Path Coefficient Analysis for Yield and Its Attributing Traits in Wheat (*Triticum aestivum* L.)

ABSTRACT

The experiment was carried out during *rabi* 2019-2020 at Crop Research Farm, Nawabganj of C.S. Azad University of Agriculture and Technology Kanpur, Uttar Pradesh (INDIA) for experiment. The experimental materials comprised of 100 treatments including 10 diverse parents, 45 F_1s and 45 F_2s were planted in randomized complete block design with three replications. Path analysis considered one of the best statistical methods which can help breeders to characterize the crop populations during the parent selection program and select the desirable genotypes for higher yield production. Path coefficients analysis showed that biological yield per plant has maximum and positive direct effect on grain yield per plant followed by number of tillers per plant at phenotypic level. Harvest index, plant height, seed hardness, tryptophan content, number of seed per spike and 1000 grain weight per plant had also positive direct influence on grain yield per plant. Rest of the traits has negative direct influenced grain yield per plant.

Keyword: *Path Coefficient analysis, direct and indirect effects, bread wheat.*

1. INTRODUCTION

Wheat is known as the “king of cereals” due to high productivity and prominent position it holds in the international food grain trade (Mandrah *et. al.* [1]) and It is the largest growing crop among all other cereal crops. “Wheat is used for both human and animal nutrition and plays an important role in the nutrition of rapidly growing populations both in our country and the world**.** It provides staple food to 40% of the world’s population with more calories and 20% of daily dietary protein than any other cereal” (LACC/IGW, 2018). Spring wheat is a highly self-pollinating annual cereal crop belonging to family Gramminae (*Poaceae*) and ploidy level is allohexaploid (2n = 6x = 42, AABBDD).

“At global level, it’s cultivated over 221.18 million ha and production of 774.74 million tons with an average productivity of 35 quintals per hectare. In India, it is grown in area of 31.36 million hectares with a production of 107.86 million tons and productivity of 34.4 quintals per hectare” (USDA [2]). **“**It is mainly grown in Indian states like Uttar Pradesh, Punjab, Haryana, Madhya Pradesh, Rajasthan, Bihar, Maharashtra, Gujarat, West Bengal, Uttarakhand and Himachal Pradesh. These states contribute about 98% of whole wheat production in the country. Uttar Pradesh ranks first with an area of 9.54 million ha and production of 32.75 million tons with an average productivity of 34.32 Q/ha. The productivity of wheat in other states compare lower than Punjab and Haryana. Punjab state has achieved the productivity level of 51.83 Q/ha” (Agricultural statistics at a glance [3]).

Breeding for high yield is the major objective in any crop improvement programme. The correlation between two traits is not a simple relationship but it is the sum of direct and indirect effects. Path analysis used firstly for plant breeding to choice of desirable characters from whole traits. It differs from correlation as it points out to cause and their relative importance whereas; the letter estimates the mutual correlation ignoring the causation. Therefore, path coefficient has emerged as a powerful and widely use in breeding programme to understanding the direct and indirect contribution of different traits to economic yield in crop plant so that relative importance of various yield contributing traits.

2. MATERIALS AND METHODS

The present experiment was conducted during *rabi* season 2019-2020 at Crop Research Farm, Nawabganj of CSAUA&T, Kanpur. The experimental material consisting of 100 treatments (10 parents, 45 F_1s and 45 F_2s) was sown in a Randomized Block Design with three replications followed by one line of each parents and 45 F_1 while two line of each 45 F_2 and length of each line was 3 meter with row to row and plant to plant distance 22.5 cm and 10 cm respectively. Harvesting and threshing are done in April and first week of May 2020. The observations were recorded for 15 quantitative and some quality traits namely, Days to flowering (75%), Days to maturity, Plant height (cm), Number of productive tillers per plant, Spike length (cm), Number of spikelet's per spike, Number of grains per spike, Biological yield per plant (g), Grain yield per plant (g), 1000 grain weight (g), Harvest index (%), biological yield per plant, Seed hardness, Protein content (%), Lysine content (%) and tryptophan content (%). The data was analyzed statistically for path-coefficient analysis was suggested by Wright [4] and as elaborated by Dewey and Lu [5].

3. RESULT AND DISCUSSION

In the present studies of path coefficient were performed for grain yield. Genotypic path diagram of yield attributing characters on grain yield in wheat for 100 treatments including 10 diverse parents, 45 F_1s and 45 F_2s wheat. Result of direct and indirect in different contributing traits and physiological traits with grain yield per plant at genotypic level. In the present studies, path coefficients analysis showed that biological yield per plant has maximum and positive direct effect on grain yield per plant followed by harvest index, plant height, seed hardness, tryptophan content, number of seed per spike and 1000-grain weight per plant had also positive direct influenced grain yield per plant. Similar result found for number of tillers per plant at genotypic level reported by Anwar *et al.* [6] and Gaurav *et al.* [7], for biological yield per plant. Rest of the traits have negative direct influenced grain yield per plant. The similar results were found by Bhushan *et al.* [8], Bhutta *et al.* [9] and Abo-Elwafa *et al.* [10].

3.1 Days to flower (75%)

Path analysis indicated the positive direct effect as well as indirect effects *via* plant height, number of productive tillers per plant, no of spikelets per spike, no. of seeds per spike, biological yield per plant, 1000 grain weight, seed hardness, protein content, lysine and tryptophan content whereas spike length, harvest index and tryptophan content contributed negative indirect effect.

3.2 Days to Maturity:

Path analysis indicated the negative direct effect to days to maturity on grain yield per plant with negative indirect effect *via* plant height, number of productive tiller per plant, number of spikelets per spike, number of grain per spike, biological yield per plant, 1000 grain weight, seed hardness, protein content and lysine content whereas positive indirect effect showed namely spike length, harvest index and tryptophan content. On the other side days to flower (75%) showed positive indirect effect on days to Maturity.

3.3 Plant height:

Path analysis indicated the positive direct effect on grain yield per plant along with positive indirect effect *via* number of productive tiller per plant, spike length, number of spikelets per spike, number of grain per spike, biological yield per plant, 1000 grain weight, and lysine content whereas negative indirect effect showed namely harvest index, seed hardness, protein content and tryptophan content. On the other side days to maturity and days to flower (75%) showed positive indirect effect on plant height. Plant height is the characters which contribute largely to grain yield reported by Bhutta *et al.* [9]. Plant height was the important contributor towards the grain yield suggested by Yadav *et al.* [11].

3.4 Number of productive tiller per plant:

Path analysis indicated the positive direct effect on grain yield per plant with positive indirect effect *via* spike length, number of spikelets per spike, number of grains per spike, biological yield per plant, 1000 grain weight, seed hardness, protein content and lysine content whereas negative indirect effect showed namely harvest index and tryptophan content. On the other side days to flower (75%) and plant height showed positive indirect effect on number of productive tillers per plant. Number of productive tillers per plant should also be considered during selection for getting high yielding genotypes reported by Joshi *et al.* (2008). Number of productive tillers per plant indicated that these were main contributor to the grain yield reported by Bhushan [8]. Number of spikes m^{-2} or number of productive tiller per plant can be used as selection criteria in breeding study to improve the high yielding wheat genotypes reported by Ojha *et al.* [12].

3.5 Spike length:

Path analysis indicated the negative direct effect on grain yield per plant along with negative indirect effect *via* number of spikelets per spike, number of grains per spike, biological yield per plant, 1000 grain weight, harvest index, seed hardness, lysine content and tryptophan content whereas positive indirect effect showed namely protein content. On the other side days to flower (75%) and days to maturity showed positive indirect effect on spike length while plant height and number of productive tiller negative indirect effect on spike length. Spike length is the character which contributes largely to grain yield suggested by Bhutta *et al.* [9]. It can be used as a selection index for the improvement of yield found by Yadav *et al.* [11].

3.6 Number of spikelets per spike:

Path analysis indicated the positive direct effect on grain yield per plant along with positive indirect effect *via* number of grains per spike, biological yield per plant, 1000 grain weight, harvest index, seed hardness, protein content, lysine and tryptophan content. On the other hand number of spikelets per spike length showed positive direct effect on grain yield per plant *via* plant height, number of productive tillers per plant, spike length and number of spikelets per spike and spike length. It can be used as a selection index for the improvement of yield suggested by Yadav *et al.* [11]. Number of spikelets per spike showed that these were main contributors to the grain yield reported by Bhushan [8]. Number of spikelets per spike is the best selection index to improve the cereal yield reported by Abdulhamed *et. al.* [13].

3.7 Number of grains per spike:

Path analysis indicated the positive direct effect on grain yield per plant along with positive indirect effect *via* biological yield per plant, 1000 grain weight, seed hardness, protein content and lysine content whereas negative indirect effect showed namely harvest index and tryptophan content. On the other hand number of grain per spike showed positive direct effect on grain yield per plant *via* plant height, number of productive tillers plant, spike length and number of spikelets per spike, spike length and number of spikelets per spike. Grain filling period is an important factor and Number of grains per spike should also be considered during selection for getting high yielding genotypes reported by Joshi *et al.* [14].

3.8 Biological yield per plant:

Path analysis indicated the highest positive direct effect of biological yield per plant on grain yield per plant along with positive indirect effect *via* 1000 grain weight, seed hardness, protein content and lysine content whereas negative indirect effect showed namely harvest index and tryptophan content. On the other hand biological yield per plant showed positive direct effect on grain yield per plant *via* days to flower (75%), days to maturity, plant height, number of productive tillers plant, spike length and number of spikelets per spike, spike length, number of spikelets per spike, number of grain per spike and biological yield per plant. Biological yield per plant observed that these were main contributors to the grain yield observed by Bhushan [8]. Sharma *et. al*. [15] suggests that biological yield per plant can be used as selection criteria in breeding study to improve the high yielding in wheat.

3.9 1000 grain weight:

Path analysis indicated the negative direct effect of 1000 grain weight on grain yield per plant along with positive indirect effect via harvest index, lysine content and tryptophan content whereas negative indirect effect showed namely seed hardness and protein content. On the other hand 1000 grain weight showed negative direct effect on grain yield per plant via days to flower (75%), days to maturity, plant height, number of productive tillers plant, spike length and number of spikelets per spike, spike length, number of spikelets per spike, number of grain per spike and biological yield per plant. 1000 grain weight is the characters which contribute largely to grain yield suggested by Bhutta *et al.* [9]; Test weight showed that these were main contributors to the grain yield reported by Bhushan [8]; 1000 grain weight is the best selection index to improve the cereal yield similar result found by Abdulhamed *et. al*. [13].

3.10 Harvest index:

Path analysis indicated the highly positive direct effect of harvest index on grain yield per plant along with positive indirect effect *via* protein content, lysine content and tryptophan content whereas negative indirect effect showed namely seed hardness. On the other hand harvest index showed negative direct effect on grain yield per plant via days to flower (75%), days to maturity, plant height, number of productive tillers plant, number of grain per spike, biological yield per plant and showed positive direct effect on grain yield per plant *via* spike length, number of spikelets per spike and 1000 grain weight. Similar result found and he suggested main contributors to the grain yield by Bhushan [8]) and Sharma *et. al*. [15] suggests that harvest index can be used as selection criteria in breeding study to improve the high yielding in wheat genotypes. Harvest index is the best selection index to improve the cereal yield suggested by Abdulhamed *et. al*. [13].

3.11 Seed Hardness:

Path analysis indicated the positive effect on grain yield per plant along with positive indirect effect *via* protein content and lysine content whereas negative indirect effect showed namely tryptophan content. On the other hand seed hardness showed positive direct effect on grain yield per plant via days to flower (75%), days to maturity, number of productive tillers plant, spike length, number of spikelets per spike, number of grain per spike, biological yield per plant and 1000 grain weight and seed hardness showed negative direct effect on grain yield per plant *via* plant height and harvest index.

3.12 Protein content:-

Path analysis indicated the negative direct effect of protein content on grain yield per plant along with positive indirect effect via lysine content and tryptophan content. On the other hand protein content showed negative direct effect on grain yield per plant *via* days to flower (75%), days to maturity, number of productive tillers plant, number of spikelets per spike, number of grain per spike, biological yield per plant, 1000 grain weight and seed hardness and seed hardness showed positive direct effect on grain yield per plant via plant height and spike length.

3.13 Lysine content:

Path analysis indicated the negative direct effect of Lysine content on grain yield per plant along with negative indirect effect via tryptophan content. On the other hand protein content showed negative direct effect on grain yield per plant via days to flower (75%), days to maturity, plant height, number of productive tillers plant, number of spikelets per spike, number of grain per spike, biological yield per plant, seed hardness and seed hardness showed positive direct effect on grain yield per plant via 1000 grain weight and protein content.

3.14 Tryptophan content:

Path analysis indicated the positive direct effect of tryptophan content on grain yield per plant. On the other hand protein content showed negative direct effect on grain yield per plant *via* days to flower (75%), days to maturity, plant height, number of productive tillers plant, number of grain per spike, biological yield per plant, seed hardness and protein content and showed positive direct effect on grain yield per plant *via* spike length, number of spikelets, harvest index and lysine content.

The contribution of residual (0.0212) effects that influenced grain yield per plant was very low at genotypic levels, indicating that the traits included in the present investigation were sufficient enough to account for the variability in the dependent character i.e. seed yield per plant.

4. CONCLUSION

Path analysis considered one of the best statistical methods which can help breeders to characterize the crop populations during the parent selection program and select the desirable genotypes for higher yield production. The results of the current study exhibit that various traits such as number of productive tiller per plant, harvest index, 1000 grain weight, biological yield per plant, number of grain per spike, number of spikelets per spike and spike length can be used to create high yielding wheat varieties under breeding or crop improvement programs.

Table 1(a). Estimates of genotypic path coefficient for 15 characters of 10 parent diallel cross set of wheat

Characters	Days to flower (75%)	Days to Maturity	Plant height (cm)	No. of productive tillers/ plant	Spike length (cm)	No. of spikelets /spike	No. of grains per spike	Bio logical yield / plant (g)	1000 grain weight (gm)	Harvest index (%)	Seed Hard nees (kg)	Protein content (%)	Lysine content (%)	Trypto phan content (%)	Grain yield per plant (g)
Days to flower (75%)	**0.0050**	-0.0879	0.0069	0.0539	0.0013	0.0020	0.0036	0.2889	-0.0003	-0.1563	0.0114	-0.0057	-0.0079	-0.0009	0.114*
Days to maturity	0.0045	**-0.0963**	0.0052	0.0497	0.0048	0.0025	0.0039	0.2711	-0.0003	-0.1469	0.0138	-0.0084	-0.0055	-0.0015	0.097
Plant height (cm)	0.0011	-0.0157	**0.0317**	0.0371	-0.0026	0.0004	0.0013	0.1853	-0.0001	-0.1054	-0.0029	0.0027	-0.0058	-0.0017	0.125*
No. of tillers / plant	0.0022	-0.0397	0.0097	**0.1206**	-0.0092	0.0031	0.0033	0.4382	-0.0002	-0.1206	0.0159	-0.0021	-0.0095	-0.0006	0.411**
Spike length (cm)	-0.0002	0.0110	0.0019	0.0263	**-0.0421**	0.0045	0.0023	0.0993	-0.0001	0.2111	0.0156	0.0014	-0.0042	0.0017	0.328**
No. of spikelets/spike	0.0007	-0.0166	0.0009	0.0254	-0.0131	**0.0145**	0.0037	0.0536	-0.0001	0.1459	0.0212	-0.0075	-0.0192	0.0035	0.213**
No. of grains/spike	0.0013	-0.0279	0.0031	0.0297	-0.0070	0.0040	**0.0135**	0.3237	-0.0005	-0.2587	0.0258	-0.0040	-0.0002	-0.0030	0.100
Biological yield/plant (g)	0.0017	-0.0306	0.0069	0.0620	-0.0049	0.0009	0.0051	**0.8526**	-0.0004	-0.7675	0.0240	-0.0011	-0.0072	-0.0018	0.140*
1000 grain weight (g)	0.0008	-0.0182	0.0011	0.0175	-0.0014	0.0010	0.0042	0.2127	**-0.0017**	0.0179	0.0179	-0.0085	0.0050	-0.0003	0.248**
Harvest index (%)	-0.0006	0.0116	-0.0027	-0.0119	-0.0073	0.0017	-0.0029	-0.0372	0.0007	**0.7170**	-0.0136	-0.0024	-0.0019	0.0006	0.651**
Seed Hardness (kg)	0.0008	-0.0187	-0.0013	0.0271	-0.0093	0.0043	0.0049	0.2881	-0.0004	-0.2342	**0.0709**	-0.0098	-0.0114	-0.0005	0.111
Protein content (%)	0.0009	-0.0247	-0.0026	0.0077	0.0017	0.0034	0.0017	0.0280	-0.0004	0.0881	0.0213	**-0.0326**	0.0015	-0.0001	0.094
Lysine content (%)	0.0008	-0.0111	0.0039	0.0239	-0.0037	0.0058	0.0001	0.1287	0.0010	0.0489	0.0159	0.0010	**-0.0479**	0.0051	0.172**
Tryptophan content (%)	-0.0002	0.0056	-0.0022	-0.0028	-0.0028	0.0020	-0.0026	-0.0605	0.0006	0.0287	-0.0021	0.0014	-0.0099	**0.0250**	-0.020

Resi = 0.0212

*, ** significant at 5% and 1% level, respectively.

Table 1(b). Estimates of phenotypic path coefficient for 15 characters of 10 parent diallel cross set of wheat

Characters	Days to flower (75%)	Days to Maturity	Plant height (cm)	No. of productive tillers / plant	Spike length (cm)	No. of spikelets / spike	No. of grains per spike	Biological yield per plant (g)	1000 grain weight (gm)	Harvest index (%)	Seed Hardnees (kg)	Protein content (%)	Lysine content (%)	Tryptophan content (%)	Grain yield / plant (g)
Days to flower (75%)	**-0.0423**	-0.0241	0.0061	0.0429	0.0004	0.0009	0.0039	0.2514	0.0021	-0.1344	0.0025	-0.0002	-0.0014	-0.0008	0.107
Days to maturity	-0.0348	**-0.0293**	0.0043	0.0345	0.0002	-0.0010	0.0046	0.2268	0.0026	-0.1320	0.0049	-0.0003	-0.0012	-0.0007	0.079
Plant height (cm)	-0.0083	-0.0040	**0.0312**	0.0216	-0.0001	0.0070	0.0014	0.1618	0.0005	-0.0939	-0.0010	0.0001	-0.0010	-0.0009	0.114*
No. of tillers / plant	-0.0155	-0.0086	0.0076	**0.1170**	-0.0005	-0.0010	0.0028	0.3183	0.0021	-0.0477	0.0043	-0.0001	-0.0017	-0.0003	0.377**
Spike length (cm)	0.0006	0.0014	0.0012	0.0178	**-0.0032**	-0.0020	0.0037	0.0748	0.0005	0.1566	0.0072	0.0002	-0.0008	0.0010	0.259**
No. of spikelets/spike	-0.0055	-0.0049	0.0002	0.0186	-0.0015	**-0.0040**	0.0047	0.0545	0.0010	0.1029	0.0057	-0.0002	-0.0032	0.0017	0.170**
No. of grains/spike	-0.0098	-0.0080	0.0026	0.0200	-0.0007	-0.0010	**0.0166**	0.2743	0.0055	-0.2189	0.0081	-0.0002	0.0000	-0.0016	0.087
Biological yield/plant (g)	-0.0137	-0.0085	0.0065	0.0479	-0.0003	0.0050	0.0059	**0.7743**	0.0037	-0.6939	0.0073	-0.0003	-0.0013	-0.0010	0.131*
1000 grain weight (g)	-0.0060	-0.0051	0.0010	0.0163	-0.0001	0.0000	0.0049	0.1898	**0.0151**	0.0493	0.0056	-0.0003	0.0007	-0.0001	0.271**
Harvest index (%)	0.0050	0.0034	-0.0026	-0.0049	-0.0004	0.0011	-0.0032	-0.0723	0.0007	**0.7425**	-0.0041	-0.0001	-0.0004	0.0003	0.665**
Seed Hardness (kg)	-0.0054	-0.0042	-0.0012	0.0140	-0.0006	-0.0010	0.0049	0.2078	0.0031	-0.1711	**0.0284**	-0.0004	-0.0013	-0.0002	0.073
Protein content (%)	-0.0049	-0.0054	-0.0027	0.0083	0.0004	-0.0010	0.0018	0.0163	0.0033	0.0832	0.0083	**-0.0015**	0.0001	-0.0010	0.105
Lysine content (%)	-0.0050	-0.0030	0.0027	0.0167	-0.0002	-0.0010	0.0002	0.0880	-0.0010	0.0431	0.0040	0.0002	**-0.0116**	0.0022	0.135*
Tryptophan content (%)	0.0022	0.0013	-0.0017	-0.0021	-0.0002	0.0014	-0.0164	-0.0343	-0.0007	0.0250	-0.0003	0.0004	-0.0016	**0.0157**	-0.011

Resi = 0.0237

*, ** significant at 5% and 1% level, respectively.

REFERENCES

1. Mandrah J, Saxena K, Shrivastava SP, Mandloi R, Vikash Singh Thakur VS. Genetic analysis, correlation and path coefficient analysis among yield and yield attributing traits in wheat (*Triticum aestivum* L.) genotypes. Eur. Chem. Bull. 2023; 12(4):2098-2104.
2. USDA. United States Department of Agriculture; 2021.
3. Agricultural statistics at a glance. 2019.
4. Wright S. Correlation and causation. J. Agric. Res. 1921; 20:557-585.
5. Dewey D, Lu KH. A correlation and path coefficient analysis in crested wheat grass seed production. Agron. J. 1959; 51:515-518.
6. Anwar J, Ali MA, Hussain M, Sabir W, Khan, MA, Zulkiffal M, Abdullah M. Assessment of yield criteria in bread wheat through correlation and path analysis. J. Anim. and Plant Sci. 2009; 19(4):185-188.
7. Gaurav BB, Verma SS, Ali PNM, Meena MR. Character association and genetic divergence for quantitative traits in bread wheat. Annals of Biology. 2014; 30(1):62-67.
8. Bhushan B, Bharti S, Ojha A, Pandey M, Gourav SS, Tyagi BS, Singh G. Genetic variability, correlation coefficient and path analysis of some quantitative traits in bread wheat. J. Wheat Res. 2013;5(1):21-26.
9. Abo-Elwafa A, El-Taib ABA, Abo-Sapra HM, Bakheit BR. Path Coefficient Analysis for Grain Yield and Some of its Attributes in Bread wheat (*Triticum aestivum* L.). Assiut J. Agric. Sci. 2023; 54(1):1-18.
10. Bhutta WM, Akhtar J, Anwar-ul-Haq M, Ibrahim M. Cause and effect relations of yield components in spring wheat (*Triticum aestivum* L.) under normal conditions. 2005 ; (ISSN: 1677-5600) Vol 17 Num 1.
11. Yadav A, Kumar A, Chandan R, Jaiswal JP. Correlation and path coefficient analyses for grain yield, its components and quality traits in bread wheat. Pantnagar Journal of research. 2013; 11(3):337-340.
12. Ojha R, Sarkar A, Aryal A, Rahul KC, Tiwari S, Poudel M, Pant KR, Shrestha J. Correlation and path coefficient analysis of wheat (*Triticum aestivum* L.) genotypes. Fmg. and Mngmt. 2018; 3(2):136-141.
13. Abdulhamed ZA, Abood NM, Noaman AH. Genetic Path Analysis and Correlation Studies of Yield and Its Components of Some Bread Wheat Varieties. IOP Conf. Series: Earth and Environmental Science 761 (2021) 012066.
14. Joshi BK, Mudwari A, Thapa DB. Correlation and path coefficients among quantitative traits in wheat (*Triticum aestivum* L.). Nep. J. of Scie. and Techn. 2008; 9(3):1-5.

15. Sharma P, Rana V, Sood V, Upmanayu S. Association and path analysis for agro-morphological traits among diverse wheat (*Triticum aestivum* L.) germplasm lines for Northern Hill Zone under rainfed conditions. Journal of Cereal Research. 2023; 14(3): 299-307.