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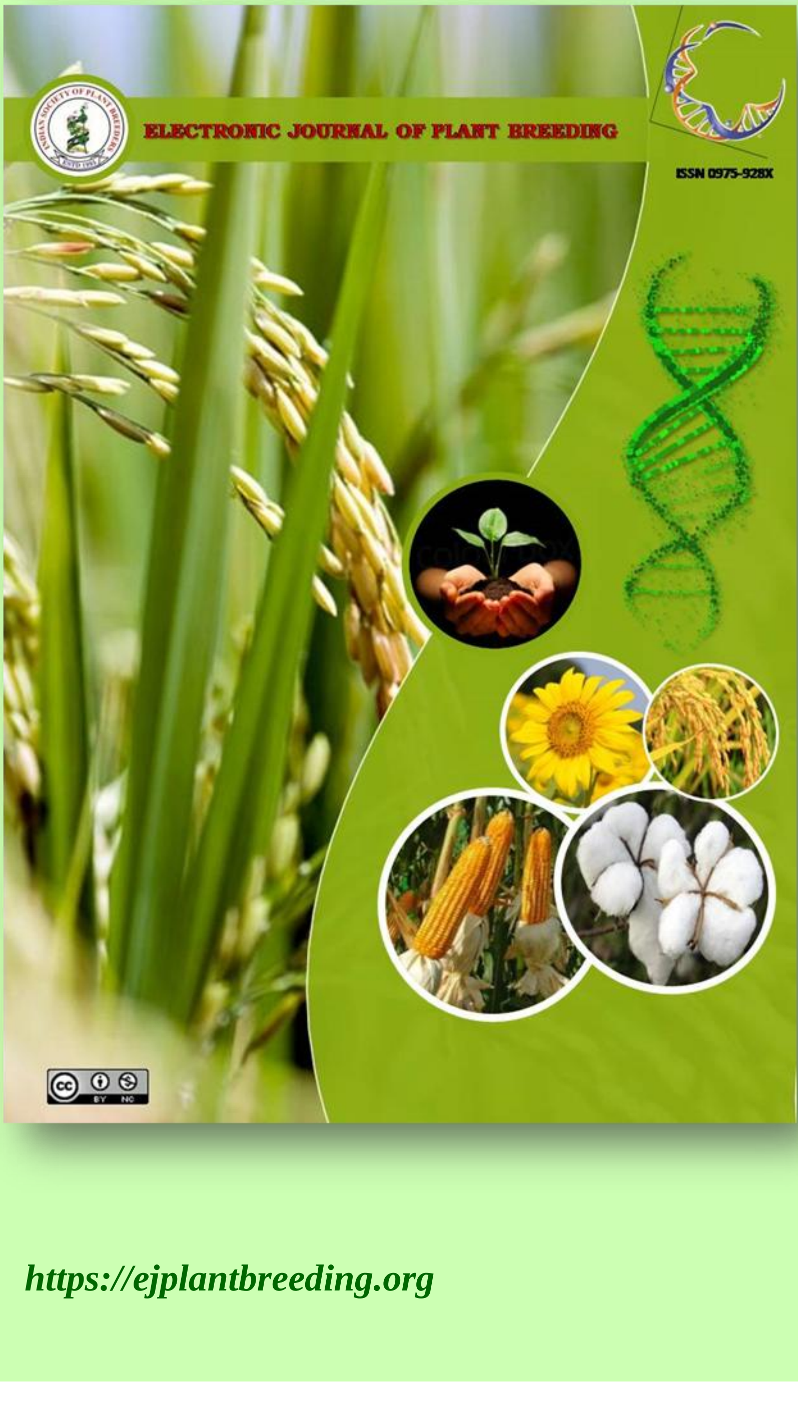

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Research Article

Broad sense and narrow sense heritability in F_4 and F_5 generations of finger millet, *Eleusine coracana* (L.) Gaertn

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Abstract
An investigation was carried out using three different finger millet crosses belonging to different maturity groups to compare their response in terms of the genetic potential transferred from F_4 to F_5 generation. The heritability in standard units or intergeneration correlation was found to be significant for plant height and finger length. Narrow sense heritability was found to be low (<30 %) for all the traits. Further, correlation studies within the F_4 and F_5 generations showed that grain yield was significantly associated with ear weight, total tillers, productive tillers and fingers per ear. Path analysis revealed that ear weight has maximum direct effect on grain yield. The study helps to dissect the traits which can still be selected in the F_4 generation when most of the traits have become fixed.

Keywords
Genetic potential, Narrow sense heritability, Correlation, Direct effect, Path analysis

Introduction

Finger millet (*Eleusine coracana* (L.) Gaertn.), also known as *ragi* in India, is the third important coarse cereal after sorghum and pearl millet. Africa (Ethiopian highlands) is believed to be its primary centre of origin while India is recognized as the secondary centre of diversity in view of its cultivation in the sub-continent for more than 3000 years [(O'Byrne (1957) and Phillips (1972)]. Karnataka alone accounts for more than half of the area and production under *ragi* in India with about 5.98 lakh ha of its area under the crop producing nearly 0.86 million tonnes (MAFW, GOI, 2016-17). It is a highly productive crop that can thrive under a variety of harsh environmental conditions, and is also organic by default. (Gupta *et al*, 2017). With regard to protein (6-8%) and fat (1-2%), it is comparable to rice and with respect to mineral and micronutrient contents it is superior to rice and wheat. The grains have high content of calcium (344 mg/100g), dietary fibre (15-20%) and phenolic compounds (0.3–3%) (Gull *et al.,* 2014). Unfortunately, due to low returns and commercialisation of other crops, the area under finger millet in Karnataka has showed drastic reduction over the past few years. Considering its importance in food and fodder security, there is a need for genetic enhancement of finger millet productivity from the current levels of 1.36 t ha^{-1} (All India average) and 1.44 t ha^{-1} (Karnataka average) (MAFW, GOI, 2016-17).

A regular practice in plant breeding experiments is to select for economically important traits in the early segregating generations like F_2 or F_3. This is due to an immediate need to utilize the quantum of genetic variability that is obtained because of segregation and recombination of genes in the F_2 or F_3 generations. There are opposing views on the genetic theory that underlies the selection of quantitative characters such as grain yield. First, the phenotype of a heterozygote is not a reliable guide to the lines which might be derived from it. Second, as the proportion of homozygotes in early generations is very small, selection should be delayed until later generations (Allard, 1960). In other words, the true estimation of the heritability of a trait is important for its genetic improvement. Parent-offspring regression is a common technique for estimating narrow sense heritability of quantitative characters in crop species. However regression of progeny means on parental values evaluated in similar environments may lead to biased heritability estimates due to genotype x environment and error covariances between parents and progenies (Casler, 1982). Frey and Horner (1957) suggested the use of heritability in standard units, a modification of the parent-progeny regression procedure to determine heritability percentage. Ravikumar (1993) used the same method and observed significant intergeneration correlation between F_2 and F_3 generation for plant height and number of fingers in finger millet.

Selection would be more meaningful if the structure of yield is probed through its components because the polygenic nature of yield eludes the breeder of the selection schemes that tend to select for yield *per se.* This is biometrically achieved by estimating the correlation coefficient. However, the correlation coefficient does not reflect the actual contribution of a character to grain yield. Hence, path coefficient analysis is employed to partition the correlation value into direct effect of the character and its indirect effect via other characters. A good number of studies have been carried out on the interrelationship between yield and its contributing traits in finger millet, but the information on correlation between segregating generations for yield and yield associated traits remains meagre. In addition to estimation of correlation between yield and its component traits, the present study aimed to determine the narrow sense heritability and intergeneration correlation between F_4 and F_5 generations of three different crosses in finger millet.

Materials and Methods

The material for the present study comprised of F_4 generation seeds of three crosses *viz.*, PS-1 × VL-315, PS-1 × OEB-526 and PS-1 × MR-6. PS-1 is the male sterile version of GPU-28, a medium duration variety of finger millet. The male parents, VL-315, OEB-526 and MR-6 belong to early, medium and late maturity groups respectively. The early generations of the three crosses were selected to have the maturity duration similar to the male parent. In each of these crosses, thirty separate progeny lines derived from the F_3 generation by within and between family selection were advanced to produce the F_4 generation during summer 2016. These F_4 family progenies were sown in plant-to-row method following augmented design using the parents as checks and were evaluated along with parents for ten quantitative traits including grain yield. Thirty best performing plants were selected from among the F_4 individuals in each of the cross based on maturity duration and mean performance of the progeny families in terms of traits such as grain yield, its component traits and maturity duration. In *kharif* 2016, F_5 generation was raised using the seeds from selected plants. Each progeny was sown in 3 rows of 1.5 m length with a spacing of 30 cm between the rows and plant to plant spacing of 10 cm. All recommended agronomic practices were followed during the crop growth period to ensure better growth and yield. Observations were recorded on a sample of 10 plants from each family in both the generations for ten quantitative traits and the mean was calculated. The phenotypic correlation coefficients were computed as per the formula suggested by Weber and Moorthy. Path coefficient analysis was carried out following the method of Dewey and Lu (1959). Lenka and Mishra (1973) have suggested scales for path coefficients in rice with values 0.00 to 0.09 as negligible, 0.10 to 0.19 low, 0.20 to 0.29 moderate and 0.30 to 0.99 high path coefficients. Intergeneration correlation or heritability in standard units for each character between F_4 and F_5 generation was estimated by regressing the progeny means (y) of F_5 generation on the individual plants (x) of F_4 generation.

Intergeneration correlation (r) = $b_{yx} \times \frac{\sigma_x}{\sigma_y}$

where,

$$b_{yx} = \frac{\text{covariance of xy}}{\text{variance of x}}$$

σ_x = Standard deviation of x

σ_y = Standard deviation of y

Narrow sense heritability was determined as per the formula given by Smith and Kinman (1965).

$$\mathbf{h^2\,(F_4F_5)} = \frac{b_{yx}}{2r_{xy}}$$

where,

b_{yx}= regression coefficient of F_5 progeny means on F_4 parental values for respective characters

$2r_{xy}$= measure of degree of genetic relationship between the parent 'x' and its offspring 'y'.

Results and Discussion

The results obtained from the present study have been discussed under the following subheads:

(a) Intergeneration correlation and narrow sense heritability

The intergeneration correlation and narrow sense heritability values for the three crosses are furnished in Table 1. The trend for these values across the crosses has been depicted in figures 1 and 2 respectively. In all the three crosses studied, finger length and plant height showed a positive value of intergeneration correlation coefficient between F_4 and F_5 generations, though this correlation was significant only in the cross PS-1 × VL-315 (0.71).This is in agreement with the results obtained by Basavaraja (1990), Bhat (1991) and Vikasa (2007) in F_2 and F_3 generations of finger millet. Plant height was also found to have positive and significant values for intergeneration correlation in two of the three crosses studied. Similar correlation was reported by Basavaraja (1990), Ravikumar (1993) and Vikasa (2007) between F_2 and F_3 generations of finger millet.

Non-significant correlation for grain yield between F_4 and F_5 generations in the three crosses confirms that selection of plants based on yield in F_4 generation is not advantageous. This is in confirmation with the results of Ravikumar (1993), Basavaraja (1990) but in contrast with the results of Bhat (1991). It can also be inferred that grain yield per plant is highly influenced by environment since the two generations were evaluated in different seasons.
All the traits showed low to moderate values for narrow sense heritability. In the cross PS-1 × VL-315 and PS-1 × MR-6, the highest value for narrow sense heritability was observed for finger length followed by plant height. Similar studies by Ravikumar (1993) and Basavaraja (1990) in F_2 and F_3 segregating generations indicate a similar trend but the heritability values were reported to be moderate to high. In the cross PS-1× OEB-526, among all the traits studied, highest heritability value was recorded for thousand grain weight (19.52 %) followed by plant height (9.81 %). Bhat (1991) observed high narrow sense heritability between F_2 and F_3 generations for thousand grain weight. Narrow sense heritability for grain yield per plant and ear weight per plant was found to be low in all the crosses. Similar trend was observed by Ravikumar (1993), Shanthakumar (1988) and Basavaraja (1990). Negative value of heritability was observed for productive tillers, ear weight per plant, grain yield and test weght. This result is attributable to negative variances and the negative values should be considered equal to zero.

The trend observed for narrow sense heritability in the three crosses implies that plant height and finger length are the traits which still hold scope for selection in F_4-F_5 generation. From this, we can infer that these traits are governed by a larger number of genes which are still to be fixed up to F_5 or F_6 generation. For other traits including grain yield, the variability available in F_4 generation is not sufficient to carry out selection. So their heritability is low and the observed variability is largely due to error variance.

(b) Correlation studies:
Grain yield: The correlation studies revealed highly significant positive association of grain yield with ear weight followed by number of total tillers in all the three crosses (Table 2).Plant height and fingers per ear also exhibited significant association with grain yield in the cross PS-1 × OEB-526. These results are in confirmation with the findings of Hardari *et al.* (2012), Ganapathy *et al.* (2011) and Jadhav *et al.* (2015). Test weight showed significant correlation with grain yield in the F_5 generation of medium and late maturing crosses. This is in agreement with the results of Bhat (1991), Lule *et al.* (2012). The positive association of a trait with grain yield results from the presence of common genetic elements that control the characters in the same direction but positive and significant correlation due to the effect of genes can be the result of strong coupling linkage between their genes or the characters may be the result of pleotropic genes that control these characters in the same direction. The trend for the association of grain yield with traits like days to 50 *per cent* flowering, plant height and test weight was found to be variable across the three crosses as well as generations. The positive and significant association of grain yield with ear weight, tillers per plant, fingers per ear and thousand grain weight implied that there is a possibility to combat the low yielding ability of finger millet through conventional improvement of these traits.

Straw yield: Association studies of yield contributing characters with straw yield showed significant correlation of straw yield with grain yield, ear weight per plant, tillers per plant and plant height (Table 3). This is similar to the results observed by Basavaraja (1990) and Jyothsna *et al.* (2016). These results indicate that ear weight, number of tillers and plant height are important yield contributing traits that should be considered for selection to achieve high grain yield as well as fodder yield.

Moreover, in the cross PS-1 x MR-6, days to 50 per cent flowering showed negative correlation with grain yield but positive correlation with straw yield. This implies that in a late maturing genotype, higher proportion of biomass is accumulated in the straw than grain.

(c) Path analysis:
Grain yield: The results of path analysis showed that ear weight had a high direct effect on grain yield among all the characters studied in F_5 generation and F_4 generation of the cross PS-1 x VL-315 (Table 4). These findings are in agreement with the results of Bendale *et al.* (2002), Nandini *et al.* (2010) and Srilakshmi (2013).

The large residual effect observed in the F_4 generation but not in the F_5 generation showed that there was significant G × E interaction in F_4 than F_5 generation which results in the chosen characters not being sufficient to explain the variability in yield in the F_4 generation. Considering the nature and magnitude of character associations and their direct and indirect effects, it can be inferred that ear weight per plant followed by total number of tillers per plant, plant height, number of fingers per ear and thousand grain weight could serve as important traits in any selection programme for selecting high yielding genotypes in finger millet.

Straw Yield: As far as path analysis for straw yield is concerned, all quantitative traits considered in the present study have direct and indirect effect on straw yield in variable degrees (Table 5). Plant height and number of tillers play a major role to achieve higher straw yield in early and medium maturing genotypes whereas in case of late maturing types, higher number of fingers per ear, productive as well as total tillers and high ear weight would help to have higher straw yield in addition to grain yield.

This is the first study on narrow sense heritability in F_4 and F_5 generations of finger millet. We found finger length and plant height to show significant standard unit heritability in the F_4 generation. The results could be more refined if the material is evaluated in more than one environment/locations. Also, the same experiment can be conducted with the early segregating generations of these crosses and results can then be compared across generations.

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Table 1. Estimates of Intergeneration correlation (r) and narrow sense heritability (h^2) between F_4 and F_5 generations derived from three finger millet crosses

	PS-1 × VL-315 (N=30)		PS-1 × OEB-526 (N=30)		PS-1 × MR-6 (N=30)	
Traits	**'r'**	**h^2 (NS)**	**'r'**	**h^2 (NS)**	**'r'**	**h^2 (NS)**
Days to 50 % flowering	0.06	2.45	0.00	-0.05	0.17	8.75
Plant height (cm)	0.24	10.45	0.32*	9.81	0.44*	17.23
Total tillers per plant	0.19	3.31	0.00	-0.05	0.20	3.89
Fingers per ear	0.22	8.64	0.19	5.55	0.14	4.69
Finger length (cm)	0.71*	25.33	0.29	11.36	0.18	19.95
Productive tillers	0.20	4.11	0.07	3.41	-0.21	-7.36
Ear weight per plant (g)	0.00	-0.05	0.14	2.83	-0.05	-1.01
Grain yield (g)	0.04	0.59	0.08	2.29	0.08	1.71
Thousand grain weight (g)	0.06	2.93	0.38*	19.52	-0.16	-5.12
Straw yield (g)	-0.09	-1.07	0.14	3.36	-0.13	-2.51

*Significant @ P= 0.05 level, ** Significant @ P= 0.01 level

Table 2. Comparison of phenotypic correlation coefficients of selected yield attributing traits with grain yield per plant in F_4 and F_5 generations of three finger millet crosses

Characters	**Phenotypic correlation with grain yield per plant**					
	PS-1 × VL-315		**PS-1 × OEB-526**		**PS-1 × MR-6**	
	F_4	**F_5**	**F_4**	**F_5**	**F_4**	**F_5**
Days to 50 % flowering	0.27	0.08	-0.01	0.30*	-0.21	-0.08
Plant height (cm)	0.02	-0.21	0.48**	0.55**	0.18	-0.16
Tillers per plant	0.31*	0.68**	0.47**	0.69**	0.22	0.63*
Fingers per ear	0.14	0.17	0.40*	0.44*	-0.08	0.37*
Finger length (cm)	0.03	-0.45*	-0.01	0.20	0.40*	0.05
Productive tillers	-0.12	0.44*	0.37*	0.49*	-0.19	0.21
Ear weight per plant (g)	0.52 **	0.91**	0.77**	0.93**	0.18	0.95**
Thousand grain weight (g)	-0.12	0.22	-0.26	0.44*	0.06	0.40*

*Significant @ P= 0.05 level, ** Significant @ P= 0.01 level

Table 3. Comparison of phenotypic correlation coefficients of selected yield attributing traits with straw yield per plant in F_4 and F_5 generations of three finger millet crosses

Characters	Phenotypic correlation with straw yield per plant					
	PS-1 × VL-315		PS-1 × OEB-526		PS-1 × MR-6	
	F_4	F_5	F_4	F_5	F_4	F_5
Days to 50 per cent flowering	-0.35*	-0.09	-0.07	0.42*	0.05	0.31*
Plant height	0.30*	-0.35*	0.60**	0.57**	0.22	0.10
Tillers per plant	0.63**	0.23	0.48**	0.49**	0.04	0.68**
Fingers per ear	-0.01	0.14	0.22	0.54**	0.41**	0.13
Finger length	-0.12	-0.01	- 0.02	0.26	0.15	-0.11
Productive tillers	0.42**	0.29	0.48**	0.49**	0.13	0.60**
Ear weight per plant	0.40**	0.38*	0.64**	0.60**	0.14	0.61**
Grain yield	0.26	0.36*	0.57**	0.65**	0.17	0.57**
Thousand grain weight (g)	0.17	0.25	0.03	0.41*	-0.19	0.19

Table 4. Estimates of direct effect of component traits on grain yield per plant among F_4 and F_5 progenies derived from three finger millet crosses

	Direct effect on grain yield per plant					
	PS-1 × VL-315		PS-1 × OEB-526		PS-1 × MR-6	
Traits	F_4	F_5	F_4	F_5	F_4	F_5
Days to 50 % flowering	0.11	0.00	0.10	0.03	-0.16	-0.08
Plant height (cm)	0.06	-0.15	0.27	-0.02	0.35	0.03
Total tillers per plant	0.18	0.11	0.60	0.18	0.24	-0.16
Fingers per ear	0.12	0.05	0.11	0.02	-0.17	0.02
Finger length (cm)	0.13	-0.01	-0.13	-0.01	0.46	-0.04
Productive tillers	-0.18	0.11	0.05	0.14	-0.28	-0.06
Ear weight per plant (g)	0.37	0.72	0.03	0.71	-0.05	1.04
Thousand grain weight (g)	-0.06	0.15	-0.18	0.10	-0.03	0.10
Residual effect	0.82	0.32	0.57	0.31	0.78	-0.29

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Table 5. Estimates of direct effect of component traits on straw yield per plant among F_4 and F_5 progenies derived from three finger millet crosses

	Direct effect on straw yield per plant					
	PS-1 × VL-315		PS-1 × OEB-526		PS-1 × MR-6	
Traits	F_4	F_5	F_4	F_5	F_4	F_5
Days to 50 % flowering	-0.22	-0.12	0.06	0.23	0.05	0.31
Plant height (cm)	0.29	0.50	0.47	0.15	0.14	0.07
Total tillers per plant	0.59	0.16	0.16	0.32	0.24	0.13
Fingers per ear	0.02	0.10	0.02	0.18	0.50	0.03
Finger length (cm)	0.18	0.01	-0.17	0.14	-0.14	-0.02
Productive tillers	0.33	0.05	0.07	0.18	0.06	0.54
Ear weight per plant (g)	-0.02	-0.04	0.28	-0.16	0.42	0.17
Grain yield (g)	0.06	0.38	0.04	0.18	0.20	0.25
Thousand grain weight (g)	0.10	-0.07	0.81	0.13	-0.05	-0.17
Residual	0.56	0.80	0.64	0.61	0.85	0.50

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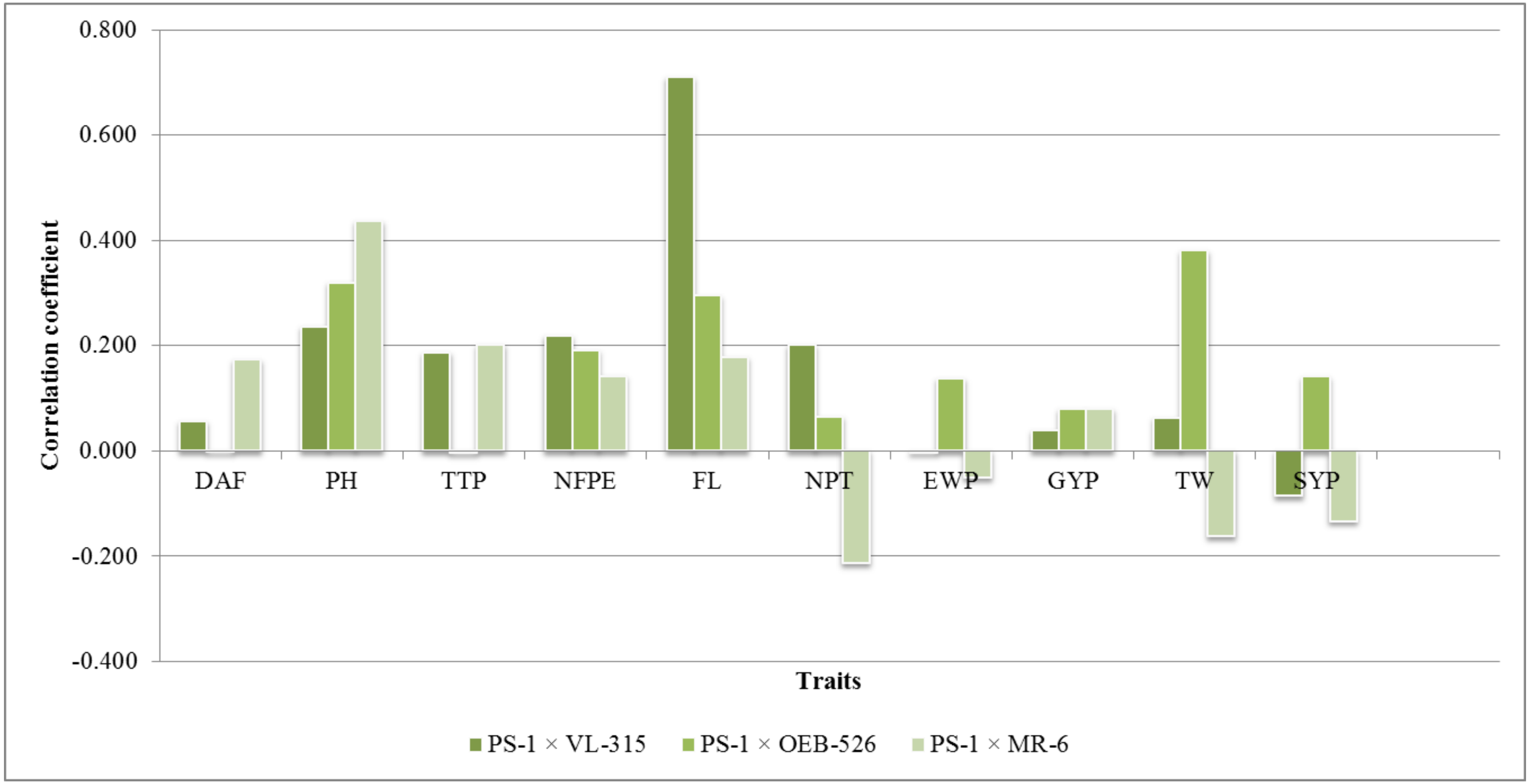

Where, DAF= Days to 50 % flowering, PH= Plant height, TTP= Total tillers per plant, FL= Finger length (cm), NPT= Number of productive tillers, EWP= Ear weight per plant, GYP= Grain yield per plant, TW= Test weight and SYP= Straw yield per plant

Fig. 1. Intergeneration correlation between F_4 and F_5 generations in three crosses of finger millet for yield and yield attributing traits

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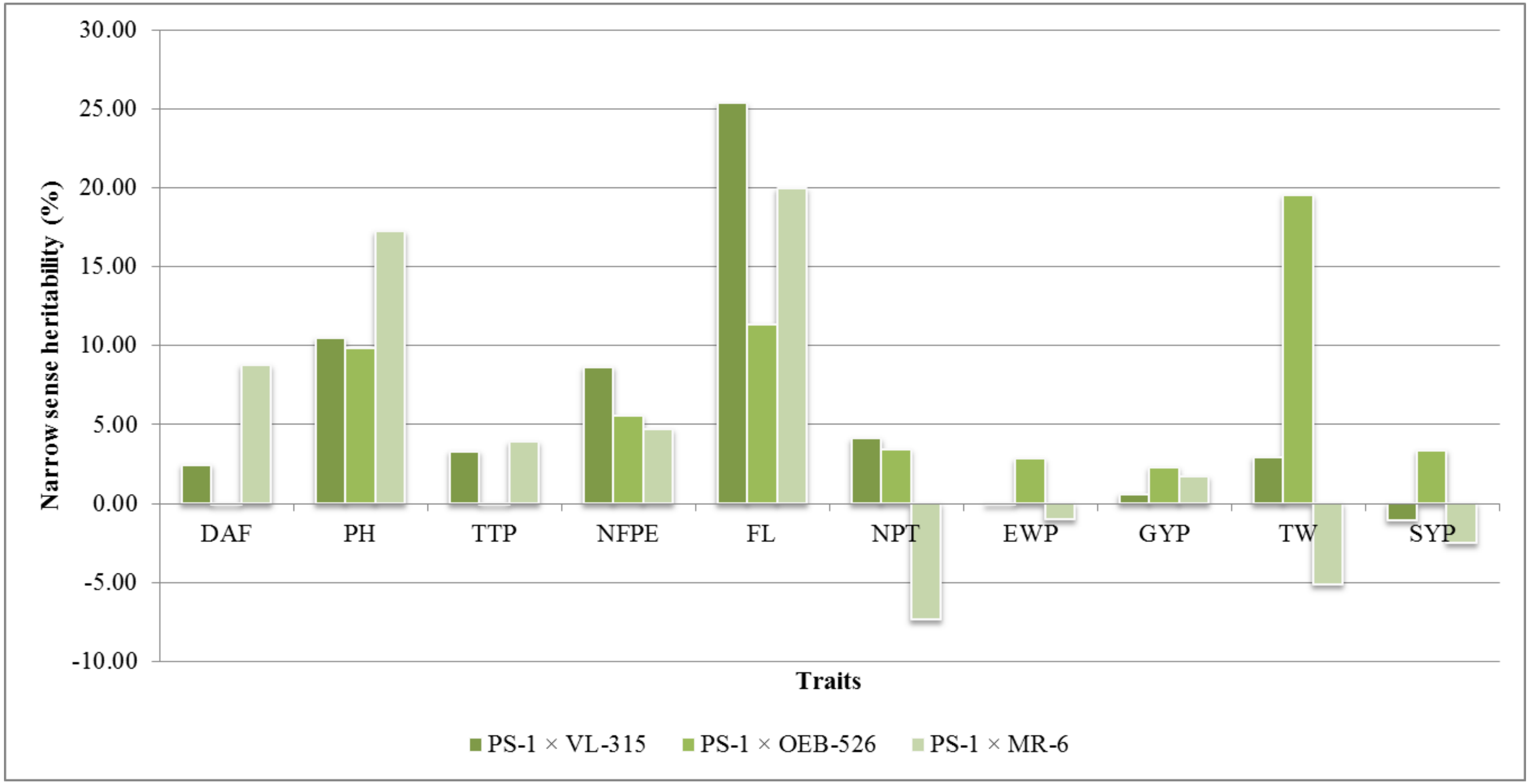

Where, DAF= Days to 50 % flowering, PH= Plant height, TTP= Total tillers per plant, FL= Finger length (cm), NPT= Number of productive tillers, EWP= Ear weight per plant, GYP= Grain yield per plant, TW= Test weight and SYP= Straw yield per plant

Fig. 2. Narrow sense heritability (%) between F_4 and F_5 generations in three crosses of finger millet for yield and yield attributing traits