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Studies on correlation of grain zinc and iron with anti-nutritional factors in sorghum for combating micronutrient malnutrition

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Abstract
At present over two billion people around the world suffer from 'hidden hunger' or micronutrient deficiencies. Besides hunger, malnutrition resulting from the intake of food poor in nutritional quality, particularly lacking in crucial micronutrients, has been recognized as a serious global health problem. Efforts are underway to address this hidden hunger by various means. The available micronutrients in the grains are occupied due to various anti-nutritional factors. These anti-nutritional factors hamper the bio-availability of micronutrients and hence are undesirable from health perspective. There are various anti-nutritional factors reported in sorghum, we studied about inorganic phosphorous, phytic acid and tannins along with grain zinc and iron contents. Keeping in view the losses caused by these anti-nutritional factors in inducing non- availability of the micronutrients, present investigation was undertaken at Akola and Buldhana locations with the objective to study the association among various micronutrients and anti-nutritional factors of sorghum. The efficiency of selection depends upon the direction and magnitude of association between grain zinc and iron with anti-nutritional factors.

Genotypic and phenotypic correlation coefficient of grain Fe and Zn contents with anti-nutritional factors in parents and crosses (obtained by 10x10 half diallel) over the environments were estimated. In the present investigation the genotypic correlation was generally higher than phenotypic correlation indicating the inherent association between various traits. Fairly high correlation (r=0.86) between grain Fe and Zn contents suggests ample scope for simultaneous improvement of both the micronutrients.

Correlation studies revealed that genotyic and phenotypic correlation coefficient for characters like inorganic phosphorous and grain yield per plant were significant and positively correlated with both grain zinc and iron content, selection of parents and cross combinations with higher magnitude of these traits will enhance grain zinc and iron content. On the contrary grain zinc and iron contents are negatively correlated with phytic acid and tannin contents and hence selections of parents and cross combinations with lower magnitude of these traits is suggested for improvement of zinc and iron content in the crop.

Amongst the parents the parent ICSR-72 performed best for grain zinc and iron content along with grain yield per plant. It exhibited positive correlation with inorganic phosphorous and negative correlation with phytic acid and tannins content. It can be further exploited for micronutrient enhancement in the crop. Amongst the crosses, the cross AKSV-440 x ICSR-72 had maximum mean value for grain zinc ppm (mg/kg) and iron ppm (mg/kg). It exhibited positive correlation with inorganic phosphorous and negative correlation with phytic acid and tannins content. Such entries with high grain yield along with high grain zinc, iron and inorganic phosphorous content can be further exploited for micronutrient enhancement in the crop.

Keywords: Cereals, sorghum, micronutrients, nutrient management

Introduction
Sorghum is primarily self-pollinated crop. It is one of the most imperative cereal crop grown in Africa, Asia, USA, Australia and Latin America. It is a heat and drought tolerant C4 plant with high photosynthetic efficiency and inherent high biomass yield potential. High levels of tolerance to drought and high temperatures, and adaptation to problem soils make it increasingly more relevant for food security in view of climate change. It is the dietary staple of more than 500 million people over 30 countries in Africa and Asia. Per capita consumption is 75 kg/year in major sorghum areas in India. It is one of the cheapest sources of energy, protein, Fe and Zn and contributes to >50% of the Fe and Zn. It is grown on more than 40 million ha globally with a production of ~65 million tonnes (Goldschein 2011) [2]. Sorghum has a great potential for expansion in entire Indian plateau by creating biofortified varieties.
Micronutrient malnutrition is primarily the result of diets poor in bio-available vitamins and

minerals, which causes blindness and anaemia (even death) in more than half of the world's population (Underwood, 2000; Sharma, 2003; Welch and Graham, 2004) [7, 6, 9] and efforts are being made to provide nutrient rich foods to the vulnerable groups of the society as deficiencies of the micronutrients, such as iron, zinc, and vitamin A, are the most devastating.

Keeping in view the losses caused by deficiency of the micronutrients and effects of various anti-nutritional factors, present investigation was undertaken with the objective to study the association ship between grain zinc and iron content with various anti-nutritional factors like, inorganic phosphorous, phytic acid and tannins content.

Knowledge on trait relationships helps in formulating an appropriate breeding strategy. The association between grain Fe and Zn concentrations and anti-nutritional factors is very complex. The significant positive association between two traits indicates the common genomic region or genes or biochemical pathway involved in expression of the trait. Literature reports a positive correlation between grain Fe and Zn concentrations in most crops.

The correlation coefficient, that indicates association between two characters, is useful as a basis for selecting desirable plant type. It enables to identify character or combination of characters which might be useful as indicator of high yield with high nutritional quality. Correlation studies provide information on the association of grain iron, zinc and other agronomic characters which in turn help in the selection of high yielding genotypes with high grain zinc and iron.

Material and Methods

Material

The experimental material consisted of ten genotypes which were selected as parents based on their diversity for various traits under study. From these ten parents 45 crosses (F1) were obtained by following 10x10 half diallel design (excluding reciprocals) (Method -2, Model -1 by Griffing, 1956 b) crossing of sorghum lines along with their parents during *Kharif* 2020-21 at two locations viz., Sorghum Research Unit, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola and Agricultural Research Station farms (ARS) Buldhana. The parent material utilized for the study are given below with their details-

1. PDKV Kalyani- (AKSV-181)

This is a dual purpose *Kharif* variety released for cultivation in Maharashtra during 2016. The plant height of this variety is around 190cm with 112 days maturity. It has tan type plant with pearly medium grains. It is developed from cross [(SU-556 x SPV-775) X (SPV-1033 x GMPR-4)]. It is high yielding variety used for grain and fodder purpose.

2. CSV – 34- (SPV-2307)

This is a high yielding, dual purpose *Kharif* variety which is nationally released. The plant height of this variety is around 225-230 cm with 110-112 days maturity. It is high yielding variety. It has tan type plant with pearly white, lustrous, medium grains. It is developed by selection from (AKMS 37 B x AKMS 60 B).

3. CSV - 20- (SPV-1616)

This is a dual purpose *Kharif* variety released for cultivation during 2006. The plant takes about 110-112 days for maturity. It is developed at IIMR Hyderabad by selection from (SPV 946 x Kh 89-246). It is high yielding variety. It has tan type plant with pearly white bold seeds.

4. SPV - 669

This is a dual purpose *Kharif* variety released for cultivation during 1988. The plant height of this variety is around 200-210cm. The plant takes about 115-120 days for maturity. It is developed at Dr.PDKV, Akola by pedigree selection from (SPV 97 x SPV 29). It has tan type plant with pearly white bold seeds.

5. AKSV - 267

This line is a developed in the biofortification program at Akola center. It has high zinc and iron content. It is developed by selection from (AKSV-267 selection 4).

6. AKSV - 440

This line is a developed in the biofortification program at Akola center. It has high zinc and iron content. It is developed by selection from (EC 488403)

7. AKSV – 438

This line is a developed in the biofortification program at Akola center. It has high zinc and iron content. It is developed by selection from (IC 286441).

8. ICSR - 34

This is a restorer line received from ICRISAT. The plant height of this line is around 110 cm. It has tan type plant with pearly white coloured seeds. The seeds are lustrous and bold in size. This is rich in zinc and iron content.

9. ICSR - 69

This is a restorer line received from ICRISAT. The plant height of this line is around 110 cm. It has tan type plant with pearly white coloured seeds. The seeds are lustrous and medium in size. This is rich in zinc and iron content.

10. ICSR - 72

This is a restorer line received from ICRISAT. The plant height of this line is around 135 cm. It has tan type plant with pearly white coloured seeds. The seeds are lustrous and bold in size. This is rich in zinc and iron content.

Methods

Experimental layout

Experiment was laid out in Randomized Block Design (RBD) with three replications at the fields of Sorghum Research Unit, Dr. PDKV, Akola and Agricultural Research Station farms (ARS), Buldana during Kharif 2020. The experimental material included ten parents and its 45 resulting F1's. The details of experimental layout was as under, The details of experimental layout was as under,

1) Name of crop	:	Sorghum (*Sorghum bicolor)*
2) Design	:	Randomized Block Design (RBD)
3) Treatment	:	55 (45 F1s + 10 parents)
4) Locations	:	→ Sorghum Research Unit, Dr. PDKV, Akola. → Agricultural Research Station farms, Buldana.
5) Replications	:	Three
6) Spacing	:	Row to Row – 45 cm Plant to Plant – 15 cm
7) Plot size	:	Two rows of three meter length. (0.90 x 3.00 m^2)
8) Season	:	*Kharif*
9) Method of sowing	:	Hand dibbling
10) Fertilizer dose	:	80:40:40 N:P:K (kg/ha)
11) Intercultural operations	:	As per recommendations

Computation of correlation coefficient of characters under study for individual and pooled environments.

Correlation coefficients are used to measure how strong a relationship is between two variables. There are several types of correlation coefficient, but the most popular is Pearson's. Pearson's correlation (also called Pearson's R) is a correlation coefficient commonly used in linear regression.

Correlation coefficient formulas are used to find how strong a relationship is between data. The formulas return a value between -1 and 1, where:

- 1 indicates a strong positive relationship.
- -1 indicates a strong negative relationship.
- A result of zero indicates no relationship at all.

A. Genotypic correlation coefficient

$$r_{xy} = \frac{S_{xy}}{S_x S_y}$$

Where,
S_x and s_y are the sample standard deviations,
s_{xy} is the sample covariance.

B. Phenotypic correlation coefficient

$$P_{xy} = \frac{\sigma_{xy}}{\sigma_x \sigma_y}$$

Where,
σ_x and σ_y are the population standard deviations,
σ_{xy} is the population covariance.

Results

1. Grain Yield per Plant (gm)

At genotypic level, grain yield per plant showed highly significant and positive association with phytic acid content, tannin%, zinc and iron content. It revealed non-significant negative association with inorganic phosphorous. At phenotypic level, grain yield per plant showed highly significant and positive association with phytic acid content, tannin%, zinc and iron content. It revealed non-significant negative association with inorganic phosphorous.

2. Zinc ppm (mg/kg)

At genotypic level, zinc ppm showed highly significant and positive association with iron content, grain yield, and inorganic phosphorous. It revealed significant negative association with phytic acid and tannin%. At phenotypic level, zinc ppm showed highly significant and positive association with iron content, grain yield, and inorganic phosphorous. It revealed significant negative association with phytic acid and tannin%.

3. Iron ppm (mg/kg)

At genotypic level, iron ppm showed highly significant and positive association with zinc content, grain yield and inorganic phosphorous. It revealed significant negative association with phytic acid and tannin%. At phenotypic level, iron ppm showed highly significant and positive association with zinc content, grain yield and inorganic phosphorous. It revealed significant negative association with phytic acid and tannin%.

4. Phytic Acid (mg/g)

At genotypic level, phytic acid showed highly significant and positive association with tannin%. It showed significant and negative association with inorganic phosphorous, zinc and iron content. At phenotypic level, phytic acid showed highly significant and positive association with tannin%. It showed significant and negative association with inorganic phosphorous, zinc and iron content.

5. Inorganic Phosphorous (mg/g)

At genotypic level, inorganic phosphorous showed highly significant and positive association with zinc and iron contents. It revealed significant negative association with phytic acid. It revealed non-significant negative association with tannin%. At phenotypic level, inorganic phosphorous showed highly significant and positive association with zinc and iron contents. It revealed significant negative association with phytic acid. It revealed non-significant negative association with tannin%

6. Tannins (%)

At genotypic level, tannin% showed highly significant and negative association with zinc and iron contents. It showed highly significant and positive association with phytic acid. It revealed non-significant negative association with inorganic phosphorous. At phenotypic level, tannin% showed highly significant and negative association with zinc and iron contents. It showed highly significant and positive association with phytic acid. It revealed non-significant negative association with inorganic phosphorous.

Table 1: Correlation coefficient (r) for different characters evaluated over the environments

		Gy	Pa	Ip	Tn%	Zn	Fe
Gy	G	1	0.371**	-0.507	0.492**	0.227**	0.627**
	P	1	0.362**	-0.516*	0.483**	0.218**	0.618**
Pa	G		1	-0.369**	0.784**	-0.654**	-0.654**
	P		1	-0.374**	0.779**	-0.659*	-0.659*
Ip	G			1	-0.633	0.557**	0.857**
	P			1	-0.640	0.550**	0.850**
Tn%	G				1	-0.901**	-0.889**
	P				1	-0.915**	-0.893**
Zn	G					1	0.881
	P					1	0.886
Fe	G						1
	P						1

Discussions

Genotypic and phenotypic correlation coefficient of grain Fe and Zn contents with agronomic and grain traits in parents and crosses over the environments were estimated. Fairly high correlation (r=0.86) between grain Fe and Zn contents suggests ample scope for simultaneous improvement of both the micronutrients these results are in uniformity with Sanjana *et al.* (2010) [5].

The genotypic and phenotypic correlation coefficient for grain yield per plant was significant and positively correlated with grain zinc and iron content, on converse 100 seed weight was significant but negatively correlated with grain zinc and iron content, similar results were recorded by Patil and Thombare (1985) [3] and Wankhede *et al.* (1985) [8]

The genotypic and phenotypic correlation coefficient for carbohydrate and phytic acid, tannin content and tannin % was significant and negatively correlated with grain zinc and iron content, on contrary inorganic phosphorous content was significant but positively correlated with grain zinc and iron content similar results were recorded by Amare *et al.* (2015) [1].

Genetic enhancement for grain Fe and Zn content does not have yield penalty. However, there was no significant negative association of grain iron and zinc content with the other traits studied. This is in conformity with the earlier study by (Reddy *et al.* 2010) [4].

Conclusions

In conclusion the genotyic and phenotypic correlation coefficient for various characters like protein, inorganic phosphorous and grain yield per plant were significant and positively correlated with both grain zinc and iron content. These traits could be considered as an important trait for improving grain yield per plant as well as grain zinc and iron content.

Grain zinc and iron contents are positively correlated with correlation coefficient of (r = 0.88) hence simultaneous improvement of both characters is possible.

On the contrary the genotyic and phenotypic correlation coefficient of various characters like 100 seed weight, proline, carbohydrates, tannins and tannins% were significant but negatively correlated with both grain zinc and iron content.

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