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Validation of Maize (*Zea mays* L.) Hybrids for the Study on Variability, Trait Association, and Path Analysis

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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

The present investigation was conducted with nine genotypes in randomized block design during *Rabi*, 2019-20 at the instructional-cum-research farm, Assam Agricultural University, Jorhat. All the characters exhibited significant genotypic mean squares in analysis of variance except anthesis silking interval, kernel rows per ear and 100 kernel weights. High heritability coupled with high genetic advance was observed for the traits plant height, ear height, ears per plant, ear length, kernels per row, chlorophyll content, leaf area index 60 days after sowing (LAI 60 DAS), LAI 90 DAS, harvest index, grain yield per plant and grain yield per hectare. Significant genetic association of grain yield per plant and grain yield per hectare with days to 50% pollen shed, days to 50% silk, days to 100% dry husk, ear height, kernels per row, LAI 60DAS and LAI 90 DAS. Genotypic path analysis revealed that the characters, days to 50% silk, days to 100% dry husk, plant height, ears per plant, ear diameter and harvest index had the highest positive direct effects on grain yield per hectare while days to 50% pollen shed and ear height had the highest negative direct effect on grain yield per hectare. The hybrids namely, PAC 751, CP 333 and PAC 751 ELITE, were found to be the three best hybrids to possess a high estimate of desirable traits such as days to 50% pollen

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shed, days to 50% silk, days to 100% dry husk, plant height, ear height, ear diameter, leaf area index at 60 days after sowing, lea area index at 90 days after sowing, grain yield per plant and grain yield per hectare.

Keywords: Genetic variability; heritability; correlation; path analysis and maize.

1. INTRODUCTION

Maize (*Zea mays* L) is a member of the grass family Poaceae. It is an important cereal crop next to rice and wheat. It is a cereal grain crop that was first grown by people in ancient Central America. It is believed to be originated in Central America (Mexico). Globally, maize ranks third in acreage, second in total production and first in grain yield per unit area. In India, maize is grown in an area of 9 m ha with a production of 24.26 m tons and average productivity of 2.7 t/ha. More than 3.5 billion people depend on cereals for more than 20% of their daily calories. Global maize consumption remains strong, driven by both population and economic growth, especially in many Asian and African countries. Maize grain contains about 70% of starch on an average, which makes it a highly suitable feedstock for bio-ethanol production. In India, maize occupies an area of 9.4 m ha with a total production of 28.72 m tones and productivity of 3032 kg/ha (Directorate of Economics and Statistics, DAC & FW, 2017-18). In Assam, maize occupies an area of 28.42 thousand ha with a total production of 87.18 thousand tones and an average yield of 3067 kg/ha (Directorate of Economics and Statistics, Govt. of Assam, 2015-16). It is one of the important cereal crops and also promotes towards food security. It is now grown in all the continents except Antarctica and under a more varied range of climates than any other cereal crop. Every part of the plant has economic value: grain, leaves, stalk, tassel and cob are all used to produce variegated food and non-food products. With the increase in human population as well as subsequent increase in the demand for food, changes in the climatic conditions and increasing concern for nutritional security, there is a need for dynamic plant breeding programme for evolving suitable maize varieties. More grain yield can be obtained by choosing, appropriate genotype, suitable seasons or locations, optimum fertilization and using other improved cultural practices. Plant breeders attempt to concentrate in the same variety several genes responsible for higher productivity, adaptability, resistance and quality. A high yielding hybrid having predominant role in maize cultivation in a particular region is considered to have possessed maximum favourable genes available in the set of germplasm handled by the breeder for development of that hybrid. Such a hybrid is expected to give higher yield in its area of adaptation.

The modern-day hybrids of maize have high grain yield potential with relatively erect leaves suitable for absorption of more solar radiation and better root system for nutrient and water use efficiency. Such maize hybrids are suitable to harvest higher grain yield per unit area through an enhanced plant density. Since the pioneering work of Shull in 1909, a number of maize hybrids has been developed in the US and many other countries including India. Since the inception of hybrids in India in 1961, the researchers and farmers have witnessed a good number of public-bred and private-bred hybrids in maize. Some of the hybrids may perform well at high planting density. There is a need to screen different maize hybrids at varying planting densities to identify the promising ones with higher grain yield, deep root system, better ability to absorb more solar radiation, erect leaves and relevant attributes of grain yield. Maize hybrids respond differently depending upon the planting density with which they are grown. However, few hybrids may show neutrality or independence to varying planting density. Thus, the genetic variability, heritability and genetic advance for a trait.

Grain yield is the most important and complex quantitative character and influenced profusely by environmental factors. Direct selection based on only yield may create confusion and give a biased result. A study on the nature and degree of association of yield and its component traits assumes greater importance for fixing up characters that are likely to play a decisive role in influencing yield. The knowledge of interrelationship between yield and its components themselves are useful if selection for simultaneous improvement in these characters is to be effective. As a greater number of variables are included in the correlation study, the associations become more complex. Sometimes it so happens that correlation coefficients do not give a true picture. In such a situation, the path coefficient analysis provides an effective means of finding out direct and indirect causes and effects of association and permits a critical examination of the specific forces acting to produce a given correlation and measures the relative importance of each factor.

2. MATERIALS AND METHODS

2.1 Planting Materials and Statistical Analysis

A set of eight test hybrids along with a recommended hybrid as check (VMH 53) were grown in a randomized block design with three replications at instructional-cum-research farm of Assam Agricultural University, Jorhat during *rabi* season of 2019-20. The data was recorded replication-wise on nineteen characters *viz.*, days to 50% pollen shed, days to 50% silk, days to 100% dry husk, anthesis-silking interval, plant height, ear height, ear length, ear diameter, ears per plant , kernels per row, kernel rows per ear, chlorophyll content, leaf area at 60 days after sowing, leaf area index at 90 days after sowing, harvest index, grain moisture, 100 kernel weight, grain yield per plant and grain yield per hectare at normal spacing (60 cm x 20 cm) with the plant populations 1,00,000 plants/ha. The seeds of the eight maize hybrids namely, ADV 756, ADV 757, ADV 759, PAC 751, PAC 751 ELITE, CP 333 and CP 838 were obtained from Department of Plant Breeding and Genetics of the university while the seeds of the hybrid 91A21 were obtained from the local market (Fig.1). The plot means were subjected to the statistical and biometrical analysis namely, analysis of variance given by Singh and Chaudhary, [1], genetic coefficient of variance by Burton [2], phenotypic coefficient of variance Burton by [2], heritability given by Allard, [3], genetic advance as percent of mean by Johnson et al, [4], correlation analysis by Singh and Chaudhary, [1] and path analysis by Dewey and Lu, [5]. The results obtained from various statistical and biometrical analysis of the present investigation are presented.

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

In the present investigation, analysis of variance clearly revealed the existence of sufficient genetic variation among the entries for various traits understudied. The analysis of variance (ANOVA) for randomized block design was carried out for fourteen morphological and five physiological traits (Table 1a and Table 1b) on which observations were recorded. The ANOVA revealed significance differences in the genotypes indicating sufficient genetic variation among the genotypes tested for all the morphological and physiological traits except anthesis silking interval, kernel rows per ear and 100 kernel weight. It was supported by V. Ram Reddy [6], M.R. Sudarshan [6] and A.Seshagiri Rao [6].

3.2 Mean Performance of Hybrids

The comparison of the mean performance of the genotypes concerning various morphological and physiological traits (Table 2) revealed that, among the entries, the hybrids namely, ADV 756, PAC 751, ADV 759, PAC 751 ELITE and CP 333 were the best performers for both grain yield per plant and grain yield per hectare. The hybrid VMH 53, CP 838 and 91A21 were the earliest hybrids in respect of days to 50% pollen shed, days to 50% silk and days to 100% dry husk. The hybrids PAC 751, CP 333, VMH 53, ADV 756 and 91A21 had earliness, shorter plant height, low ear height (low ear placement), high ear diameter, high leaf area index, low grain moisture and high grain yield. The hybrids PAC 751, CP 333, PAC 751 ELITE and ADV 759 were best for the physiological traits such as high chlorophyll content, high leaf area index at 60 days after sowing, high leaf area index at 90 days after sowing, high harvest index and low grain moisture. The hybrids namely, PAC 751, CP 333 and PAC 751 ELITE, were found to be the three best hybrids to possess a high estimate of desirable traits such as days to 50% pollen shed, days to 50% silk, days to 100% dry husk, plant height, ear height, ear diameter, leaf area index at 60 days after sowing, lea area index at 90 days after sowing, grain yield per plant and grain yield per hectare. The hybrids namely, ADV 756, PAC 751 and ADV 759 showed more than 50% superiority over the check hybrid (VMH 53) while CP 333, 91A21, ADV 757 and CP 838 showed less than 50% superiority over the check hybrid. The test hybrids except CP 838 outshined the check hybrid for grain yield.

3.3 Genetic Parameters for both Morphological and Physiological Traits

Genetic variability parameters (Table 3) studies revealed that both genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for the traits namely, ear height, kernels per row, chlorophyll content, leaf area index at 60 DAS, leaf area index at 90 DAS, grain yield per plant and grain yield per hectare. The characters with high estimate of GCV and PCV indicated prospect for genetic improvement in the material under study. All the character showed high heritability. High heritability coupled with high genetic advance as per cent of mean observed for the traits viz., plant height, ear height, ears per plant, ear length, kernels per row, chlorophyll content, leaf area index at 60 DAS (days after sowing), leaf area index at 90 DAS, harvest index, grain yield per plant and grain yield per hectare indicate the preponderance of additive gene action in controlling the above-mentioned traits. Simple selection methods such as mass selection or simple recurrent selection without progeny testing will be of helpful for improving a population through the exploitation of genes showing additive gene action. However, the progress of selection will be better if a breeder resorts to apply methods with progeny testing such as progeny selection or recurrent selection with general combining ability. Results supported by Bhalla, [7] and Debnath, [8]. Other traits viz., days to 100% dry husk and grain moisture content were found to have high heritability with low genetic advance as per cent of mean indicating that these characters were under preponderant non-additive gene action and genes responsible in the inheritance of these traits do not show phenotype stably across generations resulting from selfing or intermating. So, the progress of selection of these characters could be expected from hybrid breeding and recurrent selection methods exploiting specific combining ability.

Fig.1 Maize entries

Table 1a. Analysis of variance for different morphological and physiological traits

Source of variation	Degree of freedom	Mean squares									
		Days to 50% pollen shed	Days to 50% silk	Anthesis silking interval	Days to 100% dry husk	Plant height	Ear height	Ears per plant	Ear length	Ear diameter	Kernel rows per ear
Replication	2	10.11	3.00	0.04	2.37	1288.17	311.80	0.001	2.26	0.11	4.32
Genotype	8	67.92**	62.97**	0.68	69.48**	629.54**	268.56**	0.012**	4.10**	0.19**	3.56
Error	16	2.69	7.54	0.33	2.12	155.77	40.87	0.002	0.92	0.03	1.64

**Significant at 5% level of significance; **Significant at 1% level of significance. D.F: Degree of freedom.*

Table 1b. Analysis of variance for different morphological and physiological traits

Source of variation	Degree of freedom	Mean squares								
		Kernels per row	Chlorophyll content	Leaf area index at 60 days after sowing	Leaf area index at 90 days after sowing	Harvest index	Grain moisture content	100 kernel Weight	Grain yield per plant	Grain yield per hectare
Replication	2	5.50	0.001	105.83	681.23	0.13	0.34	1.15	221.15	1602835.59
Genotype	8	47.40**	0.570**	39,442.96**	39554.50**	19.01**	0.62*	6.58	699.34*	39,85,630.59**
Error	16	3.80	0.002	1,315.46	2,763.16	0.51	0.16	3.54	184.19	8,30,007.72

**Significant at 5% level of significance; **Significant at 1% level of significance.*

Table 2. Mean performance of hybrids

GENOTYPE	D50%PS	D50%S	D100%DH	ASI	PH	EH	E/P	EL	ED	KR/E	K/R	CHLC	LAI (60DAS)	LAI (90DAS)	HI	GMC	100KW	GY/P	GY/HA
ADV756	106	109	174	2	150	66	0.9	17	5.5	174	39	3.3	631	642	36	27	35	134	9393
CP838	104	107	166	2	154	51	0.9	16	5.9	166	29	3.6	506	524	37	26	37	100	6889
VMH53(C)	96	98	159	3	105	32	0.9	14	5.1	159	27	3.7	309	343	43	27	37	79	5357
CP333	109	111	167	2	128	55	0.8	15	5.8	167	31	3.5	680	751	43	27	35	112	7997
PAC751ELITE	107	111	173	4	141	52	0.9	16	5.6	173	35	3.2	631	641	39	26	33	113	8151
PAC 751	109	112	170	2	128	46	0.8	15	5.6	170	34	3.9	682	684	41	26	35	120	8538
91A21	103	105	171	2	141	46	0.8	15	5.3	171	28	2.9	576	591	39	26	37	108	7331
ADV759	112	114	174	2	132	46	0.8	17	5.4	174	36	3.5	607	587	40	26	36	119	8415
ADV757	110	109	172	2	133	59	0.8	18	5.5	172	36	2.5	579	618	43	27	34	107	7731
Spacing Mean	106	108	170	2	135	50	0.8	16	5.5	170	33	3.3	578	598	40	26	35	110	7756
CD (G)	3	5	3	1	24	12	0.08	2	0.3	3	4	0.1	68	99	1.4	0.8	4	26	1715

(D50%PS-Days to 50% pollen shed; D50%S-Days to 50% silk; D100%DH-Days to 100% dry husk; ASI-Anthesis silking interval; PH-Plant height; EH-Ear height; E/P-Ears per plant; EL-Ear length; ED-Ear diameter; KR/E-Kernel rows per ear; K/R-Kernels per row; CHLC-Chlorophyll content; LAI60DAS-Leaf area index at 60 days after sowing; LAI90DAS-Leaf area index at 90 days after sowing; HI-Harvest index; GMC-Grain moisture; 100 KW-100 kernel weight; GY/P-grain yield per plant; GY/HA-Grain yield per hectare) [CD (G)- Critical Difference (Genotype)]

Table 3. Estimates of genetic parameters for different morphological and physiological traits

Traits	Range	Genotypic Coefficient of variation (GCV) (%)	Phenotypic Coefficient of variation (PCV) (%)	Heritability board sense (h^2_{bs}) (%)	Genetic advance percent of mean (%)
Days to 50% pollen shed	96-112	7.71	7.86	96.14	15.57
Days to 50% silk	98-112	7.17	7.61	88.90	13.93
Days to 100% dry husk	159-174	4.89	4.97	97.01	9.92
Plant height	105-154	17.84	20.10	78.76	32.61
Ear height	32-66	31.69	34.14	86.18	60.61
Ears per plant	0.78-0.94	12.42	13.47	85.00	23.58
Ear length	14-18	12.28	13.69	80.47	22.70
Ear diameter	5.1-5.9	7.72	8.32	86.21	14.77
Kernels per row	27-39	20.76	21.60	92.39	41.11
Chlorophyll content	2.5-3.9	22.65	22.69	99.65	46.57
Leaf area index at 60 days after sowing	309-681	34.18	34.75	96.74	69.24
Leaf area index at 90 days after sowing	343-684	32.87	34.03	93.33	65.42
Harvest index	35.91-42.97	10.86	11.00	97.37	22.07
Grain moisture content	25.50-26.83	2.86	3.23	78.00	5.19
Grain yield per plant	79-134	22.92	26.02	77.60	41.60
Grain yield per hectare	5357-9393	24.83	27.47	81.71	46.24

Table 4. Genotypic (above diagonal) and phenotypic (below diagonal) correlation coefficients between yield and yield attributing characters

	D50% PS	D50%S	D100% DH	ASI	PH	EH	E/P	EL	ED	KR/E	K/R	CHLC	LAI (60DAS)	LAI (90DAS)	HI	GMC	100KW	GY/P	GY/HA
D50% PS		0.997**	0.185	0.821**	0.279	0.577	-0.24	0.841**	0.523	0.232	0.897**	-0.153	0.918**	0.888**	-0.322	0.03	-0.771*	0.895**	0.910**
D50% S	0.968**		0.201	0.867**	0.271	0.546	-0.094	0.775*	0.515	0.214	0.927**	-0.068	0.964**	0.932**	-0.356	-0.093	-0.899**	0.920**	0.926**
D100 %DH	0.169	0.259		0.319	-0.205	-0.14	0.721*	0.216	0.086	0.127	0.452	-0.361	0.070	0.053	-0.087	-0.728*	-1.311**	0.156	0.001
ASI	0.757*	0.757*	0.189		0.478	0.645	0.200	0.756*	0.228	0.077	0.906**	-0.284	0.793**	0.806**	-0.821**	0.001	-0.820**	0.860**	0.910**
PH	0.192	0.133	-0.278	0.388		0.850**	0.135	0.726*	0.574	0.677*	0.421	0.026	0.355	0.497	-0.376	0.473	0.083	0.53	0.684
EH	0.460	0.378	-0.264	0.539	0.844**		0.003	0.878**	0.602	0.571	0.622	-0.191	0.566	0.702*	-0.464	0.606	-0.215	0.710*	0.842**
E/P	-0.189	-0.149	0.43	0.172	0.092	-0.051		-0.467	0.155	0.572	0.22	0.306	-0.054	0.052	-0.774*	-0.687*	-1.108**	0.3	0.115
EL	0.533	0.453	-0.028	0.461	0.452	0.483	-0.200		0.329	0.227	0.829**	-0.481	0.478	0.606	-0.162	0.341	-0.11	0.605	0.735*
ED	0.437	0.442	0.065	0.221	0.433	0.437	-0.004	0.389		0.916**	0.388	0.391	0.650	0.735*	0.183	0.046	-0.556	0.624	0.601
KR/E	0.132	0.173	0.189	0.121	0.463	0.38	0.303	0.227	0.843**		0.300	0.488	0.359	0.495	0.09	-0.106	-0.52	0.514	0.465
K/R	0.806**	0.779**	0.099	0.813**	0.346	0.532	0.053	0.650**	0.314	0.225		-0.111	0.724**	0.773**	-0.523**	-0.191	-0.703**	0.931**	0.947**
CHLC	-0.142	-0.075	-0.262	-0.26	0.029	-0.165	0.123	-0.304	0.362	0.381	-0.088		0.142	0.139	0.251	-0.482	0.149	0.163	0.093
LAI (60DAS)	0.827**	0.822**	-0.053	0.711	0.352	0.521	-0.063	0.412	0.598	0.305	0.692*	0.133		0.997**	-0.412	0.049	-0.875**	0.908**	0.910**
LAI (90DAS)	0.825**	0.814**	-0.018	0.737**	0.465	0.634	-0.017	0.383	0.638	0.401	0.712*	0.136	0.952**		-0.436	0.09	-0.809**	0.945**	0.967**
HI	-0.306	-0.351	-0.055	-0.678*	-0.298	-0.349	-0.25	-0.17	0.12	0.103	-0.472	0.225	-0.401	-0.415		-0.047	0.706*	-0.551	-0.587
GMC	0.044	-0.05	-0.408	-0.004	0.329	0.466	-0.475	0.254	0.057	-0.073	-0.145	-0.43	0.025	0.062	-0.019		0.481	-0.145	0.03
100KW	-0.386	-0.381	-0.262	-0.424	0.091	-0.148	-0.256	0.003	-0.173	-0.085	-0.389	0.086	-0.361	-0.418	0.289	0.228		-0.873**	-0.678*
GY/P	0.765*	0.764*	0.092	0.738*	0.424	0.519	0.168	0.544	0.563	0.473	0.848**	0.168	0.802**	0.827**	-0.475	-0.107	-0.370		0.971**
GY/HA	0.743*	0.731*	0.004	0.757*	0.536	0.604	0.089	0.626	0.543	0.440	0.826**	0.102	0.794*	0.821**	-0.472	0.019	-0.279	0.975**	

(D50%PS-Days to 50% pollen shed; D50%S-Days to 50% silk; D100%DH-Days to 100% dry husk; ASI-Anthesis silking interval; PH-Plant height; EH-Ear height; E/P-Ears per plant; EL-Ear length; ED-Ear diameter; KR/E-Kernel rows per ear; K/R-Kernels per row; CHLC-Chlorophyll content; LAI60DAS-Leaf area index at 60 days after sowing; LAI90DAS-Leaf area index at 90 days after sowing; HI-Harvest index; GMC-Grain moisture; 100 KW-100 kernel weight; GY/P-grain yield per plant; GY/HA-Grain yield per hectare).

Table 5. Direct (bold) and indirect effects of various component traits on grain yield at genotypic level

	D50%PS	D50%S	D100%DH	PH	EH	E/P	EL	ED	K/R	HI	GMC	$r_{iy}^{\pm}$
D50%PS	**-2.018**	0.971	1.867	0.326	-0.246	-0.256	0.079	0.315	-0.048	-0.006	-0.040	0.943**
D50%S	-1.998	**0.981**	1.925	0.370	-0.240	-0.213	0.064	0.334	-0.048	-0.153	-0.052	0.970**
D100%DH	-1.648	0.826	**2.287**	0.424	-0.271	-0.161	0.082	0.107	-0.056	-0.580	-0.025	0.987**
PH	-1.039	0.573	1.531	**0.633**	-0.242	0.075	0.045	0.338	-0.023	-1.345	0.003	0.550
EH	-1.380	0.653	1.718	0.425	**-0.360**	-0.011	0.082	0.352	-0.045	-0.605	0.025	0.853**
E/P	1.152	-0.466	-0.818	0.105	0.009	**0.449**	-0.019	0.026	0.000	-0.684	0.029	-0.217
EL	-1.606	0.638	1.888	0.289	-0.300	-0.087	**0.099**	0.028	-0.061	-0.297	0.018	0.610
ED	-1.127	0.581	0.435	0.379	-0.225	0.020	0.005	**0.565**	-0.014	-0.230	-0.015	0.375
K/R	-1.513	0.731	1.979	0.227	-0.252	0.001	0.095	0.121	**-0.064**	-0.358	-0.011	0.956**
HI	0.009	-0.109	-0.962	-0.618	0.158	-0.223	-0.021	-0.094	0.017	**1.378**	0.004	-0.462
GMC	1.212	-0.769	-0.848	0.031	-0.134	0.194	0.026	-0.130	0.011	0.089	**0.066**	-0.250

R= 0.19338

$^{\pm} r_{iy}$= Genetic correlation coefficient of grain yield and its i^{th} component trait

(D50%PS-Days to 50% pollen shed; D50%S-Days to 50% silk; D100%DH-Days to 100% dry husk; PH-Plant height; EH-Ear height; E/P-Ears per plant; EL-Ear length; ED-Ear diameter; K/R-Kernels per row; HI-Harvest index; GM-Grain moisture)

3.4 Correlation Analysis

3.4.1 Genotypic and phenotypic correlation coefficient during *rabi* 2019-20

Correlation studies revealed that (Table 4) grain yield per hectare had either significant or highly significant positive correlation with leaf area index at 60 days after sowing, kernels per row, days to 100% dry husk and grain yield per plant at both phenotypic and genotypic levels while it had positive correlation with days to 50% pollen shed, days to 50% silking and ear height only at genotypic level. It was supported by Saleem et al., [9], Rafiq et al., [10], Noor et al., [11], Golam, [12], Reddy et al., [13], Kashiani et al., [14], Nzuve et al., [15] and Rani et al., [16]. Grain yield per hectare had significant to highly significant negative correlation with 100 kernel weight at genotypic level. On the other hand, grain yield per plant had either significant or highly significant positive correlation with leaf area index at 60 days after sowing, kernels per row, days to 100% dry husk and grain yield per hectare at both phenotypic and genotypic levels while it had positive correlation with days to 50% pollen shed, days to 50% silking and ear height at genotypic level. Patil et al., [17] and Singh et al., [18] also obtain similar result. Grain yield per plant had highly significant negative correlation with 100 kernel weight at genotypic level. The genotypic correlation might have arisen due to genetic linkage or pleiotropy between the characters or both. The traits which were genetically correlated to grain yield per plant and which also had high heritability need to be considered for indirect selection leading to improvement of the population for grain yield as grain yield is a highly complex character. Thus, results revealed the scope for simultaneous improvement of these traits through selection.

3.5 Path Analysis

3.5.1 Genotypic path coefficient during *rabi* 2019-20

Path coefficient analysis provides better means for selection by partitioning the correlation coefficient of grain yield with independent traits into direct and indirect effects. Path analysis is a straightforward extension of multiple regressions and its aim is to provide estimates of the magnitude and hypothesize casual connections between sets of variables. Considering all these facts, path coefficient analysis was carried out at genotypic levels taking grain yield per hectare as a dependent character.

Considering high to very high positive direct effects (Table 5), the traits viz., days to 100% dry husk, harvest index, days to 50% silk, plant height, ear diameter and ears per plant were the important component traits of grain yield per hectare. These traits also had high heritability. Thus, selection of plants with higher values of these component traits will enhance the grain yield per hectare. The high direct effects of these traits appeared to be the main reason for their strong association with grain yield. Hence, direct selection for these traits would be effective. Similar results were found by Choudhary and Choudhary, [19], Venugopal et al., [20], Rani et al*.,* [16], Sandeep et al., [21] and Verma et al., [22]. On the other hand, the traits namely, days to 50% pollen shed and ear height had high to very high negative direct effects and these traits proved to be important component traits of grain yield per hectare. Thus, selection of plants with lower values of these component traits i.e. early pollen shedding and low ear height would enhance the grain yield per hectare. Plant selection will be easy for these traits as the traits had high heritability. However, there were positive correlation among the phenological traits such as days to 50% pollen shed, days to 50% silk and days to 100% dry husk reflecting conflict when taken together. As for example, days to 50% pollen shed had negative direct effect and days to 50% silking as well as 100% dry husk had positive direct effect on grain yield. Selecting plants with higher values of days to 50% silking as well as days to 100% dry husk and lower values of days to 50% pollen shed might create conflict. To resolve it, selection of plants with higher values of days to 50% silking as well as days to 100% dry husk and moderate values of days to 50% pollen shed might give high grain yield. The residual was found to be low (0.19338) reflecting that the independent characters under study contributed to the variation in grain yield to a great extent, which inherently suggested the characters taken in the investigation contributed a large extent of the variability in the population.

4. CONCLUSION AND PROSPECTS

The present investigation provides some useful information on genetic variability, correlation of traits and path analysis in a set of early maturing hybrids of India bred and recommended for various states of agroclimatic Zone I of India. The considerable variation among the genotypes for yield and yield attributing characters observed in the present investigation revealed sufficient genetic variation among the hybrids and prospect for selection and recommendation of few of these hybrids for Assam situation. Considering the present investigation, the hybrids viz., PAC 751, CP 333 and PAC 751 ELITE may be tested across years and locations in Assam so as to initiate process of recommendation of these hybrids for the state. Farmers may be interested to grow maize more often at different planting densities. Testing the hybrid PAC 751 in different locations and years followed by subsequent recommendation may benefit the maize growing farmers of the state.

Based on the information derived from the present investigation, the future line of research may be proposed as follows. The hybrids which have been identified with desirable characters including yield can be tested over different locations and years so that the suitability of these hybrids may be tested for different agroclimatic zones of Assam. More morphological and physiological characteristics such as nitrogen use efficiency (NUE), radiation use efficiency (RUE) and water use efficiency (WUE) of these selected hybrids may be studied in future. Selfing in hybrids found suitable for high plant density will open avenue for derivation of superior inbred lines from pedigree selection. Study of tolerance to inbreeding depression may also be tested in segregating generations. Selection of inbred lines suitable for high plant density will result in suitable parents for future hybrid breeding programme for high plant density situation.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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