Pak. J. Bot., 54(3): 817-822, 2022. DOI: http://dx.doi.org/10.30848/PJB2022-3(12)

ASSOCIATION ANALYSIS OF FRUIT YIELD AND OTHER RELATED ATTRIBUTES IN FOUR CHILLI (*CAPSICUM ANNUM* L.) GENOTYPES GROWN IN SINDH PROVINCE, PAKISTAN

SAIMA MIR ARAIN AND MEHBOOB ALI SIAL

[1]*Nuclear Institute of Agriculture (NIA), Tandojam 70060, Pakistan*
**Corresponding author's email: saimamir_nia@yahoo.com*

Abstract

Chilli (*Capsicum spp.,)* is an important vegetable, spice and medicinal crop, exhibit great genetic diversity. To strengthen chilli breeding programs, a comprehensive characterization of *Capsicum* through morphological, physiological and molecular approaches is required. The characterization of four (04) chilli *(Capsicum annum* L.) varieties cultivated in Sindh province, Pakistan based on agronomic and physiological traits was carried out. The material was planted under randomized complete block design in three replications at the NIA (Nuclear Institute of Agriculture) experimental farm, for two consecutive years (2016-2017) during *kharif*, season. The combined analysis of variance revealed significant differences for most of the quantitative attributes of four genotypes demonstrating presence of adequate variability. The genotype Laungi-hybrid depicted the greater values for most of the traits. Correlation coefficient exhibited high degree of interrelationship among the desirable plant attributes. Fruit yield per plant exhibited highly significant positive correlation with plant height (r=0.81 canopy width (r=0.68), stem radius (r=0.87), primary branches per plant (r=0.95), leaves per plant (r=0.91), number of fruits per plant (r=0.99), fruit fresh (r=0.96), and dry weight (r=0.95), single fruit weight (r=0.84), and number of seeds per fruit (r=0.76), whereas, significantly negative relationship with days taken to flowering and fruiting, attributing role of early flowering and fruiting to higher fruit yield per plant. Hence, selection based on these traits may be fruitful to improve fruit yield per plant in chilli pepper.

Key words: Chlorophyll content, Correlation, Fruit yield, Hybrid, Stem radius.

Introduction

Chilli (*Capsicum annuum* L.) is an eminent fellow of Solanaceae (nightshade) family having great economic and cultural importance, cultivated extensively throughout the world. Chillies are being widely used as vegetable, basic spice in various cuisines, in herbal pharmaceuticals and cosmetics. The genus *Capsicum* comprises of diploid species having 12 (x=12) basic chromosome numbers, and mostly 2n+2 x= 24, cultivated as self-pollinated crop The *Capsicum* genus includes approximately thirty wild and 5 cultivated species: *C. annuum, C. baccatum, C. chinense, C. frutescence and C. pubescens* (Dewitt and Bosland, 1996; Arimboor *et al*., 2014; Sikora and Nowaczyk, 2014). *Capsicum* not only adds striking hues and mouth-watering savour to the diet, it also promotes nutritional value with vitamin A (carotene), B complex and vitamin C, E and important minerals (Bhutia *et al*., 2018).

Chilli crop thrives in temperate and tropical areas of the world (Sousa *et al*., 2015), and is perennial, thus can be planted year around (Saxena *et al*., 2016). It contains an area of 1.93 million hectares globally, with 31 million tons of production (Anon., 2013, Consuelo & Calatayud, 2018). In Pakistan, chilli is planted as economically important cash crop, especially cultivated in Sindh province followed by Punjab, Baluchistan and Khyber Pakhtunkhawa. The crop is cultivated on an area of 64.8 thousand hectares with a production of 142.1 thousand tones (Anon., 2016). It bestows 1.5% to the country's GDP, out of 1.7 tons per hectare average yield (Hussain & Abid, 2011). Sindh province cultivates chilli on an area of 54.6 thousand hectares and produces 126.5 thousand tones (Anon., 2016). Despite Pakistan ranks -fourth among the world's main chilli producers, still fall behind in export because of low yield and quality deterioration. The main reasons behind low yield are biotic (pests and pathogens) and abiotic (water shortage, salinity, low/ high temperature, poor soil quality) stresses (Khan *et al*., 2009; Zhani *et al*., 2013; Naz & Perveen, 2021), as these stress cause physiological disorders in the plants. Further, Aflatoxin (potent carcinogens) contamination, which occurs during postharvest, creates main hindrance in the export of chillies.

Most of the desirable characters in *Capsicum* breeding are polygenic, therefore, difficult to integrate through traditional breeding methods (Hill *et al*., 2013). The knowledge on genetic diversity of the existing germplasm and its agronomic performance is very important in order to improve the germplasm and its utilization (Melendez *et al*., 2009; Nsabiyera *et al*., 2013; Dias *et al*., 2013; Orobiyi *et al*., 2013). Growth and development depicts the physical status of the plant in a specific environment. In *Capsicum* growth status can be evaluated using important traits, like plant height, canopy width, number of branches and the leaf area. While, traits like number of fruits/plant, fruit length, fruits fresh and dry weight/plant is important yield contributors.

The correlation among these traits is of great importance to identify genotypes with higher fruit yield. Since the evaluation of genetic and morphological variability is a precursor to potential chilli crop improvement programs (Thul *et al*., 2009). Consequently, this research was conducted with the objective to evaluate the performance of four chilli varieties based on the agro-morphic and some physiological attributes and estimation of correlation among these traits.

Materials and Methods

A field experiment comprising four chilli (*Capsicum annuum* L.) varieties was undertaken at the experimental field of Nuclear Institute of Agriculture, TandoJam, during

the *Kharif* seasons 2016-17, in randomized complete block design (RCBD). Tando Jam is a small town, located in district Hyderabad Sindh, Pakistan, between latitudes 25° 26' 0" North, 68° 32' 0" East. Main objectives of our chilli programme are given in the figure 3. Four chilli varieties namely, Laungi-farmi (V_1), Sannam (V_2), Laungi-hybrid (V_3) and Laungi-maxi (V_4) were planted each on 6 ridges of 3 m long per genotype, distance between the rows and plants was kept 45 cm, experiment was replicated thrice consisting of fifteen plants per variety. The fertilizer was applied at the rate of N 100 kg, P 80 kg and K 40 $kgha^{-1}$ (Wahocho *et al*., 2016).The crop was irrigated as per requirement of the soil and plant status, and all the required cultural practices were applied throughout the growing season. Agronomic practices such as irrigation, stirring, weeding, fertilization, disease/ insect control were carried out in the same manner. The observation were recorded on five randomly selected plants on twenty (20) important growth and yield traits, viz., days to flowering and fruiting, plant height (cm), canopy width (cm), number of primary braches per plant, leaves per plant, fresh and dry weight of 30 leaves per plant (g), number of fruits per plant, fruit fresh and dry weight per 50 fruits (g), single fruit weight (g), fruit length and diameter, number of seeds per fruit, stem radius (using vernier caliper), chlorophyll content as SPAD index using the SPAD meter (SPAD 502, Minolta, Japan) was measured 75, DAT (ays after transplantation. Data were statically analyzed using Statistix-8.1 computer software (https://statistix.informer.com/8.1/). Means were separated using least significant difference (LSD) test at $p<$ 0.05 level of probability. The computer software XLSTAT was used to manipulate the figure for correlation among the observed traits and with fruit yield per plant (Fig. 1). Phenotypes of the fruits and leaves are given in figure 2. Main objectives of research work on chilli breeding at NIA, Tando Jam are given in the figure 3.

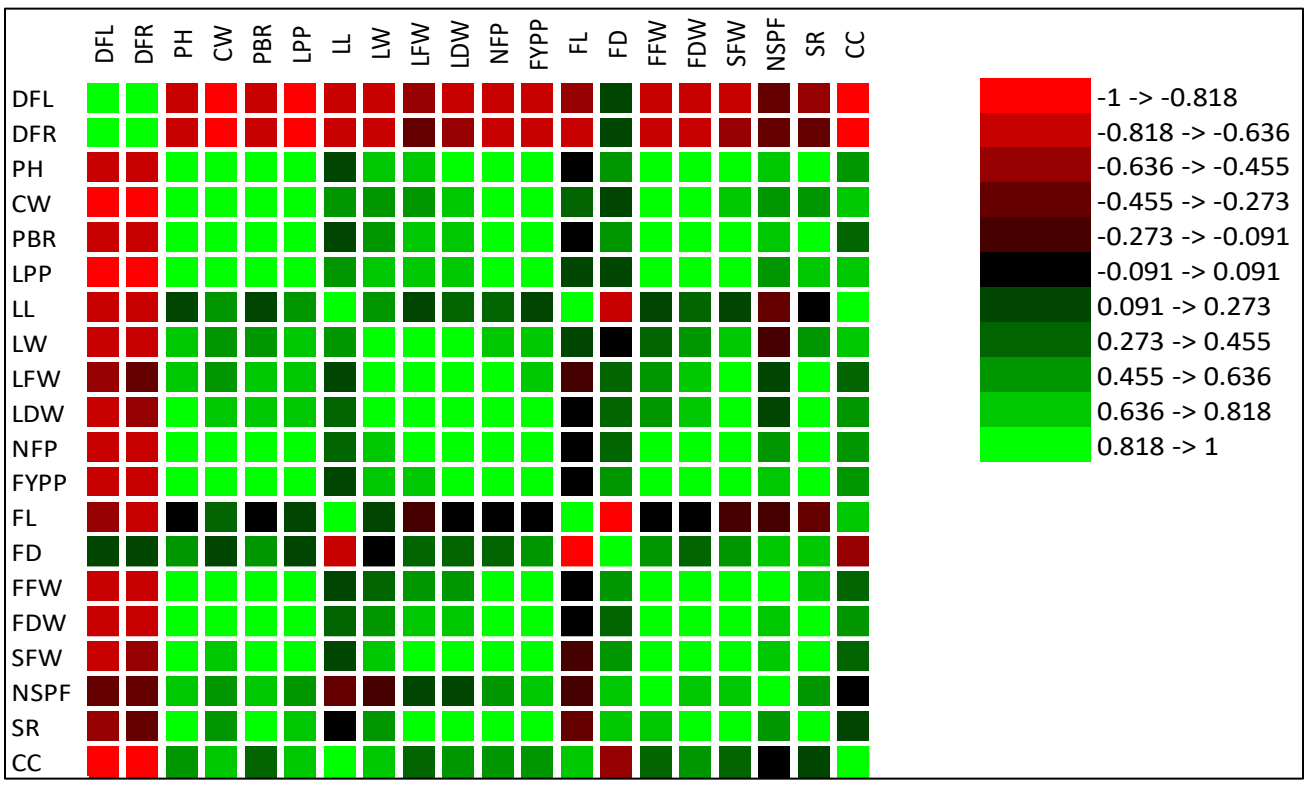

Fig. 1. Correlation heat map for yield and related traits in four chilli varieties (*Capsicum annum*). (PH= plant height in cm; CW= canopy width (cm); PBPP= primary braches per plant; LPP= leaves per plant; SR: stem radius (cm); CC= chlorophyll content SPAD index ; DFL= days to flowering; DFR= days to fruiting; LL= leaf length (cm); LW= leaf width (cm) FWL = Fresh weight of leaves. DLW= Dry weight of Leaves; FFW= fruit Fresh weight (g); FDW= fruit dry weight (g); FL=fruit length (cm); FD: fruit diameter (cm); SFW= single fruit weight (g); NFPP=number of fruits per plant; SPF: seeds per fruit and FYPP: fruit yield per plant (g).

Results and Discussion

Mean squares for various traits of chilli genotypes showed highly significant differences ($p\leq0.01$) among the genotypes, indicating the existence of genetic variability (Table 1). The other sources of variance year and genotype x year showed significant differences only for fruits per plant and fruit yield, indicates the impact of these traits over the performance of genotypes. Smith & Basavaraj, (2006) and Yatung *et al*., (2014) also reported considerable variability for these traits among the chilli genotypes. Plant height is a good predictor of plant growth and development (Phulari, 2012), as taller height helps the plant to intercept more light, thus induces higher rate of photosynthesis. According to mean performance results tallest plant height (76.10 cm) was attained by Laungi-hybrid genotype and shortest by the Laungi-maxi (39.10 cm) (Table 2). The variation in the plant height for chilli has also been stated earlier (Chowdhury *et al*., 2015). The genotypes with taller plant height could be helpful for enhancing the growth and development by increasing the plant response to

usage of sunlight and soil inputs through photosynthesis and translocation resulting in vegetative development in the plants. Our results consent with those stated by Chaudhary *et al*., (2013), who recorded plant height ranging from 40.20 cm to 61.40 cm and Amit *et al*., (2014) 89.97 cm in chilli crop. Maximum plant canopy width (54.37 cm) was measured in Laungi-hybrid and minimum in Laungi-maxi (34.42 cm). Variability in canopy formation impacts the crop significantly in two ways: firstly through light interception and distribution, and secondly through inter-related physio-morphological and developmental changes (Evans, 1975). Maximum number of primary branches was obtained by Laungi-hybrid (9.28) and minimum by Laungi-maxi (4.35). Primary branches depict the plant growth habit, higher number of primary branches shows spreading growth of the plant, whereas lower number indicate upright growth of the plant (Arya *et al*., 2018). Variation in number of primary branches in chilli was also reported previously (Smith & Basavaraja, 2006) from 3.50 to 12.70; Ukkund *et al*., (2007) from 2.05 to 6.65 and Tembhurne *et al*., (2008) from 4.33 to 5.73 in chilli. Laungi-hybrid genotype took minimum days to 50% flowering (48.17 days) and fruiting (73.50 days) thus indicated as early maturing genotype, followed by the Sannam. Laungi-hybrid genotype attained the thickest stem radius (1.57 cm) followed by Laungi-farmi (1.15 cm) and Sannam (0.95cm), thinnest radius was recorded in Laungi-maxi (0.92 cm). However, maximum number of leaves per plant was obtained by the Laungi-hybrid (611.33) genotype followed by Sannam (448.42). Longer leaf length was observed in Sannam (4.85 cm) and width was recorded in Laungi-hybrid (3.83 cm). Maximum leaf width was observed in Laungi-farmi (1.17 cm) that was statistically at par with Sannam and Laungi-hybrid genotypes, whereas minimum width was recorded in Laungi-maxi (0.89 cm). Maximum fresh and dry weight of 30 leaves per plant was recorded in Laungi-hybrid genotype (3.71; 0.99 g) followed by Laungi-farmi (3.51; 0.82 g), and minimum in Laungi-maxi (2.24; 0.56 g).

Morphological variation among four chilli genotypes for fruits and leaves.

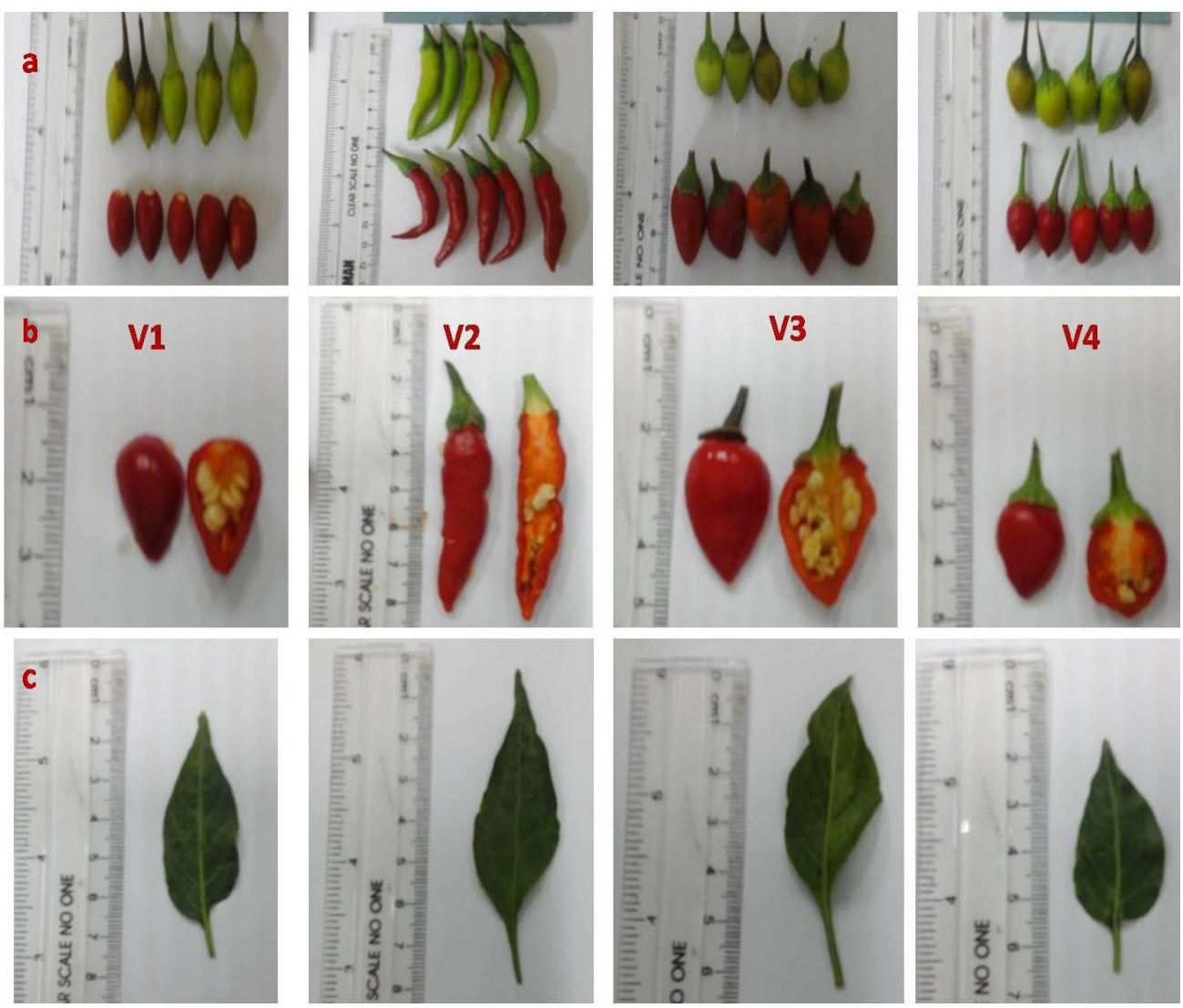

Fig. 2. Variation in fruit and leaf of four chili varieties (*Capsicum annum*) (a) Fruit phneotype of the the cilli varieiteis (b) Cross section of chilli frutis; (c) Diversity of leaves among four chilli varieites. (V_1) Laungi-farmi, (V_2) Sannam, (V_3) Laungi-hybrid and (V_4) Laungi-maxi.

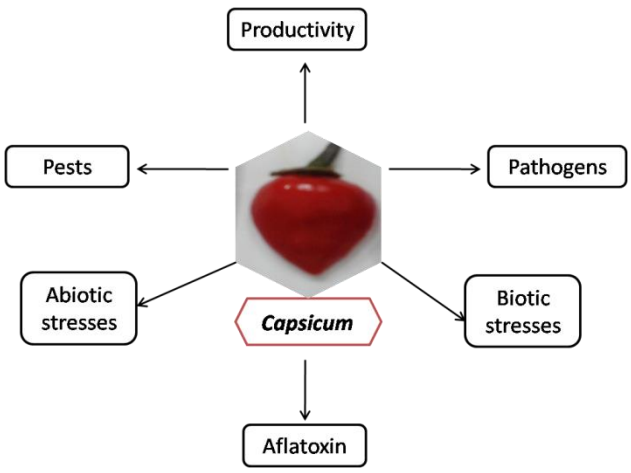

Fig. 3. Main objectives of chilli program at NIA.

Number of fruits per plant determines the final yield. The highest number of fruits per plant was noted in Laungi-hybrid (199.77), and lowest in Laungi-maxi (78.64). Maximum fruit fresh weight per 50 fruits (80.025 g), fruit dry weight per 50 fruits (32.91 g), single fruit weight (1.71g) was also recorded in Laungi-hybrid , followed by Laungi-farmi (60.56; 21.54 ; 1.41g) (Table 3). Longest fruit size was recorded in Sannam (3.79) which was statistically different from all three genotypes, and smallest in Laungi-farmi (1.70). Sharma *et al*., (1981) reported association of small fruit size with higher number of fruits and reverse result in large sized fruit varieties. Phulari (2012) also reported variation in chilli germplasm for fruit length. Maximum fruit diameter was recorded in Laungi-hybrid (1.51 cm) which was statistically at par with Laungi-maxi (1.29 cm). Highest number of seeds per fruit was also recorded in Laungi-hybrid (61.31), and was significantly different from other varieties, whereas, minimal was found in Laungi-farmi (36.32). Variability in number of seeds per fruit have also been reported by Farhad *et al*., (2008) from 37.97 to 114.00, Amit *et al*., (2014) from 40.24 to 113.85, Arya *et al*., (2018) from 44.66 to 89.33, and in chilli. Maximum fruit yield per plant (337.50 g) was recorded in Laungi-hybrid genotype, followed by the Sannam (178.16 g), and lowest yield was recorded in Laungi-maxi (106.22 g). Higher chlorophyll content (%) was recorded in Sannam (56.90%), but was statistically at par with Laungi-hybrid (54.50 %) and Laungi-farmi (53.18%), whereas, it was minimum in Laungi-maxi (50.75%). Previous studies also reported significant differences among the genotypes/ varieties related to quantitative and qualitative traits (Ukkund *et al*., 2007; Yatung *et al*., (2014); Chowdhury *et al*., (2017).

Correlation results indicated that the fruit yield per plant had strong positive association with plant height ($r=0.81^{**}$), canopy width ($r=0.68^{**}$), stem radius ($r=0.87^{**}$), main branches ($r=0.95^{**}$), leaves/plant ($r=0.91^{**}$), number of fruits/ plant ($r=0.99^{**}$), fruit fresh ($r=0.96^{**}$), and dry weight ($r=0.95^{**}$), single fruit weight ($r=0.84^{**}$), canopy width ($r=0.597^{**}$) and number of seeds/fruit ($r=0.77^{**}$) but strong negative relationship with days to flowering ($r=-0.72^{**}$) and fruiting ($r=-0.72^{**}$), exhibited great importance of early flowering and fruiting for higher fruit yield per plant (Fig. 1). These results are in line with previously (Gupta *et al*., 2009; Ullah *et al*., 2011; Chattopadhyay *et al*., 2011; Kumar *et al*., 2012; Yatung *et al*.,2014 and Bijalwan & Mishra, 2016), for number of fruits/plant, fruit length and number of primary branches/plant. Highly negative and strong association of fruit yield/plant was noted with days to 50% flowering reported previously (Basavaraj, 1997; Bijalwan & Mishra, 2016; Vidya *et al*., 2018).

In conclusion, the traits showing positive association with fruit yield and other related traits may be incorporated for enhancement of fruit yield per plant in chilli. Among the four chilli genotypes, performance of hybrid genotype was found superior over other three contestants. These results suggest that taller plant height, canopy width, more fruits per plant, fruit fresh and dry weight, single fruit weight may help to produce more yield in chilli. Hence, these traits should be given more importance in breeding programs for improvement of fruit yield.

Table 1. Mean squares from analysis of variance (ANOVA) for agro-morphic and physiological traits of four chilli varieties.

Source of variation	DF	PH	CW	PBPP	DFL	SR	DFR	LPP	LL	LW	LFW
Replicates	2	35.13	19.81	1.145	0.500	0.020	3.11	5053	0.059	0.005	0.993
Genotypes	3	1504.87**	506.28**	30.23**	204.26**	0.549**	422.36**	123914**	3.39**	0.094**	2.905 **
year	1	27.09	8.06	0.33	3.375	0.014	1.13	1144	0.052	0.0052	1.410
G*Y	3	1.05	2.22	0.35	5.708	0.004	0.35	367	0.031	0.007	0.029
Error	14	17.43	6.00	0.14	1.88	0.008	2.898	1459	0.061	0.005	0.065
Total	**23**										
Source of variation	**DF**	**LDW**	**FFW**	**FDW**	**FL**	**FD**	**SPF**	**NFPP**	**SFW**	**CC**	**FYPP**
Replicates	2	0.035	1.90	0.203	0.007	0.013	14.96	110.1	0.016	107.7	350.0
Genotypes	3	0.196**	1022.90**	393.44**	6.112**	0.44**	679.17**	15976.5**	0.152**	40.26**	61356.7**
year	1	0.107	30.15	7.315	0.044	0.005	8.40	6951.9 **	0.019	1.69	20512.0**
G*Y	3	0.011	1.99	0.163	0.006	0.002	0.39	293.4 *	0.002	0.83	748.2*
Error	14	0.010	3.26	1.540	0.022	0.022	9.05	67.2	0.010	8.53	182.8
Total	**23**										

Note: **, * - significant at 1 and 5% level of probability and ns, indicates non-significant

(PH= plant height (cm); CW= canopy width (cm); PBPP= primary braches per plant; DFL= days to flowering; SR: stem radius (cm); DFR= days to fruiting; LPP= leaves/plant; LL= leaf length (cm); LW= leaf width (cm); LFW = Leaves fresh weight (g); LDW= Leaves dry weight (g); FFW= fruit Fresh weight (g); FDW= fruit dry weight (g); FL=fruit length (cm); FD: fruit diameter (cm); SFW= single fruit weight (g); NFPP=number of fruits/plant; SPF: seeds/fruit; CC= chlorophyll content SPAD index; and FYPP: fruit yield/plant (g)

Table 2. Mean performance of the agro-morphic and physiological traits[¶] of 4 chilli varieties grown in Sindh.

Var.	PH	CW	PBPP	DFL	SR	DFR	LPP	LL	LW	LFW
Laungi-farmi	47.67 b	37.52 c	4.8 bc	57.33 b	1.15 b	87.13 b	368.63 c	3.72 b	1.17 a	3.51 a
Sannam	54.83 b	47.60 b	5.58 b	53.17 c	0.92 c	82.00 c	448.42 b	4.85 a	1.08 a	2.65 b
Laungi-hybrid	76.10 a	54.37 a	9.28 a	48.17d	1.57 a	73.50 d	611.33 a	3.83 b	1.15a	3.71 a
Laungi-maxi	38.97 c	34.42 c	4.35 c	61.83 a	0.95 c	93.30 a	271.67 d	3.02 c	0.89 b	2.24 b
GM	54.38	43.48	6.00	55.13	1.15	83.99	425.01	3.86	1.07	3.03
SE mean	2.97	1.73	0.42	1.09	0.058	1.54	27.07	0.14	0.027	0.15
LSD (0.05)	7.01	4.11	1.68	2.30	0.15	2.86	64.12	0.41	0.19	0.428
CV (%)	7.68	5.63	9.70	2.49	7.73	2.03	8.99	6.39	6.60	8.42
F-value	86.36	84.36	89.06	108.60	69.76	145.72	84.91	55.95	18.80	44.66

Note: PH= plant height (cm); CW= canopy width (cm); PBPP= primary braches/plant; DFL= days to flowering; SR: stem radius (cm); DFR= days to fruiting; LPP= leaves/plant; LL= leaf length (cm); LW= leaf width (cm); LFW= Fresh weight of leaves; GM: grand mean; SE mean: Standard error of mean; LSD: least significant difference; CV: coefficient of variation.. The means in columns bearing same letters do not differ significantly (p<0.05)

Table3. Mean performance of the agro-morphic and physiological traits of 4 chilli varieties (*Capsicum annum*) grown in Sindh.

Var.	LDW	FFW	FDW	FL	FD	SPF	NFPP	SFW	CC	FYPP
Laungi-farmi	0.82 a	50.615 d	17.195c	1.70 b	1.16 b	36.32 d	107.94 c	1.41 b	53.18 ab	147.76c
Sannam	0.72 bc	60.562 b	21.54 b	3.79 a	0.84 c	42.95 c	127.51 b	1.39 b	56.90 a	178.16 b
Aungi-hybrid	0.99 a	80.025 a	32.91 a	1.95 b	1.51 a	61.31 a	199.77 a	1.71 a	54.50 ab	337.50 a
Laungi-maxi	0.56 c	54.51 c	14.58 d	1.71 b	1.29 ab	49.51 b	78.64 c	1.33 b	50.75 b	106.22 c
GM	0.77	61.43	21.56	2.29	1.20	47.51	128.46	1.46	53.78	192.41
SE mean	0.04	2.39	1.48	0.18	0.05	1.99	10.16	0.03	0.913	19.51
LSD (0.05)	0.17	3.03	2.083	0.249	0.249	5.048	13.76	0.169	4.90	22.69
CV (%)	12.90	2.94	5.76	6.49	12.42	6.33	6.38	6.90	5.43	7.03
F-value	19.73	313.60	255.56	277.27	19.68	75.08	237.61	15.05	4.72	335.60

Note: [¶]LDW= dry weight of Leaves; FFW= fruit fresh weight (g); FDW= fruit dry weight (g); FL=fruit length (cm); FD: fruit diameter (cm); SPF: seeds/fruit;; NFPP=number of fruits/plant; SFW= single fruit weight (g); CC= chlorophyll content SPAD index and FYPP: fruit yield/plant (g); GM: grand mean; SE mean: Standard error of mean; LSD: least significant difference; CV: coefficient of variation.. The means in columns bearing same letters do not differ significantly (p<0.05)

Acknowledgements

This work was supported by Pakistan Atomic Energy Commission

References

Amit, K., I. Ahad, V. Kumar and S. Thakur. 2014. Genetic variability and correlation studies for growth and yield characters in chilli (*Capsicum annuum* L.) *J. Spices. Arom. Crops,* 23(2): 170-177.

Anonymous. 2013. (Food and Agriculture Organization of the United Nations).FAO Statistical Programme of Work. Available online at :http://faostat3.fao.org/browse/Q/*/E (accessed on 11th February 2018).

Anonymous. 2016. Pakistan Bureau of Statistics. Government of Pakistan, Islamabad. 50.

Arimboor, R., R.B. Natarajan, K. Menon, L.P. Chandrasekhar and V. Moorkoth. 2014. Red pepper *(Capsicum annuum)* carotenoids as a source of natural food colors: analysis and stability-a review. *J. Food. Sci. Tech.,* 52(3): 1258-1271.

Arya, V.K., S. Bhandari and A.C. Mishra. 2018. Evaluation of variability for growth, seed yield and its contributing characters in chilli genotypes. *Int. J. Curr. Microbiol. Appl. Sci*., 7(10): 1118-1125.

Basavaraj, N. 1997. Genetic variability and genetics of quantitative and quality characters in green chilli (*Capsicum annuum* L.) genotypes. Ph.D. thesis, University of Agricultural Sciences,

Bhutia. K.L., V.K. Khanna, T. Meetei and N.D. Bhutia. 2018. Effects of climate change on growth and development of chilli. *Agritech.* 7: 180. doi:10.4172/2168-9881.1000180.

Bijalwan, P. and A. Mishra. 2016. Correlation and path coefficient analysis in chilli (*Capsicum annuum* L.) for yield and yield attributing traits. *Int. J. Sci. Res*., 5(3): 1589-1592.

Chattopadhyay, A., A. Sharangi, N. Dai and S. Dutta. 2011. Diversity of genetic resources and genetic association analysis of green and dry chillies of eastern India. *Chil. J. Agric. Res*., 71(3): 350-356.

Chaudhary, A., R. Kumar and S. Solankey. 2013. Estimation of heterosis for yield and quality components in chilli (*Capsicum annuum* L.). *Afr. J. Biotech.,* 12(47): 6605-6610.

Chowdhury, M.S.N., F. Hoque, H. Mehraj and A.F.M.J. Uddin. 2015. Vegetative growth and yield performance of four chilli (*Capsicum frutescens*) cultivars. *Amer- Eurasian J. Agric. Environ. Sci.,* 15(4): 514-517.

Chowdhury, Md. S.N., S. Sarkar, A.F.M.J. Uddin, T. Sultana, M.Z.K. Roni and R. Islam. 2017. Morpho-physiology, yield and quality assessment on five local landrace chilli germplasms. *Asian J. Agric. Rural Dev.,* 7(11): 233-343.

Dewitt, D. and P.W. Bosland. 1996. Peppers of the World: An identification Guide. Ten Speed Press, Berkeley.

Dias, G.B., V.M. Gomes, T.M. Moraes, U.P. Zottich, G.R. Rabelo, A.O. Carvalho, M. Moulin, L.S. Gonçalves, R. Rodrigues and M. Da Cunha. 2013. Characterization of *Capsicum* species using anatomical and molecular data. *Genetic & Mol. Res.,* 12(4): 6488-6501.

Evans, L.T., I.F. Wardlaw and R.A. Fischer. 1975. Wheat. *Crop Physiology*. 101-149. (Ed.): Evans, L.T. Cambridge Univ. Press.

Farhad, M., M. Hasanuzzaman, B.K. Biswas, A.K. Azad and M. Arifuzzaman. 2008. Reliability of yield contributing characters for improving yield potential in chilli (*Capsicum annuum* L.). *Int. J. Agric. Sustain. Crop Prod*., 3(3): 30-38.

Gupta, A.M., D. Singh and A. Kumar. 2009. Genetic variability, genetic advance and correlation in chilli (*Capsicum annuum* L.). *Ind. J. Agric. Sci.,* 79(3): 221-223.

Hill, T.A., H. Ashrafi, S. Reyes-Chin-Wo, J. Yao and K. Stoffel. 2013.Characterization of *Capsicum annuum*genetic diversity and population structure based on parallel polymorphism discovery with a 30k unigene pepper genechip. *PLoS One*., 8(2):e56200. doi:10.1371/journal.pone.0056200.

Hussain, F. and M. Abid. 2011. Pests and diseases of chilli crop in Pakistan: a review. *Int. J. Biol. Biotechnol.,* 8(2): 325-332.

Khan, H.A., C.M. Ayub, M.A. Pervez, R.M. Bilal, M.A. Shahid and K. Ziaf. 2009. Effect of seed priming with NaCl on salinity tolerance of hot pepper (*Capsicum annum* L.) at seedling stage. *Environ. Exp. Bot.,* 60: 77-85.

Kumar, D., V. Bahadur, S.B. Rangare and D. Singh, 2012. Genetic variability, heritability and correlation studies in chilli (*Capsicum annuum* L.). *Hort. Flora Res. Spectrum,* 1(3): 248-252.

Melendez, A.A., P.L. Morrell, M.L. Roose and S.C. Kim. 2009. Genetic diversity and structure in semiwild and domesticated Chiles (*Capsicum annuum*; Solanaceae) from Mexico. *Am. J. Bot*., 96(6): 1190-1202.

Naz, S. and S. Perveen. 2021. Response of wheat (*Triticum aestivum* L. var. Galaxy-2013) to pre-sowing seed treatment with thiourea under drought stress. *Pak. J. Bot*., 53(4):.1209-1217.

Nsabiyera, V., M. Logose, M. Ochwo-Ssemakula, P. Sseruwagi, P. Gibson and C.O. Ojiewo. 2013. Morphological characterization of local and exotic hot pepper (*Capsicum annuum* L.) collections in Uganda. *Bioremed. Biodiv. & Bioavai.,* 7(1): 22-32.

Orobiyi A., A. Dansi, P. Assogba. L.Y. Loko, M. Dansi, R. Vodouhè, A. Akouègninou and A. Sanni. 2013. Chili (*Capsicum annuum* L.) in southern Benin: production constraints, varietal diversity, preference criteria and participatory evaluation. *Int. J. Agric. Sci. Soil Sci.,* 3(4): 107-120.

Penella, C. and A. Calatayud. 2018. Pepper crop under climate change: Grafting as an environmental friendly strategy. *Climate Resilient Agriculture: Strategies and Perspectives. IntechOpen, London,* pp. 129-155.

Phulari, S.S. 2012. Mean performance of major morphological characters in varieties of *Capsicum annuum* and *Capsicum Frutescens*. *Ind. Streams Res. J.,* 2(6): 1-5.

Saxena, A., R. Raghuwanshi, V.K. Gupta and H.B. Singh. 2016. Chilli anthracnose: The epidemiology and management. *Front. Microbiol.,* 7: 1527.

Sharma, P.P., S. Saini and B.N. Kurla. 1981. Correlation and path coefficient analysis in *Capsicum. Veg. Sci.,* 8: 35-44.

Sikora, B. and P. Nowaczyk. 2014. Application of rapid technique for identification of interspecific hybrids from genus *Capsicum*. *Acta Sci. Pol. Technol*., 13(1): 155-166.

Smith, R.P. and N. Basavaraja. 2006. Variability and correlation studies in chilli (*Capsicum annuum* L.). *Karnataka J. Agric. Sci.,* 19(4): 888-891.

Sousa, W.R.do N., A.C. de Lopes, A.R. de Carvalho, R.L.F Gomes and A.P. Peron. 2015. Karyotypic characterization of *Capsicum* sp. Accessions. *Acta Sci. Agron.,* 37(2): 147-153.

Tembhurne, B.V., Revanappa and P.H. Kuchanur. 2008. Varietal performance, genetic variability and correlation studies in chilli. *Karnataka J. Agric. Sci*., 21(4): 541-543.

Thul, S.T., R.K. Lal, A.K. Shasany, M.P. Daroka, A.K. Gupta, M.M. Gupta, R.K. Verma and P.S.S. Khanuja. 2009. Estimation of phenotypic divergence in a collection of *Capsicum* species for yield-related traits. *Euphytica,* 168(2): 189-196.

Ukkund, Krishna C., M.B. Madalageri, M.P. Patil, Ravindra Mulage and Y.K. Kotikal. 2007. Variability Studies in Green Chilli (*Capsicum annuum* L.). *Karnataka J. Agric. Sci*., 20(1): 102-104.

Ullah, M.Z., M.J. Hasan, A.I. Saki, A.H. M.A. Rahman and P.L. Biswas. 2011. Association of correlation and cause-effect analysis among morphological traits in chilli (*Capsicum frutescence* L.). *Int. J. Biores.,* 10(6): 19-24.

Vidya, C., V.S. Jagtap and N. Santhosh. 2018. Correlation and path coefficient analysis for yield and yield attributing characters in chilli (*Capsicum annum* L.) genotypes. *Int. J. Curr. Microbiol. Appl. Sci.,* 7(1): 3265-3268.

Wahocho, N.A., Z.A. Sheikh, Q. Jogi, K.H. Talpur and S.J. Leghari. 2016. Growth and productivity of chilli (*Capsicum annuum* L.) under various nitrogen levels. *Sci. Int*., 28(2): 1321-1326.

Yatung, T., R. K. Dubey, V. Singh, G. Upadhyay and A. K. Pandey. 2014. Selection parameters for fruit yield and related traits in chilli (*Capsicum annuum* L.).*Bangladesh J. Bot.,* 43(3): 283-291.

Zhani, K., H. Nina, A. Rezwan and H. Cherif. 2013. Evaluation of salt tolerance (NaCl) in Tunisian chili pepper (*Capsicum frutescens* L.) on growth, mineral analysis and solutes synthesis. *J. Stress Physiol. Biochem*., 9(1): 209-228.

(Received for publication 23 July 2020)