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Genetic Studies of Grain Yield and Resistance of Single Cross Maize Hybrids to *Turcicum* Leaf Blight

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Maize (*Zea mays* L.) is a vital cereal crop globally, yet its productivity is frequently constrained by foliar diseases such as Turcicum Leaf Blight (TLB), caused by *Exserohilum turcicum*. The present study is aimed to evaluate the genetic variability, combining ability, heterosis, and TLB resistance

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among 50 single cross maize hybrids developed through a line × tester mating design involving five lines and ten testers. The genotypes were evaluated for agronomic traits and TLB resistance under field conditions. Analysis of variance revealed significant genetic variability for all traits, with grain yield exhibiting the highest heritability (99.09%) and genetic advance (64.18%). General combining ability (GCA) and specific combining ability (SCA) analyses showed that both additive and non-additive gene actions contributed to trait expression. Hybrids such as JLML-97555 × JLSN-81 and JLML-01666 × JLSN-34 demonstrated high yield potential and favourable combining ability. Heterosis for grain yield was pronounced, with better-parent heterosis reaching up to 98%. Screening for TLB resistance showed that although all hybrids were resistant at tasselling, only 38% retained resistance at physiological maturity. Parental lines JLML-01888 and JLML-94333 and testers JLSN-34 and JLSN-73 conferred durable resistance. The findings emphasized the potential of combining ability analysis and hence, hybrids that integrate high yield and durable disease resistance were identified which serve as valuable material for maize improvement programs.

Keywords: Zea mays; combining ability; genetic variability; heterosis; Turcicum leaf blight; resistance; hybrid maize.

1. INTRODUCTION

Maize, or *Zea mays L.*, is a globally significant cereal crop cultivated across diverse climates. Its versatility in serving as food, animal feed, and raw material for biofuels and other industries makes it crucial for livelihoods and economies (Shiferaw et al., 2011), with demand growing rapidly due to its role in feed, food security, and industrial sectors (FAO, 2021). Despite its importance, maize productivity is often hampered by biotic and abiotic stresses. Among these, Turcicum Leaf Blight (TLB), caused by the fungus *Exserohilum turcicum*, poses a serious threat, capable of causing up to 50% yield loss, especially during key growth stages (Sibiya et al., 2013; Menkir et al., 2020).

Modern maize breeding aims to tackle the dual challenge of increasing yield while improving disease resistance. One powerful method for this is the line × tester mating design, which helps breeders understand trait inheritance by evaluating general combining ability (GCA) and specific combining ability (SCA) (Kempthorne, 1957). This allows for the quantification of both additive and non-additive genetic effects that influence important traits like yield, plant structure, and disease resistance. Additionally, analysing genetic parameters such as genotypic and phenotypic coefficients of variation (GCV and PCV), heritability, and genetic advance enhances the efficiency of selecting superior hybrids (Magar et al., 2021).

Past research shows that additive gene action is a key driver for traits like ear length, kernel count, and resistance to foliar diseases such as TLB. In contrast, grain yield is often more heavily influenced by non-additive effects, highlighting the importance of heterosis and hybrid development. Furthermore, assessing disease resistance at multiple growth stages, from tasseling to maturity, is vital for ensuring long-term disease management (Sibiya et al., 2013; Badu-Apraku et al., 2020). Studies from various regions have shown that combining high yield potential with biotic stress resistance is essential for sustainable maize production (Badu-Apraku et al.,2022; Gowda et al., 2015).

The current study is designed to evaluate the genetic variability, combining ability, heterosis, and TLB resistance in a collection of single-cross maize hybrids. By systematically conducting a line × tester analysis, this research intends to identify elite parental lines and hybrid combinations that possess both high productivity and durable disease resistance. The ultimate goal is to provide valuable genetic material for future maize breeding programs and for deployment in regions prone to disease outbreaks.

2. MATERIALS AND METHODS

2.1 Experimental Material Development and Screening

To understand the genetic basis of key traits in maize, a study was conducted at MRU, Hyderabad in the *Rabi* 2024 season. Sixty-five maize genotypes, consisting of five lines and ten testers, were crossed and evaluated in a randomized block design with three replications. The experiment measured eight agronomic traits viz; days to 50% flowering, plant height, ear height, ear length, ear diameter, number of rows per ear, number of kernels per row, and grain yield, along with Turcicum Leaf Blight (TLB) resistance. To assess TLB resistance, the plants were artificially inoculated with *E. turcicum* and scored the disease severity at three different growth stages using the scale developed by Mitiku et al. (2014). The statistical analysis included ANOVA, estimation of heritability, genetic advance, combining ability, and heterosis.

2.2 Preparation of Artificial Disease Inoculation

2.2.1 Collection of bacterium and mass multiplication

- *Exserohilum turcicum* inoculum was collected from the Department of Plant Pathology at Agricultural College, for artificial disease inoculation.
- The multiplication was done on sterilized sorghum grain culture (Joshi et al., 1969) for about a fortnight.
- The above impregnated sorghum grains were allowed for drying by spreading them on a clean paper sheet in shade at room temp.
- After drying, prepared a fine powder of these grains with the help of mixer- grinder and put a pinch of this powder in the leaf whorl.

2.2.2 Artificial disease inoculation

Three weeks old culture of *E. turcicum* multiplied on sorghum grains was powdered and inoculated into the whorls of test plants at 32 DAS following whorl drop method of inoculation (Frederiksen & Franklin, 1978) and was followed by water spray so as to maintain humidity for infection. The inoculation was done in the evening time between 5 and 6 pm.

2.3 Per cent Disease Index (PDI)

Based on disease severity data, per cent disease index (PDI) was calculated from the formula given by Wheeler (1969).

$$\text{PDI (\%)} = \frac{Sum\ of\ individual\ disease\ ratings}{Total\ number\ of\ plants/leaves\ observed\ x\ Maximum\ disease\ rating\ value} \text{ x } 100$$

3. RESULTS AND DISCUSSION

Analysis of variance revealed significant differences ($p < 0.01$) among genotypes for all eight traits studied, confirming substantial genetic variability within the hybrid population; given in the Tables 1 and 2.

Table 1. Analysis of variance based on mean square through maize genotypes

Source	Df	DFF	PH	EH	EL	ED	NRE	NK	GY
Replication	2	0.38	61.03	13.06	0.48	0.03	0.07	0.46	0.04
Genotype	14	257.96**	2323.18**	334.67**	32.76**	0.38**	6.18**	41.01**	536.69**
Error	28	3.38	53.07	15.57	0.41	0.02	0.20	0.65	1.64

Table 2. Analysis of variance based on mean squares and genetic components through line by tester analysis on traits of maize

Sources	DF	DFF	PH	EH	EL	ED	NRE	NK	GY
Replication	2	1.32*	28.02*	24.35*	0.71*	0.03*	0.14*	0.31*	1.24*
Genotype	64	88.19*	1157.99*	276.25*	43.58*	1.41*	7.98ns	101.18*	779.57*
Cross	49	33.49*	625.43*	265.35*	42.10*	1.64*	8.59ns	103.70*	844.79*
Line(c)	4	192.34*	306.57*	624.18*	346.68*	12.57ns	70.81*	670.33ns	7371.34*
Test(c)	9	12.85*	373.31*	118.42*	3.58*	0.27ns	2.42*	25.69*	161.78ns
LXT (c)	36	21.00*	723.89*	262.21*	17.88*	0.77*	3.22ns	60.24*	290.37*
Parent	14	263.17*	2286.74*	310.60*	28.69*	0.42ns	6.41*	45.45*	569.41*
Line (p)	4	17.98*	138.53*	433.90*	19.20*	0.57*	9.45*	44.70*	231.11*
Test (p)	9	373.03*	2900.73*	289.61*	24.55*	0.39ns	5.78*	50.82*	673.46*
L(P)vT(P)	1	255.26*	5353.67*	6.38*	103.79*	0.12*	0.03*	0.11*	986.12*
Cross vs Parent	1	318.57*	11450.97*	329.57*	324.70*	3.77*	0.11*	757.72*	525.95*
Error	128	2.31	37.75	12.42	0.43	0.02	0.17	0.84	1.13

DFF-Days to fifty per cent flowering, PH-Plant height (cm), EH-Ear height (cm), EL-Ear head length, ED-Ear diameter, NRE-Number of rows/ear, NK- Number of kernels and GY-Grain yield

Notably, grain yield exhibited the highest genotypic and phenotypic coefficients of variation (GCV and PCV) alongside a heritability estimate of 99.09% and a genetic advance of 64.18%. These values indicate that genetic factors primarily control this trait, allowing for effective improvement through selection (Owusu et al., 2020). Traits such as kernels per row (95.40% heritability) and rows per ear (91.03%) also showed high heritability and genetic advance, suggesting potential for cumulative gain under selection pressure (Lal et al., 2023) (Table 3).

In the line × tester analysis, general combining ability (GCA) and specific combining ability (SCA) effects were significant for all traits (Table 4).

This implies that both additive and non-additive gene actions were important in trait inheritance. The lines JLML-01666 and JLML-97555 were identified as the best general combiners for yield and yield-related traits, including ear length, ear diameter, and kernel number. On the tester side, JLSN-80 and JLSN-72 were strong combiners for yield traits. These findings align with earlier reports indicating that parental lines with high GCA effects are essential for hybrid development (Sibiya et al., 2013).

Specific combining ability effects were notable in certain crosses (Table 5). For instance, the hybrid JLML-01888 × JLSN-72 showed significant positive SCA for ear length and kernel traits, exceeding mid-parent expectations. Conversely, a few hybrids such as JLML-05444 × JLSN-25 had negative SCA for grain yield and component traits, suggesting unfavourable gene interactions. Such results reaffirm the need to consider both GCA and SCA in hybrid breeding programs (Antony et al., 2023).

Table 3. Genetic parameter for maize genotypes

Genetic parameter	DFF	PH	EH	EL	ED	NRE	NK	GY
Phenotypic Coefficient of Variance	15.50	12.50	8.22	12.73	6.82	9.93	10.72	31.44
Genotypic Coefficient of Variance	15.20	12.08	7.68	12.49	6.36	9.48	10.47	31.30
Environmental Coefficient of Variance	3.03	3.20	2.94	2.43	2.48	2.97	2.30	3.01
Heritability (Broad Sense)	96.17	93.45	87.23	96.34	86.76	91.03	95.40	99.09
Genetic Advance	18.61	54.78	19.84	6.64	0.67	2.78	7.38	27.38
Genetic Advance as per cent of mean	30.70	24.05	14.77	25.26	12.19	18.63	21.07	64.18

Table 4. General combining ability (GCA) values of lines and testers for all observed maize characters

Lines	DFF	PH	EH	EL	ED	NRE	NK	GY
JLML-01888	2.11 **	1.01 ns	-2.38 **	-2.35 **	-0.41 **	-1.07 **	-3.22 **	-10.19 **
JLML-05444	3.34 **	-1.40 ns	-0.15 ns	-2.26 **	-0.44 **	-0.94 **	-3.02 **	-10.97 **
JLML-94333	-1.52 **	5.14 **	7.84 **	-2.78 **	-0.55 **	-1.32 **	-4.05 **	-12.74 **
JLML-97555	-1.85 **	-2.04 ns	-1.65 *	3.12 **	0.61 **	1.44 **	4.56 **	13.69 **
JLML-01666	-2.07 **	-2.71 *	-3.65 **	4.26 **	0.80 **	1.89 **	5.72 **	20.22 **
Testers	**DFF**	**PH**	**EH**	**EL**	**ED**	**NRE**	**NK**	**GY**
JLSN-03	0.44 ns	3.39 *	3.58 **	0.10 ns	-0.00 ns	0.20 ns	0.93 **	0.95 **
JLSN-22	0.02 ns	3.25 *	1.77 ns	-0.87 **	-0.24 **	-0.47 **	-1.82 **	-6.90 **
JLSN-25	-0.26 ns	1.27 ns	-2.87 **	-0.22 ns	0.01 ns	-0.32 **	0.27 ns	-1.23 **
JLSN-31	-1.03 *	-2.26 ns	-1.23 ns	0.01 ns	-0.05 ns	0.26 *	-0.89 **	1.18 **
JLSN-34	-1.06 **	4.23 *	2.14 *	-0.34 *	-0.00 ns	0.23 *	0.19 ns	1.40 **
JLSN-66	-0.91 *	-5.31 **	-1.86 *	-0.18 ns	-0.15 **	-0.67 **	-0.49 *	-0.69 *
JLSN-72	1.13 **	4.27 *	2.25 *	0.79 **	0.13 **	0.08 ns	2.61 **	3.88 **
JLSN-73	0.43 ns	5.05 **	2.81 **	-0.27 ns	-0.04 ns	-0.27 *	-0.06 ns	-3.22 **
JLSN-80	-0.42 ns	-9.06 **	-4.44 **	0.40 *	0.17 **	0.48 **	0.85 **	4.18 **
JLSN-81	1.67 **	-4.83 **	-2.16 *	0.57 **	0.18 **	0.46 **	-1.60 **	0.45 ns

DFF-Days to fifty per cent flowering, PH-Plant height (cm), EH-Ear height (cm), EL-Ear head length, ED-Ear diameter, NRE-Number of rows/ear, NK- Number of kernels and GY-Grain yield

Table 5. Specific combining ability (SCA) values of lines and testers for all observed maize characters

Crosses	DFF	PH	EH	EL	ED	NRE	NK	GY
JLML-01888XJLSN-03	-3.50 **	-0.67 ns	-1.97 ns	0.18 ns -	0.57 **	1.52 **	1.04 ns	4.13 **
JLML-01888XJLSN-22	-3.58 **	3.80 ns	-0.23 ns	2.79 **	-0.12 ns	0.81 **	0.51 ns	7.29 **
JLML-01888XJLSN-25	-1.94 *	-2.75 ns	-15.52 **	-2.11 **	0.25 **	-0.36 ns	-4.25 **	-2.57 **
JLML-01888XJLSN-31	0.02 ns	13.80 **	12.98 **	-1.98 **	0.36 **	0.64 **	-2.93 **	-3.62 **
JLML-01888XJLSN-34	1.40 ns	-4.29 ns	-4.74 *	0.65 ns	-0.75 **	-1.57 **	1.76 **	-1.86 **
JLML-01888XJLSN-66	1.33 ns	8.35 *	6.70 **	1.95 **	-0.71 **	-0.90 **	-6.09 **	-4.61 **
JLML-01888XJLSN-72	3.26 **	7.32 *	7.69 **	3.52 **	-0.19 *	0.57 *	8.33 **	3.79 **
JLML-01888XJLSN-73	0.48 ns	5.97 ns	1.94 ns	-0.90 *	0.32 **	0.27 ns	8.78 **	5.19 **
JLML-01888XJLSN-80	-1.68 ns	-48.85 **	-19.10 **	-2.37 **	-0.41 **	-1.33 **	-3.75 **	-6.73 **
JLML-01888XJLSN-81	4.22 **	17.33 **	12.25 **	-1.73 **	0.67 **	0.34 ns	-3.41 **	-1.01 ns
JLML-05444XJLSN-03	2.45 **	13.03 **	10.35 **	1.48 **	-0.59 **	-1.09 **	4.26 **	2.17 **
JLML-05444XJLSN-22	3.26 **	-6.36 ns	-9.42 **	-0.35 ns	0.76 **	0.51 *	-1.07 *	2.49 **
JLML-05444XJLSN-25	3.47 **	-1.52 ns	3.37 ns	2.58 **	-0.44 **	0.45 ns	6.41 **	4.70 **
JLML-05444XJLSN-31	0.43 ns	-25.99 **	-17.29 **	0.13 ns	-0.10 ns	0.46 ns	2.33 **	0.36 ns
JLML-05444XJLSN-34	-8.64 **	2.52 ns	2.14 ns	-3.39 **	0.21 **	-0.26 ns	-7.78 **	-9.90 **
JLML-05444XJLSN-66	0.28 ns	22.51 **	9.73 **	-1.28 **	0.61 **	0.78 **	3.68 **	4.97 **
JLML-05444XJLSN-72	-0.15 ns	6.91 ns	4.02 ns	-0.98 **	0.40 **	-0.55 *	0.28 ns	2.70 **
JLML-05444XJLSN-73	-0.65 ns	-5.34 ns	-2.98 ns	-0.56 ns	-0.69 **	-1.11 **	-1.89 **	-1.53 *
JLML-05444XJLSN-80	-0.16 ns	23.81 **	15.02 **	-0.60 ns	0.01 ns	0.32 ns	-1.73 **	-4.03 **
JLML-05444XJLSN-81	-0.27 ns	-29.57 **	-14.95 **	2.96 **	-0.17 *	0.49 *	-4.49 **	-1.94 **
JLML-94333XJLSN-03	2.48 **	-2.80 ns	-2.11 ns	-2.49 **	-0.24 **	-0.65 **	-6.70 **	-5.54 **
JLML-94333XJLSN-22	-1.01 ns	4.23 ns	4.48 *	1.77 **	-0.08 ns	0.22 ns	4.33 **	7.40 **
JLML-9433XJLSN-25	-2.21 *	6.16 ns	5.84 **	-0.34 ns	0.33 **	-0.47 *	-0.72 ns	-2.10 **
JLML-94333XJLSN-31	-2.06 *	9.11 *	5.35 *	-0.25 ns	-0.73 **	-1.43 **	-3.53 **	-6.12 **
JLML-94333XJLSN-34	5.47 **	11.32 **	9.68 **	0.37 ns	0.25 **	1.61 **	4.58 **	5.19 **
JLML-94333XJLSN-66	-3.69 **	-42.47 **	-21.40 **	-0.01 ns	-0.02 ns	-0.77 **	2.89 **	3.13 **
JLML-94333XJLSN-72	-0.50 ns	-4.63 ns	-4.40 *	-2.66 **	-0.25 **	-0.53 *	-5.19 **	-8.09 **
JLML-94333XJLSN-73	0.27 ns	6.72 ns	2.00 ns	4.18 **	0.88 **	1.65 **	-2.84 **	6.64 **
JLML-94333XJLSN-80	1.84 *	9.74 **	1.40 ns	-0.14 ns	0.06 ns	0.39 ns	2.66 **	-2.12 **
JLML-94333XJLSN-81	-0.58 ns	2.62 ns	-0.84 ns	-0.42 ns	-0.19 *	-0.02 ns	4.52 **	1.60 *
JLML-97555XJLSN-03	-0.18 ns	-3.35 ns	2.80 ns	-2.71 **	-0.37 **	-1.07 **	-2.08 **	-19.04 **
JLML-97555XJLSN-22	0.76 ns	-0.47 ns	2.94 ns	-2.43 **	-0.35 **	-0.92 **	-2.40 **	-10.08 **
JLML-97555XJLSN-25	0.03 ns	-1.97 ns	0.80 ns	1.40 **	0.19 *	0.78 **	0.94 ns	7.98 **
JLML-97555XJLSN-31	1.00 ns	2.25 ns	0.51 ns	0.28 ns	0.09 ns	-0.16 ns	1.02 ns	0.83 ns
JLML-97555XJLSN-34	1.33 ns	-3.19 ns	-0.81 ns	-0.71 ns	-0.20 *	-0.68 **	-1.69 **	-6.51 **
JLML-97555XJLSN-66	1.49 ns	7.39 *	5.21 *	-2.23 **	-0.28 **	-0.35 ns	-2.64 **	-11.55 **

Crosses	DFF	PH	EH	EL	ED	NRE	NK	GY
JLML-97555XJLSN-72	-1.57 ns	-5.66 ns	-5.68 **	1.30 **	0.23 **	0.75 **	-0.31 ns	7.62 **
JLML-97555XJLSN-73	0.04 ns	-3.31 ns	-0.12 ns	-1.69 **	-0.32 **	-0.55 *	-2.53 **	-6.64 **
JLML-97555XJLSN-80	-0.31 ns	6.62 ns	-1.01 ns	3.03 **	0.42 **	0.90 **	3.08 **	14.44 **
JLML-97555XJLSN-81	-2.60 **	1.69 ns	-4.66 *	3.77 **	0.58 **	1.29 **	6.61 **	22.93 **
JLML-01666XJLSN-03	-1.26 ns	-6.21 ns	-9.08 **	3.54 **	0.64 **	1.30 **	3.47 **	18.27 **
JLML-01666XJLSN-22	0.57 ns	-1.19 ns	2.23 ns	-1.78 **	-0.22 **	-0.63 **	-1.37 *	-7.10 **
JLML-01666XJLSN-25	0.66 ns	0.09 ns	5.51 **	-1.53 **	-0.32 **	-0.40 ns	-2.39 **	-8.03 **
JLML-01666XJLSN-31	0.61 ns	0.83 ns	-1.55 ns	1.83 **	0.37 **	0.50 *	3.11 **	8.55 **
JLML-01666XJLSN-34	0.44 ns	-6.36 ns	-6.27 **	3.08 **	0.48 **	0.90 **	3.12 **	13.08 **
JLML-01666XJLSN-66	0.60 ns	4.23 ns	-0.25 ns	1.57 **	0.39 **	1.24 **	2.17 **	8.05 **
JLML-01666XJLSN-72	-1.04 ns	-3.94 ns	-1.64 ns	-1.19 **	-0.20 *	-0.25 ns	-3.10 **	-6.02 **
JLML-01666XJLSN-73	-0.14 ns	-4.04 ns	-0.84 ns	-1.03 **	-0.20 *	-0.26 ns	-1.52 **	-3.67 **
JLML-01666XJLSN-80	0.31 ns	8.68 *	3.70 ns	0.09 ns	-0.08 ns	-0.29 ns	-0.26 ns	-1.57 *
JLML-01666XJLSN-81	-0.76 ns	7.93 *	8.19 **	-4.57 **	-0.88 **	-2.11 **	-3.23 **	-21.58 **

DFF-Days to fifty per cent flowering, PH-Plant height (cm), EH-Ear height (cm), EL-Ear head length, ED-Ear diameter, NRE- Number of rows/ear, NK- Number of kernels and GY-Grain yield

Table 6. Mid-parent heterosis (MPH) in Hybrid maize (F1) for all observed characters

Crosses	Parent	PH	EH	EL	ED	NRE	NK	GY
JLML-01888XJLSN-03	8.94 **	17.69 **	-5.30 **	18.43 **	11.94 **	-1.16 ns	4.70 **	-17.83 **
JLML-01888XJLSN-22	-2.46 ns	13.01 **	-5.21 **	-14.20 **	-1.59 ns	-12.10 **	-8.50 **	5.61 *
JLML-01888XJLSN-25	9.99 **	16.36 **	-23.48 **	-31.71 **	12.60 **	-20.88 **	-7.88 **	-50.66 **
JLML-01888XJLSN-31	-7.37 **	2.10 ns	-4.40 **	-31.53 **	4.48 *	-11.09 **	-15.74 **	-28.83 **
JLML-01888XJLSN-34	12.49 **	16.29 **	-8.47 **	-12.37 **	-7.98 **	-14.93 **	5.99 **	-12.31 **
JLML-01888XJLSN-66	16.23 **	4.03 *	-9.68 **	-16.23 **	-12.81 **	-19.99 **	-16.42 **	-32.42 **
JLML-01888XJLSN-72	2.62 ns	7.51 **	-1.16 ns	-9.19 **	5.91 **	-8.24 **	17.71 **	-4.93 *
JLML-01888XJLSN-73	16.46 **	-24.20 **	-0.59 ns	-23.65 **	2.89 ns	-5.46 **	11.35 **	-29.05 **
JLML-01888XJLSN-80	-9.00 **	3.69 *	-27.62 **	-23.67 **	-3.13 ns	-14.84 **	-5.62 **	-20.65 **
JLML-01888XJLSN-81	23.35 **	21.54 **	1.38 ns	-16.83 **	22.73 **	-6.88 **	-20.99 **	-43.23 **
JLML-05444XJLSN-03	24.02 **	12.44 **	14.52 **	-17.22 **	-13.40 **	-6.63 **	24.30 **	-31.42 **
JLML-05444XJLSN-22	12.32 **	13.06 **	-2.21 ns	-29.18 **	11.06 **	-2.92 ns	-4.46 *	-25.83 **
JLML-05444XJLSN-25	24.06 **	-2.18 ns	-1.32 ns	-17.96 **	-5.24 **	-5.66 **	34.31 **	-42.57 **
JLML-05444XJLSN-31	-3.37 *	4.41 *	-16.92 **	-26.98 **	-7.51 **	-1.21 ns	6.65 **	-28.26 **
JLML-05444XJLSN-34	-0.50 ns	22.41 **	6.79 **	-32.41 **	6.73 **	7.27 **	-12.24 **	-46.56 **
JLML-05444XJLSN-66	19.05 **	3.36 ns	1.57 ns	-31.21 **	8.10 **	3.14 ns	21.63 **	-17.04 **
JLML-05444XJLSN-72	1.20 ns	2.26 ns	6.36 **	-28.49 **	12.88 **	-4.08 *	6.38 **	-18.66 **

Crosses	Parent	PH	EH	EL	ED	NRE	NK	GY
JLML-05444XJLSN-73	19.13 **	4.54 **	6.35 **	-25.72 **	-18.55 **	-2.58 ns	-7.35 **	-51.07 **
JLML-05444XJLSN-80	-3.42 *	-15.69 **	5.19 **	-20.35 **	0.64 ns	8.85 **	10.02 **	-24.41 **
JLML-05444XJLSN-81	20.20 **	15.24 **	-9.21 **	-1.99 ns	1.90 ns	6.42 **	-16.81 **	-50.80 **
JLML-94333XJLSN-03	10.03 **	18.42 **	9.22 **	-30.26 **	-7.62 **	-17.41 **	-6.50 **	-43.33 **
JLML-94333XJLSN-22	-6.43 **	17.66 **	13.09 **	-19.44 **	-5.53 **	-18.22 **	13.14 **	8.63 **
JLML-9433XJLSN-25	0.50 ns	14.80 **	4.81 **	-26.55 **	9.20 **	-23.93 **	15.11 **	-51.90 **
JLML-94333XJLSN-31	-17.40 **	9.14 **	3.83 *	-26.62 **	-19.35 **	-25.78 **	-8.26 **	-37.36 **
JLML-94333XJLSN-34	10.30 **	-6.60 **	16.99 **	-15.09 **	7.13 **	3.49 ns	28.12 **	12.11 **
JLML-94333XJLSN-66	-1.69 ns	-0.15 ns	-16.47 **	-24.91 **	-4.11 *	-21.78 **	22.32 **	-9.61 **
JLML-94333XJLSN-72	-10.25 **	8.40 **	4.34 *	-32.91 **	-0.03 ns	-17.68 **	-6.83 **	-37.65 **
JLML-94333XJLSN-73	6.82 **	0.02 ns	14.84 **	-5.31 **	8.54 **	0.84 ns	-8.53 **	-26.45 **
JLML-94333XJLSN-80	-11.16 **	-1.55 ns	-0.49 ns	-16.15 **	1.11 ns	-6.49 **	26.76 **	-5.83 *
JLML-94333XJLSN-81	5.96 **	11.15 **	6.44 **	-12.82 **	1.06 ns	-11.81 **	9.72 **	-39.44 **
JLML-97555XJLSN-03	10.70 **	12.42 **	8.28 **	-6.93 **	3.51 *	5.13 **	22.80 **	-20.59 **
JLML-97555XJLSN-22	0.51 ns	10.14 **	7.14 **	-11.83 **	3.55 *	-1.09 ns	8.75 **	19.11 **
JLML-97555XJLSN-25	9.38 **	8.03 **	-3.64 ns	3.15 ns	19.49 **	7.38 **	34.90 **	12.19 **
JLML-97555XJLSN-31	-9.70 **	-0.19 ns	-4.34 *	-1.88 ns	8.27 **	5.61 **	19.37 **	39.00 **
JLML-97555XJLSN-34	8.39 **	12.54 **	4.11 *	6.59 **	11.97 **	15.98 **	23.43 **	37.31 **
JLML-97555XJLSN-66	12.51 **	-3.83 *	-2.09 ns	-10.02 **	4.72 **	6.78 **	20.26 **	9.05 **
JLML-97555XJLSN-72	-8.24 **	0.84 ns	-1.49 ns	4.17 *	22.15 **	16.12 **	20.49 **	57.78 **
JLML-97555XJLSN-73	11.68 **	-4.48 **	8.31 **	-3.82 *	0.58 ns	13.88 **	7.02 **	-6.26 **
JLML-97555XJLSN-80	-10.80 **	-5.16 **	-7.03 **	22.50 **	20.15 **	24.13 **	41.70 **	101.40 **
JLML-97555XJLSN-81	7.54 **	14.05 **	-1.51 ns	32.03 **	28.11 **	22.86 **	28.71 **	46.12 **
JLML-01666XJLSN-03	7.00 **	16.39 **	-11.05 **	31.38 **	25.76 **	29.08 **	52.76 **	57.38 **
JLML-01666XJLSN-22	-1.30 ns	15.30 **	-4.05 *	2.06 ns	10.61 **	7.73 **	23.07 **	24.66 **
JLML-01666XJLSN-25	8.70 **	11.38 **	-9.68 **	3.35 ns	15.23 **	6.51 **	38.88 **	-15.73 **
JLML-01666XJLSN-31	-11.53 **	1.84 ns	-14.80 **	15.68 **	17.58 **	16.87 **	37.39 **	51.05 **
JLML-01666XJLSN-34	5.12 **	15.36 **	-10.20 **	37.85 **	29.26 **	36.22 **	51.61 **	80.05 **
JLML-01666XJLSN-66	9.07 **	0.03 ns	-14.94 **	16.43 **	21.36 **	25.73 **	48.57 **	53.49 **
JLML-01666XJLSN-72	-8.76 **	3.97 *	-8.36 **	6.20 **	19.27 **	16.85 **	24.40 **	21.49 **
JLML-01666XJLSN-73	9.54 **	-0.52 ns	-3.27 ns	11.14 **	7.02 **	24.35 **	20.34 **	0.66 ns
JLML-01666XJLSN-80	-11.15 **	0.47 ns	-12.74 **	24.21 **	16.29 **	23.86 **	46.18 **	48.26 **
JLML-01666XJLSN-81	9.01 **		-2.17 ns	9.42 **	6.94 **	7.05 **	13.61 **	-34.75 **

DFF-Days to fifty per cent flowering, PH-Plant height (cm), EH-Ear height (cm), EL-Ear head length, ED-Ear diameter, NRE- Number of rows/ear, NK- Number of kernels and GY-Grain yield

Table 7. Best-parent heterosis (BPH) in Hybrid maize (F1) for all observed characters

Crosses	DFF	PH	EH	EL	ED	NRE	NK	GY
JLML-01888XJLSN-03	-3.16 ns	-3.16 ns	-11.88 **	22.09 **	4.07 *	-5.58 **	-5.14 **	-33.62 **
JLML-01888XJLSN-22	-3.95 *	4.45 *	-11.93 **	-19.79 **	-5.26 *	-13.79 **	-13.20 **	-7.12 *
JLML-01888XJLSN-25	-1.85 ns	0.93 ns	-25.26 **	-37.30 **	10.23 **	-21.81 **	-19.74 **	-64.24 **
JLML-01888XJLSN-31	-13.73 **	6.30 **	-5.10 **	-38.00 **	-4.83 *	-11.70 **	-19.35 **	-38.18 **
JLML-01888XJLSN-34	2.09 ns	1.52 ns	-14.70 **	-14.31 **	-10.17 **	-23.96 **	-5.18 **	-14.66 **
JLML-01888XJLSN-66	2.20 ns	2.80 ns	-9.72 **	-22.87 **	-17.37 **	-25.29 **	-26.12 **	-38.34 **
JLML-01888XJLSN-72	-2.53 ns	1.84 ns	-6.31 **	-18.12 **	3.41 ns	-11.94 **	16.88 **	-19.49 **
JLML-01888XJLSN-73	2.97 ns	6.09 **	-9.78 **	-26.72 **	-7.18 **	-15.89 **	11.27 **	-44.36 **
JLML-01888XJLSN-80	-15.30 **	-25.97 **	-28.71 **	-23.81 **	-9.89 **	-20.95 **	-17.10 **	-24.45 **
JLML-01888XJLSN-81	10.66 **	0.85 ns	-6.21 **	-20.27 **	18.88 **	-11.02 **	-22.27 **	-58.51 **
JLML-05444XJLSN-03	12.10 **	8.33 **	13.64 **	-17.47 **	-16.85 **	-12.72 **	21.58 **	-38.99 **
JLML-05444XJLSN-22	11.94 **	0.20 ns	-2.79 ns	-30.55 **	10.58 **	-11.50 **	-7.01 **	-40.68 **
JLML-05444XJLSN-25	12.60 **	1.39 ns	-6.78 **	-21.07 **	-6.44 **	-16.36 **	25.86 **	-54.95 **
JLML-05444XJLSN-31	-11.56 **	-10.26 **	-22.72 **	-30.76 **	-13.06 **	-12.03 **	2.85 ns	-30.67 **
JLML-05444XJLSN-34	-8.14 **	4.30 *	5.80 **	-36.98 **	5.68 **	7.00 **	-15.34 **	-50.98 **
JLML-05444XJLSN-66	6.43 **	8.65 **	-6.12 **	-33.61 **	5.87 **	-1.36 ns	15.80 **	-18.78 **
JLML-05444XJLSN-72	-5.57 **	0.72 ns	3.51 ns	-32.50 **	11.74 **	-10.74 **	-0.99 ns	-23.63 **
JLML-05444XJLSN-73	7.10 **	1.37 ns	4.28 ns	-26.32 **	-24.20 **	-3.35 ns	-14.39 **	-57.94 **
JLML-05444XJLSN-80	-11.65 **	1.63 ns	-1.42 ns	-24.01 **	-3.32 ns	4.73 *	4.03 ns	-29.18 **
JLML-05444XJLSN-81	9.69 **	-18.37 **	-9.33 **	-10.33 **	1.70 ns	-0.55 ns	-21.89 **	-61.03 **
JLML-94333XJLSN-03	-4.16 *	1.37 ns	8.29 **	-33.58 **	-12.67 **	-21.94 **	-9.09 **	-57.58 **
JLML-94333XJLSN-22	-9.94 **	4.15 *	11.94 **	-24.90 **	-7.45 **	-20.66 **	4.93 *	5.36 ns
JLML-9433XJLSN-25	-12.13 **	4.13 *	0.55 ns	-32.75 **	8.81 **	-23.99 **	13.27 **	-67.22 **
JLML-94333XJLSN-31	-21.35 **	3.90 ns	-1.93 ns	-33.73 **	-25.33 **	-26.10 **	-15.65 **	-50.04 **
JLML-94333XJLSN-34	-1.97 ns	7.41 **	16.18 **	-16.72 **	6.44 **	-8.40 **	26.32 **	-1.11 ns
JLML-94333XJLSN-66	-15.27 **	-18.17 **	-21.62 **	-31.05 **	-7.57 **	-27.71 **	22.26 **	-24.70 **
JLML-94333XJLSN-72	-12.81 **	-1.25 ns	3.19 ns	-39.67 **	-0.64 ns	-21.84 **	-17.17 **	-51.36 **
JLML-94333XJLSN-73	-7.43 **	5.88 **	10.84 **	-9.38 **	-0.49 ns	-11.17 **	-19.23 **	-46.35 **
JLML-94333XJLSN-80	-15.47 **	-1.33 ns	-5.30 **	-16.56 **	-4.36 *	-14.09 **	25.91 **	-18.53 **
JLML-94333XJLSN-81	-6.87 **	-3.28 ns	4.87 *	-16.19 **	-0.38 ns	-16.62 **	-1.65 ns	-58.43 **
JLML-97555XJLSN-03	0.50 ns	-2.58 ns	6.61 **	-12.61 **	1.80 ns	3.17 ns	15.65 **	-32.21 **
JLML-97555XJLSN-22	-0.31 ns	-1.48 ns	5.67 *	-18.94 **	-1.74 ns	-5.47 **	7.45 **	-1.11 ns

Crosses	DFF	PH	EH	EL	ED	NRE	NK	GY
JLML-97555XJLSN-25	-0.30 ns	-2.87 ns	-9.64 **	-6.83 **	11.57 **	-0.35 ns	21.94 **	-14.93 **
JLML-97555XJLSN-31	-17.71 **	-2.59 ns	-11.65 **	-12.56 **	7.67 **	-1.54 ns	19.07 **	28.35 **
JLML-97555XJLSN-34	0.51 ns	-2.17 ns	2.35 ns	6.10 **	4.83 *	10.10 **	14.71 **	31.80 **
JLML-97555XJLSN-66	1.01 ns	-1.76 ns	-10.16 **	-18.50 **	0.96 ns	6.23 **	10.36 **	6.19 **
JLML-97555XJLSN-72	-14.75 **	-4.49 *	-4.86 *	-7.56 **	14.33 **	13.43 **	16.41 **	41.76 **
JLML-97555XJLSN-73	0.83 ns	-1.90 ns	7.03 **	-9.25 **	-1.03 ns	7.55 **	2.62 ns	-22.53 **
JLML-97555XJLSN-80	-18.76 **	-5.37 **	-13.51 **	20.11 **	18.09 **	22.71 **	29.19 **	97.62 **
JLML-97555XJLSN-81	-1.44 ns	-6.44 **	-2.42 ns	28.79 **	20.84 **	20.53 **	25.49 **	11.82 **
JLML-01666XJLSN-03	-3.86 *	3.16 ns	-17.01 **	14.71 **	25.14 **	21.86 **	51.15 **	53.76 **
JLML-01666XJLSN-22	-1.63 ns	5.26 *	-10.61 **	-12.59 **	6.16 **	-0.83 ns	16.06 **	-7.14 **
JLML-01666XJLSN-25	-1.94 ns	4.95 *	-11.53 **	-12.90 **	8.80 **	-4.68 *	34.30 **	-28.51 **
JLML-01666XJLSN-31	-18.52 **	3.75 ns	-15.18 **	-3.71 *	15.56 **	5.05 *	28.41 **	41.66 **
JLML-01666XJLSN-34	-3.55 ns	0.28 ns	-16.09 **	28.05 **	22.38 **	34.44 **	51.08 **	51.42 **
JLML-01666XJLSN-66	-3.07 ns	3.90 ns	-15.15 **	-1.63 ns	18.35 **	21.47 **	46.05 **	36.80 **
JLML-01666XJLSN-72	-14.32 **	-4.08 *	-12.90 **	-11.93 **	12.89 **	9.82 **	12.35 **	17.26 **
JLML-01666XJLSN-73	-2.11 ns	3.16 ns	-11.99 **	-2.54 ns	4.08 *	22.08 **	7.93 **	-5.36 **
JLML-01666XJLSN-80	-18.22 **	-4.83 *	-13.81 **	12.83 **	15.65 **	20.41 **	42.67 **	27.03 **
JLML-01666XJLSN-81	-1.13 ns	-4.27 *	-9.25 **	3.61 ns	2.01 ns	1.04 ns	3.48 ns	-44.04 **

DFF-Days to fifty per cent flowering, PH-Plant height (cm), EH-Ear height (cm), EL-Ear head length, ED-Ear diameter, NRE- Number of rows/ear, NK- Number of kernels and GY-Grain yield

Table 8. Screening against TLB caused by *Exserohilum turcicum* in maize (*Zea mays* L.)

S. No.	Crosses	Disease score	PDI	Disease reaction	Disease score	PDI	Disease reaction	Disease score	PDI	Disease reaction
		Tasseling stage			20 Days after Tasseling			Maturity stage		
1	JLML-01888XJLSN-03	2	2.2	R	4	8.9	MR	4	8.9	MR
2	JLML-01888XJLSN-22	2	2.2	R	2	2.2	R	3	6.7	R
3	JLML-01888XJLSN-25	2	2.2	R	4	8.9	MR	4	8.9	MR
4	JLML-01888XJLSN-31	4	4.4	R	4	8.9	MR	4	8.9	MR
5	JLML-01888XJLSN-34	2	2.2	R	3	4.4	R	3	6.7	R
6	JLML-01888XJLSN-66	2	2.2	R	3	6.7	R	5	11.1	MR
7	JLML-01888XJLSN-72	3	3.3	R	5	11.1	MR	5	11.1	MR
8	JLML-01888XJLSN-73	3	4.4	R	6	13.3	MS	6	13.3	MS
9	JLML-01888XJLSN-80	1	1.1	R	1	2.2	R	2	4.4	R

S. No.	Crosses	Disease score	PDI	Disease reaction	Disease score	PDI	Disease reaction	Disease score	PDI	Disease reaction
		Tasseling stage			20 Days after Tasseling			Maturity stage		
10	JLML-01888XJLSN-81	2	2.2	R	2	4.4	R	2	4.4	R
11	JLML-05444XJLSN-03	2	2.2	R	2	4.4	R	2	4.4	R
12	JLML-05444XJLSN-22	4	4.4	R	5	11.1	MR	5	11.1	MR
13	JLML-05444XJLSN-25	3	3.3	R	6	13.3	MS	7	15.6	MS
14	JLML-05444XJLSN-31	4	4.4	R	7	15.6	MS	7	15.6	MS
15	JLML-05444XJLSN-34	3	3.3	R	6	13.3	MS	5	10	MS
16	JLML-05444XJLSN-66	4	4.4	R	7	15.6	MS	7	15.6	MS
17	JLML-05444XJLSN-72	2	2.2	R	3	6.7	R	3	7.8	R
18	JLML-05444XJLSN-73	2	2.2	R	3	6.7	R	3	7.8	R
19	JLML-05444XJLSN-80	3	3.3	R	4	8.9	MR	4	10	MR
20	JLML-05444XJLSN-81	2	2.2	R	4	8.9	MR	4	10	MR
21	JLML-94333XJLSN-03	2	4.4	R	4	8.9	MR	3.5	7.8	MR
22	JLML-94333XJLSN-22	1	2.2	R	3	6.7	MR	3.5	7.8	MR
23	JLML-9433XJLSN-25	1	2.2	R	2	2.2	R	1.5	3.3	R
24	JLML-94333XJLSN-31	1	2.2	R	2	4.4	R	2.5	7.8	MR
25	JLML-94333XJLSN-34	2	4.4	R	4	8.9	MR	2	4.4	R
26	JLML-94333XJLSN-66	1	2.2	R	1.5	3.3	R	1.5	3.3	R
27	JLML-94333XJLSN-72	1	2.2	R	1	2.2	R	1.5	3.3	R
28	JLML-94333XJLSN-73	2	4.4	R	4	8.9	MR	3.5	8.9	MR
29	JLML-94333XJLSN-80	2.5	5.6	R	4	6.7	R	3.5	7.8	MR
30	JLML-94333XJLSN-81	1	2.2	R	3	6.7	R	5	11.1	MR
31	JLML-97555XJLSN-03	1	2.2	R	3	6.7	R	3	6.7	R
32	JLML-97555XJLSN-22	3	6.7	R	4	8.9	MR	3.5	7.8	MR
33	JLML-97555XJLSN-25	3	6.7	R	4	8.9	MR	3.5	8.9	MR
34	JLML-97555XJLSN-31	3	6.7	R	3	6.7	R	3.5	7.8	MR
35	JLML-97555XJLSN-34	1	2.2	R	1	2.2	R	1.5	2.2	R
36	JLML-97555XJLSN-66	3	6.7	R	3	6.7	R	3.5	7.8	MR
37	JLML-97555XJLSN-72	2	4.4	R	4	8.9	MR	4.5	10	MR
38	JLML-97555XJLSN-73	2	4.4	R	3	6.7	R	3.5	7.8	MR
39	JLML-97555XJLSN-80	3	6.7	R	4	8.9	MR	4	8.9	MR
40	JLML-97555XJLSN-81	2	4.4	R	4	8.9	MR	4.5	10	MR
41	JLML-01666XJLSN-03	4	8.9	R	6	13.3	MS	7	15.6	MS

S. No.	Crosses	Disease score	PDI	Disease reaction	Disease score	PDI	Disease reaction	Disease score	PDI	Disease reaction
		Tasseling stage			20 Days after Tasseling			Maturity stage		
42	JLML-01666XJLSN-22	6	11.1	R	6	11.1	MS	6.5	14.4	MS
43	JLML-01666XJLSN-25	2	4.4	R	2	5.6	R	2.5	5.6	R
44	JLML-01666XJLSN-31	1	2.2	R	2	4.4	R	2.5	5.6	R
45	JLML-01666XJLSN-34	3	6.7	R	3	6.7	R	3	6.7	R
46	JLML-01666XJLSN-66	2	4.4	R	3	6.7	R	3	6.7	R
47	JLML-01666XJLSN-72	3	6.7	R	4	10	MR	4.5	10	MR
48	JLML-01666XJLSN-73	3	6.7	R	3	6.7	R	3	6.7	R
49	JLML-01666XJLSN-80	3	6.7	R	3	7.8	MR	3	7.8	MR
50	JLML-01666XJLSN-81	1	2.2	R	2	4.4	R	2.5	5.6	R
	Lines									
51	JLML-01888	1.5	3.3	R	2	4.4	R	2	4.4	R
52	JLML-05444	2	4.4	MR	4	8.9	MR	3.5	7.5	MR
53	JLML-94333	2	4.4	R	2	5.5	R	3	6.7	R
54	JLML-97555	3	6.7	R	4	8.9	MR	4.5	10	MR
55	JLML-01666	4	8.9	MR	5	11.1	MR	6	13.3	MR
	Testers									
56	JLSN-03	2	6.7	MR	3	6.7	MR	3	8.9	MR
57	JLSN-22	4	8.9	MR	4	8.9	MR	4	8.9	MR
58	JLSN-25	5	11.1	MS	6	13.3	MS	8	17.7	S
59	JLSN-31	5	11.1	MR	5	11.1	MR	5	11.1	MR
60	JLSN-34	2	4.4	R	2	4.4	R	2.5	5.6	R
61	JLSN-66	3	6.7	MR	3	6.7	MR	5	11.1	MR
62	JLSN-72	4	8.9	MR	4	8.9	MR	4	8.9	MR
63	JLSN-73	2	4.4	R	2	5.5	R	3	6.7	R
64	JLSN-80	3	6.7	R	4	8.5	MR	4.5	10	MR
65	JLSN-81	4	4.4	R	7	14.5	MS	7	15.6	MR

Heterosis estimates supported the combining ability findings. Several hybrids demonstrated high mid-parent heterosis (MPH) and better-parent heterosis (BPH) for grain yield and yield-contributing traits (Tables 6 and 7). The cross JLML-97555 × JLSN-80 exhibited nearly 98% BPH for grain yield, nearly doubling the performance of its superior parent. Hybrids such as JLML-01666 × JLSN-34 and JLML-01666 × JLSN-03 also showed >50% heterosis for yield and kernel number. These heterotic effects confirm the presence of complementary gene action and validate the use of divergent parental lines to capture hybrid vigor (Yu et al., 2020).

Resistance to Turcicum Leaf Blight (TLB) was evaluated at tasseling, 20 days after tasseling, and physiological maturity. All hybrids exhibited resistance at tasseling, but disease pressure increased at later stages. By maturity, only 38% of hybrids remained resistant, while 48% were moderately resistant and 14% became moderately susceptible (Table 8). Durable resistance was observed in hybrids like JLML-01888 × JLSN-22 and JLML-01666 × JLSN-34, which retained resistance across all stages. These hybrids likely benefited from the additive accumulation of resistance alleles, as supported by previous reports that TLB resistance is largely governed by additive gene action (Sibiya et al., 2013; Antony et al., 2023).

Parental resistance levels further explained hybrid performance (Table 8). JLML-01888 and JLML-94333 exhibited strong resistance, while JLML-01666 was only moderately resistant, emphasizing the importance of parent selection. Testers JLSN-34 and JLSN-73 contributed consistent resistance across hybrids, whereas JLSN-25 was the most susceptible parent. These observations suggest that durable resistance is best achieved by combining highly resistant parents and maintaining additive gene effects (Lal et al., 2023).

4. CONCLUSION

In conclusion, this study confirmed that both additive and non-additive gene actions influence key agronomic traits and Turcicum leaf blight (TLB) resistance in maize. The analysis identified significant genetic variability among the genotypes, with high heritability for traits like grain yield, suggesting that they are amenable to improvement through selection. The study successfully identified superior inbred lines such as JLML-01666 and JLML-97555 based on their high general combining ability for grain yield and other key traits. Furthermore, specific hybrid combinations, particularly those involving testers JLSN-81, JLSN-80, and JLSN-34, demonstrated excellent yield potential and durable TLB resistance. The presence of high heterosis and stable disease resistance in these hybrids highlights their potential as promising candidates for commercial release. These findings underscore the value of the line × tester design as a powerful tool for developing high-yielding and disease-resistant maize hybrids for diverse agricultural environments.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that they have no known competing financial interests or non-financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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