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Association analysis in elite genetic resources of foxtail millet (*Setaria italica* (L.) Beauv) for yield and nutritional traits

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Abstract
Hundred elite foxtail millet genetic resources for 18 yield and nutritional traits were studied through association and path analysis at phenotypic level. Correlation analysis revealed a positively significant association of grain yield / plant with most of traits *viz.*, SCMR at 30 DAS, plant height, panicle length, number of grains / ear head and 1000 grain weight implying that these traits may chosen as selection criterion for developing high yielding cultivars. The path coefficient analysis showed that SCMR at 30 DAS, plant height, number of grains / ear head and 1000 grain weight exhibited high positive direct effect with grain yield per plant indicating direct selection for improvement of these traits.

Keywords: correlation, foxtail millet genetic resources, grain yield / plant, path analysis

Introduction
Small millets are tolerant to varied biotic and abiotic stresses and are of high nutritive value, arousing attraction among diet-conscious consumers. Among the small millets, foxtail millet [*Setaria italica* (L.) Beauv], a climate resilient crop ranks second in terms of global production. This small millet is widely cultivated in arid and semi-arid regions of India. Currently, this crop is fast re-expanding in the context of climate changing scenario and food security concerns across India. It is primarily cultivated in the states of Andhra Pradesh, Karnataka, Maharashtra, Tamil Nadu, Rajasthan, Madhya Pradesh, Uttar Pradesh and North Eastern states. Being an annual C_4, autogamous diploid (2n = 2x = 18) with a small genome size of ~ 515 Mb (Li and Brutnell, 2011) [6], this crop offers ample scope for molecular and genetic research as a 'model crop' to understand deeper insights into plant biology.The grains of this millet are enriched with quality protein (leucine and methionine), β carotene, minerals (Ca, Fe, K, Mg and Zn), antioxidants, dietary fibre, phytochemicals, vitamins (B_1, B_2 and B_3) and possess low glycemic index, a requisite for healthy human diet (Murugan and Nirmala kumari, 2006) [7]. Despite its nutraceutical ability and economic significance, this small millet received little research attention for enhanced production and is still tagged as a neglected and under-utilized crop. Realizing the economic importance of this small millet, efforts are required by the researchers to improve the grain yield. However grain yield is a complex polygenic character, influenced by environmental variables. Moreover knowledge of association between various quantitative traits is essential to design effective and efficient breeding strategy. Keeping the aforesaid vital aspects in view, studies on correlation and path analysis were attempted to offer a better insight, into cause and effect relationship between different pairs of characters.

Material and Methods
Field experimental studies were conducted in 100 elite foxtail millet genetic resources laid in a Augmented randomized complete block design (ARCBD) during *Kharif*, 2018 at Regional Agricultural Research Station, Nandyal, Andhra Pradesh, located at an altitude of 211.3 m above mean sea level, latitude of 18.29°N and longitude of 78.29°E. The net plot size was 40 x 3 m^2 with a recommended spacing of 22.5 cm x 10 cm. The data was collected on five randomly selected plants per genetic resource for 18 metric traits *viz.*, SCMR at 30 DAS, SCMR at 45 DAS, days to 50% flowering, plant height, panicle length, number of productive tillers /plant, days to maturity, number of grains / ear head, 1000 grain weight, protein, carbohydrate, calcium, magnesium, iron, zinc, copper, manganese and grain yield/ plant. The data obtained was subjected to analysis using WINDOWSTAT 9.2 version software.

Results and Discussion
Character association
The phenotypic correlation coefficient between yield and yield attributes was presented in the Table 1 and Fig 1 & 2. The perusal of the results revealed a positive significant phenotypic association with SCMR at 30 DAS (0.3176**), plant height (0.3729**), panicle length (0.2491*), number of grains / ear head (0.3504**) and 1000 grain weight (0.4414**) at phenotypic level. This means that these traits are predominantly governed by additive gene action and hence selection for these traits will lead to simultaneous improvement in grain yield. Similar results were reported by Shinde *et al.* (2014) [11] for plant height; Ulaganathan and Nirmala kumari (2014) [12] for 1000 grain weight and flag leaf blade length; Brunda *et al.* (2015) [3] for plant height and panicle length; Jyothsna *et al.* (2016) [4] for plant height; Kavya (2017) [5] for panicle length and 1000 grain weight; Negi *et al.* (2016) [8] for plant height,1000 grain weight; Sapkota *et al.* (2016) [10] for peduncle length, panicle length and flag leaf blade length; Amarnath *et al.* (2018) [1] for plant height, peduncle length, panicle length, flag leaf blade length, flag leaf blade width and 1000 grain weight; Ayesha *et al.* (2019) [2] for plant height, panicle length, number of productive tillers / plant, test weight and carbohydrate content.

Path coefficient analysis
The direct and indirect effects of different yield attributing components on grain yield / plant worked out through path analysis at phenotypic level is presented in the Table 2 and Fig 3. At phenotypic level, 1000 grain weight, number of grains / ear head, plant height, SCMR at 30 DAS, iron, number of productive tillers /plant, carbohydrate and zinc registered high positive direct effect on grain yield / plant suggesting the importance of direct selection for these traits. Similar results were reported by Jyothsna *et al.* (2016) [4], Renganathan *et al.* (2017) [9] and Amarnath *et al.* (2018) [1] for plant height; Ayesha (2019) [2] for number of productive tillers / plant and carbohydrate content.

The trait *viz.*, panicle length, days to maturity, days to 50% flowering, 1000 grain weight, zinc, iron, magnesium, SCMR at 30 DAS, manganese, number of grains / ear head, copper and number of productive tillers /plant. Amarnath *et al.* (2018b) [1] for number of productive tillers /plant exhibited high indirect effects on grain yield per plant via plant height.

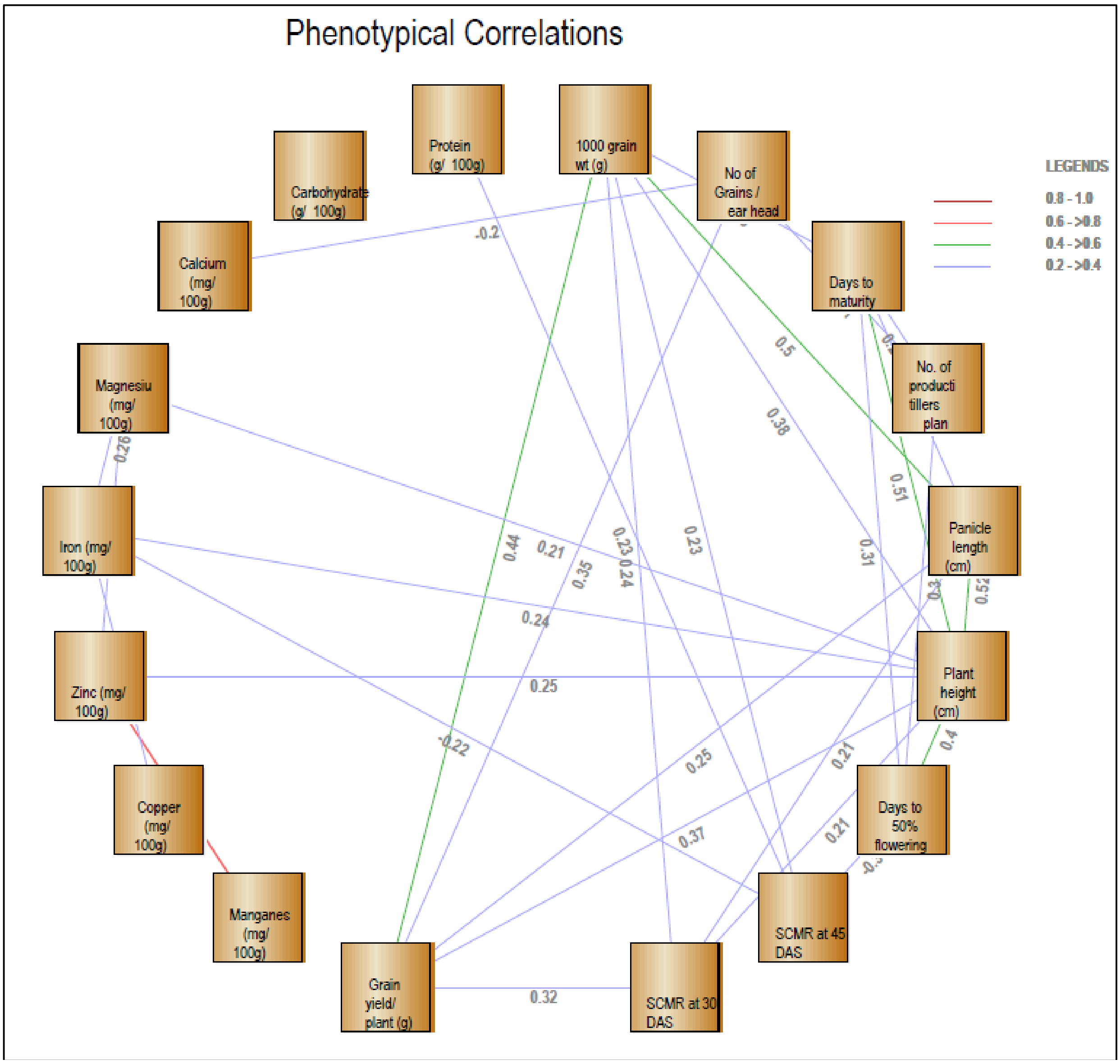

Fig 1: Pictorial representation of phenotypic correlations among the studied traits in foxtail millet [*Setaria italica* (L.) Beauv.]

Table 1: Phenotypic correlations among grain yield and yield contributing characters in foxtail millet [*Setaria italica* (L.) Beauv.]

S No	Character	SCMR at 30 DAS	SCMR at 45 DAS	Days to 50% flowering	Plant height	Panicle length	No. of prod. tillers /plant	Days to maturity	No of Grains / ear head	1000 grain wt	Protein	Carbohydrate	Calcium	Magnesium	Iron	Zinc	Copper	Manganese	Grain yield/ plant
1	SCMR at 30 DAS	1.0000	0.112	0.065	0.2052 *	0.2052 *	0.027	0.121	0.016	0.2438 *	-0.104	0.1316	0.0591	-0.0265	-0.0549	0.0032	0.0515	-0.0328	0.3176 **
2	SCMR at 45 DAS		1.0000	-0.3444 **	-0.127	0.133	0.081	-0.13	-0.111	0.2303 *	0.2263 *	0.0018	0.0959	-0.0105	-0.2160 *	0.0256	-0.0931	0.0353	0.0193
3	Days to 50 flowering			1.0000	0.4031 **	0.175	0.3018 **	0.3074 **	-0.158	-0.006	-0.026	0.0582	0.0081	-0.0086	0.0353	0.1176	-0.0459	0.0775	-0.0282
4	Plant height				1.0000	0.5155 **	0.058	0.5117 **	0.168	0.3826 **	-0.026	-0.0194	-0.1251	0.2096 *	0.2415 *	0.2477 *	0.1283	0.1866	0.3729 **
5	Panicle length					1.0000	0.164	0.2799 **	-0.026	0.4950 **	0.051	0.0592	-0.1279	0.1448	0.0613	0.0458	0.1002	-0.0398	0.2491 *
6	No. of prod. tillers /plant						1.0000	0.2572 **	-0.315	0.178	0.12	-0.0123	0.1323	0.1698	0.0143	0.0490	-0.0515	0.0640	0.0038
7	Days to maturity							1.0000	0.016	0.3546 **	0.073	0.1047	-0.0857	0.1264	0.1945	0.0216	0.1454	0.0157	0.1860
8	No of Grains / ear head								1.0000	-0.004	-0.025	-0.0797	-0.2022 *	0.0414	0.1251	-0.0489	0.0847	0.0178	0.3504 **
9	1000 grain wt									1.0000	0.175	0.1586	0.0505	0.1069	0.0674	0.1584	0.0616	0.0848	0.4414 **
10	Protein										1.0000	-0.1555	0.0524	-0.0003	-0.0161	0.0095	0.0013	0.0267	-0.1159
11	Carbohydrate											1.0000	0.1242	-0.1914	-0.1945	0.1261	-0.0738	0.0329	0.1429
12	Calcium												1.0000	-0.0894	0.1234	0.0817	-0.0552	0.0764	-0.0627
13	Magnesium													1.0000	0.2572 **	0.2776 **	-0.0151	0.0802	0.0820
14	Iron														1.0000	0.0980	0.2524 *	0.1981 *	0.1722
15	Zinc															1.0000	-0.1490	0.6812 **	0.1241
16	Copper																1.0000	-0.0624	0.0704
17	Manganese																	1.0000	0.0607
18	Grain yield/ plant																		1.0000

* Significant at 5% level
** Significant at 1% level

Table 2: Phenotypic direct and indirect effects of different traits on grain yield per plant in foxtail millet [*Setaria italica* (L.) Beauv.]

S No	Character	SCMR at 30 DAS	SCMR at 45 DAS	Days to 50% flowering	Plant height	Panicle length	No. of prod. tillers /plant	Days to maturity	No of Grains / ear head	1000 grain wt	Protein	Carbohydrate	Calcium	Magnesium	Iron	Zinc	Copper	Manganese	Grain yield/ plant
1	SCMR at 30 DAS	0.1883	0.0210	0.0122	0.0386	0.0386	0.0051	0.0228	0.0030	0.0459	-0.0196	0.0248	0.0111	-0.0050	-0.0103	0.0006	0.0097	-0.0062	0.3176 **
2	SCMR at 45 DAS	-0.0001	-0.0005	0.0002	0.0001	-0.0001	0.0000	0.0001	0.0001	-0.0001	-0.0001	0.0000	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000	0.0193
3	Days to 50 flowering	-0.0059	0.0315	-0.0914	-0.0369	-0.0160	-0.0276	-0.0281	0.0144	0.0005	0.0024	-0.0053	-0.0007	0.0008	-0.0032	-0.0108	0.0042	-0.0071	-0.0282
4	Plant height	0.0445	-0.0276	0.0875	0.2170	0.1119	0.0125	0.1111	0.0365	0.0830	-0.0057	-0.0042	-0.0272	0.0455	0.0524	0.0538	0.0278	0.0405	0.3729 **
5	Panicle length	-0.0125	-0.0081	-0.0107	-0.0314	-0.0609	-0.0100	-0.0171	0.0016	-0.0302	-0.0031	-0.0036	0.0078	-0.0088	-0.0037	-0.0028	-0.0061	0.0024	0.2491 *
6	No. of prod. tillers /plant	0.0032	0.0094	0.0350	0.0067	0.0190	0.1161	0.0299	-0.0365	0.0206	0.0139	-0.0014	0.0154	0.0197	0.0017	0.0057	-0.0060	0.0074	0.0038
7	Days to maturity	-0.0108	0.0116	-0.0274	-0.0457	-0.0250	-0.0229	-0.0892	-0.0015	-0.0316	-0.0065	-0.0093	0.0076	-0.0113	-0.0174	-0.0019	-0.0130	-0.0014	0.1860
8	No of Grains / ear head	0.0051	-0.0354	-0.0505	0.0537	-0.0083	-0.1006	0.0053	0.3196	-0.0012	-0.0078	-0.0255	-0.0646	0.0132	0.0400	-0.0156	0.0271	0.0057	0.3504 **
9	1000 grain wt	0.0860	0.0812	-0.0021	0.1350	0.1746	0.0627	0.1251	-0.0013	0.3527	0.0617	0.0559	0.0178	0.0377	0.0238	0.0559	0.0217	0.0299	0.4414 **
10	Protein	0.0132	-0.0288	0.0033	0.0033	-0.0065	-0.0152	-0.0093	0.0031	-0.0222	-0.1272	0.0198	-0.0067	0.0000	0.0020	-0.0012	-0.0002	-0.0034	-0.1159
11	Carbohydrate	0.0141	0.0002	0.0062	-0.0021	0.0064	-0.0013	0.0112	-0.0086	0.0170	-0.0167	0.1073	0.0133	-0.0205	-0.0209	0.0135	-0.0079	0.0035	0.1429
12	Calcium	-0.0036	-0.0058	-0.0005	0.0075	0.0077	-0.0079	0.0051	0.0121	-0.0030	-0.0031	-0.0075	-0.0600	0.0054	-0.0074	-0.0049	0.0033	-0.0046	-0.0627
13	Magnesium	0.0013	0.0005	0.0004	-0.0105	-0.0073	-0.0085	-0.0063	-0.0021	-0.0054	0.0000	0.0096	0.0045	-0.0502	-0.0129	-0.0139	0.0008	-0.0040	0.0820
14	Iron	-0.0078	-0.0308	0.0050	0.0344	0.0087	0.0020	0.0277	0.0178	0.0096	-0.0023	-0.0277	0.0176	0.0367	0.1426	0.0140	0.0360	0.0282	0.1722
15	Zinc	0.0003	0.0024	0.0111	0.0234	0.0043	0.0046	0.0020	-0.0046	0.0150	0.0009	0.0119	0.0077	0.0262	0.0093	0.0944	-0.0141	0.0643	0.1241
16	Copper	-0.0010	0.0018	0.0009	-0.0024	-0.0019	0.0010	-0.0028	-0.0016	-0.0012	0.0000	0.0014	0.0011	0.0003	-0.0048	0.0028	-0.0191	0.0012	0.0704
17	Manganese	0.0031	-0.0034	-0.0074	-0.0179	0.0038	-0.0061	-0.0015	-0.0017	-0.0081	-0.0026	-0.0032	-0.0073	-0.0077	-0.0190	-0.0653	0.0060	-0.0959	0.0607

* Significant at 5% level;
** Significant at 1% level
Residual Effect = 0.74

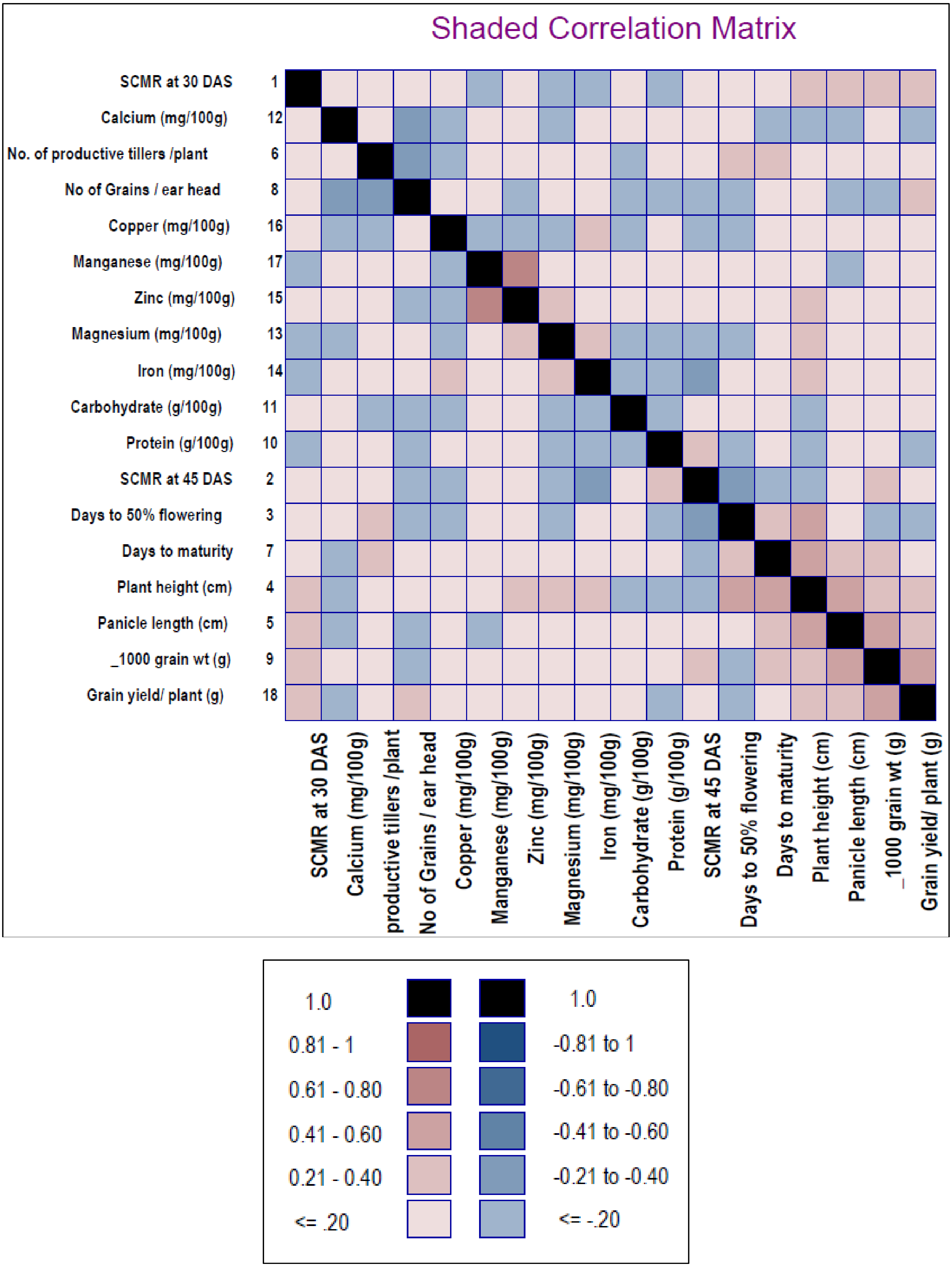

Fig 2: Shaded phenotypic correlation matrix for all the characters studied in foxtail millet [*Setaria italica* (L.) Beauv.]

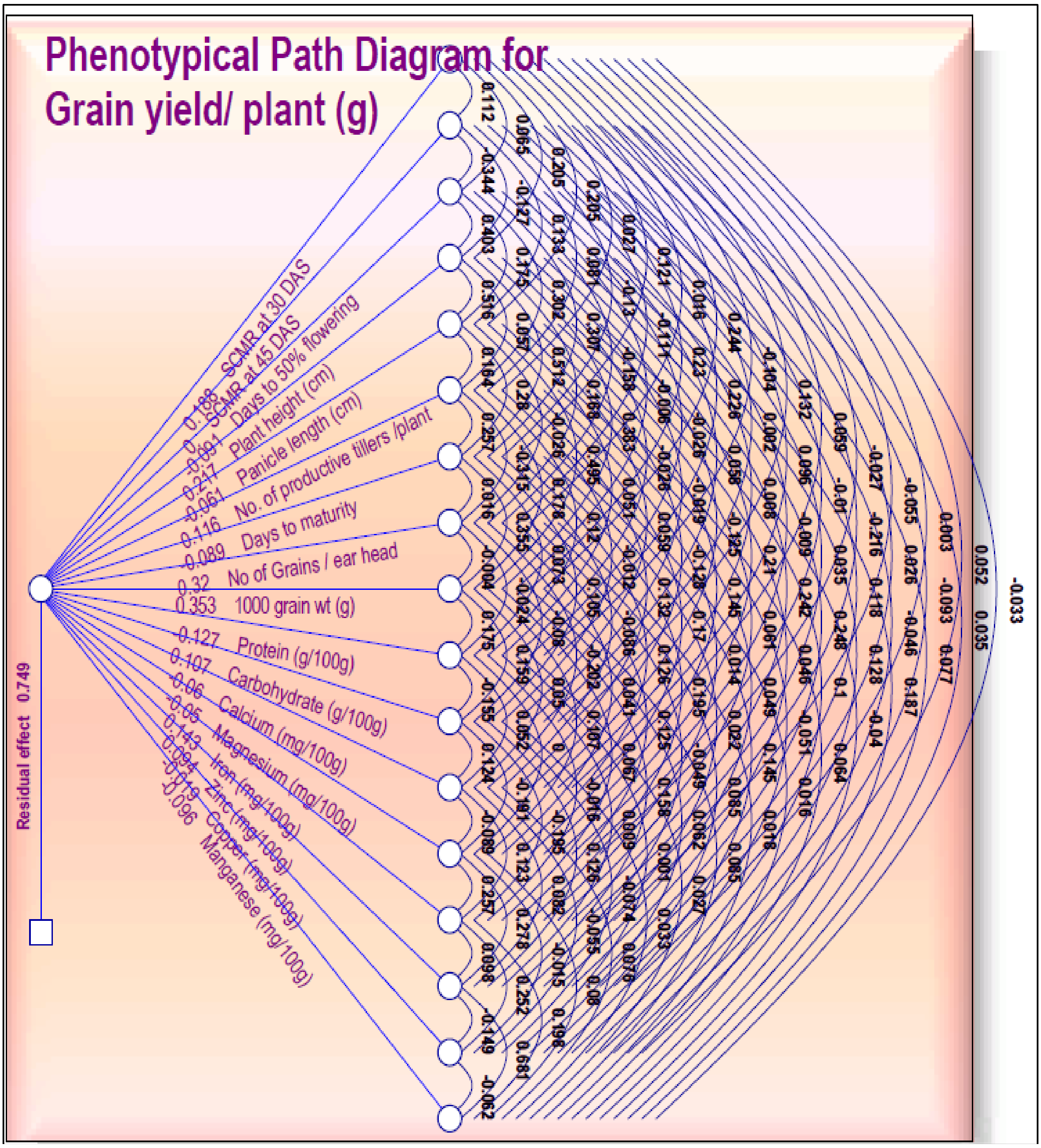

Fig 3: Phenotypic path diagram for grain yield per plant

Conclusion

Association studies through correlation and path analysis revealed that the trait SCMR at 30 DAS, plant height, number of grains / ear head and 1000 grain weight had true relationship with grain yield per plant by establishing significant positive association and positive direct effect on grain yield implying the scope of direct selection for these traits in genetic improvement of foxtail millet.

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