

Studies on Variability, Correlation and Path Analysis for Yield and Yield Contributing Characters in Broccoli (*Brassica oleracea* var. *italica*) under the Grid Region of Madhya Pradesh

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ABSTRACT

The present experiment was carried out to estimate the genetic variability, correlation and path analyses for yield and yield contributing traits in broccoli (*Brassica oleracea* var. *italica*). Analysis of variance revealed significant differences among all the genotypes for all the characters and indicated the presence of considerable variability existing among the genotypes for all the traits. High genotypic and phenotypic coefficient of variation was recorded for lateral head number (55.17 and 56.18) followed by lateral head yield (51.98 and 52.61) and average head yield (35.45 and 35.68). High heritability coupled with high genetic advance was recorded for average head yield followed by leaf length and days to head initiation, which indicated the presence of additive gene action; hence selection could be employed for these traits for exploiting higher selection response. The number of lateral heads (0.732), average head yield (0.710) and leaf width (0.519 cm) showed positive and significant correlation with total yield (g/plot). Path analysis showed that lateral head yield (0.9074), head length (0.1649 cm), average head yield (0.1128 g) and number of leaves (0.0639) had the greatest positive direct effects on overall yield (g/plot). Based on the overall findings of the present study, it was revealed that for the development of stable and high yielding varieties or F₁ hybrids, the following traits should be given more emphasis i.e. days to head initiation, leaf length, number of lateral heads, leaf width and number of leaves.

Key words: Variability, heritability, genetic advance, correlation, path analysis

INTRODUCTION

Sprouting broccoli is one of the most prominent members of the cole family, Brassicaceae. Broccoli is an Italian native that was brought to the United States of America in 1925 by Italian immigrants. Broccoli got its name from the Latin word "Brachium," which means "arm or branch". It is also referred to as Italian asparagus, sprout cauliflower and small sprouts. Broccoli is the most nutritious member of the cole family containing a variety of vitamins, iron and calcium. It is recommended for intake as a preventive measure for human cancer. Broccoli comes in a variety of colours, but green broccoli is the most popular. It's sold fresh, frozen and as salads. It includes 3.3% protein as well as significant amounts of thiamine, niacin and riboflavin and is recognized as a rich source of dietary carotenoids, which have been linked

to improved cardiovascular health. When ingested in the diet, it has health-promoting effects on humans and is known to protect humans against some specific chronic conditions such as cancer, cardiovascular disease and age-related sight degeneration. Furthermore, it is a good source of sulphorophane, a chemical with anticancer effects.

Broccoli was not considered a commercial crop in India until recently; hence, there are no genuine figures on its area and production. However, because of its high nutritional content and versatility, the crop is becoming increasingly popular in India's sophisticated cities. It is primarily grown in the hills of Himachal Pradesh, Uttarakhand, the Nilgiri Hills and India's northern plains. The total world production of cauliflowers and broccoli is 22.740 million MT. China (9.537 million MT) is the biggest producer followed by India (9.225

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million MT) and USA (0.998 million MT) in the world.

The breeding technique for developing high yielding and stable genotypes necessitates a thorough examination into the genetic make-up of all quantitative features that contribute to yield under specific agro-ecological conditions. Crop specific information on variability components such as PCV, GCV, heritability and genetic advance is vital for efficient utilization of available genetic variability. Information on genetic diversity, as well as phenotypic associations, is required to develop an efficient breeding plan for using available genetic variability. Sufficient diversity has been documented for morphological and economic features in broccoli, which could potentially be employed to improve these traits. Correlation and path coefficient analysis are the procedures that are successfully utilized for figuring out the rate of distinct yield components in different crops, leading to the selection of superior genotypes, to give a deeper insight of auxiliary features under selection.

MATERIALS AND METHODS

A field experiment was carried out at the CRC-1 farm, Department of Horticulture, School of Agriculture, ITM University Gwalior during the period October 2022 to February 2023. The experimental site was located at an altitude of 196 m above mean sea level and the area enjoys a warm sub-tropical climate. In this experiment, 10 varieties/hybrids of broccoli were evaluated in randomized block design with three replications. The seedlings were raised in nursery and one month old seedlings were transplanted into the main field at a spacing of 50 x 50 cm. All cultural operations like weeding, fertilizer application, irrigation, earthing up and spraying of pesticides were done as per the recommendations. Observations were recorded on five randomly selected competitive plants per replication for each entry on all 13 traits viz., plant height (cm), plant spread, days to central head initiation, days to central head harvest, head diameter (cm), head length, number of leaves, leaf length, leaf width, lateral head number, main head yield, lateral head yield and total yield g/plot. Data of five plants from each genotype were averaged replication-wise and

mean data were used for statistical analysis. The variability for different characters was estimated. Genotypic coefficients of variance (GCV) and phenotypic coefficients of variance (PCV), broad sense heritability (h^2), genetic advance and genetic advance as per cent over mean were calculated. Correlations between all the features under research were determined at the genotypic and phenotypic levels. The path coefficient analysis of component qualities with seed yield per plant was carried out. Statistical analyses were carried out using R Statistical Package.

RESULTS AND DISCUSSION

Variability is the most important characteristic feature of any population. Estimation of genetic variability is an important pre-requisite for realizing response to selection as the progress in breeding depends upon its amount, nature and magnitude of genetic variability. The breeder should have the capability of distinguishing the genetic and non-genetic components of variation occurring in a population. In the present investigation, a similar analysis of variability was carried out. The present study meets out, the extent of variability available in 13 genotypes collected from different sources and the scope of selection through heritability and genetic advance (Table 1).

High genotypic and phenotypic coefficients of variation were recorded for lateral head number (55.17 and 56.18), lateral head yield (51.98 and 52.61), average head yield (35.45 and 35.68) total yield (g/plot) (33.83 and 34.92). Moderate genotypic and phenotypic coefficients of variation were recorded for leaf length (18.92 and 19.81 cm), leaf width (10.91 and 13.47), plant height (9.09 and 9.97), days to initiation of head (9.10 and 9.65), head diameter (6.88 and 8.22), number of leaves (6.85 and 10.24), and plant spread (6.11 and 7.01). Low genotypic and phenotypic coefficient of variation was recorded for head length (3.98 and 5.21) and days to central head harvest (4.48 and 5.45). However the difference between the PCV and GCV was paltry, which indicated the high contribution of genetic component in phenotypic expression of these characters that provide higher selection efficiency. The results are in accordance with the findings of Kumar *et al.* (2017), Chatterjee *et al.* (2018), Gariya *et*

Table 1. Mean performance of 10 genotypes for 17 characters in broccoli

S. No.	Genotypes	Days to initiation of head	Plant height (cm)	Plant spread (cm)	Days to central head harvest	Head diameter (mm)	Head length (mm)	No. of leaves	Leaf length (cm)	Leaf width (cm)	Lateral head number	Lateral head yield (g)	Average head yield (g)	Total yield (g/plot)
1.	Flare Broccoli	52.67	45.96	49.45	73.33	27.36	13.51	12.33	38.96	19.19	7.67	19.33	215.37	4674.06
2.	Alphino Imported	53.33	49.73	48.86	76.67	28.36	13.00	10.33	43.60	17.69	4.00	14.83	113.50	3962.66
3.	Swarna F ₁	53.33	50.08	45.94	77.67	27.70	13.17	11.67	52.08	16.63	3.67	14.33	96.66	3357.17
4.	Americam Broccoli	56.33	48.89	47.00	84.00	28.13	14.14	10.33	39.72	15.21	6.33	11.17	151.72	2882.27
5.	Indica Green	53.33	41.02	45.69	74.67	29.28	12.65	12.00	26.86	15.37	3.67	8.33	124.54	2991.81
6.	Exotica Green 10	59.67	46.82	48.00	74.00	26.97	12.65	11.00	32.17	14.22	4.00	7.83	94.97	2607.47
7.	Omaxe Broccoli Green	54.67	47.37	47.63	75.33	32.43	12.02	11.67	36.12	15.93	3.00	9.15	74.50	2611.63
8.	Biocrave Broccoli	58.33	57.81	49.91	77.67	30.01	13.28	11.33	51.04	18.60	2.33	8.83	88.17	1498.67
9.	Luckey F ₁	53.00	48.46	42.43	76.00	30.60	13.13	11.00	41.88	13.13	0.00	0.00	115.16	2050.61
10.	Plantmans Giants	69.67	43.16	40.72	83.67	24.93	13.49	9.33	38.92	15.40	3.00	7.00	87.67	1805.50
	Mean	56.43	47.93	46.56	77.30	28.58	13.10	11.10	40.13	16.14	3.77	10.08	116.23	2844.18
	Min.	52.67	41.02	40.72	73.33	24.93	12.02	9.33	26.86	13.13	0.00	0.00	74.50	1498.67
	Max.	69.67	57.81	49.91	84.00	32.43	14.14	12.33	52.08	19.19	7.67	19.33	215.37	4674.06
	SE(d)	2.388	3.460	2.310	2.561	1.05	0.36	1.251	2.7.3	1.793	0.33	1.473	15.655	0.390
	C. D. (P=0.05)	5.055	7.325	4.890	5.3802	2.22	0.76	2.628	5.722	3.7679	0.69	3.118	33.145	0.825
	C. V. (%)	5.182	8.839	6.088	9.8370	4.50	3.37	13.930	8.248	13.610	10.60	17.894	16.472	16.916

al. (2019) and Lakshmi *et al.* (2022) in cauliflower.

According to the findings of this study, the phenotypic coefficient of variation was greater than the genotypic coefficient of variance for all 13 traits. Even PCV was higher than GCV, though the difference was quite small, implying that the environment had less influence on the evolution of these traits. As a result, these characters may be relied on, and easy selection can be practised to improve further.

Perusal of Table 2 indicated that the maximum heritability was recorded in average head yield (98.68%) pursued by lateral head yield (97.64%), lateral head number (96.44%), total yield (93.88%), leaf length (91.16%), days to initiation of head (88.92%) and plant height (83.09%), whereas the minimum heritability was observed in number of leaves (44.70%) followed by head length (58.25%) and leaf width (65.54%). Maximum genetic advance as per cent mean was recorded in lateral head number (111.61%), lateral head yield (105.81%), average head yield (72.54%), total yield (67.53%), leaf length (37.21%), leaf width (18.19), days to initiation of head (17.67%), plant height (17.07%) and head diameter (11.87%). However, minimum genetic advance as per cent mean was recorded in head length (6.25%), days to central head harvest (7.60%) and number of leaves (9.43%).

Low heritability along with low genetic advance was observed for plant spread (75.89 and 5.11), days to central head harvest (67.75 and 5.88), head diameter (70.06 and 3.39), head length (58.25 and 0.82), number of leaves (44.70 and 1.05) and leaf width (65.54 and 2.93). Moderate heritability along with low genetic advance was observed for days to initiation of head (88.92 and 9.97) and plant height (cm) (83.09 and 8.18). High heritability along with moderate genetic advance was observed for leaf length (91.16 and 37.21%), whereas high heritability along with high genetic advance was observed for lateral head number (96.44 and 4.20), lateral head yield (97.64 and 10.67), average head yield (98.68 and 84.31) and total yield (93.88 and 1920.62).

High heritability along with high genetic advance resulted due to additive gene effect thereby making the selection effective, whereas high heritability coupled with low genetic advance resulted in non-additive gene

Table 2. Variability, heritability (%) and genetic advance mean (%)

Genotypes	Mean	Min.	Max.	Var (g)	Var (p)	Heritability (%)	GA	GA% mean	GCV (%)	PCV (%)	% Cont.
Day to initiation of head	56.43	52.67	69.67	26.36	29.65	88.92	9.97	17.67	9.10	9.65	9.87
Plant height (cm)	47.93	41.02	57.81	18.99	22.85	83.09	8.18	17.07	9.09	9.97	8.52
Plant spread (cm)	46.56	40.72	49.91	8.09	10.67	75.89	5.11	10.97	6.11	7.01	10.45
Day to central head harvest	77.30	73.33	84.00	12.01	17.72	67.75	5.88	7.60	4.48	5.45	10.99
Head diameter (mm)	28.58	24.93	32.43	3.87	5.52	70.06	3.39	11.87	6.88	8.22	9.82
Head length (mm)	13.10	12.02	14.14	0.27	0.47	58.25	0.82	6.25	3.98	5.21	9.52
No. of leaves	11.10	9.33	12.33	0.58	1.29	44.70	1.05	9.43	6.85	10.24	8.60
Leaf length (cm)	40.13	26.86	52.08	57.64	63.24	91.16	14.93	37.21	18.92	19.81	6.28
Leaf width (cm)	16.14	13.13	19.19	3.10	4.72	65.54	2.93	18.19	10.91	13.47	9.62
Lateral head number	3.77	0.00	7.67	4.32	4.48	96.44	4.20	111.61	55.17	56.18	4.91
Lateral head yield (g)	10.08	0.00	19.33	27.46	28.12	97.64	10.67	105.81	51.98	52.61	4.91
Average head yield (g)	116.23	74.50	215.37	1697.41	1720.13	98.68	84.31	72.54	35.45	35.68	2.64
Total yield (g/plot)	2844	1499	4674	925971	986383	93.88	1920.62	67.53	33.83	34.92	3.88

effects, thereby hindering the selection effectiveness. The results are in accordance with the findings of Nagar *et al.* (2016), Singh *et al.* (2017) and Kumar *et al.* (2019).

The correlation coefficient is a statistical tool used to identify the relationships between different plant characteristics, which can then be used to inform selection for genetic yield improvement. Characters or character combinations may be a valuable predictor of high yield. In order to aid plant breeders in their selection processes, correlation studies improve the understanding of yield components. Improvement in yield requires investigation of the components' presence and the nature of their relationships with one another. For all the qualities, the amount of genotypic correlation was greater than the phenotypic correlation, indicating an inborn connection between different characters. The association between 13 characters was examined in the current study at both the phenotypic and genotypic levels (Table 3). The

number of lateral heads (0.732), average head yield (0.710), leaf width (0.519), plant spread (0.489) and number of leaves (0.486) was positively and significantly correlated with total yield. Average head yield had positive significant correlation with lateral head number (0.739) followed by total yield (710), head length (0.574), lateral head yield (0.550), and leaf width (0.396). Following total yield (0.712), leaf width (0.428), plant spread (0.449) and average head yield (0.728), lateral head yield (g) (0.837) demonstrated a positive and significant connection with lateral head number. Leaf width showed significant correlation with lateral head yield (0.691) followed by plant spread (0.511), lateral head number (0.428), leaf length (0.395) and total yield (0.383). Head length showed significant correlation with days to central head harvest (0.528) and average head yield (0.438). Head diameter, leaf count, plant spread and average head yield had positive significant correlations. Similar results were observed for curd

Table 3. Genotypic (above the diagonal) and phenotypic (below the diagonal) correlations in broccoli

Genotypes	1	2	3	4	5	6	7	8	9	10	11	12	13
1.	1												
2.	-0.102	1											
3.	-0.446*	0.406*	1										
4.	0.571**	0.079	-0.390*	1									
5.	-0.511**	0.255	0.307	-0.323	1								
6.	0.245	0.231	-0.146	0.528**	-0.405*	1							
7.	-0.497**	0.067	0.232	-0.426*	0.193	-0.189	1						
8.	-0.032	0.732**	0.13	0.253	-0.001	0.293	-0.053	1					
9.	-0.125	0.285	0.511**	-0.087	-0.018K	0.140	0.273	0.395*	1				
10.	-0.111	-0.19	0.449*	0.022	-0.380*	0.334	0.151	-0.159	0.428*	1			
11.	-0.283	0.05	0.574**	-0.137	-0.228	0.155	0.206	0.196	0.691**	0.813**	1		
12.	-0.374*	-0.206	0.245	-0.141	-0.217	0.438*	0.269	-0.155	0.301	0.728**	0.534**	1	
13.	-0.528**	-0.231	0.375*	-0.352	-0.181	0.091	0.34	-0.09	0.383*	0.712**	0.799**	0.688**	1

*Significant at P = 0.01 and **Significant at P = 0.05. Characters 1. Days to initiation of head, 2. Plant height, 3. Plant spread, 4. Day to central head harvest, 5. Head diameter, 6. Head length, 7. Number of leaves, 8. Leaf length, 9. Leaf width, 10. Lateral head number, 11. Lateral head yield, 12. Average head yield and 13. Total yield (g/plot).

Table 4. Path analysis (direct and indirect) effect on yield in broccoli (2022-23)

Genotypes		1	2	3	4	5	6	7	8	9	10	11	12	13
1.	G	-0.735	0.166	-0.318	0.187	0.266	0.177	-0.478	0.035	-0.073	0.151	-0.211	0.233	-0.600**
	P	-0.3177	0.0197	0.0207	-0.0654	0.0584	0.0404	-0.0317	0.0032	0.0203	0.0235	-0.2569	-0.0422	-0.528**
2.	G	0.133	-0.917	0.353	0.016	-0.149	0.14	-0.005	-0.387	0.164	0.214	0.047	0.13	-0.26
	P	0.0323	-0.1934	-0.0189	-0.009	-0.0291	0.0381	0.0043	-0.0719	-0.0462	0.0402	0.0456	-0.0232	-0.231
3.	G	0.366	-0.507	0.639	-0.149	-0.101	-0.097	0.392	-0.067	0.27	-0.559	0.473	-0.171	0.489**
	P	0.1417	-0.0784	-0.0465	0.0447	-0.0351	-0.0241	0.0148	-0.0128	-0.0827	-0.0949	0.5204	0.0277	0.375**
4.	G	-0.455	-0.047	-0.316	0.302	0.184	0.72	-0.576	-0.121	-0.074	-0.036	-0.098	0.101	-0.416*
	P	-0.1815	-0.0153	0.0182	-0.1145	0.037	0.087	-0.0272	-0.0249	0.0141	-0.0046	-0.1246	-0.0159	-0.352
5.	G	0.472	-0.329	0.156	-0.134	-0.414	-0.607	0.38	-0.01	-0.032	0.455	-0.235	0.138	-0.161
	P	0.1624	-0.0492	-0.0143	0.037	-0.1143	-0.0668	0.0123	0.0001	0.003	0.0803	-0.2069	-0.0245	-0.181
6.	G	-0.137	-0.135	-0.065	0.228	0.264	0.952	-0.298	-0.198	0.065	-0.472	0.18	-0.338	0.047
	P	-0.0779	-0.0447	0.0068	-0.0604	0.0463	0.1649	-0.0121	-0.0288	-0.0227	-0.0705	0.1408	0.0494	0.091
7.	G	0.672	0.008	0.479	-0.332	-0.301	-0.543	0.523	0.059	0.133	-0.267	0.3	-0.244	0.486**
	P	0.1578	-0.013	-0.0108	0.0487	-0.0221	-0.0312	0.0639	0.0052	-0.0443	-0.0319	0.187	0.0303	0.34
8.	G	0.056	-0.775	0.094	0.08	-0.009	0.411	-0.068	-0.458	0.157	0.189	0.148	0.084	-0.091
	P	0.0102	-0.1415	-0.0061	-0.029	0.0001	0.0483	-0.0034	-0.0983	-0.064	0.0335	0.178	-0.0175	-0.09
9.	G	0.155	-0.435	0.498	-0.065	0.038	0.179	0.201	-0.208	0.346	-0.587	0.63	-0.233	0.519**
	P	0.0398	-0.0552	-0.0238	0.01	0.0021	0.0231	0.0175	-0.0389	-0.1619	-0.0904	0.6267	0.0339	0.383**
10.	G	0.104	0.184	0.334	0.01	0.176	0.42	0.13	0.081	0.19	-1.069	0.606	-0.435	0.732**
	P	0.0353	0.0368	-0.0209	-0.0025	0.0435	0.055	0.0096	0.0156	-0.0693	-0.2113	0.7376	0.0821	0.712**
11.	G	0.214	-0.059	0.418	-0.041	0.134	0.237	0.216	-0.093	0.301	-0.895	0.724	-0.324	0.833**
	P	0.09	-0.0097	-0.0267	0.0157	0.0261	0.0256	0.0132	-0.0193	-0.1118	-0.1718	0.9074	0.0603	0.799**
12.	G	0.291	0.203	0.185	-0.052	0.097	0.547	0.217	0.065	0.137	-0.79	0.399	-0.589	0.710**
	P	0.1188	0.0398	-0.0114	0.0161	0.0248	0.0722	0.0172	0.0152	-0.0487	-0.1538	0.4847	0.1128	0.688**

*Significant at P=0.01 and **Significant at P=0.05. G–Genotypic and P–Phenotypic. Characters 1. Days to initiation of head, 2. Plant height, 3. Plant spread, 4. Days to central head harvest, 5. Head diameter, 6. Head length, 7. No. of leaves, 8. Leaf length, 9. Leaf width, 10. Lateral head number, 11. Lateral head yield, 12. Average head yield and 13. Total yield (g/plot).

diameter by Shree *et al.* (2019) and Lakshmi *et al.* (2022).

The path analysis reveals the relationship between the component characters and yield. It indicates the direct impact on yield as well as result of their indirect impact through one or more additional traits. As a result, route analysis aided in dividing the genotypic correlation coefficient into the direct and indirect effects of the component features on the yield, allowing for the effective development of improvement plans. If the yield and one of the components is caused by the direct effect; then selection can be done based on that relationship. But if the correlation is mainly due to indirect effect the breeder has to select the latter trait through which the indirect effect is exerted. Head length, lateral head yield, plant spread, number of leaves, leaf width and days to central head harvest all showed a favourable direct relationship (Table 4). The phenotypic path coefficient showed that lateral head yield (0.9074), head length (0.1649), average head yield (0.1128) and number of leaves (0.0639) had the greatest positive direct effects on overall yield. Similar results were shown by the Vanlalneihi *et al.* (2017). More leaves per plant had a direct, beneficial impact on yield (Lakshmi *et al.*, 2022). According to Kumar *et al.* (2017), net curd weight had a significant beneficial direct impact on the overall yield.

CONCLUSION

There was a significant range of variability existing among genotypes for practically all traits, indicating that there was a large possibility for crop genetic improvement. The small difference between GCV and PCV was maintained, demonstrating that environment had minimal influence on character expressions. As a result, selecting these features based on their phenotypic values became more successful. Head length and head diameter had high heritability and greater genetic advance suggesting that these qualities could be improved by selection. Total yield had high positive and significant correlation with lateral head yield, which was followed by lateral head number, average head yield, leaf width, plant spread, and number of leaves. This led researchers to conclude that these parameters could be taken into account for the development of elite hybrids through hybrid breeding through the development of inbred lines after pure line selection in succeeding generations.

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