Characterization of germplasm for yield, its components and quality traits in wheat (*Triticum aestivum* L. em. Thell)

Thesis

Submitted to the

G. B. Pant University of Agriculture and Technology,
Pantnagar – 263145 (Udham Singh Nagar), Uttarakhand, INDIA

By

Neha Joshi
B.Sc. (Life Science)
Id. No. 47000
IN PARTIAL FULFILMENT OF THE REQUIREMENTS

FOR THE DEGREE OF

Master of Science in Agriculture
(Genetics and Plant Breeding)

JULY, 2017

ACKNOWLEDGEMENT

To the almighty creator, I remain thankful for everything I have. Next to God, I offer my profound indebtedness to my parents who have brought me in this world and kindled in me the spark of knowledge and my elder brother for his boundless love, everlasting support and enduring patience. Also the indomitable trust, support, care, unconditional love and affection of my extended family made me able to complete this tedious task in a part of chasing my dreams.

It gives me immense pleasure to express my deep sense of gratitude and heartiest thanks to Dr. Anil Kumar, Junior Research Officer, Department of Genetics and Plant Breeding for his undaunting support, persistent encouragement, enduring patience and vital suggestions during the course of the present investigation and preparation of this manuscript. Sir, thank you for all your help and support. It was an honor working under your shelter Sir.

I would like to thank the other members of my advisory committee, Professor Dr. J.P. Jaiswal, Dr. Birendra Prasad, S.R.O, Dr Swati, J.R.O. Department of Genetics and Plant Breeding for their advice, valuable suggestions and meticulous guidance throughout the course of investigation.

I owe earnest thanks to Dr. H.S. Chawla, Professor and Head, Department of Genetics and Plant Breeding, Dean, Agriculture, Dean, College of Post Graduate Studies, Director Experiment Station, Joint Director Crop Research Centre and University Librarian for providing all the necessary facilities for conducting the research.

I deem it to be my privilege with sense of gratitude to acknowledge Dr. A.S. Jeena and Dr N.K. Singh, Professors, Department of Genetics and Plant Breeding for providing necessary help and their peerless advice.

I also convey my sincere thanks to wheat breeding staff, all other teaching and non-teaching staff of the Department of Genetics and Plant Breeding for their constant guidance and encouragement.

My most sincere and heartful gratitude flows to my senior and mentor Mr. Shoukat Ahmad Rather for guiding me, inspiring me, boosting my morale and being with me in thick and thin. There are no words to pay my regards to you Sir. I would also like to extend my thanks to Manish, Himanshu, Neetu, Monica, Seenam, shikha and juniors Anjali, Nidhi who helped me at every difficult step and gave me the necessary moral support during the course of this study.

My most sincere and heartful gratitude flows to my batchmates Bharath, Subhash, Devendra, Abdul, Deepak, Ankit and Anil for their affection, support and encouragement.

Last but not the least, I record my sincere thanks to all the respected people who helped me directly or indirectly but could not find separate mention. Thanks all!!!!

Neha Joshi

Pantnagar
July, 2017

(Neha Joshi)
Authoress

CERTIFICATE

This is to certify that the thesis entitled “Characterization of germplasm for yield, its components and quality traits in wheat (*Triticum aestivum* L. em. Thell)” **submitted in partial fulfillment of the requirements for the degree of** Master of Science in Agriculture**with major in** Genetics & Plant breeding **of the College of Post-Graduate Studies, G.B. Pant University of Agriculture and Technology, Pantnagar, is a record of bona-fide research carried out by** Ms. Neha Joshi, **Id. No.** 47000 **under my supervision, and no part of the thesis has been submitted for any other degree or diploma.**

The assistance and help received during the course of this investigationhas been acknowledged.

Pantnagar

July, 2017

(Anil Kumar)
Chairman
Advisory Committee

CERTIFICATE

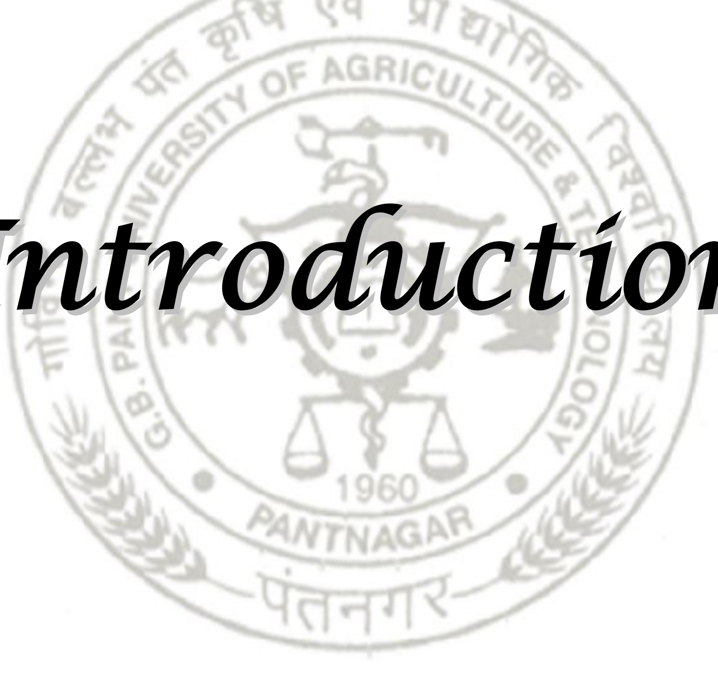
We, the undersigned, members of the Advisory Committee of Ms. Neha Joshi, Id. No. 47000,**a candidate for the degree of** Master of Science in Agriculture**with major in** Genetics & Plant Breeding,**agree that the thesis entitled** "Characterization of germplasm for yield, its components and quality traits in wheat (*Triticum aestivum* L. em. Thell)" **may be submitted in partial fulfillment of the requirements for the degree.**

(Anil Kumar)
Chairman
Advisory Committee

(Swati) Member	**(Birendra Prasad)** Member	**(J.P. Jaiswal)** Member

CONTENTS

LIST OF TABLES



Introduction

"Start by doing what is necessary, then what is possible,
And suddenly you are doing the impossible"
St. Francis of Assisi

Chapter 1

INTRODUCTION

Wheat (*Triticum aestivum* L. em. Thell) is an allohexaploid crop (2n = 6x = 42) belonging to family Graminae (Poaceae). Owing to high nutrient content and suitability to all agro-ecological regions, wheat is considered as the king of all cereals crops. It contributes almost 1/3rd of the total food grain production all over the globe and is a critical source of energy, protein and dietary fiber in human nutrition. It provides 20 per cent of energy and 25 per cent of protein in human diet **((Tandon, 2000; Dukes *et al.*, 1995).** Besides**,** it is an essential crop on account of the real estate it possesses, high profitability and productivity and coveted position it holds in the global food grain trade. Wheat contains high measure of gluten, the protein that provides the elasticity necessary for excellent bread making. It has great adaptability to various agro-ecologies. However, the crop is most successfully grown in between the latitude of 30° and 60°N, and 27° and 40°S. The crop can also be grown beyond these limits, from within the Arctic Circle to higher altitude near the equator. In India, cultivation of wheat extends from about below 9°N Palni hills in Tamil Nadu to about 30°N Srinagar, Jammu and Kashmir.

Bread wheat has a worldwide production of about 729.01 million tons from around 220.4 million hectares with a yield of 3.31 tons/ha **(FAOSTAT 2014).** In India, wheat is grown almost in all parts contributing around 30% to the food bowl of country. It is estimated that the biggest share in production of wheat is from the states of Uttar Pradesh (27.518 MT), Punjab (15.169 MT) and Haryana (10.5 MT) having productivity level 3.1 t/ha, 4.5 t/ha and 4.3 t/ha, respectively. In Uttarakhand State, the productivity of the wheat is, however, 2.3 t/ha which is fairly low when compared with the global or national average.

Grain yield is a complex trait and highly influenced by many genetic factors and environmental fluctuations. The success of a breeding programme depends upon the presence of genetic variability in a material in hand. Therefore, the assessment and use of genetic variability in desired direction is crucial in any crop improvement programme. To make the heritable improvement in characters, estimation of genetic parameters and index of their transmissibility is required. Heritability estimates provide information about the extent to which a particular character can be transmitted to the successive generations. Knowledge of heritability of a trait thus guides a plant breeder to predict behavior of succeeding generations and helps in making desirable selections. Conventional analysis of variance and statistical parameters like phenotypic and genotypic coefficients of variability, heritability and genetic advance have been used to assess the nature and magnitude of variation in wheat breeding material.

Evaluation of genetic diversity among adapted, elite germplasm can provide predictive estimates of genetic variation among segregating progeny for pure-line cultivar development. Knowledge about germplasm diversity and genetic relationships among breeding material could be an invaluable aid in crop improvement strategies **(Mohammadi and Prasanna, 2003)** and study of the genetic diversity in bread wheat is important for breeding and genetic resource conservation programs.

Precise information on the nature and degree of genetic diversity helps the plant breeder in choosing the diverse parents for purposeful hybridization. Several genetic diversity studies have been conducted on different crop species based on quantitative and qualitative traits in order to select genetically distant parents for hybridization **(Daniel *et al.*, 2011).** The more genetic diverse parents, there are greater chances of obtaining higher heterotic expression in F1's and broad spectrum of variability in segregating population. **Jagadev *et al.* (1991)** reported that the character contributing maximum to the divergence should be given greater emphasis for deciding the type of cluster for purpose of further selection and the choice of parents for hybridization.

Correlation studies provide a better understanding of the association of different characters with grain yield. **Fonsca and Peterson (1969) and Bhatt (1973)** based on their study highlighted the significance of components approach in formulating a successful breeding programme. The correlation coefficient showed a notion about the various linkages existing between the yield components.

Grain yield is much impacted by numerous genetic factors and natural changes. In any breeding program, direct selection of yield as such could be deceptive. The genotypic association is necessary in deducing how different traits are linked with grain yield **(Ali *et al.,* 2009).** A fruitful choice relies upon the data on the genetic variability and linkage of morpho-agronomic traits with grain yield. Since, the correlation coefficients by and large show direct connections among independent variables that may not adequately depict the association when a clear cause-result relationship is required between the variables. In this way, the direct and indirect impacts among yield and yield components ought to be known in breeding projects **(Albayrak *et al.,* 2003).** Path coefficient examination inferred the direct and indirect impact of one variable upon another and allows the partition of the correlation coefficient into components of direct and indirect impact **(Dewey and Lu, 1959).**

Grain quality in wheat is defined in terms of physical features like colour, texture and test weight and chemical features like protein content and sedimentation value. Among these, protein content has the greatest effect on the overall wheat processing qualities. Although varietal differences exist with respect to protein content, the environment has a significant role in determining the value.

In view of the above facts and considering the importance of wheat, the present investigation entitled **"Characterization of germplasm for yield, its components and quality traits in wheat (*Triticun aestivum* L. em. Thell)**" was, therefore, undertaken with the following objectives:

1. To determine extent of variability in wheat germplasm for different characters,
2. To estimate the heritability and genetic advance of different traits,
3. To characterize germplasm for agro-morphological and quality traits,
4. To assess the nature and magnitude of inter-character association between yield, its components and quality traits,
5. To asses genetic diversity among the genotypes studied and
6. To identify potential donors for yield, yield contributing characters and quality traits.

Review of Literature

"If you do not know history, you don't know any thing
You are a leaf that doesn't know its part of the tree"
Michael Crichton

Chapter 2 REVIEW OF LITERATURE

The relevant literature pertaining to various aspects of present study was reviewed and has been described under the following heads.

2.1 Genetic Variability

Singh *et al.* (1970) on the basis of their research on 16 varieties of durum wheat concluded that days to heading, spikelets per ear, grains per ear and 1000- grain weight had vast variations as compared to number of tillers and yield per plant, which exhibited narrow range of variations. They also inferred high genetic coefficient of variability for number of grains per ear, 1000- grains weight and grain weight per ear.

Jain and Aulakh (1971) found that there was high significant variation and very high genotypic coefficient of variation for 1000-grain weight, grain yield and grain number per ear in 20 bread wheat lines.

Purohit *et al.* (1981) noticed huge variation for number of spikes per plant and grain yield per plant, minute variations for plant height and number of grains per spike and moderate variations for spikelets per spike and 1000 grain weight in wheat.

Kumar and Kumar (1983) on the basis of their observation on 20 wheat lines inferred higher genotypic variance for grain yield and number of tillers per plant in comparison with plant height and 1000 kernel weight.

Maloo (1984) thoroughly studied the nine varieties of wheat along with their 31 F1 crosses. High estimate of genotypic coefficient of variation was noticed for grain yield, plant height and spike length. In contrast, low value of coefficient of variation was observed for spikelets per spike and days to heading indicating their restrained scope for improvement.

Sheoran *et al.* (1986) evaluated 29 genotypes of bread wheat and observed substantial differences in spike length, 1000 grain weight, grains per spike and plant height.

Gupta (1986) observed maximum variability for grain yield per plot trailed by number of grains per ear, grain hardness and grain weight per ear for the exotic lines of bread wheat, however minimal variability was found for days to heading.

Singh (1989) observed high phenotypic coefficient of variation for tillers per meter (13.11%), trailed by grains per ear (12.89%). The intermediate/moderate coefficient of variation was noticed for spiklets per spike, biological yield, 1000 grain weight, harvest index and economic yield. The Lower coefficient of variation was noticed for traits like ear length (5.04%), plant height (4.85%), days to maturity (1.31%) and days to heading (1.48%).

Bametha (1989) noticed high coefficient of variation for grain yield, harvest index, biological yield and tillers per plant. The lower coefficient of variation was noticed for plant height and 100 grain weight.

Kulshreshtha (1992) on the basis of his intense study on 1100 elite germplasm lines in two seasons, formulated some useful facts. In first season, high Coefficient of variation was noticed for grain yield trailed by peduncle length, biological yield, yield per plot and tillers per plant. Low coefficient of variation was noticed for days to heading, days to maturity and plant height. In the second season, maximum coefficient of variation was noticed for tillers per plant trailed by biological yield per plot, harvest index, grain yield per plot and grain yield per spike, and low Coefficient of variation was observed for days to maturity, ear length and days to maturity.

Getachew-Belay *et al.* (1993) on the basis of variability studies on seed yield and 9 component characters of durum wheat varieties found that highest variation was shown by seed yield trailed by number of tillers per plant and number of grains per spike. The lowest variation was exhibited by number of days to heading.

Mahak *et al.* (2003) on the basis of their observations on genetic variation for yield and yield components noticed substantial genetic variation for all traits. Harvest index and number of grains per spike showed the highest genetic (18.71 and 18.05) and phenotypic (21.78 and 20.35) coefficient of variation.

Shah *et al.* (2003) carried out an experiment using 14 wheat breeding lines and two check cultivars planted in randomized complete blocks design with three replications. Statistical analyses of the data were executed and the means were separated using the least significant difference test. Analyses of variance divulge that the genotypes differed substantially for number of spikes per meter, spikelets per spike, kernels per spike and 1000-kernel weight. Number of spikes per meter revealed substantially positive phenotypic and genotypic correlations with grain yield. Different genotypes revealed potentials for desired characters but none had preeminence in yield.

Upreti and Malik (2003) conducted replicated experiment in two different sowing dates and assessed 21 genotypes for twelve characters including grain yield. Examination of variance showed highly significant differences among the genotypes for most of the traits except spike length and spikelets/spike. High heritability with high genetic gain was observed for grain yield. Moderate genetic gain with high heritability was observed for 1000-grain weight, grains/spike and tillers/meter. It was concluded that selection for these characters might result in improvement of yield besides quality of wheat.

Sultana *et al.* (2005) conducted an experiment on 210 genotypes of bread wheat including indigenous and exotic varieties for ten yield attributing traits in order to identify the superior lines that can be used for potential donors for yield and yield contributing traits. High phenotypic coefficient of variation was observed for number of tillers per plant, grain yield, biological yield and harvest index. Moderate variability was observed for traits like plant height, number of spikelets per ear, 1000-grain weight and ear length. Low variability was observed for days to heading and days to maturity. Phenotypic correlation indicated that plant height, biological yield and 1000-grain weight were positively and significantly linked with grain yield. In accordance with genetic variability and character association it was concluded that grain yield may be improved with improvement in number of tillers per plant, ear length, biological yield, 1000-grain weight and harvest index.

Yashpal *et al.* (2005) observed genetic variability in 60 genotypes and found high magnitude of variability for productive tillers per plant, grains per spike, grain weight per spike and grain yield per plant. High to moderate heritability linked with high to moderate genetic advance was observed for traits like plant height, spike length, grains per spike, spikelets per spike, sedimentation value and 1000-grain weight, which inferred hegemony of additive gene action and possibility of enhancing these characters through simple selection.

Farshadfar (2008) screened ten bread wheat genotypes at two geographical areas in different conditions. Grain yield was positively and significantly associated with number of spikes/plant under one condition, albeit 1000 grain weight and biological yield were significant at both locations. The main source of grain yield variation reckon under one condition is 1000 grain weight trailed by number of spikes/plant, number of grains/spike and biological yield. Estimates of traits accountable for variation in order of relative importance were: number of spikes/plant, number of grains/spike, 1000 grain weight and biological yield under one condition while it could be organized in descending order as 1000 grain weight, number of grains/spike (45.5%), number of spikelets/spike (1.4%) for other geographical area.

Majumder *et al.* (2008) revealed that genotypic correlation coefficients were higher than the corresponding phenotypic correlation coefficients in most of the 22 traits. Spikes plant-1, grains spike-1, spike length, 100 grain weight and harvest index were the most important characters which possessed positive association with grain yield.

Makwana *et al.* (2008) carried out his assessment on 48 triple test cross progenies along with 16 parents and three testers for genetic components of variation. The examination of variance divulges significant difference among the families for all the characters signifying the presence of significant amount of genetic variability in the material studied. The additive as well as dominance components of genetic variation were considerable for all the traits except dominant component for number of tillers per plant. The observation signifies importance of both the components in the inheritance of most of the traits.

Mohammad *et al.* (2008) examined the relationship among yield components and their direct and indirect effect on the grain yield (GY) in 144 advance lines of bread wheat. The analysis of variance for individual plant traits divulges the presence of genetic variability among the genotypes for all the traits studied. Genotype connection of plant height, biological yield , harvest index, thousand kernel weight, number of spike/m2 and hectoliter weight were impressive and significantly associated with grain yield under normal and late planting.

Shankarrao *et al.* (2010) evaluated 38 genotypes of bread wheat in Randomized Block Design with three replications for 18 different yield contributing traits and found significant variation for all the characters studied. The approximation of PCV in all the traits examined was higher than those of the GCV. The closeness between PCV and GCV values for most of the characters signified less effect of environment on the expression of the traits studied. Assuming heritability, most of the characters exhibited high values. High heritability related along high genetic advance (in % of mean) were observed for the grain weight per spike, tillers per plant and per meter square, thousand grain weight, number of grains per spike and the grain protein content signified the characters to be under additive genetic control and the scope of enhancement in the above characters through direct selection.

KalimUllah *et al.* (2011) recorded huge genotypic contrasts for every deliberate charater, showing a lot of variability among genotypes. The appraisals of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were exceptionally huge (P=0.05) for spike length, days to 50 per cent flowering and plant height. High heritability assessments were recorded for plant height, days to 50% flowering, days to heading, spikelet's spike-1 and spike length. Plant height, days to physiological development and spikelets spike-1 likewise showed high expected hereditary progress.

Baranwal *et al.* (2012) recorded extensive genetic variation among genotypes for days to heading, plant height, tillers per plant and grains per spike. High genotypic co-efficient of variation (GCV) was reported for grains per spike, peduncle length, plant height though, low GCV was recorded for chlorophyll substance, days to heading and tillers per plant. In all cases, phenotypic fluctuations were higher than the genotypic changes.

Kaddem *et al.* (2014) found that bread wheat genotypes were significantly different for all characters except for flag leaf width, indicating existence of sufficient genetic variability within different genotypes. High estimates of phenotypic coefficient of variation was recorded for grain yield, but moderate phenotypic coefficient of variation was recorded for harvest index, biological yield, number of tillers per plant, test weight and spike length. Moderate genotypic coefficient of variation was recorded for test weight, number of tillers per plant, grain yield and spike length.

Dutamo *et al.* (2015) studied the extent of genetic variation and association among grain yield and yield related traits in germplasm of bread wheat in an augmented design and found that phenotypic coefficients of variation values were higher than genotypic coefficients of variation values. High PCV and GCV were recorded for productive tillers, spike length, kernels per spike, 1000 grain weight, biomass yield, harvest index and grain yield. High heritability values were observed for all the characters studied. The D^2 analysis showed the 68 germplasm clustered into six clusters. This shows the germplasm to be moderately divergent. Principal components (PC1 to PC3) considered eigenvalue greater than one (significant), accounted nearly 63.2% of the total variation.

2.2 Character association

Grain yield in wheat, as in any other crop, is a complex character and is contingent upon a number of yield contributing factors like ear per plant, grains per ear, 1000 grain weight and weight of grains per ear **(Paroda and Joshi, 1970).** Therefore, in pursuit to obtain higher yield, it is requisite to have information on correlation between yield and its components.

Table: Correlations between different characters

Pair of characters	**Natureof correlation**	**Authors**
Grain yield and plant height	Positive	**Joshi (1984), Kumar *et al.* (1986), Bametha (1989),** Sand**hu** and **Lal (1989), Crowley *et al.* (1993), Subhani** and **Khaliq (1994), Bergale *et al.* (2002), Hussain *et al.* (2012).**
	Negative	**Singh (1985), Sheoran *et al.* (1986), Deotule *et al.* (1991), Khokhar *et al.* (2010), Ashraf *et al.* (2012).**
Grain yield and days to maturity	Positive	**Larpik (1979), Sinha** and **Sharma (1980), Joshi (1984), Anwar *et al.* (2009), Rangare *et al.* (2010), Khokhar *et al.*(2010).**
	Negative	**Larik (1979), Shukla *et al.* (2005), Bilgin *et al.* (2011), Bhushan *et al.* (2013).**

Grain yield and spikelets per ear	Positive	**Saini (1982), Mouchan *et al.* (1987), Mandakh (1988), Sandhu** and **Lal (1989), Sudesh *et al.* (2002), Gupta *et al.* (2004).**
	Negative	**Pandilla *et al.* (1972).**
Grain yield and 1000-grainweight	Positive	**Sharma** and **Sinha (1980), Sandhu** and **Lal (1989), Pawar *et al.* (1990), Lu *et al.* (1991), Ibrahim (1994), Dwivedi *et al.* (2002), Jat** and **Dhakar (2003), Rangare *et al.* (2010), Khan *et al.* (2015).**
	Negative	**Kumar *et al.*(1986).**
	No clear relation	**Nalitolela (1990).**
Grain yield and number of grains per ear.	Positive	**Li** and **Yang (1985), Mandakh (1988), Singh (1989), Lu *et al.* (1991), Kobilijski *et al.* (1993), Mohan *et al.* (1993), Ibrahim (1994), Paul** and **Ganguli (1996), Singh *et al.* (1998), Dwivedi *et al.*(2002), Hannachi *et al.* (2013).**
	Negative	**Schmidt *et al.* (1979), Kumar *et al.* (1979), Kumar *et al.* (1986).**
Grain yield and ear length	Positive	**Li** and **Yang (1985), Sheoran *et al.* (1986), Bangarwa *et al.* (1987), Mandakh (1988), Mohan *et al.* (1993), Mohammad Shahid *et al.* (2002), Mohammadi *et al.* (2012).**
	Negative	**Pandilla *et al.* (1972) and Mandakh (1988).**
Grain yield and number of spikes/m^2	Positive	**Mohammad *et al.* (2008), Ashraf *et al.* (2012).**
Grain yield and number of grains per spikelet	Positive	**Sinha** and **Sharma (1980), Konovalenko** and **Ostroukh (1980), Srivastava *et al.* (2009), Rangare *et al.* (2010).**
	Negative	**Gholizadeh** and **Dehghani (2015).**

Grain yield and harvest index	Positive	**Bametha (1989), Singh (1989), Amin *et al.* (1992), Ibrahim (1994), Bergale *et al.*(2002), Shukla *et al.* (2005), Gholizadeh and Dehghani (2015).**
	Negative	**Getachew-Belay (1993).**
Grain yield and number of tillers per plant.	Positive	**Pawar *et al.* (1990), Saini *et al.* (1990), Baiskh** and **Nayak (1991), Thakur *et al.* (1999), Dwivedi at al. (2002), Shukla *et al.* (2005), Anwar *et al.* (2009), Srivastava *et al.* (2009), Rangare *et al.* (2010) Ashraf *et al.* (2012), Hannachi *et al.* (2013).**
Days to heading and spikelets per ear	Positive	**Tripathi (1983), Joshi (1984)** and **Gholizadeh and Dehghani (2015).**
	Negative	**Singh (1985).**
Days to heading and 1000- kernel weight	Positive	**Wan (1981), Tripathi (1983), Taya (1993), Nayeem *et al.* (2003).**
	Negative	**Joshi (1984), Dwivedi *et al.* (2002).**
Days to heading and Days to maturity	Positive	**Tripathi (1983), Joshi (1984), Soni *et al.* (2015), Mecha *et al.* (2017).**
Days to heading and harvest index	Positive	**Tripathi (1983).**
	Negative	**Joshi (1984), Singh (1985), Soni *et al.* (2015), Mecha *et al.* (2017).**
Number of tillers per plant and spikelets per spike	Negative	**Singh *et al.* (1970), Raut *et al.* (1977), Lynch *et al.* (2017).**
Ear length and grains per ear	Positive	**Sinha** and **Sharma (1980), Mandakh (1988).**
	Negative	**Mandakh (1988), Soni *et al.* (2015).**
Ear length and 1000 kernel weight	Positive	**Talwar** and **Chondrappa (1983), Faizul *et al.* (1989), Yadav *et al.* (2013).**

Ear length and spikelets per ear	Positive	**Bhuller *et al.* (1985), Bangarwa (1987), Mohibullah *et al.* (2017).**
Ear length and plant height	Positive	**Pandilla *et al.* (1972), Sinha** and **Sharma (1980), Kaddem *et al.* (2014).**
1000-grain weight and ear length	Positive	**Sinha** and **Sharma (1980), Mecha *et al.* (2017).**
1000-grain weight and peduncle length	Positive	**Chaturvedi (1987).**
1000-grain weight and grain per ear	Positive	**Sinha** and **Sharma (1980).**
1000-grain weight and spikelets per ear	Positive	**Tripathi (1983),**
	Negative	**Soni *et al.* (2015), Mecha *et al.* (2017).**
	Negative	**Joshi (1984), Singh (1985).**
1000-grain weight and plant height	Positive	**Raut *et al.* (1977), Sinha** and **Sharma (1980), Kaddem *et al.* (2014).**
	Negative	**Anand *et al.* (1972).**
1000-grain weight and grains per ear	Negative	**Side Wall *et al.* (1976), Sinha** and **Sharma (1980), Mecha *et al.* (2017).**
Plant height and ear length	Positive	**Pandilla *et al.* (1972), Sinha** and **Sharma (1980), Soni *et al.* (2015).**
	Negative	**Mecha *et al.* (2017).**
Plant height and spikelets per ear	Positive	**Gill *et al.* (1981), Yadav *et al.* (2013).**
Plant height and harvest index	Negative	**Raut *et al.* (1977), Gill *et al.* (1981), Bametha (1989).**
	Positive	**Yadav *et al.* (2013), Kaddem *et al.* (2014), Mecha *et al.* (2017).**
Grains per spikelet and plant height	Positive	**Sinha** and **Sharma. (1980), Gonzalez *et al.* (2016).**

Plant height and tillers per plant	Positive	**Kumar** and **Singh (2010).**
	Negative	**Faizul *et al.* (1989).**
Plant height and grains per ear	Positive	**Sinha** and **Sharma (1980), Jaiswal (1985), Yadav *et al.* (2013), Mecha *et al.* (2017).**
Plant height and 1000 kernel weight	Positive	**Anand *et al.* (1972), Sinha** and **Sharma (1980), Chaturvedi (1987), Faizul *et al.* (1989), Soni *et al.* (2015).**
	Negative	**Anand *et al.* (1978), Mecha *et al.* (2017).**
Plant height and peduncle length	Positive	**Gill *et al.* (1981), Saini (1982)** and **Chaturvedi (1987).**
Harvest index and plant height, tillers per plant, 1000-grain weight, biological yield	Negative	**Bametha (1989), Khan *et al.* (2013).**
Grains per spikelet and plant height	Positive	**Sinha** and **Sharma (1980); Gulnaz *et al.* (2012).**
Grains per spikelet and ear length	Positive	**Sinha** and **Sharma (1980), Kaddem *et al.* (2014).**
Grains per spikelet and spikelet per ear	Positive	**Rahman (1980), Yadav *et al.* (2013).**
Spikelets per spike and plant height	Positive	**Pandilla *et al.* (1972) , Soni *et al.* (2015).**
Spikelets per ear and grains per ear	Positive	**Raut *et al.* (1977), Mandakh (1988), Mecha *et al.* (2017).**

Bisht and Gahalain (2009) estimated correlations and path coefficients for 15 quantitative characters in 264 genotypes of wheat grown in the hills of Kumaun. High positive correlations of grain yield/plant with days to 75% spike emergence, days to maturity, flag leaf length, flag leaf width, effective tillers/plant, spike length, number of spikelets/spike were observed. Path analysis indicated the importance of days to maturity, spike length, number of grains/spike, biomass/plant, grain weight/spike, 1000-grain weight and number of spikelets/spike on grain yield suggesting using these characters for genetic improvement in wheat.

Rangare *et al.* (2010) on the basis of their study concluded that seed yield showed positive and significant correlation with effective tillers per plant, grains per spike, spike length and 1000 grain weight both at genotypic and phenotypic level. Path coefficient analysis indicated that effective tillers per plant, plant height, 1000 grain weight and days to maturity had positive direct effect on grain yield. Thus, these characters may be effective as selection indices during breeding programme for improving yield.

Singh *et al.* (2010) found that the grain yield per plant had very strong positive association with biological yield per plant, grains per spike, tillers per plant, ear length and plant height**.**

Fellahi *et al.* (2013) inferred grain yield was positively associated to biological yield, number of spikes per plant and straw yield. The outcome of regression revealed that characters including biological yield and harvest index had clarified approximately 99.7% of grain yield variations.

Pandey *et al.* (2014) in their study observed that yield per plot had huge positive connection with biomass, 1000-grain weight and plant height while the AUDPC (Area Under Disease Progress Curve) had significant positive link with plot yield. The connection between lesion mimic and AUDPC was observed to be profoundly huge and positive. Plant stature and 1000-grain weight were among the characters indicating most extreme direct commitment to plot yield while CT-3 (shade temperature at 96 DAS) and AUDPC had most astounding negative impact on plot yield.

Kumar *et al.* (2013) observed that GCV and PCV were moderate for biological yield per plant, number of effective tillers per plant. High heritability was observed for all the characters and furthermore showed high hereditary progress (except for days to 50% flowering and days to maturity). Grain yield per plant demonstrated exceedingly huge positive relationship with 1000 seed weight, plant height and number of effective tillers per plant. Spike length and 1000 seed weight had profoundly critical positive connection with grains per spike. Path coefficient examination revealed that 1000 seed weight and plant height had the most influencing impact on grain yield per plant and each must be given preference in choice of superior wheat genotypes.

Singh *et al.* (2015) studied bread wheat for morphological and quality traits and found that plant height had positive correlation with hectoliter weight and tillers per plant showed positive correlation with yield per plant. Days to 50 per cent flowering showed negative effects on grain yield. Path analysis showed that tillers per plant and days to maturity exhibited positive direct effects on yield.

Wasifulla khan *et al.* (2015) studied correlation among yield and yield components in bread wheat. Correlation analysis revealed significant positive genotypic and phenotypic association of grain yield with plant height, tillers per m^2, spike length and biological yield. Moreover, significant positive association of grain yield was observed with grains per spike and harvest index at phenotypic level only. Strong association of these traits with grain yield suggested that these traits could be safely used as selection criterion for further improvement in yield of wheat.

Mohibullah *et al.* (2017) on the basis of their study found that the recurrence appropriation for spike length gone from 6.2 to 22.1 (cm) with coefficient of variation 18.63%. The variation for grain yield/plant run from 1.26 to 4.58 (g) with coefficient of variation 21.89%. 1000-grain weight (g) differed from 15.74 to 46.65 (g) with coefficient of variation 23.55%. While, recurrence appropriation for grain yield (Kg/ha) gone from 2 610 to 5 065.9 (Kg/ha).

Lynch *et al.* (2017) indicated that variations in grains/m^2 had a larger effect on winter wheat yield than variations in individual grain weight. Variability in grains/m^2 was influenced by changes in spikes/m^2 more than the number of grains/spike. While spikes/m^2 was significantly related to the number of shoots/m^2, no significant relationship was observed between the shoots/m2 at the time of maximum tillers/plant and spikes/m^2 at harvest. Furthermore, a significantly negative linear relationship was observed between shoots/m^2 at the time of maximum tillers/plant and grains/spike.

2.3 Path coefficient analysis

Sewall Wright (1921) propounded the theory of path coefficient as a venture to examining the possible causal linkage between statistical variables in the structural equation modeling approach and provides critical examination of the specific forces acting to produce a given correlation.

Hirachand *et al.* (1978) on the basis of their study in bread wheat observed high positive direct effect of spike length (0.5071) on grain yield. The number of tillers per plant (0.1149), kernels per spike (0.0138) and 100-kernel weight (0.0029) had low direct positive effects. Albeit, indirect contribution of 1000-kernel weight on the yield per plant via length of spike was quite low.

Sharma and Singh (1983) on the basis of their study observed that harvest index had the greatest direct effect on the yield trailed by biological yield in wheat.

Singh (1989) studied a large number of elite wheat germplasm lines and noticed that tillers per meter square, biological yield and harvest index had high positive direct contribution towards grain yield. Grains per ear also had positive effects through biological yield. 1000-grain weight had high positive contribution through harvest index however, ear length and spikelets per ear had direct negative contribution towards grain yield and high positive contribution through biological yield.

Dechev (1990) studied F1 and F2 progenies from a partial diallele cross involving 10 parents and noticed that the highest direct effect on grain yield per plant was shown by the grain weight per ear trailed by ears per plant.

Ibrahim (1994) on the basis of their study formulated that the number of grains per spike and 100-grain weight had highest direct effect on grain yield at both phenotypic and genotypic level.

Jag Shoran *et al.* (2000) estimated path coefficients and correlations for 8 quantitative characters in 9 genotypes of wheat under different production conditions. High positive correlations of thousand-grain weight, grain weight per spike and number of grains per ear with grain yield were observed. Path analysis indicated the importance of thousand-grain weight, number of grains per ear and harvest index on seed yield.

Dwivedi *et al.* (2002) studied 12 metric traits in 72 genotypes of bread wheat and found positive and significant correlation of grain yield with traits like total biomass, tillers number per plant, grain weight per ear and 1000-grain weight. On the other side, negative correlation was observed with days to heading. Total biomass exhibited the highest direct effect on grain yield trailed by tillers per plant and grain weight per ear.

Singh *et al.* (2003) carried out several experiments on correlation and path analysis in 50 genotypes of bread wheat, which divulge positive and significant correlation of effective tillers/plant, biological yield and harvest index with grain yield/plant. Although, days to heading had negative significant correlation with 1000 grain weight. Moreover, path coefficient analysis showed that biological yield/plant, grain/ear, 1000-grain weight and effective tillers/plant had positive and high direct effects on grain yield/plant; therefore these should be contemplated as important selection criteria for enhancing yield.

Asif *et al.* (2004) made intense study and observation in ten bread wheat elite lines collected from various research institutes under rain fed condition. Significant variation was noticed for all characters studied like days to heading, days to maturity, plant height, grain yield, test weight. Days to heading and plant height exhibited relatively higher heritability. Grain yield exhibited significant association with plant height and test weight. Direct positive effects of plant height towards grain yield inferred the usefulness of these traits to choose and recognize desirable wheat genotypes for a target ambience.

Gupta *et al.* (2004) observed that number of spikes per plant had the highest positive direct effect on seed yield per plant trailed by grain weight and number of spikelets per spike. On the other hand, negative association on the seed yield per plant was seen in the characters like tillers per plant.

Khaliq *et al.* (2004) enumerated correlation and path coefficient in 5 wheat cultivars and their 20 hybrids. Grain yield had a highly significant and positive phenotypic correlation with plant height, number of tillers per plant, spike length, number of spikelets per spike and 1000-grain weight. On the other hand, it had a significant and positive genotypic correlation with all the characters. The direct contribution of spike length to grain yield was the highest (4.43). On the other hand, the number of spikelets per spike had the maximum negative direct effects (-4.22) on grain yield. Plant height, spike length, number of tillers per plant, spike density, peduncle length and number of grains per spike along with their indirect causal factors should be taken simultaneously as useful selection criteria for evolving high-yielding cultivars due to their direct positive contribution to grain yield.

Sherif *et al.* (2005) observed correlation between grain yield and its component in 10 bread wheat genotypes. Grain yield exhibited highly significant and positive phenotypic correlation with number of spikes per plant. It also exhibited significant positive phenotypic correlation with number of kernels per spike and 1000 kernel weight. Grain yield was directly influenced by number of spikes per plant, trailed by 1000 kernel weight and number of kernels per spike. Indirect effects of yield components on grain yield divulged that the synergy between number of kernels per spike and number of spikes per plant was the first indirect effect. It was trailed by the synergy between number of spikes per plant and 1000 kernel weight.

Muhammad *et al.* (2006) observed that days to maturity was negatively correlated at both genotypic and phenotypic levels with biological yield, harvest index and grain yield. Days to heading exhibited negative and significant correlation with harvest index and grain yield. Days to heading exhibited negative and non-significant correlation with the biological yield. Plant height exhibited negative genotypic and phenotypic correlation with harvest index and grain yield. Biological yield had positive and significant genotypic and phenotypic correlations with harvest index and grain yield. Harvest index had positive and highly significant phenotypic and genotypic correlation with grain yield. Genotypic and phenotypic correlation coefficients divulged that vital characters affecting grain yield are harvest index and biological yield. Path analysis exhibited the need and importance in order of harvest index, biological yield, plant height, days to maturity and days to heading with grain yield.

Mukherjee *et al.* (2008) studied 21 diverse genotypes of bread wheat under late sown conditions. The phenotypic correlation study divulged that the 1000 grain weight had significant and positive correlation with grain yield per plant and the genotypic correlation revealed that the same tendency with little variation with in magnitude of correlation value. Consequently, selecting genotypes with higher 1000 grain weight is probably going to enhance the grain yield per plant. The path analysis indicated that the spikelets per spike, days to maturity, number of spikes per meter and 1000 grain weight had direct influence on grain yield per plant. These characters having positive direct influence on grain yield are favorable selection norm for the evolution of high yielding genotypes under late sown conditions.

Singh *et al.* (2009) inspected the variance in 40 genotypes for seven characters. Variances owing to genotype were highly significant for all the characters in both environments. Genotypic coefficients of variation were lower than the phenotypic variations. GCV and PCV were highest for grain yield in both normal and late sowing conditions. Significant and positive correlations of grain yield with efficacious tillers per plant, biological yield and harvest index were observed in E1 and E2. Number of grains exhibited highly significant and positive correlation with grain weight. The path coefficient analysis formulated the need of biological yield as the chief contributor to grain yield.

Yucel *et al.* (2009) made intensive study on five bread wheat cultivars to assess the manner of inheritance and merging ability and the correlation of the grain's physical properties. Path coefficient analysis exhibited that grain width (GWI), number of grains per spike (GS), and grain height (GH) had the highest significant direct and indirect effects on most of the other features.

Gulmezoglu *et al.* (2010) made study on released triticale cultivars with bread and durum wheat to assess the effectiveness of path coefficient analysis for interconnection among characters which determine grain yield in triticale, bread and duram wheat at two different geographical locations. It was observed that grain yield of triticale was statistically significantly higher than the of durum wheat; albeit, triticale and bread wheat nearly had the same yield. Path coefficient analysis divulged that grain yield of triticale contingent on the effect of four yield components. These components were plant height, grain number per spike and 1000 grain weight which had positive and protein content which had negative correlation. On the other hand, grain yield of bread and durum wheat was chiefly due to plant height, length of spike, protein, besides these, spike weight for durum wheat. Although the effect of spike weight was positive, plant height and protein had a negative effect on the grain yield of Durum wheat.

Sharifi *et al.* (2012) formulated the traits influencing grain yield in 18 durum wheat (*Triticum duram* L.) genotypes by simple correlation coefficient and path analysis under two regimes (irrigated and rainfed). The result inferred that grain yield was positively and significantly correlated with test weight and thousand kernel weight in irrigated conditions. On the other hand, grain yield was positively and significantly correlated with plant height in rain fed conditions. Path coefficient analysis divulged that grain yield of durum wheat in rain fed condition contingent on plant height, test weight and spike length, however in irrigated condition contingent on test weight, peduncle length and kernel number per spike.

Dabi *et al.* (2016) made intense study on wheat and recorded that grain yield exhibited noteworthy ($p \leq 0.01$) positive phenotypic linkage with thousand kernels weight, harvest index, hectoliter weight, plant height, above ground biomass at every geographical place barring kernels per spike at Tongo and days to maturity at Kulumsa. In the same way, grain yield exhibited convincing ($p \leq 0.01$) positive genotypic linkage with 1000 kernel weight, hectoliter weight, plant height, above ground biomass, harvest index at Tongo and just with above ground biomass and harvest index at Kulumsa. On the same line, notable ($p \leq 0.01$) positive and negative phenotypic and genotypic linkage between the yield components was recorded at each and every geographical place. According to path analysis, above ground biomass and harvest index exhibited high positive phenotypic direct influence on grain yield at each geographical location although low positive phenotypic direct influence recorded for traits like plant height and number of kernels per spike at Tongo and hectoliter weight at Kulmsa. Furthermore, at genotypic level above ground biomass and harvest index revealed huge direct influence on the grain yeild at each geographical place.

Zerga *et al.* *(*2016) studied 25 bread wheat (*Triticum aestivum L.)* genotypes for hereditary variability, heritability and hereditary progress at Gurage zone at two unique conditions. Examination of fluctuation at every area demonstrated exceptionally noteworthy ($P \leq 0.01$) distinction for all characters, with the exception of harvest index at Fereziye, and harvest index and days to heading at Kotergedra. The net examination of variance over the two areas indicated exceptionally huge ($P \leq 0.01$) variations among the genotypes in every single contemplated traits. The medium estimates of PCV and GCV were recorded for above ground biomass and tillers per plant across environments over two areas.

2.4 Genetic Diversity

Bhatt (1970) investigated the relative contributions of distinct traits to genetic divergence in wheat and found that yield per se contributed very little (3.2) towards the genetic divergence. Consequently, the parental material taken only on the reference of yield may not give transgressive segregants in the succeeding generation.

Yadav *et al.* (1974) investigated the clustering pattern of 32 wheat strains under rainfed conditions. They grouped 32 strains into 13 clusters. Clustering pattern appeared to be little affected by the pedigree relationship of genotypes. Flowering duration and height appeared to have substantial influence on the clustering pattern. None of the genotype with distinct flowering period or plant height were in the same group. Flowering time trailed by coleoptile length, 1000 grain weight and yield per ear were reported to be chief forces of differentiation at the inter cluster level.

Jatasra *et al.* (1978) studied 10 distinct and diverse varieties in six different environments. The varieties were differing in height, maturity and awn character. The varieties were assembled into different clusters on the basis of estimates of genetic divergence calculated on the reference of 11 traits. The cluster and their constituents differed across the environments. The data showed that plant height trailed by 100 grain weight contributed maximum towards the genetic divergence.

Dhedhi *et al.* (1990) studied the genetic divergence in 100 genotypes of macaroni wheat *(T. tugidum).* The genotypes were assembled into 19 clusters. The geographical heterogeneity was not related with the genetic heterogeneity. Plant height, number of spikelets per spike, days to maturity and number of grains per spike were chief indicator for computing the genetic divergence.

Metha *et al.* (1992) observed 60 populations of Triticum aestivum for 9 characters. All populations were assembled into 20 genetically distinct clusters. Number of tillers per plant, plant height, days to 75% flowering and number of grains per ear contributed maximum towards divergence. Cluster 15 produced highest 100 seed weight and yield per plant.

Singh (1994) studied genetic divergence in 90 durum wheat genotypes by the cluster analysis for twelve yield components and five morphological characters. The genotypes were amassed into 7 clusters and had a high level of genetic divergence that was not associated to geographical origin.

Redhu *et al.* (1995) on the basis of their study on 121 indigenous and exotic varieties of wheat and assembling them into 27 clusters, observed that assembling of varieties in distinct cluster was not associated to their geographical origin.

Reddy (2001) conducted experiment in 52 strains of hexaploid Triticale containing two wheat genotypes for genetic diversity analysis. These genotypes were assembled into 4 clusters to compute genetic divergence. Cluster III was the largest group consisting of 36 genotypes trailed by the cluster IV with 8; cluster II with 6 genotypes and cluster I with 2. Cluster I and II were the most diverse and distinct among the groups and the intercluster distance between them was the highest.

Reif *et al.* (2005) studied the genetic diversity in elite bread wheat germplasm to investigate the loss of genetic diversity in spring bread wheat. The loss of genetic diversity was during its domestication, the change from traditional landrace cultivars to modern breeding varieties and 50 years of international breeding.

Singh and Dwivedi (2005) evaluated genetic divergence for 12 characters in 24 wheat genotypes. The characters studied were days to 50% flowering, number of effective tillers per plant, days to maturity, plant height, ear length, spikelets per ear, number of grains per ear, grain weight per ear, 1000-grain weight, biological yield per plant, grain yield per plant and harvest index. The genotypes were assembled into 6 clusters. The cluster I consisted of 19 genotypes and the other clusters were having one genotype each. Maximum generalized distance was noticed between cluster II and IV. On the other hand, minimum generalized distance was observed between cluster I and V.

Yadav *et al.* (2006) studied genetic diversity among 90 germplasm lines of bread wheat for yield, its components and quality traits. On the reference, the 90 wheat genotypes were assembled into 11 clusters. The dispersal pattern of genotypes in distinct clusters was random. Moreover, there was little association of genetic divergence with agro-ecological distribution of genotypes.

Rawashdeh *et al.* (2007) studied genetic diversity in durum wheat landraces under rainfed condition for 15 morphological and agronomic characters. The interconnection among accessions were measured and observed using cluster analysis and dendrogram similarity matrix. The result divulged the existence of a wide range of variability among landraces, which endowed with high levels of variability for biological yield, fertile tillers, seed weight per spike and weight of 1000 seeds and number of seeds per spike.

Rangare *et al.* (2008) reported genetic divergence analysis in 84 advanced genotypes of bread wheat including one standard control of bread wheat. Genetic improvement chiefly contingent on the magnitude of genetic variability and divergence exist in the population. All the genotypes were assembled into ten clusters. Intra cluster distance was highest for cluster IX, cluster V included largest number of genotypes, cluster IV had the largest intercluster distance with cluster X trailed by cluster VII and cluster X. The inference on the basis of the study of genetic divergence was that the maximum divergence clusters were cluster IV and X.

Yousaf *et al.* (2008) evaluated wheat for variability parameters, correlations and path coefficients for eight metric traits i.e., plant height, number of productive tillers per plant, number of spikelets per spike, spike length, number of grains per spike, fertility %, 1000 grain weight and yield per plant. The estimates of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) were high for yield per plant, number of productive tillers per plant and number of grains per spike. The remaining traits recorded moderate to low PCV and GCV estimates. Grain yield per plant showed positive correlation with number of productive tillers per plant, number of spikelets per spike and number of grains per spike and significant positive correlation with spike length. Path coefficient analysis revealed that number of productive tillers per plant and number of grains per spike had the highest direct effect on grain yield per plant. The cluster analysis grouped 70 wheat genotypes into 4 different clusters. Five genotypes of China were grouped in cluster I that showed the maximum diversity. From the cluster mean values, Chinese genotypes deserve consideration for their direct release as a variety(s) or as parents in hybridization programmes to develop high-yielding wheat varieties. The genotypes in cluster II may be used for the improvement of plant height and 1000 grain weight in wheat.

Santos *et al.* (2009) carried out experiment to investigate 52 wheat populations representing Madeira's Triticum diversity and an ample range of ecological conditions. This experiment was on the basis of 46 biometrical and cytometrical characters associated to plant morphology, cytological and grain features. Taxonomic identification of the collected materials divulged the presence of 3 species, 2 subspecies and 16 botanical varieties among the Madeiran wheat germplasm. The results obtained were validated by the multivariate analysis because all accessions were assembled in clusters analogous to different taxonomic levels. The study signified that comprehensive description of the Madeiran wheat landraces may contribute to the protection of the already present Triticum diversity and to support endeavors of conservation of landraces, proper germplasm preservation and utilization.

Singh *et al.* (2009) carried out experiment for studying the nature and magnitude of genetic divergence in bread wheat. They used non-hierarchical Euclidean cluster analysis in 300 genotypes of bread wheat for grain yield and its linked characters. All the genotypes were assembled into 7 different clusters. The clustering pattern divulged the distribution of the genotypes associated to the same origin in more than one cluster signifying non-parallelism between geographic and genetic diversity. The intra cluster variation was highest in cluster VI.

Jaiswal *et al.* (2010) made intensive study in three hundred indigenous germplasm of bread wheat. The main areas of study were genetic diversity for yield, yield contributing traits and quality traits. On the reference of dissimilarity coefficient, these genotypes were assembled into twenty three clusters. The genotypes possessing desired value from different clusters can be used in breeding program for enhancing yield and quality characters.

Shahryari *et al.* (2011) carried out experiment to study the genetic diversity in phenological and morphological characters of 18 bread wheat cultivars and lines. Characters such as days to anthesis, grain filling period, days to physiological maturity, grain yield and its components, plant height, peduncle length and weight, peduncle length to height ratio and spike length were evaluated. Assessment and investigation of phenotypic and genotypic coefficients for distinct characters exhibited that genotypes had more genetic diversity for plant height, spike length and weight, seed number per spike, 1000 seed weight, peduncle length and weight, and grain yield.

Saifullah *et al.* (2013) evaluated the wheat germplasm comprising of 50 genotypes contributed by CIMMYT for seven quantitative traits through cluster and principal component analyses. The first three PCs with eigen values >1 contributed 70.59% of the variability amongst genotypes. The characters contributing more positively with PC1 were number of spikelets per spike, spike length and grain yield (gram per plot). The cluster analysis sequestrated 50 genotypes into 5 clusters based on Ward's method. The cluster IV and V were more clearly separated than cluster I, II and III.

Tewari *et al.* (2015) observed the genetic diversity for yield, yield contributing traits and resistance to spot blotch disease in two hundred exotic germplasm accessions of bread wheat. The germplasm along with 4 checks were evaluated in augmented design for eight quantitative traits and spot blotch incidence. These, 200 wheat accessions were categorized into 8 clusters. The intra cluster distance was maximum for the cluster VII (2.431) and minimum for the cluster VIII (1.813). Inter cluster distance was maximum between cluster I and VIII (7.263) and minimum between cluster III and IV (2.292).

Materials and Methods

"Everyone has a will to win
But very few have the will to prepare for win"
Vinci Lombardi

Chapter 3

MATERIALS AND METHODS

The present investigation was conducted at the N.E. Borlaug Crop Research Centre, G.B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand; during *Rabi* season 2015-2016 and quality analysis in wheat laboratory, Department of Genetics and Plant Breeding, G.B. Pant University of Agriculture and Technology, Pantnagar.

3.1 Location and experimental site

Pantnagar geographically falls in the humid subtropical zone and is located between 79.3°E longitude and 29°N latitude with an altitude of 243.84 m above mean sea level. It comes under the state of Uttarakhand.

3.2 Climate and Weather

The weather condition during the crop growing season, *Rabi* 2015-16 were quite favourable for normal growth of wheat crop. The weather conditions prevailing during the course of experimental period are given under Appendix-I.

3.3 Experimental Material and Design

The experimental material consisted of 180 germplasm lines of bread wheat along with four prominent checks obtained from National Bureau of Plant Genetic Resources (NBPGR), New Delhi. The germplasm lines along with checks were evaluated in Augmented Block Design during *Rabi* season of 2015-2016.The checks included in the study were:

(a) WH 1105
(b) DPW 621-50
(c) PBW 343
(d) AGRA LOCAL

3.3.1 Experimental Details

The experiment was carried out in an Augmented Block Design with each block containing 35 test entries and 4 checks (randomly allocated) with the total of 39 genotypes in each block. Each genotype was sown in two rows of 2 meter length with a row spacing of 20 cm. Recommended package of practices was followed to grow the normal healthy crop.

3.3.2 Observations recorded

Observations were recorded on different qualitative and quantitative traits as follows:

a) Days to 75% heading

Recorded as number of days taken from the date of sowing to the day on which the ears come out of the flag leaf completely in 75 per cent of the plants.

b) Days to maturity

Recorded as number of days taken from the date of sowing to physiological maturity.

c) Plant height (cm)

The plant height was measured from soil surface to the tip of the spike excluding awns in centimetre.

d) Peduncle Length (cm)

Peduncle length of the plant were measured in centimetre as the distance from the last node to the base (collar) of spike.

e) Number of tillers per running meter

The number of tillers bearing ear heads per metre recorded at maturity.

f) Spike length (cm)

The length of the spike on the main culm was measured from the base of the first spikelet to the top of the last spikelet excluding awns in centimetre.

g) Number of spikelets per spike

Total number of spikelets on main spike were counted at the time of maturity.

h) Number of grains per spike

After harvesting and threshing of the spike, total number of grains in a spike were counted.

i) Grain weight per spike (g)

Grains obtained from a spike were weighed on electronic balance.

j) 1000 grain weight (g)

A sample of 1000 grains was weighed in grams on an electronic weighing balance.

k) Biological yield (g)

Biological yield was recorded by weighing the sun dried plants along with ears.

l) Grain yield per plot (g)

Recorded after harvesting and threshing of the whole plot in grams.

m) Harvest index (%)

Calculated as the ratio of economic (grain) yield to biological yield.

n) Quality traits

a) Protein content (%)

For assessing protein content, samples were analysed with NIT based whole grain analyser (Infratech 1241 grain analyser).

b) Test weight (kg/hl)

Test weight, also known as hectolitre mass, is a measure of the volume of grain per unit. It is usually expressed as kilograms per hectoliter.

c) Sedimentation value (ml)

SDS sedimentation test was used to know the protein quantity as well as quality. The procedure for estimating sedimentation value as given by **Lawrence Zeleny (1947)** is given below:

- Take five gram wheat flour (including bran) into graduated glass stoppered cylinder
- Add 50ml distil water into it
- Shake the cylinder 15 times and wait for 120 seconds
- Repeat the above step twice
- Now add 50 ml of SDS solution (lactic acid-sodium dodecyl sulfate)
- Invert these cylinder 4 times and again wait for 120 seconds
- Repeat the above step twice
- Now tubes are kept on smooth surface undisturbed for 500 seconds
- Measure the volume of sediments in the cylinders in ml. Volume of sediments will indicate quality of gluten protein.

3.4 Statistical Analysis

The following statistical methods were followed for analysis and for drawing results from the present investigation.

3.4.1 Analysis of Variance

For augmented block design analysis of variance was done by using the method given by **Federer (1956, 1961), Ragavarao (1975), and Petersen (1985).** The two way table of checks is depicted in Table 3.2.

Table 3.1 A two way table of check yields, totals and mean

Checks	**Blocks 1 2 3……. J**			**Total**	**Mean**
	1	**2**	**3……. J**		
Check 1	$X_{1.1}$	$X_{1.2}$	$X_{1.3}$ …. $X_{1.j}$	C_1	X_1
Check 2	$X_{2.1}$	$X_{2.2}$	$X_{2.3}$ …. $X_{2.j}$	C_2	X_2
Check n	$X_{i.1}$	$X_{i.2}$	$X_{i.3}$ …. $X_{i.j}$	C_n	X_i
Total	B_1	B_2	B_3 …. B_j	G	

Where,

X_{ij} = Yield of the i^{th} check in the j^{th} block

$B_j = \sum X_{ij}$ = Sum of all checks in j^{th} block

$C_i = \sum X_{ij}$ = Sum of all the yields of the i^{th} check

$G = \sum B_j = \sum C_j$ = grand total of all check yields

$X_i = C_i / b$ = Mean yield of the i^{th} check

$M = \sum X_i = G/b$ = Sum of the checks mean

b= Number of blocks

c = Number of checks

The next step is to calculate adjustment factor r_j, for each block. It is calculated as:

$r_j = (1/c)\ (B_j - M)$

Where,

c = Number of checks

$B_j = \sum X_{ij}$ = Sum of all checks in j^{th} block

Note: as check on the calculation, $r_j = 0$

A table of actual yields of the new selections, and the yields adjusted for the effect of the block in which the new selection was grown can now be constructed.

Selection	**Block**	**Yield**	
		Observed	**Adjusted**
1		Y_{1j}	Y_1
2		Y_{2j}	Y_2
-		-	-
-		-	-
-		-	-
-		-	-
V		Y_{vj}	Y_v

Where,

Y_{ij} = Yield of the ith new selection (in jth block)

$Y_v = Y_{ij} - r_j$ = Adjusted yield of the ith new selection (adjusted for the block effect)

An estimate of the experimental error which can be used to calculate standard errors and Least Significant Difference (LSD) is most easily obtained using an analysis of variance of check yields. The format of ANOVA is as follows:

Table 3.2 Analysis of Variance

Source of Variation	**Degree of freedom**	**Sum of squares**	**Mean sum of squares**
Block	b-1	SSB	MSB
Checks	c-1	SSC	MSC
Error	(b-1)(c-1)	SSE	MSE
Total	bc-1	SST	

Where,

$SSB= (1/c) \sum_j B_j^2 - G^2/ bc$

$SSC= (1/ b)\sum_j C_j^2 - G^2/ bc$

$SST= \sum_i\sum_j Xij^2 - G^2 / bc$

$SSE= SST - SSB - SSC$

$MSB= SSB / (b-1)$

$MSC= SSC/ (c-1$

$MSE= SSE/ (b-1) (c-1)$

Variance for pair wise comparison

1. Difference between the means of two check varieties = 2MSE / b

2. Difference between adjusted yields of two selections in the same block = 2MSE
3. Difference between adjusted yields of two selections in different blocks = 2MSE (c+1) / c
4. Difference between an adjusted selection yield and a check mean = MSE (b+1) (c+1) / bc
5. Average variance of the difference between two adjusted yields = MSE (2c+1) / c

Least significant difference

LSD's were be computed using the variance, given above, in the following way:

1. For the check means = $t\sqrt{\frac{2MSE}{b}}$

2. For the two adjusted new selections in the same block = $t\sqrt{2MSE}$

3. For two adjusted new selections in different blocks = $t\sqrt{\frac{2MSE(c+1)}{c}}$

4. For an adjusted genotype against check means = $t\sqrt{\frac{MSE(b+1)(c+1)}{bc}}$

For all LSD's, the 't' value at (p=0.05) and error degree of freedom will be used. The analysis gave adjusted values for all characters in each genotype. Further, classificatory analysis will be done on these adjusted values of variables.

3.4.2. Estimation of phenotypic and genotypic coefficients of variation:

The phenotypic and genotypic coefficients of variation were computed by the following formulae given by **Burton (1952).**

Genotypic coefficient of variation (GCV)

$$GCV\ \% = \frac{genotypic\ standard\ deviation}{population\ mean}$$

$$PCV\ \% = \frac{phenotypic\ standard\ deviation}{population\ mean}$$

3.4.3 Heritability:

Heritability in per cent in broad sense was estimated by the following formula given by **Singh and Choudhary (1977)**.

$$\% h^2 b = \frac{\sigma^2 g}{\sigma^2 p}$$

Where, h^2b = Heritability

σ^2g = Genotypic variance

σ^2p = Phenotypic variance

3.4.4 Genetic advance (GA): The estimates of expected genetic advance from selection was obtained by the formula suggested by **Robinson, Comstock, and Harvey (1949).**

$$GA = K \times \sigma p \times h^2 b$$

Where,

k = Selection differential, the value of which is 2.06 at 5 % selection intensity

σp = Phenotypic standard deviation

Genetic Advance as percentage of mean= $\frac{Genetic\ advance}{Population\ mean}$

3.4.5 Correlation coefficients

The estimation of correlation coefficient is based on the variance and covariance of x and y variables. Correlation ranges between +1 to −1. The intensity of relationship was measured by correlation coefficients (r). The correlation coefficient was computed as per the formula given by **Searle (1961)** as

$$r_{xy} = \frac{\mathrm{Cov\ (xy)}}{\sqrt{\mathrm{Var(x)Var(y)}}}$$

Where,

r_{xy} = Correlation coefficient between x and y

Cov (xy) = Covariance between x and y

Var. (x) = Variance of x

Var. (y) = Variance of y

n = Number of observations

Variance and covariance will be calculated by following formula:

$$\text{Var. }(x) = \frac{1}{n}\left[\sum x^2 - \frac{(\sum x)^2}{n}\right]$$

$$\text{Var. (y)} = \frac{1}{n}\left[\sum y^2 - \frac{(\sum y)^2}{n}\right]$$

$$\text{Cov. }(xy) = \frac{1}{n}\left[\sum xy - \frac{(\sum x)(\sum y)}{n}\right]$$

To test the significance of correlation coefficient, the t-value will be calculated as per **Snedecor and Cochran (1967)** as

$$t = \frac{r}{\sqrt{1-r^2}} \times \sqrt{n-2}$$

Where,

r = correlation coefficient

n = number of observations

3.4.6 Path coefficient analysis

The phenotypic and genotypic correlation coefficients were further divided into direct and indirect effects with the help of path coefficient analysis as suggested by **Wright (1921)** and elaborated by **Dewey and Lu (1959).** As grain yield was influenced by the other characters called independent variable causes so it was considered as dependent variable. The path coefficient was estimated by solving following set of simultaneous equations indicating the basic relationship between correlation and path coefficients.

$$r_{iy} = P_{iy} + r_{i1}P_{1y} + r_{i2}P_{2y} + \ldots\ldots\ldots\ r_{i(i-1)}P_{iy}$$

$i = 1, 2, 3\ldots\ldots..n$

where,

i = number of independent characters (causes)

r_{1y} to r_{iy} = coefficient of correlation between independent variable (1……. i) with dependent variable y

r_{i1} to $r_{i(i-1)}$ = coefficient of correlation among all possible combination of caused factors (independent variable)

P_{1y} to P_{iy} =direct effects of independent variable on dependent variable ‘y’

The above equation can be written in a matrix form as follows:

$$\overset{\textbf{A}}{\begin{bmatrix} r_{1y} \\ r_{2y} \\ r_{3y} \\ r_{4y} \end{bmatrix}} = \overset{\textbf{B}}{\begin{pmatrix} 1 & r_{12} & r_{13} & r_{14} \ldots\ldots\ldots\ldots & r_{1i} \\ & 1 & r_{23} & r_{24} \ldots\ldots\ldots\ldots & r_{2i} \\ & & 1 & r_{34} \ldots\ldots\ldots\ldots & r_{3i} \\ & & & 1 \ldots\ldots\ldots\ldots & r_{4i} \end{pmatrix}} \quad \overset{\textbf{C}}{\begin{bmatrix} P_{1y} \\ P_{2y} \\ P_{3y} \\ P_{4y} \end{bmatrix}}$$

$B = C^{-1} A$

$$\text{Let} \qquad C^{-1} = \begin{pmatrix} C_{11} & C_{12} \ldots\ldots\ldots & C_{1i} \\ & C_{22} \ldots\ldots\ldots & C_{2i} \\ & & C_{ii} \end{pmatrix}$$

Path coefficient was estimated as follows:

$P_{iy} = r_{i1} .C_{1i} .\ r_{iy}$;

$P_{2y} = r_{i1} .C_{2i} .\ r_{iy}$

The effect of residual factors (z) which measure the contribution of rest of characters is not considered in casual scheme. It was though calculated as follows:

$$P_{zy} = \sqrt{1 - R^2}$$

Where,

$$R^2 = \sum_{i=1}^{r} P^2 iy + 2\sum_{\substack{i=1 \\ j<1}} P_{iy}\, P_{jy}\, r_{ij}$$

R^2 denotes coefficient of multiple determination.

3.4.7 Non-hierarchical cluster analysis

Non-hierarchical Euclidean cluster analysis described by **Beale (1969)** and elaborated by **Spark (1973)** was used to study the genetic divergence among genotypes. The principal component scores obtained from original variables were utilized for this analysis. According to **Beale (1969)** initially each observation is located to closest cluster center. The mean clusters are then calculated and are taken to new cluster centers. At the same time, the sum of square deviation of the observations from their respective cluster center is computed. The observation are then checked in turn to see if a shift to a different cluster center results in decrease in total sum of squares. This assumes that d_j^2 is less than d_k^2, where d_j^2 is the distance from the center of cluster *i.e.* however, a more effective criterion involves re-assigning the observation, if cluster I, is less than that from the center of cluster k, even when the cluster center are simultaneously reposition that is when:

$$\frac{ni}{ni + 1} d_i^2 \frac{nk}{nk + 1} d_k^2$$

Where *ni* is the number of observation in cluster 'i'

In delimiting cluster usually average among a subset of 'm' points is considered, not the individual $i^2m(m-1)$ deviances. If the ith variable on the jth member is $X_{ij,}$ average of the mean deviance of set of 'm' is as follows:

$$= \frac{1}{m(m - 1)} \sum_{i=1}^{D} \sum_{j=1}^{-M} \sum_{k=1}^{-M} (x_{ij} - x_{kj})^2$$

$$= \frac{1}{m(m - 1)} \sum_{i=1}^{D} \sum_{j=1}^{-M} \sum_{k=1}^{-M} [(x_{ij} - x_i) - (x_{ik} - x_i)]$$

Where, x_i is the mean of x_i over m members

$$= \frac{1}{m(m - 1)} \sum \left[\sum_{j} \sum_{k} (x_{ij} - x_i) + \sum_{j} \sum_{k} (x_{ik} - x_i)^2 - 2 \sum_{j} \sum_{k} (x_{ij} - x_j)(x_{ik} - x_i) \right]$$

The cross product term vanishes and other two are equal:

$$\text{Average deviation} = \frac{2}{m-1} \sum_{i=1}^{m} \sum_{j=1}^{p} [x_{kj} - x_i]^2$$

Thus, now, instead of calculating *1/m (m-1)* deviance, '*m*' deviation from the centre of gravity was calculated.

Hence, assumptions in this method were that the Euclidean distances 'D' separating '*n*' point in a '*p*' dimensional space are proportional to the dissimilarities between the objects, and secondary, that no object belongs simultaneously to two clusters.

Initially, a given number of vector D of cluster center are located in the '*p*' space. The position of three centers can be chosen arbitrary or randomly, however, a good choice of initial cluster centers reduces the amount of computation to a considerable extent. To start with '*n*' cases are allocated to a predator-mixed maximum number of clusters (c. max) according to the procedure suggested by **Beale (1969).** The residual sum of sequences RSS (c) for the solution involving '*c*' clusters was calculated.

Then the number of cluster 'c' was reduced by 1 (unless c = min) and this procedure was repeated till 'c' maximum was reached i.e. further reduction is negligibly small. For each step RSS (c) was calculated when RSS (c) values for 'c' max.., c min were available, these were used in a sequential ration test of the null hypothesis that the solution for 'c' cluster provided no better fit than the solution for the C_2 with $C_l > C_2$. This F ratio was calculated as:

$$F = \frac{RSS(c_1) - RRS(c_1)}{RRS(c_1)} / \frac{\frac{(n-c_1c_2)^2}{p} - 1}{n - c_1c_2}$$

With *p (c_1-c_2)* and *p (n-c_1)* degree of freedom, the null hypothesis is rejected if this *F* exceeds the table value of *F*.

For calculating the number of clusters by 1 till c min was reduced, **Beale** had suggested certain procedure instead of using Belays procedure for merging two clusters. **Doshi *et al.* (1981)** had adopted a simple procedure. When a solution is found for 'c' clusters "c" of new cluster are calculated. From this set of new cluster centre vectors, last vector is dropped and (c-l) vector were used as initial vector of cluster centers for arriving at (c-l) cluster.

The classificatory analysis gave clusters of genotypes where similar types occur in one cluster. The solution provides classified genotypes.

Results and Discussion

> *"Do not believe in anything because it is presented so*
> *It is said to you, unless and until you, yourself,*
> *explore the truth"*
>
> **Swami Vivekanand**

Chapter 4 RESULTS AND DISCUSSION

The knowledge about nature and amount of genetic diversity is of utmost importance for a systematic breeding effort. The presence of ample genetic diversity in the base material causes better chance of evolving desirable plant types. Yield is a complex polygenic character and is resultant of interactions of several genetic and environmental factors hence it requires continuous improvement involving the diverse material. Keeping this in view, the present Investigation entitled “Characterization of germplasm for yield, its components and quality traits in wheat (*Triticum aestivum* L. em. Thell)” was conducted using 180 genotypes of bread wheat to study variability, genetic diversity for various morphological, yield and quality traits along with the association between them. In addition, the investigation was used to study the direct and indirect effects of component characters on yield. The tested genotypes were also grouped into different clusters based on the genetic distance between them. The salient findings of the present investigation are mentioned under the following headings:

4.1 Analysis of variance

4.2 Estimation of variability

4.3 Estimates of coefficients of variation, heritability and genetic advance

4.4 Character association

4.5 Path coefficient analysis

4.6 Estimation of genetic divergence

4.1 Analysis of variance

The analysis of variance was carried out for 16 characters *viz.,* days to 75% heading, days to maturity, plant height, number of tillers per meter, peduncle length, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000 grain weight, biological yield, grain yield, harvest index, protein content, sedimentation value, and test weight of genotypes in augmented block design (Table 4.1). The adjusted means are presented in Appendix- I.

The analysis of variance depicted significant differences among genotypes for all the characters studied. Variance (mean sum of squares) was found highest for biological yield followed by grain yield, number of tillers per meter, peduncle length, plant height, test weight and days to maturity.

Table 4.1: Analysis of variance for different characters in germplasm of wheat

S.No.	Characters	Mean Sum of Squares (df)		
		Block (4)	Check (3)	Error (12)
1	Days to 75% heading	96.55**	11.64	7.56
2	Days to maturity	159.93**	16.33	21.63
3	Plant height (cm)	284.80*	613.15**	86.21
4	No. of tillers per meter	3456.26*	4405.92**	364.34
5	Peduncle length (cm)	609.12**	70.30	20.51
6	Spike length(cm)	8.99**	2.09	1.24
7	No. of spikelets per spike	116.54**	1.92	1.92
8	No. of grains per spike	115.65**	48.99	20.37
9	Grain weight per spike (g)	7.88**	0.94*	0.18
10	Thousand grain weight (g)	104.04**	54.49*	12.95
11	Biological yield (g)	387325.47**	339618.87	79460.91
12	Grain yield (g)	22695.41*	4988.27	5273.64
13	Harvest index	0.05**	0.0012	0.0035
14	Test weight (Kg/hl)	196.87**	6.92	4.73
15	Protein content (%)	3.32**	0.46	0.37
16	Sedimentation value (ml)	63.46**	47.33**	2.21

**Significantly different at 1 % level of significance; *Significantly different at 5 % level of significance

The basic requirement for any crop improvement programme is the availability of genetic variation. Greater the variability in the experimental material, higher is the chance of recovering improved lines. The above mentioned results of the present investigation reveal the abundance of genetic variability in the germplasm pool (180 lines) of wheat for all the characters. Biological yield, grain yield and number of tillers per meter exhibited maximum variance followed by peduncle length, plant height, test weight and days to maturity. Low amount but significant variance was showed by ear length, grain weight per spike and protein content. These results are in agreement with the findings of **Kumar and Kumar (1983), Shah *et al.* (2003), Asif *et al.* (2004) and Baranwal *et al.* (2012)**. Traits like grain yield, number of tillers per meter must be given due importance while practicing selection in wheat improvement programmes.

4.2 Estimation of variability

The mean, range of variation and least significant differences for various characters studied during the course of investigation are mentioned in Table 4.2. The character-wise results are discussed below:

4.2.1 Days to 75 % heading

Days to 75% heading ranged from 82.20 to 104.01 with general mean of 91.24 days. Coefficient of variation was found to be 2.78 per cent. Minimum number of days to 75 % heading were recorded in IC-82219 (82.20) followed by IC-78924 (82.26) and IC-73351 (83.20), whereas the maximum was found in genotype IC-79005 (104.01).

4.2.2 Days to maturity

This character ranged from 120.9 to 152.4 days with general mean of 134.87 days. Coefficient of variation for this character was found to be 3.18 per cent. Genotype IC-78924 took least number of days to maturity (120.9 days) followed by IC-534430 and IC-532472 (122.9 days). The maximum number of days to maturity were taken by the genotype IC-38870 (152.4 days).

4.2.3 Plant height (cm)

Plant height ranged from 72.35 to 149.35 cm with general mean of 105.42. The coefficient of variation for this character was found to be 8.11 per cent. The most dwarf genotype was found to be IC-78938 (72.35 cm) followed by IC-55636 (73.22 cm) and IC-534820 (80.35 cm). The tallest genotype was IC-61836 (149.35 cm).

4.2.4 Number of tillers per meter

It varied from 28.75 to 242.75 with a general mean of 116.43. Coefficient of variation for this character was observed to be 20.6 per cent. The genotype IC-73683 produced maximum number of tillers (242.75) followed by IC-532373 (217) and IC-594790 (201).

4.2.5 Peduncle length (cm)

The character showed a range from 17.14 to 74.43 cm with a mean value of 41.08 cm. Coefficient of variation for this character was observed to be 10.16 per cent. Peduncle length was highest for genotype IC-75353 (74.43 cm) and lowest for IC-532809 (17.14 cm).

4.2.6 Spike length (cm)

It ranged from 7.40 to 17.84 cm with genotype IC-532409 showing smallest ear (7.40 cm) and genotype IC-60208 showing the maximum ear length (17.84 cm). The coefficient of variation for this trait was found to be 8.87 per cent.

4.2.7 Number of spikelets per spike

The trait showed a general mean of 20.82 with a range from 12.90 to 28.60. The genotypes IC-138729 and IC-73497 had highest number of spikelets per spike (28.60) whereas, the lowest were found for the genotype IC-534870 (12.90). The coefficient of variation for this character was 9.79 per cent.

4.2.8 Number of grains per spike

It ranged from 16.20 to 81.42 with a mean value of 48.10. The coefficient of variation for the character was found to be 8.56%. The genotype IC-532245 exhibited highest number of grains per spike (81.42) followed by IC-532212 (79.07) and IC-55636 (78.62).

4.2.9 Grain weight per spike (g)

The trait showed a general mean of 2.18 g with a range from 0.77 to 5.30 g. The genotype IC-78962 exhibited highest grain weight per spike (5.30 g) followed by IC-79056 (5.26 g) and IC-75321 (4.50 g). The coefficient of variation for this character was found to be 17.52 per cent.

4.2.10 Thousand grain weight (g)

1000 grain weight ranged from 20.27 to 67.40 g with general mean of 40.26 g. The coefficient of variation for this character was found to be 8.19 per cent. The maximum 1000 grain weight was exhibited by the genotype IC-532931 (67.39 g) followed by IC-138846 (61.00 g) and IC-5324208 (60.70 g) whereas; the lowest value was exhibited by genotype IC-28637 (20.27 g).

4.2.11 Biological yield (g)

Biological yield ranged from 223.90 to 2632.40 grams per meter with a mean value of 995.47. Coefficient of variation was found to be 15.14 per cent. Maximum biological yield was recorded in the genotype IC-532150 (2632.40) followed by IC-82219 (2532.40) and IC-532420 (2294.90).

4.2.12 Grain yield (g)

This trait showed a general mean of 273.31 g with a range from 77.85 to 964.00 g. The coefficient of variation for this character was found to be 27.47 per cent. Maximum grain yield was recorded in the genotype IC-532150 (964.60 g) followed by IC-82219 (883.60 g) and IC-753957 (587.85 g).

4.2.13 Harvest Index (%)

Harvest index ranged from 10 to 68 % with general mean of 29%. The coefficient of variation for this character was found to be 18.62 per cent. The maximum harvest index was exhibited by the genotype IC-532152 (68%) followed by IC-79022 (65%) and IC-75354 (63%).

4.2.14 Test weight (Kg/hl)

It ranged from 61.10 to 88.11 Kg/hl with genotype IC-532420 having maximum value followed by IC-532463 (82.91 Kg/hl) and IC-532952 (82.58 Kg/hl). The lowest hectoliter weight was recorded in genotype IC-73650. The coefficient of variation for this character was found to be 2.63 per cent.

4.2.15 Protein content (%)

The mean value of this character was found to be 11.67 % with a range of 9.32 to 14.88 %. Genotype IC-208906 exhibited highest protein content followed by IC-73650 (14.48 %) and IC-75353 (14.12 %). The coefficient of variation for this character was found to be 4.82 %.

4.2.16 Sedimentation value (ml)

The mean value of this character measured over 40 genotypes having high protein content was recorded to be 24.07 with a range of 20.85 to 48.60. Genotype IC-73650 exhibited highest sedimentation value followed by IC-208906 (42.85) and IC-79046 (34.6). The coefficient of variation for this character was found to be 20.63%.

The results showed that the coefficient of variation (CV) was found to be highest for grain yield (27.47) followed by number of tillers per meter (20.6), harvest index (18.62), grain weight per spike (17.52) and biological yield (15.14).

4.2.18 Least significant difference between means of two check varieties (CM)

It was found to be highest for biological yield (218.46) followed by grain yield (108.49), number of tillers per meter (34.71), plant height (12.34) and days to maturity (6.18). The other characters exhibited quite lesser values of CM.

4.2.19 Least significant difference between the adjusted value of two selections in the same block (AVSB)

It was found to be highest for biological yield (546.16) followed by grain yield (271.23), number of tillers per meter (86.79), plant height (30.84), days to maturity (15.45), peduncle length (15.04) and number of grains per spike (14.99).

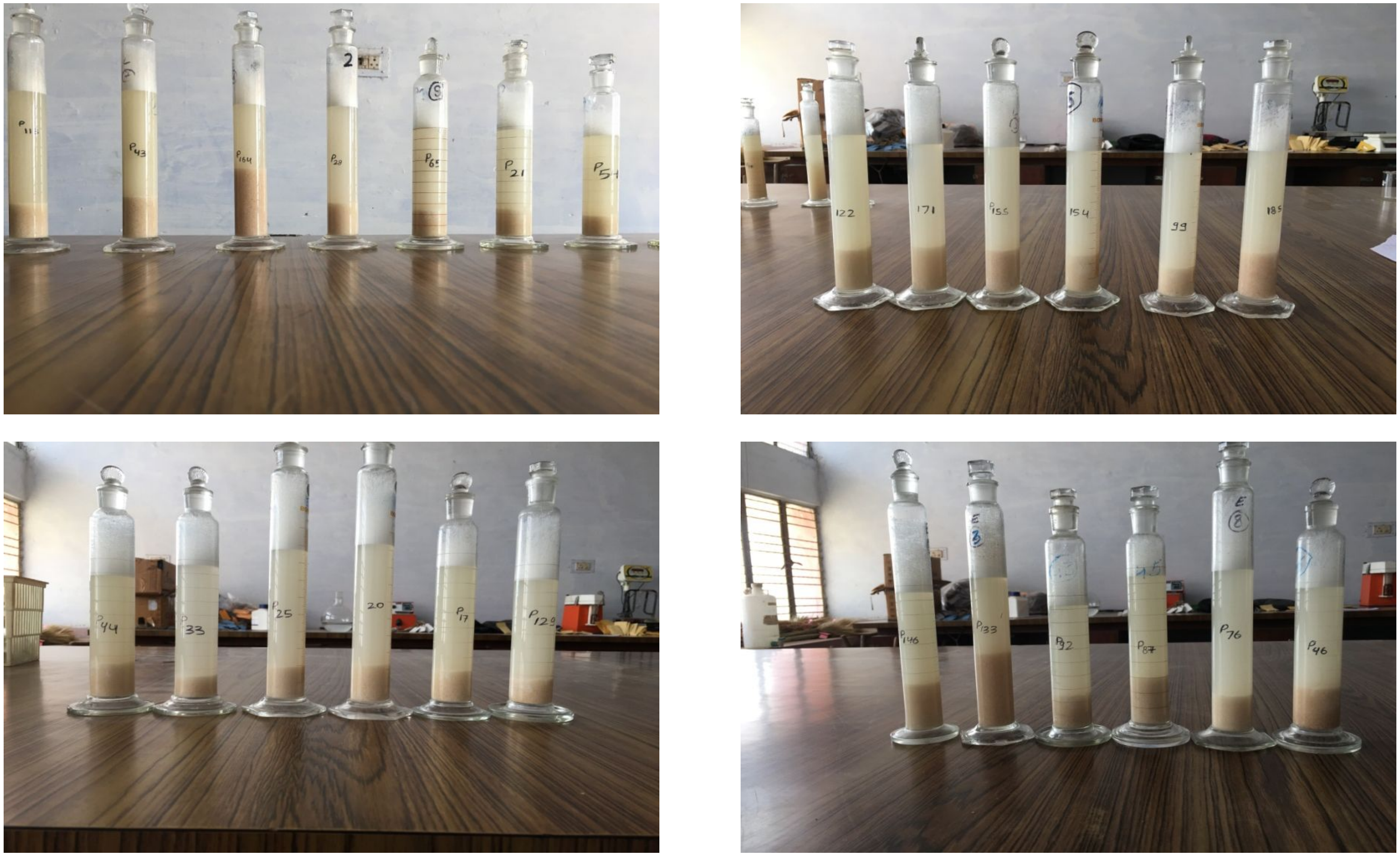


Plate 1: Sedimentation test

Table 4.2: Mean, range and least significant differences in wheat germplasm

Characters	Genotypes		Checks				CV%	CM (5%)	AVDB (5%)	AVSB (5%)	AVAC (5%)
	Mean	Range	1	2	3	4					
Day to 75% heading	91.24	82.20 – 104.01	89.05	90.00	91.55	87.95	2.78	3.65	8.17	9.14	7.08
Days to maturity	134.86	120.90-152.40	133.20	132.8	135.00	130.60	3.18	6.18	13.82	15.45	11.97
Plant height (cm)	105.42	72.35 -149.35	107.80	99.70	93.40	119.05	8.11	12.34	27.59	30.84	23.89
No. of tillers per meter	116.43	28.75 - 242.75	120.40	116.80	83.60	156.20	20.6	34.71	77.62	86.79	67.22
Peduncle length (cm)	41.08	17.14 - 74.43	37.70	39.52	36.70	45.10	10.16	6.02	13.46	15.04	11.65
Spike length (cm)	11.57	7.40 - 17.84	12.23	11.80	10.71	11.77	8.87	1.48	3.32	3.71	2.87
No. of spikelets per spike	20.82	12.90 - 28.60	21.40	20.60	19.00	21.40	9.79	2.94	6.58	7.35	5.69
No. of grains per spike	48.10	16.20 -81.42	51.08	54.51	48.00	54.50	8.56	5.997	13.41	14.99	11.62
Grain weight per spike (g)	2.18	0.77 - 5.30	2.73	1.96	1.93	2.65	17.52	0.56	1.25	1.39	1.07
Thousand grain weight (g)	40.26	20.27 - 67.40	41.65	37.75	41.86	46.88	8.19	4.78	10.69	11.95	9.26
Biological yield (g)	995.47	223.90 - 2632.40	823.60	794.00	1232.00	1284.00	15.14	218.46	488.50	546.16	423.05
Grain yield (g)	273.31	77.85 - 964.60	269.40	268.20	242.60	318.20	27.47	108.49	242.59	271.23	210.09
Harvest Index (%)	29	10 - 68	29	28	26	26	18.62	0.079	0.18	0.196	0.15
Test Weight (kg/hl)	76.06	61.10 - 88.11	75.78	73.52	74.22	75.92	2.63	2.89	6.46	7.22	5.59
Protein content (%)	11.67	9.32 - 14.88	11.01	11.45	11.02	10.71	4.82	0.81	1.81	2.02	1.57
Sedimentation value (ml)	24.07	20.85 – 48.60	20.20	18.00	14.80	13.40	20.63	1.98	4.41	4.93	3.82

CM= Least significant difference between the mean of two check varieties; AVSB= Least significant difference between adjusted value of two selections in same block; AVDB= Least significant difference between adjusted value of two selections in different blocks; AVAC= Least significant difference between an adjusted selection value and a check mean.

4.2.20 Least significant difference between the adjusted value of two selections in the different blocks (AVDB)

This was observed to be highest for biological yield (488.5) followed by grain yield (242.59), number of tillers per meter (77.62), plant height (27.59), days to maturity (13.82), peduncle length (13.46) and number of grains per spike (13.41).

4.2.21 Least significant difference between an adjusted selection value and a check mean (AVAC)

It was found to be highest for biological yield (423.05) followed by grain yield (210.09), number of tillers per meter (67.22), plant height (23.89), days to maturity (11.97), peduncle length (11.65) and number of grains per spike (11.62).

From the above results, it is clear that a wide range of variation was observable in the genotypes for most of the characters. A high magnitude of coefficient of variability was recorded for characters like biological yield, grain yield, number of tillers per meter, plant height, days to maturity, peduncle length and number of grains per spike. These results are in concordance with the reports of **Bametha (1989), Singh (1989), Kulshreshtha (1992), Getachew-Belay *et al.* (1993), Sultana *et al.* (2005), Shankarrao *et al*. (2010).** The estimates of coefficient of variability were moderate for 1000-grain weight as also suggested by **Sultana *et al.* (2005).**

High genetic variability in any crop improvement programme is always essential and useful for effective selection and genetic up gradation of concerned crop species. The results of the present investigation revealed that significant and high amount of variability is existing in the germplasm pool of wheat evaluated during the study. The desirable genotypes identified to be superior for particular characters can be crossed in several fashions with each other to accumulate as many desirable alleles as possible in the same genotype, popularly known as combination breeding.

4.3 Estimates of coefficients of variation, heritability and genetic advance

In self pollinated crops, the assessment of genotypic variance, estimates of heritability and genetic advance of yield contributing characters are important for successful hybridization programme to evaluate new cultivars (**Amin *et al.*, 1992**). Selection on the basis of phenotypic variation is not efficient and selection therefore, based on evaluation and utilization of genetic variability in a desired direction is extremely important in wheat improvement programme. The estimates of heritability, genetic advance and genotypic, phenotypic, and environmental coefficients of variation obtained from the present investigation are mentioned in Table 4.3.

Table 4.3: Heritability and genetic advance (GA), genotypic, phenotypic and environmental coefficient of variation for different characters

Characters	**GCV (%)**	**PCV (%)**	**ECV (%)**	**Heritability (broad sense) %**	**GA (% of mean)**
Days to 75% heading	2.84	4.14	3.01	47.00	5.14
Days to maturity	1.70	3.84	3.44	19.70	2.00
Plant height (cm)	10.54	13.74	8.80	58.90	21.37
No. of tillers per meter	15.17	27.08	22.43	31.40	22.44
Peduncle length (cm)	18.13	21.21	11.00	73.10	40.92
Spike length (cm)	12.58	15.85	9.64	63.00	26.37
No. of spikelets per spike	7.86	13.22	10.62	35.40	12.35
No. of grains per spike	22.58	24.45	9.38	85.30	55.06
Grain weight per spike (g)	30.99	36.43	19.15	72.40	69.61
Thousand grain weight (g)	15.34	17.75	8.94	74.60	34.98
Biological yield (g)	37.44	40.92	16.51	83.70	90.45
Grain yield (g)	26.96	40.24	29.87	44.90	47.69
Harvest index (%)	27.25	33.86	20.09	64.80	57.92
Test weight (Kg/hl)	3.63	4.62	2.85	61.80	7.54
Protein content (%)	6.07	8.00	5.21	57.60	12.17

A wide range of phenotypic coefficient of variation (PCV) was observed for all the traits ranged from 3.84 (days to maturity) to 40.92 (biological yield). Higher magnitude of PCV was recorded for biological yield (40.92), grain yield (40.24), grain weight per spike (36.43), harvest index (33.86), number of tillers per meter (27.08) and number of grains per spike (24.45). Genotypic coefficient of variation (GCV) ranged from 1.70 (days to maturity) to 37.44 (biological yield). Biological yield had maximum estimate of both the coefficients of variation in the present study. Low value of genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV) was observed for characters like days to 75 % heading and days to maturity. **Shoran (1995)** also indicated little variability and scope for selection for days to heading and days to maturity in his study. These findings of genotypic and phenotypic variance for different quantitative characters in wheat are in accordance with the findings of **Sharma *et al.* (2006)**. On an average, the higher magnitude of GCV and PCV were recorded for grain yield, harvest index, number of tillers per meter and number of grains per spike suggesting sufficient variability and thus scope for genetic improvement through selection for these traits. These findings were in agreement with those of **Amin *et al*. (1992), Panwar and Singh (2000), Bergale *et al.* (2001), Dwivedi *et al.* (2004)** and **Dutamo *et al.* (2015).** They also observed the PCV values higher than GCV values for different quantitative characters in wheat.

The estimates of phenotypic coefficient of variation were found little higher than their corresponding genotypic coefficient of variation, indicating the little influence of environment on the expression of these characters. Less difference in the estimates of genotypic and phenotypic variance and higher genotypic values compared to environmental variances for all the characters suggested that the variability present among the germplasm pool were mainly due to genetic reason with minimum influence of environment and hence heritable.

Heritability in broad sense is the ratio of genotypic variance to the total variance. It is that portion of total variability or phenotypic variability which is heritable and due to the genotype. It is a measure of the extent of phenotypic variation caused by the action of genes. Heritability plays an important role in deciding the suitability and strategy for selection of a character. In the present investigation, the heritability estimates ranged from 19.70 to 85.30 per cent**.** **Pramoda** and **Gangaprasad (2007)** had classified the heritability values into various categories from low (<40%) to very high (>80%) estimates. High heritability estimates were shown by number of grains per spike (85.30 %) and biological yield (83.70 %). This indicates that the selection for these characters in segregating generations will be quite effective. Whereas, other characters like days to 75% heading (47.00 %), plant height (58.90 %), ear length (63.00 %), peduncle length (73.10 %), 1000-grain weight (74.60 %), grain yield (44.90 %), harvest index (64.80 %), test weight (61.80 %) and protein content (57.60 %) showed intermediate heritability estimates. Low estimates of heritability were shown by days to maturity (19.70 %), number of tillers per meter (31.40 %) and number of spikelets per spike (35.40 %) which indicates that selection for these characters will be less effective. Similar results have also been reported by **Amin *et al.* (1992), Panwar and Singh (2000), Asif *et al.* (2004)** and **Rasal *et al.* (2008).**

Heritability alone provides no indication of amount of genetic improvement that would result from selection of individual genotype, hence knowledge about genetic advance coupled with heritability is most useful (**Vashistha *et al.*, 2013**). Genetic advance is the improvement in the mean of selected family over the base population (**Lush 1949; Johnson *et al.* 1955**). Characters exhibiting high heritability may not be necessarily give high genetic advance. **Johnson *et al.* (1955)** showed that high heritability should be accompanied by high genetic advance to arrive at more reliable conclusion. A breeder must be cautious in making selection based on heritability as it includes both additive and non-additive gene effects. A perusal of the data mentioned in Table 4.3 reveals that high genetic advance was recorded for biological yield (90.45) followed by grain weight per spike (69.61), harvest index (57.92), number of grains per spike (55.06), peduncle length (40.92), ear length (26.37), number of tillers per meter (22.44) and plant height (21.37). Intermediate estimates of genetic advance were shown by number of spikelets per spike (12.35) and protein content (12.17). Whereas, low estimates were obtained for days to maturity (2.00), days to 75 % heading (5.14) and test weight (7.54).

High heritability accompanied with high genetic advance was found for biological yield and number of grains per spike. It indicates that most likely the heritability is due to additive gene effects and selection may be effective. **Gupta and Verma (2000)** also reported high values of heritability and high genetic advance for number of grain per spike. High heritability and high genetic advance indicates the preponderance of additive gene effects (**Panse, 1967**) therefore, characters can be better exploited through selection. The same was suggested through the findings of **Mandal *et al.* (2008)**. Days to 75 % heading and test weight showed intermediate heritability with low genetic advance which indicates that their heritability estimates are due to non-additive genetic variance and selection for these characters may not be effective.

4.4 Character association

The association among various characters was worked out by calculating the simple correlation coefficients which were then subdivided into measures of direct and indirect effects using path coefficient analysis. The results pertaining to the association among the characters are briefly discussed below:

4.4.1 Correlations

The correlation coefficient among yield and yield contributing characters is presented in Table 4.4. It was observed that grain yield showed significant positive correlation with harvest index (0.437), 1000- grain weight (0.255), biological yield (0.238), spike length (0.232), days to maturity (0.224), number of grains per spike (0.200), days to 75% heading (0.192), number of spikelets per spike (0.175) and grain weight per spike (0.153). However, grain yield showed significant negative correlation with plant height (-0.225) and non-significant correlation with number of tillers (0.113), test weight (0.102), peduncle length (0.060) and protein content (0.049).

Harvest index showed significant positive correlation with grain weight per spike (0.181), days to 75 % heading (0.160), 1000-grain weight (0.154), number of grains per spike (0.148) and days to maturity (0.146). However, it exhibited significant negative correlation with biological yield (-0.194).

Biological yield exhibited significant positive correlation with peduncle length (0.306), days to 75% heading (0.223), number of tillers per meter (0.209), days to maturity (0.191), test weight (0.156) and plant height (0.153). Whereas, non-significant correlation was observed with rest of the characters.

Test weight showed significant positive correlation with 1000-grain weight (0.285), grain weight per spike (0.245), days to 75% heading (0.176), days to maturity (0.167) and ear length (0.148).

Protein content exhibited significant positive correlation with days to maturity (0.239), peduncle length (0.238) and days to 75 % heading (0.169). With rest of the characters, it exhibited non-significant correlation.

1000- grain weight showed significant positive correlation with grain weight per spike (0.402), test weight (0.285), economic yield (0.255) and harvest index (0.154). With other characters, it exhibited non-significant correlation.

Grain weight per spike depicted significant positive correlation with grains per spike (0.584), 1000-grain weight (0.402), days to 75% heading (0.264), test weight (0.245), days to maturity (0.241), harvest index (0.181) and grain yield (0.153).

Number of grains per spike exhibited significant positive correlation with grain weight per spike (0.584), ear length (0.236), number of spikelets per spike (0.194) and harvest index (0.148).

Number of spikelets per spike showed significant positive correlation with ear length (0.296), number of grains per spike (0.194), grain yield (0.175) and days to 75% heading (0.160).

Spike length exhibited significant positive correlation with number of spikelets per spike (0.296), number of grains per spike (0.236), grain yield (0.232) and test weight (0.148).

Peduncle length showed positive significant correlation with plant height (0.466), biological yield (0.306) and protein content (0.238). Number of tillers per meter showed significant positive correlation with biological yield (0.209) and plant height (0.179).

Plant height exhibited significant positive correlation with peduncle length (0.466), number of tillers per meter (0.179) and biological yield (0.153). Days to maturity showed significant positive correlation with days to heading (0.902), protein content (0.239), grain yield (0.224), biological yield (0.191), test weight (0.167) and harvest index (0.146).

The above results revealed that grain yield was positively and significantly associated with days to 75 % heading, days to maturity, ear length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000-grain weight, biological yield and harvest index. Thus, it can be stated that such characters must be considered while practicing selection in segregating populations for yield improvement in wheat crop. Similar associations between yield and component characters were recorded by **Sinha** and **Sharma (1980), Joshi (1984), Kumar** ***et al.*** **(1986), Bametha (1989), Sandhu** and **Lal (1989), Crowley** ***et al.*** **(1993), Subhani** and **Khaliq (1994), Bergale** ***et al.*** **(2002), Anwar** ***et al.*** **(2009), Pawar** ***et al.*** **(1990), Lu** ***et al.*** **(1991), Mohan** ***et al.*** **(1993), Ibrahim (1994), Larpik (1979), Paul** and **Ganguli (1996), Dwivedi** ***et al.*** **(2002), Mohammad** ***et al.*** **(2008), Rangare** ***et al.*** **(2010), Ashraf** ***et al.*** **(2012), Bhushan** ***et al.*** **(2013), Kumar** ***et al.*** **(2014)** and **Khan** ***et al.*** **(2015).**

Among other important characters, 1000- grain weight showed significant positive correlation with grain weight per spike, similar relationship has also been reported by **Sinha** and **Sharma (1980) and Tripathi (1983).** Number of grains per spike had positive significant association with spike length and number of spikelets per spike. Similar findings have also been reported by **Rahman (1980), Sinha** and **Sharma (1980), Raut** ***et al.*** **(1977), Mandakh (1988)** and **Lynch** ***et al.*** **(2017).** Number of spikelets per spike showed positive significant association with spike length which were also reported by **Pandilla** ***et al.*** **(1972), Tripathi (1983), Joshi (1984), Bhuller** ***et al.*** **(1985), Bangarwa (1987) and Gill** ***et al.*** **(1981).**

Table 4.4: Correlations between yield, its components and quality traits

Characters	Days to 75 % heading	Days to maturity	Plant height (cm)	Number of tillers per meter	Peduncle length (cm)	Spike length (cm)	Number of spikelet per spike	Number of grains per spike	Grain weight per spike (g)	1000-grain weight (g)	Protein content (%)	Hectoliter weight (Kg/hl)	Biological yield (g)	Harvest index (%)	Grain yield (g)
Days to 75% heading	1.000	0.902**	-0.045	-0.007	-0.165*	0.126	0.160*	-0.109	0.264**	0.121	0.169**	0.176*	0.223**	0.160*	0.192*
Days to maturity		1.000	-0.07	-0.027	-0.171*	0.07	0.105	-0.11	0.241**	0.135	0.239**	0.167*	0.191**	0.146*	0.224*
Plant height			1.000	0.179*	0.466**	0.023	0.041	-0.333**	-0.124	0.063	0.138	-0.185*	0.153*	-0.062	-0.225*
Number of tillers				1.000	0.052	-0.074	-0.051	-0.163*	0.058	0.038	0.100	0.011	0.209**	0.026	0.113
Peduncle length (cm)					1.000	-0.074	-0.114	-0.255**	-0.228**	-0.042	0.238**	-0.064	0.306**	-0.097	0.060
Spike length (cm)						1.000	0.296**	0.236**	0.107	-0.037	-0.132	0.148*	-0.032	-0.040	0.232**
Number of spikelets per spike							1.000	0.194**	0.194	-0.108	-0.044	0.050	-0.106	-0.040	0.175*
Number of grains per spike								1.000	0.584**	-0.055	-0.236**	-0.068	0.065	0.148*	0.200*
Grain weight per spike (g)									1.000	0.402**	0.063	0.245**	0.019	0.181**	0.153*
1000- grain weight (g)										1.000	0.102	0.285**	0.100	0.154*	0.255**
Protein content (%)											1.000	0.013	0.052	0.012	0.049
Test weight (kg/lit)												1.000	0.156*	0.058	0.102
Biological yield (g)													1.000	-0.194**	0.238**
Harvest index (%)														1.000	0.437**
Grain yield (g)															1.000

**significant at 1% probability level; *significant at 5 % probability level

4.4.2 Path coefficient analysis

It is the standardized partial regression analysis which partitions total correlation into measures of direct and indirect effects. The direct and indirect effects of various characters on grain yield are presented in Table 4.5.

4.4.2.1 Direct effects

Harvest index (0.502) exerted high positive direct effect on grain yield followed by days to maturity (0.362), days to 75% heading (0.347), 1000-grain weight (0.310), spike length (0.284) and number of spikelets per spike (0.279). However, plant height (-0.467) had negative direct effect on grain yield.

4.4.2.2 Indirect effects

Days to heading made high positive contribution to grain yield via days to maturity (0.326). However, it made negative contribution towards grain yield via number of tillers per meter, peduncle length and grain weight per spike.

Days to maturity caused high positive indirect effects on grain yield via days to 75% heading (0.313) followed by harvest index and biological yield. It made negative contribution to yield via peduncle length, grain weight per spike and test weight.

Plant height caused maximum positive indirect effects on grain yield via peduncle length followed by biological yield. It made negative contribution to yield through days to maturity, number of grains per spike and harvest index.

Number of tillers contributed positively maximum to grain yield indirectly through biological yield and it made negative indirect effects on grain yield through days to maturity, ear length, number of spikelets per spike, number of grains per spike, grain weight per spike and test weight.

Peduncle length caused indirect effects on grain yield positively via biological yield and negatively via days to maturity, plant height, number of spikelets per spike, number of grains per spike and harvest index.

Ear length caused positive indirect effects on grain yield through days to maturity, number of spikelets per spike and number of grains per spike. It caused negative indirect effects on grain yield through days to 75% heading, plant height, number of tillers per meter, peduncle length, grain weight per spike, 1000-grain weight, protein content, biological yield, test weight and harvest index.

Number of spikelets per spike caused positive indirect effects on grain yield through ear length followed by days to maturity. Negative indirect effects were caused by this character on grain yield through days to 75 % heading, plant height, number of tillers, peduncle length, grain weight per spike, 1000-grain weight, protein content, test weight, biological yield and harvest index.

Number of grains per spike caused positive indirect effects on grain yield via plant height followed by ear length, harvest index and days to 75 % heading. Negative indirect effects were caused through days to maturity, number of tillers per meter, peduncle length, grain weight per spike, 1000-grain weight and protein content.

Grain weight per spike contributed positively to grain yield through days to maturity, plant height, number of tillers per meter, ear length, number of spikelets per spike, grains per spike, 1000-grain weight, protein content, biological yield and harvest index. Negative contribution was made by this character via days to 75 % heading, peduncle length and test weight.

1000-grain weight contributed positively to grain yield through harvest index, followed by days to maturity and biological yield, whereas, test weight contributed positively to grain yield through 1000-grain weight followed by plant height, days to maturity and biological yield. Biological yield caused positive indirect effects on grain yield through peduncle length, days to maturity and 1000-grain weight. Harvest index caused positive indirect effect on grain yield through days to maturity and 1000-grain weight.

The path coefficient analysis undertaken in the present investigation showed that dependent variable (grain yield) is a function of concomitant variables *viz.,* days to 75% heading, days to maturity, plant height, number of tillers per meter, peduncle length, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, thousand grain weight, test weight, biological yield and harvest

Table 4.5: Direct and indirect effects of different characters on grain yield

Characters	Days to 75%heading	Days to maturity	Plant height (cm)	No. of tillers per meter	Peduncle length (cm)	Spike length(cm)	Spikelet per spike	Grains per spike	Grain weight per spike (g)	Thousand grain weight (g)	Protein (%)	Test weight (kg/hl)	Biological yield (g)	Harvest index (%)
Days to 75% heading	**0.347**	0.326	0.021	-0.009	-0.040	0.036	0.045	0.001	-0.036	0.038	0.004	-0.032	0.081	0.080
Days to maturity	0.313	**0.362**	0.033	0.004	-0.041	0.020	0.029	0.000	-0.033	0.042	0.005	-0.030	0.069	0.073
Plant height(cm)	0.016	-0.025	**-0.467**	0.023	0.112	0.007	0.011	-0.001	0.017	0.020	0.003	0.033	0.055	-0.031
No. of tillers per meter	0.002	-0.010	-0.084	**0.130**	0.013	-0.021	-0.014	-0.001	-0.008	0.012	0.002	-0.002	0.076	0.013
Peduncle length(cm)	0.057	-0.062	-0.218	0.007	**0.241**	-0.021	-0.032	-0.001	0.031	0.013	0.005	0.012	0.111	-0.049
Spike length(cm)	-0.044	0.025	-0.011	-0.010	-0.018	**0.284**	0.083	0.001	-0.015	-0.011	-0.003	-0.027	-0.012	-0.020
Spikelet per spike	-0.056	0.038	-0.019	-0.007	-0.027	0.084	**0.279**	0.001	-0.026	-0.033	-0.001	-0.009	-0.038	-0.020
Grains per spike	0.038	-0.040	0.155	-0.021	-0.061	0.067	0.054	**0.004**	-0.080	-0.017	-0.005	0.012	0.023	0.074
Grain weight per spike (g)	-0.092	0.087	0.058	0.008	-0.055	0.030	0.054	0.002	**-0.136**	0.125	0.001	-0.044	0.007	0.091
Thousand grain weight (g)	-0.042	0.049	-0.029	0.005	-0.010	-0.011	-0.030	0.000	-0.055	**0.310**	0.002	-0.051	0.036	0.077
Protein (%)	-0.059	0.086	-0.064	0.013	0.057	-0.038	-0.012	-0.001	-0.009	0.032	**0.021**	-0.002	0.019	0.006
Test weight (kg/hl)	-0.061	0.060	0.086	0.001	-0.015	0.042	0.014	0.000	-0.033	0.088	0.000	**-0.181**	0.056	0.029
Biological yield (g)	-0.077	0.069	-0.071	0.027	0.074	-0.009	-0.030	0.000	-0.003	0.031	0.001	-0.028	**0.361**	-0.097
Harvest Index (%)	-0.056	0.053	0.029	0.003	-0.023	-0.011	-0.011	0.001	-0.025	0.048	0.000	-0.010	-0.070	**0.502**

index. These findings were close confirmations with the results of **Hirachand *et al.* (1978), Sharma** and **Singh (1983), Singh (1989), Ibrahim (1994), Dwivedi *et al.* (2002), Singh *et al.* (2003), Asif *et al.* (2004), Khaliq *et al.* (2004), Sherif *et al.* (2005), Mukherjee *et al* .(2008), Singh *et al.* (2009), Gulmezoglu *et al.* (2010), Cifci (2012)** and **Abd El-Mohsen *et al.* (2014).** The knowledge of such relationships is of utmost importance while undertaking selections in segregating generations to enhance the gain in selection. Such type of analysis helps us to attempt simultaneous selections or restricted simultaneous selections of characters **(Singh** and **Chaudhary 1977**).

4.5 Genetic Divergence Analysis

Non-hierarchical Euclidean cluster analysis was used to compute the generalized distance for each pair of genotypes.

4.5.1 Group constellations

All the 180 genotypes were classified into 10 clusters in such a way that average intra cluster distance remained minimum. The clustering pattern of genotypes is presented in Table 4.6. Cluster I, II, III, IV, V, VI, VII, VIII, IX, X had 24, 22, 4, 15, 41, 8, 18, 35, 11 and 6 genotypes, respectively.

4.5.2 Average intra and inter cluster distances

The average inter and intra cluster distances are mentioned in Table 4.7. The maximum intra cluster distance was observed in cluster X (69.43) which revealed maximum genetic diversity among its constituents. Followed by cluster VII (36.68), cluster V (32.77), cluster VIII (26.94), cluster II (19.34), cluster I (19.03), cluster IX (16.05), cluster VI (13.28), cluster IV (14.04) and cluster III (13.04) in terms of intra cluster distances.

Inter cluster distance was found maximum between cluster VI and cluster X (526.53) followed by cluster IX and cluster X (489.87), cluster IV and cluster X (455.32) and cluster III and cluster X (454.46). This indicates that the genotypes of cluster VI and cluster X, genotypes of cluster IX and cluster X are distinctly related to each other. Minimum inter cluster distance was observed for cluster I and cluster II (32.33) followed by cluster IV and cluster IX (36.95), indicating that the genotypes of cluster I and cluster II and genotypes of cluster IV and cluster IX were genetically closer as compared to other clusters.

Table 4.6: Grouping of genotypes into 10 different clusters

Cluster number	Number of genotypes	Accession number							
1	24	IC-59553,	IC-36857,	IC-532948	IC-532966	IC-104547	IC-75359	IC-75317	IC-78938
		IC-59577	IC-532800	IC-60244	IC-118771	IC-532245	IC-59727	IC-532194	IC-73650
		IC-532123	IC-199660	IC-532933	IC-75318	IC-53134	IC-532076	IC-35063	IC-82414
2	22	IC-82162	IC-59555	IC-532066	IC-532311	IC-532376	IC-55588	IC-78845	IC-104581
		IC-59193	IC-79024	IC-82410	IC-594790	IC-534561	IC-79080	IC-532391	IC-138764
		IC-36761	IC-79001	IC-532809	IC-78820	IC-107371	IC-79043		
3	4	IC-532952	IC-138846	IC-75354	IC-532152				
4	15	IC-82835	IC-75356	IC-82247	IC-532963	IC-532087	IC-532208	IC-534789	IC-118702
		IC-534784	IC-532446	IC-532053	IC-59572	IC-78789	IC-532823	IC-532092	
5	41	IC-78812	IC-75394	IC-532384	IC-75321	IC-532336	IC-532330	IC-532732	IC-532855
		IC-55601	IC-32586	IC-532112	IC-534820	IC-35057	IC-532394	IC-532832	IC-79651
		IC-78847	IC-79086	IC-79056	IC-532435	IC-145935	IC-212181	IC-79995	IC-79046
		IC-82452	IC-107942	IC-73497	IC-78779	IC-534322	IC-534435	IC-78857	IC-532927
		IC-208906	IC-532382	IC-145969	IC-30276	IC-73661	IC-82188	C1 C2	C3
6	8	IC-41504	IC-138868	IC-78851	IC-79005	IC-532967	IC-79036	IC-82332	IC-78738
7	18	IC-79082	IC-753957	IC-532313	IC-61836	IC-78867	IC-82461	IC-66548	IC-532373
		IC-78924	IC-82281	IC-82172	IC-82410	IC-64230	IC-532307	IC-75436	IC-78966
		IC-532409	IC-73683						
8	35	IC-532128	IC-532463	IC-532296	IC-532315	IC-38870	IC-532308	IC-58012	IC-532279
		IC-75353	IC-82210	IC-73351	IC-532931	IC-532390	IC-534481	IC-534432	IC-75341
		IC-59580	IC-55636	IC-534430	IC-532093	IC-532472	IC-532213	IC-104582	IC-532211
		IC-532212	IC-31242	IC-60208	IC-73663	IC-28637	IC-82177	IC-78826	IC-104587
		IC-79095	IC-82260	C4					
9	11	IC-78962	IC-82189	IC-79022	IC-534810	IC-79027	IC-36699	IC-82403	IC-138729
		IC-55129	IC-60203	IC-534870					
10	6	IC-534562	IC-82219	IC-532150	IC-532933	IC-532420	IC-138884		

Table 4.7: Estimates of average intra and inter cluster distances for ten clusters

Cluster No.	1	2	3	4	5	6	7	8	9	10
1	**19.03**	32.33	52.71	37.95	81.74	109.13	239.29	141.37	72.90	417.58
2		**19.34**	72.88	69.98	51.85	140.01	208.98	111.36	103.42	386.61
3			**13.04**	43.16	124.01	80.59	278.91	182.50	48.46	454.46
4				**14.04**	119.45	72.02	276.83	178.94	36.95	455.32
5					**32.77**	190.81	157.62	59.76	154.41	335.92
6						**13.28**	348.33	250.45	37.25	526.53
7							**36.68**	97.95	312.00	179.44
8								**26.94**	214.11	276.65
9									**16.05**	489.87
10										**69.43**

The results from the present study suggested that crossing among genotypes from different clusters exhibiting good mean performance may help in achieving high yield. Incorporation of more divergent parents in hybridization can enhance the chances of attaining better heterosis and provide broad spectrum of genetic variability in segregating generation. The greater distance between clusters, indicated that the genotypes included in these clusters revealed broad spectrum of genetic diversity and may be used in hybridization programme for wheat improvement. The hybrids developed from the selected genotypes within the limit of compatibility of these clusters may produce desirable transgressive segregants. This would be useful in wheat breeding programme for developing the high yield potential varieties (**Yadav** ***et al.,*** **2006, Chapla** ***et al.,*** **2008, Singh** ***et al.,*** **2010, Tewari** ***et al,.*** **2015**). On the basis of divergence and cluster mean it may be suggested that maximum heterosis and good recombinants could be obtained in crosses between superior genotypes of cluster III and cluster X, cluster VI and cluster X, cluster IX and cluster X. The accessions/ genotypes categorized in these clusters are mentioned in Table 4.6.

4.5.3 Identification of genetic donors for different characters

The superior germplasm accessions were found on the basis of highest cluster mean of a cluster for a particular character, which is presented in Table 4.8. The mean of clusters for different characters indicated considerable differences between them for all the characters. Cluster III and VI had the lowest and highest mean for days to 75 % heading, respectively. For days to maturity, cluster VI and VII represented the lowest and highest mean values. Mean values of plant height were lowest in cluster IV and highest in cluster VII. Cluster mean for number of tillers per meter was highest in cluster III. Likewise, cluster means were highest for peduncle length, ear length, spikelets per spike, grains per spike, grain weight per spike, 1000- grain weight, protein content, test weight, biological yield, grain yield and harvest index in cluster X, IX, II, IV, III, X, I, X, X, III and X, respectively.

The best performing five genotypes for each character identified on the basis of their mean values are mentioned in Table 4.9. The genotypes with earlier days to 75 % heading were identified as IC-82219, IC-78924, IC-73351, IC-66548 and IC-78789. For days to maturity, the genotypes taking lesser number of days were found to be IC-78924, IC-534430, IC-532472, IC-532087 and IC-212181.

The top five dwarf genotypes identified were IC-78938, IC-55636, IC-534820, IC-532053 and IC-532963. Likewise, the lines IC-73683, IC-532373, IC-594790, IC-532308 and IC-532948 were identified to be having higher number of tillers per meter. As far as ear length is concerned, the genotypes with higher ear length were IC-60208, IC-534810, IC-75354, IC-78779 and IC-145935.

For number of spikelets per spike, the best genotypes identified were IC-138729, IC-73497, IC-532212, IC-31242 and IC-532800. Whereas, for number of grains per spike, IC-532245, IC-532212, IC-55636, IC-532093 and IC-79024 were found to be the best performing ones. Genotypes IC-78962, IC-79056, IC-75321, IC-79022 and IC-78938 showed higher grain weight per spike. Higher 1000-grain weight was recorded in genotypes IC-532931, IC-138846, IC-532420, IC-75394 and IC-532311. For biological yield IC-532150, IC-82219, IC-532420, IC-532933 and IC-138884 were identified as the genotypes with lower values. Similarly, genotypes IC-532150, IC-82219, IC-753957, IC-58012 and IC-532931 were found to be the best for grain yield. For harvest index, the genotypes with higher values were found to be IC-532152, IC-79022, IC-75354, IC-78851 and IC-82189.

As far as test weight is concerned, genotypes IC-532420, IC-532463, IC-532952, IC-753957 and IC-78924 were found to be the best. Likewise, genotypes IC-208906, IC-73650, IC-75353, IC-78938 and IC-534481 had higher protein content as compared to others. Genotypes IC-73650, IC-208906, IC-79046, IC-78857 and IC-532809 were found to be superior in terms of sedimentation value.

From the perusal of estimates presented in Table 4.8, it is apparent that considerable diversity existed for all characters in various genotypes studied. Cluster X recorded high mean values for majority of the characters (five out of 15). The genetic resources play a vital role and will continue to do so for development of improved crop varieties. The improved genetic donors identified in the study may be crossed with each other in definite patterns in order to combine all the desirable traits in one genotype. The most superior grain yielding genotypes IC-532150, IC-82219, IC-753957, IC-58012 and IC-532931 identified during the study can be crossed with genotypes superior to other traits so that we can develop one high yielding variety with all the desirable traits.

Table 4.8: Cluster means of different clusters for 16 different characters.

Characters	Cluster 1	Cluster 2	Cluster 3	Cluster 4	Cluster 5	Cluster 6	Cluster 7	Cluster 8	Cluster 9	Cluster 10
Days to 75%heading	92.88	91.83	89.33	92.03	90.12	95.28	89.91	90.91	90.88	89.79
Days to maturity	136.50	135.07	134.46	136.30	133.34	139.68	132.69	134.81	134.51	134.44
Plant height (cm)	102.76	105.13	109.33	98.22	101.57	105.99	111.90	110.03	106.94	108.67
No of tillers per m	108.43	117.94	141.00	102.17	115.86	113.16	139.08	121.46	93.11	118.00
Peduncle length(cm)	40.04	38.67	37.99	35.48	41.90	36.16	42.45	46.24	35.28	48.32
Ear length(cm)	11.80	11.61	11.76	10.78	11.64	10.85	10.63	12.07	12.09	11.51
Spikelets per spike	21.46	21.59	19.08	20.72	20.45	20.95	19.20	21.28	21.26	20.58
Garins per spike	50.39	49.12	48.44	52.07	46.63	45.72	49.55	45.45	48.35	51.75
Grain weight per spike (g)	2.13	2.19	2.60	2.05	2.31	2.26	2.01	2.07	2.46	2.32
1000 grain weight (g)	40.42	39.99	44.58	39.14	40.66	41.82	39.29	39.60	38.47	45.90
Protein content (%)	11.84	11.59	11.53	11.43	11.67	11.77	11.57	11.79	11.45	11.71
Test weight (kg/hl)	75.79	76.05	76.21	75.22	75.37	77.08	77.21	76.11	76.49	77.37
Biological yield (g)	711.98	824.99	539.65	568.47	1032.26	282.02	1654.21	1269.00	422.45	2337.65
Harvest index	0.30	0.33	0.58	0.29	0.27	0.42	0.23	0.24	0.41	0.25
Grain yield (g)	210.98	273.05	327.60	162.43	275.98	136.10	376.17	307.01	181.03	594.22

Table 4.9: Promisingtop five genotypes identified for different characters

S.No.	Character	Genotypes
1	Day to 75% heading	IC-82219, IC-78924, IC-73351, IC-66548, IC-78789
2	Days to maturity	IC-78924, IC-534430, IC-532472, IC-532087, IC-212181
3	Plant height (cm)	IC-78938, IC-55636, IC-534820, IC-532053, IC-532963
4	No. of tillers per meter	IC-73683, IC-532373, IC-594790, IC-532308, IC-532948
5	Peduncle length (cm)	IC-75353, IC-532313, IC-55601, IC-61836, IC-82219
6	Ear length (cm)	IC-60208, IC-534810, IC-75354, IC-78779, IC-145935
7	No. of spikelets per spike	IC-138729, IC-73497, IC-532212, IC-31242, IC-532800
8	No. of grains per spike	IC-532245, IC-532212, IC-55636, IC-532093, IC-79024
9	Grain weight per spike (g)	IC-78962, IC-79056, IC-75321, IC-79022, IC-78938
10	Thousand grain weight (g)	IC-532931, IC-138846, IC-532420, IC-75394, IC-532311
11	Biological yield (g)	IC-532150, IC-82219, IC-532420, IC-532933, IC-138884
12	Grain yield (g)	IC-532150, IC-82219, IC-753957, IC-58012, IC-532931
13	Harvest Index	IC-532152, IC-79022, IC-75354, IC-78851, IC-82189
14	Test Weight (Kg/hl)	IC-532420, IC-532463, IC-532952, IC-753957, IC-78924
15	Protein content (%)	IC-208906, IC-73650, IC-75353, IC-78938, IC-534481
16	Sedimentation value (ml)	IC-73650, IC-208906, IC-79046, IC-78857, IC-532809

Summary and Conclusion

"If you think you can, you can
If you think you can't, you are right"

Henry Ford

Chapter 5 SUMMARY AND CONCLUSION

The present Investigation entitled “Characterization of germplasm for yield, its components and quality traits in wheat (*Triticum aestivum* L. em. Thell)” was undertaken with following objectives:

1. To determine extent of variability in wheat germplasm for different characters,
2. To estimate the heritability and genetic advance of different traits,
3. To characterize germplasm for agro-morphological and quality traits,
4. To assess the nature and magnitude of inter-character association between yield, its components and quality traits,
5. To asses genetic diversity among the genotypes studied and
6. To identify potential donors for yield, yield contributing characters and quality traits.

The experiment was carried out during *Rabi season* of 2015-16 with 180 germplasm accessions along with four checks in Augmented Block Design (ABD) at the N.E. Borlaug Crop Research Centre and wheat laboratory, Department of Genetics and Plant Breeding, G. B. Pant University of Agriculture and Technology, Pantnagar.

The data were recorded for 16 characters viz days to 75% heading, days to maturity, plant height, number of tillers per meter, peduncle length, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000 grain weight, biological yield, grain yield, harvest index, protein content, sedimentation value, and test weight. Data obtained were subjected to appropriate statistical analysis and results have been summarized as below.

1. Analysis of variance showed highly significant differences among the genotypes for number of grains per spike, spike length and harvest index and significant differences for grain yield per meter and plant height and grain weight per spike. Variance (mean sum of squares) was found highest for biological yield followed by grain yield, number of tillers per meter, peduncle length, plant height, test weight and days to maturity.

2. The coefficient of variability was highest for grain yield (27.47) followed by sedimentation value (20.63), number of tillers per meter (20.6), harvest index (18.62), grains weight per spike (17.52) and peduncle length (10.16). The characters which have sufficient variability suggested that a crossing programme involving diverse genotypes may lead to an overall improvement in yield.

3. The highest genotypic coefficient of variation was observed for biological yield (37.44%) followed by grain weight per spike (30.99%), harvest index (27.25%) and grain yield per meter (26.96%), whereas, it was moderate for rest of the traits.

4. The estimates of heritability in broad sense were high for number of grains per spike (85.3) followed by biological yield (83.70), thousand grain weight (74.60), peduncle length (73.10), grain weight per spike (72.40). High heritability estimates was associated with high estimates of genetic advance (GA) as per cent of mean for biological yield (90.45), grain weight per spike (69.61), harvest index (57.92) and number of grains per spike (55.06), thereby, indicating the presence of additive variance for these traits.

5. Grain yield showed significant positive correlation with harvest index (0.437), 1000 grain weight (0.255), biological yield (0.238), ear length (0.232), days to maturity (0.224), number of grains per spike (0.200), days to 75% heading (0.192), number of spikelets per spike (0.175) and grain weight per spike (0.153). However, grain yield showed significant negative correlation with plant height (-0.225) and non-significant correlation with number of tillers per meter (0.113), test weight (0.102), peduncle length (0.060) and protein content (0.049). These relationships may be helpful for improving grain yield in wheat.

6. Path coefficient analysis revealed that harvest index (0.502) exerted high positive direct effect on grain yield followed by days to maturity (0.362), days to 75% heading (0.347), 1000-grain weight (0.310), ear length (0.284) and number of spikelets per spike (0.279). However, plant height (-0.467) had negative direct effect on grain yield.

7. The 180 genotypes were grouped into 10 non-overlapping clusters. Cluster-I had 24 genotypes, whereas cluster II comprised of 22 genotypes, cluster III had 4 genotypes, cluster IV had 15 genotypes, cluster V had 41 genotypes, cluster VI had 8 genotypes, cluster VII contained 18 genotypes, cluster VIII had 35 genotypes, cluster IX comprised of 11 genotypes and cluster X had 6 genotypes.
8. The maximum intra cluster distance was observed in cluster X (69.43) which reveals maximum genetic diversity among its constituents. This cluster was followed by cluster VII (36.68), cluster V (32.77), cluster VIII (26.94), cluster II (19.34), cluster I (19.03), cluster IX (16.05), cluster VI (13.28), cluster IV (14.04) and cluster III (13.04) in terms of intra cluster distances. This intra cluster distance revealed genetic diversity among its constituents.
9. Inter cluster distance was found maximum between cluster VI and cluster X (526.53) followed by cluster IX and cluster X (489.87), cluster IV and cluster X (455.32) and cluster III and cluster X (454.46). This indicates that the genotypes of cluster VI and cluster X, genotypes of cluster IX and cluster X are distinctly related to each other. Therefore, the crosses between the genotypes from these cluster pairs may give desirable transgressive segregants. Minimum inter cluster distance was observed between cluster I and cluster II (32.33) followed by cluster IV and cluster IX (36.95), indicating that the genotypes of cluster I and cluster II and genotypes of cluster IV and cluster IX are genetically closer as compared to other clusters.
10. On the basis of present investigation, five potential donors for each character were identified on the basis of character mean. IC-532150, IC-82219, IC-753957, IC-58012 and IC-532931 were found to be the most promising donors for grain yield. These genotypes can be used in future breeding programme to improve the yield potential of the variety. For other characters, genotypes can be picked up from different groups, formed on the basis of ranking.

The findings of this investigation might be useful in the future to formulate the effective breeding programmes for developing improved genotypes for yield and quality traits in wheat.

Literature Cited

"When you achieve the goal,
Let's remember the former's role"

Anonymous

LITERATURE CITED

Ajmal, S. U.; Minhas, N. M.; Hadmani, A.; Shakir, A.; Zubair, M. and Ahmad, Z. 2013. Multivariate analysis of genetic divergence in wheat germplasm. *Pakistan Journal of Botany*. **45**(5): 1643-1648.

Albayrak, S.; Sevimay, C. S. and Tongel, M. O. 2003. Determination of characters regarding seed yield using correlation and path analysis in inoculated and non-inoculated common vetch. *Turkish Journal of Field Crops.* **8**(2): 76-84

Ali, Y.; Atta, B. M.; Akhter, J.; Monneveux, P. and Lateef, Z. 2008. Genetic variability, association and diversity studies in wheat (*Triticum aestivum* L.) germplasm. *Pakistan Journal of Botany*. **40**(5): 2087-2097.

Amin, M.R.J.; Barma, N.C.D. and Razzaque, M.A. 1992. Variability, heritability, genetic advance and correlation study for some quantitative characters in duram wheat. *Rachis*. **11**(1/2): 30-32.

Anand, S.C.; Aulakh, H.S. and Sharma, S.K. 1972. Association among yield components in dwarf wheat. *Indian Journal of Agricultural Science*. **42**(1):22-29.

Anwar, J.; Ali, M.A.; Hussain, M.; Sabir, W.; Khan, M.A.; Zulkiffal, W. and Abdullah, M. 2009. Assessment of yield criteria in bread wheat through correlation and path analysis. *Journal of Animal and Plant Sciences.* **19** (4): 185-188.

Arunachalam, V. and Ram, J. 1967. Geographical diversity in relation to genetic divergence in cultivated sorghum. *Indian Journal of Genetics*. **27**: 369-380

Asif, M.; Mujahid, M.Y.; Kisana, N.S.; Mustafa, S.Z. and Ahmad, I. 2004. Heritability, genetic variability and path coefficient of some traits in spring wheat. *Sarhad Journal of Agriculture.* **20** (1): 87-91.

Baisakh, B. and Nayak, S.K. 1991. Genetic variability and correlation studies of yield contributing characters in wheat. *Environment and Ecology.* **9**(3): 694-696.

Bametha, B.C. 1989. Studies on early generation selection based on correlation and heritability in durum wheat (*Triticum durum* Desf.). Unpublished M.Sc. (Ag.), thesis submitted to G.B Pant Univ. of Agriculture and Technology. Pantnagar.

Bangarawa, K.S. and Verma, P.K. 1987. Correlation and path coefficient analysis of grain yield and its component in macaroni wheat (*Triticum durum Desf.*). *Agricultural Science Digest*. **7**(2): 83-86.

Baranwal, D.K.; Mishra, V. K.; Vishwakarma, M.; Yadav, K.; Punam, S. and Arun, B. 2012. Studies on genetic variability, correlation and path analysis for yield and yield contributing traits in wheat (*Triticum aestivum* L. em Thell.). *Plant Archives*. **12**(1): 99-104.

Beale, E.M.L. 1969. Euclidean cluster analysis. Contributed paper to the 37th session of the International Statistical Institute, U.K. pp36.

Bergale, S.; Billore, M.; Holkar, A.S.; Ruwali, K.N. and Prasad, S.V.S 2002. Pattern of variability, character association and path analysis in wheat (*Triticum aestivum* L.). *Agricultural Science Digest*. **22**(4): 258-260.

Bhatt. G.M. 1970. Multivariate analysis approach for selection of parents for hybridization aiming at yield improvement in self-pollinated crops. *Australian Journal of Agricultural Research.* **21**: 1-7.

Bhushan, B.; Bharti, S.; Ojha, A.; Pandey, M.; Singh, G. S.; Tyagi, S. B. and Singh, G. 2013. Genetic variability, correlation coefficient and path analysis of some quantitative traits in bread wheat. *Journal of Wheat Research*. **5** (1): 21-26.

Bilgin, O. G. U. Z.; Korkut, K. Z.; Başer, I.; Daglioglu, O. R. H. A. N.; Ozturk, I.; Kahraman, T. U. R. H. A. N., and Balkan, A. 2011. Genetic variation and inter-relationship of some morpho-physiological traits in durum wheat (*Triticum durum* L. Desf.). *Pakistan Journal of Botany*. **43**(1): 253-260.

Bisht, D., and Gahalain, S. S. 2009. Interrelationships and path coefficient analysis in wheat germplasm of Kumaun Himalayas. *Vegetos*, **22**(2): 19-26.

Burton, G.W. (1952). Quantitative inheritance in grasses. *Proceedings of 6th International Grassland Congress*. **1**: 277-283.

Chaturvedi, R. 1987. Variability and character association in advance breeding lines of bread wheat. Unpublished M.Sc. (Ag.) thesis submitted to G.B. Pant Univ. of Agric. and Tech. Pantnagar.

Crowley, C.; Jones, P. and Foley, L. 1993. Analysis of crop physiology in a high biomass winter variety, using induced mutants. *Aspects of Applied Biology*. **34**: 173-178.

Dabi, A.; Mekbib, F. and Desalegn, T. 2016. Estimation of Genetic and Phenotypic Correlation Coefficients and Path Analysis of Yield and Yield Contributing Traits of Bread Wheat (*Triticum aestivum* L.) Genotypes. *International Journal of Natural Resource Ecology and Management*. **1**(4):145-154.

Dechev, D. 1990. Path analysis of yield components in durum wheat. *Genetika- I-Selcktsiya.* **23**(3): 213-216.

Deotale, R.D.; Sorte, N.V. and Blance, A. 1978. Variability of agronomic traits in genetically distant durum in wheat. Proc. 5th Int. Wheat Genet. Sym. New Delhi. pp. 681-684.

Dewey, D. R. and Lu, K. H. 1959. A correlation and path coefficient analysis of components of crested wheat grass seed production. *Agronomy Journal***. 51**(9)**:** 515-518.

Dhedhi, K.K. 1990. Genetic analysis of variability, character association, path coefficient and genetic divergence in macaroni (*Triticum durum Desf.)* under irrigated condition. Unpublished M.Sc. thesis submitted to G.A.U. Sardar Krishinagar.

Dixet, P. and Dubey, D. K. 1984. Path analysis in lentil (*Lens culinaris* Med.). *Lens Newsletter*. **11**: 15-17.

Doshi, S.P.; Jain, D. and Chaudhary, M.L. 1981. User's manual and Fortran programmes for classificatory analyses (i) Fisher's Discriminant function analysis, (ii) Non-hierarchical cluster analysis. *Indian Agricultural Statistics Research Institure*. New Delhi. pp140.

Dutamo, D., Alamerew, S., Eticha, F. and Assefa, E. 2015. Genetic variability in bread wheat (*Triticum aestivum* L.) germplasm for yield and yield component traits. *Journal of Biology*. **5(**17).

Dwivedi, A. N. and Panwar, I. S. 2005. Evaluation of genetic diversity among bread wheat germplasm lines for yield and quality-attributing traits. *Journal of Research,* **34**(1): 35-39.

Dwivedi, A.N.; Pawar, L.S. and Shashi M. 2002. Studies on variability parameters and character association among yield and quality attributing traits in wheat. *Haryana Agricultural University Journal of Research*. **32**(2): 77-80.

Faizul, H.; Fazl-E-Subhan and Swati, M. S. 1989. A biometrical approach for studying character and their association with grain yield in wheat. *Sarhad Journal of Agriculture*. **5**(1): 75-85.

FAOSTAT 2013- 2015. www.fao.org

Farshadarfar, E. 2008. Incorporation of AMMI stability value and grain yield in single non-parametric index (GSI) in bread wheat. *Pakistan Journal of Biological Sciences*. **11**(14): 1791-1796.

Federer, W. T. 1961. Augmented designs with one way elimination of heterogeneity, *Biometrics*. **17**: 447-443.

Federer, W. T. and Ragavarao, D. 1975. Augmented designs. *Biometrics*. **31**: 29-35.

Fellahi, Z.; Hannachi, A.; Bouzerzour, H. and Boutekrabt, A. 2013. Correlation between traits and path analysis coefficient for grain yield and other quantitative traits in bread wheat under semi arid conditions. *Journal of Agriculture and Sustainability*, **3**(1): 16.

Getachew Belay; Tesfaye Tesemma; Demissie Mitikul; Belay, G.; Tesemma, T. and Mitiku, D. 1993. Variability and correlation studies in durum wheat in alem-Tena, *Ethopia. Rachis.* **12**(2): 38-41.

Gill, K.S.; Handa, G.S.; Sharma, S.K. and Anand, B.C. 1981. Variability for peduncle length in tall and semi dwarf wheats. *Science and Culture.* **47**(12): 447-448.

Gonzalez-Navarro, O. E.; Griffiths, S.; Molero, G.; Reynolds, M. P., and Slafer, G. A. 2016. Variation in developmental patterns among elite wheat lines and relationships with yield, yield components and spike fertility. *Field Crops Research*. **196:** 294-304.

Gulmezoglu, N.; Alpu, O. and Ozer, E. 2010. Comparative performance of triticale and wheat grains by using path analysis. *Bulgarian Journal of Agricultural Science*. **16**(4): 443-453.

Guo, P.Z. and Zhang, J.D. 1989. Method of distance analysis and heterosis. Acta Genetica. Sinica. **16**(2): 97-10

Gupta, R.S.; Singh, R.P. and Tiwari, D.K. 2004. Analysis of path-coefficient for yield and its related characters in bread wheat (*Triticum aestivum* L. em Thell). *Advances in Plant Sciences.* **17**(1): 299-302.

Gupta, S.K. 1987. Evaluation of exotic germplasm of bread wheat (*Triticum aestivum* L.) for different quantitative characters. Unpublished M.Sc. (Ag.), Thesis submitted to G. B. Pant Univ. of Agric. and Tech. Pantnagar.

Hannachi, A.; Fellahi, Z. E. A.; Bouzerzour, H. and Boutekrabt A. 2013. Correlation, Path Analysis and Stepwise Regression in Durum Wheat (Triticum Durum Desf.) under Rainfed Conditions. *Journal of Agriculture and Sustainability*. **3**(2): 122-131.

Haq, W. U.; Malik, M. F.; Rashid, M.; Munir, M. and Akram, Z. 2008. Evaluation and estimation of heritability and genetic advancement for yield related attributes in wheat lines. *Pakistan Journal of Bot*any. **40**: 1699-1702.

Hirachand, Srivastava, K. S. and Metha, S. K. 1978. Genetic variability, correlation on coefficient analysis in wheat *(Triticum aestivum* L*.). Madras Agricultural Journal.* **65**:17-37.

Humphreys, M.O. 1991. A genetic approach for the multivariate differentiation of perennial rye grass (*Lolium perenne* L.) cultivars. J. Heredity. **66**: 437-443

Hussain, M.; Khan, A. S. ; Khaliq, I. and Maqsood, M. 2012. Correlation studies of some qualitative and quantitative traits with grain yield in spring wheat across two environments. *Pakistan Journal of Agricultural Science.* **49**(1): 1-4.

Ibrahim, K.I.M. 1994. Association and path coefficient analysis of some traits in bread wheat. *Annals of Agricultural science Moshtohor*. **32**(3): 1189-1198.

Jag Shoran, Hariprasad, AS, Lakshmikant, Mani, VP and Chauhan, V.S. 2000. Association and contribution of yield attributes to seed yield in wheat under varying environments in N.W. Hills. *Annals of Agricultural Research.* **21**(2): 274-278.

Jain, R. P. and Aulakh, H. S. 1971. Variability in wheat. *Indian Journal of Agricultural Sciences.* **41**: 297-299.

Jaiswal, J. P.; Arya, M.; Kumar, A.; Swati and Rawat R. S. 2010. Assessing Genetic diversity for yield and quality traits in indigenous bread wheat germplasm. *Electronic Journal of Plant Breeding.* **1**(4): 370-378.

Jat, B.L. and Dhakar, L.L. 2003. Correlation and regression studies in wheat. *Environment and Ecology*. **21**(1): 34-36.

Jatasara, D.S. and Paroda, R.S. 1978. Genetic divergence in wheat under different environment conditions. *Cereal Research Communications*. **6**(3): 307-317.

Jatasara, D.S. and Paroda, R.S. 1983. Genetic divergence in wheat. *Indian Journal of Agronomy*. **13**: 200-202.

Joshi, R.P. 1984. Character association analysis in wheat, across varying environments. Unpublished M.Sc. (Ag.), thesis submitted to G.B. Pant Univ. of Agric. and Tech. Pantnangar.

Kalim Ullah; Shah Jahan Khan; Saeed Muhammad; Muhammad Irfaq ; Tila Muhammad. 2011. Genotypic and Phenotypic Variability, Heritability and Genetic Diversity for Yield Components in Bread Wheat (*Triticum aestivum* L.) germplasm. *African Journal of 119 Agricultural Research*. **6**(2): 5204-5207.

Keddem, W.K.; Markar, S. and Lavanya G.R. 2014. Investigation of genetic variability and correlation analysis of wheat (*Triticum aestivum* L.) genotypes for grain yield and its component traits. *European Academic Research.* **2**(5): 2286-4822.

Khaliq, I.; Parveen, N. and Chowdhry, M.A. 2004. Correlation and path coefficient analyses in bread wheat. *International Journal of Agriculture and Biology.* **6**(4): 633-635.

Khan, A. A.; Alam, M. A.; Alam, M. K.; Alam, M. J. and Sarker, Z. I. 2013. Correlation and path analysis of durum wheat (*Triticum turgidum* L. Var. Durum). *Bangladesh Journal of Agricultural Research*. **38**(3), 515-521.

Khokhar, I. M., Hussain, M., Anwar, J., Zulkiffal, M., Iqbal, M. M., Khan, B. S. and Mehmood, S. 2010. Correlation and path analysis for yield and yield contributing characters in wheat (*Triticum aestivum* L.). *Acta agriculturae Serbica*. **15**(29), 19-24.

Khokhar, M.I.; Hussain, M.; Zulkiffal, M,; Ahmad, N. and Sabar, W. 2010. Correlation and path anaylsis for yield and yield contributing characters in wheat (*Triticum aestivum* L.). *African Journal of Plant Science*. **4**: 464-466.

Kobiljski, B.; Dencic, S. and Khairallah, S. 1996. Effect of spike size on yield components and grain yield in wheat. *Selekcija-I-Semenarstva*. **3**(4): 27-32.

Konovalenko, V. V., and Ostroukh, L. N. 1980. Use of morphological and physiological analysis in relation to yield in winter bread wheat varieties**.** *Sb. nauch. tr. Krasnodar. NII s. kh.*. **(23):** 26-31.

Kulshrestha, N. 1992. Non-hierarchical cluster analysis in elite germplasm lines of wheat. Unpublished Ph.D. thesis submitted to G.B. Pant Univ. of Agric. and Tech., Pantnagar.

Kumar, B.; Singh, C. M. and Jaiswal, K. K. 2013. Genetic variability, association and diversity studies in bread wheat (*Triticum aestivum* L.). *The Bioscan*. **8**(1): 143-147.

Kumar, D. and Kumar, P. 1983. G × E interaction in wheat under salinity. *SABRAO Journal* **15**(2): 93-98.

Kumar, D.; Sharma, S.C. and Gupta, S.C. 1986. Correlation and path studies in wheat under normal and saline condition. *Wheat Information Service*, **61/62**: 64-67.

Kumar, N., Markar and Kumar, V. 2014. Studies on heritability and genetic advance estimates in timely sown bread wheat (*Triticum aestivum* L.). *Bioscience Discovery.* **5(1):** 64-69.

Larik, A.S. 1979. Correlation and path coefficient analysis of yield components in mutant of *Triticum aestivum*. *Wheat Information Service*. **51**: 36-40.

Lebsock, K. L., and Amaya, A. 1969. Variation and covariation of agronomic traits in durum wheat. *Crop Science*. **9**(3): 372-375.

Leonard, W.H. and Martin, J.H. 1963. Cereal crops. New York, USA. MacMillan Publishing pp 28.

Li, Z.L. and Yang, W.L. 1985. Studies of heritability and genetic correlation of main quantitative characters of winter wheat. Shanxi Science. **1**: 11-13.

Lu, P.; Huang, H.L.; Liu, Q.Y. and Gu, M.Z. 1991. Heritability and usefulness of traits of Tibetan wheat varieties. *Crop Genetic Resources*. **1**: 11-13.

Lynch, J. P.; Doyle, D.; McAuley, S.; McHardy, F.; Danneels, Q.; Black, L. C., and Spink, J. 2017. The impact of variation in grain number and individual grain weight on winter wheat yield in the high yield potential environment of Ireland. *European Journal of Agronomy*. **87**: 40-49.

Mahak; Srivastava, R.L. and Dixit, R.K. 2003. Stability analysis for certain advanced lines of bread wheat under rain-fed condition. *Advances in Plant Science*. **15**(1): 295-300.

Mahammadi, S. A. and Prasanna, B. M. 2003. Analysis of genetic diversity in crop plants salient statistics tools and consideration. *Crop Science***. 43**(1): 1235-1248.

Makwana, S. M.; Dobariya, K. M., and Mehta, D. R. 2008. Triple test cross analysis for grain yield and its component characters in Bread wheat. *National Journal of Plant Improvement*. **10**(2): 148-143.

Malik, S. K. 1980. Study of genetic divergence and combining ability in bread wheat. Unpublished Phd thesis submitted to G. B. Pant university of Agriculture and Tech., Pantnagar.

Maloo, S. 1984. Genotypic variability for grain yield and its components in durum wheat (*Triticum durum Oist*.). *Madras Agricultural Journal*. **71**(7): 472-473.

Mandakh, S. 1988. Correlation of yield characters in spring bread wheat and its variation at different sowing dates. Ref. Z., B. **65**.166.

Mecha B, Alamerew S, Assefa A, Dutamo D, Assefa E 2017. Correlation and Path Coefficient Studies of Yield and Yield Associated Traits in Bread Wheat (*Triticum aestivum* L.) Genotypes. *Adv Plants Agric Res.* **6**(5): 00226.

Mehak, Srivastava, R. L. and Dixit, R. K. 2003. Stability analysis to certain advanced lines of bread wheat under rain. *Advances in Plant Science*, **15**(1): 295-300.

Metha, A.K. and Dhagat, N.K. 1992. Genetic divergence in wheat. *Advances in plant Sciences*. **5**: 369-378.

Mohammad, T.; Muhammad, A.; Fazal, E.S.; Khan, M.I. and Khan, A.J. 2008. Identificatin of traits in bread wheat genotypes (*Triticum aestivum* L.) contributing to grain yield through correlation and path coefficient analysis. *Pakistan Journal of Botany*. **40**(6): 2393-2402.

Mohammadi, M.; Sharifi, P.; Karimizadeh, R.; Shefazadeh, M. K. 2012. Relationships between Grain Yield and Yield Components in Bread Wheat under Different Water Availability (Dryland and Supplemental Irrigation Conditions). *Notulae Botanicae Horti Agrobotanici Cluj*. **40**(1): 195-200.

Mohan, D.S.R.; Harbir Singh; Khola, O.P.S. and Singh, H. 1993. Correlation and path analysis in late sown bread wheat (*Triticum aestivum*). *Crop Research Hisar.* **6**(1): 72-77.

Mohibullah, M.; Rabbani, M. A.; Amin, A.; Rehman, H.; Islam, T.; Khakwani, A. A. and Batool, K. (2017). Allelic Variation and Correlation Analysis in Bread Wheat (*Triticum Aestivum L.*) Accessions Based on Various Polygenic Traits. *International Journal of Horticulture*, **7**.

Mouchan, V.K. and Malyutina, O.M. 1987. Variability and Inheritance of qualitative characters in hybrids of winter wheat. **2**(65): 155.

Muhammad, T.; Haider, S.; Amin, M.; Khan, M.I. and Zamir, R. 2006. Path coefficient and correlation studies of yield associated traits in candidate bread wheat (*Triticum aestivum* L.). Lines. *Suranaree journal of Science Technology*. **13**(2): 175-180.

Mukherjee, S.; Gupta, D.; Maji A.; Gupta, S. and Bhowmik, N. 2008. Character association and path coefficient analysis of wheat (*Triticum aestivum* L.) genotypes under late sown condition. *Environment and Ecology*. **26**(4C): 2218-2220.

Natitolela, A.J.; Morris, E. and Maimu, Z.Y. 1990. Reliability of kernel weight and test weight as components determining yield potential in wheat. *Sixth Regional Wheat Workshop for Eastern and Southern Africa*. **30**: 298-314.

Nayeem, K.A.; Baig, K.S. and Karad, N.S. 2003. Genetic variability and character association studies for export quality parameters in *Triticum durum* wheat. *Journal of Research Angrau*. **30**(4): 5-10.

Pandilla, B. E.; Gallon, J.M. and Diaz, C. 1972. An extension on diallele design including each parent (n-1) times and its application in wheat. *Agrocieneia*. **8**: 178-180.

Paroda, R. S. and Joshi, A. B. 1980. Genetic architecture of yield and components of yield in wheat. *Indian Journal of Genetics.* **30**(2): 298-314.

Paul, A. and Ganguli, D.K. 1996. Association of grain yield and its component characters over environment in wheat (*Triticum aestivum* L.). *Journal of research Birsa Agricultural University*. **8**: 127-129.

Pawar, I.S.; Paroda, R.S. and Singh, S. 1990. A study of correlation and path analysis in spring wheat. *Wheat Information Service*, 71: 24-26.

Petersen, G.R. 1985. Augmented Designs for Preliminary yield Trials. *Rachis* **4**(1): pp28.

Purohit, J.P.; Sharma, A.K. and Yadava, H.S. 1981. Genetic variability and G × E interaction in wheat (*Triticum aestivum* L.). *JNKVV Research Journal*. **15**(3): 123-126.

Rahman, M.S. 1980. A case of closely studying spikelet number and its possible determinants for increasing yield in wheat. *Journal of the Australian Institute of Agricultural Science*. **46**(4): 229-232.

Rangare, N. R.; Krupakar, A.; Kumar, A. and Singh, S. 2010. Character association and component analysis in wheat (*Triticum aestivum* L.). *Electronic Journal of Plant Breeding*. **1**(3): 231-238.

Rangare, N.R.; Anurag, P.J.; Chaurasia, A.K. and Tirkey, A. 2008. Genetic analysis in wheat employing classificatory statistics. Progressive Research. **3**(2): 126-128.

Raut, R.S.; Deshmukh, N.Y. and Phalke, A.M. 1977. Interrelationship among yield and its components in *Triticum aestivum* L. and *Triticum durum* Defs.. College of Agriculture Nagpur Magazine. **49**: 39-44.

Rawashdeh, N.K.; Haddad, N.I.; Ajlouni, M.M. and Turk, M.A. 2007. Phenotypic diversity of durum wheat (*Triticum durum* Desf.) from Jordan. *Genetic Resources and Crop Evolution*. **54** (1): 129-138.

Reddy, V. R. K. 2001. Genetic divergence in hexaploid triticale. *Research on Crops,* **2(2):** 206-212.

Redhu, A.S.; Solanki, Y.P.S.; Sethi, S.K. and Singh, I. 1995. Genetic diversity in some Indian and exotic wheat varieties. *Crop improvement* . **22**(2): 214-217.

Reif, J. C.; Jhang, P.; Dreisigacker, S.; Wareburton, M. L.; Van, G. M.; Hoisington, D.; Bohn, M. and Melchinger, A. E. 2005. Wheat genetic diversity trends during domestication and breeding. *Theoretical and Applied Genetics***.** **110**(5): 859-864.

Saini, D.P. 1982. Correlation and path coefficient analysis in some crosses of bread wheat (*Triticum aestivum* L.) under different environments. Unpublished thesis, M.Sc. (Ag.) submitted to G.B. Pant. Univ. of Agric. and Tech., Pantnagar.

Sandhu, D.K. and Lal Roshan. 1989. Divergence analysis of wheat genotypes through discrimination functions. *Crop Improvement.* **16**(2): 185-187.

Santos, T.M.M.D.; Gananca, F.; Slaski, J.J. Carvalho, M.A.P.D. 2009. Morphological characterization of wheat genetic resources from the island of Madeira, Portugal. *Genetic Resources and Crop Evolution.* **56** (3): 363-375.

Schmidt, J.W. and Ahed, A.A. 1979. Yield component study in winter wheat. *American Society of Agronomy*. **76**: 237-242.

Shah, S.M.A.; Mohammad, F.; Swati, M.S. and Iqbal, S. 2003. Genotypic variability for yield associated traits in bread wheat. *Sarhad Journal of Agriculture (Pakistan)*. **19**(4): 535-538.

Shahryari, R.; Mahfoozi, B.; Mollasadeghi, V. and Khayatnezhad, M. 2011. Genetic diversity in bread wheat for phenological and morphological traits under terminal drought stress condition. *Advances in Environmental Biology*. **5**(1): 169-172.

Shankarrao, B.S; Mukherjee, S.; Pal, A.K. and De, D.K. 2010. Estimation of variability for yield parameters in bread wheat (*Triticum aestivum* L.) grown in Gangetic West Bengal. *Electronic Journal of Plant Breeding*. **1**(4): 764-768.

Sharifi, P.; Karimizadeh, R. and Mohammadi, M. 2012. Correlation and path coefficient analysis of grain yield and yield components in durum wheat under two irrigated and rainfed condition. *International Journal of Agriculture: Research and Review*. **2**(3): 277-283.

Sharma, S. K. and Singh, R. K. 1983. Path coefficient of harvest index and its related characters in wheat. *Haryana Agricultural University Journal of Research*, **13**(2): 218-226.

Sheoran, I.S.; Luthra, O.P. and Kuhad, M.S. 1986. Association of physiological and biochemical characters with yield of rainfed wheat. *Indian Journal of Agricultural Science.* **56**: 271-274.

Sherif, H.S.; El Hosary, A.A.; Bekhit, M.M.; Moustafa, M.A. and Meghraby, M.A. 2005. Correlation and path coefficient analysis of yield characters in bread wheat (*Triticum aestivum* L.). *Annals of Agricultural Science, Moshtohor*. **43**(4): 1677-1687.

Shukla, R.S.; Rao, S.K. and Singh, C.B. 2005. Character association and path analysis in bread wheat under rainfed and partially irrigated condition. *JNKVV Research Jounral*. **39**(2): 20-25.

Sidewall, R, J.; Smith E.L.; New, M. C. 1976. Inheritance and interrelationship of grain yield and selected yield related traits in hard red winter wheat crosses. *Crop Science*. **16**(5): 650-654.

Singh P.K. 1985. Germplasm evaluation, character association, genetic divergence and combining ability analysis in durum wheat (*Triticum durum* Desf.). Unpublished thesis, Ph.D. G.B. Pant Univ. of Agric. and Tech., Pantnagar, 120 p.

Singh V.; Singh, D. and Singh, N. 2003. Studies on correlation and path coefficient analysis in bread wheat (*Triticum aestivum* L.). *National Journal of Plant Improvement*. **5**(2): 106-109.

Singh, B. N.; Vishwakarma, S. R., and Singh, V. K. 2010. Character association and path analysis in elite lines of wheat (*Triticum aestivum* L.). *Plant Archives*. **10**(2): 845-847.

Singh, D.; Singh, S.K. and Singh, K.N. 2009. Diversity of salt resistance in a large germplasm collection of bread wheat (*Triticum aestivum* L.). *Crop Improvement*. **36**(1): 9-12.

Singh, J.; Chawla, V.; Garg, P.; Gupta, M., and Chugh, L. K. 2015. Correlation and path analysis in advanced lines of wheat (*Triticum aestivum* L. em. Thell). *Indian Research Journal of Genetics and Biotechnology*. **7**(1): 22-26.

Singh, N.K. 1989. Studies on variability, character association and path analysis in elite wheat lines. Unpublished thesis, M.Sc. (Ag.) G. B. Pant Univ. of Agric. and Tech. Pantnagar, 86 p.

Singh, N.K.; Singh, S.P. and Singh, G.S. 1995. Relationship of physiological attributes with yield components in bread wheat (*Triticum aestivum* L.) under rainfed condition. *Agricultural Science Digest.* **15**: 11-14.

Singh, P.K. 1994. Genetic diversity in durum wheat (*Triticum durum* Desf.) germplasm. *Annals of Agricultural Research.* **15**(4): 418-422.

Singh, S. P. and Dwivedi, V. K 2005. Genetic divergence in wheat. *Agricuture-Science-Digest.* **25**(3): 201-203.

Sinha, G. C. P., and Sharma, N. N. 1980. Correlation regression and path analysis studies in wheat varieties. *Indian Journal of Agronomy*. **25**(2): 225-229.

Smith, S.E.; DOS, A.L. and Warburton, M. 1991. Morphological and agronomic variations in North African and Arabian alfalfa. *Crop science* **31**: 1159-1163.

Soni, B. 2015. Studies on assessment of genetic diversity for yield and quality traits in elite lines of bread wheat (*Tritcum aestivum* L. em. Thell). Unpublished thesis, M.Sc. (Ag.) G. B. Pant Univ. of Agric. and Tech. Pantnagar, 64p.

Spark, D. N. 1973. Euclidean cluster analysis algorithm. *Journal of the Royal Statistical Society*. **22**(1): 126-130.

Srivastava, A.; Srivastava, N.; Kushwaha, A. and Nigam, R. 2009. Study on quality improvement through biometrical approaches in bread wheat (*Triticum aestivum* L.). *Asian Journal of Bio Sciences*. **4**(2): 212-215.

Sultana, R. and Malik, S.K. 2005. Genetic variability and character association between yield and yield attributing traits in bread wheat (*Triticum aestivum* L. em. Thell). *Annals of Agricultural Research*. **26**(1): 118-125.

Talwar, S.N. and Chandrappa, H.M. 1983. Flag leaf area relationship with yield and ear characters in tetraploid wheat. *The Madras Agricultural Journal*. **70**: 333-334.

Taya, S. 1993. Breeding of early maturing wheat (*Triticum aestivum*) varieties with higher grain yield in southwestern regions of Japan. *Bulletin of the Kyushu National Agricultural Experiment Station (Japan)*.

Tewari, R.; Jaiswal, J. P.; Gangwar, R. P. and Singh, P. K., 2015. Genetic diversity analysis in exotic germplasm accessions of wheat (*Triticum aestivum* L.) by cluster analysis. *Electronic Journal of Plant Breeding.* **6(4)**: 1111-1117.

Tripathi, R.K. 1983. Studies on character association, combining ability and heterosis in durum wheat (*Triticum durum* Desf.). Unpublished thesis, M.Sc. (Ag) submitted to G.B. Pant, University of Agriculture and Technology., Pantnagar.

Upreti, M.C. and Malik S.K. 2003. Genetic variability, heritability and genetic gain in bread wheat. *Agricultural and Biological Research*. **19**(1): 18-21.

Wan, X.L. 1981. A preliminary study on introduced Mexican wheat varieties analysis of regions suitable for Maxican wheat. *Acta Agronomica Sinica*. **7**(4): 249-257.

Yadav, A.; Kumar, A.; Chandan, R., and Jaiswal, J. P. (2013). Correlation and path-coefficient analysis for grain yield, its components and quality traits in bread wheat. *Pantnagar Journal of Research*. **11**(3): 337-340.

Yadav, D.K.; Pawar, I.S.; Sharma, G.R. and Lamba, R. 2006. Genetic diversity in some germplasm lines of bread wheat. *National Journal of Plant Improvement*. **8**(2): 138-141.

Yadav, S.P.; Sharma, J.R.; Roy, N.N. and Jain O.P. 1974. Note on genetic divergence in some varieties of wheat grown under rainfed conditions. *Indian Journal of Agricultural Sciences.* **44:** 778-780.

Yadava, R.K. and Rana, O.P.S. 2002. Association and path analysis in homogenous generation of 'gigas' spike of wheat (*Triticum aestivum* L.). *Crop Research*. **24**(1): 67-71.

Yashpal, P.; Mridula, B. and Prasad, S.V.S. 2005. Morphological variability and genetic diversity in relation to grain yield and its component traits in wheat. *National Journal of Plant Improvement*. **7**(2) 69-72.

Yucel, C.; Baloch, F. S. and Ozkan, R. 2009. Genetic analysis of some physical properties of bread wheat grain (*Triticum aestivum* L. em. Thell). *Turkish Journal of Agriculture and Forestry*. **33**(6): 525-535.

Zeleny, L. 1962. Wheat sedimentation test. *Cereal Science Today*. **7:** 226-228.

Zerga, K.; Mekbib, F. and Dessalegn, **T. 2016** Genetic Variability, Heritability and Genetic Advance in Bread Wheat (*Triticum aestivum* L.) Genotypes at Gurage Zone, Ethiopia. *International Journal of Microbiology and Biotechnology*. **1**(1): 1-9.

Appendices

APPENDIX 1

STATION NAME :Pantnagar LONGITUDE : 79 deg. 30' E

LATITUDE : 29 deg. N ALTITUDE : 243.84 m. AMSL

Month	Date	Year	Metro Week No. 2011	Temperature (oC)		Relative Humidity (%)		Rainfall (mm)	No. of Rain Days	Sun-Shine Hrs.	Wind Velocity (Km/hr.)	Evap. (mm)
				Max.	Min.	712 am	1412 pm					
Nov	'05-11	2015	45	28.00	12.10	91.00	43.00	2.00	1.00	6.60	3.00	2.50
Nov	'12-18	2015	46	29.00	11.90	91.00	38.00	0.00	0.00	7.80	2.80	2.70
Nov	'19-25	2015	47	27.70	11.30	92.00	41.00	0.00	0.00	7.20	1.60	2.30
Nov-Dec	'26-02	2015	48	26.70	12.60	91.00	46.00	0.00	0.00	3.70	2.70	2.10
Dec	'03-09	2015	49	24.60	10.20	96.00	49.00	0.00	0.00	1.80	2.30	1.60
Dec	'10-16	2015	50	21.10	10.30	94.00	64.00	0.00	0.00	2.10	4.30	1.30
Dec	'17-23	2015	51	20.50	4.60	96.00	50.00	0.00	0.00	5.30	2.50	1.50
Dec	'24-31	2015	52	21.00	5.00	95.00	46.00	0.00	0.00	6.10	3.00	1.50
Jan	01-07	2016	1	23.60	6.90	92.00	39.00	0.00	0.00	6.00	2.70	1.50
Jan	08-14	2016	2	22.30	7.00	94.00	49.00	0.00	0.00	4.30	3.30	1.70
Jan	15-21	2016	3	17.40	6.60	94.00	64.00	0.00	0.00	2.30	4.60	1.40
Jan	22-28	2016	4	17.90	4.10	94.00	53.00	0.00	0.00	3.30	3.20	1.30
Jan-Feb	29-04	2016	5	22.20	6.80	96.00	48.00	0.00	0.00	4.80	5.30	1.90
Feb	05-11	2016	6	23.30	8.30	93.00	46.00	0.00	0.00	5.40	3.70	2.40
Feb	12-18	2016	7	26.40	9.40	82.00	32.00	0.00	0.00	6.80	5.50	3.10
Feb	19-25	2016	8	26.40	11.80	87.00	44.00	2.50	0.00	4.60	6.30	2.90
Feb-Mar	26-04	2016	9	28.80	12.10	88.00	37.00	0.00	0.00	7.40	3.00	3.00
Mar	05-11	2016	10	30.40	13.40	86.00	37.00	0.00	0.00	8.40	6.10	4.20
Mar	12-18	2016	11	29.10	13.50	83.00	37.00	0.90	1.00	7.10	7.70	4.70
Mar	19-25	2016	12	31.30	14.00	80.00	28.00	0.00	0.00	8.80	6.60	4.70
Mar-Apr	26-01	2016	13	33.74	15.99	78.43	32.29	0.00	0.00	7.04	5.07	4.80
April	02-08	2016	14	35.60	20.37	64.86	31.57	0.00	0.00	6.91	5.99	6.70
April	9-15	2016	15	37.26	17.17	63.71	28.86	0.00	0.00	10.37	8.79	8.93
April	16-22	2016	16	38.66	21.51	69.57	32.00	0.00	0.00	7.53	7.19	9.46
April	23-29	2016	17	38.91	16.89	71.00	26.71	0.00	0.00	11.06	9.23	12.54
April-May	30-06	2016	18	37.16	20.83	63.86	27.29	19.60	1.00	7.54	6.93	9.19
May	7-13	2016	19	33.86	22.40	72.71	42.86	39.20	2.00	3.93	5.47	5.83
May	14-20	2016	20	38.53	23.90	61.29	36.00	0.00	0.00	10.69	8.44	8.54
May	21-27	2016	21	33.87	22.80	72.86	48.00	41.40	4.00	8.30	8.81	7.44

Appendix 2: Adjusted mean of genotype for different characters

Genotypes	Days to 75 % heading	Days to maturity	Plant height (cm)	Number of tillers	Peduncle length (cm)	Spike length (cm)	Number of spikelet per spike	Number of grains per spike	Grain weight per spike (g)	1000-grain weight (g)	Protein content (%)	Hectoliter weight (Kg/hl)	Biological yield (g)	Harvest index	Grain yield (g)
IC-78962	95.763	139.400	106.663	139.250	33.185	12.503	20.400	69.798	5.301	39.004	11.628	81.338	407.900	0.446	201.850
IC-82189	90.763	137.400	123.413	133.250	40.185	11.003	21.100	25.398	2.467	53.731	9.807	81.458	401.900	0.563	255.850
IC-79022	98.013	142.400	114.913	107.250	28.185	11.503	23.100	66.798	4.001	36.061	11.798	81.828	364.900	0.657	275.850
IC-41504	92.763	140.400	98.913	123.250	30.685	10.403	20.400	56.398	3.491	51.304	10.778	79.468	297.900	0.561	193.850
IC-532952	90.763	134.400	105.913	143.250	40.685	9.753	20.400	49.598	2.825	44.653	11.818	82.588	515.900	0.495	281.850
IC-138868	90.513	132.400	105.413	112.250	34.685	10.253	23.100	58.398	2.835	38.276	13.508	80.408	277.900	0.438	137.850
IC-82162	94.263	137.400	95.913	138.250	31.285	12.503	27.100	61.598	3.601	32.463	12.018	79.568	777.900	0.432	363.850
IC-138846	95.013	138.400	139.913	162.250	42.185	9.753	18.400	21.398	3.189	61.004	12.288	73.128	577.900	0.522	331.850
IC-78851	95.763	139.400	97.913	148.250	32.185	10.753	23.100	46.198	2.067	31.308	12.098	76.008	287.900	0.566	189.850
IC-79082	100.263	145.400	105.579	139.250	34.085	11.536	21.100	69.398	3.737	45.483	12.058	80.898	1777.900	0.237	455.850
IC-59555	92.763	139.400	107.913	133.250	39.185	10.003	20.400	40.198	1.949	32.840	12.638	77.208	737.900	0.461	368.850
IC-78812	96.013	145.400	100.413	137.250	34.185	12.003	19.100	41.398	2.459	44.361	12.498	79.188	1120.900	0.276	326.850
IC-532128	96.763	146.400	108.413	111.250	40.185	13.503	20.400	20.398	2.037	49.889	12.018	74.428	1173.900	0.206	259.850
IC-532463	94.263	137.400	120.913	109.250	39.185	12.253	21.100	53.398	2.899	42.954	12.218	82.918	1249.900	0.164	221.850
IC-532296	101.763	147.400	88.913	146.250	37.185	13.753	21.100	43.398	2.501	43.343	12.838	74.598	1266.900	0.097	133.850
IC-75394	93.513	136.400	127.413	165.250	53.685	12.503	21.100	55.398	2.773	60.346	12.638	76.828	979.900	0.189	197.850
IC-532384	94.763	137.400	103.413	133.250	38.185	11.503	20.400	38.548	3.351	44.733	13.248	78.068	989.900	0.189	199.850
IC-59553	92.013	134.400	114.913	128.250	29.685	9.253	21.100	37.698	2.401	47.059	13.938	76.898	817.900	0.159	135.850
IC-753957	95.763	139.400	130.413	143.250	45.685	10.003	19.100	68.128	3.035	35.943	12.358	82.268	1651.900	0.332	587.850
IC-532066	94.763	137.400	109.413	136.250	38.685	12.003	19.100	33.598	1.707	31.784	13.568	77.938	877.900	0.229	213.850
IC-36857	91.763	132.400	131.413	83.250	44.685	11.503	25.100	23.398	1.061	42.816	13.498	81.288	737.900	0.237	185.850
IC-82835	101.763	147.400	120.413	119.250	35.185	13.003	21.100	43.398	2.351	39.855	13.078	79.988	585.900	0.255	157.850
IC-532948	91.763	133.400	100.413	184.250	26.685	12.303	19.100	67.198	2.901	34.417	11.308	73.358	661.900	0.323	229.850
IC-532311	101.763	147.400	106.413	103.250	37.185	12.253	20.400	42.398	2.983	55.816	10.858	78.078	807.900	0.296	255.850

IC-532315	89.763	146.400	114.413	154.250	33.685	13.253	21.100	34.398	2.001	39.718	12.958	76.448	1169.900	0.206	259.850
IC-75321	96.763	140.400	111.413	175.250	24.935	13.953	23.100	49.398	4.501	38.217	11.218	76.168	1057.900	0.187	211.850
IC-532966	96.763	144.400	128.913	104.250	46.385	11.153	20.400	50.198	3.741	42.447	12.578	79.838	639.900	0.323	221.850
IC-104547	98.763	143.400	101.413	148.250	37.685	13.253	21.100	46.398	2.563	41.961	13.328	76.628	691.900	0.297	219.850
IC-38870	100.763	152.400	99.413	134.250	37.685	10.503	15.100	30.398	1.733	35.883	11.568	77.618	1177.900	0.230	291.850
IC-75356	97.763	139.400	120.413	137.250	46.685	13.253	23.100	39.398	2.593	49.996	12.768	79.678	555.900	0.262	153.850
IC-79005	104.013	150.400	122.913	113.250	40.685	9.503	21.100	17.398	0.771	44.949	11.918	77.318	223.900	0.329	79.850
IC-532376	95.763	139.400	107.413	133.250	31.185	11.753	23.100	44.198	2.453	41.483	13.718	78.228	815.900	0.348	305.850
IC-82247	94.263	137.400	102.913	123.250	35.685	11.253	21.100	36.398	2.025	38.261	12.398	74.848	593.900	0.329	209.850
IC-532967	95.013	138.400	103.913	123.250	38.185	12.253	23.100	56.398	3.323	48.304	11.558	76.798	275.900	0.479	151.850
IC-79036	95.763	139.400	109.913	128.250	38.935	10.753	22.100	42.998	2.381	40.919	11.168	75.218	315.900	0.323	109.850
IC-75359	100.263	145.400	99.163	121.250	44.685	12.003	25.100	50.098	2.622	40.195	11.848	77.418	633.900	0.340	231.850
IC-75317	90.700	132.650	100.050	145.250	42.635	10.828	22.900	40.998	1.178	37.928	12.775	77.860	668.400	0.409	251.600
IC-55588	98.200	142.650	102.500	122.250	51.035	10.178	23.600	26.198	2.058	36.320	12.295	76.240	760.400	0.371	263.600
IC-532308	91.200	134.650	113.150	187.250	57.535	10.728	20.900	30.198	3.186	32.320	12.095	80.820	1264.400	0.385	455.600
IC-532336	94.450	137.650	95.450	103.250	56.785	8.628	23.600	46.198	3.898	45.820	11.995	76.560	942.400	0.349	309.600
IC-58012	88.450	129.650	106.550	68.250	53.535	9.578	21.600	53.198	2.864	53.229	12.725	81.870	1232.400	0.435	499.600
IC-78938	89.200	136.650	72.350	96.250	41.085	9.428	19.600	44.998	3.922	40.055	14.115	77.770	704.400	0.444	285.600
IC-534562	94.450	137.650	97.150	92.250	64.935	14.278	21.600	61.598	2.500	46.863	13.485	73.190	2176.400	0.179	366.600
IC-532279	93.200	138.650	96.350	144.250	54.435	11.378	21.600	54.198	1.958	27.356	12.385	76.370	1222.400	0.184	221.600
IC-75353	94.200	140.650	131.350	96.250	84.435	14.278	21.600	32.998	2.308	27.033	14.125	78.130	1292.400	0.210	263.600
IC-532313	91.200	134.650	125.350	131.250	74.235	12.278	22.900	36.398	1.488	33.996	13.085	78.520	1692.400	0.181	293.600
IC-532330	89.450	132.650	116.350	121.250	60.185	11.278	18.900	35.198	2.082	35.961	10.955	73.870	1132.400	0.291	313.600
IC-82210	86.450	128.650	103.350	133.250	60.935	11.378	19.600	56.398	1.974	33.277	11.545	71.240	1232.400	0.225	268.600
IC-532732	90.950	134.650	107.350	110.250	60.935	10.678	15.600	40.798	1.758	42.383	10.955	78.370	932.400	0.371	323.600
IC-532855	87.200	129.650	99.350	168.250	60.435	12.178	20.900	34.198	2.442	44.005	11.245	71.560	1082.400	0.289	298.600
IC-55601	86.450	128.650	129.850	111.250	73.935	9.378	23.600	55.198	1.960	40.049	13.645	73.870	1134.400	0.325	348.600
IC-32586	90.950	134.650	85.350	104.250	47.935	10.728	17.600	51.798	2.472	33.810	12.405	62.530	1134.400	0.236	259.600
IC-59577	87.200	129.650	97.350	102.250	56.085	9.678	25.600	58.598	1.428	38.365	11.305	75.420	750.400	0.234	175.600
IC-82219	82.200	130.650	136.350	134.250	67.435	11.378	24.900	34.198	2.018	35.320	11.545	73.340	2532.400	0.371	883.600
IC-532800	90.950	134.650	106.850	86.250	55.935	12.278	27.600	43.198	1.212	41.171	11.545	74.280	732.400	0.371	253.600
IC-61836	89.200	128.650	149.350	143.250	68.435	11.278	24.900	27.598	1.300	35.798	11.095	73.370	1732.400	0.235	385.600
IC-73351	83.200	127.650	123.850	135.250	63.435	11.228	22.900	32.798	1.608	33.162	11.135	74.470	1332.400	0.246	313.600

IC-532112	87.200	129.650	90.850	113.250	56.435	10.078	21.600	41.198	2.714	33.876	10.995	73.480	1132.400	0.271	293.600
IC-532931	87.950	130.650	112.850	141.250	58.435	13.078	19.600	35.198	1.038	67.397	11.185	77.830	1332.400	0.374	467.600
IC-532390	88.700	131.650	101.350	83.250	58.435	13.778	21.600	18.198	1.928	36.474	11.395	75.440	1432.400	0.282	383.600
IC-534481	92.450	136.650	115.350	103.250	63.435	10.278	22.900	39.798	1.672	42.293	14.025	76.360	1232.400	0.177	215.600
IC-534432	90.950	134.650	93.150	88.250	57.435	11.028	21.600	29.198	3.134	48.017	13.865	74.320	1332.400	0.226	289.600
IC-78867	91.700	135.650	99.517	129.250	38.835	10.311	17.600	65.198	2.156	44.320	11.455	77.970	1632.400	0.203	317.600
IC-534820	90.200	133.650	80.350	121.250	30.435	8.778	15.600	50.798	1.832	38.013	11.315	74.370	1032.400	0.354	343.600
IC-82461	86.450	128.650	95.850	133.250	42.935	9.028	18.600	45.198	1.896	35.708	13.115	75.470	1932.400	0.237	433.600
IC-35057	85.700	127.650	94.850	104.250	41.435	10.428	17.600	44.998	2.136	37.165	11.795	74.420	1022.400	0.470	443.600
IC-532963	93.200	141.650	80.850	148.250	30.785	8.378	18.600	57.198	1.358	33.730	10.955	76.590	532.400	0.358	178.600
IC-75341	89.200	127.650	99.850	155.250	35.935	7.928	18.600	28.598	2.304	39.209	11.525	71.430	1232.400	0.230	273.600
IC-532150	86.450	128.650	100.100	92.250	42.935	9.028	15.600	45.198	1.328	45.341	12.375	76.690	2632.400	0.389	964.600
IC-66548	83.450	124.650	97.350	135.250	53.435	8.378	18.900	50.448	1.078	25.422	11.265	74.660	1732.400	0.199	328.600
IC-532394	85.700	127.650	104.350	130.250	55.935	9.028	19.600	16.198	1.662	49.320	12.325	75.210	1032.400	0.154	163.600
IC-78845	84.950	126.650	120.850	118.250	48.435	9.778	15.600	32.798	1.163	43.053	11.505	73.280	832.400	0.292	233.600
IC-59580	87.513	127.900	125.725	135.000	38.810	12.178	23.400	28.823	2.315	40.760	11.715	75.526	1284.900	0.187	227.850
IC-104581	88.263	128.900	96.225	94.000	36.310	13.178	24.100	63.823	2.201	36.426	10.935	76.576	884.900	0.327	289.850
IC-532087	84.513	123.900	90.475	141.000	26.310	9.328	20.100	54.423	3.321	40.837	11.125	73.596	584.900	0.383	233.850
IC-55636	85.263	124.900	73.225	119.000	32.310	14.678	21.400	78.623	1.927	42.707	11.095	74.426	1284.900	0.285	355.850
IC-532832	89.513	125.900	104.725	126.000	43.310	14.678	20.100	39.823	2.099	49.542	12.175	79.316	1084.900	0.318	339.850
IC-60244	86.763	126.900	109.725	76.000	42.910	7.927	20.100	42.023	1.403	51.195	11.035	76.726	684.900	0.341	239.850
IC-59193	91.263	132.900	93.225	122.000	41.310	13.178	17.400	34.223	2.107	41.470	11.505	72.926	784.900	0.277	219.850
IC-532208	93.513	135.900	88.225	66.000	28.310	9.627	20.100	57.023	2.627	37.120	11.095	74.426	584.900	0.223	137.850
IC-79651	86.513	129.900	112.225	94.000	42.810	13.678	18.100	60.223	2.093	44.204	12.975	77.726	1026.900	0.290	293.850
IC-79024	92.513	137.900	84.225	75.000	30.310	12.278	23.400	71.423	1.197	29.131	10.675	72.376	884.900	0.293	259.850
IC-78847	95.763	138.900	110.725	63.000	43.310	11.278	22.100	37.423	1.387	31.543	10.125	77.636	1084.900	0.236	249.850
IC-79086	91.263	132.900	109.725	76.000	39.810	13.678	20.100	45.923	1.789	29.778	10.915	74.236	1066.900	0.215	223.850
IC-82332	89.763	130.900	121.725	83.000	39.310	10.678	20.100	44.723	1.115	40.366	11.375	76.066	306.900	0.207	77.850
IC-534789	90.513	131.900	122.725	106.000	45.310	10.678	20.100	34.423	1.237	31.915	11.525	74.526	634.900	0.199	131.850
IC-118771	88.263	128.900	130.225	106.000	42.810	9.177	21.400	41.423	1.859	29.314	10.695	75.216	684.900	0.312	219.850
IC-532373	86.763	126.900	93.225	217.000	45.810	9.927	19.400	54.423	2.037	34.131	10.775	76.516	1584.900	0.281	425.850
IC-534430	87.513	122.900	96.725	107.000	41.810	10.228	18.100	45.423	2.777	45.605	10.605	74.286	1384.900	0.248	329.850
IC-118702	93.513	138.900	88.225	74.000	35.810	11.178	19.400	61.423	1.279	45.884	10.845	75.516	534.900	0.327	184.850

IC-78924	82.263	120.900	140.725	109.000	44.810	11.578	18.100	29.823	2.167	43.624	9.455	81.966	1734.900	0.231	377.850
IC-534784	96.513	139.900	93.725	55.000	32.810	12.578	22.100	70.423	1.297	39.107	10.605	73.866	584.900	0.257	157.850
IC-79056	85.263	124.900	89.725	123.000	32.560	10.278	18.100	38.423	5.267	33.509	12.105	75.176	1084.900	0.269	285.850
IC-532093	94.263	136.900	99.225	147.000	35.810	14.178	25.400	74.423	1.937	30.395	10.815	74.616	1384.900	0.270	359.850
IC-532435	88.263	128.900	83.225	141.000	26.810	12.678	24.100	54.673	2.419	35.488	10.595	75.636	1084.900	0.299	319.850
IC-145935	91.263	132.900	86.225	132.000	35.810	15.778	24.100	55.023	2.813	44.591	10.805	74.286	984.900	0.317	309.850
IC-82410	85.263	124.900	129.295	140.000	43.810	10.678	24.100	62.823	3.749	45.417	11.095	74.426	784.900	0.339	269.850
IC-532245	95.763	138.900	101.725	99.000	37.810	13.678	25.400	81.423	2.815	46.674	10.955	76.306	684.900	0.355	249.850
IC-532472	86.513	122.900	94.725	89.000	32.310	11.178	22.100	67.023	1.267	42.473	10.175	70.076	1184.900	0.323	375.850
IC-534810	87.513	127.900	102.725	117.000	34.810	17.678	24.100	39.023	1.537	32.108	11.225	72.366	484.900	0.307	159.850
IC-79027	87.513	127.900	89.975	86.000	32.810	10.428	19.400	38.173	1.823	40.654	11.125	73.596	384.900	0.377	159.850
IC-594790	89.013	129.900	122.725	201.000	37.910	12.428	20.100	41.823	2.311	44.273	10.695	72.186	784.900	0.439	349.850
IC-59727	89.763	130.900	106.225	94.000	39.310	12.678	20.100	48.423	1.389	48.678	10.855	74.596	684.900	0.455	319.850
IC-532194	93.513	135.900	99.225	79.000	35.810	13.678	20.100	35.423	3.109	39.491	11.555	81.596	734.900	0.387	289.850
IC-532213	92.763	134.900	99.725	108.000	39.810	13.178	20.100	62.823	2.299	50.400	10.735	75.406	1384.900	0.242	321.850
IC-534561	92.013	133.900	115.385	163.000	40.760	12.178	22.100	56.023	2.117	41.469	10.315	77.576	884.900	0.160	139.850
IC-212181	84.513	123.900	85.475	99.000	41.810	8.677	19.400	48.623	1.907	44.172	12.485	75.726	934.900	0.248	229.850
IC-79080	95.013	137.900	107.225	109.000	37.810	10.678	20.100	59.223	1.836	32.087	10.695	76.516	834.900	0.279	233.850
IC-75354	85.388	136.150	102.038	121.750	35.135	16.640	22.600	55.873	1.690	31.791	11.803	71.003	519.900	0.639	379.850
IC-104582	88.138	132.150	145.038	74.750	46.985	12.740	21.900	35.073	2.640	47.308	12.133	80.233	1169.900	0.166	177.850
IC-36699	87.388	131.150	116.538	97.750	34.385	11.740	22.600	52.873	2.304	49.247	12.393	78.353	469.900	0.275	129.850
IC-79995	86.638	130.150	111.988	146.750	40.185	11.540	18.600	57.673	2.016	39.060	10.853	76.003	969.900	0.338	333.850
IC-532446	88.138	132.150	96.638	64.750	43.135	13.740	19.900	60.273	1.890	32.438	12.143	73.873	519.900	0.282	147.850
IC-532391	89.638	134.150	111.038	160.750	40.335	11.890	22.600	45.873	1.482	40.229	11.083	75.373	769.900	0.344	272.850
IC-79046	88.138	132.150	118.038	50.750	38.235	12.740	22.600	47.873	1.596	29.728	11.483	77.133	969.900	0.278	267.850
IC-82452	88.888	133.150	89.038	110.750	37.635	11.490	22.600	60.273	1.932	25.319	12.173	78.113	1069.900	0.368	403.850
IC-82403	89.638	134.150	107.838	84.750	36.235	13.240	22.600	50.673	1.814	37.128	12.293	73.653	419.900	0.405	187.850
IC-107942	90.388	135.150	97.788	114.750	42.135	14.640	22.600	59.673	2.536	29.317	10.603	72.823	1069.900	0.288	307.850
IC-138764	91.888	137.150	117.338	70.750	37.635	10.440	23.900	55.873	1.640	44.612	11.413	74.423	874.900	0.353	317.850
IC-36761	88.888	133.150	97.538	64.750	43.635	11.090	23.900	42.473	1.934	37.518	11.963	76.703	869.900	0.325	287.850
IC-532211	89.638	134.150	120.038	132.750	39.135	10.240	24.600	53.873	2.814	34.880	11.693	76.493	1169.900	0.251	287.850
IC-532053	90.388	140.150	80.538	64.750	25.785	8.440	25.900	64.873	2.272	42.607	10.063	75.273	569.900	0.253	141.850
IC-82281	88.138	132.150	119.038	166.750	35.135	9.440	24.600	49.273	2.352	45.307	12.553	74.183	1869.900	0.230	417.850

IC-82172	97.888	145.150	88.538	90.750	18.635	12.990	24.600	63.673	1.754	36.031	10.033	78.123	1769.900	0.205	347.850
IC-138729	89.388	131.150	94.538	70.750	31.635	12.340	28.600	56.473	1.676	29.955	13.323	73.553	469.900	0.355	177.850
IC-73497	88.888	133.150	97.038	88.750	34.635	13.290	28.600	38.473	2.592	42.567	10.113	78.293	1069.900	0.301	323.850
IC-59572	92.388	135.150	95.538	106.750	42.135	10.290	25.900	58.273	3.312	43.697	12.023	73.483	519.900	0.312	167.850
IC-532212	89.638	134.150	87.038	90.750	36.635	14.940	27.900	79.073	1.676	41.150	11.843	73.703	1319.900	0.294	387.850
IC-78738	98.638	146.150	87.238	73.750	34.635	12.240	14.600	43.273	2.066	39.100	11.723	75.333	269.900	0.455	147.850
IC-78779	94.138	140.150	104.538	105.750	41.135	15.940	20.600	37.273	1.682	54.834	11.763	75.813	969.900	0.276	265.850
IC-73650	92.638	138.150	106.538	174.750	60.635	15.240	20.600	49.873	1.410	32.602	14.483	61.103	769.900	0.209	151.850
IC-31242	96.388	143.150	126.538	82.750	57.635	14.440	27.900	40.673	2.646	33.415	11.653	69.473	1269.900	0.269	337.850
IC-60208	91.138	136.150	105.038	64.750	36.635	17.840	19.200	57.073	1.964	45.614	11.723	78.333	1249.900	0.334	421.850
IC-55129	90.388	135.150	112.538	78.750	37.635	13.740	21.200	53.473	2.574	35.725	11.483	71.933	419.900	0.292	125.850
IC-79001	94.388	133.150	129.038	101.750	61.635	14.840	20.600	60.073	1.732	42.040	11.393	78.153	769.900	0.360	287.850
IC-60203	95.638	142.150	111.038	28.750	43.135	10.140	17.900	42.073	2.464	40.145	10.293	72.703	427.900	0.381	177.850
IC-73663	88.138	132.150	143.538	130.750	56.135	10.940	20.600	54.273	2.294	44.613	11.173	74.273	1319.900	0.260	337.850
IC-532809	88.888	133.150	91.038	104.750	17.135	14.040	26.600	55.873	2.784	40.179	12.823	73.333	873.900	0.290	253.850
IC-532123	89.638	134.150	95.038	36.750	37.635	10.640	18.600	60.473	1.598	45.300	11.023	74.573	769.900	0.278	213.850
IC-534322	91.138	136.150	124.038	138.750	41.635	7.790	19.900	33.473	1.682	46.824	11.603	79.573	1069.900	0.263	277.850
IC-534435	86.638	130.150	90.038	64.750	33.135	11.940	20.600	45.473	1.852	35.892	10.973	73.463	969.900	0.259	247.850
IC-78857	87.388	131.150	118.538	110.750	45.635	10.540	19.900	56.673	1.968	31.614	12.633	74.723	969.900	0.305	297.850
IC-78820	93.388	139.150	94.038	85.750	31.635	11.540	22.600	45.273	2.354	42.557	11.883	75.843	921.900	0.357	337.850
IC-107371	91.888	137.150	85.038	136.750	34.135	10.740	18.600	54.873	2.482	42.057	11.873	75.643	819.900	0.325	271.850
IC-532927	85.388	127.900	107.475	98.750	34.435	13.603	21.600	62.110	2.616	43.075	12.610	74.913	994.900	0.288	281.850
IC-199660	97.388	143.900	87.475	82.750	26.435	13.103	23.600	47.510	1.572	34.120	13.280	75.723	694.900	0.205	136.850
IC-82410	86.888	129.900	128.975	100.750	35.935	10.903	17.600	51.910	1.980	39.180	11.900	78.393	1494.900	0.195	310.850
IC-28637	87.638	130.900	137.475	128.750	42.435	10.003	19.600	41.710	0.808	20.274	12.390	79.853	1194.900	0.142	184.850
IC-64230	91.388	135.900	99.475	144.750	32.435	11.303	19.600	55.310	2.260	41.885	11.240	73.783	1644.900	0.241	414.850
IC-82177	92.138	136.900	94.475	136.750	32.435	10.553	19.600	51.210	1.868	37.501	10.300	76.133	1294.900	0.255	336.850
IC-532933	92.888	137.900	90.475	136.750	29.268	10.069	18.900	69.710	2.762	40.477	11.310	74.843	2194.900	0.190	456.850
IC-532933	93.638	138.900	97.975	138.750	37.435	13.703	16.900	44.710	1.772	40.819	11.310	78.203	694.900	0.201	134.850
IC-75318	90.638	134.900	91.975	98.750	30.935	13.203	21.600	56.110	2.286	41.754	10.570	72.053	794.900	0.177	140.850
IC-532307	89.888	133.900	103.475	148.750	35.935	9.303	15.600	44.710	1.464	33.819	11.510	72.613	1494.900	0.193	306.850
IC-78789	84.138	132.900	93.975	112.750	32.435	11.303	18.900	44.510	1.552	35.982	10.690	72.443	544.900	0.316	151.850
IC-208906	93.138	143.900	92.975	128.750	31.935	9.903	20.900	46.110	2.408	53.578	14.880	75.663	934.900	0.178	170.850

IC-75436	92.138	134.900	109.975	107.750	42.935	13.903	18.900	68.710	2.764	41.097	12.180	78.423	1494.900	0.218	341.850
IC-53134	98.138	144.900	113.975	93.750	43.935	12.903	17.600	66.910	2.748	41.966	9.320	74.293	694.900	0.313	201.850
IC-532076	100.388	147.900	81.975	78.750	31.935	11.903	20.900	65.710	1.822	28.489	10.780	74.703	704.900	0.250	166.850
IC-532420	91.388	135.900	111.475	110.750	39.435	11.403	22.900	56.310	3.348	60.705	10.430	88.113	2294.900	0.185	466.850
IC-532382	92.888	137.900	92.975	93.750	33.935	9.403	22.900	46.910	2.198	48.109	10.790	75.243	1004.900	0.169	176.850
IC-145969	96.638	142.900	100.475	143.750	33.435	9.403	17.600	43.010	1.968	47.082	10.690	78.063	994.900	0.171	176.850
IC-30276	91.138	127.900	104.475	93.750	42.935	14.903	16.900	54.910	2.008	37.543	12.900	72.093	1094.900	0.221	246.850
IC-78966	86.888	129.900	109.975	112.750	40.135	9.403	14.900	44.110	1.398	32.762	10.960	74.313	1494.900	0.243	376.850
IC-534870	87.638	130.900	96.175	80.750	35.935	8.653	12.900	37.110	1.048	29.394	10.570	80.603	394.900	0.445	138.850
IC-35063	93.138	133.900	87.475	78.750	34.935	12.403	21.600	61.910	2.660	43.934	9.970	76.213	744.900	0.236	168.850
IC-78826	92.888	137.900	91.675	158.750	37.435	11.903	24.900	41.310	1.360	34.067	11.310	75.403	1194.900	0.280	336.850
IC-79043	85.388	127.900	88.975	80.750	39.435	7.853	15.600	49.910	2.260	46.453	10.000	80.613	794.900	0.274	208.850
IC-532152	86.138	128.900	89.475	136.750	33.935	10.903	14.900	66.910	2.676	40.878	10.220	78.123	544.900	0.682	316.850
IC-82414	90.138	130.900	103.975	165.750	32.935	11.403	18.900	44.710	1.708	39.365	11.990	76.923	704.900	0.365	236.850
IC-138884	91.388	135.900	116.475	141.750	45.935	12.903	19.600	43.510	1.976	46.722	11.130	78.063	2194.900	0.176	426.850
IC-73661	90.638	134.900	103.975	154.750	42.935	14.403	19.600	50.710	1.764	35.794	11.000	75.063	1074.900	0.318	336.850
IC-532823	90.638	134.900	107.675	153.750	37.435	9.253	17.600	47.710	1.550	33.508	10.550	74.513	584.900	0.267	141.850
IC-532409	89.888	133.900	92.975	107.750	36.635	7.403	13.600	33.110	1.568	49.039	11.180	79.213	1494.900	0.235	366.850
IC-104587	87.638	130.900	128.975	127.750	47.435	11.403	18.900	46.710	1.844	40.622	11.450	78.573	1394.900	0.220	320.850
IC-82188	90.638	134.900	81.475	131.750	28.435	10.903	17.600	36.110	1.588	45.472	10.440	75.383	1094.900	0.105	130.850
IC-73683	88.138	127.900	124.475	242.750	38.035	12.403	15.600	34.460	1.788	53.607	12.100	79.083	1544.900	0.167	280.850
IC-79095	89.888	133.900	119.975	108.750	40.135	11.403	16.900	31.110	0.810	27.313	12.450	79.173	1244.900	0.166	220.850
IC-82260	97.388	143.900	113.475	161.750	43.435	10.903	19.600	54.110	1.804	34.281	11.110	77.663	1244.900	0.222	284.850
IC-532092	89.138	132.900	90.975	59.750	34.435	9.403	16.900	51.310	2.104	42.092	11.570	75.623	594.900	0.255	138.850
C1	89.050	133.200	107.800	120.400	39.340	11.120	21.400	51.080	2.348	42.827	11.008	75.776	959.600	0.289	269.400
C2	90.000	132.800	99.700	116.800	38.500	11.210	20.600	54.510	2.079	37.882	11.452	73.524	980.000	0.282	268.200
C3	91.550	135.000	93.400	83.600	39.800	10.710	19.000	48.000	1.977	39.499	11.016	74.216	980.000	0.256	242.600
C4	87.950	130.600	119.050	156.200	45.100	11.550	21.400	54.500	2.251	41.192	10.714	75.916	1260.000	0.263	318.200

VITA

The authoress Ms. Neha Joshi was born on April 13, 1990 at Lucknow, Uttar Pradesh. She completed her Higher Secondary School in the year 2005 from PT D D U S V M H S SCH Lakhimpur Kheri and Senior Secondary School in the year 2010 from RANI LAXMI BAI MEM SCH VIKAS NGR LUCKNOW UP. Thereafter she joined Mahila Mahavidyalaya Aminabad in the year 2011 for B.Sc. Life science degree and Graduated in June 2014. She joined G.B. Pant University of Agriculture and Technology, Pantnagar in July 2014 for Master's Degree in Agriculture with major in Genetics and Plant Breeding.

Permanent Address

Neha Joshi
D/o – Mr. Prabhakar Joshi
14/395
Vikas Nagar
District – Lucknow
Pin Code – 226022
State – Uttar Pradesh
Mobile No. - +919568572143
Email – njoshi1304@gmail.com

ABSTRACT

Name	:	Neha Joshi	**Id. No.**	:	47000
Semester and Year of Admission	:	Ist, Semester, 2014-15	**Degree**	:	M. Sc. (Ag.)
Department	:	Genetics and Plant Breeding	**Major**	:	Genetics and Plant Breeding
Advisor	:	Dr. Anil Kumar	**Minor**	:	Nil

Thesis title : **Characterization of germplasm for yield, its components and quality traits in wheat (*Triticum aestivum* L. em. Thell)**

Bread wheat (*Triticum aestivum* L. em. Thell) an allohexaploid (2n= 6x= 42), is the premier food crop of worldwide importance. Low level of gene pool variation exhibited by modern wheat cultivars may be due to the use of narrow genetic base in breeding programmes and also due to environment conditions. The investigation of genetic distance is an auxillary apparatus of incredible use in breeding programs. The presence of ample genetic diversity in the base material causes better chance of evolving desirable plant types. Yield is a complex polygenic character and is resultant of interactions of several genetic and environmental factors, hence it requires continuous improvement involving the diverse material.

The present investigation was carried out in *rabi* season, 2015-16 at N.E. Borlaug Crop Research Centre, G. B. Pant Univ. of Agriculture & Technology, Pantnagar. The experimental materials for the present investigation comprised of 180 germplasm accessions and four checks, namely, WH 1105, DPW 621-50, PBW 343 and AGRA LOCAL. These genotypes were evaluated in augmented block design and observations were recorded for 16 characters *viz*., days to 75% heading, days to maturity, plant height, number of tillers per meter, peduncle length, spike length, number of spikelets per spike, number of grains per spike, grain weight per spike, 1000 grain weight, biological yield, grain yield, harvest index, protein content, sedimentation value and test weight.

Variance (mean sum of squares) was found highest for biological yield followed by grain yield. The coefficient of variability was found to be the highest for grain yield and lowest for test weight. Highest genotypic coefficient of variation was observed for biological yield per meter and estimates of heritability in broad sense were high for number of grains per spike. High heritability estimates were associated with high estimates of genetic advance (GA) as per cent of mean for biological yield which indicates the presence of additive variance. Grain yield showed significant positive correlation with harvest index and negative correlation with plant height. Harvest index exerted high positive direct effect on grain yield.

The genotypes were grouped into 10 different clusters by non-hierarchical Euclidean cluster analysis. Cluster I had 24 genotypes, whereas cluster II comprised of 22 genotypes, cluster III had 4 genotypes, cluster IV had 15 genotypes, cluster V had 41 genotypes, cluster VI had 8 genotypes, cluster VII contained 18 genotypes, cluster VIII had 35 genotypes, cluster IX comprised of 11 genotypes, cluster X had 6 genotypes. The intra cluster distance was highest for cluster VII (36.68) and minimum for cluster III (13.04). Inter cluster distance was maximum between cluster-VI and cluster X (526.53) and minimum cluster distance was observed between cluster I and cluster II (32.33).

On the basis of findings of the study, six desirable donors for each character were identified on the basis of character mean. IC-532150, IC-82219, IC-753957, IC-58012 and IC-532931 were found to be the most promising donor genotypes for grain yield. These genotypes can be used for future breeding programme to improve the yield potential of the variety. For other characters, genotypes can be picked up from different groups, formed on the basis of their ranking.

Nehajoshi

(Anil Kumar)
Advisor

(Neha Joshi)
Authoress

नाम : नेहा जोशी **परिचयांक** : ४७०००

षट्मास एवं प्रवेश वर्ष : प्रथम, २०१४-१५ **उपाधि** : स्नातकोत्तर (कृषि)

मुख्य विषय : आनुवांशिकी एवं पादप प्रजनन

विभाग : आनुवांशिकी एवं पादप प्रजनन

शोध शीर्षक : "गेहुँ (*ट्रिटिकम एसटिवम* एल.एम. थेल) में उपज, इसके घटकों और गुणवत्ता वाले लक्षणों के लिए जननद्रव्य का विश्लेषण।

सलाहकार : डॉ. अनिल कुमार

सारांश

गेहूँ, एक विश्वव्यापी महत्व की प्रमुख खाद्य फसल है। आधुनिक गेहूँ की फसल द्वारा प्रदर्शित जीन पूल का निम्न स्तर प्रजनन कार्यक्रमों में संकीर्ण अनुवांशिक आधार के उपयोग और पर्यावरण की स्थिति के कारण भी हो सकता है। आधार साम्रगी में प्रर्याप्त आनुवांशिक विविधता की उपस्थिति के कारण वांछनीय पौधे के प्रकार विकसित किये जा सकते है। उपज एक जटिल पॉलीजीनिक लक्षण है, और यह कई अनुवांशिक और पर्यावरणीय कारकों के संपर्क के परिणाम स्वरूप प्राप्त होता है, इसलिए इसके विविध सामग्री में लगातर सुधार की आवश्यकता होती है।

प्रस्तुत शोधकार्य रबी 2015–16 में गो0 ब0 पंत कृषि एवं प्रौद्योगिकी विश्वविद्यालय पंतनगर के नॉरमन ई. बोरलॉग फसल अनुसंधान केन्द्र पर किया गया। गेहूँ के 180 जननद्रव्यों को चार मानक प्रजातियों यथा डब्ल्यू एच. 1105, डीपीडब्ल्यू 621–50, पीबीडब्ल्यू 343 और आगरा लोकल के साथ ऑगमेन्टेड विन्यास में लगाया गया और 16 लक्षणों क्रमशः 75 फीसदी बाली का समय, परिपक्वता अवधि, पौधो की ऊचांई, पिडन्कल की लम्बाई, कल्लों की संख्या, बाली की लम्बाई, पुष्पगंधो की संख्या, प्रति बाली दानों की संख्या, प्रति बाली दानों का भार, 1000 दानों का भार, जैविक उपज, अनाज उपज, फसल सूचकांक, प्रोटीन का प्रतिशत, अवसादन मूल्य तथा परीक्षण भार के लिए आंकडे एकत्रित किये गये।

भिन्नता जैविक उपज के बाद अनाज उपज के लिए सर्वोच्च पाया गया, विभिन्नता गुणांक अनाज उपज के लिए सबसे ज्यादा एवं परीक्षण भार के लिए सबसे कम पाया गया। विविधता के उच्चतम जीनोटाइपिक गुणांक प्रति मीटर जैविक उपज के लिए पाया गया था, और व्यापक अर्थो में आनुवंशिकता प्रति बाली दानों की संख्या के लिए अधिकतम थी। जैविक उपज के लिए उच्च आनुवंशिकता का अनुमान अग्रिम (जीए) के उच्च अनुमानों के साथ जुडें थे। अनाज उपज ने फसल सूचकांक के साथ सकारात्मक और पौधे की ऊचांई के साथ नकारात्मक संबंध दिखाया। फसल सूचकांक ने अनाज उपज पर उच्च सकारात्मक प्रभाव डाला।

नॉन हेरार्किकल यूक्लिडियन विश्लेषण द्वारा जननद्रव्यों को 10 विभिन्न समूहों में बांटा गया था। समूह I में 24, समूह II में 22, समूह III में 4, समूह IV में 15, समूह V में 41, समूह VI में 8, समूह VII में 18, समूह VIII में 35, समूह IX में 11 एवं समूह X में 06 जननद्रव्य थे। अन्तर समूह दूरी समूह VII (36.68) के लिए सबसे ज्यादा और समूह III (13.04) के लिए न्यूनतम थी। VIII और समूह X के बीच अर्न्तसमूह दूरी न्यूनतम देखी गई थी।

अध्ययन के निष्कर्षो के आधार पर प्रत्येक लक्षण के लिए पाँच वांछनीय दाताओं की पहचान लक्षण के औसत के आधार पर की गई थी। IC-532150, IC-82219, IC-753957, IC-58012 एवं IC-532931 जननद्रव्यों द्वारा अनाज उपज के लिए उच्च क्षमता प्रदर्शित की गयी। यह जननद्रव्य विभिन्न प्रकार के उपज क्षमता में सुधार के लिए भावी प्रजनन कार्यक्रम के लिए इस्तेमाल किये जा सकते है। अन्य लक्षणों के लिए, जननद्रव्य, श्रेणी के आधार पर गठित विभिन्न समूहों से चयनित किये जा सकते हैं।

Nehajoshi

(अनिल कुमार)
सलाहकार

(नेहा जोशी)
लेखिका