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Correlation and Path Coefficient Analysis for Yield and Its Related Traits in Buckwheat (*Fagopyrum esculentum* Moench)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

An experiment was carried out to study the correlation and path analysis in 40 buckwheat genotypes during Rabi, 2021-2022 at the Department of Genetics and Plant Breeding, SHIATS, Allahabad in Randomized BlºCk Design with three replications to analyze correlation and path Analysis. Analysis of variance showed significant difference for seed yield and its components indicating presence of large amount of variability in the genotypes. The magnitude of GCV and PCV recorded highest for economic yield, plant height, time of beginning of flowering, number of branches, test weight, days to 50% flowering. High heritability coupled with high genetic advance as percent mean was recorded for economic yield, plant height, time of beginning of flowering, test weight, number of branches, days to 50% flowering, days to 80% maturity. Seed yield per plant showed a highly significant positive correlation with test weight and days to 80% maturity at both

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the genotypic and phenotypic levels. Path analysis revealed that test weight and time of beginning of flowering registered high and positive direct effect on seed yield per plant. It suggests that there is a true relationship between these traits, and that direct selection for these traits will be beneficial for yield improvement.

Keywords: Buckwheat; association; path analysis; correlation; Fagopyrum esculentum Moench.

1. INTRODUCTION

Buckwheat (*Fagopyrum esculentum* L.) has been a crop of secondary importance in many countries and being cultivated in every growing country. It is an underutilized and neglected crop from the last decades. Fagopyrum esculentum Moench is a herbaceous erect annual plant with diploid chromosome number (2n=16) that belongs to the Polygonaceae family. One of the most significant pseudo-cereal crops in the mountainous area is buckwheat, which is commonly grown between 1800 and 4500 metres above sea level during the kharif season in the middle and upper Himalayas. The optimum temperature required for germination is 25-28ºC and slightly high temperature (above 30ºC) at reproductive stage may result in floral abscission, poor grain quality and fruit abscission. The origin of buckwheat is temperate Central Asia. This crop is produced extensively in India's northern states of Sikkim, Assam, Arunanchal Pradesh, Nagaland, and Manipur as well as in Jammu & Kashmir, Himanchal Pradesh, and Uttarakhand. It is also sporadically cultivated in the Niligiris and Palni hills in Southern India.

Buckwheat seeds contains variety of nutrients, main compounds are starch 70 to 91% in flour. Starch is 25% amylose and 75% amylopectin and 7 to 37% of resistant starch Skrabanja et al. 2004. Protein content is around 15% with biological values above 90%. The buckwheat flour is gluten free [1], contains proteins with good balanced amino acids and it is particularly rich in lysine and arginine [2].

Buckwheat contains 2.5 times more lysine than wheat. It is a good source of rutin and kaempferol-3-rutinoside, and contains in traces flavonol triglycoside [3]. In addition to common buckwheat, in recent times tatary buckwheat is increasingly researched, which is also promoted and recommended as a valuable raw material in both the food and the pharmaceutical industry. Grains of tatary buckwheat contain traces of quercitrin and quercetin, flavonoids, which are not found in common buckwheat grain. Proteins of buckwheat are nutritionally more valuable than proteins of cereals, but do not contain gluten and are therefore suitable for people with celiac disease.

Genetic variability plays an important role in a crop for best selecting of genotypes for making rapid improvement in yield and other desirable characters as well as to select the potential parent for hybridization programmes. This crop having a greater genetic variation in seed yield and yield components. Heritability is an index for calculating the relative influence of environment on expression of genotypes. It becomes very difficult to judge how much of the variability is heritable and how much is non-heritable. Genetic advance under selection measures the role of genetic progress as the deviation between the mean genotypic value ofthe selected families and the mean genotypic value of the base population due to selection. Hence, correlation coefficients are worked out to describe the degree of association between independent and dependent variables.

2. MATERIALS AND METHODS

2.1 Experimental Site and Design

The experimental material for the present investigation comprised of a 40 accessions of buckwheat. The experimental materials carried out at Department of Genetics and Plant Breeding, Naini Agricultural Institute, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj. The genotypes are proured from National Bureau of Plant Genetic Resources, Shimla (Table 1). The experiment was laid out with three replications in a randomized blºCk design during *Rabi* 2021-2022. For the purpose of cultivating a healthy crop, the suggested packages of practices were followed, and all necessary steps were taken to protect the plants from pests and diseases.

Table 1. The genotypes used for this experiment

S. No.	Name of the genotype	Source	S. No.	Name of the genotype	Source
1	IC- 46160	ICAR	22	IC – 582990	ICAR
2	IC- 599211	ICAR	23	IC -107575	ICAR
3	IC- 16552	ICAR	24	IC- 582984	ICAR
4	IC- 356112	ICAR	25	IC- 1O7616	ICAR
5	IC- 47929	ICAR	26	IC- 37275	ICAR
6	IC- 341674	ICAR	27	IC- 329201	ICAR
7	IC- 37279	ICAR	28	IC- 329456	ICAR
8	IC- 447576	ICAR	29	IC- 37296	ICAR
9	EC- 216635	ICAR	30	EC- 125940	ICAR
10	EC- 323723	ICAR	31	IC- 341679	ICAR
11	SHIMLA- B-1	ICAR	32	IC- 26755	ICAR
12	HIMPRIYA	ICAR	33	IC – 318859	ICAR
13	VL-7	ICAR	34	IC -8817	ICAR
14	PRB- 1	ICAR	35	NIC- 24300	ICAR
15	CGBW 20-1	ICAR	36	IC- 329196	ICAR
16	CGBW 20-2	ICAR	37	IC- 42412	ICAR
17	IC-381463	ICAR	38	IC-14889	ICAR
18	IC-341672	ICAR	39	IC-37312	ICAR
19	IC-258233	ICAR	40	IC-26600	ICAR
20	IC-108508	ICAR	41	IC-329195	ICAR
21	IC –582972	ICAR			

2.2 Observations Recorded

The observations recorded on seven characters namely, plant height, time of beginning of flowering, days to 50% flowering, days to 80% maturity, no of branches, test weight and economic yield were subjected to statistical analysis. Statistical analysis of the data was subjected to analysis of variance (ANOVA). Calculations of ANOVA can be characterized as computing a number of means and variances, dividing two variances and comparing the ratio to a handbook value to determine statistical significance.

2.3 Statistical Analysis

1. Analysis of variance [4]
2. Coefficient of variation [5]
   a. Genotypic coefficient of variation (GCV)
   b. Phenotypic coefficient of variation (PCV)
3. Heritability broad sense [5]
4. Genetic advance [6]
5. Correlation coefficient analysis [7]
6. Path coefficient analysis [8]

3. RESULTS AND DISCUSSION

3.1 Analysis of Variance

The mean sum of squares values for 7 biometrical traits was presented Table 2. The mean sum of squares due to the genotypes were significant for all the characters studied at both level of significance 1% and 5%, suggesting the existence of high genetic variability among the genotypes for all the traits.

Table 2. Analysis of variance for 7 yield and yield contributing traits of 41 genotypes of Buckwheat

S. No.	Source	Replication	Treatment	Error
	Degrees of freedom	**2**	**40**	**80**
1	Plant height	48.53*	1060.28**	12.742
2	Time of beginning offlowering	0.1060	394.857**	0.797
3	Days to 50% flowering	2.9840	419.967**	1.959
4	Days to 80% maturity	0.1790	294.151**	1.381
5	No of branches	0.0350	5.401**	0.11
6	Test weight	2.386*	93.486**	0.572
7	Economic yield	1.662**	60.199**	0.19

*** Level of significance at 1%*

3.2 Phenotypic and Genotypic Coefficient of Variation

In the present investigation, it is depicted from the Table 3 that in general, estimates of phenotypic coefficient of variation was found higher than their corresponding genotypic coefficient of variation, indicating that the influence of environment on the expression of these characters. However, there was good correspondence between the genotypic coefficient of variation and the phenotypic coefficient in all characters. The genotypic and phenotypic coefficients of variation present are outlined below. High magnitude of genotypic coefficient of variation was recorded for economic yield (78.51), plant height (39.98), time of beginning of flowering (27.74), number of branches (25.9), test weight (25.58), days to 50% flowering (23.3) while it was moderate for days to 80% maturity (11.98). High magnitude of phenotypic coefficient of variation was observed for economic yield (78.89), plant height (40.7), time of beginning of flowering (27.83), number of branches (26.7), test weight (25.81), days to 50% flowering (23.46) while it was moderate for days to 80% maturity (12.06). From Table 3, it is clear that the phenotypic coefficient of variation values for all the traits under study were higher than the genotypic coefficient of variation values, implying the influence of environment on the studied characters. On an average high phenotypic and genotypic coefficient of variation were recorded for economic yield, plant height, time of beginning of flowering, number of branches, test weight, days to 50% flowering suggesting sufficient variability among these characters and thus offer scope for genetic improvement through effective selection. The outcomes are in agreement with the findings of Patial et al. [9], Hiremath et al. [10], Bisht et al. [11], Albert et al. [12] and Sowmya, et al. [13].

3.3 Heritability

High heritability was recorded (Table 3) for time of beginning of flowering (99.397), economic yield (99.057), days to 50% flowering (98.614), days to 80% maturity (98.604), test weight (98.188), plant height (96.479), number of branches (94.122). Estimates of broad sense heritability are calculated in this study, which contains both additive and non-additive gene effects. Higher values of broad sense heritability for the traits time of beginning of flowering, economic yield, days to 50% flowering, days to 80% maturity, test weight, plant height, number of branches indicate that these characters are less influenced by environment effect and selection on the basis of phenotypic performance of genotypes would be more efficient in further improvement of these traits. Most of the traits in the current study had high to moderate heritabilities, which suggested that there was a good chance that high yielding varieties could be developed through desirable selection in succeeding generations. Similar findings were reported by Patial et al. [9], Hiremath et al. [10], Bisht et al. [11] and Albert et al. [12].

3.4 Genetic Advance

High genetic advance was recorded (Table 3) for plant height (37.81), days to 50% flowering (24.147),time of beginning of flowering (23.538), days to 80% maturity (20.208) and moderate for test weight (11.36) while it was low for economic yield (9.17), number of branches (2.654). Moderate estimates of genetic advance were recorded for test weight indicating both additive and dominance gene effects. Hence, careful selection may lead towards improvement of these traits in Buck wheat.

3.5 Genetic Advance as Percent of Mean

High genetic advance as percent of mean was recorded (Table 3) for economic yield (160.971), plant height (80.887), time of beginning of flowering (56.981), test weight (52.212), number of branches (51.767), days to 50% flowering (47.659), days to 80% maturity (24.506). In the present investigation, high genetic advance as percent of mean coupled with high heritability was recorded for economic yield, plant height, time of beginning of flowering, test weight, number of branches, days to 50% flowering, days to 80% maturity indicating that these traits are most probably under the control of additive gene action and hence these traits can be fixed by proper selection. Similar results in Buck wheat have been reported by Patial et al. [9], Hiremath et al. [10], Misra et al. [14], Aubert et al. [12], Sowmya et al. [13].

Table 3. Genetic parameters for 7 biometrical traits of Buckwheat

Characters	GCV	PCV	h2 (Broad Sense)	Genetic Advance 5%	Gen. Adv as % of Mean 5%
Plant height	39.970	40.690	96.470	37.810	80.880
Time of beginning of flowering	27.744	27.829	99.397	23.538	56.981
Days to 50% flowering	23.297	23.461	98.614	24.147	47.659
Days to 80% maturity	11.980	12.064	98.604	20.208	24.506
No of branches	25.900	26.690	94.120	2.654	51.760
Test weight	25.578	25.813	98.188	11.360	52.212
Economic yield	78.512	78.885	99.057	9.170	160.971

PCV: Phenotypic Coefficient of Variation, GCV: Genotypic Coefficient of Variation, h^2bs:heritability (broad sense), GA: Genetic Advance, GAM: Genetic Advance as Percent of Mean

3.6 Correlation

Correlation coefficient analysis identifies the elite characters that serve as the foundation for selection in the genetic improvement of yield and reveals the mutual relationships between various yield components in the manifestation of yield. The genotypic correlation coefficients in the current study were typically higher than their corresponding phenotypic correlation coefficients (Table 4 and 5). Seed yield per plant had significant positive association with test weight (0.543**), days to 80% maturity (0.392**) and non-significant positive association with plant height (0.0965), number of branches per plant (0.0008) while it had significant negative association with days to 50% flowering (0.327**) and time of beginning of flowering (0.313**). Plant height had significant positive association with days to 80% maturity (0.332**), number of branches (0.274*), and non-significant positive association with test weight (0.0795), days to 50% flowering (0.0554), time of beginning of flowering (0.0330). Number of branches had significant negative association with test weight (-0.200*).

The traits *viz.,* test weight and days to 80% maturity were found to possess positive significant association with grain yield per plant at both genotypic and phenotypic levels. Hence, selection for these characters will help in selecting Buck wheat genotypes with high grain yield. Further, most of the character pairs had higher genotypic correlation coefficients compared to phenotypic correlation coefficients. Such high amounts of genotypic correlations could result due to masking effect of environment on the association of characters. This signifies that, while there was a high degree of association between two variables at the genotypic level, its phenotypic expression was deflated by the influence of environment. The above findings are in agreement with the findings of Dutta et al. [15], Debnath et al. [16], Li et al. [17], Huang et al. [18] and Bisht et al. [11].

3.7 Path Analysis

Path coefficient analysis reveals that the association of the characters with yield is due to their direct effect on yield or is a result of their indirect effects via other components characters. It is a reliable statistical technique, devised by Wright [19]. The estimates of path coefficients for yield attributing traits on seed yield are furnished in Table 6 and Fig. 1. The findings from the current investigation into both direct and indirect effects are described character-wise as follows:

Seed yield per plant had positive direct effect with test weight (0.6245), time of beginning of flowering (0.5291), number of branches (0.0869), plant height (0.0383) while it had negative direct effect with days to 50% flowering (-0.4709) and days to 80% maturity (-0.0201).

Plant height had positive indirect effect with days to 80% maturity (0.0127), no of branches (0.0105), test weight (0.003), days to 50% flowering (0.0021), time of beginning of flowering (0.0013). Time of beginning of flowering had positive indirect effect with days to 50% flowering (0.514), no. of branches (0.0418), plant height (0.0175) while it had negative indirect effect with days to 80% maturity -(0.2391) and test weight -(0.3408). Days to 50% flowering had positive indirect effect with test weight (0.2883), days to 80% maturity (0.188) while it had negative indirect effect with no. of branches (-0.0117), plant height (-0.0261), time of beginning of flowering (-0.4575). Days to 80% maturity had positive indirect effect with time of beginning of flowering (0.0091), days to 50% flowering (0.008) while it had negative indirect effect with no of branches(-0.0018), plant height (-0.0067) and test weight (-0.0142) [20-22].

Table 4. Phenotypic correlation among different traits in Buckwheat genotypes evaluated under rain fed conditions during *Rabi* 2021-2022

	Plant height	Time of beginning of flowering	Days to 50% flowering	Days to 80% maturity	No of branches	Test weight	Economic yield
Plant height	1.000	0.033	0.055	0.332**	0.274*	0.080	0.097
Time of beginning of flowering		1.000	0.972**	-0.452**	0.079	- 0.644**	-0.313**
Days to 50% flowering			1.000	-0.399**	0.025	- 0.612**	-0.327**
Days to 80% maturity				1.000	0.089	0.709**	0.392**
No of branches					1.000	-0.200*	0.001
Test weight						1.000	0.543**
Economic yield							1.000

Table 5. Genotypic correlation among different traits in Buckwheat genotypes evaluated under rainfed conditions during *Rabi* 2021-2022

	Plant height	Time of beginning of flowering	Days to 50% flowering	Days to 80% maturity	No of branches	Test weight	Economic yield
Plant height	1.000	0.035	0.062	0.338**	0.290*	0.079	0.098
Time of beginning of flowering		1.000	0.981**	-0.454**	0.086	-0.649**	-0.314**
Days to 50% flowering			1.000	-0.403**	0.021	-0.619**	-0.330**
Days to 80% maturity				1.000	0.092	0.714**	0.394**
No of branches					1.000	-0.203*	0.005
Test weight						1.000	0.547**
Economic yield							1.000

Table 6. Direct (in bold) and indirect effects of 7 traits on grain yield in Buckwheat

Traits	Plant height	Time of beginning of flowering	Days to 50% flowering	days to 80% maturity	No of branches	Test weight	Economic yield
Plant height	0.0383	0.0013	0.0021	0.0127	0.0105	0.003	0.0965
Time of beginning of flowering	0.0175	0.5291	0.514	-0.2391	0.0418	-0.3408	-0.313**
Days to 50% flowering	-0.0261	-0.4575	-0.4709	0.188	-0.0117	0.2883	-0.327**
Days to 80% maturity	-0.0067	0.0091	0.008	-0.0201	-0.0018	-0.0142	0.392**
No of branches	0.0238	0.0069	0.0022	0.0078	0.0869	-0.0174	0.0008
Test weight	0.0496	-0.4023	-0.3824	0.4428	-0.1249	0.6245	0.543**
Economic yield	0.0965	-0.313**	-0.327**	0.392**	0.0008	0.543**	1.000
Partial R^2	**0.0037**	**-0.1658**	**0.154**	**-0.0079**	**0.0001**	**0.3394**	

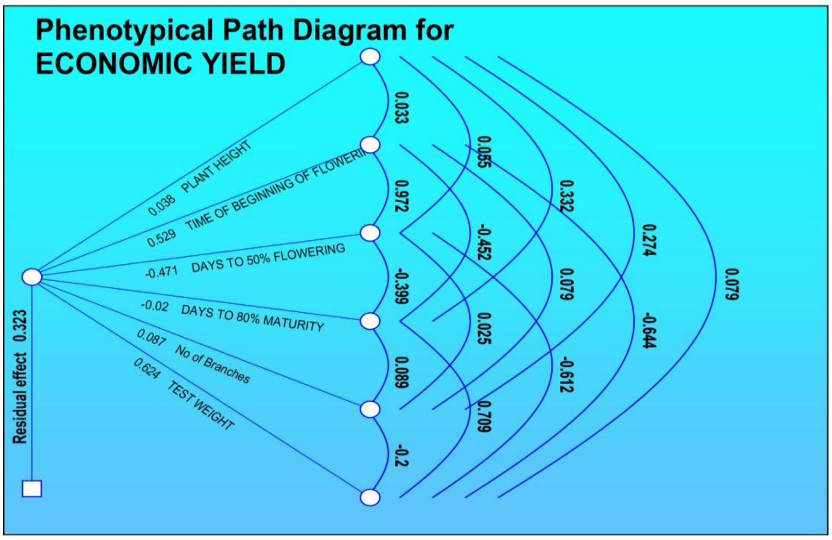

Fig. 1. Phenotypic path diagram for seed yield per plant

No. of branches had positive indirect effect with plant height (0.024), days to 80% maturity (0.008), time of beginning of flowering (0.007), days to 50% flowering (0.002) while it had negative indirect effect with test weight (-0.02). Test weight had positive indirect effect with days to 80% maturity (0.443), plant height (0.05) while it had negative indirect effect with no of branches (-0.12), days to 50% flowering (-0.38), time of beginning of flowering (-0.4). Similar results were observed with the findings of Kolaric et al. (2021), Bisht et al. [11], Li et al. [17] and Huang et al. [18].

4. CONCLUSION

The analysis of variance revealed a significant difference in seed yield and its components, indicating a high level of variability in the genotypes. The magnitude of GCV and PCV recorded highest for economic yield followed by plant height, time of beginning of flowering, number of branches, test weight, days to 50% flowering. High heritability coupled with high genetic advance as percent mean was recorded for economic yield followed by plant height, time of beginning of flowering, test weight, number of branches, days to 50% flowering, days to 80% maturity. Correlation at both genotypic and phenotypic level, seed yield per plant exhibited highly significant positive association with test weight and days to 80% maturity. According to path analysis, test weight and the time of flowering's onset had a significant, favorable direct impact on a plant's capacity for producing seeds. It suggests a real relationship between these traits, and that yield improvement in Buck wheat will benefit from direct selection for these traits.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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