The Pharma Innovation Journal 2022; 11(6): 596-600

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277-7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2022; 11(6): 596-600
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www.thepharmajournal.com
Received: 14-03-2022
Accepted: 27-05-2022

PS Kamble
Botany Section, College of Agriculture, Dhule, Maharashtra, India

KK Barhate
Botany Section, College of Agriculture, Dhule, Maharashtra, India

GR Andhale
Botany Section, College of Agriculture, Dhule, Maharashtra, India

Corresponding Author:
GR Andhale
Botany Section, College of Agriculture, Dhule, Maharashtra, India

Correlation and path analysis for zinc, iron and yield contributing characters in pearl millet [*Pennisetum glaucum* (L.) R.Br.] Genotypes

PS Kamble, KK Barhate and GR Andhale

Abstract
The present investigation was carried out to study correlation between seed yield and yield contributing characters, to know the direct and indirect effects of different traits on seed yield. Fifty-two genotypes of Pearl Millet were grown at Bajra Research Scheme, College of Agriculture, Dhule, during *Kharif,* 2020, in a Randomized Block Design with three replications. Correlation study revealed that seed yield per plant had positive and significant correlations with days to flowering, days to maturity, plant height, panicle length and test weight and had non-significant positive correlation with zinc content at genotypic and phenotypic levels. Days to flowering, panicle girth, test weight, and number of productive tillers per plant all had a positive direct effect on grain yield at both the genotypic and phenotypic levels, as shown by the above results. At both the genotypic and phenotypic levels, days to maturity, panicle length, iron content and zinc content showed a negative direct effect on grain yield per plant. Plant height had a negative genotypic direct effect on grain yield per plant and a positive phenotypic direct effect on grain yield per plant.

Keywords: Correlation, path analysis, pearl millet

Introduction
Pearl Millet is vital for food and nutritional security because it has various advantages, including early maturity, drought tolerance, low input costs, and resistance to biotic and abiotic challenges. Its grains are high in protein, have a well-balanced amino acid profile, and are high in zinc, iron, and insoluble dietary fiber. A lack of availability to minerals and vitamins in the diet causes micronutrient malnutrition, sometimes known as "hidden hunger." More than two billion people worldwide are affected by a lack of micronutrients, particularly iron and zinc, in their diets, with pregnant women and children under the age of five being the most vulnerable (World Health Organization, 2012) [17]. Anemia, caused by an iron (Fe) deficiency, is the most common condition in low-income nations, and residents of these countries who consume a poor-quality diet are at risk of child mortality and other physiological problems (Tako *et al*. 2015) [15]. Correlation coefficient measures the degree of association, and also the genetic or non-genetic relationship between two or more characters which forms the basis for selection. Path analysis simply splits the correlation coefficient into the measures of direct and indirect effect of a set of independent variables on the dependent variables.

Material and Methods
The present investigation studied fifty-two genotypes of pearl millet evaluated in randomized block design with three replications in kharif-2020 at Bajara Research Station Farm, College of Agriculture, Dhule (MS). The genotypic, phenotypic and environmental covariance adapting method suggested by Singh and Chaudhari (1977) as below.

Environmental covariance (COVe1.2) = EMP
Genotypic covariance (COVg1.2) = (GMP-EMP)/r
Phenotypic covariance (COVp1.2) = (COVg1.2) + (COVe1.2)

Where
EMP = Environmental mean product
GMP = Genotypic mean product

To understand the association among the different characters, genotypic and phenotypic correlation co-efficient were worked out by adopting the method described by Johnson *et al.* (1955).

Path co-efficient analysis was carried out by the procedure originally proposed by Wright (1921) which was subsequently elaborated by Dewey and Lu (1959) to estimate the direct and indirect effects of the individual characters on yield.

The following set of simultaneous equations were formulated and solved for estimating various direct and indirect effects.

r1y = p1y + r12p2y + r13p3y + ……… + r1ipiy
r2y = r21p1y + p2y + r23p3y + ……… + r2ipiy
riy = ri1p1y + ri2p2y + ri3p3y + ……… + piy

Where

r12 to ri-1 = Co-efficient of correlation among causal factors.
p1y to piy = Direct effects of characters '1' to i on character 'y'.

Results and Discussion

A) Correlation coefficient analysis

The action and interactions of a number of significant characters influenced the expression of yield in crop plants. This is owing to the fact that most of the characters in the integrated plant structure are inter-related, and a change in one is likely to influence the other, thus the net benefit received by selecting one may be counterbalanced by a simultaneous change in another. Therefore, correlation is helpful in determining the component characters of a complex trait like yield. Tables No.1 and No.2 show the estimated correlation co-efficient at genotypic and phenotypic levels respectively, between seed yield per plant and all of the characters.

Grain yield per plant had high significantly positive genotypic correlation with panicle girth (0.47) followed by plant height (0.34), test weight (0.33), days to flowering (0.22) and days to maturity (0.20). Grain yield per plant had a non-significant and positive genotypic correlation with panicle length (0.06) and zinc content (0.05), but a significant and negative genotypic correlation with the number of productive tillers per plant (-0.16) and a non-significant and negative genotypic correlation with iron content (-0.07). Panicle girth (0.40), plant height (0.32), test weight (0.28), days to flowering (0.21) and days to maturity (0.19) all demonstrated substantial positive phenotypic correlations with grain yield per plant. Zinc content (0.06) revealed a non-significant and positive phenotypic correlation with grain yield per plant. While grain yield per plant had a non-significant and negative phenotypic correlation with the number of productive tillers per plant (-0.11), iron content (-0.06), and panicle length (-0.03). Similar results were confirmed by, Choudhary *et al.* (2012) [3] for plant height, ear girth and test weight; Bikash *et al.* (2013) [2] for panicle girth; Mukesh *et al.* (2013) [11] for test weight; Vinodhana *et al.* (2013) [16] for test weight; Kannati *et al.* (2014) [8] for iron content; Kannati *et al.* (2014) [8] for iron and zinc content; Kumar *et al.* (2014) for plant height; Ezeakuet *et al.* (2015) [5] for plant height; N. Anuradha *et al.* (2017) [1] for iron content; Kali *et al.* (2018) [7] for plant height and test weight; and Kaushik *et al.* (2018) [9] for days to flowering and test weight, 1000 seed weight; and Pujar *et al.* (2020) [12] for iron content.

Iron content and zinc content had a strong substantial positive genotypic correlation (0.77). It showed significant negative correlation with days to maturity (-0.23), days to flowering (-0.18) and test weight (-0.18). Plant height (0.08) and the number of productive tillers per plant (0.01) revealed a non-significant and positive correlation with iron content. It also revealed a non-significant and negative correlation with panicle length (-0.11) and panicle girth (-0.07). In phenotypic correlation, iron content exhibited the significant positive correlation with zinc content (0.71). It had a substantial negative correlation with days to maturity (-0.21), test weight (-0.17) and days to flowering (-0.17). Plant height (0.07) and the number of productive tillers per plant (0.06) exhibited a non-significant and positive correlation (0.06). It also had a non-significant and negative correlation with panicle length (-0.09), and panicle girth (-0.06). From the above results it is clear that, iron content had significant positive correlation with zinc content at both genotypic as well as phenotypic level. The same findings were recorded by N Anuradha *et al.* (2017) [1], showed that significant and positive correlation between iron and zinc content and by Rai *et al.* (2012) [13] for iron content.

Iron content (0.77) and plant height (0.22) exhibited strong significant and positive genotypic correlation with zinc content. Zinc content had a significant and negative correlation with test weight (-0.19). It also exhibited non-significant and positive correlation with panicle length (0.01) and non-significant and negative correlation with days to maturity (-0.15), days to flowering (-0.10), panicle girth (-0.07) and number of productive tillers per plant (-0.04). In phenotypic correlation, zinc content exhibited significant and positive correlation with iron content (0.71) and plant height (0.20). It showed significant negative correlation with test weight (-0.18). Panicle length (0.03) and panicle girth (0.03) found a non-significant and positive correlation with zinc content. It also revealed the non-significant and negative correlation with the days to maturity (-0.12), days to flowering (-0.08) and number of productive tillers per plant (-0.02). Similar findings were reported by N. Anuradha *et al.* (2017) [1] for zinc content showed positive significant correlation with iron content.

B) Path Coefficient Analysis

The direct and indirect effects of grain yield and its nine characters at the genotypic and phenotypic levels were shown in Tables No. 3 and 4, respectively, in this study.

Direct effect of yield components on grain yield per plant

Days to flowering, panicle girth, test weight, and number of productive tillers per plant all had a positive direct effect on grain yield at both the genotypic and phenotypic levels, as shown by the above results. At both the genotypic and phenotypic levels, days to maturity, panicle length, iron content and zinc content showed a negative direct effect on grain yield per plant. Plant height had a negative genotypic direct effect on grain yield per plant and a positive phenotypic direct effect on grain yield per plant. The same findings were recorded by Dhakar *et al.* (2012) [4], for panicle girth, number of productive tillers per plant and days to flowering; Govindraj *et al.* (2012) [6], for number of productive tillers; Singh *et al.* (2015) [14], for days to flowering and panicle girth; and Bhasker *et al.* (2017) [10] for number of productive tillers per plant and test weight. The high magnitudal direct effect of days to flowering, panicle girth, number of productive tillers per plant and test weight, as well as the highly significant correlation in the desired direction towards grain yield, indicates a true and perfect relationship between them, as evidenced by the above results. It suggests direct selection based on these characters would help in selecting the high grain yielding genotypes.

Indirect effect of yield components on grain yield per plant

The trait days to maturity had a significant and positive correlation with grain yield per plant and contributed through its indirect effect via., positively with number of productive tillers per plant, iron content, zinc content and negatively with days to flowering, plant height, panicle length, panicle girth and test weight at both genotypic and phenotypic levels. Plant height has a significant and positive correlation with grain yield per plant at both the genotypic and phenotypic levels, and contributed through its indirect effect via., positively with number of productive tillers per plant and negatively with days to flowering, days to maturity, panicle girth, iron content, zinc content, panicle length and test weight at genotypic level. Plant height contributed through its indirect effect via., positively with days to flowering, days to maturity, panicle girth, panicle length, test weight, iron content, zinc content and negatively with number of productive tillers per plant at phenotypic levels. The number of productive tillers per plant had a significant and negative correlation with grain yield per plant, and contributed through its indirect effect via., positively with length of panicle, iron content and negatively with days to flowering, days to maturity, test weight, panicle girth and zinc content at both genotypic as well as phenotypic levels. That panicle length contributed to grain yield per plant through an indirect effect via, positively with panicle girth, iron content, and test weight and negative with days to flowering, days to maturity, plant height, number of productive tillers per plant and zinc content, as shown in the above results. With the exception of zinc content, panicle girth showed a significant and positive correlation with grain yield per plant and contributed through its indirect effect via., positively with days to flowering, days to maturity, plant height and test weight and negatively with number of productive tillers per plant, panicle length and iron content at both the genotypic and phenotypic levels. With the exception of days to flowering, test weight showed a significant and positive correlation with grain yield per plant and contributed through its indirect effect via., positively with days to maturity, days to flowering, plant height, panicle girth and negatively with panicle length, number of productive tillers per plant, iron content and zinc content at both genotypic and phenotypic levels at both genotypic and phenotypic levels, as shown in the above results. Iron content had non-significant and negative correlation with grain yield per plant and contributed through its indirect effect via., positively with days to maturity, panicle girth, panicle length, test weight and negatively with plant height, number of productive tillers per plant and zinc content at both genotypic and phenotypic levels except days to flowering, as shown in the above results. zinc content exhibited non-significant and positive correlation with grain yield per plant and contributed through its indirect effect via., positively with days to flowering, days to maturity, panicle girth, number of productive tillers per plant, test weight and negatively with iron content, plant height and panicle length, as shown in the above results. At phenotypic level, zinc content contributed through its indirect effect via, positively with plant height, panicle length, panicle girth, iron content and negatively with days to flowering, days to maturity, number of productive tillers per plant, test weight, as shown in the above results.

Table 1: Genotypic correlation co-efficient for ten characters in Pearl Millet:

Sr. No.	Characters	Days to flowering	Days to maturity	Plant height	No. of productive tillers/plant	Panicle length	Panicle girth	Test weight	Iron content	Zinc content	Correlation with grain Yield/plant (g)
1	Days to flowering	1	0.99**	0.45**	-0.37**	0.21**	0.48**	0.35**	-0.18*	-0.10	0.22**
2	Days to maturity		1	0.43**	-0.38**	0.17*	0.53**	0.42**	-0.23**	-0.15	0.20**
3	Plant height			1	-0.39**	0.18*	0.40**	0.18*	0.08	0.22**	0.34**
4	No. of productive tillers per plant				1	0.08	-0.60**	-0.47**	0.01	-0.04	-0.16*
5	Panicle length					1	-0.11	-0.04	-0.11	0.01	0.06
6	Panicle girth						1	0.65**	-0.04	-0.07	0.47**
7	Test weight							1	-0.18*	-0.19*	0.33*
8	Iron content								1	0.77**	-0.07
9	Zinc content									1	0.05

*and** indicates significance at 5% and 1% levels, respectively.

Table 2: Phenotypic correlation co-efficient for ten characters in Pearl Millet

Sr. No.	Characters	Days to flowering	Days to maturity	Plant height	No. of productive tillers/ plant	Panicle length	Panicle girth	Test weight	Iron content	Zinc content	Correlation with grain Yield /plant
1	Days to flowering	1	0.91**	0.40**	-0.26**	0.17*	0.42**	0.33**	-0.17*	-0.08	0.21**
2	Days to maturity		1	0.38**	-0.32**	0.12	0.45**	0.37**	-0.21**	-0.12	0.19*
3	Plant height			1	-0.28**	0.17*	0.36**	0.17*	0.07	0.20*	0.32**
4	No. of productive tillers per plant				1	0.07	-0.40**	-0.34**	0.06	-0.02	-0.11
5	Panicle length					1	-0.08	-0.04	-0.09	0.03	-0.03
6	Panicle girth						1	0.58**	-0.06	0.03	0.40**
7	Test weight							1	-0.17*	-0.18*	0.28**
8	Iron content								1	0.71**	-0.06
9	Zinc content									1	0.06

* and ** indicates that significance at 5% and 1% levels, respectively.

Table 3: Genotypic path co-efficient for ten characters in Pearl Millet

Sr. No.	Characters	Days to flowering	Days to maturity	Plant height	No. of productive tillers/ plant	Panicle length	Panicle girth	Test weight	Iron content	Zinc content	Yield per plant
1	Days to flowering	4.13	4.10	1.89	-1.55	0.88	1.98	1.48	-0.77	-0.42	0.22**
2	Days to maturity	-4.27	-4.29	-1.88	1.64	-0.76	-2.31	-1.84	1.00	0.65	0.20*
3	Plant height	-0.02	-0.02	-0.05	0.02	-0.01	-0.02	-0.01	-0.04	-0.01	0.34**
4	No. of productive tillers/ plant	-0.05	-0.06	-0.06	0.15	0.01	-0.09	-0.07	0.02	-0.06	-0.16*
5	Panicle length	-0.01	-0.01	-0.01	-0.07	-0.08	0.09	0.03	0.09	-0.01	0.06
6	Panicle girth	0.13	0.15	0.11	-0.17	-0.03	0.29	0.18	-0.02	-0.02	0.47**
7	Test weight	0.07	0.09	0.04	-0.10	-0.08	0.14	0.02	-0.04	-0.04	0.33**
8	Iron content	0.02	0.02	-0.09	-0.01	0.01	0.08	0.02	-0.11	-0.08	-0.07
9	Zinc content	0.07	0.01	-0.01	0.03	-0.01	0.05	0.01	-0.05	-0.07	0.05
Residual Effect = (1 – 21.7318) Bold values indicated the direct effect											

Table 4: Phenotypic path co-efficient for ten characters in Pearl Millet

Sr. No.	Characters	Days to flowering	Days to maturity	Plant height	No. of productive tillers/plant	Panicle length	Panicle girth	Test weight	Iron content	Zinc content	Yield per plant
1	Days to flowering	0.10	0.09	0.04	-0.02	0.01	0.01	0.03	-0.01	-0.09	0.21**
2	Days to maturity	-0.13	-0.15	-0.05	0.04	-0.01	-0.06	-0.05	0.03	0.01	0.19*
3	Plant height	0.09	0.08	0.22	-0.06	0.04	0.08	0.03	0.01	0.04	0.32**
4	No. of productive tillers/ plant	-0.02	-0.03	-0.03	0.10	0.08	-0.04	-0.03	0.07	-0.02	-0.11
5	Panicle length	-0.07	-0.05	-0.07	-0.03	-0.04	0.03	0.01	0.03	-0.01	-0.03
6	Panicle girth	0.12	0.13	0.11	-0.12	-0.02	0.30	0.17	-0.02	0.01	0.40**
7	Test weight	-0.04	0.04	0.02	-0.04	-0.05	0.07	0.12	-0.02	-0.02	0.28**
8	Iron content	-0.02	0.03	-0.01	-0.01	0.01	0.01	0.02	-0.16	-0.11	-0.06
9	Zinc content	-0.01	-0.01	0.03	-0.04	0.04	0.05	-0.02	0.10	0.15	0.06
Residual effect = 0.8745 Bold values indicated direct effect											

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