Journal of Pharmacognosy and Phytochemistry

Available online at www.phytojournal.com

E-ISSN: 2278-4136
P-ISSN: 2349-8234
JPP 2018; 7(5): 1810-1812
Received: 25-07-2018
Accepted: 26-08-2018

Nirmal Raj R
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

Renuka Devi CP
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

Gokulakrishnan J
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

Correspondence
Nirmal Raj R
Department of Genetics and Plant Breeding, Faculty of Agriculture, Annamalai University, Chidambaram, Tamil Nadu, India

Indirect selection for various yield attributing characters of maize hybrids across environments using correlation and path analysis

Nirmal Raj R, Renuka Devi CP and Gokulakrishnan J

Abstract
The efficiency of selection can be broadened for certain traits using estimates of genetic parameters, which are fundamental for plant breeding. Selections of Maize (*Zea mays)* hybrid cultures using yield attributing characters are essential to ensure least deviation from mean yield while going for multi-location recommendations. In this study 23 maize hybrids were taken for evaluation using randomized block design with three replications. Hybrids were grown across three environments and their pooled performance is taken for observations. Ten morphological characters are taken for correlation and path analysis studies. The studies revealed both direct and indirect effects of attributing characters towards yield in which number of leaves, cob placement height, 50% tasselling, days to maturity showed indirect effect whereas ear length, number of kernels per row, number of kernels per ear, 100 seed weight, plant height showed direct effect. The highest direct effect on grain yield was shown by number of kernels per ear and 100 seed weight, hence indirect selection based on KPE and SW for gains in grain yield can be performed to select suitable hybrids across environments with varying climate. Residual effect in path analysis confirmed that these characters considerably contributed to yield with only a negligible effect of environment.

Keywords: *Zea mays*, indirect selection, correlation, genetic parameters, path analysis.

Introduction
Maize (*Zea mays* L.) is the third most important cereal in India after rice and wheat (Centre for monitoring Indian economy, 2015) [2]. It provides food, feed, fodder, fuel and severe as a source of basic raw material for a number of industrial products *viz*., starch, oil, protein, alcoholic beverages, food sweeteners, cosmetics and bio-fuel etc. Maize being a C4 plant is physiologically more efficient, has higher grain yield and wider adaptation over wide range of environmental conditions.

Morphologically maize exhibits greater diversity of phenotypes than any other grain crop (Kuleshov, 1933) [5] and is extensively grown in temperate, subtropical and tropical regions of the world. Yield of maize is considered as a complex inherited character and therefore, direct selection for yield *per se* may not be the most efficient method for its improvement, but indirect selection for other yield related characters will be more effective.

As the study of correlations among traits does not consider the cause / effect relationships between primary and secondary traits, a method called path analysis was developed which studies the direct and indirect effects of traits towards a dependant variable. The path analysis provides a detailed understanding of the influences of the traits involved in a predetermined diagram and justifies the existence of positive and negative correlations, either of high or low magnitudes among the studied traits. The correlations of cause and effect with grain yield, particularly for maize are important tools to assist breeders in defining priority traits for selection and the relationship between them. It allows identifying the genetic changes that should be done to increase the yield.

Therefore, this work is aimed to verify the existence of correlation between morphological traits in maize hybrid populations, in order to practice indirect selection.

Materials and Methods
For this investigation twenty-three Maize hybrids were grown in three locations *viz.*, Villupuram, Trivandrum and Nagercoil. The experiment was laid out in Randomized Block Design with three replications. The crops were raised following proper agronomical practices. The observations were recorded for ten quantitative characters *viz.,* number of leaves, days to

50% tasseling, number of kernels per row, number of kernels per ear, ear length, days to maturity, plant height, cob placement height, 100 seed weight and yield per plant. Correlation co-efficient were calculated at both genotypic and phenotypic level by following Aljibouri *et al.* (1958) [1] method. The direct and indirect effect of yield attributing traits on grain yield were calculated through path coefficient analysis suggested by Wright (1921) [9] and elaborated by Dewey and Lu (1959) [4].

Results and Discussion

Grain yield is a complex character and is dependent on several contributing characters. Hence, character association was studied to assess the relationship among yield and its components for enhancing the efficiency of selection.

The pooled analysis of variance revealed significant differences for all the ten quantitative traits studied. Genotypic correlations revealed the existence of real associations whereas; phenotypic correlations may occur by chance (Table.1 & 2). Significant phenotypic correlations without significant genotypic associations are of no value. If the genotypic correlation is significant and phenotypic is not, it means that the existing real association is masked by environmental effect. In our observations both the correlations were significant hence the expression of genes were not masked but as their magnitudes were within the range to each other, environment plays a role in the expression of these characters.

Table 1: Phenotypic correlation among various characters in pooled analysis

Characters	NL	EL	KR	KPE	SW	CPH	PH	TS	DM	YPP
NL	1.000	0.010	-0.089	-0.129	0.138	0.401	0.483*	0.047	0.223	-0.002
EL		1.000	0.433*	0.325	0.320	0.164	0.384	-0.093	-0.192	0.439*
KR			1.000	0.544**	-0.256	0.281	0.320	-0.089	-0.153	0.192
KPE				1.000	-0.217	0.187	0.242	-0.067	-0.136	0.607**
SW					1.000	-0.160	0.206	-0.159	-0.086	0.602**
CPH						1.000	0.543**	0.092	0.090	-0.034
PH							1.000	-0.021	0.064	0.329
TS								1.000	0.844**	-0.159
DM									1.000	-0.165
YPP										1.000

TS-Days to 50% tasseling, NL-No.of leaves, PH-Plant height, CPH-Cob placement height, DM-Days to maturity, EL-Ear length, KR-Kernels per row, KPE-Kernels per ear, SW-Hundred seed weight, YPP-Yield per plant.

The correlation coefficient estimates of ear length, kernels per ear and 100 seed weight showed positive significant association with yield per plant. It indicated that yield per plant was highly correlated with these attributing variables (Table.2). These observations are in consistent with the findings of other researchers for 100-seed weight (Kumar *et al.* 2006) [6], number of kernels per row (Sadek *et al.* 2006) [7] and ear length (Choudhary and Chaudhary, 2002) [3]. None of the characters showed negative significant association with yield per plant except days to maturity and days to 50% tasseling which showed negative correlation. Similar results were reported by Umakanth and Sunil (2000) [8].

Table 2: Genotypic correlation among various characters in pooled analysis

Characters	NL	EL	KR	KPE	SW	CPH	PH	TS	DM	YPP
NL	1.000	-0.058	-0.142	-0.276	0.049	0.316	0.424*	0.226	0.443*	-0.196
EL		1.000	0.433*	0.297	0.332	0.167	0.429*	-0.071	-0.195	0.430*
KR			1.000	0.542**	-0.306	0.310	0.357	-0.076	-0.132	0.171
KPE				1.000	-0.267	0.136	0.256	-0.038	-0.174	0.599**
SW					1.000	-0.283	0.156	-0.117	-0.015	0.604**
CPH						1.000	0.525*	0.261	0.215	-0.162
PH							1.000	0.028	0.147	0.314
TS								1.000	0.863**	-0.109
DM									1.000	-0.142
YPP										1.000

TS-Days to 50% tasseling, NL-No.of leaves, PH-Plant height, CPH-Cob placement height, DM-Days to maturity, EL-Ear length, KR-Kernels per row, KPE-Kernels per ear, SW-Hundred seed weight, YPP-Yield per plant.

The path coefficient analysis was conducted to obtain further information on interrelationships among traits and their effects on grain yield (Table 3). Path coefficient analysis at genotypic level revealed that 100 seed weight had the greatest direct effect followed by number of kernels per ear and other traits recorded values of lower magnitude for both direct and indirect effects. Thus the traits 100 seed weight and number of kernels per ear would directly influence the dependant variable yield per plant.

Table 3: Path co-efficient analysis among various characters in 23 Maize hybrids in pooled analysis

Characters	NL	EL	KR	KPE	SW	CPH	PH	TS	DM	YPP
NL	0.008	0.010	-0.008	-0.230	0.044	-0.017	0.023	0.032	-0.058	-0.196
EL	-0.001	-0.164	0.023	0.248	0.294	-0.009	0.023	0.010	0.025	0.430*
KR	-0.001	-0.071	0.054	0.452	-0.271	-0.017	0.019	0.011	0.017	0.171
KPE	-0.002	-0.049	0.029	0.833	-0.236	-0.007	0.014	0.005	0.022	0.599**
SW	0.0004	-0.054	-0.017	-0.222	0.887	0.015	0.008	0.017	0.002	0.604**
CPH	0.003	-0.027	0.017	0.114	-0.251	-0.054	0.028	0.037	-0.028	-0.162
PH	0.004	-0.070	0.019	0.214	0.138	-0.029	0.054	0.004	-0.019	0.314
TS	0.002	0.012	-0.004	-0.032	-0.103	-0.014	0.002	0.142	-0.113	-0.109
DM	0.004	0.032	-0.007	-0.146	-0.014	-0.012	0.008	0.123	-0.130	-0.142

Residual Effect = -0.0173

TS-Days to 50% tasselling, NL-No.of leaves, PH-Plant height, CPH-Cob placement height, DM-Days to maturity, EL-Ear length, KR-Kernels per row, KPE-Kernels per ear, SW-Hundred seed weight, YPP-Yield per plant.

Conclusion

From the above results, it can be said that the high direct effects of the traits 100 seed weight and number of kernels per ear appears to be the main reason for their strong association with grain yield. Hence, direct selection for these traits would be effective for the indirect selection of high yielding hybrids.

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