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Viveka Nand Yadav
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

RK Yadav
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

HC Singh
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Shweta
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Ajay Kumar
Department of Plant breeding and Genetics, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India

Nrendra Kumar
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Corresponding Author:
Viveka Nand Yadav
Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture & Technology, Kanpur, Uttar Pradesh, India

Studies on Genetic variability and traits association in maize (*Zea mays* L.) under diverse ecosystem

Viveka Nand Yadav, RK Yadav, HC Singh, Shweta, Ajay Kumar and Nrendra Kumar

Abstract
An experiment consisting 45 single crosses derived from Line x Tester with parents and two standard check of maize were conducted at two different locations Kanpur and Aligarh with two diverse environments during Kharif (2018) and Rabi (2018-19). The data were collected on five randomely selected plants from each parent and their F_1s in each replication for 13 yield attributed traits namely Days to 50% tasseling, Days to 50% silking, Days to 75% dry husk, Plant height (cm), Number of cobs per plant, Cob weight (g), Number of grain rows per cob, Number of grains per row, Grain weight per cob (g), Shelling percentage (%), 100 kernel weight (g), Grain yield per plant and Seed vigour index. The data so generated were subjected for statistical analysis as usual procedure while Variability was computed by Burton (1952) and Johnson *et al.* (1955). Similarly. The phenotypic, genotypic and environmental coefficients of correlation were computed as per the methods suggested by Robinson *et al.* (1951). The analysis of variance over the environments showed highly significant differences among parents and crosses revealing sufficient quantity of variations in the genetic materials used in study. Highest PCV was observed for grain yield per plant (g) followed by grain weight per cob (g), cob weight (g) and number of grains per row similarly the GCV was higher for grain yield per plant (g) followed by grain weight per cob (g), cob weight (g) and number of grains per row while lower PCV was observed for days to 75% dry husk followed by days to 50% silking, Days to 50% tasseling and shelling percentage (%) and lower PCV was observed for days to 75% dry husk followed by Days to 50% tasseling, days to 50% silking, and shelling percentage (%).At genotypic level the grain yield per plant showed positive and significant correlation with all the characters except days to 50% tasseling, days to 50% silking and days to 75% dry husk which had negatively significant correlation with yield. At phenotypic level in general the associations of characters were lower in magnitude as compared with corresponding genotypic one but same in direction.

Keywords: Maize, variability and genotypic and phenotypic correlation

Introduction

Zea mays L. (2n = 20) is a versatile crop known as "Miracle Crop" and "Queen of the Cereals" due to its productivity potential and diverse uses. It belongs to the tribe Maydeae of the grass family *Graminae* or Poaceae. It is originated in Southern Mexico or Northern Guatemala (Weatherwax, 1955) [27]. The genus *Zea* consists of four species of which only *Zea mays* L. is economically important out of four species of the genus *Zea*.

Maize crop has diverse uses like feed, food, industrial products, bio fuel and bio plastic, forage and silage and it also provides basic raw material for various industries like starch, protein, oil, alcoholic beverages, food, sweeteners, cosmetics and bio-fuels.

To fulfil the increasing demand of maize, breeders should pay special attention to investigate the genetic diversity of maize that could develop improved genotypes with high yield. To start any breeding programme Selection is the basic step. The efficiency of selection depends on the direction and magnitude of association between yield and its components. The estimates of genetic parameters like coefficients of Variability, genotypic, phenotypic and environmental correlations, allow knowing the magnitude of the genetic variability of a population, and the selection gains. Therefore Present study was conducted to understanding the genetic parameters which determine the relationship between maize yield and other traits.

Materials & Methods

The experimental material for the present investigation comprises 15 diverse inbred lines namely WiN-19, WiN-21, WiN-22, WiN-26, WiN-29, WiN-30, WiN-31, WiN-32, WiN-33, WiN-34, WiN-35, WiN-36, WiN-38, WiN-39, WiN-40 of maize and 3 testers *viz*. TSK-4, TSK-44 and D-15 of Maize, selected on the basis of variability for various characters available in genetic material maintained in the section of maize, Department of Genetics and Plant Breeding, Chandra Shekhar Azad University of Agriculture and Technology, Kanpur-(UP). 15 lines X 3 testers were crossed into Line X Tester design to produce 45 single crosses during Rabi (2017-18). Evaluated all 45 F_1s, parental lines and composite (Azad Uttam) and hybrid (DKC 9108) checks in randomized block design with three replications at two different locations (Kanpur and Aligarh) and two diverse environments Kharif (2018) and Rabi (2018-19). The observations were recorded on following yield and maturity traits namely; Days to 50% tasseling, Days to 50% silking, Days to 75% dry husk, Plant height (cm), Number of cobs per plant, Cob weight (g), Number of grain rows per cob, Number of grains per row, Grain weight per cob (g), Shelling percentage (%), 100 kernel weight (g), Grain yield per plant and Seed vigour index. Observations were recorded on plot basis. The data so generated were pooled and all the onward calculation was carried out on based on pooled basis. The estimates of Variability were computed by Burton (1952) [6] and Johnson *et al.* (1955) [8]. Similarly The phenotypic, genotypic and environmental coefficients of correlation were computed as per the methods suggested by Robinson *et al.* (1951) [23]

Results and Discussion

The analysis of variance of experiments pooled over the environments is presented in Table-1 which revealed that the treatments were highly variable for the characters indicating the presence of high level of variability among the selected genotypes/inbreds and their crosses derived from it.

The orthogonal partitioning of treatments revealed that the lines, testers, F1s, lines vs F1s, lines vs testers and testers vs F1s were also showed significant values for all the characters indicating the variability in lines, testers and their interactions were also highly variable for all the characters in the material studied implying that the genotypes can be deployed in the development of varieties adapted to different environments (Allard, 1999) [2]. The parents chosen for the present study produced high yielding hybrids besides exhibiting high amount of variance for yield contributing traits. Similar trends for variances and its components in maize were reported by Lal and Kumar (2012) [12], Anusheela *et al.*(2013) [4], Abrha *et al*. (2013) [1], Singh *et al.*(2013) [26], Motamedi *et al.*(2014) [15], Rajesh *et al.*(2014) [20], Rastgari *et al.* (2014) [21], Kuchanur *et al.* (2014) [10], Ruswandi (2015), Kumar *et al.* (2016) [24] and Ertiro *et al.* (2017) [7] for grain yield, quality traits and maturity traits.

The coefficients of genotypic, phenotypic and environmental variability was measured for all the characters based on each environment and pooled over the environments and presented in Table-2 and the same is described here accordingly as under

Highest PCV was observed for grain yield per plant (g) followed by grain weight per cob (g), cob weight (g) and number of grains per row similarly the GCV was higher for grain yield per plant (g) followed by grain weight per cob (g), cob weight (g) and number of grains per row while lower PCV was observed for days to 75% dry husk followed by days to 50% silking, Days to 50% tasseling and shelling percentage (%) and lower PCV was observed for days to 75% dry husk followed by Days to 50% tasseling, days to 50% silking, and shelling percentage (%).

Higher the difference between these two for grain yield per plant (g), grain weight per cob (g), number of grains per row and cob weight (g) showed that these characters were highly influenced by environment. While lower the difference between PCV and GCV for days to 75% dry husk, days to 50% silking, Days to 50% tasseling and shelling percentage (%) indicated that these characters less influenced by environment.

The actual understanding of variability can be gained by comparing relative phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV). Based on pooled over the environments highest PCV was observed for grain yield per plant (g) followed by grain weight per cob (g), cob weight (g) and number of grains per row similarly the GCV was higher for grain yield per plant (g) followed by grain weight per cob (g), cob weight (g) and number of grains per row while lower PCV was observed for days to 75% dry husk followed by days to 50% silking, Days to 50% tasseling and shelling percentage (%) and lower PCV was observed for days to 75% dry husk followed by Days to 50% tasseling, days to 50% silking, and shelling percentage (%).

Higher the difference between these two for grain yield per plant (g), grain weight per cob (g), number of grains per row and cob weight (g) showed that these characters were highly influenced by environment. While lower the difference between PCV and GCV for days to 75% dry husk, days to 50% silking, Days to 50% tasseling and shelling percentage (%) indicated that these characters less influenced by environment. This indicates that selection can be effective for these traits even at phenotypic level. Mustafa *et al.*, 2014, Kandel *et al.* (2017) [9], Sharma *et al.* (2018) [25], Nzuve *et al.* (2014) [17] Bhiusal *et al.* (2017) [5] Ahmed *et al.* (2020) [3] Manjunatha *et al.* (2019) [14] and Magar *et al.* (2021) [13] reported similar findings.

Table 1: Analysis of variance for 13 quantitative characters over the environments in maize

	Df	Days To 50% Tasseling	Days To 50% Silking	Days To 75% Dry Husk	Plant Height (Cm)	Number of Cobs Per Plant	Cob Weight (G)	Number of Grain Rows Per Cob
Replicates	2	3.462 **	4.354 **	5.565 **	36.513	0.109 **	1323.189 **	2.940 *
Environments	3	306635.600 **	310206.800 **	305930.700 **	206814.100 **	0.410 **	133308.300 **	183.931 **
Rep * Env.	6	0.830	0.556	1.383 *	1432.487 **	0.033	209.667	0.838
Treatments	62	58.375 **	66.705 **	111.274 **	6311.033 **	0.057 **	8062.825 **	8.726 **
Parents	17	41.658 **	45.355 **	90.914 **	1042.576 **	0.075 **	821.037 **	4.675 **
Parents (Line)	14	45.776 **	50.470 **	100.012 **	1124.966 **	0.021	759.073 **	4.842 **
Parents(Testers)	2	11.861 **	18.694 **	42.583 **	65.636	0.314 **	561.770 *	0.927
Parents (L vs T)	1	43.601 **	27.075 **	60.208 **	1843.001 **	0.348 **	2207.062 **	9.838 **
Parent vs Crosses	1	1887.001 **	2209.467 **	2259.483 **	308466.400 **	0.078 *	428018.100 **	249.087 **
Crosses	44	23.275 **	26.254 **	70.318 **	1479.405 **	0.049 **	1316.351 **	4.828 **
Line effect	14	33.407	38.641	144.403 **	3076.707 **	0.036	1720.879 *	6.929 *

Tester effect	2	12.669	18.502	98.052	613.390	0.020	6290.083 **	14.018 *
Line * Tester effect	28	18.966 **	20.615 **	31.294 **	742.612 **	0.058 **	758.820 **	3.121 **
Env * Treat	186	22.694 **	22.115 **	39.072 **	524.805 **	0.031 **	760.696 **	1.739 **
Env * Parents	51	22.993 **	23.595 **	37.324 **	636.824 **	0.029 *	793.362 **	2.372 **
Env * Parents (L)	42	17.698 **	16.978 **	39.763 **	591.040 **	0.016	725.705 **	1.873 **
Env * Parents (T)	6	7.417 **	9.806 **	35.287 **	197.995	0.070 **	203.634	4.433 **
Env * PAR (L vs T)	3	128.278 **	143.816 **	7.245 **	2155.461 **	0.130 **	2920.010 **	5.241 **
Env * Parent vs Cross	3	145.589 **	124.392 **	197.423 **	4433.814 **	0.085 **	6660.121 **	1.106
Env * Crosses	132	19.785 **	19.219 **	36.148 **	392.683 **	0.030 **	613.997 **	1.508 **
Env * Line effect	42	31.784 **	31.000 **	66.658 **	475.930	0.028	679.449	1.947
Env * Tester effect	6	18.935	17.225	9.857	227.796	0.059	363.090	0.841
Env * L * T effect	84	13.847 **	13.471 **	22.771 **	362.838 **	0.030 **	599.193 **	1.336 **
Error	496	0.429	0.390	0.507	162.950	0.019	173.302	0.861
Total	755	1229.102	1243.808	1234.740	1587.855	0.027	1498.240	2.456

Table 1: Continue…..

	Df	Number of Grains per row	Grain weight Per cob (g)	Shelling Percentage (%)	100 kernel Weight (g)	Seed vigour Index	Grain yield per Plant (g)
Replicates	2	36.254	1024.281 **	0.475	2.218	33729.880	1421.993 **
Environments	3	872.273 **	84889.510 **	144.060 **	1106.233 **	66434.580 **	97101.640 **
Rep * Env.	6	57.179	184.834	9.932	6.435	10784.830	280.192
Treatments	62	207.180 **	6236.380 **	69.063 **	70.142 **	1145589.000 **	6808.107 **
Parents	17	54.612 *	576.245 **	54.319 **	44.594 **	57440.600 **	676.068 **
Parents (Line)	14	62.685 **	561.335 **	44.641 **	40.091 **	64665.290 **	631.682 **
Parents(Testers)	2	5.078	361.329	146.484 **	62.111 **	1259.661	261.389
Parents (L vs T)	1	40.659	1214.803 **	5.480	72.593 **	68656.760 *	2126.836 **
Parent vs Crosses	1	8955.568 **	328194.400 **	2195.509 **	2206.224 **	62532190.000 **	349642.900 **
Crosses	44	67.299 **	1106.022 **	26.432 **	31.466 **	170859.400 **	1385.603 **
Line effect	14	70.812	1510.481 *	37.267	43.039	186370.700	1742.305
Tester effect	2	61.780	5415.365 **	53.782	4.591	21603.420	6463.892 **
Line * Tester effect	28	65.938 **	595.983 **	19.060 **	27.599 **	173764.900 **	844.517 **
Env * Treat	186	34.442	584.841 **	15.559 **	19.080 **	35319.590 **	638.455 **
Env * Parents	51	24.082	608.123 **	21.041 **	25.087 **	9437.388	630.369 **
Env * Parents (L)	42	25.417	565.330 **	19.764 **	26.630 **	7726.121	613.867 **
Env * Parents (T)	6	0.330	148.144	32.014 **	16.852 *	19790.600	133.490
Env * PAR (L vs T)	3	52.893	2127.179 **	16.978 *	19.953 *	12688.710	1855.146 **
Env * Parent vs Cross	3	51.494	5016.127 **	30.113 **	141.222 **	45975.270 **	5941.498 **
Env * Crosses	132	38.057 *	475.134 **	13.110 **	13.984 **	45077.360 **	521.056 **
Env * Line effect	42	31.612	512.164	17.692 *	15.715	58004.610	547.684
Env * Tester effect	6	47.340	323.908	5.728	41.576 **	26758.780	515.136
Env * L * T effect	84	40.616 *	467.421 **	11.346 **	11.147 **	39922.210 **	508.165 **
Error	496	28.555	123.134	5.391	7.077	11225.350	161.161
Total	755	48.274	1078.591	13.698	19.563	110589.600	1214.068

* Significant at 5%, ** Significant at 1%

Table 2: Genetic variability for 13 quantitative characters over the environments in maize

	Days to 50% Tasseling	Days to 50% Silking	Days to 75% dry Husk	Plant height (cm)	Number of cobs Per plant	Cob weight (g)	Number of grain Rows per cob	Number of Grains per row	Grain weight Per cob (g)	Shelling Percentage (%)	100 kernel Weight (g)	Seed vigour Index	Grain yield per Plant (g)
Var Phenotypical	10.996	11.594	19.759	752.021	0.025	968.468	1.719	43.985	739.509	13.127	15.312	108866	824.241
PCV	3.576	3.541	3.404	18.18	14.53	31.389	10.104	22.84	33.211	4.409	14.144	12.095	34.047
Var Genotypical	4.44	5.173	8.355	488.664	0.003	633.68	0.619	14.385	490.213	4.904	4.889	91185.04	534.015
GCV	2.272	2.365	2.213	14.655	4.966	25.39	6.063	13.062	27.04	2.695	7.992	11.069	27.405
Var Environmental	6.556	6.422	11.404	263.358	0.022	334.788	1.1	29.6	249.296	8.223	10.424	17680.96	290.226
ECV	2.761	2.635	2.586	10.759	13.655	18.455	8.082	18.737	19.283	3.49	11.67	4.874	20.203

Table 3: Genotypic correlation coefficients between 13 quantitative characters over the environment in maize

Traits	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Number of cobs per plant	Cob weight (g)	Number of grain rows per cob	Number of grains per row	Grain weight per cob (g)	Shelling percentage (%)	100 kernel weight (g)	Seed vigour index	Grain yield per plant (g)
Days to 50% tasseling	1.000	0.973**	0.542**	-0.689**	-0.270**	-0.745**	-0.630**	-0.558**	-0.736**	-0.585**	-0.626**	-0.744**	-0.735**
Days to 50% silking		1.000	0.541**	-0.696**	-0.314**	-0.750**	-0.602**	-0.599**	-0.745**	-0.629**	-0.647**	-0.750**	-0.746**
Days to 75% dry husk			1.000	-0.439**	-0.059	-0.536**	-0.540**	-0.382**	-0.535**	-0.476**	-0.376**	-0.633**	-0.531**
Plant height (cm)				1.000	0.336**	0.952**	0.707**	0.852**	0.952**	0.778**	0.844**	0.855**	0.953**
Number of cobs per plant					1.000	0.336**	0.193**	0.292**	0.339**	0.329**	0.228**	0.213**	0.391**
Cob weight (g)						1.000	0.757**	0.895**	0.999**	0.798**	0.862**	0.884**	0.996**
Number of grain rows per cob							1.000	0.600**	0.750**	0.557**	0.475**	0.717**	0.747**
Number of grains per row								1.000	0.900**	0.786**	0.699**	0.862**	0.898**
Grain weight per cob (g)									1.000	0.824**	0.856**	0.877**	0.998**
Shelling percentage (%)										1.000	0.596**	0.692**	0.829**
100 kernel weight (g)											1.000	0.723**	0.849**
Seed vigour index												1.000	0.869**
Grain yield per plant (g)													1.000

* Significant at 5%, ** Significant at 1%

Table 4: Phenotypic correlation coefficients between 13 quantitative characters over the environments in maize

Traits	Days to 50% tasseling	Days to 50% silking	Days to 75% dry husk	Plant height (cm)	Number of cobs per plant	Cob weight (g)	Number of grain rows per cob	Number of grains per row	Grain weight per cob (g)	Shelling percentage (%)	100 kernel weight (g)	Seed vigour index	Grain yield per plant (g)
Days to 50% tasseling	1.0000	0.979**	0.556**	-0.373**	-0.127**	-0.410**	-0.264**	-0.216**	-0.406**	-0.248**	-0.300**	-0.421**	-0.408**
Days to 50% silking		1.0000	0.567**	-0.401**	-0.143**	-0.437**	-0.260**	-0.240**	-0.435**	-0.280**	-0.315**	-0.447**	-0.439**
Days to 75% dry husk			1.0000	-0.248**	0.0020	-0.282**	-0.273**	-0.148**	-0.286**	-0.216**	-0.152**	-0.377**	-0.279**
Plant height (cm)				1.0000	0.159**	0.723**	0.406**	0.449**	0.723**	0.408**	0.450**	0.644**	0.727**
Number of cobs per plant					1.0000	0.127**	0.0520	0.079*	0.131**	0.101**	0.089**	0.072*	0.285**
Cob weight (g)						1.0000	0.508**	0.590**	0.994**	0.521**	0.521**	0.651**	0.978**
Number of grain rows per cob							1.0000	0.254**	0.501**	0.273**	0.139**	0.393**	0.488**
Number of grains per row								1.0000	0.589**	0.321**	0.273**	0.431**	0.580**
Grain weight per cob (g)									1.0000	0.600**	0.510**	0.649**	0.985**
Shelling percentage (%)										1.0000	0.205**	0.376**	0.595**
100 kernel weight (g)											1.0000	0.377**	0.507**
Seed vigour index												1.0000	0.638**
Grain yield per plant (g)													1.000

* Significant at 5%, ** Significant at 1%

The genotypic, phenotypic and environmental correlations between pair of characters based on parents and F1s were calculated for each environment separately and pooled over environment and presented in Table- 3, 4 respectively and described as under.

At genotypic level the grain yield per plant showed positive and significant correlation with all the characters except days to 50% tasseling, days to 50% silking and days to 75% dry husk which had negatively significant correlation with yield.

Among characters themselves positive and significant correlation for days to 50% tasseling was noted with days to 50% silking and days to 75% dry husk while other characters showed negatively significant correlation with it.

Among characters themselves, positive and significant correlation for days to 50% silking was noted with days to 75% dry husk while other characters showed negatively significant correlation with it.

Negative and significant correlation for days to 75% dry husk was noted with plant height, cob weight, number of grain rows per cobs, number of grains per row, grain weight per cob, shelling percentage, 100 kernel weight, seed vigour index and grain yield per plant while only one character number of cobs per plant showed negative non-significant correlation with it.

Among characters themselves, positive and significant correlation for plant height was noted with number of cobs per plant, cob weight, number of grain rows per cob, number of grains per row, grain weight per cob, shelling percentage, 100 kernel weight, seed vigour index and grain yield per plant.

Among characters themselves, positive and significant correlation for number of cobs per plant was noted with cob weight, number of grain rows per cob, number of grains per row, grain weight per cob, shelling percentage, 100 kernel weight, seed vigour index and grain yield per plant.

Cob weight had positive and significant correlation with number of grain rows per cob, number of grains per row, grain weight per cob, shelling percentage, 100 kernel weight, seed vigour index and grain yield per plant.

Significant and positive correlation for number of grain rows per cob was noted with number of grains per row, grain weight per cob, shelling percentage, 100 kernel weight, seed vigour index and grain yield per plant.

Among characters themselves, positive and significant correlation for number of grains per row was noted with grain weight per cob, shelling percentage, 100 kernel weight, seed vigour index and grain yield per plant.

Among characters themselves, positive and significant correlation for grain weight per cob was noted with shelling percentage, 100 kernel weight, seed vigour index and grain yield per plant.

Positive and significant correlation for shelling percentage was noted with 100 kernel weight, seed vigour index and grain yield per plant.

Among characters themselves, positive and significant correlation for 100 kernel weight was noted with seed vigour index and grain yield per plant.

Among characters themselves, positive and significant correlation for seed vigour index was noted with grain yield per plant.

At phenotypic level in general the associations of characters were lower in magnitude as compared with corresponding genotypic one but same in direction. It showed that associations between characters are due to peliotrophic effect rather than linkage.

Association of character studies provides information yield attributing traits and this information is useful for selecting superior genotypes from diverse genetic populations (Robinson *et al*., 1951; Johnson *et al*., 1955) [8, 23]. In the present investigation association of characters over the environments revealed that Grain yield per plant showed positive and significant phenotypic and genotypic correlations with plant height, number of cobs per plant, cob weight, number of grain rows per cobs, number of grains per row, grain weight per cob, shelling percentage, 100 kernel weight and seed vigour index. This suggested that hybrids with taller plants, number of cobs per plant, cob weight, number of grain rows per cobs, number of grains per row, grain weight per cob, shelling percentage, higher 100 kernel weight and high seed vigour index were high yielders. Hence, these traits could be considered for indirect selection criteria to improve grain yield. These results are in consistent with earlier report of Reddy and Jabeen (2016) [22]. Similarly, Parajuli *et al*. (2018) [18] reported positive and significant association of grain yield with plant height and 1000-kernel weight. Days to 50% tasseling and days to 50% silking exhibited positive significant genotypic and phenotypic correlation with days to maturity. significant and positive association of Days to 50% tasseling and days to 50% silking with days to maturity is also reported by Patil *et al*. (2016) [19]. Significant positive association could be observed either due to the strong coupling linkage between the genes or as a result of pleiotropic effects of genes that controlled these characters in the same direction. Generally, higher genotypic correlation coefficients than phenotypic correlation coefficients were observed for most of the traits. This suggests that the apparent associations might be largely due to inherent relationship among the traits.

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