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Research Article

GxE Interaction and Stability Analysis of Maize Genotypes for Certain Quantitative Traits

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Abstract

Stability analysis helps in understanding the adaptability of a genotype for its performance over a wide range of environments. In the present field work, 54 single cross hybrids, 21 parental lines and 2 checks were evaluated under three date of sowing to assess their stability under different environments. Analysis of variance for stability revealed significant linear genotype x environment interaction for plant height and shelling percentage indicating that the behavior of the genotypes on the basis of such characters could be predicted over the environments more precisely and accurately as the G × E interaction was the outcome of the linear function of the environmental components. Among the hybrids, L3 x T1, L7 x T2 and L9 x T3 showed non- significant S^2di and regression coefficient greater than unity (bi >1) with high mean value than the population mean for grain yield per plant, thereby indicating its stability under favourable environments and suitability for maximum grain yield per plant. Hybrid, L10 x T2 showed non- significant S^2di and regression coefficient regression coefficient less than unity (bi<1) with high mean value than the population mean for grain yield per plant, thereby indicating its stability under unfavorable environments and suitability for maximum grain yield per plant.

Keywords: Maize hybrids, Quantitative traits, Stability, Regression coefficient and grain yield.

1. Introduction

Maize (*Zea mays* L.) is the third major cereal crop in the world after wheat and rice (Das *et al.*, 2018). It is one of the most important cereal crops of India (Ambikabathy *et al.*, 2019). It is the most versatile crop among cereals with respect to its types, uses and geographical distribution. Maize is known as queen of cereals due to its highest productivity among the cereals. Despite its highest productivity potential, farmers are facing the problem of inconsistent yield across different environments due to lack of high yielding stable hybrids. A genotype is considered to be most stable, when it registers high mean yield but show a minimum interaction with the environment. Therefore, knowledge of genotype × environment interaction and yield stability are important parameters in breeding new cultivars with improved adaptation to environmental constraints prevailing in the target environments, (Kumar *et al.*, 2020). Testing open pollinated maize varieties in more seasons and locations could enhance breeding efficiency with respect to genotypic stability and adaptation across environments, (Abate, 2020). Different planting dates showed significant effect on the growth and yield traits in maize (Bhusal *et* *al*., 2016, Abate, 2020) and sowing date manipulation constitutes a useful method for mitigating heat and chilling stresses for maize production. (Tian *et al*., 2019). Significant effect of date of sowing on the expression of different characters in maize have also been reported by Maga *et al.* (2015), Kharazmshahi *et al.* (2015), Franco *et al.* (2016), Shrestha *et al.* (2016), Damor *et al.* (2017), Patel *et al.* (2017), Belay and Patil (2018), Liaqat *et al.* (2018) and Cao *et al.* (2019). Taking above point in the consideration the present investigation was carried out to identify most stable high yielding hybrids.

2. Materials and Methods

The experimental material for the present investigation comprises of fifty-four newly synthesized single cross maize hybrids, twenty-one parents and two check varieties. These hybrids along with checks were evaluated during Rabi 2018-19 in a Randomized Block Design with three replications at Student Instructional Farm of CS Azad University of Agriculture and Technology, Kanpur under three different date of sowing namely, 28 November, 13 December and 28 December. The plot length was 4 m with inter and intra row spacing of 60 cm and 25 cm, respectively. The crop was raised under irrigated conditions following the recommended package of practices. Five plants from each genotype from each replication were randomly selected and tagged for recording the observations. The data was recorded on yield and maturity parameters. For stability analysis Eberhart and Russell (1966) model was used.

3. Results and Discussion

A reliable method of estimation of stability was proposed by Finlay and Wilkinson (1963) using regression analysis. Later, Eberhart and Russell (1966) modified this method and applied it in maize. The regression coefficient and deviation from regression were used as parameters to estimate stability. They suggested that in order to identify superior genotypes that can give reproducible performance over environment the breeder has to resort to test his materials over a number of locations and/or seasons. They stated that a desirable cultivar should have an average yield performance that is higher under favourable conditions and less fluctuating under unfavourable conditions than that of the group of cultivars when tested in many environments.

Analysis of variance for stability (Table 1.) revealed significant linear genotype x environment interaction for plant height and shelling percentage indicating that the behavior of the genotypes on the basis of such characters could be predicted over the environments more precisely and accurately as the G × E interaction was the outcome of the linear function of the environmental components. Significant genotype x environment interaction (linear) for plant height was also reported by Gami *et al.* (2017), Raj *et al*. (2019) and Kumar *et al.* (2020). Gami *et al.* (2017) also reported significant linear genotype x environment interaction for plant height and shelling percentage. Highly significant non-linear genotype x environment interaction (pooled deviation) was found for all the characters under study which suggested that deviation from linear regression also contributed substantially towards the differences in the stability of the genotypes. Significant differences among maize genotypes and GxE interaction for grain yield and other characters have also been reported by Dev *et al.* (2009) Synrem *et al.* (2017) and Sowmya *et al.* (2018).

An ideal stable genotype is defined as the one possessing high mean performance, with regression coefficient around unity (bi=1) and deviation from regression (S^2di) close to zero. The linear regression is regarded as the measure of linear response of a particular genotype to the changing environment. If the regression coefficient (bi) is greater than unity, the genotype is said to be highly sensitive to environmental fluctuations but adapted to high yielding environments. If regression coefficient (bi) is equal to unity, it indicates the average sensitivity to environmental fluctuations and adaptable to all environments. If the regression coefficient (bi) is less than unity, it indicates less sensitivity to environmental changes and if accompanied by a high mean value, then the genotype is said to be better adapted for unfavorable environment. In the present study, stability parameters such as mean (X), regression coefficient (bi) and deviation from regression (S2di), as suggested by Eberhart and Russell (1966) were considered to explain and discuss the stability of different genotypes for various characters under consideration. Different stability parameters are given in Table 2.

A perusal of data revealed that out of seventy-seven genotypes, 16 genotypes exhibited non-significant deviation from regression (S^2di), for grain yield per plant

Table 1: ANOVA table for Stability

	DF	Days to 50%tasseling	Days to 50%silking	Plant height (cm)	Shelling percentage (%)	Grain yield/plant (g)
Rep within Env.	6	1.417	1.780	2.940	0.983	1.408
Varieties	76	23.666 *	23.943 *	585.332 **	66.365 **	1665.025 **
Env.+ (Var.* Env.)	154	72.194 **	70.310 **	683.887 **	31.469	546.381
Environments	2	4536.690 **	4381.586 **	26860.980 **	92.326 *	873.713
Var.* Env.	152	13.450	13.583	339.451	30.669	542.074
Environments (Lin.)	1	9073.380 **	8763.172 **	53721.960 **	184.653 **	1747.427
Var.* Env.(Lin.)	76	11.549	11.334	404.286 *	37.397 *	604.640
Pooled Deviation	77	15.153 **	15.627 **	271.050 **	23.629 **	473.280 **
Pooled Error	456	1.003	0.958	2.150	1.322	2.385
Total	230	56.158	54.989	651.321	43.000	916.020

*, ** significant at 5% and 1% level, respectively

Table 2: Character wise list of the stable parents and hybrids for general and specific environments

Characters	Genotypes with general adaptability		Specific adaptability to favourable environment		Specific adaptability to unfavourable environment	
	Parents	Hybrids	Parents	Hybrids	Parents	Hybrids
Days to 50% tasseling	-	L6 x T3, L13 x T2	L16	L1 x T3, L2 x T3, L3 x T2, L9 x T2, L10 x T1, L17 x T3	-	L4 x T2, L6 x T1, L9 x T3, L15 x T2, L16 x T2
Days to 50% silking	L1	L3 x T2, L6 x T3, L13 x T2	L16	L1 x T3, L9 x T2, L10 x T1, L13 x T3, L17 x T3	-	L6 x T1, L7 x T1, L9 x T3, L15 x T2, L16 x T2
Plant height (cm) (Tall plant stature)	-	L11 x T1	T3	L13 x T3, L18 x T3	-	-
Shelling percentage (%)	L13	-	L1, L10, L15	L2 x T1, L4 x T2, L6 x T1, L6 x T2, L6 x T3, L13 x T2, L14 x T1, L14 x T2, L18 x T1	L3, L6, L12	L8 x T1, L11 x T2, L17 x T1
Grain yield per plant (g)	-	-	-	L3 x T1, L7 x T2, L9 x T3	-	L10 x T2

L= lines (used as female in the cross), T= testers (used as male in the cross).

Table 3: Stability Parameters

	Days to 50% tasseling			Days to 50% silking			Plant height (cm)			Shelling percentage (%)			Grain yield/plant (g)		
	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di
L1xT1	115.222	1.169	9.6206 **	119.222	1.137	5.4084 *	180.382	0.507	1524.3035 **	81.172	-0.132	7.6143 **	142.052	1.975	1067.8866 **
L1xT2	119.444	0.916	3.2168 *	122.778	0.932	3.3419 *	189.968	0.398	114.3408 **	79.988	1.509	13.6538 **	108.583	6.492	675.4088 **
L1xT3	113.667	1.173	1.1703	118	1.219	2.5773	195.496	1.119	173.4657 **	80.628	-0.496	43.6885 **	151.298	-4.123	294.0069 **
L2xT1	119	1.119	22.2761 **	123.444	1.062	14.8661 **	181.515	1.075	382.7415 **	80.342	5.655	2.5133	99.362	10.82	178.4354 **
L2xT2	116.778	0.851	18.6825 **	121.111	0.839	6.5623 **	181.003	1.031	70.0898 **	74.709	1.201	-1.3169	82.372	-3.719*	-2.1304
L2xT3	113.222	1.221	2.8551	118.111	1.098	8.7470 **	186.922	-0.17	124.4783 **	76.331	-1.262	-1.2252	96.408	2.988	648.3924 **
L3xT1	117.889	0.852	3.4528 *	121.778	0.795	6.2875 **	207.3	0.456	15.6017 **	79.668	4.4	5.1813 *	101.812	7.707**	-2.2431
L3xT2	115.556	1.239	1.3449	119.667	1.097	-0.3416	186.265	1.756	48.3170 **	80.329	-0.334	6.5653 *	87.058	0.344	304.5267 **
L3xT3	116.556	0.856	46.8589 **	120.778	0.753	39.8341 **	203.678	0.123	66.0532 **	75.176	-3.127	207.7042 **	87.027	-1.094	2108.5045 **
L4xT1	116.778	0.864	10.2152 **	121.222	0.777	3.5161 *	186.16	2.210*	-0.3825	76.723	-0.822	2.0884	82.403	2.958	4.6548
L4xT2	113.222	0.842	0.3980	117.889	0.865	3.0983 *	176.501	1.374	-0.0366	82.557	1.627	-0.1201	107.242	-2.873	663.1964 **
L4xT3	120.111	0.729	11.0418 **	124.333	0.678	9.5541 **	185.15	0.619	71.1301 **	72.274	5.822	192.3615 **	88.686	9.584	824.5284 **
L5xT1	117.111	0.772	1.1470	120.667	0.783	1.9946	203.428	1.333	26.3320 **	77.288	1.649	62.0644 **	116.089	5.464	165.3633 **
L5xT2	118.111	1.142	-0.7003	121.667	1.053	-0.2590	190.136	2.317	969.3810 **	80.251	-0.556	7.1875 *	84.107	-5.287	18.8005 **
L5xT3	114.778	1.057	10.9064 **	118.667	0.986	11.9739 **	187.057	1.3	167.0277 **	73.953	7.816	112.8527 **	77.508	4.57	801.3865 **
L6xT1	114.333	0.88	-0.6562	117.556	0.918	-0.4453	187.591	0.585	1493.1686 **	84.708	1.299	-1.0337	120.196	2.121	452.4507 **
L6xT2	114.556	1.489	5.0836 *	118.222	1.576	3.1120 *	185.398	1.373	214.6175 **	84.112	2.226*	-1.3034	135.597	-2.922	1265.6954 **
L6xT3	112	0.974	0.6867	116.333	0.957	-0.9509	209.669	0.336	323.7339 **	82.068	6.522	0.4276	103.249	4.343	618.6883 **
L7xT1	116.889	0.592*	-0.9448	119.889	0.594	-0.6692	212.673	0.106	9.9408 *	80.371	6.81	4.8425 *	120.703	11.09	4331.8377 **
L7xT2	112.889	1.354	17.9431 **	116.889	1.387	11.3594 **	194.616	1.421	9.2027 *	82.507	1.156	5.0335 *	107.817	1.643	-0.7084
L7xT3	113.111	1.065	5.9621 **	117.667	1.004	15.2620 **	207.966	1.139	199.8090 **	75.949	1.081	3.3326	88.886	-0.733	133.9300 **
L8xT1	115.667	0.983	3.4587 *	120.444	0.958	5.0672 *	192.967	0.869	1.5915	82.094	0.274	3.0736	106.973	0.96	137.1089 **
L8xT2	118.222	0.453	12.7121 **	121.667	0.454	9.1001 **	180.437	2.038	245.0029 **	74.464	10.343	16.6844 **	63.401	1.454	1444.1876 **
L8xT3	115.556	0.457	19.3771 **	118.667	0.434	28.4793 **	200.928	-0.551	64.4401 **	76.367	4.049	-0.7399	127.523	10.892	4912.3102 **
L9xT1	116.111	1.515	11.8560 **	119.444	1.542	11.6529 **	176.244	1.979	226.0799 **	75.683	-2.867	106.6786 **	89.759	-13.108	368.6944 **
L9xT2	113.667	1.276	-0.1219	116.778	1.319	-0.3128	170.849	2.543*	7.9462 *	80.663	-3.032	7.3711 *	95.88	-13.392	1390.4700 **
L9xT3	112.778	0.271	0.6344	118	0.395*	-0.7614	196.887	0.957	53.5233 **	76.616	0.459	9.1010 **	110.184	4.895	0.5698

	Days to 50% tasseling			Days to 50% silking			Plant height (cm)			Shelling percentage (%)			Grain yield/plant (g)		
	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di
L10xT1	113.778	1.142	-0.7003	117.222	1.216	1.6315	193.098	1.747	24.1337 **	72.383	-2.333	0.3037	94.24	-12.007	1714.5590 **
L10xT2	114.111	1.316	13.1349 **	117.444	1.394	24.2785 **	196.938	1.209	1176.4153 **	71.977	2.294	12.0965 **	103.321	-3.820*	-0.4921
L10xT3	117.667	1.191	0.0127	122.333	1.23	1.0334	194.406	1.122	648.2318 **	77.118	7.747	19.6653 **	82.101	7.293	195.5117 **
L11xT1	118.556	1.195	12.2432 **	123.667	1.218	14.5372 **	199.942	1.014	3.6799	75.456	-1.845	29.5306 **	73.048	1.878	-0.7624
L11xT2	117.778	1.281	7.3881 **	121.556	1.211	9.9810 **	192.328	0.27	162.7345 **	79.386	0.595	-0.9263	110.656	-1.567	788.7151 **
L11xT3	115.778	0.941	19.1546 **	121.222	0.872	22.8765 **	187.207	1.051	508.4315 **	76.283	1.813	29.4491 **	77.347	3.549	98.4547 **
L12xT1	113.444	1.481	21.8243 **	117.556	1.624	16.6287 **	170.22	-0.011*	1.0998	81.166	-1.465	6.3022 *	116.686	-7.517	189.4169 **
L12xT2	115.222	1.29	4.2546 *	119.444	1.204	5.7125 **	205.767	0.738	21.4256 **	75.859	-3.012	7.4902 *	97.601	-2.076	23.5033 **
L12xT3	118.556	0.405	26.8187 **	122.667	0.558	39.8630 **	187.772	0.241	89.6949 **	79.433	1.663	4.8097 *	106.579	5.992	3166.3497 **
L13xT1	113.778	1.11	21.5202 **	118	1.251	34.4988 **	195.759	1.139	114.6005 **	80.249	-0.563	4.6383 *	89.604	4.639	22.6536 **
L13xT2	112	1.035	-0.3377	116.333	1.019	-0.8454	199.839	0.329	0.9782	80.189	4.792	-0.2838	101.438	1.28	108.6655 **
L13xT3	112.778	1.184	5.5357 *	117.333	1.167	0.2900	193.345	1.904	4.9873	76.487	-3.845	14.8494 **	99.911	-1.029	364.4854 **
L14xT1	118.556	0.921	2.1729	122.444	1.085	5.8762 **	192.207	0.945	518.5864 **	81.102	5.755	-0.8676	85.299	6.835	2.6403
L14xT2	116.889	1.542	-0.2314	122.667	1.528	-0.6919	189.362	1.814	941.7729 **	82.388	2.653	-1.0246	111.262	-2.23	338.3390 **
L14xT3	115.889	0.957	21.0953 **	119.667	0.838	24.7317 **	204.137	0.667	8.8467 *	78.688	0.017	24.8048 **	116.973	4.582	102.9719 **
L15xT1	113.333	0.674	4.9806 *	117.556	0.578	3.7425 *	186.978	1.524	716.5832 **	82.597	4.644	6.0123 *	116.537	-4.928	255.1134 **
L15xT2	114.333	0.215	2.2221	117.222	0.329	2.3118	179.061	-0.151	21.6951 **	75.427	-0.903	35.3898 **	69.489	3.306	21.6108 **
L15xT3	121.333	0.929	28.8354 **	125.222	0.932	40.7138 **	189.316	0.484	-0.6647	77.361	1.339	117.4317 **	84.616	6.02	34.4208 **
L16xT1	111.222	1.389	26.2028 **	115	1.497	32.9907 **	170.304	-0.211*	4.0970	66.199	-8.932	1.0050	32.234	-0.359	17.6888 **
L16xT2	114.444	0.892	-0.8642	118.111	0.784	-0.6033	175.972	2.174	368.3976 **	71.373	-8.639	41.0774 **	54.358	-6.260*	-1.0509
L16xT3	114.111	1.334	16.5671 **	117.556	1.307	5.7825 **	185.689	0.907	8.9631 *	77.946	-1.667	4.4858 *	61.948	1.188	4.7088
L17xT1	118.556	1.16	19.2719 **	122.667	1.157	4.6233 *	190.527	1.372	55.5336 **	78.494	-0.665	-1.2361	103.457	-2.441	1223.8382 **
L17xT2	119.556	1.251	33.4901 **	123	1.225	39.1773 **	192.213	0.824	110.6302 **	76.97	5.981*	-0.9570	122.156	5.72	347.1866 **
L17xT3	115.222	1.43	0.3337	119.444	1.513*	-0.9370	200.258	1.404	51.5712 **	79.878	1.09	114.5276 **	110.852	1.932	73.8889 **
L18xT1	118.222	0.799	0.5228	122.889	0.673	-0.6141	193.278	0.7	-1.6172	81.811	2.177	-1.2634	90.209	8.187	17.5927 **
L18xT2	122.889	0.887	7.8437 **	126.667	0.898	11.2570 **	211.058	0.115	2.9825	77.954	-0.635	39.4204 **	114.704	-1.905	172.5967 **
L18xT3	118	0.649	6.9851 **	123.111	0.733	3.9245 *	214.544	2.264*	0.4931	75.232	6.883	1.6275	87.512	7.06	28.3667 **

	Days to 50% tasseling			Days to 50% silking			Plant height (cm)			Shelling percentage (%)			Grain yield/plant (g)		
	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di	mMean	bi	s^2di
L1	110.444	0.96	3.0077 *	113.889	1.041	2.3241	158.735	1.107	1076.9477 **	79.243	1.506	3.6736	71.478	1.397	653.3725 **
L2	114.111	0.968	6.9193 **	118.889	0.819	16.0213 **	171.274	0.163	117.6200 **	76.286	1.959	4.9238 *	72.01	-1.666	135.5212 **
L3	117.333	0.634	72.2656 **	120.333	0.541	63.2482 **	179.91	1.639	522.7046 **	85.599	-1.453	1.0971	73.296	3.303	70.7848 **
L4	122.778	0.789	2.6003	126.667	0.799*	-0.9586	159.013	-0.146	138.9405 **	67.522	10.917	5.4738 *	46.574	5.665	3.8422
L5	115.444	1.347	11.9177 **	119.556	1.267	18.6422 **	185.357	1.539	45.8654 **	81.102	-1.307	11.7676 **	98.16	-3.62	172.6668 **
L6	117.111	1.052	45.5333 **	119.667	1.11	41.6028 **	180.292	2.12	396.0221 **	82.231	0.887	-1.1874	61.311	-0.705	78.8343 **
L7	115.667	0.741	2.9556 *	120.556	0.734*	-0.9553	171.056	0.281	0.3833	81.869	5.342	6.8472 *	77.236	4.949	310.4129 **
L8	118.333	0.272	54.9206 **	122.111	0.304	65.2245 **	144.359	2.484	75.6909 **	70.224	2.812	-0.6748	68.892	2.564	47.1985 **
L9	113.111	1.037	8.8774 **	116.444	1.046	4.5809 *	154.032	1.186	28.7180 **	80.454	-1.18	4.2683 *	72.563	-0.193	703.6082 **
L10	118.889	0.956	5.9966 **	122.444	0.951	-0.8002	171.977	1.161	84.2242 **	82.412	2.411	-0.6314	72.063	2.135	3.3627
L11	117.222	1.272	21.8441 **	122.222	1.126	32.9379 **	169.111	0.672	1127.4058 **	69.991	-5.368	128.9309 **	55.532	-3.225	18.9198 **
L12	114.889	0.867	12.1010 **	119.667	0.822	18.3253 **	194.422	1.484	1459.9001 **	78.352	-0.668	-0.9523	65.253	-1.127	77.8444 **
L13	112.444	0.982	74.7072 **	116.889	0.846	73.6435 **	170.57	1.056	150.1562 **	84.078	1.046	-0.9693	81.868	5.276	811.5511 **
L14	115.778	1.241	80.1799 **	119.222	1.364	63.0507 **	180.6	1.942	304.9487 **	73.967	-6.201	30.5839 **	78.463	-10.553	488.0313 **
L15	117.222	0.309	2.5044	121.222	0.552	5.5396 **	177.819	-0.421	365.7063 **	78.041	5.184	1.8136	64.56	4.701	208.4005 **
L16	112.222	1.076	1.4192	115.444	1.119	1.0589	164.418	0.171	191.1214 **	69.698	-10.159	69.7011 **	45.704	-3.76	143.2699 **
L17	120.556	0.738	1.9516	124.222	0.681	1.0111	177.318	-0.205	1472.0559 **	68.898	0.651	51.1741 **	54.31	1.536	-1.1779
L18	121	0.742*	-1.0041	124.333	0.773	-0.7394	195.756	0.482	42.4669 **	73.472	-1.487*	-1.3002	64.946	1.547	25.4331 **
T1	115.556	1.029	44.0510 **	119.667	1.04	37.4041 **	184.144	0.39	137.8443 **	79.981	1.772	4.4826 *	65.707	0.682	67.5242 **
T2	119.778	1.233	54.1633 **	123.667	1.337	82.5449 **	178.361	0.507	228.7408 **	77.718	-2.107	30.5225 **	85.274	-1.619**	-2.3695
T3	122.889	1.624	51.3342 **	126.778	1.561	49.4669 **	193.99	2.041*	-1.5319	59.318	5.537	26.8063 **	47.812	0.314	3.3919
C1	118.556	1.344	0.1056	122.333	1.466**	-0.9662	199.927	1.276	266.7404 **	83.533	0.123	17.7667 **	91.437	1.513	5.5407
C2	117.556	1.077	12.0439 **	121.333	1.048	15.6717 **	206.57	2.242	305.6021 **	83.357	0.572	1.2325	105.591	1.516	116.9935 **
Population Mean	116.209			120.214			187.243			77.711			89.823		

*, ** significant at 5% and 1% level, respectively. L= lines (used as female in the cross), T= testers (used as male in the cross), C= check.

indicating their predictable behavior for this trait. Among the hybrids, L3 x T1, L7 x T2 and L9 x T3 showed non-significant S^2di and regression coefficient greater than unity (bi >1) with high mean value than the population mean, thereby indicating its stability under favourable environments and suitability for maximum grain yield per plant. Hybrid, L10 x T2 showed non- significant S^2di and regression coefficient regression coefficient less than unity (bi<1) with high mean value than the population mean, thereby indicating its stability under unfavorable environments and suitability for maximum grain yield per plant. The genotypes which found stable for one or more characters are given in Table 3. Synrem *et al.* (2017), Sowmya *et al.* (2018), Kumar *et al.* (2020) have also reported stable performance of the maize genotypes for grain yield per plant and other component characters.

Author contributions

The conceptualization of research (K.L., S.K., A.K.S. and A.J.); Designing of the experiments (K.L.., D.P., H.C.S. and A.K.S.); Execution of field experiments and data collection (K.L., A.K.S., S.P.S. and V.S.); Analysis of data and interpretation (K.L., D.P. and A.K.S.); writing–original draft preparation, K.L., S.K., H.C.S. and A.K.S.; writing–review and editing, K.L., S.K., A.K.S, A.J. and S.P.S.; Preparation of the manuscript (K.L. and A.K.S.).

Conflict of interest

No

Declaration

The authors declare no conflict of interest.

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