Original Research Article

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

Abstract

The present study on correlation and path coefficient analysis for yield and yield contributing characters in forty genotypes of buckwheat to ascertain the genetic and phenotypic correlation and contribution of these traits towards the yield directly and indirectly in buckwheat. 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. Correlation at both genotypic and phenotypic level, seed yield per plant exhibited highly significant positive association with test weight and days to 80% maturity. Path analysis revealed that test weight and time of beginning of flowering registered high and positive direct effect on seed yield per plant. It indicates true relationship between these traits and direct selection for these traits will be rewarding for yield improvement.

Comment [A1]: The sentence structure in the abstract needs to be rearranged: Aims, study design, place and duration of study, methodology, results, and conclusion

Key Words: Buckwheat,Association, Path analysis, Correlation**,** *Fagopyrum esculentum*Moench

Introduction

Comment [A2]: the number of citations is very small, it is necessary to add citations from the latest recent research in this field

Fagopyrum esculentumMoench 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 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

(Joshi, 1999).

Buckwheat contains 2.5 times more lysine than wheat. It is a good source of rutin and kaempferol-3-rutinoside, and contains in traces flavonoltriglycoside (Wijngaard and Arendt, 2006). 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 (Kitabayashi et al., 1995). 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.

Geneticvariabilityplaysanimportantroleinacropforbestselectingofgenotypesfor making rapid improvement in yield and other desirable characters as well as to select thepotential parent for hybridization programmes. This crop having a greater genetic variation inseed yield and yield components. Heritability is an index for calculating the relative influenceof environment on expression of genotypes.It becomes very difficult to judge how much ofthe variability is heritable and how much is non-heritable. Genetic advance under selectionmeasuresthe role ofgenetic progress asthe deviation between themeangenotypicvalueofthe 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 betweenindependentanddependentvariables.

Materials and Methods

Comment [A3]: Material and Methods
With subtitle : area study, experimental design, data collection methods/measurement of research results, data analysis

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 procured from National Bureau of Plant Genetic Resources, Shimla (Table 1).

Table1. Thegenotypesusedforthisexperiment

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			

The experiment was laid out with three replications in a randomized block design during *Rabi* 2021-2022. The recommended packages of practices were followed for raising a healthy crop and all necessary plant protection measures were taken to control the pest and diseases. 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.

STATISTICAL ANALYSIS

1.Analysis of variance (**Cochran and Cox, 1957**)
2. Coefficient of variation (**Burton and De vane, 1952**)
   a. Genotypic coefficient of variation (**GCV**)
   b. Phenotypic coefficient of variation (**PCV**)
3. Heritability broad sense (**Burton and Devane, 1953**)
4. Genetic advance (**Johnson *et al.*, 1955**)
5. Correlation coefficient analysis (**Al Jibouri*et al.*, 1958**)
6. Path coefficient analysis (**Dewey and Lu, 1959**)

Results and Discussion

Comment [A4]: Discussion needs to be added by comparing with the latest studies in this field. not just the same or has been confirmed by previous research

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.

Table2:Analysisofvariancefor7yieldandyieldcontributingtraitsof41genotypesofBuckwheat

S.No.	Source	Replication	Treatment	Error
	Degreesoffreedom	**2**	**40**	**80**
1	**Plant height**	48.53*	1060.28**	12.742
2	**Time of beginning offlowering**	0.1060	394.857**	0.797
3	**Daysto50%flowering**	2.9840	419.967**	1.959
4	**Daysto80%maturity**	0.1790	294.151**	1.381
5	**Noofbranches**	0.0350	5.401**	0.11
6	**Testweight**	2.386*	93.486**	0.572
7	**Economicyield**	1.662**	60.199**	0.19

****Level ofsignificanceat1%**

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, good correspondence was observed genotypic coefficient of variation and phenotypic coefficient in all characters. The result of genotypic coefficient of variation and phenotypic coefficient of variation present are summarized below.

Genotypic coefficient of variation

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).

Comment [A5]: data in the table?.

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Phenotypic coefficient of variation

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 evident that phenotypic coefficient of variation values was higher than genotypic coefficient of variation for all the traits under study indicating the influence of environment on 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 results are in confirmity with the findings of **Patial et al. (2014)** and **Hiremath et al. (2017).**

Comment [A7]: How similarity.... the discussion needs to be added

Heritability

High heritability was recorded 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). In the present study estimates of broad sense heritability are computed which includes 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. High to moderate heritability for most of the traits in the present study indicated considerable potential for the development of high yielding varieties through desirable selection in succeeding generations. Similar findings were reported by **Patial et al. (2014)** and **Hiremath et al. (2017).**

Comment [A8]: data in the table?.

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Genetic advance

High genetic advance was recorded 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. Similar results were reported by Patial et al. (2014) and Hiremath et al. (2017).

Comment [A10]: data in the table?.

Comment [A11]: How similarity.... the discussion needs to be added

Genetic advance as percent of mean

High genetic advance as percent of mean was recorded 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. (2014) and Hiremath et al. (2017).

Comment [A12]: data in the table?.

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Table3:Geneticparametersfor7biometricaltraitsofBuckwheat

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:PhenotypicCoefficientofVariation,GCV:GenotypicCoefficientofVariation,h^2bs:heritability (broad sense), GA:GeneticAdvance,GAM: GeneticAdvanceas Percentof Mean

Correlation

Correlation coefficient analysis reveals about the mutual relationship between various yield components in the manifestation of yield and determines the elite characters which are the basis for selection in genetic improvement of yield. In the present investigation, the genotypic correlation coefficients were generally higher than their respective phenotypic correlation coefficients (Table 4 and 5).

Seed yield per plant had significant positive association with test weight (0.543**), days to80% 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 daysto50% flowering (0.327**) and time ofbeginning of flowering (0.313**). Plantheighthadsignificantpositiveassociationwithdaysto80%maturity(0.332**),numberofbranches(0.274*),andnon-significantpositiveassociationwithtestweight(0.0795),days to 50%flowering (0.0554), timeof beginning offlowering (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 possesspositive significant association with grain yield per plant at both genotypic and phenotypiclevels. Hence, selection for these characters will help in selecting Buck wheat genotypes withhighgrainyield.Further,mostofthecharacterpairshadhighergenotypiccorrelationcoefficients compared to phenotypic correlation coefficients. Such high amounts of genotypiccorrelationscouldresultduetomaskingeffectofenvironmentontheassociationofcharacters. This indicates that though there was high degree of association between two variables atgenotypic level, its phenotypic expression was deflated by influence of environment. Theabovefindings arein agreementwith thefindingsof**Li*et al*.(2012)** and**Huang *et al*.(2014).**

Comment [A14]: the discussion needs to be added

Table4:PhenotypiccorrelationamongdifferenttraitsinBuckwheatgenotypesevaluatedund

errainfed conditionsduring *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

Table5:GenotypiccorrelationamongdifferenttraitsinBuckwheatgenotypesevaluatedunderrainfed conditionsduring*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

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 (1921). The estimates of path coefficients for yield attributing traits on seed yield arefurnished in table 6. The result obtained from present investigation for direct and indirecteffectsarepresented characterwiseas:

Comment [A15]: data in the table?.

Seed yield per plant had positive direct effect with test weight (0.6245), time ofbeginning of flowering (0.5291), number of branches (0.0869), plant height (0.0383) while ithad 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 ofbranches (0.0105), test weight (0.003), days to 50% flowering (0.0021), time of beginning offlowering(0.0013). Timeofbeginningof floweringhadpositiveindirecteffectwithdaysto50%flowering (0.514), no. of branches (0.0418), plant height (0.0175) while it had negativeindirecteffect with daysto 80%maturity -(0.2391)and test weight-(0.3408). Days to 50% floweringhad positive indirect effect withtest weight (0.2883), daysto 80% maturity (0.188) while it had negative indirect effect with no. of branches (-0.0117),plantheight(-0.0261), time ofbeginning offlowering (-0.4575). Daysto80%maturityhadpositiveindirecteffectwithtimeofbeginningofflowering(0.0091), days to 50% flowering (0.008) while it had negative indirect effect with no ofbranches(-0.0018),plant height(-0.0067)and test weight(-0.0142).

No. of branches had positive indirect effect with plant height (0.024), days to 80%maturity(0.008),timeofbeginningofflowering(0.007),daysto50%flowering(0.002) whileit had negativeindirect effect withtest weight(-0.02). Test weight had positive indirect effect with days to 80% maturity (0.443), plantheight (0.05) while it had negative indirect effect with no of branches (-0.12), days to 50%flowering(-0.38),time ofbeginning offlowering(-0.4). Similar results wereobservedwith thefindings of **Li *et al*. (2012) and Huang*et al*. (2014).**

Comment [A16]: the discussion needs to be added

Table6:Direct(in bold)andindirecteffectsof7traitsongrain yieldin 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**	

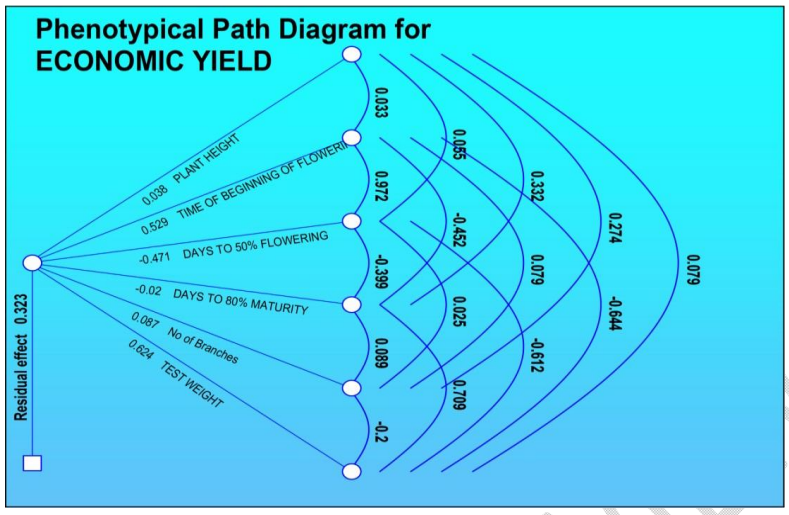

Figure 1 Phenotypic path diagram for seed yield per plant

Conclusion

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 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. Path analysis revealed that test weight and time of beginning of flowering registered high and positive direct effect on seed yield per plant. It indicates true relationship between these traits and direct selection for these traits will be rewarding for yield improvement in Buck wheat.

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Comment [A17]: Some references are very old. Need to add the recent references

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