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Variability Parameters in Wheat- A Review

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ABSTRACT

Wheat is an immensely important cereal crop of the world. At global level India ranks as second largest wheat producing country, contributing about one-tenth of the global wheat production. Introduction, evaluation and identification of potentially useful germplasm forms the first and foremost step in a crop improvement programme. Genetic variability existing in nature or created through crop breeding is of immense value for crop improvement programmes. Genetic variability in a population can be partitioned into heritable and non-heritable variation with the aid of genetic parameters such as variance, genotypic coefficient of variation, heritability and genetic advance, which serve as a basis for selection of some outstanding genotypes from existing ones Heritability is the ratio of genetic variance to total variance for a plant trait and is related with progress from selection It expresses the extent to which phenotypes are determined by the genes transmitted from parents. Similarly Knowledge of the association of quantitative characters specifically for yield and its attributes is of immense practical value during selection. The selection of one character will lead to indirect change(s) of other character(s) if the two are correlated. Therefore, the knowledge of phenotypic and genotypic correlation and path analysis is important for a plant breeder. Path coefficient analysis measures the direct and indirect effects of various characters.

Keywords: *Wheat, Heritability, Correlation, Path coefficient.*

INTRODUCTION

Wheat (*Triticum aestivum* L.) on account of its wide adaptation to various agroclimatic conditions, has a prominent position among the grain crops in the world both in area and production. It is the leading grain crop of the temperate climate of the world just as rice is the leading grain crop in the tropics. Wheat (*Triticum aestivum* L.) is one of the significant staple crops with global production being 672 million tonnes in 2012[1]. At global level India ranks as second largest wheat producing country, contributing about one-tenth of the global wheat production.

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Introduction, evaluation and identification of potentially useful germplasm forms the first and foremost step in a crop improvement programme. The high yielding genotypes with good adaptation and agronomically desirable attributes could be directly utilised for general cultivation. However, an effective and massive hybridization programme would be a viable approach and for such a hybridization programme to be successful, the characterisation and variability pattern of the available germplasm holds a promise. To sustain the high productivity level of wheat, genetic variability existing in nature or created through crop breeding is of immense value. Genetic uniformity within a crop is readily brought about by using the same gene or gene complexes during breeding programmes. When uniformity becomes the cause of genetic vulnerability, genetic diversity is the only insurance against it. To overcome the menace of this uniformity, it is essential that genetic variability, present in both the cultivated and wild species, is systematically exploited and used to generate new gene complexes for higher grain yield and tolerance to biotic and abiotic stresses. The effectiveness of selection depends upon the range of genetic variability already existing in the population in respect of important economic characters. The progress of breeding in such a population is primarily conditioned by the magnitude, nature and inter relationship of genetic variation for various plant characters. Genetic parameters, therefore, help in partitioning the overall variability into heritable and non heritable components.

Breeding through component traits for grain yield in wheat has recently been getting the attention of plant breeders. The grain yield of a crop is a complex character and is the final product of actions and interactions of various characters [2]. Since no independent gene system is present for grain yield, a complete understanding of the relationships among yield and its components merits more attention[3].

Phenotypic and genotypic variability

Genetic variability in a population can be partitioned into heritable and non-heritable variation with the aid of genetic parameters such as variance, genotypic coefficient of variation, heritability and genetic advance, which serve as a basis for selection of some outstanding genotypes from existing ones [4] Falconer and Mackay [5] also indicates the three ways of assessing the existence of variability in breeding population; (1) by using simple measures of variability, such as range, mean, variance, standard deviation, coefficient of variability and standard error (2) by estimating the various components of variance and (3) by measuring the genetic diversity e.g. D2 statistics.

Jain and Aulakh[6] reported high coefficients of phenotypic and genotypic variation for productive tillers plant^{-1} and 1000-grain weight and high genetic advance for most of the traits. The highest coefficient of variation was shown by grain yield plant^{-1} followed by grains spike^{-1}; spikelets spike^{-1}, spike length and germination per cent [7,8]. Jag [9] reported high estimates of phenotypic coefficient of variation, genotypic coefficient of variation, heritability and genetic advance which indicates scope for improvement through simple selection for grain weight spike^{-1}, grain yield plot^{-1}, grains spike^{-1}, 1000- grain weight and tillers plant^{-1}. Uddin *et al.*[10] observed the highest coefficient of variation for grains spike^{-1} followed by 1000-grain weight and grain yield plant^{-1} . Bergale *et al.*[11] reported high phenotypic and genotypic coefficients of variation for the number of spikes plant^{-1}, grain yield plant^{-1}, plant height, flag leaf area and 1000-grain weight. Jedynski[12] explained the correlation and path coefficient for grain yield and its components in wheat. He also reported heritability estimates as very high for plant height, high for 1000-grain weight, intermediate for number of grains spike^{-1} and very low for grain yield plant^{-1}. Pramod *et al.*[13] reported highest genotypic coefficient of variation for number of effective tillers plant^{-1} and kernel yield. Ali *et al.*[14] in their study of seventy local and exotic wheat genotypes found that the estimates of GCV were high for yield plant^{-1}, number of productive tillers plant^{-1} and number of grains spike^{-1}. The remaining traits recorded moderate to low GCV estimates. The PCV values were higher than GCV values for all the traits which reflect the influence of environment on the expression of these traits. Kalim-Ullah *et al.*[15] reported that the estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were highly significant (P≤0.05) for spike length, days to 50% flowering and plant height. High genotypic coefficient of variation (GCV) was observed for number of tillers per running meter (20.35) followed by grain yield per plant (18.08) biomass yield (17.06) and thousand seed weight (15.47) while as medium to low GCV was observed for other characters. High phenotypic coefficient of variation was exhibited by flag leaf width (25.96) followed by Number of tillers (20.36) while as other characters showed moderate to low phenotypic coefficient of variation[16].

Heritability and expected genetic gain

Heritability is the ratio of genetic variance to total variance for a plant trait and is related with progress from selection It expresses the extent to which phenotypes are determined by the genes transmitted from parents. In other words, it expresses the magnitude of genotypic variance in the population, which is mainly responsible for changing the genetic composition of a population through selection[5]. It indicates the effectiveness with which selection of genotypes can be based on phenotypic performance. The broad-sense heritability is useful if the target is in relative importance of genotype and environment in determination of phenotypic value. But, it does not indicate the progress that might be made through selection within a particular population[17]. As for many field crops, the studies regarding the new cultivars for wheat are being conducted and the selection continues to be the basic method. The efficacy of the selections of both yield (a quantitative character) and the yield components depend on the genetic variation and percentage of heritability. It is necessary to identify the components that create the phenotypical difference in order to calculate the genetic variability and heritability based on that variation. Yield performance continues to be of importance in wheat breeding, though it will be necessary to improve traits involved in yield stability, if further yield increases are to be achieved. Das and Rehman[18] studied 8 quantitative traits in 9 varieties of wheat and observed a wide genotypic and phenotypic variability for plant height with a high value of heritability. Low values of heritability for grain weight spike^{-1} have been obtained in the studies conducted by Pawas *et al.* [19] and Al-Marakby *et al.*[20]. Contrary to this, Chaturvedi and Gupta[21] have obtained middle values. Ghimiaray and Sarkar [22] estimated heritability (broad sense) and genetic advance in wheat. High heritability coupled with high genetic advance were recorded for number of tillers plant^{-1}. High heritability estimates were reported for days to 50% heading, grains spike^{-1}, 1000-grain weight, spikelets spike$^{-1,}$ spike length, tillers plant^{-1} and days to maturity. Also low estimates were observed for germination per cent and grain yield plant^{-1}[23]. Jedynsky [12] reported high heritability estimates for plant height and 1000- grain weight, intermediate for number of grains spike^{-1} and very low for grain yield plant^{-1}. Kumar *et al.*[4] reported high heritability coupled with high genetic advance for plant height, number of spikelets spike^{-1}, 1000- grain weight and number of days to 50% heading in wheat. Kashif and Khaliq[24] reported moderate to very high broad sense heritability for all morphological characters except fertile tillers plant^{-1}.

Ali *et al.*[14] reported moderate heritability for number of productive tillers^{-1} plant. High heritability estimates were recorded for plant height, number of spikelets^{-1} spike, spike length, number of grains spike^{-1}, 1000 grain weight and yield plant^{-1}. Maniee *et al.*[25] reported that high heritability estimates of morphophysiological traits indicate that the selection for these traits will be effective being less influenced by the environmental factors.

Ferdous *et al.*[26] reported that plant height, grains spike^{-1}, grain yield plant^{-1} had the maximum genetic advance with relative efficiency. Among others, the indices based on grains spike^{-1}, grain yield, days to maturity, grains spike^{-1}, grain yield, effective tillers plant^{-1}, grains spike^{-1}, 100-grain weight and grain yield showed high genetic advance with relative efficiency over straight selection for grain yield alone. Zecevic *et al.*[27] reported broad sense heritability value for number of grains spike^{-1} as 60 per cent and for grain weight spike^{-1} as 40 per cent and high significant difference in mean values for number of grains spike^{-1} and grain weight spike^{-1} was established. Kalim-Ullah *et al.*[15] reported that high heritability estimates were recorded for plant height, days to 50% flowering, days to heading, spikelets spike^{-1} and spike length. Plant height, days to physiological maturity and spikelets spike^{-1} also indicated high expected genetic advance.

Heading days (HD), plant/ m2 (PPM), spikelet per spike (SPS) and 1000 grains weight (TGW) exhibited high heritability coupled with a moderate genetic advance. These characters had also medium to high genotypic coefficient of variation and phenotypic coefficient of variation coupled with high to moderate heritability and genetic advance. [28]. Thousand-kernel weight, tillers per plant, grain yield, harvest index, spike length and kernels per spike at two locations were found to have high coefficient of variability, intermediate to high heritability and genetic advance as percent of the mean. This means that effective and satisfactory selection for practical improvement of these important traits is possible[29].

Phenotypic and genotypic correlation studies

Yield is an ultimate criterion which a plant breeder has always to keep in view in his attempt to evolve improved cultivars of any crop species. However, yield is a polygenic character and highly influenced by environment. Knowledge of the association of quantitative characters specifically for yield and its attributes is of immense practical value during selection. The selection of one character will lead to indirect change(s) of other character(s) if the two are correlated. Therefore, the knowledge of phenotypic and genotypic correlation and path analysis is important for a plant breeder. Path coefficient analysis developed and described by Wright [30] and used by Dewey and Lu [31] measures the direct and indirect effects of various characters. The genetic parameters like genotypic coefficient of variation, heritability and genetic advance are the tools in the hands of a plant breeder for ensuring efficient selection. For shifting the mean population under study in the desired direction, a thorough understanding of nature and extent of association of various component characters with yield is essential. The correlation coefficients, however, measure the nature and magnitude of association between different characters. Component analysis of this relationship (cause and effect) reveals the importance of most important traits towards the yield.

A highly significant and positive correlation was observed between number of spikelets spike^{-1} and number of grains spike^{-1} by Mohammad *et al.*[32]. Grains spike^{-1} had a negative and significant association with 1000-grain weight but a positive and significant relationship with grain yield plant^{-1}[33] . Dencic *et al.*[34] and Garc *et al.*[35] concluded that number of kernels per spike is one of the main yield components which might improve directly the yielding ability in new varieties. Negative association of plant height with grain yield was also reported by Patel and Jain [36]. Amin *et al.*[37] reported that the genotypes that took more days to heading were likely to have more spike length. They also reported that grain yield was positively and significantly correlated with plant height and number of spikes m^{-2}. Vaishnavi and Bijral[38] and revealed a positive significant correlation of grain yield with effective tillers plant^{-1}, spikelets spike^{-1}, 1000-grain weight and biological yield plant^{-1}. Vaishnavi and Bijral[38] and Singh *et al.*[39] in a study reported that in general genotypic correlation coefficients were higher than the corresponding phenotypic values. Similar results were obtained by Munir *et al.*[40] in their correlation studies among yield and its component traits in bread wheat under drought conditions in 2007. Days to heading showed negative association with yield at both genotypic and phenotypic levels. However, the associations were insignificant[41]. Baser *et al.*[42]; Aycecik and Yildirim[43] and Inamullah *et al.*[44] observed positive association of 1000-grain weight with grain yield. Subhani and Chowdhry [45] reported that harvest index had negative correlation with days to heading and tillers plant^{-1}, Attarbashi *et al.*[46] reported contrasting results. Subhani and Chowdhry[45] also observed highly significant differences among the genotypes and found that grain yield was positively and significantly correlated with flag leaf area, tillers plant^{-1}, spike length, grains spike^{-1} and 1000-grain weight. Vaishnavi [2] reported negative correlation between plant height and days to maturity. The grain yield was significantly and positively correlated with 1000-kernel weight and the number of spikes m^{-2} [46]. Ismail[41] reported that days to heading showed negative but insignificant association with yield at both genotypic and phenotypic levels. Number of grains spike^{-1} and grain weight spike^{-1} with high variability estimates, are in positive correlation with each other and directly influence the wheat yield[47]. Patel and Jain [36] found a negative correlation between spike length and 1000-grain weight. Sarkar *et al.*[48] found that 1000-kernel weight showed positive association with yield both at genotypic and phenotypic levels. Shahid *et al.*[49] and Saleem *et al.*[50] found that 1000-kernel weight was negatively and insignificantly correlated with plant height both at genotypic and phenotypic levels. Significant indirect negative correlations at both the levels were recorded for harvest index with plant height and biological yield while days to 50% flowering had negative association with number of productive tillers plant^{-1} but were significant only at genotypic level[51]. However, Burio *et al.*[52] observed that harvest index had positive effects on plant height. It was reported by Lad *et al.*[53] that grain yield exhibited highly significant and positive correlation with tillers plant^{-1}; spikelets spike^{-1} both at genotypic and phenotypic levels. Kashif and Khaliq [24] reported that plant height, spike length, spikelets spike^{-1} and 1000-grain weight were positively and significantly correlated with grain yield at genotypic level. They also found positive correlation between spike length and yield at both genotypic and phenotypic levels.

Usman *et al.*[54] revealed that number of tillers plant^{-1} had positive genotypic correlation with grain yield plant^{-1} at 0.05 probability level. Gupta *et al.* [55] also observed the highest contribution towards grain yield by biological yield, harvest index, test weight and spikelets spike^{-1}. However, plant height, number of grains spike^{-1} and days to 50% flowering had direct negative effect on grain yield. Iqbal *et al.*)[56] observed that correlation between plant height and grain yield was negative and highly significant, at both genotypic and phenotypic level which indicates that selection of short stature genotype may be effective for better grain yield. A positive significant correlation was found for spike length, number of spikelets spike^{-1}, grain yield plant^{-1} and 1000-grain weight with yield (kg ha^{-1}) by Khan *et al.* [57]. Akram *et al.* [58] while studying the correlation among some yield parameters of wheat under rainfed conditions found that spike length had positive relationship with number of spikelets spike^{-1} at both genotypic and phenotypic levels. While it was positively correlated with number of grains spike^{-1} at genotypic level. They also observed that spike length had significant positive genotypic correlation with grain yield plot^{-1}, while plant height showed a strong negative genotypic correlation with grain yield plot^{-1}. Negative correlation of plant height with grain yield was also reported by Shahid *et al.*[59].

Anwar *et al.*[60] emphasized that selection of long duration genotypes would have higher 1000-grain weight compared to short duration genotypes in the breeding material under study. Spike length had significantly negative genotypic correlation with days to 50% maturity and it would decrease in long maturity genotypes. Days to 50% heading had non significant either negative or positive correlation with days to maturity but spike length had non-significant correlation with grain yield plant^{-1} so this negative association had ignorable hurdle in selection of long duration genotypes for grain yield improvement. Similarly, days to 50% maturity had also non-significant association with plant height. They further reported that days to maturity had positive genotypic correlation with grain yield plant^{-1}, number of tillers plant^{-1} and 1000-grain weight, and had positive direct effect on grain yield plant^{-1}. Therefore, more days to maturity and more tillers plant^{-1} would be important selection criteria for improved grain yield plant^{-1}. Dharmendra and Singh[61] reported that days to maturity had negative and significant association with 1000-grain weight, spike length and yield plant^{-1}. Laghari *et al.*[62] reported that days to heading were positively and significantly correlated with days to maturity, grains spike^{-1}, spike length and spikelet spike^{-1} and negatively and significantly correlated with grain filling period. Also days to maturity was negatively and significantly correlated with grain filling period and 1000 grain weight. Plant height was found to be positively and significantly correlated with spike length.

Singh *et al.*[63] while studying one hundred fifty genetically diverse exotic germplasm along with three indigenous checks (HP 1731, PBW 343 and NW 2036) of wheat (*Triticum aestivum* L.) reported that the grain yield plant^{-1} showed very strong positive association with biological yield plant^{-1}, grains spike^{-1}, tillers plant^{-1}, ear length and plant height. Days to heading showed highly significant and positive association with days to maturity. Waqar-ul-Haq *et al.* [64] reported that days to heading were negatively and non significantly correlated with number of spikes plant^{-1} and grain yield plant^{-1}, similar results were also observed by Ahmad *et al.*)[65] for spikes plant^{-1} and by Zar and Khan [66] for grain yield plant^{-1}. They also reported a negative and non significant correlation between spike length and number of tillers meter^{-1} and also spike length and 1000-grain weight were associated negatively and non-significantly. A positive and significant correlation between spike length and grain yield plant^{-1} was observed by Khaliq *et al.*[67].

Path coefficient analysis

It is imperative to deal with correlated characteristics of traits in all the crop improvement programmes to be conducted.. Path coefficient is defined as the degree of influence of one variable on the other in quantitative traits. Path analysis is a special type of multivariate analysis which deals with a closed system of variables (each variable in the system is either a linear combination of some other variables in the system or is one of the basic factors in the system) are linearly related[68]. Path coefficient analysis measures the direct influence of one variable upon the other, and permits separation of correlation coefficients into components of direct and indirect effects which provides actual information on contribution of characters and thus forms the real basis of selection for the yield improvenment[69].

Path coefficient analysis by Subhani and Chowdhry [45] showed that tillers plant^{-1} and spikelets spike^{-1} had positive direct effects on grain yield under irrigated conditions. Bergale *et al.*[68] also reported that grains spikes^{-1} and tillers plant^{-1} had high positive direct effects on grain yield. Singh and Dwivedi[69] suggested that number of effective tillers plant^{-1}, number of grains ear^{-1}, grain weight ear^{-1}, biological yield plant^{-1} and harvest index should be included in selection criteria for improvement of grain yield in wheat. Mahak *et al.* [70] reported that grains spike^{-1} exhibited the greatest direct effect on grain yield followed by spike length and 1000-grain weight. The number of grains spike^{-1}, spike length and 1000- grain weight were the major yield contributing characters. Days to maturity was positively and non significantly correlated with number of grains spike^{-1} [71] while as a negative and non significant correlation between days to maturity and number of tillers meter^{-2} and a negative and non significant correlation was found between days to maturity and 1000-grain weight was reported by Waqar-ul-Haq *et al.* [64]. The direct effect of plant height on grain yield plant^{-1} was positive showing a computed path coefficient value of 7.599. The indirect effects via flag leaf area, fertile tillers plant^{-1}, spike length and grains spike^{-1} were positive. The indirect negative effects were contributed through spikelets spike^{-1} and 1000-grain weight. However, the deleterious negative indirect effects were neutralized by its positive indirect effects [24]. Silva *et al.* [72] reported that spikelet number and hectolitre weight had the high potential for selection of superior genetic constituents for grain yield. Leilah *et al.*[73] reported that number of spikes m^{-2}, 100-grain weight, weight of grain spike^{-1} and biological yield were the most effective variables influencing grain yield. Through path analysis Sen *et al.*[74] reported that 1000-grain weight, grains spike^{-1}, tillers meter^{-1}, days to maturity showed direct effect on yield. Anwar *et al.* (2009)[60] observed that days to maturity and tillers plant^{-1} had positive direct effect on grain yield plant^{-1}. Therefore, more days to maturity and more tillers plant^{-1} would be important selection criteria for improved grain yield plant^{-1} in the breeding material studied. The study of correlation and path analysis by Khokhar *et al.*[75] revealed that high plant height causes low yield due to its negative correlation with yield, while days to maturity is the best selection parameter for breeding high yielding wheat cultivars due to its positive significant genotypic association and highest direct effect on yield so that early maturing line with moderate plant height give more yield compared to late maturing variety with high plant height. Dharmendra and Singh[61] while carrying out the variability analysis for yield and yield attributes of bread wheat under salt affected condition reported that spikelets spike^{-1} had highest positive direct effect on grain yield, followed by tillers plant^{-1}, days to maturity and plant height. The indirect effect via spikelets spike^{-1} was also higher when compared with any other indirect effect. Ferdous *et al.*[26] while studying twenty bread wheat genotypes reported that path coefficient analysis showed that all the characters viz. plant height, effective tillers plant^{-1}, grains spike^{-1}, 100-grain weight and harvest index influenced grain yield directly in positive direction and they are the primary yield components in spring wheat. Among them, grains spike^{-1} had high positive correlation with grain yield. Grains spike^{-1} also influenced grain yield indirectly via plant height, spike length and harvest index in positive direction. Path analysis by Singh *et al.* [63] divulged that, the biological yield plant^{-1} and days to maturity emerged as direct contributors towards the expression of grain yield plant^{-1} while tillers plant^{-1}, ear length, grains spike^{-1} and 1000- grain weight were identified as most important indirect yield contributors. Tripathi *et al.*[51] in their study reported that the character association analysis revealed that biological yield plant^{-1}, spike length, number of productive tillers plant^{-1}, number of grains spike^{-1}, test weight and days to maturity are the most important characters that contributed directly to yield. Thus a genotype with higher magnitude of these traits could be selected for improvement in wheat yield.

Path coefficient analysis was carried out by Khan *et al*.,[76] with grain yield plot^{-1}as response trait. Days to heading showed highest positive direct effect (2.71) on grain yield plot-1 followed by grain filling period (2.23) and 1000-grain weight (0.66). Four genotypes viz., SKW- 355, HPW-366, UP-2831 and HPW-367 matured in 221.33, 225.00, 225.33 and 226.66 days, respectively and recorded the grain yield of 31.11, 22.22, 31.77 and 23.03 q ha-1 respectively thus were found suitable for cultivation under rice-wheat cropping system in Kashmir.

REFERENCES

1. FAO, FAO STAT Production Statistics, Food and Agriculture Organisation, Rome. http//:ww.faostat.fao.org (2014).
2. Vaishnavi, R. Association among grain yield traits in bread wheat (*Tritucum*

aestivum L. em. Thell). *SKUAST Journal of Research* **2:** 167-170 (2000).

3. Grafius, T.E., Components of yield in oats: geometric interpretation. *Agronomy Journal* **48 :** 419-423 (1989)
4. Kumar, S., Dwivedi, V.K., Tyagi, N.K. and Kumar, S.. Genetic variability in some metric traits and its contribution to yield in wheat (*Triticum aestivum* L.). *Progressive Agriculture* **3(1-2):** 152-153 (2003)
5. Falconer, D.S., and Trudy F.C. Mackay.. *Introduction to Quantitative Genetics 4th ed.* Longman Group Limited Malaysia. (1996)
6. Jain, R.P. and Aulakh, H.. Variability in wheat. *Indian J. Agric. Sci.* **41:** 297-299 (1971).
7. Ehdaie, B. and Waines, J.G. 1989. Genetic variation, heritability and path analysis in land races of bread wheat from South Western Iran. *Euphytica* **41:** 183-190 (2000)
8. Dhonde, S.R., Kute, N.S., Kanawde, D.G. and Sarode, N.D.. Variability and Character association in wheat (*Triticum aestivum* L.). *Agriculture Science Digest* **20:** 99-101.
9. Jag, S., Estimation of variability parameters and path coefficients for certain metric traits in winter wheat (*Triticum aestivum* l.). *Indian Journal of Genetics and Plant Breeding* **55(4):** 399-405 (1995).
10. Uddin, M.J., Mitra, B., Chowdhry, M.A.Z. and Mitra, B.. Genetic parameters, correlation, path-coefficient and selection indices in wheat. *Bangladesh Journal of Science and Industrial Research* **32:** 528-538 (1997).
11. Bergale, S., Mridulla, B. and Holkar, A.S.. Genetic variability, diversity and association of quantitative traits with grain yield in bread wheat. *Madras Agricultural Journal* 88(3): 457- 461 (2001).
12. Jedynski, S., Heritability and path-coefficient analysis of yield components in spring wheat. Grupy Problemowej Wodowli Pszenicy. *Proceedings of Symposium, Zakopane, Poland,* **218/219:** 203-209 (2001).
13. Pramod, K. and Mishra, Y., Genetic variability in wheat. Biodiversity and sustainable utilization of biological resources conference. (M.P), pp. 144-149 (2004).
14. Ali, Y., Babar, M.A., Javed, A., Philippe, M. and Zahid, L.. Genetic variability, Association and diversity studies in wheat (*Triticum aestivum* L.) germplasm. *Pakistan Journal of Botany* **40(5):** 2087-2097 (2008).
15. Kalim-Ullah, Khan, S., Muhammad, S., Irfaq, M. and Muhammad, T., Genotypic and phenotypic variability, heritability and genetic diversity for yield components in bread wheat (*Triticum aestivum* L.) germplasm. *African Journal of Agricultural Research* **6(23):** 5204-5207 (2011).
16. Nusrat Jan and Subhash C. Kashyap. Studies on Genetic Variability in Wheat (*Triticum aestivum* L. Em Thell) Under Temperate Conditions of Kashmir. *International Journal of Science and Research.* **5 (8):** 1442-1445.
17. Dabholkar, A.R., *Elements of Biometrical Genetics*. Concept Publishing Company, New Delhi. (1992).
18. Das, M.K. and Rehman, L.. Estimates of genotypic variability, heritability and genetic gain in common wheat. *Bangladesh Journal of Agriculture Science* **9:** 15-18 (1984).
19. Pawas, I.S., Paroda, R.S. and Singh, S.. Study of heritability and genetic advance in three wheat populations. *Bangladesh Journal of Agriculture Research* **14(1):** 24-26 (1989).
20. Al-Marakby, A.M., Mohamed, A.A., Yasein, M. and Tolba, A.M.. Heritability estimates and selection for high-yielding and early-heading recombinants in segregating generations of five wheat crosses. *Annals of Agricultural Science, Moshtohor.* **32(3):** 1089-1106 (1994).
21. Chaturvedi, B.K. and R.R. Gupta., Selection parameters for some grain and

quality attributes in spring wheat (*Triticum aestivum* L.). *Agricultural Science Digest, Karnal* **15(4):** 186-190 (1995).

22. Ghimiaray, T.S. and Sarkar, K.K.. Estimation of genetic parameters for some quantitative traits in wheat (*Triticum aestivum* L.) grown in terai soils of west Bengal. *Environment and Ecology* **18:** 338-340 (2000).
23. Imbrahim, A.M.H. and Quick, J.S., Heritability of heat tolerance in winter and spring wheat. *Crop Science* **41:** 1401-1405 (2001).
24. Kashif, M. and Khaliq, I.. Heritability, correlation and path coefficient analysis for some metric traits in wheat. *International Journal of Agriculture and Biology* **6(1):** 138-142 (2004).
25. Maniee, M., Kharizi, D. and Mohammadi, R., Genetic variability of some morpho-physiological traits in durum wheat (*Triticum durum* Desf.). *Journal of Applied Sciences* **9(7):** 1383-1387 (2009).
26. Ferdous, M.F., Shamsuddin, A.K.M., Hasna, D. and Bhuiyan, M.M.R., Study on relationship and selection index for yield and yield contributing characters in spring wheat. *Journal of Bangladesh Agricultural University* **8(2):** 191-194 (2010).
27. Zecevic, V. and Knezevic, D., Variability of grain weight per spike in wheat. *Proceedings of International Symposium Breeding of Small Grains*, Kuagujevac, pp 139-143. (1998).
28. Rahman, M.A., Kabir, M.L., Hasanuzzaman3, M., Rahman, M.A., Rumi, R.H., and Afrose, M.T. Study of variability in bread wheat (Triticum aestivum L.) *International Journal of Agronomy and Agricultural Research* **8(5):** 66-76 (2016).
29. Negasa, Desalegn and Chauhan, D.K. Variability, Heritability and Genetic Advances in Wheat (*Triticum aestivum* L) Breeding lines grown at Horro Guduru Wollega Zone, Western Ethiopia. *International Journal of Advanced Scientific Research and Management*, **1 (1):** 24-28 (2016).
30. Wright, S., Correlation and causation. *Journal of Agriculture Research* **20:** 557-85 (1921).
31. Dewey, D.R. and Lu, K.M., A correlation and path co-efficient analysis of crested wheat grass seed production. *Agronomy Journal* **51:** 515-518 (1959).
32. Mohammad, F., Deniel, H. Shahzad, K. and Khan, H., Heritability estimates for yield and its components in wheat. *Sarhad Journal of Agriculture* **17(2):** 227-234 (2001).
33. Dhaual, L.S., Sastry, E.V.D. and Jakhar, M.L., Character association in wheat (*Triticum aestivum* L) grown under normal and saline conditions. *Crop Improvement* **30:** 95-98 (2003).
34. Dencic, S., Kastori, R., Kobiljski, B. and Duggan, B., Evaluation of grain yield and its components in wheat cultivars and landraces under near optimal and drought conditions. *Euphytica* **113(1):** 43-52. (2000).
35. Garc-a-del-Moral, L.F., Rharrabtia, Y., Villegasb, D. and Royob, C., Evaluation of Grain Yield and Its Components in Durum Wheat under Mediterranean Conditions. *An Ontogenic Approach of Agronomy Journal* **95:** 266-274 (2003).
36. Patel, A.K. and Jain, S., Studies of genetic variability in wheat under rainfed conditions. *JNKVV Research Journal* **36(½):** 25-28 (2002).
37. Amin, M.R., Haque, M.M., Shaheed, M.A., Sapker, A.K.D. and Kabir, Z., Genetic variability, character association and path analysis in wheat. *Bangladesh Journal of Agricultural Research* **15(2):** 1-5 (1990).
38. Vaishnavi, R. and Bijral, J.S. . Impact of biparental mating on the association among grain yield traits in bread wheat (*Triticum aestivum* L. em. Thell). *Annals of Agriculture Biological Research. India,* **1:** 61-65 (1996).
39. Singh, S.P. and Dwivedi, V.K., Genetic divergence in wheat (*Triticum aestivum* L). *New Agriculturist* **13:** 5-7 (2002).

40. Munir, M., Chowdhry, M.A. and Malik, T.A., Correlation studies among yield and its components in bread wheat under drought conditions. *International Journal of Agriculture & Biology* **9(2):** 287-290 (2007).
41. Ismail, A.A., Identification of selection traits for yield improvement of bread wheat using path analysis. *Australian Journal of Agriculture Science* **32(2):** 63-84 (2001).
42. Baser, I., Bilgin, O., Bilgin, A.Y. and Genctan, T.. Relationship between characters selected to tillering and grain yield in bread wheat. *Acta Agronomy Hungary* **48(3):** 254-256 (2000).
43. Aycecik, M. and Yildirim, T., Path coefficient analysis of yield and yield components in bread wheat (*Triticum aestivum* L.) genotypes. *Pakistan Journal of Botany* **38(2):** 417-424 (2006).
44. Inamullah, H., Ahmad, F.S., Hassan, M.G. and Gul, R., Diallel analysis of the inheritance pattern of agronomic traits of bread wheat. *Pakistan Journal of Botany* **38(4):** 1169-1175 (2006).
45. Subhani, G.M. and Chowdhry, M.A., Correlation and path coefficient analysis in bread wheat under drought stress and normal conditions. *Pakistan Journal of Biological Science* **3:** 72-77 (2000).
46. Attarbashi, M.R., Galeshi, S., Soltni, A. and Zinali, E.. Relationship of phenology and physiological traits with grain yield in wheat under rain-fed conditions. *Iranian Journal of Agriculture Science* **33:** 21-8. (2002).
47. Korkut, K.Z., Baser, I. and Bilgin, O., Genotypic and phenotypic variability, heritability and phenotypic correlation for yield and yield components in bread wheat varieties. *Acta Agronomica Hungarica* **49(3):** 237-242 (2001).
48. Sabo, M., Bede, M. and Hardi, Z.U., Variability of grain yield components of some new winter wheat genotypes (*Triticum aestivum* L.). *Rostlinna Vjroba* **48(5):** 230-235 (2002).
49. Sarkar, C.K.G., Srivastava, P.D.L. and Deshmukh, P.S., Effect of terminal high temperature stress tolerance in bread wheat (*Triticum aestivum* L. Em. Thell): Estimation of character association and contribution of yield attributes to grain yield. *Annals of Agriculture Research* **23:** 75-78 (2002)
50. Shahid, M., Fida, M. and Tahir, M., Path coefficient analysis in wheat. *Sarhad Journal of Agriculture* **18(4):** 383-388 (2002).
51. Saleem, U., Khaliq, I., Mahmood, T. and Rafique, M., Phenotypic and genotypic correlation coefficients between yield and yield components in wheat. *Journal of Agriculture Research* **44(1):** 1-6 (2006).
52. Tripathi, S.N., Marker, S., Pandey, P., Jaiswal, K.K. and Tiwari, D.K.. Relationship between some morphological and physiological traits with grain yield in bread wheat (*Triticum aestivum* L. em. Thell.) *Trends in Applied Sciences Research* **6(9):** 1037-1045 (2011).
53. Burio, U.A., Oad, F.C. and. Agha, S.K., Correlation coefficient (r) values of growth and yield components of wheat under different nitrogen levels and placements. *Asian Journal of Plant Science* **3:** 372-374 (2004).
54. Lad, D.B., Bangar, N., Bhor, T.J., Mukherkar, G.D. and Biradar, A.B., Correlation and path coefficient analysis in wheat. *Journal of Maharashtra Agricultural University* **28(1):** 23-25 (2003).
55. Usman, S., Iihsan, K., Mehmood, T. and Rafique, M.. Phenotypic and genotypic correlation coefficients between yield and yield components in wheat. *Journal of Agricultural Research* 44(1):1-6. (2006)
56. Gupta, D., Mittal, R.K. Kant, A. and Singh, M., Association studies for agro physiological and quality traits of triticale x bread wheat derivatives in relation to drought and cold stress. *Journal of Environmental Biology* **28:** 265-269 (2007).

57. Iqbal, M., Nawabi, A., Salmon, D.F., Yang, R.C. and Spaner, D.. Simultaneous selection for early maturity, increased grain yield and elevated grain protein content in spring wheat. *Plant Breeding* **126(3):** 244-250 (2007).
58. Khan, M.M., Khan, Q., Khan, R.D. and Rabani, M.A., Correlation and phenotypic variability studies for some agronomic traits among bread wheat (*Triticum aestivum* L.) accessions. *Gomal University Journal of Research* **23(2):** 18-24 (2007)
59. Akram, Z., Ajmal, S.U. and Munir, M.. Estimation of correlation coefficient among some yield parameters of wheat under rainfed conditions. *Pakistan Journal of Botany* **41(2):** 1777-1781 (2008)
60. Anwar, J., Ali, M.A., Hussain, M., Shabir, W., Khan, M.A., Zulkiffal, M. and Abdullah, M., Assessment of yield criteria in bread wheat through correlation and path analysis. *The Journal of Animal and Plant Sciences* **19(4):** 185-188 (2009).
61. Dharmendra, S. and Singh, K.N., Variability analysis for yield and yield attributes of bread wheat under salt affected condition. *Wheat Information Service* **110:** 35-39 (2010).
62. Laghari, K.A., Sial, M.S., Arain, M.A., Dahot, M.U., Mangrio, M.S. and Pirzada, A.J., Comparative Performance of Wheat Advance Lines for Yield and its Associated Traits. *World Applied Sciences Journal* 8 (Special Issue of Biotechnology & Genetic Engineering): 34-37 (2010).
63. Singh, B.N., Vishwakarma, S.R. and Kumar, S.V. Character association and path analysis in elite lines of wheat (*Triticum aestivum* L.) *Plant Archives* **10(2):** 845-847 (2010).
64. Waqar-ul-Haq, Munir, M. and Akram, Z., Estimation of interrelationships among yield and yield related attributes in wheat lines. *Pakistan Journal of Botany* **42(1):** 567-573. (2010).
65. Ahmad, H.M., Khan, B.M. and Kissana, N.S., Path coefficient analysis in bread wheat. *Asian Journal of Plant Sciences* **2(6):** 491-494 (2003).
66. Zar, Q. and Khan, S., Correlation studies of some factors affecting yield in wheat (*Triticum aestivum* L.) under field conditions. *Front. Journal of Agricultural Research* **7:** 22-23 (1980).
67. Subhani, G.M. and Chowdhry, M.A., Correlation and path coefficient analysis in bread wheat under drought stress and normal conditions. *Pakistan Journal of Biological Science* **3:** 72-77 (2000).
68. Dabholkar, A.R., *Elements of Biometrical Genetics.* Concept Publishing Company, New Delhi. 209-219 (1999).
69. Khan, M.H., and Dar, A.N., Correlation and Path coefficient Analysis of some quantitative traits in wheat. *African Crop Science Journal,* **18(1):** 9 – 14 (2009).
70. Bergale, S., Billore, M., Holkar, A.S., Ruwali, K.N. and Prasad, S.V.S., Pattern of variability, character association and path analysis in wheat (*Triticum aestivum* L.). *Agricultural Science Digest* **22(4):** 258-260 (2002).
71. Mahak, S., Swarnak, G.B. and Latta, P., Genetic variability and path analysis in advanced generations of bread wheat under rainfed conditions. *Plant Archives*. **3:** 89-92 (2003).
72. Silva, S.A., Carvalhoi, F.I.F., Neblei, J.L. and Cruz, P.J., Path analysis for yield components of seeds in wheat. *Bragantia* **64(2):** 191-196 (2005).
73. Hassan, M.S.U., Munir, M., Mujahid, M.Y., Kisana, N.S., Akram, Z. and Nazeer, A.W. Genetic analysis of some biometric characters in bread wheat (*Triticum aestivum* L.). *Journal of Biology Science* **4(4):** 480-485 (2004).
74. Leilah, A.A. and Al-Khateeb, S.A, Statistical analysis of wheat yield under drought conditions. *Journal of Arid Environments* **61(3):** 483-496 (2005).
75. Sen, Chaitali and Toms-Bini,. Character association and component analysis in wheat (*Triticum aestivum* L.). *Crop Research,* (Hisar). **34(1-3):** 166-170 (2007).
76. Khokar, M.I., Hussain, M., Zulkiffal, M., Ahmad, N. and Sabasr, W.. Correlation

and path analysis for yield and yield contributing characters in wheat (*Triticum aestivum* L.). *African Journal of Plant Science* **4(11):** 464-466 (2009).
77. Khan, G. H, Vaishnavi, R., Shikari ,A. B. and Dar, Z. A. Genotypic variability partial regression analysis and identification of early maturing wheat suitable for Kashmir valley. *The Bioscan* **10(2):** 763-767 (2015).