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PATTERN OF RELATIONSHIPS AMONG PRODUCTIVITY AND NUTRITIONAL TRAITS IN PEARL MILLET (*Pennisetum Glaucum* (L.) R. Br.)

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ABSTRACT

The present investigation was carried out to study the correlation and path analysis amonggrain yield, yield-related and nutritional traits in pearl millet hybrids. This experiment was conducted in a total of 168 hybrids, which were developed by crossing 84 advanced generation seed parental (B) lines with two restorer (R) line testers by line x tester mating design. These hybrids were evaluated in 4 trials (each with 42 hybrids) during rainy season of 2020 at four locations. Observations were recorded on days to 50% flowering, plant height, 1000-seed weight, grain iron content, grain zinc content and grain yield. Correlation analysis revealed that significant positive correlation was found between grain yield and plant height; days to 50% flowering and plant height; and grain Fe and Zn content. Significant negative correlation was observed between grain yield with grain Fe and Zn content. The results of path analysis showed that plant height showed highest direct effect and days to 50% flowering showed highest indirect effects on grain yield. These results suggests that plant height and days to 50% flowering should be given maximum consideration for total grain yield improvement.

KEYWORDS: correlation, grain yield, nutritional traits, path analysis, pearl millet

Pearl millet [*Pennisetum glaucum* (L.) R. Br.] is commonly grown in the arid and semi-arid regions of Asia and Africa. It serves as staple food for the people living in relatively dry areas of the India and Sub-Sahelian Africa and an important source of fodder/ feed for livestock and poultry. It can be cultivated even in the poor infertile soils and drought prone environments, where no other cereal crop can survive. It is a rich source of nutrients like iron (Fe) and zinc (Zn). Globally, pearl millet is cultivated in an area about 27 m ha with 31 m tons of production and is staple food for more than 90 million people. India is the largest producer of pearl millet with the of 7.65 m ha of area, 11.6 m tons of production and 1420 kg^{-1}ha of productivity (Indiastat, 2021). In Telangana, pearl millet grown in 10,000 ha of area with 9300 tons of production and 930 kg^{-1}ha productivity (Indiastat, 2021). The ultimate aim in most plant breeding programs is the improvement in the productivity of grains as measured in terms of the yield per unit area. The possibilities of achieving this goal through genetic improvement have been elucidated by evolving high yielding hybrids of pearl millet. The possibilities of achieving this goal through genetic manipulation have been elucidated by evolving high yielding hybrids. These newly evolved varieties and hybrids gets their high yielding ability by reconstruction of an ideal plant type. It is now widely recognized that the improvement in plant type can make a very significant contribution to increase total grain yield. Grain yield character in pearl millet and as in all crop plants is quantitative in nature and is polygenically controlled. Selection based on grain yield character alone is usually not very effective. However, selection based on its component characters could be more efficient and reliable. Knowledge of the association between yield and its component characters and among the

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component characters themselves can improve the efficiency of selection in plant breeding. This necessitates study of the relationship and effects of various yield-contributing traits on grain yield in current breeding programs to derive proper selection criteria for enhancing productivity in pearl millet crop. The present study was undertaken to study the correlations and path analysis in pearl millet hybrids to develop a criterion for selection that could be effectively used for selecting the desirable genotypes with high yield potential in the future.

MATERIAL AND METHODS

A total of 168 hybridswere developed by crossing 84 advanced generation (>F5/F6) seed parental (B) lines with two restorer (R) line testers by line x tester mating design at International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, and these hybrids were used for the study. Because the material is too large to evaluate in a single trial, it is divided into four trials, each with 42 hybrids, to reduce experimental error. The experiment was conducted during rainy season of 2020, each trial is evaluated in alpha-lattice design with two replications at 4 locations. In each replication, the size of the plot consisted of 2 rows with a length of 4 meters. The spacing between and within the rows was maintained at 75 cm and 12-15 cm, respectively. Seeds after germination were thinned down to one plant per hill after two weeks of sowing. A basal dose of 100 kg of di-ammonium phosphate (18% N and 46% P) was applied at the time of field preparation and 100 kg of urea (46% N) was applied as top dressing in two-split dose at the stage of three weeks and five weeks after sowing. Trials were regularly irrigated to avoid any moisture stress. All the recommended agronomic practices were followed for raising good crop.

Data collection

Data collection was done for the grain yield, Fe content, Zn content and other yield component characters. The observations were taken on 3 random plants in each replication for plant height (cm) and data for days to 50% flowering, grain yield, 1000-grain weight (g) were recorded on plot basis. Further, data of grain yield was converted to kg ha^{-1}. Grain Fe and Zn densities were estimated by Energy-Dispersive X-ray Fluorescence Spectrometry (ED-XRF) machine.

Data analysis

Phenotypic and genotypic linear correlation coefficients were calculated for all the possible comparisons using the formula suggested by Falconer (1964). The correlation coefficients were partitioned into direct and indirect effects using the path coefficient analysis according to Dewey and Lu (1959). Data analysis was carried out using SAS v 9.4 software (SAS, Inc., 2017).

RESULTS AND DISCUSSION

Phenotypic and genotypic correlation

Correlation analyses the relationship among the characters has great value in the evaluation of the most effective procedures for selection of superior genotypes. Positive association between major yield contributing characters would be desirable and it eases the selection process in breeding program. Correlation analyses was computed at both genotypic and phenotypic level. The genotypic correlation is the heritable association among the traits, and the phenotypic correlation is environmental deviations together with non-additive genetic deviations (Allard, 1960; Falconer and Mackay, 1996). The genotypic correlations were of higher magnitude than their corresponding phenotypic correlations for most of the traits, indicating a strong inherent relationship among the characters studied. This strong genotypic correlation over phenotypic correlations were reported in previous studies in pearl millet (Khairwal *et al.,* 1999, Izge *et al.,* 2006, Bhuri Singh *et al.,* 2015 and Bhasker *et al.,* 2017).

Trial wise correlation coefficient values and across trial significance of correlation between traits were presented in the Tables 1 and 2 respectively. It was observed that at both genotypic and phenotypic level, significant positive correlation was observed between plant height and days to flowering; and between grain yield and plant heightin all 4 trials (TCB (Testcross B-line Trial) 1, TCB 2, TCB 3, TCB 4). Significant positive correlation was observed between Fe content and Zn content at genotypic level in 3 trials and at phenotypic level in all 4 trials. Significant negative correlation was observed between grain yield and Fe content in all 4 trials at genotypic level and in 2 trials at phenotypic level. Significant negative correlation was

Table 1: Trial wise genotypic and phenotypic correlation coefficients between grain yield, nutritional and yield related traits

	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
Days to 50% flowering	TCB 1	G	0.39**	-0.11	-0.28	-0.09	0.06
		P	0.30*	0.24	0.01	0.17	-0.04
	TCB 2	G	1.40***	-0.43**	0.73***	0.43**	1.99***
		P	0.55***	0.1	-0.01	-0.24	0.21
	TCB 3	G	0.65***	0.08	-0.44**	0.55***	1.98***
		P	0.35*	0.05	-0.12	0.11	0.45**
	TCB 4	G	0.61***	-0.17	-0.05	-0.54***	0.18
		P	0.47**	-0.12	-0.03	0.10	-0.09
Plant height	TCB 1	G		0.17	-0.52***	-0.38**	0.64***
		P		0.18	-0.23	0.04	0.46**
	TCB 2	G		-0.31*	0.19	0.32*	2.11***
		P		0.11	-0.18	-0.08	0.46**
	TCB 3	G		0.25	-0.51***	-0.55***	1.92***
		P		0.25	-0.33*	-0.03	0.63***
	TCB 4	G		0.39**	-0.38*	-0.20	0.75***
		P		0.29	-0.21	0.22	0.36*
1000-seed weight	TCB 1	G			0.26	0.43**	-0.44**
		P			0.09	0.28	-0.28
	TCB 2	G			1.99***	1.62***	-0.31*
		P			0.39**	0.36*	0.18
	TCB 3	G			-0.14	-0.16	0.47**
		P			0.10	0.15	0.34*
	TCB 4	G			0.09	-0.16	0.33*
		P			0.03	-0.19	0.22
Iron content	TCB 1	G				0.53***	-0.32*
		P				0.57***	-0.27
	TCB 2	G				0.92***	-1.58***
		P				0.65***	-0.09
	TCB 3	G				0.75***	-2.31***
		P				0.64***	-0.49***
	TCB 4	G				0.24	-0.46**
		P				0.34*	-0.36*
Zinc content	TCB 1	G					-0.12
		P					-0.19

	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
	TCB 2	G					-0.38*
		P					-0.01
	TCB 3	G					-1.18***
		P					-0.16
	TCB 4	G					-0.62***
		P					0.02

*P < 0.05; ** P < 0.01; ***P < 0.001

Table2: Number of trials showing significantgenotypic and phenotypic correlationsbetween grain yield, nutritional and yield related traits

		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
Days to 50% flowering	G	**4 (+)**	3 (NS) 1 (-)	2 (NS) 1 (+) 1 (-)	2 (+) 1 (-) 1 (NS)	**2 (+) 2 (NS)**
	P	**4 (+)**	4 (NS)	4 (NS)	4 (NS)	**3 (NS) 1 (+)**
Plant height	G		2 (NS) 1 (+) 1 (-)	3 (-) 1 (NS)	2 (-) 1 (+) 1 (NS)	**4 (+)**
	P		4 (NS)	3 (NS) 1 (+)	4 (NS)	**4 (+)**
1000 Seed Weight	G			3 (NS) 1 (+)	2 (+) 2 (NS)	2 (+) 2 (-)
	P			3 (NS) 1 (+)	3 (NS) 1 (+)	3 (NS) 1 (+)
Iron Content	G				**3 (+)1 (NS)**	**4 (-)**
	P				**4 (+)**	**2 (NS) 2 (-)**
Zinc Content	G					**3 (-) 1 (NS)**
	P					**4 (NS)**

+ Significantly positive, - Significantly negative, NS Non-significant

observed between grain yield and Zn content in 3 trials at genotypic level and non-significant at phenotypic level in all 4 trials.

High correlation between Fe and Zn content and negative or no correlation between grain yield and grain Fe content were well reported in earlier studies by Velu *et al.,* (2007), Gupta *et al.,* (2009), Rai *et al.,* (2012), Govindaraj *et al.,* (2013) and Kanatti *et al.,* (2014). Between grain yield and days to 50% flowering significant positive correlation was observed in 2 trials at genotypic level and 1 trial at phenotypic level and non-significant in remaining trials. Sudharshan *et al.,* (2018) and Kamble *et al.,* (2022) reported positive correlation between grain yield and days to 50% flowering, onthe contrary to this, Izge *et al.,* (2006), Bhuri Singh *et al.,* (2015) and Kumar *et al.,* (2020) found negative genotypic correlation between grain yield and days to 50% flowering. Some other studies reported no correlation between days to 50% flowering and grain yield (Chaudhary, 1992, Ezeaku and Mohammed 2006 and Izge al., 2004). Above result suggested that significant positive correlation was found between days to 50% flowering and plant height; grain yield and plant height; grain Fe and Zn content. Significant negative correlation was observed between grain yield with grain Fe and Zn content.

Direct and Indirect effects

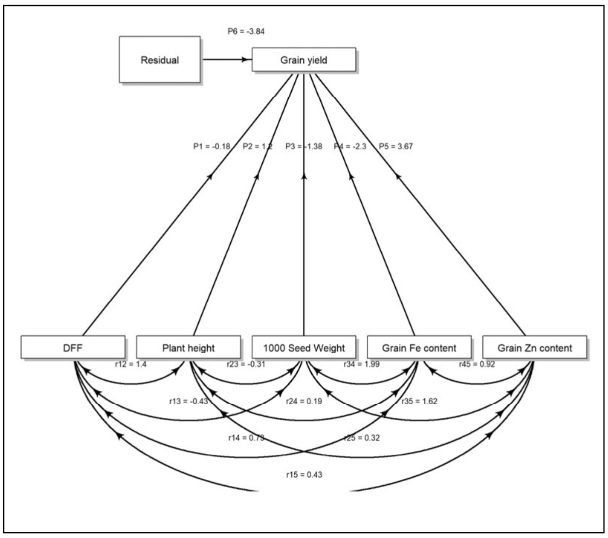
Seed yield is a complex character which is highly influenced by interaction of various component traits and the environment. Compartmentalization of correlation coefficients into direct and indirect effects reveals the true nature of associations observed among various characters. Path coefficients provides an effective way of finding direct and indirect sources of correlation. Path analysis results of 4 trials revealed that plant height showed highest direct effect and days to 50% flowering showed highest indirect effect via plant height on grain yield. Trial wise path coefficient analysis results were mentioned in Table 3. Direct and indirect effects of all characters on grain yield at genotypic level in 4 trials were presented in Figure 1.

Table 3: Trial wise direct and indirect effects of different characters on grain yield at genotypic and phenotypic level

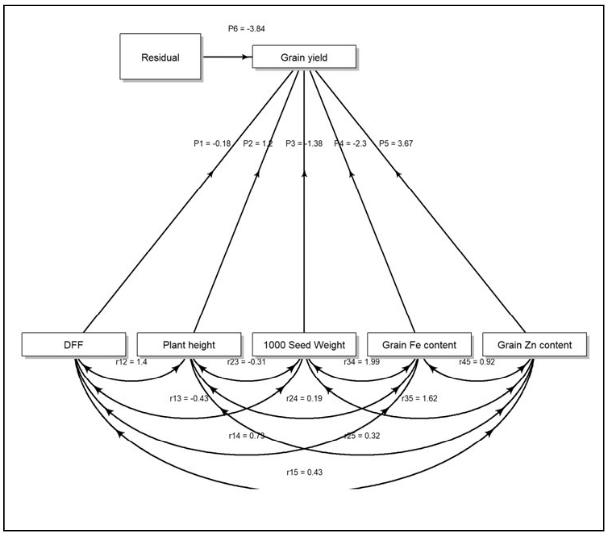
	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
Days to 50% flowering	TCB 1	G	**-0.49**	0.54	0.12	-0.04	-0.07
		P	**-0.11**	0.16	-0.08	0.00	-0.01
	TCB 2	G	**-0.18**	1.68	0.59	-1.68	1.58
		P	**-0.06**	0.26	0.02	0.01	0.01
	TCB 3	G	**0.67**	0.42	0.01	0.79	0.09
		P	**0.27**	0.12	0.01	0.05	0.01
	TCB 4	G	**-32.33**	19.19	3.74	-0.82	10.40
		P	**-0.27**	0.17	-0.01	0.01	0.01
Plant height	TCB 1	G	-0.19	**1.37**	-0.18	-0.07	-0.29
		P	-0.03	**0.53**	-0.06	0.02	0.00
	TCB 2	G	-0.26	**1.20**	0.43	-0.44	1.17
		P	-0.03	**0.46**	0.02	0.01	0.01
	TCB 3	G	0.44	**0.65**	0.01	0.92	-0.09
		P	0.09	**0.34**	0.07	0.13	0.01
	TCB 4	G	-19.72	**31.46**	-8.58	-6.26	3.85
		P	-0.13	**0.36**	0.03	0.07	0.02
1000-Seed Weight	TCB 1	G	0.05	0.23	**-1.09**	0.04	0.32
		P	-0.03	0.10	**-0.33**	-0.01	-0.01
	TCB 2	G	0.08	-0.37	**-1.38**	-4.58	5.95
		P	-0.01	0.05	**0.16**	-0.03	-0.01

	Trial		Plant height	1000 Seed Weight	Iron content	Zinc content	Grain yield
	TCB 3	G	0.05	0.16	**0.03**	0.25	-0.03
		P	0.01	0.08	**0.28**	-0.04	0.01
	TCB 4	G	5.50	12.27	**-22.00**	1.48	3.08
		P	0.03	0.10	**0.11**	-0.01	-0.02
Iron content	TCB 1	G	0.14	-0.71	-0.28	**0.14**	0.40
		P	0.00	-0.12	-0.03	**-0.09**	-0.03
	TCB 2	G	-0.13	0.23	-2.75	**-2.30**	3.38
		P	0.00	-0.08	0.06	**-0.07**	-0.01
	TCB 3	G	-0.29	-0.33	0.01	**-1.81**	0.13
		P	-0.03	-0.11	0.03	**-0.39**	0.02
	TCB 4	G	1.62	-11.96	-1.98	**16.48**	-4.62
		P	0.01	-0.08	0.00	**-0.33**	0.03
Zinc content	TCB 1	G	0.04	-0.52	-0.47	0.08	**0.75**
		P	-0.02	0.02	-0.09	-0.05	**-0.05**
	TCB 2	G	-0.08	0.38	-2.24	-2.12	**3.67**
		P	0.01	-0.04	0.06	-0.05	**-0.01**
	TCB 3	G	0.37	-0.36	0.01	-1.35	**0.17**
		P	0.03	-0.01	0.04	-0.25	**0.03**
	TCB 4	G	17.46	-6.29	3.52	3.96	**-19.26**
		P	-0.03	0.08	-0.02	-0.11	**0.10**

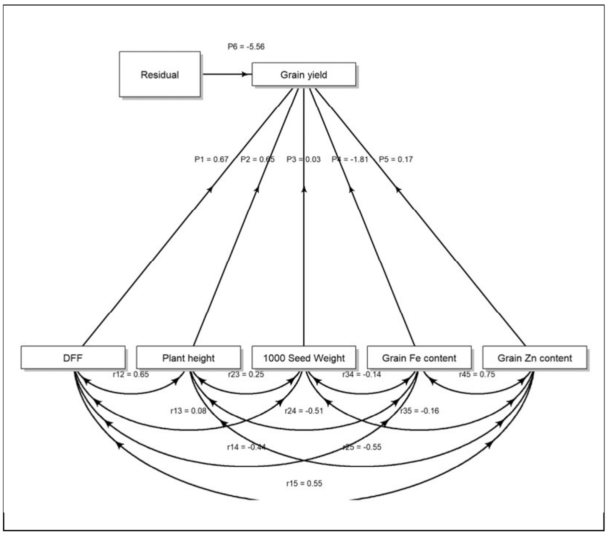
Diagonal and bold values represent direct effects



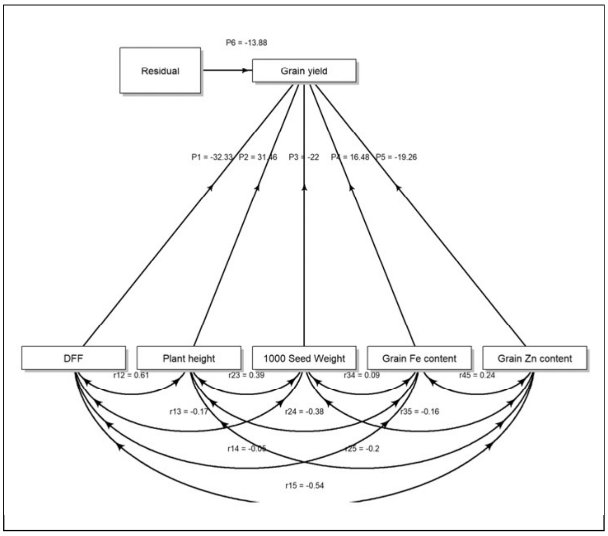
TCB-1



TCB-2



TCB-3



TCB-4

Figure 1. Trial wise path diagrams showing direct and indirect effects of different characters on grain yield at genotypic level

In TCB 1, at genotypic level, plant height (1.37) followed by grain Zn content (0.75) and grain Fe content (0.14) had high and positive direct effect on grain yield. At phenotypic level also plant height (0.53) showed highest direct effect on grain yield. At genotypic level, highest indirect effects on grain yield were showed by days to 50% flowering via plant height (0.54) followed by grain Fe content via grain Zn content (0.40) and 1000-seed weight (0.32) via grain Zn content.

In TCB-2, at genotypic level grain Zn content (3.67) followed by plant height (1.20) showed highest direct effect on grain yield, whereas at phenotypic level plant height (0.46) followed by 1000 seed weight (0.16) showed highest direct effect on grain yield. The highest indirect effects on grain yield at genotypic level showed by 1000-seed weight via grain Zn content (5.95) followed by grain Fe content via grain Zn content (3.38) and days to 50% flowering via plant height (1.68).

In TCB-3, at genotypic level highest direct effect on grain yield was showed by days to 50% flowering (0.67) followed by plant height (0.65) whereas at phenotypic level highest direct effect was showed by plant height (0.34) followed by days to 50% flowering (0.27). The highest indirect effects at genotypic level were caused by days to 50% flowering (0.79) via grain Fe content followed by plant height (0.44) via days to 50% flowering and days to 50% flowering (0.42) via plant height.

In TCB 4, at both genotypic (31.46) and phenotypic level (0.36) plant height showed highest direct effect on grain yield. Highest indirect effect at genotypic level caused by days to 50% flowering (19.19) via plant height, grain Zn content (17.46) via days to 50% flowering and 1000-seed weight (12.27) via plant height.

This study revealed that plant height showed highest direct effect and days to 50% flowering showed highest indirect effect on grain yield. Our results are in accordance with Izge *et al.,* (2006) and Kumar *et al.,* (2020) where they found high direct effects of plant height on grain yield. Bhasker *et al.,* (2017) and Rakesh *et al.,* (2015) reported high direct effects for plant height and 1000-grain weight on grain yield. On the contrary, Sumanth *et al.,* (2014) found high negative direct effects of plant height on grain yield. Thangasamy and Gomathinayagam (2003) and Bhuri Singh *et al.,* (2015) reported that plant height and days to 50% flowering are important traits to consider in selection process to improve grain yield in pearl millet. This investigation therefore suggests that plant height, 1000-seed weight and days to 50% flowering should be given maximum consideration for total yield improvement in pearl millet.

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