104.38	85	17.83	289.67	7969.82
16.	L_4×T_2	56	60	167.33	86.78	89	15.73	274.20	4986.16
17.	L_5×T_2	54	58	185.33	102.76	82	16.67	249.12	6119.95
18.	L_6×T_2	54	58	178.00	96.17	88	16.93	314.19	6461.94
19.	L_7×T_2	53	57	198.33	104.01	86	19.13	313.18	7428.13
20.	L_8×T_2	52	56	196.00	101.46	83	14.80	287.03	3474.69
21.	L_9×T_2	53	57	201.00	102.41	87	17.05	313.07	6196.23
22.	L_{10}×T_2	54	58	211.00	110.44	90	15.60	218.15	5532.76
23.	L_{11}×T_2	53	57	211.00	114.45	89	17.63	285.51	6928.24
24.	L_{12}×T_2	53	58	194.93	106.76	90	17.07	255.18	7221.76
25.	C_1	52	56	176.00	102.45	89	17.95	298.72	7075.47
26.	C_2	54	60	212.33	115.01	94	19.77	296.73	6728.11
Mean		53.65	57.76	196.16	101.48	87.26	16.81	278.11	6231.58
CV%		2.27	2.33	5.18	5.59	1.54	4.26	4.34	10.83
SEm±		0.74	0.81	4.72	2.61	0.78	0.37	6.17	285.64
CD (p=0.05)		2.07	2.29	13.28	7.34	2.19	1.04	17.37	804.21

DFS: Days to 50% tasseling; DTS: Days to 50% silking; PH: Plant height; EH: Ear height; DTBH: Days to 75% brown husk; CL: Cob length; 1000 GW: 1000 grain weight; GY: Grain yield

considerable genetic variability among maize hybrids and identified superior cross combinations exhibiting enhanced grain yield and desirable agronomic characteristics.

3.3. Estimation of GCA

The estimates of general combining ability (GCA) effects for the eight agronomic and yield-related traits are presented in Table 5. Significant variation in GCA effects among the parental lines and testers indicated the existence of considerable additive genetic variability for the traits under study. The identification of parents with desirable GCA effects is of paramount importance in hybrid breeding, as such parents are expected to transmit favourable alleles consistently to their progenies and contribute to the development of superior hybrids. For days to 50% tasseling, the GCA effects among the lines ranged from −1.58 (L_1) to 2.25 (L_4), whereas among the testers they varied from −0.03 (T_2) to 0.19 (T_1). Lines L_1 (−1.58) and L_{12} (−1.25) exhibited significant negative GCA effects and were identified as good general combiners for early tasseling. Similarly, for days

Table 5: General combining ability (GCA) effects for yield and yield contributing characters of lines and testers

Sl. No.	Lines	DFS	DTS	PH	EH	DTBH	CL	1000 GW	GY
1.	L_1	-1.58**	-2.03**	24.17**	10.17**	0.33	1.13**	20.04**	1319.87**
2.	L_2	1.75**	1.14	12.84**	-1.45	0.67	-0.11	12.92**	546.17*
3.	L_3	0.42	0.81	11.34**	4.07*	-0.33	0.40	-25.72**	779.30**
4.	L_4	2.25**	2.31**	-19.66**	-11.12**	2.00**	0.32	21.99**	147.63
5.	L_5	0.58	0.47	-8.00*	0.89	-0.83	-0.85**	-2.31	550.15**
6.	L_6	-0.92	-0.36	-6.50	-1.96	0.67	-0.98**	16.63**	212.889*
7.	L_7	-0.42	-0.19	3.67	0.20	-1.33*	2.79**	64.45**	1455.27**
8.	L_8	-0.92	-0.86	-9.00*	-3.48	-2.50**	-0.76**	-31.36**	1276.66**
9.	L_9	-0.25	-0.53	-6.00	-2.02	0.00	0.07	5.27	-145.96
10.	L_{10}	-0.92	-0.53	3.00	2.89	-0.33	-0.09	-39.52**	281.72
11.	L_{11}	1.25*	0.97	-1.16	2.19	1.83**	-0.33	-20.84**	221.49
12.	L_{12}	-1.25*	-1.19*	-4.70	-0.39	-0.17	-1.59**	-21.54**	-100.78
13.	T_1	0.19	-0.08	2.64	-0.23	0.18	0.50	3.23**	-138.16
14.	T_2	-0.03	0.07	-2.34	1.23	-0.08	-0.20	-5.23**	126.22
CD (*p*=0.05) (Line)		1.05	1.17	6.79	3.72	1.11	0.52	8.60	410.04
CD (*p*=0.05) (tester)		0.43	0.48	2.77	1.52	0.45	0.21	3.51	167.40

*; ** significant at *p*=0.05 and *p*=0.01 level; respectively; DFS: Days to 50% tasseling; DTS: Days to 50% silking; PH: Plant height; EH: ear height; DTBH: Days to 75% brown husk; CL: Cob length; 1000 GW: 1000 grain weight; GY: Grain yield

to 50% silking, the GCA effects ranged from −2.03 (L_1) to 2.31 (L_4) among the lines and from −0.08 (T_1) to 0.07 (T_2) among the testers. Lines L_1 (−2.03) and L_{12} (−1.19) recorded significant negative GCA effects, indicating their suitability for developing early flowering hybrids. Earliness is an important breeding objective in kharif maize, as it enables the crop to escape terminal moisture stress, facilitates timely harvesting, and allows efficient crop rotation.

For plant height, the GCA effects among the lines ranged from -19.66 (L_4) to 24.17 (L_1), while among the testers they varied from −2.34 (T_2) to 2.64 (T_1). Lines L_4 (-19.66), L5 (-8.00) and L_8 (-9.00) exhibited significant negative GCA effects, indicating their potential for developing shorter and lodging-resistant hybrids. Similarly, for ear height, the GCA effects ranged from -11.12 (L_4) to 10.17 (L_1) among the lines and from −0.23 (T_1) to 1.23 (T_2) among the testers. Line L_4 (-11.12) recorded the highest significant negative GCA effect and was identified as a desirable general combiner for reduced ear placement. Lower plant and ear heights are generally preferred because they improve lodging resistance, enhance plant stability and facilitate mechanical harvesting. The GCA effects for days to 75% brown husk ranged from -2.50 (L_8) to 2.00 (L_4) among the lines and from -0.08 (T_2) to 0.18 (T_1) among the testers. Lines L_7 (-1.33) and L_8 (-2.50) exhibited significant negative GCA effects, indicating their usefulness in developing early maturing hybrids. Early maturity is advantageous in regions where the crop is exposed to erratic rainfall or where maize forms part of intensive cropping systems.

For cob length, the GCA effects among the lines ranged from −1.59 (L_{12}) to 2.79 (L_7), while among the testers they ranged from −0.20 (T_2) to 0.50 (T_1). Lines L_1 (1.13) and L_7 (2.79) exhibited significant positive GCA effects, indicating their ability to contribute favourable alleles for longer cobs, which are often associated with a greater number of kernels and enhanced yield potential. The GCA effects for 1000-grain weight ranged from −39.52 (L_{10}) to 64.45 (L_7) among the lines and from −5.23 (T_2) to 3.23 (T1) among the testers. Six parents, namely L_1 (20.04), L_2 (12.92), L_4 (21.99), L_6 (16.63), L_7 (64.45) and T_1 (3.23), recorded significant positive GCA effects, indicating their superior ability to improve kernel weight. Higher 1000-grain weight reflects efficient grain filling and contributes directly to increased grain yield. Grain yield, the most economically important trait, exhibited GCA effects ranging from −145.96 (L_9) to 1455.27 (L_7) among the lines and from −138.16 (T_1) to 126.22 (T_2) among the testers. Seven lines, namely L_1 (1319.87), L2 (546.17), L_3 (779.30), L_5 (550.15), L_6 (212.88), L_7 (1455.27) and L_8 (1276.66), exhibited significant positive GCA effects and were identified as superior general combiners for grain yield. The superior GCA effects of these lines indicate that they possess favourable additive alleles governing grain yield and can effectively transmit these genes to their progenies. The present results indicate that no single parent was a superior general combiner for all the traits studied; however, several parental lines exhibited favourable GCA effects for multiple economically important traits. In particular, L_1, L_7, and L_8 consistently displayed desirable GCA effects for grain yield and several associated traits, suggesting that these lines possess high breeding value and broad utility in hybrid breeding programmes. The simultaneous expression of favourable GCA effects for earliness, yield components, and grain yield indicates the presence of a substantial proportion of additive gene effects, making these parents valuable resources for population improvement and inbred line development. From a breeding perspective, parents with high GCA effects are particularly valuable because they contribute favourable additive alleles that can be fixed through selection in successive generations. Such parents are also expected to produce superior hybrids when crossed with genetically diverse testers. Therefore, the identified good general combiners-particularly L_1, L_2, L_3, L_5, L_6, L_7, and L_8-may be effectively utilized in hybrid breeding, recurrent selection, and pedigree breeding programmes aimed at developing high-yielding maize hybrids adapted to kharif conditions in Bihar. The findings of the present investigation are in close agreement with those of Elmyhun et al. (2020), Belay (2022), Subba et al. (2022), Bisen et al. (2023), Ismail et al. (2023), Khan et al. (2023), Mishra et al. (2024), Mitiku et al. (2024), Sree et al. (2024), and Bhatla et al. (2025), who also reported significant GCA effects among maize inbred lines and emphasized the importance of additive gene action in the improvement of grain yield and its component traits.

3.4. Estimation of SCA

The estimates of specific combining ability (SCA) effects for the eight agronomic and yield-related traits are presented in Table 6. The SCA effects exhibited considerable variation among the hybrids, indicating the presence of substantial non-additive gene action governing the expression of these traits. High SCA effects generally reflect favourable interactions between parental genomes, resulting from dominance and epistatic gene effects, and therefore play a crucial role in the identification of superior hybrid combinations for heterosis breeding.

For days to 50% tasseling, the SCA effects ranged from −1.36 (L_3×T_1) to 2.63 (L_8×T_1). Among the hybrids, L_{11}×T_2 (−1.81) exhibited a significant negative SCA effect and was identified as the best specific combiner for early tasseling. Early flowering hybrids are advantageous under kharif conditions because they facilitate timely crop maturity, reduce exposure to adverse weather conditions, and improve cropping system efficiency. The SCA effects for days to 50% silking varied from −1.83 (L_4×T_1) to 2.31 (L_{10}×T_2). Although negative SCA estimates were observed in several crosses, none of the hybrids exhibited a statistically significant SCA effect for earlier silking, suggesting that this trait may be influenced by a relatively balanced contribution of additive and non-additive gene effects under the present experimental conditions.

For plant height, the SCA effects ranged from -8.45 (L_2×T_2) to 18.35 (L_2×T_1). Six hybrids, namely L_8×T_1 (-0.48), L_9×T_1 (-3.48), L_{10}×T_1 (-4.48), L_{11}×T_1 (-1.86), L_1×T_2 (-7.23), and L_2×T_2 (-8.45), exhibited significant negative SCA effects, indicating their suitability for developing shorter and lodging-resistant hybrids. Reduced plant height is a desirable attribute in maize because it enhances standability, minimizes lodging losses, and improves harvest efficiency. The SCA effects for ear height varied from -3.83 (L_{10}×T_1) to 9.54 (L_{11}×T_2). Among the hybrids, L_{11}×T_1 (-0.54) and L_1×T_2 (-1.56) recorded significant negative SCA effects and were identified as superior specific combiners for lower ear placement. Lower ear height contributes to improved plant stability and reduces the risk of lodging under high rainfall and strong wind conditions. The SCA effects for days to 75% brown husk ranged from -1.02 (L_3×T_2) to 4.66 (L_7×T_2). Four hybrids, namely L_{10}×T_1 (-0.25), L_{12}×T_1 (-0.42), L_5×T_2 (-0.57) and L_8×T_2 (-0.26), exhibited significant negative SCA effects, indicating their potential for developing early maturing hybrids. Early maturity is particularly desirable in kharif maize, as it enables timely harvesting and facilitates the cultivation of succeeding crops.

For cob length, the SCA effects varied from -0.90 (L_5×T_1) to 2.14 (L1×T_1). Ten hybrids, namely L_1×T_1, L_2×T_1, L_4×T_1, L_8×T_1, L_{10}×T_1, L_3×T_2, L_5×T_2, L_6×T_2, L_{11}×T_2, and L_{12}×T_2, exhibited significant positive SCA effects, indicating favourable parental interactions for increased cob length. Longer cobs generally accommodate a greater number of kernels, thereby contributing positively to grain yield. The SCA effects for 1000-grain weight ranged from -2.51 (L_3×T_1) to 4.73 (L_1×T_1). Eleven hybrids, namely L_1×T_1, L_2×T_1, L_4×T_1, L_5×T_1, L_7×T_1, L_{10}×T_1, L_3×T_2, L_6×T_2, L_8×T_2, L_9×T_2 and L_{11}×T_2, recorded significant positive SCA effects. These hybrids are expected to possess superior grain-filling ability and improved assimilate partitioning, resulting in heavier kernels and enhanced productivity. Grain yield exhibited the widest range of SCA effects, varying from -779.56 (L_{11}×T_1) to 1680.01 (L_1×T_1). Seven hybrids, namely L_1×T_1 (1680.01), L_2×T_1 (904.04), L_4×T_1 (1431.64), L_8×T_1 (1518.82), L_3×T_2 (1478.43), L_{11}×T_2 (1678.06) and L_{12}×T_2 (1052.37), exhibited significant positive SCA effects and were identified as superior specific combiners for grain yield. The high SCA effects observed in these hybrids

Table 6: Specific combining ability (SCA) effects for yield and yield contributing characters obtained from line×tester mating design

Sl. No.	Hybrid	DFS	DTS	PH	EH	DTBH	CL	1000 GW	GY
1.	$L_{1}\times T_{1}$	1.35	0.53	13.69**	9.06**	1.28	2.14**	4.73**	1680.01*
2.	$L_{2}\times T_{1}$	-0.43	0.57	18.36**	6.14	1.64	1.26**	3.85**	904.04**
3.	$L_{3}\times T_{1}$	-1.36	-1.43	10.75	3.40	1.47	-0.82*	-2.51**	-247.95**
4.	$L_{4}\times T_{1}$	-0.82	-1.83	6.53	4.82	-0.64	1.20**	2.67**	1431.64**
5.	$L_{5}\times T_{1}$	0.85	0.58	5.19	4.84	3.58**	-0.90*	1.95**	-399.93
6.	$L_{6}\times T_{1}$	-0.69	-0.63	9.03	6.58	-0.92	-0.30**	-0.68**	-404.66
7.	$L_{7}\times T_{1}$	2.47	0.21	-1.14	-1.10	-0.58	1.26	2.16**	697.31
8.	$L_{8}\times T_{1}$	2.64	1.83	-0.48*	-2.22	1.58*	1.05**	-0.51**	1518.82**
9.	$L_{9}\times T_{1}$	0.81	0.77	-3.48**	-1.72	1.57	-0.38	-0.92**	-725.03
10.	$L_{10}\times T_{1}$	-1.03	-1.17	-4.48**	-3.83	-0.25**	0.91*	1.21*	455.69
11.	$L_{11}\times T_{1}$	1.81*	1.33	-1.86**	-0.54**	-0.08	-0.35**	-0.47**	-779.56**
12.	$L_{12}\times T_{1}$	-0.63	-1.05	-0.61	-2.43	-0.42**	-0.16**	-0.84	-105.14**
13.	$L_{1}\times T_{2}$	-0.31	-0.45	-7.23**	-1.56**	-0.08	-0.41**	-1.58**	-676.01*
14.	$L_{2}\times T_{2}$	1.23	-1.07	-8.45**	-2.14	-0.42	-0.35**	-0.84**	-413.10**
15.	$L_{3}\times T_{2}$	1.61	1.67	-4.85	-1.74	-1.02	0.97*	4.69**	1478.43**
16.	$L_{4}\times T_{2}$	1.19	-0.42	-1.53	-2.82	2.82	-1.19**	-0.63**	-431.41**
17.	$L_{5}\times T_{2}$	-0.47	-0.25	-1.17	-1.28	-0.57**	1.24*	-1.46**	1367.33
18.	$L_{6}\times T_{2}$	1.27	1.25	-4.03	-2.16	1.12	1.56**	4.68**	1402.46
19.	$L_{7}\times T_{2}$	-0.57	-0.19	10.14	5.25	4.66	-0.35	-0.82**	-265.86
20.	$L_{8}\times T_{2}$	-0.85	-0.58	11.48*	6.43	-0.26*	-1.05**	4.57**	-518.22**
21.	$L_{9}\times T_{2}$	0.06	-0.50	8.44**	7.72	-0.61	0.68	1.55**	372.15
22.	$L_{10}\times T_{2}$	0.93	2.32	5.45**	2.81	3.25**	-0.11*	-0.44*	-205.19
23.	$L_{11}\times T_{2}$	-0.58*	-0.72	12.16**	9.54**	0.36	1.35**	3.68**	1678.06**
24.	$L_{12}\times T_{2}$	0.57	1.57	6.38	5.64	3.08**	2.06**	1.86	1052.37**
CD (p= 0.05)	1.48	1.65	9.60	5.27	1.572	0.741	12.16	579.88	

*; ** significant at 0.05 and 0.01 level; respectively; DFS: Days to 50% tasseling; DTS: Days to 50 % silking; PH: Plant height; EH: Ear height; DTBH: Days to 75% brown husk; CL: Cob length; 1000 GW: 1000 grain weight and GY: Grain yield

indicate the presence of favourable dominance and epistatic interactions, which are responsible for the enhanced hybrid performance and heterotic expression. The predominance of high SCA effects for grain yield and its associated traits is consistent with the higher SCA variance observed in the combining ability analysis, confirming that non-additive gene action plays a major role in the inheritance of these characters. This suggests that the exploitation of heterosis through single-cross hybrid development would be more effective than selection for pure-line improvement for these traits. It is noteworthy that several hybrids exhibiting high SCA effects involved one or both parents with good GCA effects, such as $L_{1}\times T_{1}$ and $L_{2}\times T_{1}$. Such combinations often result from the interaction of favourable additive and non-additive gene effects and are therefore highly desirable for commercial hybrid development. Conversely, some hybrids with high SCA effects were derived from parents with moderate or low GCA effects, indicating that superior hybrid performance may also arise from complementary gene interactions rather than the per se performance of the parents. This highlights the importance of evaluating both GCA and SCA simultaneously while selecting parental lines for hybrid breeding programmes.

Among all the hybrids evaluated, $L_{1}\times T_{1}$, $L_{2}\times T_{1}$, $L_{4}\times T_{1}$, $L_{8}\times T_{1}$, $L_{3}\times T_{2}$, $L_{11}\times T_{2}$ and $L_{12}\times T_{2}$ consistently exhibited favourable SCA effects for grain yield and several yield-contributing traits. These hybrids possess considerable potential for the exploitation of heterosis and should be evaluated further across diverse environments to assess their stability, adaptability, and commercial suitability under kharif conditions in Bihar. The present findings are in close agreement with those reported by Ravikesavan et al. (2020), Hombaradi et al. (2021), Karim et al. (2021), Belay (2022), Subba et al. (2022), Ismail et al. (2023), Khan et al. (2023), Mishra et al. (2024), Mitiku et al. (2024), and Sree et al. (2024), who also reported the predominance of non-additive gene action and identified superior hybrid combinations with significant SCA effects for grain yield and its component traits in maize.

4. CONCLUSION

The predominance of SCA variance over GCA variance indicated that non-additive gene action played a major role in the inheritance of grain yield and its associated traits. Among the parental lines, L_1, L_2, L_3, L_5, L_6, L_7, and L_8 were identified as superior general combiners due to their favourable GCA effects for grain yield and other important agronomic traits. Similarly, the hybrids $L_1×T_1$, $L_2×T_1$, $L_4×T_1$, $L_8×T_1$, $L_3×T_2$, $L_{11}×T_2$ and $L_{12}×T_2$ exhibited high SCA effects, indicating their potential for heterosis exploitation. Based on mean performance, $L_1×T_1$, $L_7×T_1$, and $L_3×T_2$ outperformed the standard check for grain yield and other desirable traits.

5. ACKNOWLEDGEMENT

The author is highly thankful to Bihar Agricultural College, Sabour, Bhagalpur & RRSS, Jalalgarh, Purnea for providing necessary guidelines and support to complete the research work. Dr. Shreya Sen and Dr. Fozia Homa have cooperated and helped in collection of field data, statistical analysis and Dr. Tushar Ranjan preparation of manuscript.

6. REFERENCES

Abdel-Moneam, M., Sultan, M., Khalil, A., El-Awady, H., 2024. Heterosis and combining abilities for certain maize inbreds and their F_1 crosses relating to quality traits, yield, and its components. Journal of Plant Production 15(5), 225–233. DOI: 10.21608/jpp.2024.283524.1330.

Anonymous, 2023a. FAOSTAT crop statistics. Food and Agriculture Organization of the United Nations. Available from: https://www.fao.org/faostat/en/#data/QCL. Accessed on: 20th November, 2025.

Anonymous, 2023b. DA&FW, Department of agriculture and farmers welfare. Available from: https://agriwelfare.gov.in/en/CropSituation. Accessed on: 20th November, 2025.

Assefa, T., Zeleke, H., Afriye, T., Otyama, P., 2017. Line×tester analysis of tropical highland maize (*Zea mays* L.) inbred lines top crossed with three east African maize populations. American Journal of Plant Sciences 8(2), 126–136. DOI: 10.4236/ajps.2017.82010.

Azad, M.A.K., Biswas, B.K., Alam, N., Alam, S.S., 2012. Genetic diversity in maize (*Zea mays* L.) inbred lines. The Agriculturists 10(1), 64–70. DOI: https://doi.org/10.3329/agric.v10i1.11066.

Belay, N., 2022. Combining ability studies from line×tester mating design for grain yield and its related traits of Mid-Altitude maize inbred lines. International Journal of Food Science and Agriculture 6(1), 64–75. DOI: http://dx.doi.org/10.26855/ijfsa.2022.03.009.

Begna, T., 2021. Combining ability and heterosis in plant improvement. Open Journal of Plant Science. 6(1), 108–117. DOI: https://dx.doi.org/10.17352/ojps.000043.

Bhatla, A., Angidi, S., Thomas, N., Madankar, K., Shahi, J.P, 2025. Classification of maize inbred lines into heterotic groups based on yield and yield attributing traits. Plant Genetic Resources: Characterization and Utilization 23(1), 27–39. https://www.cambridge.org/core/journals/plant-genetic-resources/article/classification-of-maize-inbred-lines-into-heterotic-groups-based-on-yield-and-yield-attributing-traits/AF438A639B4D089143D3C1EA8B44BF33.

Bisen, P., Dadheech, A., Namrata, Nagar, O., Meena, R.K., 2023. Exploitation of heterosis in single cross hybrids of quality protein maize (*Zea maize* L.) for yield and quality traits. International Journal of Bio-resource and Stress Management 8(1), 012–019. Available from: https://ojs.pphouse.org/index.php/IJBSM/ article/view/1061.

Chavan, S., Bhadru, D., Swarnalatha, V., Mallaiah, B., 2022. Identification of promisingparental lines and sweet corn (*Zea mays* L. saccharata). Electronic Journal of Plant Breeding 13 (2), 549–557. DOI: https://doi.org/10.37992/2022.1302.067.

Elmyhun, M., Liyew, C., Shita, A., Andualem, M., 2020. Combining ability performance and heterotic grouping of maize (*Zea mays*) inbred lines in testcross formation in Western Amhara, North West Ethiopia. Cogent Food and Agriculture 6(1). DOI: https://doi.org/10.1080/23311932.2020.1727625.

El Ghonemy, M.A., Aboyousef, H.A., Shosha, A., El Shahed, H.M., Shalof, M.S., 2023. Combining ability, main performance and superiority percentages of maize (*Zea mays* L.) inbred lines using line×tester analysis. Egyptian Journal of Agricultural Research 101(3), 939–951. DOI: 10.21608/ejar.2023.196478.1375.

Fasahat, P., Rajabi, A., Rad, J.M., Derera, J., 2016. Principles and utilization of combining ability in plant breeding. Biometrics and Biostatistics International Journal 4(1),

1–22. DOI: 10.15406/bbij.2016.04.00085.
Hombaradi, P.R., Kachapur, R.M., Harlapur, S.I., 2021. Studies on combining ability for yield and it's component traits in maize [*Zea mays* (L.)]. Journal of Farm Sciences 34(01), 1–4. DOI: https://doi.org/10.61475/jfm.v34i01.125.
Ibrahim, K.A., Said, A.A., Kamara, M.M., 2021. Evaluation and classification of yellow maize inbred lines using line×tester analysis across two locations. Journal of Plant Production 12(6), 605–613. DOI: 10.21608/jpp.2021.77256.1030.
Ismail, M.R., Mostafa, A.K., Abd-Elaziz, M.A.A., Rizk, M.S., El-Mouslhy, T.T., 2023. Heterotic grouping of maize inbred lines using line×tester analysis. Electronic Journal of Plant Breeding 14(4), 1293–1301. DOI: https://doi.org/10.37992/2023.1404.161.
Karim, A., Talukder, Z., Omy, S., Sultana, R., Alam, M., 2021. Assessment of inbred lines of field corn for yield and yield attributes through line×tester method. Bangladesh Journal of Agricultural Research 46(4), 469–489. DOI: https://doi.org/10.3329/bjar.v46i4.64719.
Karim, A., Ahmed, S., Akhi, A., Talukder, M., Mujahidi, T, 2018. Combining ability and heterosis study in maize (*Zea mays* L.) hybrids at different environments in Bangladesh. Bangladesh Journal of Agricultural Research 43(1), 125–134. DOI: https://doi.org/10.3329/bjar.v43i1.36186.
Kempthorne, O., 1957. An introduction to genetic statistics. John Wileyand Sons Inc., New York., 323–331p. Available from: https://psycnet.apa.org/record/1958-01083-000.
Khan, S., Dadheech, A., Dubey, R.B., Bharti, B., 2023. Combining ability and gene action studies for grain yield and quality parameters in yellow seeded maize(*Zea mays* L.) using line×tester crosses. International Journal of Bio-resource and Stress Management 12(4spcl), 508–514. Available from: https://ojs.pphouse.org/index.php/IJBSM/article/view/ 923.
Lal, K., Kumar, S., Shrivastav, S. P., Singh, L., Singh, V., 2023. Combining ability effects and heterosis estimates in maize (*Zea mays* L.). Electronic Journal of Plant Breeding 14(1). DOI: 10.37992/2023.1401.001.
Kumar, A.C., Lohithaswa, H.C., Uma, M.S., Mahadevu, P., 2018. Analysis of combining ability and heterosis for yield and yield contributing traits in newly developed inbred lines of maize (*Zea mays* L.). International Journal Agricultural Science 10(6), 5460–5464. Available from: http://www.bioinfopublication.org/jouarchive.php?opt=&jouid=BPJ0000217.
Kumari, M., Meena, L., Singh, R., 2015. Problems and prospects of maize crop in eastern zone of Bihar. International Journal of Agricultural Science and Research 5, 137–146. Available from: https://www.researchgate.net/publication/299285413_Problems_and_Prospects_of_Maize_Crop_in_Eastern_Zone_of_Bihar.
Mosa, H.E., Abd El Moula, M.A., Abd El Aal, A.M.M., El Gazzar, I.A.I., Hassan, M.A.A., El Haress, S.A., Abd Elaziz, M.A.A., 2024. Combining ability and relationships among heterotic grouping classification methods for nine maize inbred lines. Egyptian Journal of Plant Breeding 28, 1–20. DOI: 10.12816/ejpb.2024.352178.
Mishra, D.K., Singh, B., Manigopa, C., Verma, N., Surin, S., Mishra, S., 2024. Combining ability heterosis in maize (*Zea mays* L.) inbred lines. Journal of Scientific Research and Reports 30, 943–954. DOI: 10.9734/jsrr/2024/v30i62112.
Mitiku, T., Negera, D., Nepir, G., 2024. Mean performance and heterotic pattern of maize (*Zea mays* L.) Inbred Lines Adapted to Sub-humid Central Highland of Ethiopia (July 08, 2024). SSRN. DOI: http://dx.doi.org/10.2139/ssrn.4993176.
Panse, V.G., Sukhatme, P.V., 1985. Statistical methods for Agricultural Workers. ICAR, New Delhi, 235–246. Available from: https://www.cabidigitallibrary.org/doi/full/10.5555/19561604178.
Prasanna, B.M., Cairns, J.E., Zaidi, P.H., Beyene, Y., Makumbi, D., Gowda, M., Magorokosho, C., ZamanAllah, M., Olsen, M., Das, A., Worku, M., 2021. Beat the stress: Breeding for climate resilience in maize for the tropical rainfed environments. Theoretical and Applied Genetics 7, 1–24. DOI: 10.1007/s00122- 021-03773-7.
Ravikesavan, R., Suhasini, B., Yuvaraja, A., Kumarivinodhana, N., 2020. Assessment of combining ability for yield and yield contributing traits in sweet corn. Electronic Journal of Plant Breeding 11 (1), 224–229. DOI: https://doi.org/10.37992/2020.1101.038.
Sharma, B.B., Sharma, V.K., Dhakar, M.K., Punetha, S., 2013. Combining ability and gene action studies for horticultural traits in garden pea: A review. African Journal of Agricultural Research 8(38), 4718–4725. DOI: 10.5897/AJAR2013.7268.
Sharma, P., Kamboj, M.C., Punia, M.S., 2019. Assessment of combining ability effects using quality protein maize donors as testers for yield and yield traits in maize. Electronic Journal of Plant Breeding 10(4), 1367–1375. DOI: 10.5958/0975-928X.2019.00175.3.
Sprague, G.F., Tatum, L.A., 1942. General vs. Specific combining ability in single crosses of corn. Agronomy Journal 34(10), 923–932. DOI: 10.2134/agronj1942.00021962003400100008x.

Sree, K.K., Kumar, M.V.N., Ramya, V., Sunil, N., Bhadru, D., Chary, K.S., 2024. Identification of potential tropical maize inbred lines with early maturity for drought-prone environments. International Journal of Bio-resource and Stress Management 15(2), 01–10. DOI: https://doi.org/10.23910/1.2024.5045.

Subba, V., Nath, A., Kundagrami, S., Ghosh, A., 2022. Study of combining ability and heterosis in quality protein maize using line×tester mating design. Agricultural Science Digest 42(2), 159–164. DOI: 10.18805/ag.D-5460.

Zhang, X., Lv, L., Lv, C., Guo, B., Xu, R., 2015. Combining ability of different agronomic traits and yield components in hybrid barley. PloS One 10(6), e0126828. DOI: https://doi.org/10.1371/journal.pone.0126828.