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ASSESSMENT OF GENETIC VARIABILITY AND ASSOCIATION BETWEEN YIELD AND YIELD COMPONENTS IN INDIGENOUSLY DEVELOPED CHILLI HYBRIDS (*Capsicum annuum* L.)

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ABSTRACT

There is a considerable scope for developing hybrids in chillies. Impact of indigenously developed chilli hybrids was assessed for the major yield determining traits viz; number of fruits, fruit weight, pericarp weight, seed weight, fruit length, fruit width and fresh fruit yield. Difference among the genotypes was observed to be significant for all the traits. The indigenous chilli hybrids HYB-5 (36.69 t/ha) and HYB-1 (36.17 t/ha) contributed maximum green fruit yield as compared to the commercial hybrid 222-HYB (28.42 t/ha) and the local varieties [Tatapuri (16 t/ha) and Lounghi (4.60 t/ha)]. The traits like number of fruits per plant, fruit length, fruit weight, pericarp weight and fresh fruit yield not only exhibited high PCV and GCV values but also high worth of heritability in broad sense (86% to 99%) and high genetic advance (32.85% to 60.66%) which signified the existence of large variability, with the least involvement of the environmental factors on the expression of these traits which may be utilized through selection for better improvement. Moreover, the correlations (genotypic) were generally higher than the correlations at phenotypic basis. Fruit length, number of fruits per plants, pericarp weight and fruit weight were positively and significantly correlated to fresh fruit yield. This, in other, words signposted the involvement of additive gene action in the manifestation of these characters and can perform well to selection after establishing a meaningful correlation with fresh fruit yield. However, a non-significant correlation existed between fresh fruit yield and seed weight.

Keywords: Fresh fruit yield, chillies, correlation, GCV, PCV, GA and h^2.

INTRODUCTION

Chilli (*Capsicum annuum* L.) is the third most cultivated vegetable crop of the family *Solanaceae* after potato and tomato. Chillies are one of the rich sources of vitamin A (292 IU) and C (111 mg) per 100 g fresh weight available (Kumar *et al.*, 2012). Chillies are grown on an area of 64829 hectares worldwide with the production of 143153 tonnes. In Pakistan, chilli is well known as an important economic vegetable and condiment crop. In Pakistan, a major chill production comes from the Sindh province adding approximately 89% in the total domestic production and 1.6 percent of the Pakistan's GDP (GOP, 2015-16).

The chillies are used as fresh, dried and in processed form as vegetables, as spices and as condiments but mostly as spice throughout the world due to its pungency and unique flavour. Chillies, based on fruit characteristics are divided into various groups like pungency, colour, shape, intended use and genetics (Yadeta *et al.,* 2011).

There is a good scope for increasing its export by pushing up production. Genetically, variable breeding material not only provides the basis for selection but also provides information regarding the diverse selection of parents for hybridization programme. The plant breeder has to identify the sources of favourable genes, so as to improve the breeding material. Thus, the perfection of performance in any genetic back ground is based on the degree of genetic variation and the unit improvement depends upon the extent of available beneficial genetic variability. Similar studies were practiced by some of earlier researchers such as Ibrahim *et al*. (2001) and Munshi *et al*. (2002). The yield hectare^{-1} of chilli is very low in comparison to the yield potentials of the advanced agricultural countries. This is because of the non-availability of productive varieties and hybrids. To realize a substantial boost in yield per hectare, the phenomenon of hybrid breeding can be exploited as yield is the ultimate objective of any breeding programme.

Therefore, the hybrid breeding programme has been commenced for the identification of the top acting hybrid combinations (Ganeshreddy *et al*., 2008). The focus was given to the yield and its related traits. In the first phase; evaluation of the indigenously developed elite chilli hybrids for their green fruit yield in comparison to the commercial cultivar/hybrids was assessed in order to deduce the extent of variability. In the second phase, the assessments regarding the heritable portion of phenotypic variance, improvement of mean genotypic value over parental populations and correlation between the yield and other traits associated to yield for getting the information of the association of different traits with the ultimate objective of yield.

MATERIALS AND METHODS

Plant Material: On the basis of the primary evaluation, secondary evaluation of the five elite hybrids of chilli (HYB-1, HYB-2, HYB-3, HYB-4 and HYB-5) with six best parents/inbred lines (NARC-14/9, NARC-15/6, NARC-16/4, NARC-16/5, NARC-16/8 and NARC-16/9), two checks (Lounghi and Tatapuri) and one commercial hybrid (222-HYB) of chilli were under taken. Self fertilization was ensured by planting the inbred/parental lines in net tunnels for the maintenance of their purity. The best combiners were crossed to reconstitute the mentioned hybrids from April through May, 2012.

Nursery Raising and Experimental Design: The nursery of the plant material was sown on 1-meter wide raised beds in the first week of October, 2012 under a tunnel structure. The day and night temperatures of tunnel were retained at 30 ± 3°C and 23 ± 3°C, respectively. The nursery was transplanted in mid of March, 2013. Triplicated Randomized Complete Block Design (RCBD) was followed. A plot bed (3 m × 1 m); comprising of 12 plants on both sides of the bed was prepared. The plant × plant (50 cm) and row × row distance (75 cm) was maintained. Farm yard manure @ 30 t ha^{-1} and N-P-K @ 120, 75 and 50 kg ha^{-1}, respectively were applied. All K, P and half of N were applied during the land/plot preparation. The remaining half (Nitrogen) was applied in two equal dosages.

Statistical Analysis: The recorded data was analyzed following the method given by Steel *et al*. (1997) to investigate the significance of differences in studied plant traits. The coefficients of variation (genotypic and phenotypic) were calculated and categorized as low, medium and high following Shivasubramanian and Menon (1973). Genetic advance and heritability in broad sense was calculated as suggested by Burton (1952), Johnson *et al*. (1955) and Allard (1960). The heritability (%) was computed and categorized as low, moderate and high as suggested by Robinson *et al*. (1949). The GA as per cent of mean was calculated and categorised as low, moderate and high following Johnson *et al*. (1955). Correlation coefficients were estimated according to Dewey and Lu (1959) using Minitab programme.

RESULTS AND DISCUSSION

Analysis of variance: Mean squares for different yield assessing traits depicted highly significant (Tembhurne *et al*., 2008; Chattopadhyay *et al*., 2011; Elahi *et al*., 2017) differences between the genotypes which indicated the presence of sufficient genetic variability and considerable scope for improvement (Table 1). The parental lines may be utilized in different cross combinations for exploiting the genetic in chilli.

The performance of chilli hybrids, local and exotic genotypes, is presented in Table 2. From the mean values for number of fruits per plant it was deduced that the international hybrid (222-HYB) gave significantly maximum fruits (285.0) tracked by HYB-5 (191.5), NARC-16/9 (185.0), NARC-16/5 (169.0) and HYB-4 (166.5). However, the difference between the later (NARC-16/5 and HYB-4) was found non-significant. Whereas, the local varieties (Tatapuri and Lounghi) produced 139.50 and 39.20 fruits/plant, respectively (Sreelathakumary and Rajamony, 2002; Chattopadhyay *et al*., 2011). HYB-2 gave a maximum fruit weight of 9.0 g followed by NARC-16/8 (8.85 g) though this difference between them is non-significant. But the indigenously developed hybrid (HYB-2) gave a significantly maximum fruit weight of 9.0 grams than the other genotypes viz; NARC-14/9 (8.70 g), HYB-3 (8.0 g), HYB-4 and NARC-16/4 with 7.80 grams of fruit weight. In contrary, a considerable difference was observed for fruit weight (4.70 g) for the check hybrid (222-HYB) and the check varieties (Tatapuri & Lounghi) with 5.85 g and 5.30 g, respectively. However, Manju and Sreelathakumary (2002) recorded fruit weight from 1.22 g to 8.63 g while Sreelathakumary and Rajamony (2002) recorded a range from 2.55 g to 16.40 g. Low variation was recorded for fruit length among different chilli genotypes (Sharma *et al*., 2010). Maximum fruit length was recorded for NARC-14/9 (12.06 cm) followed by HYB-1 (11.43 cm), NARC-16/8 (11.34 cm), HYB-3 (11.23 cm) HYB-4 (11.08 cm), HYB-2 (11.02 cm) and HYB-5 (10.95 cm). It was revealed that all these genotypes were found statistically at par for fruit length. However, significant statistical difference observed for other genotypes including the check hybrid (222-HYB) and check varieties (Tatapuri and Lounghi). Maximum fresh fruit width was recorded for NARC-16/5 (1.43 cm) followed by NARC-14/9 (1.38 cm) and NARC-16/9 (1.33 cm). The difference between these three genotypes for fruit width was non-significant. However, the indigenous chilli hybrid (HYB-5) and NARC-16/8 had fruit width of 1.28 cm. The difference of these two genotypes and the previously mentioned genotypes for fruit width was significant. The international hybrid (222-HYB) and local variety (Tatapuri) had thin with fruit width of 0.97 cm and 0.88 cm, respectively. The presented range of fruit width from the Table 2 corroborates to the conclusions of Tembhurne *et al*. (2008) and Chattopadhyay *et al*. (2011). Maximum pericarp weight was recorded for NARC-14/9 (7.60 g) followed by HYB-2 (6.80 g) and NARC-16/8 (6.65 g). The differences among these mentioned genotypes were statistically non-significant. However, 2.90 g of pericarp weight was recorded for the international hybrid (222-HYB) and 4.05 g and 3.55 g for

Tatapuri and Lounghi, respectively. Significant differences for seed weight (fresh) were observed. Maximum seed weight was recorded in NARC-14/9 (2.30 g) followed by HYB-2 (2.25 g) and NARC-16/8 (2.20 g) which were statistically at par. The check hybrid (222-HYB) and the commercial cultivars (Tatapuri and Lounghi) vary significantly for their seed weights (1.75 g, 2.00g and 2.00 g, respectively) as compared to NARC-14/9, HYB-2 and NARC-16/8. The observations regarding the ripen/fresh seed weight was also recorded by Chattopadhyay *et al*. (2011). The indigenous hybrid (HYB-5) gave the highest fresh fruit yield (36.69 t/ha) followed by the indigenous hybrid (HYB-1) with 36.17 t/ha. Statistically, both indigenously developed hybrids were found at par to each other because of their least significant difference. The parental lines (NARC-16/8 and NARC-15/6) and indigenous hybrids (HYB-4 and HYB-2) gave green chilli yields as 35.63 t/ha, 33.16 t/ha and 31.15 t/ha and 28.78 t/ha, respectively. The international hybrid (222-HYB) gave 28.42 t/ha while the commercially grown varieties (Tatapuri and Lounghi) gave 16 t/ha and 4.60 t/ha, respectively which significantly differed from the top yielding indigenously developed chilli hybrids (HYB-5 and HYB-1) as evident from the Table 2.

Genetic components: High PCV and GCV values (Table 3) were recorded for fruit length, pericarp weight, number of fruits, weight of fruit and green fruit yield. These high values specified the existence of considerable variability which ensured the room of perfection through selection (Sharma *et al*., 2010). It was mostly observed that value of PCV were higher than the GCV (Table 3). Though, this difference was low but indicated involvement of environmental factors in the expression of the traits. The higher PCV than their corresponding GCV were also reported in chillies by Smitha and Basavaraja (2006), Tembhurne *et al*., (2008) and Chattopadhyay *et al*., (2011). Under such a situation, there is a scope of improvement through selection. The high GCV and PCV values, respectively, were recorded for number of fruits (43.9%; 44%), fruit length (28.9%; 30.1%), fruit weight (22.5%; 22.6%), pericarp weight (28.6%; 30.9%) and fresh fruit yield (37.6%; 37.7%). The moderate GCV and PCV were observed for fruit width (13.6%; 14.8%). However, the values of GCV and PCV for seed weight were considered as low (7.4%; 8.1%). High GCV and PCV showed the presence of greater variability, which may be utilized through selection for better improvement in the traits like number of fruits, fruit length, weight of single fruit, pericarp weight and fresh yield as indicated by Rosmaina *et al*. (2016).

Heritability and Genetic advance: High heritability in broad sense ranging from 84% to 99% was accounted for almost all parameters (Table 3). However, high genetic advance over the mean (32.85% to 60.66%) was recorded for some of the traits. Although, high values of heritability and genetic advance indicated the direction of selection. But the estimates of heritability alone are not satisfactory to express the response to selection; therefore, it is important to line up these values with genetic advance (Shashikanth *et al.,* 2010). High heritability (86% to 99%) and high genetic advance ranging (32.85% to 60.66%) were observed for number of fruits, fruit length, pericarp weight, weight of single fruit and green fruit yield, pointing the slight effect of environment on above parameters thus, improvement could be made by mean of selection as in Figure. 1. This suggested additive gene action (Panse, 1957; Elahi *et al*., 2017) and these traits can give good response to selection because almost all of phenotypic variance was credited towards the genotypic variance and selection could be used as the best tool for improving these parameters based on their phenotypic expression. High genetic advance and heritability have also been suggested by many workers for these afore mentioned traits (Sreelathakumary and Rajamony, 2002; Manju and Sreelathakumary, 2002; Bharadwaj *et al*., 2007; Tembhurne *et al*., 2008; Sharma *et al*., 2010 and Chattopadhyay *et al*., 2011). While, high h^2 (84%) with low GA (9.52%) was recorded for seed weight while high value of h^2 (84%) with moderate GA (16.66%) was observed for fruit width as shown in the Table 3 which depicted involvement of non-additive type of gene action. In case of seed weight and fruit width; the high value of heritability was exhibited due to favourable environmental influence rather than the genotype which resulted in moderate to low values of the genetic advance. Though, the values of the genotypic variance were higher than that of the environmental variances for seed weight and fruit width. But this difference was not much high. Hence, selection for these characters may not be achieved.

It is interesting to point out here is that the high estimates of heritability were recorded for fruit width (84%) and seed weight (84%) which were accompanied with moderate values of PCV (14.8%), GCV (13.6%) and GA (16.66%) for fruit width. The same trend was followed for seed weight where, low estimates of PCV (8.1%), GCV (7.4%) and GA (9.52%) were observed. This observation matches to the results of Sharma *et al*. (2010) and Chattopadhyay *et al*. (2011).

Correlation Studies: From the breeder's point of view, the type of association of yield with other agronomic characters is of paramount importance. Correlation among the traits may result from pleiotropy or the physiological association among the character. Correlation coefficients between fresh yield and other yield parameters are exhibited in Table 4. These results also confirm the finding of Hasanuzzaman and Golam (2011) and Kumar *et al*., 2012. A positive value gives the indication of uni-direction of the two variables and vice-versa (Nawab *et al*., 2011 and Elahi *et al*., 2017).

The correlation of fruit length and number of fruits per plants with fresh fruits yield was positively significant at genotypic and positively highly significant at phenotypic levels. This meant that the environmental effect was very limited. Fresh fruit yield is highly dependent upon the number of fruits per plant. It is major yield contributing trait. This showed that an increase in fruit yield is likely due to give increase in the number of fruits. These results were confirmed by Ibrahim *et al*. (2001), Munshi *et al*. (2002), Kumar *et al.* (2003) and Yadawad (2005). Similarly, fresh yield was also linked with fruit length as the length of the fruit might have increased the average fruit weight. Fresh fruit yield is positively and significantly correlated with pericarp weight and average fruit weight genotypically and phenotypically. These results are in line with the outcomes of Kumar *et al*., (2012) and Smitha and Basavaraja (2006). However, the correlation between fresh fruit yield and fruit width was non-significant (Table 4). This meant that the fruit width has no significant effect on the yield. However, literature still supports that fruit width has a positive association with yield as evident from the findings of Ibrahim *et al*. (2001) and Hasanuzzaman and Golam (2011). Similarly, a negative and non-significant correlation of fresh yield is recorded both at the genotypic (-0.10) and phenotypic (-0.09) levels with seed weight. This explained that pericarp weight is more important than that of the seed weight. Seed weight has no significant effect on the fruit yield. So, selection pressure may be exerted on other yield contributing traits than that of this trait (Table 4). However, the results from the studies of Ullah *et al*. (2011) reported an existence of positive correlation of fruit yield with seed weight in different chillies cultivars.

Table 1. Mean squares for different agronomic traits of chillies

SOV	Df	NFPP	FWt.	FL	FW	PWt.	SWt.	FFY
Replications	2	23.27	0.446	1.189	0.00	0.13	0.00	0.702
Genotypes	13	8680.57**	75.63**	17.45**	0.065**	5.23**	0.054**	110.56**
Error	26	17.61	1.02	0.67	0.005	0.36	0.004	0.226

NFPP = Number of fruits per plant, FWt. = Fruit weight (g), FL = Fruit length (cm), FW = Fruit width (cm), PWt. = Pericarp weight (g), SWt. = Seed weight (g), FFY = Fresh fruit yield (t/ha)
** = Highly significant ($P \leq 0.01$) * = Significant at $P \leq 0.05$ level

Table 2. Mean performance of chilli hybrids/inbred lines and other exotic/local genotypes

S.No.	Genotypes	NFPP	FWt.	FL	FW	PWt.	SWt.	FFY
1	HYB-5	191.50	7.50	10.95	1.28	4.80	2.00	36.69
2	HYB-1	126.00	7.65	11.43	1.19	5.37	2.00	36.17
3	NARC 16/8	124.50	8.85	11.34	1.28	6.65	2.20	35.63
4	NARC 15/6	152.50	6.05	9.99	1.11	3.90	2.00	33.16
5	HYB-4	166.50	7.80	11.08	1.24	5.80	2.00	31.15
6	HYB-2	125.00	9.00	11.02	1.24	6.80	2.25	28.78
7	NARC 16/4	119.50	7.80	10.57	1.18	5.50	2.10	28.63
8	222-HYB	285.00	4.70	8.29	0.97	2.90	1.75	28.42
9	NARC 16/9	185.00	7.00	9.60	1.33	5.25	2.00	27.97
10	HYB-3	150.50	8.00	11.23	1.25	6.00	2.00	27.93
11	NARC 14/9	123.50	8.70	12.06	1.38	7.60	2.30	25.95
12	NARC 16/5	169.00	6.90	10.12	1.43	5.25	2.05	25.22
13	Tatapuri	139.50	5.85	6.64	0.88	4.05	2.00	16.00
14	Lounghi	39.20	5.30	3.02	1.24	3.55	2.00	4.60
	LSD (0.05)	**7.04**	**0.16**	**1.37**	**0.12**	**1.01**	**0.11**	**0.81**

NFPP = Number of fruits per plant, FWt. = Fruit weight (g), FL = Fruit length (cm), FW = Fruit width (cm), PWt. = Pericarp weight (g), SWt. = Seed weight (g), FFY = Fresh fruit yield (t/ha)

Table 3. Some simple statistics for yield contributing traits in *Capsicum annuum* L.

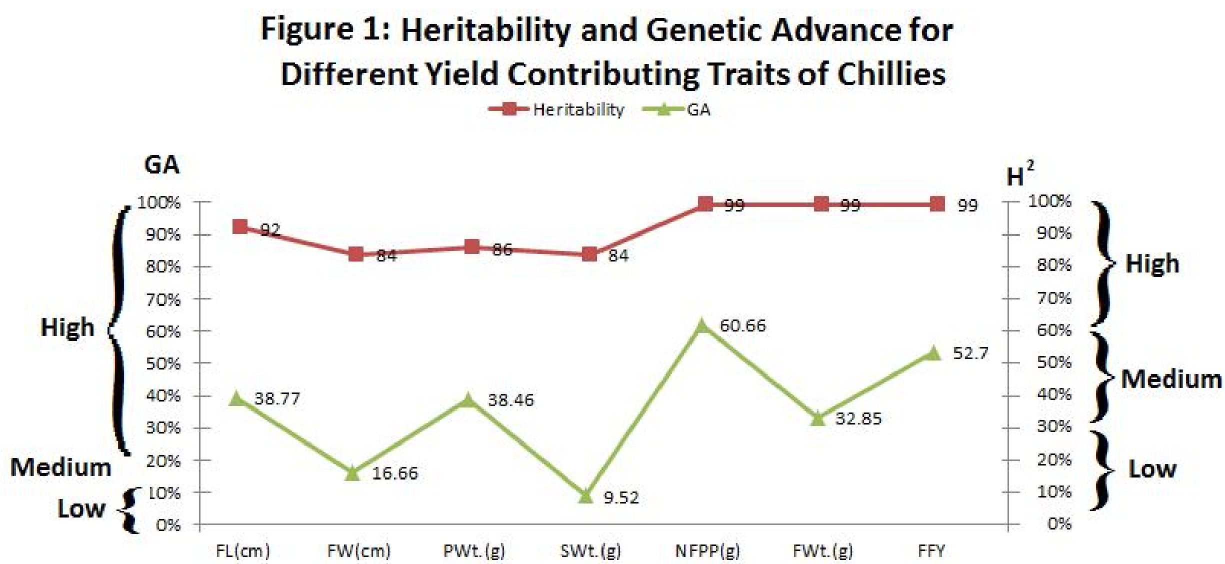
Traits	Mean	Range	Variances			Coefficient of variation			h^2%	GA%
			Vg	Vp	Ve	GCV%	PCV%	ECV%		(Over mean)
FL(cm)	09.80	12.1-03.0	08.0	08.7	0.70	28.9	30.1	08.4	92	38.77
FW(cm)	01.20	01.4-00.9	0.03	00.3	0.01	13.6	14.8	06.0	84	16.66
PWt.(g)	05.20	07.6-02.9	02.3	02.6	0.40	28.6	30.9	11.0	86	38.46
SWt.(g)	02.10	02.3-01.7	0.02	0.03	0.01	07.4	08.1	03.3	84	9.52
NFPP(g)	150.0	285-39.5	4322	4340	17.0	43.9	44.0	02.8	99	60.66
FWt.(g)	07.20	09.0-04.7	02.60	02.6	0.01	22.5	22.6	01.4	99	32.85
FFY	27.59	36.69-4.60	108.15	108.38	0.23	37.6	37.7	02.2	99	52.70

FL = Fruit length (cm), FW = Fruit width (cm), PWt. = Pericarp weight (g), SWt. = Seed weight (g), NFPP = Number of fruits per plant, FWt. = Fruit weight (g), FFY = Fresh fruit yield (t/ha)

Table 4. Genotypic (rg) and phenotypic (rp) correlation coefficients of fresh fruit yield with other yield components

	Fresh fruit yield	Rg	Rp
Vs	Fruit length	0.76*	0.73**
Vs	Fruit width (cm)	0.20	0.18
Vs	Pericarp weight	0.46*	0.39*
Vs	Seed weight (g)	-0.10	-0.09
Vs	Number of fruits per plant (g)	0.79*	0.79**
Vs	Average fruit weight (g)	0.50*	0.48*

* = Significant at 5% level of probability
** = Highly significant at 1% level of probability



Conclusion: The presented work has novelty in its nature as it has come up with the evaluation of the indigenous development of high yielding hybrids in chillies. From this study it was concluded that the indigenous chilli hybrid (HYB-5) contributed maximum green fruit yield of 36.69 t/ha following HYB-1 (36.17 t/ha) which were statistically at par to each other. The results have clearly indicated the scope of hybrid development. The traits like number of fruits, fruit length, weight of single fruit, pericarp weight and fresh yield not only exhibited high PCV and GCV values but also high worth of heritability in broad sense (86% to 99%) and high genetic advance (32.85% to 60.66%) which signified the existence of large variability, which may be utilized through selection for better improvement with the least influence of environmental factors on the expression of these traits. This in other words points towards the additive gene action for these characters and can perform fine to selection and can be taken into account for hybrid development.

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