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Tarunkumar Patel
Research Scholar, Department of Vegetable Science, IGKV, Raipur, Chhattisgarh, India

Dr. PC Chaurasiya
Assistant Professor, Department of Horticulture, CARS, Mahasamund, Chhattisgarh, India

Corresponding Author:
Tarunkumar Patel
Research Scholar, Department of Vegetable Science, IGKV, Raipur, Chhattisgarh, India

Genetic variability, correlation studies and path analysis in chilli (*Capsicum annuum* L.)

Tarunkumar Patel and Dr. PC Chaurasiya

Abstract
The present experiment title "Genetic Variability, Correlation Studies and Path Analysis in Chilli (*Capsicum annum* L.)" was conducted at the College of Agriculture and Research Station, Mahasamund, Chhattisgarh during the Rabi season of 2022-2023. The experimental setup included twelve genotypes of Chilli, which were arranged in a Randomized Block Design with three replications.
Analysis of variance indicated that significant differences exist among the genotypes with respect to both quantitative and qualitative characters.
Correlation studies revealed that, plant height, number of fruits per plant, fruit weight per plant, fruit length, fruit girth, fresh fruit weight, total nm. of picking and fruit yield per plot had positive significant association, with yield per plant indicating the importance of these traits in selection for yield because of their direct contribution to yield.
Maximum positive direct effect was observed for fruit yield per ha. (0.515) followed by numbers of fruit per plant (0.464), fruit weight (0.428), fruit weight per plant (0.233), days to last pickings (0.353), while, negative direct effect was observed for total numbers of pickings (-0.225), fruit length (0.163).

Keywords: Genetic variability, path analysis, chilli, *Capsicum annuum* L.

Introduction
The fruit and vegetable chilli (*Capsicum annuum* L.) is widely grown around the world. It is a member of the Solanaceae family and has 2n = 24 chromosomes. Chilli is a cross-pollinated crop that produces berries that resemble pods and is one of the most widely produced spices in India. It is frequently referred to as hot pepper and was brought to India from Brazil by the Portuguese in the 16th century. Chilies are an excellent source of vitamin C and contain other essential vitamins such as A, K, E, and minerals (Singh, 2007) [13]. They are nutritionally rich, with high amounts of ascorbic acid (111.07 mg), moisture (85.7 g), protein (2.9 g), fat (0.6 g), minerals (1.0 g), calcium (30.0 mg), carbohydrate (3.0 g), fiber (6.8 g), sodium (6.5 mg), magnesium (24.0 mg), chlorine (15.0 mg), sulfur (34.0 mg), copper (1.6 mg), iron (1.2 mg), phosphorus (80 mg), Riboflavin (0.39 mg), and vitamin A (292 IU).
On an area of 0.377 million hectares, India produced roughly 3.783 million metric tonnes of chilies in 2019–20 (NHB Database 2019–20). Chilies are grown on 10,706 hectares in Chhattisgarh, producing 65,673 metric tonnes in 2021–22 (Agri site cg.nic.in).
Breeders can find viable genotypes by thoroughly knowing the variety that is present in the breeding material for desirable qualities in a crop species. Phenotypic variation is caused by phenotypic, genotypic, and genotype-environment interactions. However, the most important factor for making wise breeding decisions is genetic variation because it is heritable. The enormous genetic diversity that chilli breeders have access to has aided in the creation of new kinds and hybrids. A secondary centre of origin for chilies is India, and the majority of features have a wide genetic range. Understanding the correlations and contributions of various character features is essential for successful breeding initiatives.
Breeders can create improved cultivars with desirable qualities by utilising the genetic diversity found in chillies, which will increase production and the long-term viability of chilli agriculture. Meeting the various consumer needs and preserving the financial security of chilli producers will depend on the ongoing exploration and use of the genetic resources found in chillies.

Materials and Methods
The current study, "Genetic variability, correlation studies and path analysis in chilli (*Capsicum annum* L.)" was carried out at the College of Agriculture and Research Station,

Mahasamund, Chhattisgarh, during the rabi season of 2022–2023. Mahasamund is situated at coordinates 21.1° North latitude and 82.1° East longitude in the central-east region of Chhattisgarh state.

Twelve different hot pepper genotypes, including Arka Khyati, Arka Shweta, Arka Haritha, Arka Yasashwi, Arka Tejashwi, Local Genotype-1, Arka Sanvi, Selection Local Chilli-1, Arka Tanvi, Selection Chilli-2, Arka Meghna, and Selection Chilli-1, were used in the trial. These genotypes were sown in separate rows on raised bed nurseries using conventional nursery techniques as part of the experimental design. The experiment used three replications of a Randomised Block Design and kept a 45 cm distance between the rows of plants.

To guarantee a healthy harvest, appropriate cultural practises were adopted at every stage of the growth cycle. Plant height (cm), number of branches per plant, fruit length (cm), weight (g), girth (cm), number of fruits per plant, weight per plant, total fruit yield per hectare (q), days to first flowering, days to 50% flowering, number of pickings, days to last picking, and days to first picking are just a few of the growth and yield parameters that were observed and recorded.

The collected data were statistically analysed to assess the performance of the chilli genotypes, investigate the relationship between fruit yield and growth and yield parameters, compute the path coefficient for growth and yield parameters, and determine which genotype is best for growth and yield in the Chhattisgarh plains.

This study aims to provide valuable insights for selecting the best performing genotypes that can lead to improved yield and overall productivity of chillies in the Chhattisgarh region.

Results and Discussion

Pooled data over one years (2022-23) have been utilized to study genetic variability among the twelve chilli genotypes for the studied fourteen characters. The analysis of variance, presented in Table 1, clearly suggests significant differences among the genotypes for all the characters (at P=0.01), indicating presence of significant genetic variability in the experimental material. This finding was in accordance with those of Khurana *et al*., (2003) [17].

Table 1: Analysis of variance for fruit yield and its attributing traits in hot pepper

Mean Sum of Square				
S. No.	**Characters**	**Replication**	**Treatment**	**Error**
	Degree of freedom			
		2	**11**	**6**
1	Plant height (cm)	4.64	73.950*	32.12
2	Number of branches per plant	1.11	4.53**	0.785
3	Days to first flowering	15.36	69.32**	16.088
4	Days to 50% flowering	20.08	44.980*	19.902
5	Days to first picking	122.33	123.77**	28.848
6	Number of pickings	0.01	2.67**	0.288
7	Days to last picking	122.33	85.58**	93.545
8	Fruit length (cm.)	0.53	12.99**	0.398
9	Fruit girth (cm.)	0.15	1.02**	0.069
10	Fruit weight (g)	0.33	2.85**	0.165
11	Number of fruits per plant	149.05	267.33**	24.97
12	Fruit weight per plant (g)	492.88	17336.62**	172.35
13	Fruit yield per plot (kg.)	14.26	58.03 *	3.14
14	Fruit yield per (ha)	17.08	6433.2 **	128.86

** Significant at 1% levels of significance

* Significant at 5% levels of significance

The estimates of mean, range, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability (h^2) and genetic advance as percentage of mean (GA) for different characters are presented in Table 2.

High magnitude to genotypic coefficient of variation (GCV) coupled with phenotypic coefficient of variation (PCV) *i.e*., (>20%) were observed in characters namely; fruit weight per plant (35.394 and 35.923), Fruit yield per plot (28.684 and 30.047), fruit yield per hac. (24.077 and 24.804), fruit length (21.161 and 22.142) and fruit weight (20.791 and 22.142). Moderate magnitude of genotypic and phenotypic coefficient of variance observed character namely; numbers of fruit per plant (19.568 and 22.388), total numbers of picking (16.696 and 19.178), fruit girth (14.942 and 16.474).Low genotypic and phenotypic variability observed in days to last picking (4.059 and 6.103), plant height (5.132 and 9.327), days to 50% flowering (5.333 and 10.174), and days to first fruit picking (6.703 and 9.268) numbers of branches (8.576 and10.948) days to first flowering (9.213and 12.722).

These findings are in consonance with the findings by number of primary branches and number of fruits per plant, Sharma *et al*. (2010) [2] for fruit yield per plant Rosmania *et al*. (2016) for days to first fruit flowering and Kavitha *et al*. (2018) [5] for fruit length. The traits which showed high genotypic and phenotypic coefficient of variation are important for improvement in yield. There is scope for improvement of these traits through selection.

High heritability (>70%) was recorded for fruit weight per plant (97.076%), fruit yield per hac. (94.223%), fruit length (91.338.%), fruit yield per plot (85.3%), fruit weight (84.422%), fruit girth (82.267%), numbers of fruit per plant (76.389%), total numbers of picking (75.784%).

The present findings on heritability align with the findings reported by Ganiger and Yenjierappa (2001) regarding plant height and number of primary branches. Similarly, Datta *et al*. (2013) [16] reported similar findings for the number of primary branches, Usman *et al*. (2014) [6] for fruit length, and Nahak *et al*. (2018) [7] for fresh fruit weight.

Highest estimates of heritability coupled with genetic advance as % of mean (>40%) observed for fruit weight per plant

(71.83%), fruit yield per plot (54.590%), fruit yield per hactare (48.144%), fruit length (41.661) The high genetic advance % for these characters showed that these characters are governed by additive gene action and selection will be rewarding for the further improvement of such traits.

Similar finding reported by Shrishat *et al*. (2007) [8] for fruit length, number of fruits per plant, Sharma *et al*. (2010) [2] for fruit girth and fresh weight, number of primary branches, Patel *et al*. (2015) for fruit weight and fruit yield per plant and Kumar *et al*. (2020) [9] for fruit yield per hactare Moderate heritability coupled with moderate genetic advance was observed for characters namely; fresh fruit weight, plant height. Similar finding reported by Sharma *et al*. (2010) [2] for fresh weight.

Table 2: Estimation of genetic parameter of variation for fruit yield and its attributing traits in hot pepper

S. No.	Parameters	Mean	Range		Coefficient of variation (%)	Heritability (%)		Genetic Advance	Genetic Advance
			Minimum	Maximum	Genotypic	Phenotypic		K=20.6	as% of mean
1	Plant height (cm)	72.767	65.82	80.17	5.132	9.327	30.270	4.232	5.816
2	Number of branches	13.022	10.8	14.7	8.576	10.948	61.36	1.80	13.84
3	Days to first flowering	45.722	37.67	51.33	9.213	12.722	52.448	6.28	13.74
4	Days to 50% flowering	52.25	45.67	59.33	5.533	10.174	29.577	3.23	6.199
5	Days to first fruit picking	83.917	77.00	94.67	6.703	9.268	52.307	8.38	9.98
6	Total number of picking	5.52	3.67	6.67	16.696	19.178	75.784	1.66	29.94
7	Days to last picking	164.22	157.67	173.67	4.059	6.103	44.234	9.035	5.56
8	Fruit length (cm)	9.680	6.68	13.31	21.161	22.142	91.338	4.033	41.661
9	Fruit girth (cm)	3.773	2.84	4.72	14.942	16.474	82.267	1.053	27.918
10	Fresh fruit weight (g)	4.555	3.15	6.17	20.791	22.628	84.422	1.793	39.352
11	Number of fruits per plants	45.993	28.74	56.52	19.568	22.388	76.389	16.183	35.231
12	Fruit weight per plant (g)	213.71	88.82	331.54	35.394	35.923	97.076	153.53	71.83
13	Fruit yield per plot (kg)	14.91	7.30	21.22	28.684	31.047	85.3	8.141	54.590
14	Fruit yield per hactare (q)	190.40	127	261.22	24.077	24.804	94.223	91.669	48.144

The study conducted simple correlation coefficients (both phenotypic and genotypic) (Table-3 & 4) to examine the relationship between yield and its various components, as well as quality parameters.

Fruit yield per ha. (yield)had highly positively and significantly correlated both at genotypic and phenotypic levels with fruit yield per plot, numbers of fruit per plant, fruit weight per plant, fresh fruit weight, fruit length, fruit girth, plant height, total numbers of picking. whereas days to first flowering and days to 50% flowering this character showed negative significant correlation. Similar finding is reported by Nehru *et al*. (2003) [10], Gogoi and Gautam (2002) [11], Sandeep (2007) [12], Datta and Jana (2010), and Patel *et al*. (2009).

Table 3: Geno Table-4: phenotypic coefficient of correlation for fruit yield and yield attributing character in chilli

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		0.086	-0.232	-0.289	-0.104	0.520**	-0.079	0.581**	0.501**	0.464**	0.406*	0.607**	0.626**	0.611**
2			0.294	0.252	0.096	0.002	-0.160	0.163	-0.273	0.392*	-0.401*	0.010	-0.159	-0.087
3				0.550**	0.255	-0.375*	0.063	-0.488**	-0.334*	-0.272	-0.492**	-0.511**	-0.556**	-0.489**
4					0.222	-0.337*	-0.022	-0.366*	-0.280	0.019	-0.358*	-0.333*	-0.498**	-0.369*
5						-0.285	0.115	-0.293	0.023	0.025	-0.379*	-0.166	-0.367*	-0.179
6							0.128	0.501**	0.413*	0.446**	0.626**	0.712**	0.724**	0.733**
7								-0.219	-0.169	-0.314	-0.137	-0.238	-0.180	0.022
8									0.510**	0.667**	0.262	0.724**	0.569**	0.492**
9										0.545**	0.311	0.706**	0.512**	0.510**
10											0.062	0.793**	0.478**	0.559**
11												0.569**	0.730**	0.702**
12													0.831**	0.861**
13														0.888**
14														

1. Plant height (cm)
2. Number of branches per plant
3. Days to first flowering
4. Days to 50% flowering
5. Days to first fruit picking
6 Total number of picking
7. Days to last picking
8. Fruit length (cm)
9. Fruit girth (cm)
10. Fruit weight (g)
11. Number of fruits per plants
12. Fruit weight per plant (g)
13. Fruit yield per plot (kg)
14.fruit yield per hac. (q.)

Table 4: Phenotypic coefficient of correlation for fruit yield and yield attributing character in chilli

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1		0.086	-0.232	-0.289	-0.104	0.520**	-0.079	0.581**	0.501**	0.464**	0.406*	0.607**	0.626**	0.611**
2			0.294	0.252	0.096	0.002	-0.160	0.163	-0.273	0.392*	-0.401*	0.010	-0.159	-0.087
3				0.550**	0.255	-0.375*	0.063	-0.488**	-0.334*	-0.272	-0.492**	-0.511**	-0.556**	-0.489**
4					0.222	-0.337*	-0.022	-0.366*	-0.280	0.019	-0.358*	-0.333*	-0.498**	-0.369*
5						-0.285	0.115	-0.293	0.023	0.025	-0.379*	-0.166	-0.367*	-0.179
6							0.128	0.501**	0.413*	0.446**	0.626**	0.712**	0.724**	0.733**
7								-0.219	-0.169	-0.314	-0.137	-0.238	-0.180	0.022
8									0.510**	0.667**	0.262	0.724**	0.569**	0.492**
9										0.545**	0.311	0.706**	0.512**	0.510**
10											0.062	0.793**	0.478**	0.559**
11												0.569**	0.730**	0.702**
12													0.831**	0.861**
13														0.888**
14														

1. Plant height (cm)
2. Number of branches per plant
3. Days to first flowering
4. Days to 50% flowering
5. Days to first fruit picking
6 Total number of picking
7. Days to last picking
8. Fruit length(cm)
9. Fruit girth (cm)
10. fruit weight (g)
11. Number of fruits per plants
12. Fruit weight per plant (g)
13. Fruit yield per plot (kg)
14.fruit yield per hac.(q.)

Phenotypic Path coefficient analysis revels that Maximum positive direct effect was observed for fruit yield per plot (0.515) followed by numbers of fruit per plant (0.464), fruit weight (0.428), fruit weight per plant (0.233), days to last pickings (0.353), fresh fruit weight (0.428) while, negative direct effect was observed for total numbers of pickings (-0.225), fruit length (-0.163).

The value of residual factor (0.05019) was found to be low thereby, suggesting that the effect of all the yield attributing characters on fruit yield per hectare has been studied and that not more contribution of other major yield component traits has been left to be monitored.

The above findings of path studies are in accordance with the finding of Sarkara *et al*. (2009), Singh *et al*. (2005) [13], Soares *et al*. (2017) [15], Srinivas *et al*. (2020) [14].

	Characters													
S. No.	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**
1	0.0153	0.00646	-0.01685	0.02459	-0.00598	-0.11722	-0.02795	-0.09482	-0.02396	0.19872	0.18888	0.14143	0.3228	0.611**
2	0.00131	0.07534	0.02138	-0.02151	0.00552	-0.00039	-0.05655	-0.02656	0.01304	0.16776	-0.18639	0.00233	-0.08184	-0.087
3	-0.00355	0.02215	0.0727	-0.04689	0.01469	0.08452	0.02238	0.07974	0.01596	-0.11645	-0.22856	-0.11907	-0.28653	-0.489**
4	-0.00442	0.01902	0.04001	-0.0852	0.01275	0.07601	-0.00775	0.05975	0.01337	0.00813	-0.16636	-0.07762	-0.25666	-0.369*
5	-0.00159	0.00724	0.01857	-0.0189	0.0575	0.06423	0.0407	0.04783	-0.00109	0.01051	-0.17597	-0.03879	-0.1893	-0.179
6	0.00795	0.00013	-0.02725	0.02872	-0.01638	-0.22551	0.04522	-0.08178	-0.01974	0.19108	0.29094	0.16594	0.3732	0.733
7	-0.00121	-0.01205	0.0046	0.00187	0.00662	-0.02883	0.35367	0.03567	0.00809	-0.13449	-0.06378	-0.0554	-0.0928	0.022
8	0.00889	0.01226	-0.0355	0.03118	-0.01684	-0.11295	-0.07728	-0.16327	-0.02438	0.28566	0.12161	0.16884	0.2933	0.492
9	0.00767	-0.02055	-0.02426	0.02383	0.00132	-0.09311	-0.05988	-0.08327	-0.04781	0.23327	0.14455	0.16466	0.2638	0.510
10	0.0071	0.02952	-0.01977	-0.00162	0.00141	-0.10063	-0.11108	-0.10892	-0.02604	0.42819	0.02891	0.18486	0.2465	0.559
11	0.00622	-0.03022	-0.03576	0.0305	-0.02177	-0.1412	-0.04855	-0.04273	-0.01487	0.02664	0.46465	0.13252	0.3762	0.702
12	0.00928	0.00075	-0.03714	0.02837	-0.00957	-0.16054	-0.08405	-0.11826	-0.03377	0.33958	0.26417	0.23309	0.4287	0.861
13	0.00958	-0.01196	-0.04039	0.04241	-0.02111	-0.16324	-0.06368	-0.09287	-0.02446	0.20475	0.33901	0.1938	0.5156	0.888

Effect =0.05019; Diagonal and bold values showed direct effect

1. Plant height (cm)
2. Number of branches per plant
3. Days to first flowering
4.Days to 50% flowering
5. Days to first fruit picking
6 Total number of picking
7. Days to last picking
8. Fruit length(cm)
9. Fruit girth (cm)
10. fruit weight (g)
11. Number of fruits per plants
12. Fruit weight per plant (g)
13. Fruit yield per plot (kg)
14. Fruit yield per hactare (q)

Conclusion

The analysis of variance, presented in Table 1, clearly suggests significant differences among the genotypes for all the characters (at P=0.01), indicating presence of significant genetic variability in the experimental material. High magnitude to genotypic coefficient of variation (GCV) coupled with phenotypic coefficient of variation (PCV) *i.e*., (>20%) were observed in characters namely; fruit weight per plant (35.394 and 35.923), Fruit yield per plot (28.684 and 30.047), fruit yield per hac. (24.077 and 24.804). High heritability (>70%) was recorded for fruit weight per plant (97.076%), fruit yield per hac. (94.223%), fruit length (91.338.%), fruit yield per plot (85.3%), fruit weight (84.422%), fruit girth (82.267%), numbers of fruit per plant (76.389%), total numbers of picking (75.784%). Fruit yield per ha. (yield)had highly positively and significantly correlated both at genotypic and phenotypic levels with fruit yield per plot, numbers of fruit per plant, fruit weight per plant, fresh fruit weight, fruit length, fruit girth, plant height, total numbers of picking. whereas days to first flowering and days to 50% flowering this character showed negative significant correlation .Phenotypic Path coefficient analysis revels that Maximum positive direct effect was observed for fruit yield per plot (0.515) followed by numbers of fruit per plant (0.464), fruit weight (0.428), fruit weight per plant (0.233), days to last pickings (0.353), fresh fruit weight

(0.428) while, negative direct effect was observed for total numbers of pickings (-0.225), fruit length (-0.163).

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