

***Stability analysis of genotypes with concern to
yield performance and quality traits in bread
wheat (*Triticum aestivum* L)***

**By
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(2018A59D)**

***Thesis submitted to the Chaudhary Charan Singh
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2022

CERTIFICATE-I

This is to certify that this thesis entitled, “**Stability analysis of genotypes with concern to yield performance and quality traits in bread wheat (*Triticum aestivum* L.)**” submitted for the degree of **Doctor of Philosophy** in the subject of **Genetics and Plant Breeding** of the **Chaudhary Charan Singh Haryana Agricultural University, Hisar** is a bonafide research work carried out by **Ibrahim Hassani, Admission No. 2018A59D** under my supervision and that no part of the thesis has been submitted for any other degree. The assistance and help received during the course of investigation has been fully acknowledged.

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CHAPTER-I

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the world's leading cereal crops for human food and animal feeding. It belongs to the botanical sub-tribe *Triticineae*, tribe *Triticeae* (Hordeae) in the family *Poaceae* (*Gramineae*) (Briggle and Rietz, 1963). The genus *Triticum* is included two commercially cultivated species, *Triticum aestivum* L. (bread wheat) and *Triticum durum* L. (durum or macaroni wheat). It is the most important grain and is being used as a staple food for more than one third of the world. According to the USDA (2014), one cup of whole wheat grain contains 33% protein, 29% carbohydrate and 5% fat. About 65% of the wheat crop is used for human food, 17% for animal feed and 12% for industrial applications. Due to growing populations across the globe, the world's demand for cereals is projected to grow by 56% while demand in the developing world is projected to increase by 60% by 2050 compared to the demand in 2000 and 26% of that demand is expected to be for wheat (FAO, 2015).

Wheat is the second important cereal crop after rice in the world and that is a source of nutrition for 35% of the world population and currently ranks first among cultivated plants in terms of area and production. Wheat is the first most important cereal crop of Afghanistan and plays a vital role in food and nutritional security. It occupies a central position in agricultural economy and policies. Many countries like Afghanistan have been a net importer of wheat for the past several decades. Worldwide, wheat is cultivated in an area about 224.49 million hectares and producing 792.40 million tons of grain (Anonymous, 2021). Nutritionally it is the most important cereal crop, essential for the food security, poverty alleviation and livelihood improvement.

India is the second largest wheat producing country after China. Currently occupied an area nearly 31.76 million hectares, and a production of 109.52 million tons (13% of the globally wheat production) and the productivity is 3464 q/ha (Anonymous, 2021). Haryana, Uttar Pradesh, Punjab, Madhya Pradesh, Rajasthan and Bihar are the major wheat producer of India. The aforementioned six states undertake around 92 percent of total wheat production. Uttar Pradesh is reported the highest area and production of wheat and Punjab is ranked first in productivity.

Wheat cultivation under diverse agro climatic conditions and wide variations in productivity from region to region, crop becomes restricted due to sudden fluctuations in environmental changes. The main objective of a crop breeding programme is to develop varieties that perform well over a broad spectrum of environments. Further, a variety having wide or good adaptability is one which gives consistently superior performance over several environments (Frey, 1964).

At several international research centres all over the world wheat breeders are working to improve grain yield with better quality including agronomic traits. Variety developments along with subsequent selection are one of the most successful approaches utilized for wheat breeding. The breeding programme and baseline strategy depends primarily on the target traits and subsequent choice of parents to be involved under hybridization programme. The genetic distance between parents is directly proportional to the extent of heterosis found in progenies. The experiments on genetic variability provide the base of information regarding traits variation in the experimental material. The correlation studies is helpful to quantify and evaluate the proportion of the phenotypic correlation associated with genetic backgrounds. Therefore, the result come out of the above facts, the extent of genetic variability present in a set of bread wheat genotypes for various traits and the phenotypic correlation coefficients between yield and component traits (Shabir, H. *et al.*, 2018).

Wheat grain yield is a complex quantitative genetic parameter and is the result of numerous factor contributing to affect grain yield directly or indirectly. It seems that the wheat grain yield varies widely as a consequence of its interaction with a variety of environmental factors. The production of wheat grain can be improved through the development of productive varieties which adopt better in diverse agro-climatic situation and give the positive reaction or shows resistance in all types of biotic stresses. Through the adequate genetic variability exists in the breeding materials, selection and improvement of grain yield can only be efficient (Ali, Y *et al.* 2008).

The significant and correlated response studied between diverse and desirable morpho-physiological and other yield attributing traits serves as proxy indicators and potential candidate traits in the selection of genotypes for achieving the genetic gain, which are highly important for improving grain yield in crop and its productivity. The yield of wheat can be predicted if the yield component traits are functionally modelled like days to heading, days to maturity, plant height, 1000 grain weight, biological yield, grain yield etc.

Wheat is unique among cereals in containing large quantities of gluten, a complex of proteins giving dough the capacity of retaining the CO₂ bubbles that allow leavened bread to rise. Gluten may be chemically partitioned into gliadins, important in dough viscosity and extensibility and glutenins, considered to affect dough strength and elasticity and thus loaf volume (Mansur *et al.*, 1990).

Yield and grain protein content are primary important traits in wheat breeding programs. The first one is obviously a major determinant of farmer's incomes, while the second one is very important for bread quality. Genotype and its interaction with prevailing environment is the basic factor determining the quality and the final yield. The genotype x environment interaction is particularly important in the expression of quantitative characters, which are controlled by polygenic inheritance and are greatly influenced by the environmental

factors. Thus, in order to have unbiased estimates of various genetic components, it is imperative that the experiment should be repeated over different environments. Crop yield in which the plant breeder is most interested is dependent on the genotype, the environment and the interaction between genotype and environment. The result of the genotype x environment interaction is expressed as adaptability and stability of the genotype. (Groos, *et al.*, 2003).

Wheat quality is affected by environmental conditions such as temperature in the growing season, humidity during grain filling, duration of grain filling, sowing time and date. Wheat varieties are grown in varied agro climatic conditions which cause fluctuations in yield and quality traits. So it is necessary to develop and identify phenotypically stable genotypes, which could perform consistently better over a wide range of environments. Besides categorization of varieties, it is essential to identify the suitable genotypes for specific favourable and unfavourable environments for sustainable wheat production. The genotype environment interaction is occurred when two or more genotypes are compared in multiple environments and their relative performances (responses to the environment) found to differ. It revealed that one genotype shows high performance but the other showed low performance in the same environment as to compare the first one. On the other hand, over different environments, the relative performance of genotypes is inconsistent. G x E is a differential genotypic expression across multiple environments. It confer the important issue of adaptation, because in a breeding selection if in one environment raise to superior performance, it may not hold true in another environment.

Wheat cultivation under diverse agro climatic conditions and wide variations in productivity from region to region, crop becomes restricted due to sudden fluctuations in environmental changes. The main objective of a crop breeding programme is to develop varieties that perform well over a broad spectrum of environments. Further, a variety having wide or good adaptability is one which gives consistently superior performance over several environments (Frey, 1964).

A genotype is considered to be stable if its variance is small among-environment. This is called stability statistic, or a biological concept of stability. A stable genotype possesses an unchanged or least changed performance regardless of any variation of the environmental conditions. This concept of stability is useful for quality traits, disease resistance and for stress characters like winter hardiness (Becker and Leon, 1988).

Studies of correlation along with path analysis is being able to provide a better way of understanding of the inter-relationship among different characters with grain yield that helps the breeder during the selection time. Correlation studies are useful to find out the magnitude and direction of the relationship between yield and its component traits. Meanwhile, study of path coefficient analysis measures the direct and indirect contribution which reveal the independent variables on dependent variables and thus can give idea to breeders in

determining the yield components that making understandable the cause of association between two variables. Obtaining information by path coefficient analysis provide information in indirect selection for yield genetic improvement, because direct selection is not provide enough information for low heritable trait such as yield.

Breeders have been utilizing the enhanced genetic resources to modify the varieties to meet requirements of ever increasing population. The crop breeding aim is to improve varieties with higher yield and qualitative traits to sustain the food security and food deficiency elements to reduce the hunger and provide sufficient source of high quality food. New varieties may originate through introduction, selection, hybridization, mutation and genetic engineering. It is well understand fact that quantitative characters, depending on the nature of gene action, are differently influenced by environmental variation, while the qualitative characters are depend to the nature of the genetic material. Moreover, the extents of heritability of quantitative traits are negatively correlated with environment. Heritability of traits indicated greater influence of environmental factors over genetic makeup of traits.

Therefore, the present study was conducted to identify stable wheat genotypes for grain yield, its components and quality traits in bread wheat with the following objectives.

- To assess the nature and magnitude of the correlation between yield, its components and quality traits
- To find out genotypic and phenotypic correlations between grain yield, its component traits and quality traits in wheat
- To estimate the stability of the genotypes for yield and its component traits under different environment

CHAPTER-II

REVIEW OF LITERATURE

From long time (back to the history) wheat was considered the main important food crop that received the attention of the consumers and after the initiation of crop improvement the scientist particularly intended on wheat improvement.

Yield or productivity, adaptation to a production environment, and resistance to biotic and abiotic stresses will always be important. However, with time, as they are resolved, breeders shift their emphasis to other quality traits. Therefore, several experiments have been conducted to understand the stability analysis for yield and quality traits by different researcher's worldwide and a review of earlier researches and reports in wheat pertaining to our investigation is presented comprehensively in this chapter.

Allard (1960) revealed the heritability is one of the useful quantitative parameter, which reveal the role of heredity and environmental determination from the expression of traits. The effective selection is being achieved only when additive effects are substantial and the environmental effect be small.

Shewry, P.R., *et al.* (2000) observed the sedimentation value according to (Zeleny value) describes the degree of sedimentation of flour suspended in a lactic acid solution during a standard time interval and this is taken as a measure of the baking quality. Swelling of the gluten fraction of flour in lactic acid solution affects the rate of sedimentation of a flour suspension. Both a higher gluten content and a better gluten quality give rise to slower sedimentation and higher Zeleny test values. The sedimentation value of flour depends on the wheat protein composition and is mostly correlated to the protein content, the wheat hardness, and the volume of pan and hearth loaves. A stronger correlation between loaf volume and Zeleny sedimentation volume compared to SDS sedimentation volume could be due to the protein content influencing both the volume and Zeleny value).

Ahmad *et al.* (2003) investigated that the correlation and genetic variability analysis could be used as an important tool to bring information about appropriate cause and effects relationship between yield and some yield components in wheat. Correlation and genetic variability analysis leads us to a clear understanding of the genetic association of various plant traits and their contribution to yield.

Tawfelis (2006) studied the performance and stability of forty bread wheat genotypes under eight environments. The joint regression analysis of variance indicated highly significant differences among genotypes for all studied characters. The heterogeneity of linear responses and remainder sums of squares were highly significant for all traits. The regression coefficient was positively correlated with the mean performance indicating that high yielding genotypes had generally, and positive β_i values and revealed a good response to the

improving environments. The objectives of this study were to study the magnitude of G x E interactions as well as to assess the stability parameters of morpho-physiological characteristics of twelve bread wheat genotypes under heat stress conditions at Upper Egypt to identify the most stable genotypes under these conditions.

Korkut, *et al.*, (2007) Stated that pre requisite of breeding programme is the screen and identify phenotypically stable genotype for grain yield, which could perform uniformly under diverse environmental conditions and/or agro-climatic conditions. However, to understand the future demand of wheat production, it is necessary to count the challenges such as climate change, depleting natural resources and various type of biotic and abiotic stress etc. Some genotypes frequently show fluctuations in yield performance in different environments as a result of genotype environment interactions (G x E). Thus, G x E interactions are of major consequence to the breeders in the process of evaluation of improved genotypes when genotypes are grown at multi locations for testing their performance. Demonstrating significant superiority of any genotype. The information about phenotypic stability could be useful for the selection of desirable genotypes for yield and quality traits as well as for breeding programme.

Ali *et al.* (2008) reported high GCV and PCV estimates on grain yield per plant. In this study the lowest GCV and PCV was recorded for days to heading (9.84% and 9.70%), and protein content (7.56% and 7.27%) respectively, that's indicating difficulty of improvement for these traits through selection because of the lowest record of genetic coefficient variation and phenotypic coefficient variation in concern to the days to heading and protein content. But indicating to GCV values were higher than PCV values for all the traits, it reflect the less influence of environment in expression of traits. In order to the study the result of genotypic and phenotypic coefficient of variation indicated that grain yield per plot and sedimentation value exhibited highest genotypic coefficient of variation (52.38 percent and 23.33 percent) and highest phenotypic coefficient of variation (51.65 percent and 23.20 percent). The high PCV and GCV observed is evident from the higher variability that in turn provide good scope for selection.

Labuschagne, *et al.*, (2009) studied the carbohydrates is the most abundant constituents of wheat kernel, forming about 83 per cent of the dry matter. Starch, a major constituent of wheat endosperm plays an important role in determining wheat quality. Characterization of genes encoding starch biosynthetic enzymes along with better understanding of structure and properties of starch will help in manipulating starch functionality of different end-use products and nutritional quality. Sweetness of the product is related to simple sugars whereas nature of starch depicts the cooking quality Protein quality and composition, wet and dry gluten content present in wheat flour, water absorption capacity of whole-wheat flour play a role in overall acceptability of chapatti.

Zhao, *et al.*, (2010) stated, due to the importance of essential ingredients such as protein and starch in bread making, end-product quality, nutritional value, and economic impact, wheat quality breeding mainly focused on improving these basic ingredients. Additionally, several physical, and chemical, rheological properties have to be determined to predict the quality of flour and dough. Among the quality traits, grain protein content (GPC) has received special attentions as a conventional indicator for measuring the nutritional value of food.

Tawfelis, *et al.* (2011) the performance of the studied genotypes in the nine environments. Some of the individual was the earliest in physiological maturity in the three planting dates, while the cultivar other was the latest in physiological maturity in the first sowing date. Meanwhile, line # 7 was the latest in physiological maturity in the second and third sowing dates. It is clear shows that the individual was the earliest in physiological maturity in the 1st, 2nd and 3rd sowing dates although it was the latest in number of days to heading. The average number of days to maturity over all environments ranged from 131 days for the latest in physiological maturity individual and 94 to 137 days for Line # 7 with an average of 134 days. It is clear that, late planting date reduced number of days to maturity in the second and third planting dates by an average of 6.63 and 14.00 %, respectively, compared to the optimum planting date.

Aslani *et al.* (2012) the effects of two irrigation regimes on grain yield were studied in 8 wheat cultivars, and the results of variance analysis showed that there is a significant difference in grain yield and yield component among the testing cultivars. This difference is due to the different grain yield reduction among the genotypes under different irrigation regimes.

Maphosa, *et al.*, (2013) according to the solubility of protein components in different solvents, wheat protein can be divided into gliadin, glutenin, albumin and globulin. Among them, gliadin and glutenin are the main storage proteins of wheat, and the main constituents of wet gluten. Their content and composition affect the viscoelasticity and baking quality of wheat dough several studies indicate that GPC and wet gluten content (WGC) are controlled by multiple genes, and some quantitative trait loci (QTLs) or genes are reported.

Purchase, *et al.*, (2013) studied the stability of the 13 wheat genotypes, according to the six different G x E statistical analysis procedures respectively. Spearman's coefficient of rank correlation was then determined for comparisons of the different stability analysis procedures for the respective production regions. Significance of Spearman's rank correlation coefficients was noted over the three region production. Over all three regions Shukla's stability analysis procedure correlated highly significantly ($P_{0.01}$) with those of Eberhart and Russel. No significant rank correlation coefficients were found in the pairwise comparisons of Lin and Binns. The Lin and Binns procedure showed the greatest deviation from the other procedures, generally having negative rank correlation coefficients over all three the regions concerned. It means a genotype with an inherently high yield would be classified as stable as

its yields over sites will always be close to that of the top performer over the respective sites. The mean yield (main effect) could then rather be used to identify a genotype with superior yield performance. This implies that stability in one trial is determined against a specific genotype, but in another trial against another genotype. In the case of crossover interaction, which has clearly been illustrated, this leads to distortion of the data. This method is unacceptable for the purpose of characterizing wheat genotype x environment interaction in the Free State.

Fellahi *et al.* (2013) investigated by splitting the correlation coefficient into direct and indirect effects by utilising simple correlation, stepwise regression, and path analysis, it was possible to ascertain the kind of link between grain yield and yield-contributing features by analysing 29 bread wheat genotypes. The results of the study showed that biological yield, straw production, and the number of spikes per plant were all positively correlated with grain yield. Because these features had a favourable direct effect on boosting grain yield, path coefficient analysis revealed that biological yield and harvest index were the key components of yield.

Nukasani *et al.* (2013) studied the correlation and route analysis, 114 pre-breeding lines of wheat were examined. According to studies, there is a strong correlation between three traits—namely, the number of tillers plant⁻¹, grain weight spike⁻¹, and number of grains spike⁻¹ and yield.

Kumar *et al.* (2014) For 11 quantitative traits among 30 bread wheat cultivars, an estimated association and path coefficient were calculated. The outcome showed that, both at the genotypic and phenotypic levels, grain yield plant⁻¹ was extremely significant and significantly linked with the number of grains plant⁻¹ and the harvest index. However, at the genotypic level, the harvest index was positively correlated with the number of tillers plant⁻¹, grain weight ear⁻¹, and number of grains spike⁻¹. Studies of path coefficients revealed a direct relationship between grain production and the number of grains spike⁻¹, biological yield plant⁻¹, and harvest index. Depending on the results of this investigation, all of these characteristics could be employed to create wheat types with high yields.

Abd *et al.* (2014) in this study, eight environments (combinations of two years) were used to evaluate ten bread wheat genotypes over the 2011–2012 and 2012–2013 For grain yield (ton/fed), there were notable variations across combined analysis of the variance in grain yield across eight environments revealed genotype (G), environment (E), and genotype x environment interaction (GEI)-related mean squares with highly significant ($p < 0.01$) values, indicating that genotypes respond differently to the various environments under study and supporting the validity of the stability analysis. Analysis of grain yield stability Wheat genotypes' stability assessments for grain yield found that Bohouth 8, Cham 8, L-R 40, and Sids 1 were the most stable. In terms of 4, 4, 3, 3, Cham 10 and Sahel 1 were more stable than the rest. Out of the six stability statistics employed, 3 and 3 respectively. So, there is a

possibility that some genotypes are more stable than others for these statistics. Consequently, the aforementioned genotypes may be suggested as cultivars that are very productive and commercially stable, and/or included as breeding stocks in any upcoming breeding initiatives intending to breed wheat lines with high yields.

Kaushik, *et al.*, (2014) the major factor for the suitability of wheat varieties for making different types of bakery products is the ability to form gluten network. Gluten, the protein component of flour which gives the dough elasticity and strength, can be defined as the rubbery mass that remains when wheat dough is washed to remove starch granules and water soluble constituents. Wheat bran is the outer layer of wheat grain making up about 13 % of weight of whole grain and a good source of proteins and minerals apart from being a rich source of dietary fiber.

Mohtasham *et al.* (2014) the aim of this study were to identify the stable durum wheat (*Triticum turgidum* var. durum Desf.) genotypes for grain and to assess the effects of genotype environment (GE) interactions of yield in Iran's warm winter regions. Twenty varieties of durum wheat, including 18 test lines and two local inspections were assessed throughout the course of three crop seasons (2004–2006) at five research facilities. The combined analysis of variance revealed that location and genotype were the primary influences. The effects of genotype, year, location, and genotype, year, location interactions were Linear regression methods were used to examine GE interaction. Grain yield varied significantly depending on the conditions and genotypes. By applying the Eberhart and Russell technique, stability was calculated. Grain yield stability research in several conditions revealed significant variation among the genotype and genotype environment (linear) relationships. Genotype 12 (D68-1-93A-1A/Ruff /Fg/3/ Mtl-5/4/Lahn) showed a reasonably low value for S²_d and a b-value close to unity in the stability analysis, it may be regarded as stable for grain yield across all conditions. As a result of its stability in high-yielding conditions, G10 (Bcr/ Memo/go) was also favoured, the data revealed. With a broad sense heritability of 77%, selection should produce a good response in terms of grain output.

Rudra, *et al.* (2015) investigated the highly significant mean squares for all the characters due to genotypes except plant height. In seventy eight wheat genotypes the presence of enough genetic variability revealed in the material under study. The result of the study implied that of wheat genotypes population would respond positively for selection. The magnitude of genetic variability for days to heading was ranged from 50.50 to 74.50 days with the mean value of 61.08 days and for thousand grain weight 20.03 to 51.85g with the mean value of 39.63g. Genetic variability is essential for wide adaptability and resistance to biotic and abiotic factors. Variability of protein content is ranged from 12.25 to 17.25 percent while the mean value of 14.36 percent and wide variation been estimated from 20.50 to 65.50

ml with the mean value of 48.45 ml. Thus, these results indicate the presence of wide range of genetic variability among the genotypes material.

Dargicho *et al.*, (2015) studied that the PCV and GCV ranged for some yield component traits such as maturity date and thousand grain weight where the phenotypic coefficients of variation were generally higher than genotypic coefficients of variation for both traits indicated that the influence of growing environments. In most of the cases, two values indicated less influence of environmental factors due to slightly differ in values.

Kumar *et al.* (2014) in an investigation, wide variations were found for the micronutrients iron (24.90- 50.60 mg/kg), zinc (25.25-58.80 mg/kg), manganese (20.10-42.50 mg/kg), copper (3.10- 5.60 mg/kg), and magnesium (1001.00-1833.00 mg/kg).s research. However, 37 genotypes were found to have higher grain iron content, 23 for zinc, 40 for manganese, 23 for copper In addition, Phuke *et al.* (2017) demonstrated that the RIL population exhibits significant heterogeneity for both agronomic traits and micronutrients (Iron = 10.8 to 76.4 mg kg¹ and Zinc = 10.2 to 58.7 mg kg¹, across - 9 - environments).

Dutamo *et al.* (2015) studied the length of spike, grain yield/plant, productive tillers/plant, plant height, grains/spike, spikelets/spike, 1000 grain weight, days to maturity exhibited low environmental influence on the expression of the traits. This indicated the availability of more chances of improvement through selection breeding programme. Perhaps, High degree of phenotypic coefficient of variation give sufficient scope for improvement of those characters. Genotypic coefficient of variation is more important than that of phenotypic coefficient of variation because higher amount of genotypic variation assist in formulation of effective crop improvement breeding.

Bilgin, *et al.*, (2016) studied the effects of environment (E) and genotype (G) $\times$ E interactions (GGE) for quality traits and grain yield in bread wheat. ANOVA and GGE biplots were used to assess quality performance and stability in 36 genotypes of bread wheat through a three-location trial over two cropping seasons. The data showed a wide range of variation for milling quality parameters with regard to gluten quantity and quality, as well as for grain yield. Genotypes, location, and year, in this order, contributed to diversity. Remarkably, all the traits except grain protein content showed a larger genotype effect than location (L) effect; the interaction G $\times$ L was usually more important than the G $\times$ Y.

Sheraz, A. K. *et al.*, (2017) stated the phenotypic correlations of different parameters, on the base of yield and related traits expressed different trends of relationship among themselves. Grain yield showed significant positive association with plant height (0.50), flag leaf area (0.44), spike length (0.31), tillers plant⁻¹ (0.51), 1000-grain weight (0.57) and grains per spike (0.23). However, phenotypic correlation revealed positive correlation of grain yield with leaf area, plant height, spike length, fertile tillers, 1000-grain weight and grains per

spike, suggesting that more importance should be given to these traits for improving the yield in wheat.

Polat *et al.* (2016) in a study find out that in Turkey, 22 advanced lines and three cultivars of bread wheat during the course of three consecutive years, 2010, 2011, and 2012. Eberhart and Russell (1966) and Finlay and Wilkinson (1963) models were used to estimate stability. Analysis of variance revealed a substantial relationship between genotype and environment. Only two genotypes showed negative b_i values, and only for check Flamura were they significant. The stability of the wheat genotypes in the experimental material was investigated, and the quantifiable impacts of cultivars, environment, and genotype environment interactions were evaluated. The study's findings allowed for the separation of three lines, namely (G x 22-1)-4, (G x 22-1)-6, and (G x K), which were distinguished by greater adaptability, capability, and stability than the other genotypes.

Singh *et al.* (2018) research was conducted on 3 cultivars—HD-3086, WH-1105, and PBW-725—and 18 genotypes of bread wheat. The experiment was repeated at three other locations Ludhiana, Bhatinda, and Gurdaspur. For all traits under study, the combined analysis of variance for environment (E), genotype (G), and environment genotype interaction was extremely significant, indicating the necessity for stability analysis based on the different genotype responses. The findings showed that stable high producing genotypes are also possible. The genotypes BWL-6003, BWL-6065, BWL-6066, BWL-6068, and BWL-6069 as well as the check HD-3086 and PBW-725 all produced the desired grain yield/plot performance in terms of high mean, unit regression coefficient (b_i), and least deviation from regression (S^2_{di}), indicating the importance of the linear portion of G E interaction and average stability in the performance of these varieties. The genotypes BWL-6006, BWL-6007, BWL-6013, and BWL-6062 had high means, unit regression coefficients (b_i), and the least amount of deviation from regression (S^2_{di}) for grain Zn content, indicating that they were thought to have been specially adapted to unfavourable settings.

Krupal (2017) examined nine wheat genotypes along with two check varieties on three sowing dates at Latur settings (Maharashtra). The Eberhart and Russell model was used to estimate stability (1966). The analysis of variance for all fourteen characters revealed 12 significant variations between genotypes and environments, proving that there is enough genotypic variability as well as environment-to-environment variation for the characters under study. Except for days to heading, G E interactions were shown to be significant for all characters. All parameters, with the exception of days to 50% flowering, days to maturity, tillers per plant, and grain yield per plant, exhibited high significance for the linear component of the G E interaction. Six characters were used: plant height, days to maturity, and days to 50% flowering, and length of ear heads. Grains per spike and test weight none of eleven genotypes had significant regression coefficient except one genotype for ear head length and

two genotypes for grains per spike. This was contradictory with highly significant $G \times E$ (linear) interaction for yield per plant of three genotypes viz., MACS-6222, PBN-3958 and GW-480.

Mecha *et al.* (2017) to evaluate the genetic diversity, 64 bread wheat genotypes were tested. For seven characters (days to heading, number of tillers per plant, spike length, number of spikelets per spike, 1000 kernel weight, grain yield per plot, test weight), analysis of variance (ANOVA) revealed highly significant genotype differences, while the remaining six characters (days to 75 percent maturity, grain filling period, plant height, number of kernels per spike, biological yield, and harvest index) were only marginally different.

Sheraz, A. K. *et al.*, (2017) heritability plays a predictive role regarding improvement in a desirable traits and determines the effectiveness of selection for different traits. High values of heritability will mean simpler selection procedures. But heritability estimates alone do not give information regarding expected gain in the next generation. Expected genetic gain resulting from selection can be estimated through genetic advance.

Girnam, *et al.*, (2017) observed that the analysis of variance for grain yield and its contributing components namely days to 50% flowering, days to maturity, productive tillers, plant height, spike length, spikelets per spike, grains per spikelet, biological yield, harvest index, 1000 grain weight, grain yield and gluten content showed highly significant differences (at <1% level of significance) among the genotypes under present study. High heritability along with high genetic advance and high phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) for grain yield (g), biological yield (g), harvest index (%), spike length (cm) and 1000 grain weight (g) indicated substantial contribution of additive gene action in the expression and thus selection would be effective for genetic improvement of these traits for improving grain yield in wheat.

Poudel *et al.* (2020) 50 bread wheat genotypes were used in the experiments to determine the morpho-physiological qualities, yield, and yield potential attributes. The results of the analysis of variance 6 and mean comparisons showed substantial variations between the drought and irrigated environments for all genotypes.

Ayer *et al.* (2017) 50 wheat genotypes were examined for 16 quantitative traits. Studies of correlation found that the relationship between grain yield and biological yield was favourable and highly significant, with the harvest index, plant height, test weight, and area under the SPAD retread curve (AUSRC) at anthesis following closely behind. According to path analysis research, biological yield and harvest index have a strong positive impact on grain yield, whereas other attributes indirectly yet considerably increased grain output. They claimed that there was a strong positive association between biological yield and harvest index as well as a high direct effect on grain production, indicating that the direct selection of

genotypes based on these qualities would be successful for programmes aimed at increasing wheat yield.

Mecha *et al.* (2017) evaluated 64 wheat genotypes to determine the type and strength of correlation between yield and characteristics that contribute to yield. According to studies, grain yield was positively correlated with the following traits at the genotypic and phenotypic levels: grain filling period, number of productive tillers plant⁻¹, spike length, number of spikelets spike⁻¹, and number of seed spike⁻¹, test weight, biomass yield plot⁻¹, hectolitre weight, and harvest index. Path coefficient research revealed that qualities that are advantageous for indirect selection, such as biological yield, test weight, harvest index, and number of seed spike-1, have a positive direct impact on grain production.

Rathod (2018) assessed wheat genotype yield potential under limited irrigation and adequate irrigation over multiple locations, estimating genotype environment interaction for grain yield and its components, and estimating predictability for grain yield and its components separately, researchers evaluated 12 wheat genotypes, including 2 checks, over three locations, namely Niphad, Savalivihir, and Rahuri. Stability parameters were calculated using the Eberhart and Russell model (1966). For all eight parameters, including days to 50% blooming, days to maturity, plant height (cm), earhead length (cm), grains per spike, thousand grain weight (g), yield (q/ha), and grain protein, genotypic variations were significant under both limited and adequate watering (percent). All of the characters' M.S.S. because of the environment were significant when there was sufficient irrigation. All the characteristics except grain protein showed significant genotype environment relationships. All the characteristics, with the exception of grain protein, showed significant linear and non-linear components of G x E.

Sallam *et al.* (2018) studied a population of 146 recombinant inbred lines (F9) and reported a high genetic variation among all genotypes for all seedling traits scored. He identified genotypes with a high drought tolerance at the seedling stage combined with high grain yield in low rainfall.

Babita *et al.* (2018) the aim of the experiment was to assess the type and extent of genetic variability as well as the relationships between certain spike features and other personality factors and grain yield. To determine the degree of relationship between spike characteristics and grain yield, 72 F1 lines and 18 different bread wheat (*Triticum aestivum* L.em Thell.) genotypes were investigated. When compared to the equivalent phenotypic correlation coefficient, the genotypic correlation coefficient for the majority of the character combinations was larger in size, showing the strong intrinsic nature of the traits observed in the current study. With the exception of hundred grain weight, yield per plant showed a positive and robust correlation with all the parameters. The amount of relationship was estimated using 72 F1 lines and 18 different bread wheat (*Triticum aestivum* L.em Thell)

genotypes. The most common genotypic correlation coefficient compared to related characters, the magnitude of the character combination the strong inherent nature of traits as indicated by the phenotypic correlation coefficient.

Ahmed *et al.* (2018) examined 308 spring wheat genotypes to investigate the genetic diversity and associations between traits. The analysis of variance results showed substantial differences between all of the genotypes. The estimated CV showed that agronomic variables including grain weight per spike, grain yield per plant, tiller number per plant, 1000 grain weight, grain number per spike, and biological yield had the highest levels of variability.

Singh *et al.* (2018) studied 10 wheat genotypes of diverse genetic background with popular cultivar of India for morpho-physiological traits for drought condition and observed that genotypes Raj 1555, DBW17, PDW 291, PBW226, VL 421, and WH1021 performed better for drought condition.

Arain *et al.* (2018) nine features from 19 advanced wheat lines from the Semi-Arid Wheat Yield Trial (SAWYT) were compared to a local cultivar as the control. According to correlation studies, test weight was highly and significantly correlated with grain yield, whereas all other attributes were favourably but insignificantly correlated with grain yield.

Kumar *et al.* (2018) 50 wheat genotypes were examined for 8 quantitative features in order to evaluate correlation and path analysis. Plant height, productive tillers plant⁻¹, spikelets spike⁻¹, grains spike⁻¹, and 1000-grain weight were all positively correlated with grain yield plant⁻¹, as these features may be useful in selection for future improvement.

Nagar *et al.* (2018) examined 169 wheat genotypes' 11 yield components. According to the findings, plant height considerably but negatively connected with grain yield plant⁻¹, whereas it significantly but positively correlated with spike length, number of grains spike⁻¹, test weight, biological yield plant⁻¹, and harvest index. As these traits may be useful in early generation selections, path analysis revealed that the characters biological yield plant⁻¹, number of effective tillers plant⁻¹, number of grains spike⁻¹, plant height, and harvest index showed positive direct effect on grain yield at both genotypic and phenotypic levels.

Ojha *et al.* (2018) For 11 characters in 20 different wheat genotypes, estimated correlation coefficient and path coefficient analysis were performed. The experiment's findings revealed a strong and favourable correlation between the number of spikes per square metre and grain production. Similarly, plant height, spike weight, spike length, number of grains spike⁻¹, flag leaf length, and test weight all showed favourable phenotypic connection with grain yield. The number of spikes per m², the weight of the spikes, the number of grains they contained, the length of the spikes, and the weight of the 1000 grains all had a positive direct impact on grain yield.

Anurag *et al.* (2018) the resultant analysis of variance revealed the treatment was significant for all the characters. As the value of PCV was significantly higher than GCV at

all, the traits which signified the traits expressed variation, was due to both treatments and environmental influence. High GCV and PCV value was recorded just due to spikes weight. It also showed low heritability for biological yield/plant that was accompanied with high magnitude of genetic advance, traits was governed by additive gene effect but low heritability observed due to high environmental effects, it states that selection may be effective only to a certain extent. The positive and significant genotypic and phenotypic correlation coefficient estimated due to harvest index and spike weight, while correlation between day to 50% heading and grain yield/plant was negative and significant. The study was revealed path coefficient analysis was showed highest positive direct effects for harvest index and followed by plant height, days to maturity, biological yield/plant, spike weight, number of grains/plant and 1000 grain weight on the dependent character.

Babita *et al.* (2018) studied, the coefficient for genotypic correlation is indicated to be higher in magnitude as compared to phenotypic correlation coefficient and exhibited the strong inherent nature of characters. The interrelationship between different traits is showed to be vary depending upon the genetic makeup. The coefficient for genotypic correlation is exhibited to be with higher magnitude as it's compared to the corresponding value of phenotypic correlation coefficient, thus exhibiting a strong inherent tendency of the traits to be transmitted together to the extent that observed for specific characters combination (10; 15; 17; 20; 22). The yield per plant was exhibited positive and significant association with days to heading, plant height, tillers per plant, and weight of grains per spike, likewise it had negative and significant association with thousand grains weight. In other hand the thousand grain weight was found to have non-significant correlation coefficients with spike length, spikelets per spike and number of grains per spike.

Kumar *et al.* (2018) studied correlation coefficient and path analysis for yield and its contributing traits in wheat experiment. The result came out, that harvest index and ear weight showed significant and committed to positive correlation at both genotypic and phenotypic levels, while significant association but negative between days to 50% heading and grain yield per plants. The path coefficient study indicated that highly and positive direct effect was observed for days to maturity, plant height, number of grains plant per plant, harvest index, biological yield plant per plants, and harvest index, respectively.

Solomon, *et al.*, (2018) observed that quantitative trait like yield mainly dependent on ($G \times E$) interaction as it obscures the interpretation of genetic experiments and makes predictions difficult. In such circumstances it is difficult to select and suggest one better genotype across various locations. A wider adapted genotype performs consistently over a wider range of environment. To ensure valid genotype recommendation and to identify promising genotypes, a breeder should conduct multi location yield trials across different environments.

Sowmya, *et al* (2018) using the Eberhart and Russell model, a study was conducted to assess the stability for grain yield of 20 maize hybrids in the three settings of Dharwad, Sankeshwar, and Nippani. The single cross hybrids DMH 100-1, DMH 100-2, DMH 100-4, DMH 100-8, DMH 100-12, and DMH 100-16 showed high mean performance throughout the locations during summer and were promising for the majority of examined traits. In the areas for the monsoon season, the hybrids DMH 100-1, DMH 100-2, DMH 100-12, and DMH 100-14 were found to be stable. The hybrids DMH 100-1, DMH 100-2, and DMH 100-14 were stable throughout the locations and seasons and were not greatly impacted by the season or environment.

Haydar *et al.* (2020) studied 17 genotypes of wheat to analyse the genetic variability that showed significant differences in among traits yield contributing characters. Significant positive correlation was showed in case of plant height along with number of tillers/plant and grain yield/plant, tillers/plant with spike length, spike length with grain yield and grain yield with the high phenotypic and genotypic coefficients of variation was studied in plant height and lowest values were indicated in spike length to concern of both. Estimated heritability was found to be high due to grain yield/plant, was followed by 100 grain weight. 100 grain weight. Negative correlation was to be revealed in plant height with 100 grain weight. Plant height, effective tillers/plant, spike length.

Upadhyay (2020) studied 30 wheat genotypes for 13 quantitative traits to assess correlation and to study the path analysis of yield contributing traits on grain yield. The grain yield of wheat was showed positive genotypic and phenotypic correlation significant ($P \leq 0.01$) with number of tiller per meter, grains per spike, thousand kernel weight, maturity days, biomass yield and harvest index of wheat. The genotypic correlation was to be found in higher magnitude than the phenotypic correlation for mainly all the studied traits. Path analysis of genotypic correlation showed a high positive direct effect of above ground biomass, plant height, spike length, and harvest index on grain yield of wheat. Therefore, the above components was showed a positive direct effect on grain yield of wheat as those traits was to be helpful for indirect selection for better performing genotypes.

Baye *et al.* (2020) investigated 49 bread wheat advanced lines to assess correlation and reveal the direct and indirect effect of yield contributing characters on grain yield. The analysis result of variance showed significant differences among the tested advanced lines for the majority of the yield component traits under study for two different location. The grain yield indicated the presence of high variability among the tested bread wheat lines and had significant positive correlation with days to maturity, plant height, grain-filling period, kernels per spikes, hectolitre weight, thousand seeds weight, biomass yield, and harvest index for both of the genotypic as well as phenotypic levels including spike length at phenotypic levels at both location with plant height, thousand seed weight, biomass yield and harvest

index at both genotypic and phenotypic levels. Days to maturity and grain-filling period also showed significant positive phenotypic correlation with grain yield.

Gauravrajsinh *et al.* (2021) using forty-four different bread wheat genotypes, the current experiment was conducted. During Rabi 2019–2020, they were sown and tested under timely sown conditions using a randomised full block design with four replications. 11 morphological features and 2 biochemical traits were examined in the current study. All of the investigated characters had substantial genotype variation, according to the analysis of variance, showing that there was enough diversity among the forty-four genotypes. For the number of tillers per metre, number of grains per spike, grain production per plant, leaf area per plant, and peduncle length, strong heritability related with high genetic progress as percent of mean was identified, indicating the features were simply inherited in nature. All of the investigated characters had genotypic correlations that were higher than their corresponding phenotypic correlations. The path coefficient study showed that the harvest index, followed by plant height, the number of grains per spike, and protein content, had the greatest direct impact on grain yield per plant. It may be concluded that in order to increase wheat grain yield, harvest index, grain yield per spike, protein content, days to heading, and spike length should be given more consideration.

Zewdu *et al.* (2021) next to bread wheat, durum wheat is the most significant *Triticum species*. One of the diversification hotspots for durum wheat is Ethiopia. This study set out to evaluate some yield and yield-related variables' genetic progress, heritability, and variability. In 10 x 10 simple lattice patterns, a total of 97 durum wheat accessions and 3 enhanced types were assessed. Twenty variables were gathered and examined. Materials assessed for significant quantitative and qualitative features showed statistically significant ($p < 0.01$) variance. Days to maturity and grain yield (tonnes/ha) showed genotypic coefficients of variation (GCV) ranging from 3.77 to 44.81 percent, respectively. Broad sense heritability ranged from 72.33 to 99.95% for plant height and number of kernels per spike, respectively. The highest genetic advance as percent of mean recorded for grain yield (88.80%) and the least for moisture (5.22%). Generally, the magnitude of genetic variability among the studied durum wheat accessions showed great variations for desirable traits and thus confident enough to expect genetic progress if further breeding activities are carried out.

CHAPTER–III

MATERIALS AND METHODS

The details of the materials used and the methods adopted during the course of this investigation are described in this chapter.

The present investigation titled, “**Stability analysis of genotypes with concern to yield performance and quality traits in bread wheat (*Triticum aestivum* L.)**”, was conducted in India and Afghanistan where in India the experiments was conducted at Wheat and Barley section, Department of Genetics and Plant Breeding at CCS Haryana Agricultural University, Hisar and in Afghanistan at central research farm, Agricultural Research Institute of Afghanistan (ARIA) Research Station, 2020-21. Hisar falls in semitropical region of western zone of India and geographically situated at a latitude of 29° 10’N and longitude of 75° 46’E and attitude 215.2 M above mean sea level and Beni Hisar at a latitude of 34° 48’ N and longitude of 69° 21’E and attitude above sea level 1791M

Material

In present study the experimental material consisting of 54 genotypes including checks. The experimental material was selected on from the CIMMYT Nursery which was grown common in India as well as Afghanistan (39th ESWYT) in year 2018. The pedigree of all 49 genotypes received from CIMMYT is given in table 3.1

Experimental Details:

- Locations : Hisar (India) and Kabul (Afghanistan)
- No. of Genotypes : 49 + 05 (Checks)
- Replication : 02
- Design : RBD
- Plot Size : 6 rows of 3.0 meter

Environments

- E₁ = Rabi 2019-20 (Normal Sown), Hisar, India
- E₂ = Rabi 2019-20 (Late Sown), Hisar, India
- E₃ = Rabi 2020-21 (Normal Sown), Hisar, India
- E₄ = Rabi 2020-21 (Late Sown), Hisar, India
- E₅ = Spring 2020 (Normal Sown), Beni Hisar, Kabul, Afghanistan
- E₆ = Spring 2021 (Normal sown), Beni Hisar, Kabul, Afghanistan

The experiment were grown under irrigated conditions in both the locations and recommended package and practices were followed to raise the crop.

Table 3.1: List of genotypes along with their pedigree

S. No.	Genotypes	Pedigree
1	EC 1075892	Sulh-02
2	EC 1075893	MUCUY
3	EC 1075894	CROC_1/AE.SQUARROSA (205)//BORL95/3/PRL/SARA//TSI/VEE#5/4/FRET2/5/CIRO16
4	EC 1075895	KACHU/SAUAL/4/ATTILA*2/PBW65//PIHA/3/ATTILA/2*PASTOR
5	EC 1075896	NELOKI//SOKOLL/EXCALIBUR
6	EC 1075897	SUP152/QUAIU #2//BECARD/QUAIU #1
7	EC 1075898	BORL14//BECARD/QUAIU #1
8	EC 1075899	KACHU//WBLL1*2/BRAMBLING/3/KACHU/KIRITATI
9	EC 1075900	WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING/4/BORL14
10	EC 1075901	SUP152/AKURI//SUP152/3/MUCUY
11	EC 1075902	PRL/2*PASTOR*2//MISR2, EGY/3/2*BECARD//ND643/2*WBLL1
12	EC 1075903	SUP152/BLOUK #1/3/PRL/2*PASTOR*2//VORB/4/SUP152/BLOUK #1
13	EC 1075904	BOKOTA//BECARD/QUAIU #1/3/BOKOTA
14	EC 1075905	SUP152/HUIRIVIS #1//2*BORL14
15	EC 1075906	KSW/SAUAL//SAUAL/3/TRCH/HUIRIVIS #1/5/UP2338*2/SHAMA/3/MILAN/KAUZ//CHIL/CHUM18/4/UP2338*2/S HAMA
16	EC 1075907	BORL14*2/7/MUU/5/WBLL1*2/4/YACO/PBW65/3/KAUZ*2/TRAP//KAUZ/6/WBLL1*2/SHAMA
17	EC 1075908	WBLL1/4/BOW/NKT//CBRD/3/CBRD/5/WBLL1*2/TUKURU/6/2*BORL14
18	EC 1075909	NADI#2//TRCH/HUIRIVIS #1/3/NADI#1
19	EC 1075910	KACHU//WBLL1*2/BRAMBLING/3/BAJ #1/AKURI/4/KACHU//WBLL1*2/BRAMBLING
20	EC 1075911	SUP152/BAJ #1/4/BAJ #1/3/KIRITATI//ATTILA*2/PASTOR/5/SUP152/BAJ #1
21	EC 1075912	WBLL1*2/BRAMBLING//WBLL1*2/BRAMBLING/3/2*BORL14
22	EC 1075913	KIRITATI/WBLL1//2*BLOUK #1*2/3/KACHU #1/KIRITATI//KACHU
23	EC 1075914	KACHU #1/3/T.DICOCCON PI94624/AE.SQUARROSA (409)// BCN/4/2*KACHU/5/MUTUS*2/TECUE #1/6/MUTUS*2/TECUE #1
24	EC 1075915	BAJ #1/3/SUP152//WBLL1*2/BRAMBLING
25	EC 1075916	TACUPETOF2001/BRAMBLING//KACHU/8/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA(213)//PGO/4/HUITES/5/T.DICOCCONPI94624/AE.SQUARROSA(409)//BCN/6/REH/HARE//2*BCN/3/CROC_1/AE.SQUARROSA (213)//PGO/4/HUITES/7/MUTUS
26	EC 1075917	BORL14/4/BAJ #1/3/KIRITATI//ATTILA*2/PASTOR
27	EC 1075918	MUTUS/ROLF07//MUCUY
28	EC 1075919	MUTUS/AKURI//SUP152/BAJ #1
29	EC 1075920	BAJ #1/TECUE #1//MUTUS*2/TECUE #1
30	EC 1075921	KINGBIRD #1//INQALAB 91*2/TUKURU/3/BECARD/FRNCLN
31	EC 1075922	SUP152/BAJ #1/3/KACHU//WBLL1*2/BRAMBLING
32	EC 1075923	WBLL4/KUKUNA//WBLL1/3/WBLL1*2/BRAMBLING/4/BECARD/FRNCLN

33	EC 1075924	BECARD/QUAIU #1//ONIX/KBIRD
34	EC 1075925	KACHU/BECARD//WBLL1*2/BRAMBLING/3/FRNCLN*2/TECUE #1
35	EC 1075926	OASIS/SKAUZ//4*BCN*2/3/PASTOR/4/HEILO/5/PAURAQ/6/BECARD/QUAIU #1
36	EC 1075927	CIRO16/2*BORL14
37	EC 1075928	BORL14*2/3/KBIRD//WBLL1*2/KURUKU
38	EC 1075929	BORL14*2//KFA/2*KACHU
39	EC 1075930	BORL14*2//KFA/2*KACHU
40	EC 1075931	BORL14*2//BECARD/QUAIU #1
41	EC 1075932	CNO79//PF70354/MUS/3/PASTOR/4/BAV92*2/5/HAR311/6/BECARD/QUAIU #1/7/BECARD/QUAIU #1
42	EC 1075933	FITIS*2/3/ATTILA*2/PBW65*2//MURGA
43	EC 1075934	SUP152/BLOUK #1*2/4/TUKURU//BAV92/RAYON*2/3/KIRITATI
44	EC 1075935	NADI#1*2/3/MUTUS/AKURI #1//MUTUS
45	EC 1075936	KACHU//WBLL1*2/BRAMBLING*2/3/KACHU/KIRITATI
46	EC 1075937	KACHU//WBLL1*2/BRAMBLING*2/3/KACHU/KIRITATI
47	EC 1075938	ONIX/KBIRD//BORL14/3/ONIX/KBIRD
48	EC 1075939	STLN/MUNAL #1//2*BORL14
49	EC 1075940	WBLL1*2/BRAMBLING//CHYAK*2/3/KINGBIRD #1//INQALAB 91*2/TUKURU
50	EC 1075941	FRET2*2/BRAMBLING//BECARD/3/WBLL1*2/BRAMBLING*2/4/BECARD/QUAIU #1
	Checks used at Hisar location	Checks used at Afghanistan location
51	WH1105	Koshan
52	WH1184	Mazar#00
53	WH1021	Dehdadi
54	WH1024	Ghori#96

Observations recorded: The following observations were recorded per genotype per replication.

- 1. Days to heading:** The date of initiation of ear head emergence was observed for the developmental stage in which the spike or ear partially or fully appears to emerge from its enclosing sheath is also called ear emergence or heading. The time taken for a spike or ear to emerge from its enclosing sheath is entirely dependent on growth conditions as well as the genetic makeup of a genotype. The numbers of days from sowing to heading were counted and recorded.
- 2. Days to maturity:** The number of days required from date of sowing to date of physiological maturity. Days to maturity when the grains in the spikelets becomes hard and easily be removed from the glumes, that observation was recorded as maturity.
- 3. Number of effective tillers per meter square:** The total numbers of effective tillers were counted in per meter square in each plot and each replication.

4. **Plant height (cm)** : Plant height of five randomly selected plants were measured in centimetres from ground level to the top of the tallest panicle (excluding awn) at the time of maturity and mean plant height of each treatment per replication was worked out.
5. **Spike length (cm)**: Spike length is another important trait, as large spikes are likely to produce more grains which lead to more yield per plant. It was measured in cm from the base of the main spike up to the tip of ear in five randomly selected plants in each replication.
6. **Number of spikelet per spike**: The numbers of spikelets per spike of main tiller were counted at the time of maturity randomly of five plants and then divided to get the spikelets number per spike
7. **Grains per spike**: The total number of grains in each of the spike was counted from five randomly selected spikes and averaged.
8. **Grain yield per plot (g)**: It's the most important major component to know yield per hectare. Grain yield was calculated by weighing the threshed grain yield per plot.
9. **1000-grain weight (g)**: One thousand sun-dried seeds from the bulked sample were randomly counted from each genotypes per replication and weighed on electronic balance to record weight in gram.
10. **Biological yield**: Biological yield is the total dry matter produced per plant or per unit area (i.e., biomass). Biological yield was calculated by weighing the harvested biomass per plot
11. **Harvest index (%)**: Harvest index is the ratio of seed yield to biological yield calculated by using the following formula: $\text{Harvest index}(\%) = \frac{\text{seed yield}}{\text{Biological yield}} \times 100$.

B. Quality traits:

1. **Gluten content (%)**: When water is mixed with wheat flour and the contents are kneaded, a cohesive of dough is formed. This mass on washing removes starch, bran and yield a viscoelastic gum like material known as gluten and it is responsible for physical dough properties. The weight of gluten is taken for wet and dry gluten estimation.

Reagents: KI solution

Procedure: Weigh 6g of the given sample in a beaker. Add to it 4 ml distilled water and mix the contents for around 2 minutes, make a dough with the help of glass rod. Immerse the dough ball in a beaker containing water for 2 hours. Place the beaker under tap water, put a sieve (100m) on it. Now the dough is washed gently under running water till a chewing gum type cohesive mass separates out. Bran will settle over the sieve and starch will pass down to the beaker. To ensure complete removal of bran, washed the extracted gluten with excess of water. To check whether whole of starch is washed out or not, add KI to last extract. Absence of any violet colour indicates complete removal of starch.

Wash the gluten with hands under the tap water until free from starch. Squeeze out the adhered water from the extracted gluten and weigh. This will be the weight of wet gluten. Dry at 105⁰c for 6 hours and weigh it again to get the yield of dry gluten. Express in percentage.

Wet gluten (%) = weight of moist gluten/weight of sample taken *100

Dry gluten (%) = weight of dry gluten/weight of sample taken *100

2. **Crude Protein (%):** The protein amount in a food material is mainly determined by measuring the nitrogen content of the material and multiplying that value by a factor. It is known that the nitrogen content of the protein varies depending on its source. For milk products a factor of 6.38 is used, for most cereal grains the factor is 6.25. These factors depend on the percentage of nitrogen in the respective proteins.

By following Micro Kjeldhal method (AOAC, 1980) protein content is analysed by determining nitrogen in the sample. The procedure is as follows

- Take 1gram of wheat flour
- Add catalyst mixture (8gr) of potassium sulphate & copper sulphate admixture in ratio of 10:1%.
- Add 12 ml of sulphuric acid to digest at a temperature 420⁰C by utilizing a catalyst mixture.
- Then dis utilizing 40% NaOH (add 2kg NaOH to 5 L distilled water)
- Use indicator 0.1% of methyl red in to 75 ml of methanol (0.1gr:100ml).
- Use indicator 0.1% bromocresol green in to 100 ml of methanol (0.1gr:100ml)
- Using excess amount of 1% boric acid absorb ammonia.
- Perform titrate 0.1% HCl for estimation of protein content. s
- 0.5gr Ammonium ferrous sulphate is use for standard
- The protein content can be estimated by using the following calculation

$$\text{Protein (\%)} = 6.25 \times \text{Nitrogen content \%}$$

$$\text{Nitrogen content \%} = \frac{\text{Sample titre} - \text{Blank titre} \times \text{Normality of HCl} \times 14 \times 100}{\text{weight of sample flour} \times 100}$$

3. β -carotene

Beta carotene was estimated following approved AACC (14-50, 1995) method as described below.

- Two gram flour was taken in 50 ml glass stoppered Erlenmeyer flask and 10 ml water saturated butanol (WSB) was added.
- WSB is prepared by mixing n-butanol with distilled water in 8:2 ratios. Calibration curve is made from known amounts of pure β -carotene from 0.25 $\mu\text{g/ml}$ to 1.5 $\mu\text{g/ml}$ which are prepared after suitable dilutions of original stock with WSB in calibrated 10 ml volumetric flasks (from 0.5 ml to 3 ml of standard solution in 10 ml).

- The contents of the flasks were mixed vigorously for 1 minute and kept overnight (16-18 hrs) at room temperature under dark for complete extraction of β -carotene.
- Next day, the contents were shaken again and filtered completely through the Whatman no.1 filter paper into a 20 ml volumetric flask.
- The optical density of the clear filtrate was measured at 440 nm.
- Standard solution of β -carotene was prepared in water saturated butanol (WSB) at the concentration of 5 $\mu\text{g/ml}$.
- Absorbance (A) of each filtrate dilution is measured at 440 nm in spectronic-20/spectrophotometer using saturated n-butanol as a blank
- The β -carotene content (mean of two replications) in 54 wheat genotypes.
- Calculated amount of β -carotene from the following equation:

$$\beta\text{-carotene content (ppm)} = 0.0105 + 23.5366 \times A$$

4. Fe Content (ICP-MS Method)

5. Zn Content (ICP-MS Method)

6. Cu Content (ICP-MS Method)

7. Magnesium Content (ICP-MS Method)

ICPMS for analysis of micro elements (Fe, Zn, Cu, Mg): Inductively coupled plasma mass spectrometry (ICP-MS) is a type of mass spectrometry which is capable of detecting metals and several non-metals at concentrations as low as parts per billion on non-interfered low-background isotopes. In this method, trace element analysis was carried out using a destructive sample treatment.

Sample preparation and microwave digestion:

- Materials or tubes utilized in microwave digestion were previously decontaminated using 5% (v/v) HNO_3 bath and thus rinsed with deionized water. An aliquot of 200 mg of sample of wheat were weighed on a semi micro analytical balance and transferred to a Teflon polytetrafluoroethylene (PTFE) digestion vessel. 5 ml of Nitric acid (HNO_3) and 2 ml of Hydrogen peroxide (H_2O_2) is used for each sample for digestion in microwave. Samples decomposition was performed at maximum temperature of 160 $^\circ\text{C}$ for 45 while the cooling was at 55 $^\circ\text{C}$ in 18 minute. The temperature and time for digestion and cooling of the digested sample was setup.

Step	Program	Temperature	Time	Stirrer Speed	FanLevel
		$^\circ\text{C}$	hh:mm:ss		
1	Temperature ramp	160	10:00	Off	1
2	Temperature hold		45:00	Off	1
3	Cooling	55	18:00	Off	3

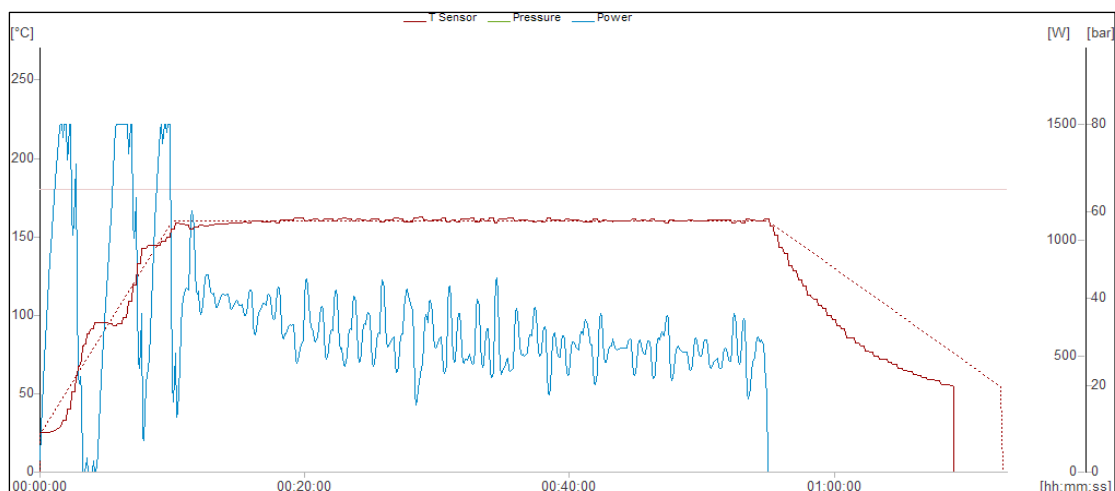


Figure 3.1a: Graph of the samples for microwave digestion

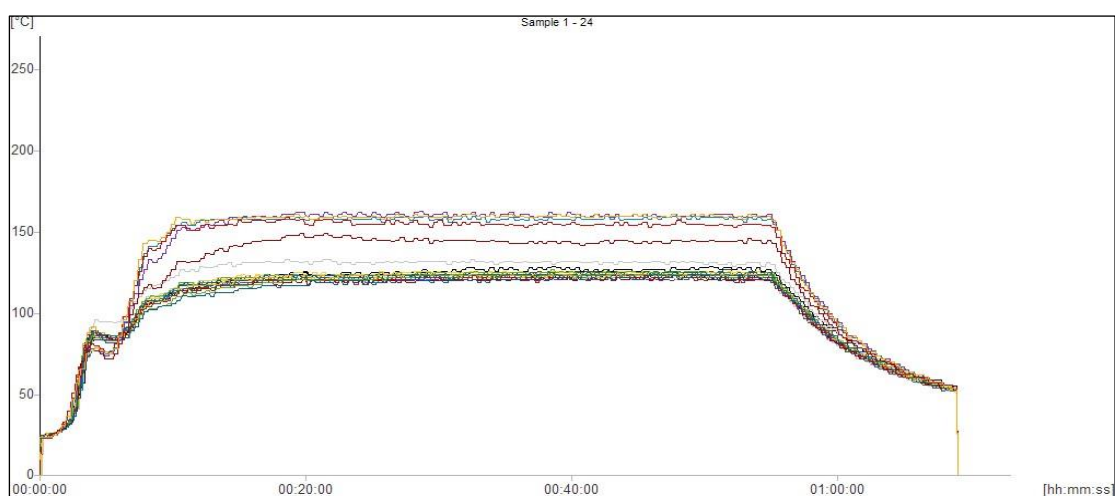


Figure 3.1b: Graph of the samples for microwave digestion

Acid dilution: In this step, 500 μ L of each sample were taken and diluted 24.5 mL of Milli-Q water, Mark Ω were transferred to a 50 mL falcon tube. Next 100 μ L of the solution is transferred to the tube than diluted in to 9.9 ml of Milli-Q water that in total 5000 times were diluted and the resultant solutions were transferred to ICP-MS auto sampler vials for quantification. The measurements were performed with an inductively coupled-plasma mass spectrometer (ICP-MS), equipped with a Peltier cooled spray chamber.

Standard curve

Standards were prepared directly by dissolution of multi-elemental analyses were being performed on a routine basis. Prepared solutions were also commercially available.

Pipetted 1 ml of Analyte from a stock solution of 1000 ppm to a volumetric flask (100 ml). Made the solution up to volume with water. The concentration in this intermediate solution was: 10 ppm for Analyte. Transferred 1 ml of the above solution to a volumetric flask (100 ml) and made up to volume using dilute trace metal grade nitric acid. The resulting concentration of Analyte was 0.1 ppm or 100 ppb. Prepared 5 Standards in accordance with

concentrations that expected in our sample but less than 500 ppb. Each standard sample (10 ml) was prepared in Millipore water and 2% trace metal grade HNO₃.

Analytical curves were prepared by successive dilutions of a 1000 mg L⁻¹ certified standard solutions (Merck, Darmstadt, Germany): 0.1-100 µg L⁻¹ for Fe, Zn, Mg, Cu, and other elements in 0.2% (v/v) nitric acid.

No	Sample	Stock solution	Serial Diluted
1	Blank		
2	5µg	50µL	950µL
3	10µg	100µL	900µL
4	15µg	150µL	850µL
5	20µg	200µL	800µL
5	25µg	250µL	750µL

³⁹K (KED)

$$f(x) = 553.3169 \cdot x + 1048.6333 \quad R^2 = 0.9978$$

BEC = 1.895 ppb LoD = N/A

⁵²Cr (KED)

$$f(x) = 17750.9633 \cdot x + -42309.1364 \quad R^2 = 0.9990$$

BEC = -2.383 ppb LoD = N/A

⁵⁷Fe (KED)

$$f(x) = 419.5768 \cdot x + -473.4354 \quad R^2 = 0.9988$$

BEC = -1.128 ppb LoD = N/A

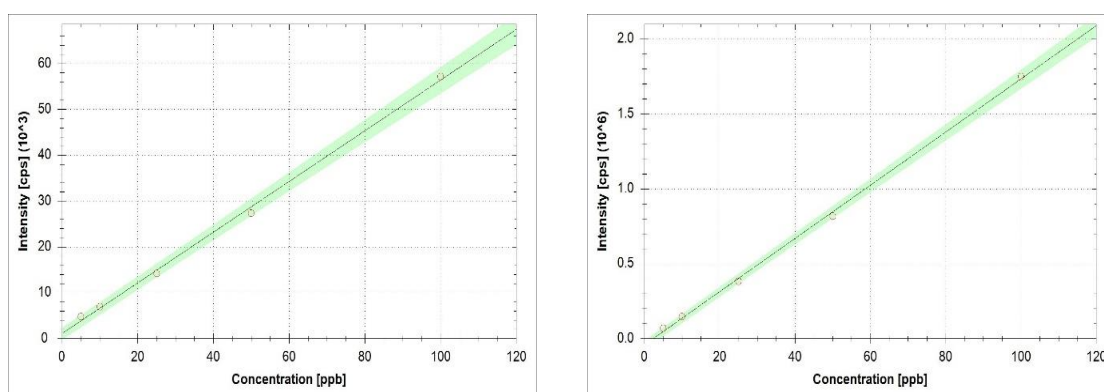


Figure 3.2: Standard curve micro elements Fe, k and Cr.

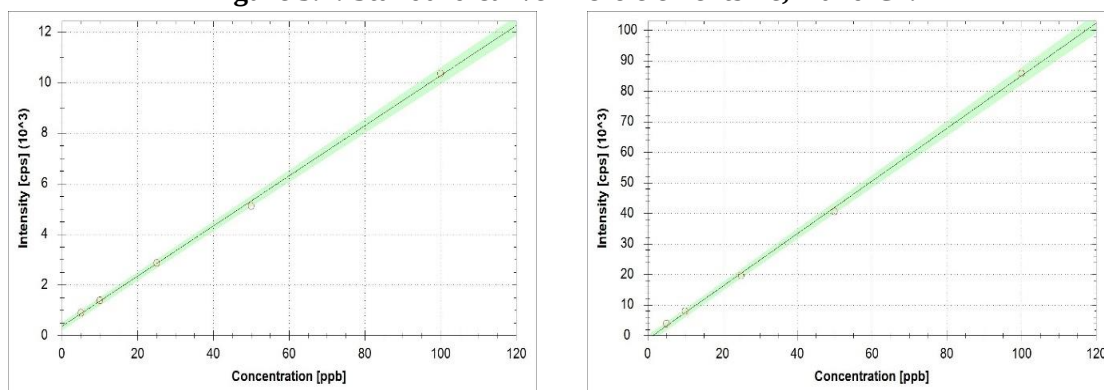


Figure 3.3: Standard curve micro elements B, and Mg.

11B (KED)

$$f(x) = 99.0700 \cdot x + 364.5018 \quad R^2 = 0.9991$$

BEC = 3.679 ppb LoD = N/A

24Mg (KED)

$$f(x) = 862.1658 \cdot x + -1158.2176 \quad R^2 = 0.9991$$

BEC = -1.343 ppb LoD = N/A

59Co (KED)

$$f(x) = 29963.6383 \cdot x + -7990.2915 \quad R^2 = 0.9992$$

BEC = -0.267 ppb LoD = N/A

63Cu (KED)

$$f(x) = 27220.6697 \cdot x + -59856.8441 \quad R^2 = 0.9987$$

BEC = -2.199 ppb LoD = N/A

71Ga (KED)

$$f(x) = 5460.7149 \cdot x + -16743.2857 \quad R^2 = 0.9973$$

BEC = -3.066 ppb LoD = N/A

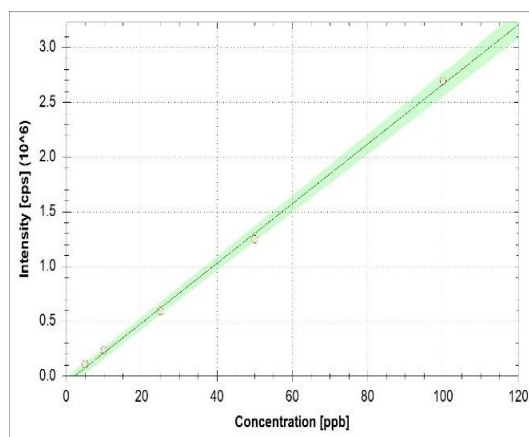
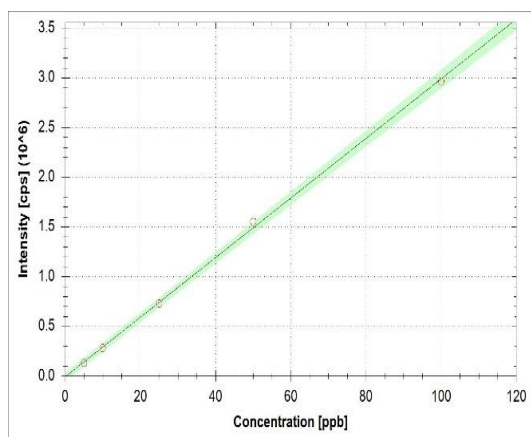


Figure 3.4: Standard curve micro elements B, and Mg and Ga.

60Ni (KED)

$$f(x) = 9417.9088 \cdot x + -21933.2825 \quad R^2 = 0.9985$$

BEC = -2.329 ppb LoD = N/A

66Zn (KED)

$$f(x) = 6297.1963 \cdot x + -13172.0071 \quad R^2 = 0.9975$$

BEC = -2.092 ppb LoD = N/A

88Sr (KED)

$$f(x) = 9312.3396 \cdot x + -34935.9696 \quad R^2 = 0.9967$$

BEC = -3.752 ppb LoD = N/A

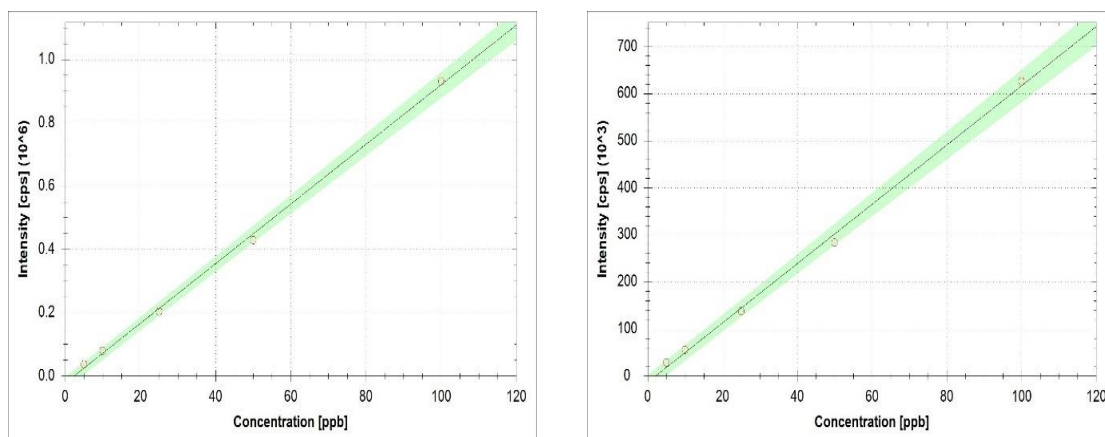


Figure 3.5: Standard curve micro elements Ni, and Zn and Sr.



Figure 3.6: Digestion of the IC-PMS Samples.

8. Sedimentation value

Preparation of solution: SDS/Lactic acid reagent. This reagent was prepared by mixing 20% SDS (w/v), 80% lactic acid (v/v) and distilled water in ratio of 20:1:8.

Procedure

Whole meal (6g) was added to 50 ml water in a 100 ml cylinder, a stop clock set going and the material dispersed by rapid shaking horizontally for 15 sec. The contents of material were again shaken for 15 sec. after 2 min. and 4 min. immediately after the last shake, 50 ml of SDS lactic acid reagent was added and mixed in by inverting the cylinder 4 times. Inversion (four times) was repeated at 6, 8 and 10 min. The contents of the cylinder were allowed to settle for 20 min before the sedimentation volumes were read.

Finally, for 15 seconds contents were mixed once again and allowed to stand for exactly 5 minutes. After 5 minutes of interval, the volume of solid phase of the material in

graduated cylinder was recorded. This is uncorrelated sedimentation value (12% moisture basis factor 0.98) multiply the incorrect sedimentation value by factor 0.98.

9. Hectolitre weight

The instrument used for the hectolitre weight is using for wheat hectolitre test which is available in wheat quality lab.

Procedure: Using directly the cleaned grain sample was filled by utility of funnel into the metallic cylinder of the hectolitre weight instrument keeping its outlet closed. Once the grain is filled well, the outlet was opened to allow the free flow of the grain in metallic cylinder container below till it is completely filled. After the cylinder is filled, the shuttered grain was slide to remove the excess grain and to level it. The grain contained in the in the cylinder for hectolitre was then weighed using an electronic balance. The hectolitre weight was recorded that was expressed as kg/ hectolitre.

10. Grain Hardness (Hardness Index)

Grain hardness is used as a grading factor to determine the type of wheat. It's a key determination for classification of wheat and end product quality. Grain hardness is important for the flour industry because it has significant impacts on milling, baking and qualities of wheat. The hardness is tested by using teeth pressed the seeds to determine as:

- Hardness
- Semi hardness and
- Softness

11. Grain Density (g/cc): Grain density was determined by using liquid displacement method. Grain density was worked out by dividing the weight of the grain by its volume.

$$\text{Grain density (g/cc)} = \frac{\text{Weight of grain (g)}}{\text{Grain volume (cc)}}$$

12. Grain appearance analysis: Grain appearance analysis was recorded on visual basis and on visual basis the data were recorded as a.) White b) Amber and c) Red.

13. Total Soluble Sugar (TSS).

Processing Phenol-sulfuric-acid method is the most reliable method among all the quantitative assays for carbohydrate estimation.

Reagents: 96% sulfuric acid, standard glucose, 2.5 N HCl, sodium carbonate, distilled H₂O, phenol solution.

Procedure for standardized sample: Used 100 mg of glucose into test tube.

Add 10 ml of 2.5 N HCl and boil in water bath for 3 h to hydrolyze the sugars and cool it to room temperature.

Add sufficient quantity of solid sodium carbonate until the effervescence ceases. This indicates complete neutralization. Filter and make the volume up to 100 ml.

Pipette out 0.2, 0.4, 0.6, 0.8, and 1 ml of working standard into a series of test tubes.

The blank was set initially with all reagents without sample. Add 1 ml of phenol solution to each tube and shake well. Then, add 5 ml of sulfuric acid 96% and again shake well. Keep aside for 10 min.

Now measure the color at 490 nm. After that switch on the spectrometer, first take the absorbance (optical density [OD]) of blank and make it zero. Take the OD of all the test tubes and wash the cuvette each time after taking OD.

The values obtained of absorbance were helpful to plot a graph which is very crucial in estimating carbohydrate content. The values should be positive, above zero to plot a graph. After the plotting of a graph, the total amount of carbohydrate in the sample from glucose standard graph was calculated. The standard curve of absorbance was plotted at 490 nm on “Y” axis representing absorbance at 490 nm versus concentration of glucose in µg/ml on X axis.

From the above graph, we get an equation,

$$Y = mx + c$$

Y = Absorbance of drug at 490 nm on Multiskan Skyhigh 1550-800392c

m = Mass

x = Carbohydrate concentration of drug

c = Velocity constant.

$$Y = 0.0054x - 0.0043$$

$$(Y + 0.0043)/0.0054 = x$$

Absorbance corresponds to 0.01 ml of the test = x mg of glucose

One hundred millilitre of the sample solution contains = $x/0.1 \times 100$ mg of glucose = % of total carbohydrate present in it.

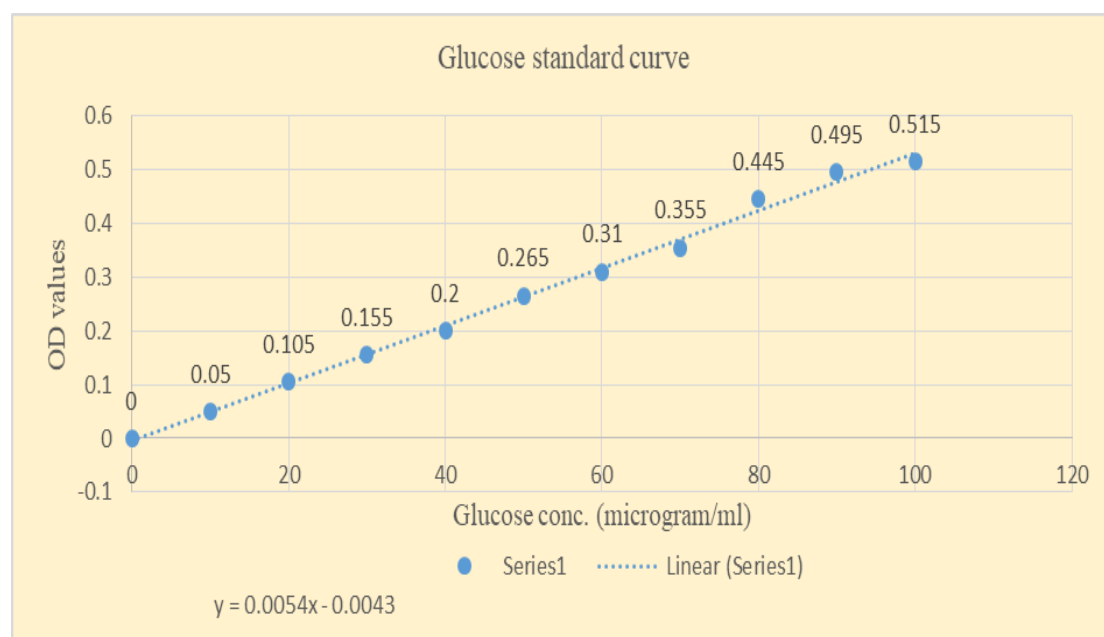


Figure 3.7: Standard curve of total soluble sugar (TSS ppm)

Standard curve of absorbance at 490 nm on “Y” axis representing absorbance Multiskan-SkyHigh 1550-800392C spectrophotometer plate test tube versus concentration of glucose in µg/ml on X axis. From the above graph, we get an equation, $Y = mx - c$. Y = Absorbance of drug at Multiskan-SkyHigh 1550-800392C spectrophotometer plate test tube, m = Mass, x = Carbohydrate concentration of drug, c = Velocity constant

Table 3.2: Standard curve concentration using glucose.

Glucose conc. (microgram/ml)	OD values
0	0
10	0.05
20	0.105
30	0.155
40	0.2
50	0.265
60	0.31
70	0.355
80	0.445
90	0.495
100	0.515

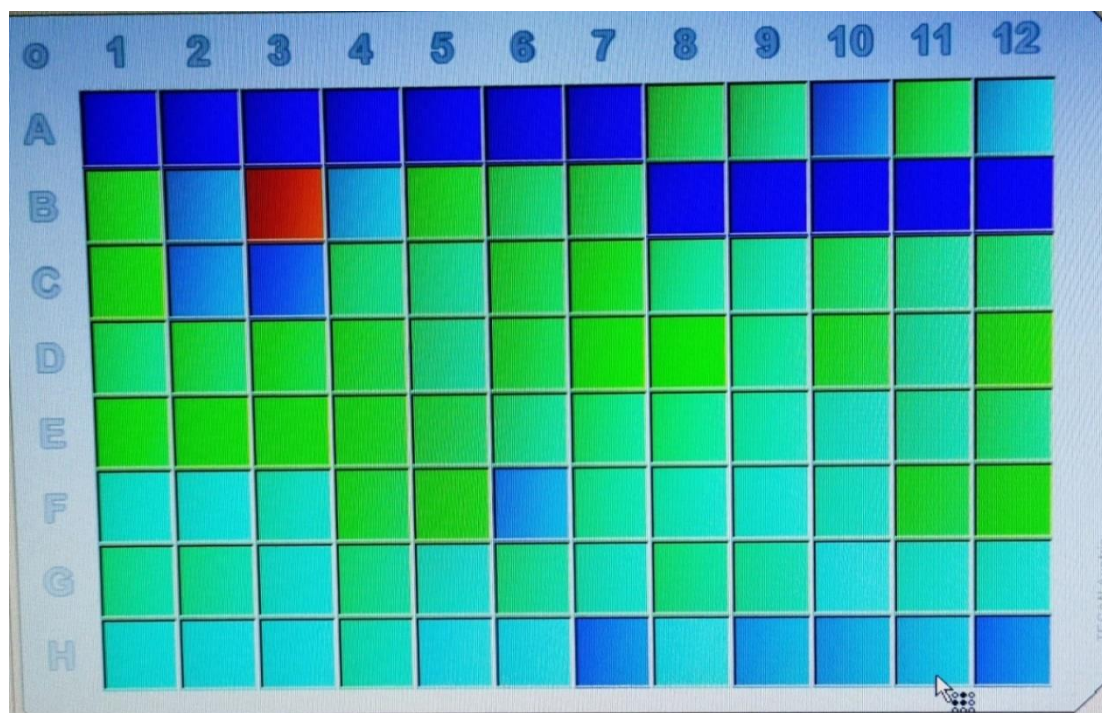


Figure 3.8: Total Soluble Sugar (TSS) Reading using Multiskan absorbance

Statistical analysis: Statistical analysis of recorded phenotypic data was performed using OPSTAT (software available at <https://www.hau.ernet.in>) and INDOSTAT and R package.

The experimental data recorded on these characters will subjected to statistical and biometrical analysis as Coefficient of variation, Phenotypic coefficient of variation (PCV),

Genotypic coefficient of variation (GCV), Estimation of heritability (Burton and Devane, 1952), Genetic advance (Johnson *et al.*, 1955), Correlation coefficient analysis (Al-Jibouri *et al.*, 1958), Path analysis (Dewey and Lu, 1959) and Stability analysis as per model suggested by Eberhart and Russell (1966).

The analysis of variance will be worked out to test the differences among genotypes by F-test. It will carry out according to the procedure of Randomized Complete Block Design for each character as per methodology advocated in the book written by Panse and Sukhatme (1967). ANOVA helps in partitioning the total variance into three component viz., replication, treatment and error.

Table 3.3: The details of analysis of variance (ANOVA)

Source of variation	d.f.	S.S.	M.S.S expected	F-table
Replication (Block)	(r-1)	SSr	$M_1 = MSSr = (Q^2e + rQ^2r)$	V_r/EMS
Treatments(Genotypes)	(g-1)	SSg	$M_1 = MSSg = (Q^2e + rQ^2g)$	V_t/EMS
Error	(r-1)(g-1)	SSe	$M_3 = MSSe = (Q^2e)$	

Analysis of variance was done under the fixed effective model given below:

$$y_{ij} = \mu + g_i + r_j + e_{ij}$$

Where,

μ = Overall mean

y_{ij} = Phenotypic observation in the i^{th} treatment and j^{th} replication

g_i = Effect of i^{th} treatment

r_i = Effect of j^{th} replication

e_{ij} = Random error associated with i^{th} treatment and j^{th} replication

Here, $i = 1, 2, 3 \dots \dots \dots 20$.

$j = 1, 2, 3$

Null hypothesis, H_0 ; $g_1 = g_2 \dots \dots g_{20}$.

The sum of squares was arranged in following manner to test the significance of difference between treatments as given in the following ANOVA.

Genetic variability

Standard error of means (SEM)

Standard error of means was calculated by following formula:

$$SEM = \sqrt{\frac{2EMS}{r}}$$

Critical difference (C.D): Critical difference was calculated by following formula:

$$C. D. = \sqrt{\frac{2EMS}{r}} \times t \text{ value}$$

Where,

r = Number of replications.

EMS = Error mean sum of squares

t value = Table value of error difference at 5% level of significance

Significant 'F' value indicates that, there is significant difference among the genotypes. But to compare any two particular treatments it is against C.D. value.

Mean: Mean value of each character was worked out by dividing the totals by the corresponding number of observations.

$$Mean = \frac{\sum X}{N}$$

Where,

$\sum X$ = Sum of all the observations for each character in each replication

N = Corresponding number of observations

Range: Range is the difference between the lowest and highest mean values for each character were taken in the observation in a sample.

$$R = R_2 - R_1$$

Where:

R_1 = Highest mean

R_2 = Lowest mean

Components of Variance:

It is defined as the average of the square deviation from the mean on it is the square of the standard deviation; it is an effective measure of variability, which permits partition of variance into various components.

Coefficient of variation (CV)

It is the measure of variability evolved. Coefficient of variation is the ratio standard deviation of a sample to its mean and expressed in percentage.

$$CV (\%) = \frac{\text{Standard deviation}}{\text{Mean}} \times 100$$

This was calculated by the formula suggested by **Burton (1952)**.

a. Genotypic variance (σ^2_g)

The genotypic variance (VG or σ^2_g) is the variance due to the genotypes present in the population. The formula used for calculation of genotypic variance was:

$$VG = \frac{V_t - EMS}{r}$$

Where,

V_t = MSS due to treatment

EMS = Error mean sum of squares

b. Phenotypic variance (σ^2_p)

Phenotypic variance (VP or σ^2_p) denotes the total variance present in a population for particular character and is calculated by following formula:

$$\sigma^2_p = \sigma^2_g + \sigma^2_e$$

Where,

σ^2_g = Genotypic variance

σ^2_e = Error variance

Environmental or error variance (σ^2_e): The environmental variance (VE or σ^2_e) is the variance due to environmental deviation.

$$VE = EMS$$

The phenotypic coefficient of variation (PCV) and genotypic coefficient of variation (GCV) and environmental coefficient of variation (ECV) were calculated by formula given by **Burton (1952)**.

$$GCV (\%) = \frac{\text{Genotypic standard deviation}}{\text{Grand mean}} \times 100 = \frac{\sqrt{VG}}{\bar{X}} \times 100$$

$$\begin{aligned} PCV (\%) &= \frac{\text{Phenotypic standard deviation}}{\text{Grand mean}} \times 100 \\ &= \frac{\sqrt{VP}}{\bar{X}} \times 100 \end{aligned}$$

$$\begin{aligned} ECV (\%) &= \frac{\text{Error standard deviation}}{\text{Grand mean}} \times 100 \\ &= \frac{\sqrt{VE}}{\bar{X}} \times 100 \end{aligned}$$

The PCV and GCV were classified as suggested by

Low : Less than 10%

Moderate : 10 to 20%

High : More than 20%

Heritability

Heritability in broad sense is estimated the ratio of genotypic variance to the total phenotypic variance. It is that portion of total variability or phenotypic variability which is heritable and due to the genotype. It was calculated by the formula given by **Burton and Devane (1952)**.

$$h^2 = \frac{VG}{VP} \times 100$$

Where,

VG = Genotypic variance

VP = Phenotypic variance

Genetic advance

Genetic advance is the improvement in mean genotypic value of selected plants over the parental population. The estimates of genetic advance were obtained by the formula given by **Johnson *et al.* (1955)**.

$$GA = h^2 \cdot k \cdot \sigma_p$$

Where,

h^2 = Heritability

K = Selection differential standard units which is 2.06 for 5% selection intensity.

σ_p = Phenotypic standard deviation

Genetic advance as percent of mean (GA % M)

The formula of Genetic advance as percent of mean was as follow:

$$GA\% M = \frac{GA}{\bar{X}} \times 100$$

Correlation coefficient analysis

Correlation coefficient is the mutual association between variables without implying any cause and effect relationship. Simple correlation coefficients were computed at genotypic and phenotypic levels between pair of characters adopting following formulae given by **Al-Jibouri *et al.* (1958)**.

Genotypic correlation between traits x and y:

$$R_{xy}(g) = \frac{\sigma^2 g(xy)}{\sqrt{\sigma g^2 x \times \sigma g^2 y}}$$

Phenotypic correlation between traits x and y:

$$R_{xy}(p) = \frac{\sigma^2 p(xy)}{\sqrt{\sigma p^2 x \times \sigma p^2 y}}$$

Where,

$\sigma^2 g(xy)$ = Genotypic co-variance between the two traits x and y

$\sigma^2 p(xy)$ = Phenotypic co-variance between the two traits x and y

$\sigma^2 g_x$ and $\sigma^2 p_y$ = Phenotypic variance for traits x and y respectively.

Linear Regression Model for the analysis of the GE Interaction

In a pooled analysis, the main point is interested (i) to estimate the mean response of varieties and (ii) to test what is the consistency response from place to place or time to time *i.e.* the interaction of the varietal effects in places or years. The average response of varieties, thus, depend largely upon the absence or presence of Variety X Place or Genotype X Environment (GE) interaction.

Let the average phenotypic value Y_{ij} , of i th genotype ($j=1,2,\dots,t$) at the j th environment ($j=1,2,\dots,s$) be

$$Y_{ij} = \mu + d_i + (1+\beta_i)e_j + \delta_{ij} + \bar{\epsilon}_{ij} \quad (2.1)$$

Where μ is the general mean, d_i is the effect of i th genotype, e_j is the effect of j th environment, $(1+\beta_i)$ is the regression of Y_{ij} on e_j , δ_{ij} is the deviation from regression for the i th genotype in the j th environment and $\bar{\epsilon}_{ij}$ is the deviation from regression genotype-environment interaction effect g_{ij} the following relationship, holds:

$$g_{ij} = \beta_i e_j + \delta_{ij}$$

In model (2.1), the effects d_i , e_j , δ_{ij} are such that

$$\sum_i d_i = \sum_j e_j = \sum_i \delta_{ij} = \sum_j \delta_{ij} = \sum_{i,j} \delta_{ij} = 0$$

Further, the least square estimates of μ , d_i , e_j and β_i are:

$$\hat{\mu} = \bar{Y}_{..} = \left(\sum_{i,j} Y_{ij} \right) / st$$

$$\hat{d}_i = \bar{Y}_{i.} - \bar{Y}_{..}; \hat{e}_j = \bar{Y}_{.j} - \bar{Y}_{..}$$

$$\hat{\beta}_i = 1 + \hat{\beta}_i = \sum_j Y_{ij} \hat{e}_j / \sum_j \hat{e}_j^2 \text{ and } \hat{g}_{ij} = (Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{Y}_{..})$$

$$\text{Where, } \bar{Y}_{i.} = (\sum_j Y_{ij} / s), \bar{Y}_{.j} = (\sum_i Y_{ij} / t)$$

The deviation mean squares for the i^{th} genotype ($s_{d_i}^2$) can be defined as,

$$s_{d_i}^2 = \frac{\sum_j \delta_{ij}^2}{s-2}, \text{ where } \sum_i \delta_{ij}^2 = \sum_{i,j} Y_{ij}^2 - s \bar{Y}_{i.}^2 - b_i^2 \sum_j e_j^2$$

The form of analysis based on the model (2.1) is as presented in Table 3.8. It is possible to determine whether GE interaction is significant when compared to $\bar{S}_e^2$ and also testing whether the GE interaction is a linear function of the additive environmental component. For this purpose the GE interaction with $(s-1)(t-1)$.

Table 3.4: Analysis of Variance for G x E interaction

Source	d.f.	S.S	M.S
Genotypes (G)	(t-1)	$s \sum_i g_i^2$	MS1
Environments (E)	(s-1)	$t \sum_j e_j^2$	
G x E interaction	(t-1)(s-1)		
Heterogeneity between Regression	(t-1)	$\sum_i \beta_i^2 (\sum_j e_j^2)$	MS2
Residual	(t-1)(s-2)	$\sum_{i,j} \delta_{ij}^2$	MS3
Average error	S(t-1)(r-1)		$\bar{S}_e^2$

Degrees of freedom is partitioned into two components:

1. Heterogeneity between regression sum of squares with (t-1) degrees of freedom and
2. The reminder sum of squares with (t-1)(s-2) degrees of freedom.

Source	d.f.	MS
Regression	1	$(1 + \beta_i^2)(\sum_j e_j^2)$
Residual	(s-2)	$\sum_j \delta_{ij}^2 / (s - 2)$
Total	(s-1)	$\sum_j (y_{ij} - y_{i.}/s)^2 / (s - 1)$

Here we are testing the hypothesis that $(1+\beta_i)$ has non zero expectation. The component

$\beta_i^2 \sum_j e_j^2$ for each genotype can also be extracted and compared with the same residual.

Model of Eberhart and Russell (1966).

It is the improvement upon the model of Finley and Wilkinson (1963). According to this model, the regression of the variety mean on the environmental index and a function of the squared deviations from regression can provide estimates of desirable stability parameters. The term stable genotypes has been used for a genotype that express over the average in all environments. Hence the stable variety has high mean (X_i), unit regression ($b_i = 1.0$) and the deviation from regression as small as possible ($s^2 d_j \approx 0$).

Eberhart and Russell (1966) considered the regression coefficient, b_i as his first measure of stability; $b_i = \sum_j (Y_{ij} - \bar{Y}_{i.})(\bar{Y}_{.j} - \bar{Y}_{..}) / \sum_j (\bar{Y}_{.j} - \bar{Y}_{..})^2$

$$= 1 + \left[\sum_j (Y_{ij} - \bar{Y}_{i.} - \bar{Y}_{.j} + \bar{Y}_{..})(\bar{Y}_{.j} - \bar{Y}_{..}) / \sum_j (\bar{Y}_{.j} - \bar{Y}_{..})^2 \right]$$

As a second measure, he considered $s'^2_{d_i} [\sum_j \delta_{ij}^2 / (s - 2)] - \bar{S}_e^2$

Table 3.5: Analysis of stability by Eberhart and Russell (1966) model

Source	d.f.	S.S.	MS
Total	(gn-1)	$\sum i \sum j Y_{ij}^2 - CF$	
Genotype(G)	(g-1)	$1/n \sum i Y_i^2$	MS1
Environment (E)	(n-1)	$1/g \sum j Y_j^2 - CF$	
G x E	(n-1)(g-1)	T.S.S. - (G.S.S. + E.S.S.)	MS2
E + (G x E)	g(n-1)	$\sum i \sum j Y_{ij}^2 - \frac{1}{n} \sum i Y_i^2$	
E (linear)	1	$1/g (\sum j Y_{jl})^2 / \sum j l_j^2$	
G x E (linear)	(g-1)	$\sum i [(\sum j Y_{ij} l_j)^2 / \sum j l_j^2] - E(linear) S.S$	MS3
Pooled deviation	g(n-2)	$\sum i \sum j S_{ij}^2 = \sum i [(\sum j Y_{ij})^2 - \left(\frac{Y_i^2}{n}\right) - (\sum j Y_{ij} l_j)^2 / \sum j l_j^2]$	MS4
Genotype 1	(n-2)	$[\sum j Y_{ij}^2 - Y_i^2/n] - (\sum j Y_{ij} l_j)^2 / \sum j l_j^2 = \sum j \delta_{ij}^2$	
Genotype gi	(n-2)	$[\sum j Y_{gj}^2 - Y_g^2/n] - (\sum j Y_{gi} l_j)^2 / \sum j l_j^2 = \sum j \delta_{gi}^2$	
Pooled error	n(n-1)(g-1)	$\sum j S_{ej}^2 / r$	MS5

Where,

g = number of genotypes

n = number of environments

r = number of replications

S_{ej}^2 = Estimate of error mean square at each environment, and

C.F. = Correction factor = Y^2/gn

The stability parameters for individual genotypes were calculated as follows:

i. Mean (X)

The mean value of the i^{th} genotype over all the environments was simply calculated by taking the mean of that genotype over all the environment i.e.,

$$X_i = \sum j Y_{ij} / n$$

ii. Regression coefficient (bi)

The regression coefficient of genotype mean values over the environmental indices, for the individual genotypes was calculated as:

$$b_i = (\sum j Y_{ij} l_j) / \sum j l_j^2$$

iii. Deviation from regression ($S^2 di$)

The third stability parameters for individual genotype i.e. non-linear components of G x E interaction $S^2 di$ was obtained:

$$S^2 di = (\sum j \delta_{ij}^2) / n - 2 - S_e^2 / r$$

Where,

S_e^2 = The estimated value of pooled error for the variance of variety mean

$$\sum_j \delta_{ij}^2 = \sum_j Y_{ij}^2 - (Y_i)^2/n - (\sum_j Y_{ij} I_j)^2 / \sum_j I_j^2$$

The significance of individual bi was tested by an appropriate “t” test.

$$t = (b-0)/SE \text{ bi and}$$

$$t = (bi-1)/SE \text{ bi for } n-2 \text{ degrees of freedom}$$

The significance of individual $S^2 di$ was tested by an appropriate ‘F’ test.

$$F = [(\sum \delta_{ij}^2)/n-2] / \text{Pooled error for } (n-2) \text{ and } n(r-1)(g-1) \text{ degrees of freedom}$$

Path Analysis

The cause and effect of relationship is well defined in path analysis. It is simply a standard partial regression coefficient which divides the correlation coefficient into the measures of direct and indirect effects. The method suggested by Wright (1921) and elaborated by Dewey and Lu (1959).

Direct effect.

$$r_{(x_1,y)} = P_{1y} + r_{(x_1,x_2)}P_{2y} + r_{(x_1,x_3)}P_{3y} + \dots r_{(x_1,x_{13})}P_{13y}$$

$$r_{(x_1,y)} = \text{Correlation coefficient between } x_1 \text{ and } y$$

$$R_{(x_1,x_{13})}P_{13y} = \text{Indirect effect of } x_1 \text{ on } y \text{ via } x_2$$

$$r_{(x_1,x_{13})}P_{13y} = \text{Indirect effect of } x_1 \text{ on } y \text{ via } x_{13}$$

Similar procedure used for $r(x_2, y)$ to $r(x_{13}, y)$.

Residual effect

$$R = \sqrt{1 - (\sum P_{iy} - r_{iy})}$$

Where,

R = Residual effect

P_{iy} = Direct effect of x_i on y

r_{iy} = Correlation coefficient between x_i and y .

The present investigation of experiment entitled “**Stability analysis of genotypes with concern to yield performance and quality traits in bread wheat (*Triticum aestivum* L.)**” was conducted with 49 genotypes of 39th Elite Spring Wheat Yield Trial (ESWYT) from CIMMYT + 5 checks during *Rabi* season of 2019-20 and 2020-21 at Wheat and Barley section, Department of Genetics and Plant Breeding at CCS Haryana Agricultural University, Hisar and in Afghanistan at Central Research Farm, Agricultural Research Institute of Afghanistan (ARIA) Research Station, 2020-21.

Data obtained to the effects of different created test environments (*viz.*, dates of sowing) on bread wheat genotypes were analyzed statistically to estimate the nature and magnitude of variability parameters and characters associations.

The experimental results are presented under the following sub heads:

- 4.1 Analysis of variance
- 4.2 Mean performance of genotypes for morphological traits.
- 4.3 Mean performance of Wheat genotypes for quality traits
- 4.4 Genetic variability parameters
- 4.5 Correlation coefficient of variation.
 - 4.5.1 Genotypic correlation for morphological traits of pooled environments
 - 4.5.2 Phenotypic correlation for morphological traits
 - 4.5.3 Genotypic correlation for Quality traits of pooled environments.
 - 4.5.4 Phenotypic correlation for quality traits
- 4.6 Path coefficient analysis.
 - 4.6.1 Direct Effect
 - 4.6.2 Indirect Effect
- 4.7 G x E interaction and stability analysis

After evaluating them for test of significance, the results obtained have been compiled and presented with the help of suitable Tables and figures.

4.1 Analysis of variance

The analysis of variance of different characters recorded during experimentation under all the six test environments are presented in Table 4.1. In this study the mean sum of squares due to genotypes were observed highly significant for all the morphological characters namely, days to heading, days to maturity, number of effective tillers per m², plant height(cm), spike length (cm), number of spikelets spike⁻¹, number of grains per spike, grain yield per plot (g), 1000 grain weight (g), biological yield per plot (kg), harvest index and grain yield per plot in all the environments like E₁, E₂, E₃, E₄, E₅ and E₆ the genotypes showed

significant differences for most of the characters indicated that environmental influence on various characters of the material investigated the genotypic differences were well maintained by them. Mean sums of squares due to replications were also observed non-significant for all traits in E₁, E₂, E₃, E₄, E₅ and E₆ on account of sampling error or more number of genotypes interacting with block effects.

For the quality traits also the mean square test was done to identify the significant difference among the genotypes in all the environments. The analysis of variance indicated that the mean sum of squares due to genotypes were highly significant for the all quality traits like gluten content (%), crude protein content (%), β -carotene (ppm), Fe content (ppm), Zn content (ppm), Copper content (ppm), Magnesium content (ppm), sedimentation value (ml), hectolitre weight (kg/ hectolitre), total soluble sugar (ppm), in all the environments study which indicated the difference in the material under study were due to genotypes

Table 4.1: Mean sum of squares for morphological traits in four different environments at Hisar location

Source of Var.	Df	DH	DM	No. ET	PH (cm)	SL(cm)	NSS	NGS	TSW(g)	BY(g)	HI%	GY(g)
ENVIRONMENT- 1												
Replicate	1	4.08	0.01	65.02	11.34	0.96*	2.37	0.93	1.18	122075.56	3.87	61108.90
Treatments	53	16.15**	4.40**	3810.66**	76.39**	2.14**	4.48**	91.35**	38.43**	1091249.16**	22.88**	75398.66*
Error	53	2.22	0.78	807.27	7.53	0.19	1.24	9.00	2.04	361524.36	7.68	17442.52
ENVIRONMENT- 2												
Replicate	1	0.454	0.148	1.815	4.083	0.391	0.01	1.389	1.057	1239489.875*	43.981	1193.343
Treatments	53	3.179*	2.253*	3953.519**	50.852*	0.600*	2.19*	69.652*	34.079*	976386.251*	11.346*	137046.875*
Error	53	0.454	0.544	161.777	13.555	0.146	1.28	6.581	1.514	164572.834	4.689	9917.588
ENVIRONMENT- 3												
Replicate	1	4.083	0.009	65.023	11.343*	0.963	2.370	0.926	1.182	122075.563	3.865	61108.898
Treatments	53	16.146*	4.404*	3810.664*	76.385*	2.139*	4.484*	91.349*	38.434*	1091249.158*	22.884*	75398.655*
Error	53	2.215	0.783	807.273	7.531	0.192	1.238	9.001	2.040	361524.357	7.676	17442.521
ENVIRONMENT- 4												
Replicate	1	0.009	0.454	266.963	240.009*	0.391	0.037	14.815	1.060	4934.259	0.750	156.481
Treatments	53	4.179*	3.329*	3997.873*	42.787*	1.233*	2.966*	75.129*	17.651*	725599.528*	13.909*	62647.956*
Error	53	1.122	0.718	919.865	14.594	0.481	1.207	12.437	2.099	73481.429	2.901	12577.236

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY),

Table 4.2: Mean sum of square for morphological traits in two different environments at Kabul location.

Source of Var.	df	DH	DM	No. ET	PH (cm)	SL(cm)	NSS	NGS	TSW(g)	BY(g)	HI%	GY(g)
ENVIRONMENT-5												
Replicate	1	1.333	2.370*	261.333	0.000	0.113	2.370	3.067	29.768*	71143.109	0.107	12549.645
Treatments	53	4.408**	1.452**	2234.472*	88.729	0.564**	3.695**	59.822**	22.360*	1113475.282*	7.129*	196417.040*
Error	53	2.465	0.578	558.748	5.868	0.194	1.163	12.793	1.802	84395.051	1.502	14887.287
ENVIRONMENT-6												
Replicate	1	0.454	1.565	1274.454	1.947	0.836	2.370	6.502	0.000	28877.371	0.535	5092.320
Treatments	53	3.033**	3.127**	2090.612*	109.511*	1.554*	4.069*	69.619*	17.574*	854532.990*	5.941*	150738.376*
Error	53	0.397	0.621	507.057	6.768	0.859	0.993	4.552	2.889	21072.592	2.387	3717.274

*, ** Differences significant at P= 0.05 and 0.01 level

Table 4.3: Mean sum of squares for quality traits in four different environments at Hisar location

Source of Var.	df	WG%	DG%	CP (%)	β-C (ppm)	Fe(ppm)	Zn(ppm)	Cu (ppm)	Mg(ppm)	SV(ml)	HW (kghectolitre)	TSS	GD (cc)
ENVIRONMENT- 1													
Replicate	1	0.05*	1.367	0.102	0.002	1.817	6.772	4.792	0.179	0.733	2.056	49.668	0.078
Treatments	53	22.965*	3.294*	3.501*	0.772*	42.385*	70.862*	0.876*	35.478*	74.188*	8.758*	429.852*	0.426*
Error	53	4.671	0.451	0.75	0.064	2.64	5.703	0.271	6.265	7.998	3.161	49.488	0.025
ENVIRONMENT- 2													
Replicate	1	10.416	0.268	0.904**	0.023	0.477	3.981	4.481**	0.153**	3.696	0.799	3.392	0.007*
Treatments	53	23.537*	2.632*	3.132*	0.802*	44.582*	68.963*	0.825*	31.221*	74.834*	5.632*	284.534*	2.005*
Error	53	6.842	0.547	0.288	0.052	5.598	4.990	0.255	4.508	4.212	3.060	10.718	0.542
ENVIRONMENT- 3													
Replicate	1	22.965*	3.294*	3.501	0.772	42.385	70.862	0.876*	35.478*	74.188	8.758*	429.852	0.426
Treatments	53	4.671*	0.451*	0.750*	0.064*	2.640*	5.703*	0.271*	6.265*	7.998*	3.161*	49.488*	0.025*
Error	53	0.050	1.367	0.102	0.002	1.817	6.772	4.792	0.179	0.733	2.056	49.668	0.078
ENVIRONMENT- 4													
Replicate	1	2.370*	0.037	0.750	0.009	18.113	0.037	0.593*	32.719*	10.704	37.926	0.333	2.083
Treatments	53	21.148*	2.717*	3.915*	0.932*	24.737*	30.428*	1.815*	120.742*	72.943*	5.697*	1669.528*	1.470*
Error	53	0.691	0.113	0.090	0.141	4.843	9.641	0.064	7.067	2.855	2.567	77.994	0.744

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

Table 4.4: Mean sum of squares for quality traits in two different environments at Kabul location

Source of Var.	df	WG (%)	DG(%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV(ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
ENVIRONMENT-5													
Replicate	1	0.053	0.127	0.021	0.033	0.733	9.807	0.049	35.363	7.259	4.281*	43.067	2.836
Treatments	53	97.731*	9.425*	3.492*	1.607*	13.282*	32.825*	0.388*	103.819*	77.830*	1.747*	723.183*	1.553*
Error	53	2.175	0.605	0.358	0.127	2.892	3.165	0.010	8.875	3.467	2.6509	29.263	0.729
ENVIRONMET-6													
Replicate	1	0.078	0.049	8.557*	0.480*	0.000	0.540	0.454*	31.688	0.148	0.008	291.068	0.068
Treatments	53	97.716*	8.671*	2.385*	0.695*	104.442*	31.341*	35.469*	92.322*	76.800*	11.355*	575.822*	2.080*
Error	53	4.024	0.716	0.282	0.042	0.543	4.195	0.042	7.897	3.978	3.949	173.889	0.125

*, ** Differences significant at P= 0.05 and 0.01 level

4.2 Mean performance of genotypes for morphological traits.

4.2.1 Days to heading

4.2.2 Days to maturity

4.2.3 Number of effective tillers per meter²

4.2.4 Plant height (cm)

4.2.5 Spike length (cm)

4.2.6 No. of spikelet's per spike

4.2.7 No. of grains per spike

4.2.8 Grain Yield per plot (g)

4.2.9 1000 grain weight (g)

4.2.10 Biological yield per plot (g)

4.2.11 Harvest Index

(i) Days to heading

Genotypes showed significant variation for days to heading under six different conditions. Under E₁, days to heading ranged from 94 to 105 days with a general mean of 98.7 days. The genotypes EC 1075897, EC 1075911, EC 1075922 and EC 1075927 were the earliest in days to heading with a mean of 94 days while genotypes EC 1075905 and EC 1075906 were the late to show heading with a mean of 105 days. Under E₂ mean range of days to heading was from 79 for genotype (EC 1075923) to 84.5 for genotype (EC 1075921) days with the mean of 81 days to show heading. Under E₃ days to heading was ranged from 94 (EC 1075903) to 99 (EC 1075905) with overall mean of 96.3 days to show heading. Under E₄ days to heading performance was ranged from 76 days for genotype (EC 1075923) to 83 days for genotype (EC 1075905) to show heading. Under E₅ days to heading was ranged from 66.5 – 78 with the mean of 72.1 days that shows the reduction in heading days duration. The minimum days to heading was noted for genotype EC 1075894 and maximum for genotype EC 1075906. In E₆ days to heading was ranged from 65.5 days for genotype EC 1075894 to 72.5 days for genotype EC 1075905 with the mean of 69.4 days to show heading.

(ii) Days to maturity

Maturity duration was ranged from 146 days (EC 1075892) and (EC 1075895) to 152.5 for genotype EC 1075940 with the mean of 148.5 days to maturity under E₁. While in E₂ days to maturity was ranged from 115.5 for genotype EC 1075902 to 122 days for genotype EC 1075905 & EC 1075921 with the mean of 119.8 days. Under E₃ days to maturity was ranged from 140 days for genotype EC 1075892 to 146 days for genotype EC 1075932 took maturity. The duration mean of days to maturity was noted 142.7 days. The E₁ and E₃ were noted long days in days to maturity as compression of the four other environments. Hence, in E₄ it's ranged from 110 days for genotype EC 1075892 to 119 days for genotype EC 1075905 with the overall mean of 115.4 days. The duration of days to

maturity in E₅ was ranged from 112.5 days for genotype EC 1075903 to 116 days for genotype EC 1075937, and the overall mean of these characters is recorded 114 days. The estimation of days to maturity in E₆ is ranged from 109 days for genotype WH1105 to the maximum 114.5 days for genotype EC 1075898 and EC 1075899 with mean of 111.8 days took maturity. The earliest days to maturity was took in E₅ and E₆ with the maximum duration of days to maturity depicted in E₁ and E₃.

(iii) Effective tiller per meter square

The general mean of effective tiller per meter square was 381.5 with ranging from 295.5 for genotype EC 1075930 to 485 tillers for genotype EC 1075921 under E₁. In E₂ the number of effective tiller square meter was ranged from 259.5 for genotype EC 1075936 to 485 for genotype EC 1075921 and overall means 379.6 respectively. As regards to the range of mean, from 251- 412 for genotype EC 1075930 and EC 1075922 with the mean of 324.3 were counted. The number of effective tiller m⁻², was ranged from 266 – 436.5 for the genotype EC 1075930 and EC 1075921 with the mean of 343 respectively in E₄. The range of mean under E₅ was noted from 293 for genotype EC 1075897 to 419 for genotype EC 1075940 with overall mean of 370.2. While in E₆ it was ranged from 242 – 388.5 for genotype EC 1075893 and EC 1075910 with a mean of 321.1. With compared to the environments, wide variation was indicated and the maximum number of effective tiller per meter square estimated in E₁.

(iv) Plant height (cm)

Plant height was varied from 92.5 cm for genotype EC 1075905 noted as dwarf and 122.5cm for genotype EC 1075927 with an overall mean of 112.6 cm in E₁. In E₂ the range of plant height was took place from 80.5 cm – 106 cm for genotype EC 1075938 and EC 1075894 with overall mean of 94.8 cm. Under E₃, plant height was recorded a mean of 99cm, ranging from the minimum 82.5 cm for genotype EC 1075936 and maximum height of 112.5 cm for genotype EC 1075916. The character varied from 85cm for genotype EC 1075905 to 107.5 cm maximum height for genotype EC 1075910 with overall mean of 96.8 cm under E₄. Under E₅ the plant height with a mean of 98.1 cm was noted. The wide range of variation for height is exhibited from 83 cm for genotype EC 1075905 to 115cm maximum height for genotype EC 1075940. For genotype 84 minimum height under E₆ was 84 cm with maximum height of 115 cm for genotype EC 1075914, and the mean for this character is expressed 96.6cm in E₆. Narrow variation was observed among the genotypes and environments respectively.

(v) Spike length (cm)

The mean of spike length measured from 8.8cm to 14.5 cm with an average length of 10.8 cm. The minimum length of spike length noted for genotype EC 1075905 and the maximum length of spike was recorded for genotype WH1105 under E₁. In E₂ the spike

length ranging from 8.8cm – 11.3 cm with a mean of 9.9 cm that the minimum length was took by genotype EC 1075929 and genotype WH1021 was took the maximum length of spike length in this environment. It shows the reduction of length size as compare to E₁. The estimation of spike length in E₃ was ranged from 8cm – 12cm for genotype EC 1075934 and EC 1075933 respectively with a mean of 9.8cm. As regards to the measurement of spike length size in E₄, it's ranging from 8.25cm – 11.5cm with a mean of 9.5cm. Similarly in E₅ the minimum spike length size was noted 8.25cm for genotype EC 1075934 and the maximum was observed 15cm for genotype EC 1075893 with mean of 9.5cm. Therefore, the same measurement in E₆ showed the minimum range of spike length was noted 6cm for genotype EC 1075911 and maximum was expressed 11.25cm for genotype EC 1075941 and WH1184 with the mean of 9.5cm.

(vi) Number of spikelets per spike

The number of spikelets per spike was ranged from 16 to 23 in genotype EC 1075931 and EC 1075901 with a mean of 20.1 under E₁. Wherein E₂ it was estimated from 17 for genotype EC 1075896, EC 1075912, EC 1075931 to 22 spikelets per spike for genotype WH1021 with corresponding mean of 19 respectively. The spikelets per spike was ranged from 16 to 25 for genotype EC 1075919 and EC 1075920, while genotype EC 1075894 was recorded with maximum 25 spikelets per spike and the mean of 18.4 spikelets per spike. The observation showed all the maximum number of spikelets per spike was noted, out of checks with wide variation among the genotypes. Under E₄ the minimum number of spikelets (15) was observed for genotype EC 1075892 and the maximum number (20) was reported for genotype EC 1075914 with mean of 17.4 respectively. Hence, the range of number of spikelets per spike was noted from 16 for genotype EC 1075934 and the maximum 22 was noted for genotype EC 1075909 under E₅. While in E₆ the corresponding range was noted from 16 – 22 with the mean of 18.2 that maximum number of expressed for genotype WH1021 and the minimum was depicted for genotype EC 1075916, and EC 1075917 respectively with the mean of 18.2 under E₆ with low variation among the environments and within the genotype.

(vii) Number of grains per spike

The overall mean of grains number per spike recorded in E₁ was 58.8 with a wide range of 44.5 -72.5. The highest number of grains in a spike was exhibited through genotype EC 1075928 (72.5) and minimum number of grain was noted by genotype EC 1075923 (44.5). In E₂ the mean was ranged from 45.3 by genotype EC 1075923 to 68.5 by genotype EC 1075928 with the mean performance of 19 respectively. In the same manner the mean of grain per spike was dedicated 53.3 with the range of 40.5 – 71 that shows a wide variation. The maximum number of grain per spike is indicated by genotype EC 1075913 (71) and least number of grain observed by genotype EC 1075907 and EC 1075919 (41) under E₃ respectively. In order to the E₄ the mean was ranged from 40.5 – 66.5 with overall average of

51. While the maximum number was recorded by genotype EC 1075913 (66.5) and the least number of grain was noted for genotype EC 1075919 and EC 1075928 (40.5). In the same way the number of grain was noted from 49.4 -74.75 with an average grain number 58.4, hence the maximum number was appeared for genotype EC 1075926 and least number was indices through genotype EC 1075915. Wherein, in the E₆ the grain number was ranged from 40.5 – 75.4 along with a mean of 52.8. The minimum grain number is allotted to genotype EC 1075918 and EC 1075919 (40.5) and the highest number by genotype EC 1075932 (75.4). As regard to the observation of all environments the no any highest number of grain is registered on checks.

(viii) Thousand-grain weight (g)

The 1000-grain weight ranged from 30.6 – 49.7g with the mean of 41.5g in the in E₁. It shows the genotype EC 1075909 recorded the highest value of 49.7g among over all 54 genotypes which is significantly higher than all the checks selected in the study. Genotype EC 1075920 (30.6g) is noted with the minimum range of 1000 grain weight. In E₁, average performance of genotypes was 39.3 which ranged from 29.9g to 46.7g. In E₂ the highest value record for genotype EC 1075929 (46.7g) and EC 1075909 (46.2g). A wide range of variation is expressed among the genotype that ranged from 33g – 47g with an average value of 40.2. The maximum value of 1000 grain weight was pointed out for genotype EC 1075920 (47g) in E₃. The average estimation of 1000 grain weight under E₄ was ranged from 27.9g-43.15g with a mean of 43.2g. The maximum value of 1000 grain weight was noted for genotype EC 1075908 (43.15g) with less value for genotype EC 1075905 (27.85g). The study of 1000 grain weight under E₅ was ranged from 34.9g for genotype EC 1075939 to 49.2g for genotype EC 1075935 with a mean of 42.6g. It indicted the narrow variation among the genotypes. In E₆ the maximum value was depicted for genotype EC 1075915 (48g) with a minimum magnitude was pointed out for genotype EC 1075912 and WH1184 (36.3g). The average value is noted 41.3g in this trait.

(ix) Biological yield per plot(g)

The overall mean expression for this traits was took place (6629.6g) with range of 4500g -7800g in E₁. The maximum value due to this trait was pointed out for genotype EC 1075928 (7800g) and the lower value was note out for genotype EC 1075899 (4500g). In E₂ the average value of biological yield was trended 5207g with the range of 3700g for genotype EC 1075939 and maximum value of 6400g for genotype EC 1075913, EC 1075920 and EC 1075921. Under E₃, the minimum value of biological yield was noted for genotype EC 1075936 (3650g) and highest value for genotype EC 1075894 (6750g), while the average (5477.8g). In the same manner in E₄ the average value of biological yield was noted (4335.8g). The maximum value was depicted for genotype WH1024 (5785g) and the lower value was registered for genotype EC 1075917 (2750g). The average value of biological yield

in E₅ expressed (6198.1g) while in this traits it was ranged from 4300g- 7300 which genotype EC 1075921 was took the maximum value and the minimum rate was obtained from genotype WH1105 (4300). Through evaluation under E₁ the genotype was rated from 4150g - 7000g with the average yield 5637g. Hence, the maximum value was expressed for genotype EC 1075932 (7000g) and minimum rate was noted for genotype EC 1075918 (4150g).

(x) Harvest Index (%)

From the estimated performance of genotypes in this trait averaged with value obtained 29.3%. It's ranged from 24.7% – 37.1%, while the maximum value was obtained for genotype EC 1075905 (37.1%) and the least was indicated for genotype EC 1075913 (24.7%). Under E₁ the average value is recorded 35% with maximum rate on genotype EC 1075918 (41%) and minimum rate on genotype EC 1075919 (29.6%). In E₂ the trait was ranged from 29.6% - 41% with an average range of 35%. In E₃ the maximum range was noted for genotype EC 1075918 (41%) and the minimum value was noted for genotype EC 1075919 (29.6%). The estimated value in E₄ was ranged from 29% - 39% with an average value of 34.7%. In order, genotype EC 1075933 (39%) was rated the maximum value and minimum value (29%) was noted for genotype EC 1075920 respectively. Similarly, under E₅ the genotype EC 1075926 (40.6%) with maximum value and the minimum rate was noted for genotype EC 1075915 (32.25%) with an average value of 36.7%. Hence, in E₆ the maximum value was noted for genotype EC 1075934 (39.35%) and minimum was noted for genotype EC 1075899 (32%) with an average value (36.6%).

(xi) Grain yield per plot (g)

Grain yield is the ultimately important trait in any crop improvement programme. In E₁, the grain yield, ranged from genotype 1230g to 2367.5g which the minimum value for (EC 1075899) and maximum value for (EC 1075910) and genotype 2360g (EC 1075928) with an average of 1949g. From the study of E₂ observed, the higher value of grain yield per plot obtained from genotype EC 1075913 (2290g) and genotype EC 1075920 (2300g), while the lower yield was observed on genotype EC 1075929 (1210g), with a mean of 1784g. The maximum grain yield under E₃ was estimated for genotype EC 1075914 (2475g) and minimum was obtained from genotype EC 1075938 (1205) with an average yield 1876g. In E₄ grain yield was showed the maximum performance for genotype EC 1075934 (1795g) while the minimum was recorded for genotype EC 1075917 (995) with the average magnitude of grain yield was expressed 1454.7g. In a comparative study between E₁, E₂, E₃ and E₄ the higher grain yield noted for E₃. Though the study of late sown and timely sown revealed timely sown (E₁ & E₃) is the highest with the maximum period of days to heading and days to maturity that increased the grain yield magnitude

Table 4.5: Performance of wheat genotypes for morphological characters in E₁

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
EC 1075892	96.5	146.0	426.5	111.0	10.3	19.0	59.5	44.8	7600.0	27.5	2087.5
EC 1075893	101.0	148.5	446.5	110.5	12.5	22.0	67.5	43.1	7200.0	30.9	2225.0
EC 1075894	98.0	148.5	425.5	122.5	10.8	21.0	60.5	37.0	7000.0	29.4	2055.0
EC 1075895	99.0	146.5	443.5	112.5	11.5	22.0	62.0	42.0	6900.0	28.3	1950.0
EC 1075896	97.5	147.5	462.5	107.5	11.0	19.0	50.5	45.5	7200.0	27.3	1965.5
EC 1075897	94.0	146.5	483.5	105.0	11.3	20.0	58.0	48.0	6300.0	31.6	1989.0
EC 1075898	96.0	147.5	461.0	107.5	10.3	19.0	54.0	47.3	6400.0	33.0	2115.0
EC 1075899	95.5	147.0	340.0	105.0	10.0	21.0	59.5	44.5	4500.0	27.3	1730.0
EC 1075900	98.0	147.5	415.0	117.5	11.0	21.0	67.5	48.9	6600.0	30.5	2010.0
EC 1075901	102.0	150.5	310.0	112.5	10.8	23.0	67.0	42.2	7000.0	29.3	2050.0
EC 1075902	94.5	147.0	345.5	110.0	10.3	18.0	50.0	43.5	7200.0	25.1	1810.0
EC 1075903	95.5	146.5	450.5	112.5	10.5	21.0	56.5	43.5	6900.0	29.3	2022.5
EC 1075904	98.5	147.5	397.5	107.5	11.0	22.0	56.0	47.1	7300.0	27.7	2025.0
EC 1075905	105.0	150.5	387.5	92.5	9.8	21.0	57.5	38.0	5500.0	37.1	2040.0
EC 1075906	105.0	149.5	401.5	122.5	10.8	22.0	67.0	42.3	7300.0	27.8	2030.0
EC 1075907	98.0	147.0	370.5	112.0	11.3	20.0	64.0	46.3	7000.0	28.6	2000.0
EC 1075908	99.0	148.0	417.5	114.0	10.0	22.0	56.5	48.0	7000.0	29.0	2032.5
EC 1075909	98.5	148.0	365.0	112.5	11.5	22.0	62.0	49.7	7400.0	31.9	2362.5
EC 1075910	98.0	147.5	416.0	120.0	10.8	19.0	66.0	37.0	7200.0	32.9	2367.5
EC 1075911	94.0	147.5	360.5	110.0	11.5	19.0	59.0	38.1	6900.0	30.8	2125.0
EC 1075912	97.5	148.0	327.5	113.5	10.0	18.0	53.5	38.9	6600.0	30.5	2012.5
EC 1075913	99.0	149.0	372.5	112.5	10.3	19.0	55.0	42.6	7200.0	24.7	1777.5
EC 1075914	99.0	148.5	367.5	110.0	9.5	21.0	51.5	37.0	6100.0	29.2	1782.5
EC 1075915	99.0	147.5	406.0	115.0	10.0	22.0	57.0	35.0	6600.0	26.7	1765.0
EC 1075916	100.0	150.0	377.5	122.5	11.8	21.0	64.5	36.9	6100.0	27.5	1680.0
EC 1075917	100.5	149.5	306.5	117.5	11.3	21.0	54.0	37.8	6100.0	30.0	1832.5
EC 1075918	100.0	149.5	322.0	112.5	11.0	19.0	69.0	38.6	6500.0	28.3	1837.5
EC 1075919	96.0	149.0	460.5	102.5	9.8	21.0	61.0	37.1	6400.0	30.8	1970.0
EC 1075920	97.0	147.5	407.0	105.0	9.8	17.0	46.0	30.6	7000.0	26.3	1837.5
EC 1075921	102.0	149.0	485.0	105.0	10.0	21.0	57.0	34.6	6000.0	35.6	2135.0
EC 1075922	94.0	148.0	468.0	117.5	10.0	18.0	52.0	38.1	5900.0	30.3	1787.5
EC 1075923	96.5	148.0	415.5	102.5	10.0	20.0	44.5	35.7	6800.0	28.2	1915.0
EC 1075924	101.0	147.5	345.0	119.0	9.8	19.0	57.5	34.8	5800.0	25.6	1482.5
EC 1075925	102.0	149.5	310.0	117.5	10.0	20.0	64.0	35.7	7000.0	25.6	1795.0
EC 1075926	98.0	150.0	345.0	115.0	10.8	19.0	52.0	39.0	6600.0	28.5	1882.5
EC 1075927	94.0	147.0	342.5	122.5	10.5	19.0	54.0	41.7	6700.0	27.1	1812.5
EC 1075928	101.0	150.0	342.5	114.0	11.8	22.0	72.5	38.6	7800.0	30.3	2360.0
EC 1075929	98.0	149.0	316.5	117.5	9.8	19.0	68.0	45.5	6500.0	31.1	2019.0
EC 1075930	99.0	151.5	295.5	115.0	11.0	21.0	69.0	48.9	5800.0	31.6	1832.5
EC 1075931	97.5	149.0	367.5	107.5	8.8	16.0	45.5	40.1	6100.0	31.2	1905.0
EC 1075932	102.5	152.0	347.5	112.5	12.8	21.0	58.0	43.4	7200.0	28.0	2015.0
EC 1075933	103.5	147.5	379.0	120.0	12.8	22.0	61.0	45.5	6400.0	30.7	1965.0
EC 1075934	99.0	148.5	382.0	117.5	11.8	19.0	58.0	43.6	6600.0	29.5	1945.0
EC 1075935	99.5	147.5	298.5	115.0	10.0	20.0	55.0	45.1	6100.0	27.6	1683.0
EC 1075936	98.5	150.5	320.0	107.5	9.5	18.0	48.0	39.6	6600.0	33.7	2222.5
EC 1075937	97.5	148.5	306.0	105.0	10.8	19.0	54.0	40.5	6700.0	29.2	1955.0
EC 1075938	96.5	149.0	352.0	115.0	9.8	20.0	59.0	40.6	6200.0	31.4	1947.5
EC 1075939	104.5	148.5	335.5	122.5	10.5	19.0	58.5	46.1	6800.0	29.1	1977.5
EC 1075940	101.0	152.5	406.0	115.0	11.8	22.0	59.0	38.2	7100.0	27.8	1972.5
EC 1075941	98.0	149.0	346.5	111.0	12.5	21.0	70.0	37.1	6200.0	29.8	1847.5
WH1105	98.0	148.5	350.0	105.0	14.5	21.0	71.5	43.6	6000.0	28.7	1722.5
WH1184	104.5	147.5	367.5	117.5	11.8	21.0	63.5	42.2	6800.0	28.5	1937.5
WH1021	95.0	147.5	378.5	120.0	12.0	20.0	59.0	41.1	6000.0	26.5	1587.5
WH1024	99.0	149.0	423.5	110.0	10.6	19.0	52.5	41.5	7300.0	28.7	2097.5
Mean	98.7	148.5	379.6	112.6	10.8	20.1	58.8	41.3	6629.6	29.3	1949.7
Maximum	105.0	152.5	485.0	122.5	14.5	23.0	72.5	49.7	7800.0	37.1	2367.5
Minimum	94.0	146.0	295.5	92.5	8.8	16.0	44.5	30.6	4500.0	24.7	1482.5
C.D. at 5%	2.9	1.7	56.9	5.5	0.8	2.2	6.0	2.8	1205.9	5.5	264.9
C.V. (%)	1.5	0.6	8.7	2.4	4.0	5.5	5.1	3.4	9.6	8.8	6.8

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index (HI) and Grain yield per plot(GY)

Table 4.6: Performance of wheat genotypes for morphological characters in E₂

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
EC 1075892	81.5	119.5	412.5	90.0	10.0	19.0	56.5	41.2	4900.0	37.9	1830.0
EC 1075893	83.0	120.5	395.5	91.5	9.3	17.0	63.5	38.1	5300.0	34.2	1805.0
EC 1075894	83.5	120.0	377.5	106.0	9.8	21.0	57.0	36.8	5900.0	35.2	2060.0
EC 1075895	81.0	120.0	440.5	97.5	10.0	19.0	58.9	39.0	5700.0	34.3	1955.0
EC 1075896	82.5	119.5	359.5	88.0	9.8	17.0	49.2	42.9	5700.0	33.5	1910.0
EC 1075897	79.5	119.0	412.0	91.0	10.0	19.0	55.0	44.6	5800.0	36.6	2120.0
EC 1075898	80.5	119.0	406.0	94.0	9.8	19.0	51.3	45.4	6200.0	35.7	2195.0
EC 1075899	80.0	120.0	400.5	87.0	10.3	20.0	56.5	42.9	5400.0	34.3	1835.0
EC 1075900	82.0	119.5	409.0	97.5	10.0	19.0	64.1	46.3	5300.0	35.4	1845.0
EC 1075901	81.0	118.0	308.0	88.5	10.8	18.0	63.7	39.1	4500.0	38.8	1745.0
EC 1075902	80.0	115.5	345.5	92.5	9.3	19.0	47.0	38.1	4700.0	39.3	1845.0
EC 1075903	79.5	118.0	410.0	87.0	9.8	17.0	53.7	40.3	5000.0	34.0	1700.0
EC 1075904	80.0	120.0	401.5	89.0	10.0	19.0	53.2	44.6	5500.0	36.1	1965.0
EC 1075905	84.0	122.0	387.5	86.5	9.0	20.0	54.6	36.4	5200.0	33.8	1740.0
EC 1075906	82.0	120.5	380.0	96.0	10.8	20.0	61.0	39.4	5600.0	34.0	1905.0
EC 1075907	81.5	119.5	365.5	96.0	10.0	19.0	62.9	44.4	5400.0	34.6	1867.5
EC 1075908	83.0	120.0	417.5	99.0	10.0	19.0	52.5	44.4	5600.0	37.0	2055.0
EC 1075909	82.0	120.5	443.5	96.5	9.5	18.0	58.9	46.2	5600.0	36.4	2025.0
EC 1075910	81.0	120.0	346.0	103.5	9.8	19.0	62.0	34.5	5300.0	36.1	1910.0
EC 1075911	80.0	120.0	349.0	97.0	10.0	19.0	56.0	35.1	5100.0	37.3	1900.0
EC 1075912	82.0	120.0	327.5	98.0	8.8	17.0	50.8	36.7	5100.0	37.2	1880.0
EC 1075913	79.5	119.0	400.5	97.5	10.3	18.0	52.0	40.2	6400.0	36.1	2290.0
EC 1075914	80.5	120.0	314.5	97.5	10.3	20.0	49.5	34.7	5200.0	33.7	1747.5
EC 1075915	80.0	118.5	321.5	98.0	9.0	19.0	54.2	33.7	5800.0	31.6	1825.0
EC 1075916	83.5	121.0	331.0	97.0	9.3	18.0	60.0	35.2	5300.0	34.0	1780.0
EC 1075917	82.0	119.5	312.5	99.0	10.3	20.0	51.3	34.5	5600.0	30.6	1692.5
EC 1075918	80.5	119.5	322.0	97.0	10.0	19.0	65.6	35.6	5000.0	41.0	1992.5
EC 1075919	81.0	120.5	300.0	93.5	10.3	20.0	58.0	34.4	5200.0	29.6	1517.5
EC 1075920	80.0	119.0	400.0	96.5	10.3	19.0	56.0	29.9	6400.0	36.0	2300.0
EC 1075921	84.5	122.0	338.5	97.0	10.0	21.0	54.2	32.9	6400.0	30.2	1887.5
EC 1075922	79.5	119.5	412.5	95.5	9.5	19.0	49.4	37.1	5100.0	37.1	1892.5
EC 1075923	79.0	120.0	279.0	91.0	10.0	19.0	42.3	34.6	5200.0	34.1	1750.0
EC 1075924	81.0	120.0	335.5	98.5	9.5	19.0	59.0	35.6	4600.0	33.9	1542.5
EC 1075925	82.5	121.0	310.5	98.5	9.3	19.0	59.5	35.2	5200.0	31.4	1612.5
EC 1075926	80.5	119.0	345.0	94.5	10.0	19.0	49.4	39.8	4800.0	33.8	1597.5
EC 1075927	81.5	120.5	339.0	95.5	10.0	20.0	51.3	44.4	4400.0	30.4	1322.5
EC 1075928	81.5	120.5	330.0	90.5	9.8	19.0	68.5	39.4	4000.0	34.0	1357.5
EC 1075929	82.5	119.5	319.0	91.0	8.8	19.0	64.6	46.7	4000.0	34.8	1387.5
EC 1075930	83.0	120.0	277.5	91.5	9.3	19.0	65.6	43.1	4000.0	31.2	1210.0
EC 1075931	81.5	119.5	334.5	86.0	9.8	17.0	43.0	35.8	4000.0	34.3	1370.0
EC 1075932	80.5	120.5	400.0	99.5	9.8	18.0	55.0	41.3	6200.0	33.9	2087.5
EC 1075933	83.0	120.0	379.0	102.0	10.8	20.0	57.5	41.7	5000.0	33.9	1695.0
EC 1075934	82.0	120.5	382.0	101.0	9.8	18.0	55.1	41.3	6100.0	31.6	1910.0
EC 1075935	81.5	120.0	259.5	97.0	8.8	18.0	52.0	44.1	4600.0	35.5	1612.0
EC 1075936	82.5	121.0	342.0	91.5	9.5	20.0	54.0	40.2	4000.0	36.4	1455.0
EC 1075937	81.0	119.5	306.0	90.0	9.3	18.0	51.3	38.1	4100.0	30.7	1242.0
EC 1075938	79.5	119.0	338.0	80.5	9.3	18.0	56.1	41.5	4300.0	31.4	1335.0
EC 1075939	82.0	120.5	335.5	98.5	9.5	19.0	55.6	42.2	3700.0	35.2	1300.0
EC 1075940	81.5	120.0	396.5	103.0	10.3	20.0	55.5	34.6	5200.0	35.9	1855.0
EC 1075941	81.5	119.5	420.5	91.5	10.8	19.0	66.5	33.2	6300.0	32.9	2070.0
WH1105	82.0	119.5	401.5	95.0	10.0	20.0	67.9	41.1	5800.0	33.1	1930.0
WH1184	83.0	119.0	383.0	101.5	10.3	19.0	60.3	43.4	5800.0	33.3	1935.0
WH1021	82.0	121.0	359.0	98.0	11.3	22.0	59.5	40.1	5700.0	33.8	1925.0
WH1024	80.5	120.0	412.0	94.0	10.8	20.0	58.5	41.9	5000.0	36.3	1795.0
Mean	81.4	119.8	361.7	94.8	9.8	19.0	56.4	39.3	5207.0	35.0	1784.0
Maximum	84.5	122.0	443.5	106.0	11.3	22.0	68.5	46.7	6400.0	41.0	2300.0
Minimum	79.0	115.5	259.5	80.5	8.8	17.0	42.3	29.9	3700.0	30.0	1210.0
C.D. at 5%	1.3	1.4	25.5	7.3	0.7	2.2	5.1	2.4	813.6	4.3	199.7
C.V. (%)	0.8	0.6	3.5	3.8	3.8	5.9	4.5	3.1	7.8	6.2	5.5

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

Table 4.7: Performance of wheat genotypes for morphological characters in E₃

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
EC 1075892	95.0	140.0	363.0	104.0	11.0	20.0	48.0	42.0	5750.0	38.0	2185.0
EC 1075893	96.0	143.0	380.0	101.0	9.0	17.0	50.0	44.0	6050.0	37.0	2230.0
EC 1075894	96.0	143.0	362.0	109.0	11.0	25.0	64.0	39.0	6750.0	33.0	2205.0
EC 1075895	95.0	141.0	377.0	103.0	11.0	20.0	60.0	36.0	5450.0	37.0	2040.0
EC 1075896	95.0	142.0	393.0	97.0	10.0	18.0	51.0	37.0	6000.0	34.0	2055.0
EC 1075897	95.0	141.0	411.0	96.0	10.0	17.0	59.0	39.0	6400.0	36.0	2330.0
EC 1075898	95.0	142.0	392.0	91.0	9.0	16.0	51.0	42.0	6200.0	32.0	1995.0
EC 1075899	96.0	141.0	374.0	92.0	10.0	19.0	51.0	38.0	6050.0	34.0	2055.0
EC 1075900	96.0	142.0	353.0	100.0	9.0	18.0	54.0	42.0	5550.0	36.0	1980.0
EC 1075901	97.0	145.0	264.0	93.0	10.0	18.0	52.0	41.0	5950.0	35.0	2070.0
EC 1075902	96.0	141.0	294.0	90.0	9.0	18.0	55.0	43.0	5700.0	29.0	1635.0
EC 1075903	94.0	141.0	383.0	96.0	10.0	19.0	46.0	39.0	5750.0	36.0	2065.0
EC 1075904	100.0	142.0	338.0	99.0	10.0	20.0	47.0	43.0	5700.0	35.0	1995.0
EC 1075905	99.0	145.0	329.0	84.0	10.0	18.0	47.0	42.0	5700.0	31.0	1775.0
EC 1075906	98.0	144.0	341.0	105.0	10.0	19.0	60.0	38.0	5550.0	33.0	1815.0
EC 1075907	99.0	141.0	315.0	100.0	9.0	17.0	50.0	40.0	5250.0	35.0	1810.0
EC 1075908	99.0	142.0	355.0	96.0	9.0	18.0	41.0	29.0	5050.0	32.0	1625.0
EC 1075909	98.0	142.0	310.0	102.0	10.0	19.0	52.0	40.0	5200.0	33.0	1735.0
EC 1075910	96.0	142.0	354.0	102.0	10.0	19.0	54.0	37.0	5550.0	37.0	2050.0
EC 1075911	96.0	142.0	306.0	106.0	10.0	19.0	48.0	38.0	5550.0	32.0	1760.0
EC 1075912	96.0	142.0	278.0	100.0	10.0	17.0	47.0	44.0	5500.0	38.0	2070.0
EC 1075913	95.0	144.0	317.0	108.0	11.0	20.0	71.0	42.0	6050.0	38.0	2270.0
EC 1075914	97.0	143.0	312.0	104.0	10.0	18.0	55.0	41.0	6300.0	39.0	2475.0
EC 1075915	96.0	142.0	345.0	113.0	10.0	19.0	51.0	41.0	6400.0	33.0	2085.0
EC 1075916	100.0	145.0	321.0	103.0	11.0	18.0	61.0	40.0	6050.0	32.0	1960.0
EC 1075917	99.0	144.0	261.0	104.0	10.0	18.0	58.0	41.0	5900.0	34.0	1995.0
EC 1075918	99.0	144.0	274.0	97.0	10.0	18.0	59.0	39.0	5700.0	35.0	2000.0
EC 1075919	95.0	143.0	391.0	105.0	9.0	16.0	41.0	37.0	5200.0	34.0	1745.0
EC 1075920	96.0	142.0	346.0	99.0	9.0	16.0	47.0	47.0	6350.0	34.0	2180.0
EC 1075921	99.0	143.0	412.0	98.0	11.0	18.0	58.0	40.0	5950.0	35.0	2085.0
EC 1075922	95.0	142.0	398.0	101.0	10.0	19.0	47.0	38.0	5250.0	37.0	1930.0
EC 1075923	95.0	142.0	353.0	100.0	11.0	19.0	52.0	42.0	5050.0	30.0	1495.0
EC 1075924	98.0	142.0	293.0	103.0	8.0	16.0	43.0	23.0	5300.0	33.0	1745.0
EC 1075925	100.0	145.0	264.0	98.0	9.0	19.0	56.0	40.0	4850.0	33.0	1580.0
EC 1075926	96.0	144.0	293.0	95.0	10.0	18.0	59.0	41.0	4950.0	34.0	1700.0
EC 1075927	96.0	141.0	291.0	100.0	11.0	20.0	66.0	43.0	5450.0	33.0	1795.0
EC 1075928	96.0	144.0	291.0	103.0	10.0	18.0	61.0	45.0	4700.0	32.0	1500.0
EC 1075929	95.0	143.0	269.0	89.0	10.0	18.0	51.0	43.0	5300.0	38.0	1995.0
EC 1075930	97.0	145.0	251.0	98.0	10.0	19.0	66.0	40.0	4850.0	34.0	1640.0
EC 1075931	95.0	143.0	312.0	103.0	10.0	18.0	50.0	40.0	4300.0	35.0	1490.0
EC 1075932	97.0	146.0	295.0	101.0	10.0	17.0	46.0	42.0	5450.0	35.0	1905.0
EC 1075933	97.0	142.0	322.0	103.0	12.0	22.0	67.0	37.0	5500.0	35.0	1910.0
EC 1075934	96.0	143.0	325.0	90.0	8.0	16.0	55.0	37.0	5400.0	34.0	1820.0
EC 1075935	97.0	142.0	254.0	95.0	9.0	19.0	53.0	40.0	4900.0	38.0	1880.0
EC 1075936	98.0	145.0	272.0	83.0	9.0	17.0	59.0	47.0	3650.0	36.0	1305.0
EC 1075937	97.0	144.0	260.0	92.0	10.0	19.0	57.0	38.0	4600.0	34.0	1545.0
EC 1075938	95.0	143.0	299.0	100.0	9.0	17.0	52.0	44.0	3800.0	32.0	1205.0
EC 1075939	99.0	143.0	285.0	99.0	9.0	17.0	45.0	47.0	4800.0	33.0	1555.0
EC 1075940	96.0	146.0	345.0	105.0	11.0	19.0	47.0	41.0	6400.0	33.0	2105.0
EC 1075941	95.0	145.0	295.0	98.0	11.0	18.0	54.0	44.0	4700.0	33.0	1545.0
WH1105	97.0	143.0	298.0	98.0	10.0	19.0	53.0	40.0	4950.0	38.0	1885.0
WH1184	97.0	142.0	312.0	101.0	11.0	20.0	51.0	36.0	5800.0	33.0	1905.0
WH1021	94.0	142.0	322.0	103.0	11.0	19.0	55.0	41.0	5750.0	29.0	1660.0
WH1024	96.0	144.0	360.0	101.0	11.0	17.0	57.0	44.0	5550.0	35.0	1935.0
Mean	96.3	142.7	324.3	99.0	9.8	18.4	53.3	40.2	5477.8	34.3	1876.0
Maximum	99.5	146.4	412.3	112.5	11.8	25.0	71.0	47.3	6750.0	39.3	2475.0
Minimum	94.0	140.2	251.2	82.5	8.0	16.0	40.5	22.6	3650.0	28.7	1205.0
C.D. at 5%	2.40	1.85	43.06	9.49	0.81	2.19	5.98	7.11	775.27	3.29	201.31
C.V. (%)	1.24	0.64	6.57	4.78	4.11	5.95	5.60	8.81	7.06	4.80	5.35

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

Table 4.8: Performance of wheat genotypes for morphological characters in E₄

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
EC 1075892	80.0	110.0	383.9	86.5	9.0	15.0	43.0	33.1	4100.0	36.0	1480.0
EC 1075893	78.0	115.5	401.9	95.5	8.5	15.5	47.5	34.5	4400.0	35.0	1540.0
EC 1075894	80.5	114.5	383.0	104.0	10.3	17.5	52.5	31.7	4350.0	30.5	1335.0
EC 1075895	78.5	116.0	399.2	100.0	9.8	18.0	50.5	33.2	4300.0	35.0	1510.0
EC 1075896	78.0	115.0	416.3	92.5	8.5	15.0	46.0	37.6	4750.0	35.0	1675.0
EC 1075897	77.5	116.0	435.2	97.5	9.8	17.0	47.0	33.9	4500.0	36.0	1625.0
EC 1075898	80.5	114.0	414.9	93.5	8.8	15.0	41.0	41.0	4150.0	38.0	1590.0
EC 1075899	78.0	113.5	396.0	90.0	9.0	19.0	59.5	35.7	4150.0	39.0	1610.0
EC 1075900	79.0	117.0	373.5	98.5	9.0	17.0	49.0	34.8	4550.0	32.0	1450.0
EC 1075901	79.0	115.0	279.0	96.5	9.5	18.0	54.0	33.0	4300.0	37.0	1605.0
EC 1075902	78.5	113.5	311.0	93.5	9.5	20.0	57.5	34.9	4550.0	32.5	1475.0
EC 1075903	76.5	114.5	405.5	94.0	8.5	16.0	41.0	37.8	4200.0	34.0	1440.0
EC 1075904	79.5	115.5	357.8	94.0	9.5	17.0	56.0	40.9	4250.0	39.5	1665.0
EC 1075905	83.0	119.0	348.8	85.0	8.8	17.0	40.0	27.9	4050.0	31.5	1275.0
EC 1075906	80.0	116.0	361.4	97.5	9.5	16.5	56.0	31.5	4350.0	32.5	1405.0
EC 1075907	80.5	116.0	333.5	100.0	9.3	17.0	50.0	36.1	4100.0	37.5	1520.0
EC 1075908	80.0	116.5	375.8	97.5	10.8	18.5	42.0	43.2	3950.0	36.0	1420.0
EC 1075909	79.0	115.0	328.5	100.0	9.3	18.0	51.5	38.8	4500.0	37.0	1660.0
EC 1075910	80.5	115.5	374.4	107.5	9.5	17.0	53.0	38.3	4900.0	32.0	1575.0
EC 1075911	78.0	116.0	324.5	96.5	9.3	17.0	55.0	37.6	4800.0	32.5	1565.0
EC 1075912	78.5	114.5	294.8	96.0	8.5	16.0	53.0	38.0	4350.0	37.5	1625.0
EC 1075913	78.0	114.5	335.3	99.0	11.5	20.0	66.5	38.3	4800.0	36.5	1745.0
EC 1075914	79.0	115.0	330.8	100.0	10.0	18.0	49.0	33.5	4950.0	31.0	1515.0
EC 1075915	79.0	116.0	365.4	102.5	8.8	17.5	50.0	31.8	4350.0	35.5	1545.0
EC 1075916	79.5	115.0	339.8	99.0	8.8	17.5	51.0	37.0	3650.0	32.0	1165.0
EC 1075917	80.0	116.5	275.9	107.5	9.8	17.0	49.5	34.9	2750.0	36.0	995.0
EC 1075918	78.0	114.5	289.8	97.5	10.5	19.0	62.5	34.9	3900.0	37.0	1445.0
EC 1075919	77.0	114.5	414.5	94.0	8.5	15.0	40.5	39.9	3600.0	36.5	1315.0
EC 1075920	77.5	114.5	366.3	92.5	9.5	16.5	51.0	35.8	4500.0	29.0	1300.0
EC 1075921	81.5	115.5	436.5	96.5	9.8	18.0	54.5	33.7	3550.0	35.5	1275.0
EC 1075922	77.5	115.5	421.2	96.0	9.8	19.0	47.5	37.2	4350.0	35.0	1530.0
EC 1075923	76.0	113.0	374.0	90.0	9.0	18.0	43.0	28.1	3850.0	35.0	1345.0
EC 1075924	78.5	114.5	310.5	91.0	10.0	18.5	44.0	34.1	4300.0	29.5	1285.0
EC 1075925	80.0	115.5	279.0	95.0	8.8	16.0	43.5	36.3	4150.0	35.5	1475.0
EC 1075926	77.5	114.5	310.5	97.0	9.3	16.0	51.5	36.2	4250.0	32.0	1375.0
EC 1075927	77.5	116.0	308.3	95.5	9.8	18.0	50.0	35.9	3700.0	35.0	1305.0
EC 1075928	79.0	116.0	308.3	96.0	9.5	18.0	40.5	37.0	4350.0	37.0	1595.0
EC 1075929	79.0	116.0	284.9	97.0	8.8	17.0	52.0	36.4	4350.0	31.0	1350.0
EC 1075930	81.5	117.0	266.0	99.5	9.8	18.0	60.0	35.7	4400.0	37.0	1625.0
EC 1075931	78.5	115.5	330.8	89.5	10.0	18.0	52.5	35.0	3600.0	34.5	1240.0
EC 1075932	79.5	116.0	312.8	100.0	11.0	18.0	52.5	36.3	3300.0	39.0	1280.0
EC 1075933	80.5	115.5	341.1	105.0	10.8	18.0	58.0	30.9	4800.0	33.5	1620.0
EC 1075934	78.0	116.0	343.8	100.0	9.0	18.0	50.5	38.9	4700.0	38.5	1795.0
EC 1075935	79.0	116.0	268.7	96.5	9.5	18.0	58.0	38.5	4200.0	30.5	1285.0
EC 1075936	78.5	115.0	288.0	91.0	8.3	18.0	45.5	36.0	4150.0	32.5	1350.0
EC 1075937	79.5	115.5	275.4	92.5	9.0	16.0	51.5	37.2	5000.0	35.5	1790.0
EC 1075938	76.5	116.0	316.8	93.5	9.0	16.0	51.5	39.2	3750.0	37.0	1375.0
EC 1075939	82.5	118.0	302.0	94.5	9.5	18.0	52.5	39.0	2950.0	37.0	1090.0
EC 1075940	78.5	115.0	365.4	101.0	9.8	16.0	52.0	36.2	4700.0	37.5	1735.0
EC 1075941	77.5	114.5	311.9	101.0	11.3	18.0	64.0	38.3	5550.0	30.5	1250.0
WH1105	79.0	116.0	315.0	97.5	8.5	17.0	49.5	35.2	5350.0	34.5	1540.0
WH1184	81.0	117.0	330.8	102.5	11.0	19.0	60.0	33.2	5750.0	33.5	1340.0
WH1021	79.0	115.5	340.7	100.0	11.0	19.0	51.5	33.6	5250.0	33.0	1410.0
WH1024	80.0	115.5	381.2	99.5	9.5	17.0	51.0	35.5	5785.0	33.5	1225.0
Mean	79.0	115.4	343.3	96.8	9.5	17.4	51.0	35.8	4335.8	34.7	1454.0
Maximum	83.0	119.0	436.5	107.5	11.5	20.0	66.5	43.2	5785.0	39.5	1795.0
Minimum	76.0	110.0	266.0	85.0	8.3	15.0	40.0	27.9	2750.0	29.0	995.0
C.D. at 5%	2.1	1.7	60.8	7.7	1.4	2.2	7.1	2.9	543.7	3.4	224.9
C.V. (%)	1.3	0.7	9.1	4.0	7.3	6.3	6.9	4.1	6.3	4.9	7.7

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

Table 4.9: Performance of wheat genotypes for morphological characters in E₅

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
EC 1075892	69.5	114.0	321.5	90.0	9.0	20.0	50.7	43.1	5250.0	36.9	1942.2
EC 1075893	73.0	114.0	296.0	93.0	10.5	22.0	50.7	45.1	5850.0	32.1	1880.7
EC 1075894	66.5	114.0	332.5	105.0	9.3	22.0	57.2	41.0	5500.0	33.2	1814.5
EC 1075895	70.0	113.5	381.5	96.0	9.0	20.0	59.2	42.1	6300.0	38.8	2439.0
EC 1075896	71.0	113.5	380.0	90.0	10.0	20.0	62.4	45.1	5050.0	35.9	1809.4
EC 1075897	70.5	114.5	293.0	90.0	9.8	20.0	52.7	46.2	6050.0	35.9	2161.8
EC 1075898	72.0	114.5	365.5	96.0	9.8	20.0	55.3	46.2	6550.0	39.1	2559.1
EC 1075899	73.0	115.5	329.5	96.0	9.5	20.0	56.6	45.1	6300.0	35.4	2231.1
EC 1075900	73.0	114.0	347.5	96.0	9.8	21.0	57.2	45.2	6400.0	35.4	2263.0
EC 1075901	72.5	113.0	376.0	96.0	9.3	22.0	61.1	44.1	6200.0	36.1	2235.0
EC 1075902	72.5	114.5	364.5	98.5	8.8	18.0	56.6	39.0	6250.0	35.7	2232.0
EC 1075903	71.5	112.5	387.5	96.0	10.0	21.0	63.1	41.0	6500.0	39.4	2557.8
EC 1075904	72.5	112.5	409.0	99.0	10.3	22.0	55.9	47.2	7150.0	38.3	2735.0
EC 1075905	72.5	114.5	345.5	83.0	10.0	20.0	60.5	35.9	6900.0	38.3	2632.5
EC 1075906	78.0	113.5	361.0	95.5	9.5	21.0	63.7	39.0	6250.0	37.7	2342.1
EC 1075907	70.0	114.0	361.0	96.0	8.8	20.0	62.4	38.0	6300.0	33.4	2093.1
EC 1075908	71.0	112.5	360.5	96.0	8.8	21.0	53.3	44.1	5600.0	37.4	2075.0
EC 1075909	72.0	114.5	412.5	102.0	10.3	22.0	68.9	46.2	6400.0	37.4	2384.1
EC 1075910	73.5	115.0	383.0	102.0	9.3	19.0	52.7	47.2	6250.0	34.5	2155.0
EC 1075911	73.0	114.0	364.5	102.0	10.0	20.0	57.2	40.0	6200.0	36.0	2223.0
EC 1075912	72.0	114.0	388.5	99.0	10.3	20.0	59.8	38.9	7100.0	38.4	2713.5
EC 1075913	74.0	113.5	408.5	108.0	10.0	19.0	54.0	41.0	7000.0	37.8	2631.6
EC 1075914	72.0	113.5	407.0	114.5	10.0	21.0	57.9	49.2	6100.0	38.0	2325.6
EC 1075915	71.0	114.5	340.0	99.0	8.3	18.0	49.4	44.1	5600.0	32.3	1789.2
EC 1075916	73.5	113.5	367.5	102.0	9.3	21.0	61.8	45.1	5750.0	37.3	2125.0
EC 1075917	72.5	114.5	407.0	106.5	9.0	21.0	52.0	41.0	6150.0	34.8	2130.3
EC 1075918	72.5	113.5	354.0	106.5	8.8	19.0	52.0	45.1	5100.0	36.2	1845.0
EC 1075919	72.5	113.5	409.5	96.0	9.8	21.0	65.0	46.2	6650.0	35.9	2375.6
EC 1075920	72.0	113.0	357.0	85.0	9.3	18.0	59.2	42.1	5950.0	35.5	2105.0
EC 1075921	72.5	114.0	378.5	102.0	10.3	21.0	57.2	44.8	7300.0	33.9	2465.0
EC 1075922	72.5	115.0	370.0	96.0	9.0	20.0	67.6	43.1	6600.0	37.0	2429.4
EC 1075923	72.0	114.5	396.5	96.0	9.5	20.0	55.9	40.0	6600.0	37.3	2445.0
EC 1075924	73.0	113.0	414.5	105.0	10.0	19.0	67.0	43.1	6650.0	35.7	2379.8
EC 1075925	73.0	113.5	356.0	102.0	10.3	19.0	54.0	45.1	6250.0	33.3	2080.0
EC 1075926	73.5	114.5	412.5	106.5	10.0	20.0	74.8	44.1	7050.0	40.6	2860.2
EC 1075927	72.0	113.5	401.0	96.0	9.8	20.0	70.9	43.1	7000.0	37.0	2570.0
EC 1075928	72.5	113.5	337.5	93.0	9.5	20.0	65.0	40.0	6250.0	36.4	2270.0
EC 1075929	73.5	113.0	305.0	93.0	9.0	19.0	56.6	37.5	5400.0	37.3	1990.8
EC 1075930	71.0	113.0	325.5	95.5	9.3	21.0	55.3	39.0	6700.0	36.8	2451.6
EC 1075931	72.5	115.5	392.5	87.0	9.3	17.0	57.2	43.1	6600.0	36.6	2405.0
EC 1075932	71.5	113.5	412.0	102.0	9.5	20.0	54.6	45.1	7300.0	38.6	2806.1
EC 1075933	72.0	115.0	393.0	102.0	9.5	22.0	54.0	40.0	6750.0	37.8	2552.0
EC 1075934	71.0	115.0	386.0	101.0	8.3	16.0	54.6	46.5	6400.0	33.8	2163.6
EC 1075935	71.5	113.5	395.0	102.0	9.8	21.0	54.0	49.2	6000.0	38.8	2339.1
EC 1075936	72.5	115.0	372.0	90.0	10.3	18.0	64.4	41.0	6300.0	36.8	2308.5
EC 1075937	71.5	116.0	385.0	95.5	9.5	19.0	59.2	43.1	6200.0	39.8	2471.4
EC 1075938	71.5	114.0	411.0	93.0	9.8	20.0	55.9	38.7	6900.0	38.0	2603.9
EC 1075939	72.0	113.5	370.5	90.0	9.3	19.0	55.9	34.9	5250.0	37.1	1937.7
EC 1075940	72.5	113.0	419.0	115.0	9.5	22.0	61.8	40.0	6800.0	38.8	2625.3
EC 1075941	71.5	115.0	406.0	106.5	9.8	22.0	65.7	44.1	7200.0	38.7	2790.0
Koshan	72.5	113.0	308.5	106.5	9.0	21.0	53.3	43.1	4300.0	36.3	1570.0
Mazar#00	72.0	114.5	304.0	90.0	8.8	18.0	60.5	40.0	4400.0	36.7	1605.0
Dehdadi	72.0	116.0	385.0	101.0	9.3	20.0	55.9	35.6	4550.0	38.5	1750.0
Ghori#96	74.5	113.5	342.5	99.0	9.8	19.0	54.0	45.1	5300.0	37.2	1973.7
Mean	72.1	114.0	370.2	98.1	9.5	20.0	58.4	42.6	6198.1	36.7	2271.3
Maximum	78.0	116.0	419.0	115.0	10.5	22.0	74.8	49.2	7300.0	40.6	2860.2
Minimum	66.5	112.5	293.0	83.0	8.3	16.0	49.4	34.9	4300.0	32.1	1570.0
C.D. at 5%	3.2	1.5	47.4	4.9	0.9	2.2	7.2	2.7	582.7	2.5	244.7
C.V. (%)	2.2	0.7	6.6	2.5	4.6	5.4	6.1	3.2	5.4	3.3	5.4

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

Table 4.10: Performance of wheat genotypes for morphological characters in E₆

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
EC 1075892	67.5	110.5	271.0	85.8	9.8	16.5	49.4	38.6	4800.0	37.6	1811.2
EC 1075893	69.0	109.5	242.0	90.0	9.0	17.0	50.1	41.5	4400.0	36.0	1539.2
EC 1075894	65.5	112.0	306.5	102.0	9.3	18.0	50.1	42.0	5350.0	33.2	1759.2
EC 1075895	69.5	111.5	313.0	96.0	9.8	21.0	52.0	43.3	5250.0	38.9	2051.2
EC 1075896	68.5	114.0	286.5	90.0	9.3	18.0	49.4	41.6	4300.0	35.3	1512.0
EC 1075897	68.0	112.5	289.0	90.0	9.8	18.0	59.8	43.5	5250.0	38.3	2007.2
EC 1075898	69.5	114.5	308.5	87.0	9.5	17.0	56.6	44.6	5450.0	36.4	1980.0
EC 1075899	71.0	114.5	292.0	96.0	9.3	18.0	54.6	43.9	5200.0	32.0	1668.8
EC 1075900	70.5	112.5	316.5	90.0	9.5	17.0	56.6	44.2	5600.0	35.4	1960.0
EC 1075901	68.0	110.5	297.0	90.0	9.5	18.0	57.9	42.2	5600.0	36.1	2022.4
EC 1075902	71.0	112.5	271.0	90.0	9.3	17.0	51.4	43.9	5500.0	37.2	2055.2
EC 1075903	72.0	111.5	377.0	93.0	9.8	18.0	53.3	39.0	6250.0	37.9	2371.2
EC 1075904	70.5	111.0	294.0	106.0	10.3	19.0	54.6	43.2	6300.0	37.9	2382.4
EC 1075905	72.5	113.0	319.5	87.0	9.8	18.0	55.3	42.0	6350.0	36.8	2324.0
EC 1075906	69.5	113.5	309.5	96.0	9.5	20.0	60.5	36.0	6350.0	35.7	2256.8
EC 1075907	69.5	112.5	315.0	102.0	8.8	17.0	49.4	39.6	5050.0	32.8	1653.6
EC 1075908	70.0	111.5	287.5	90.0	8.5	17.0	48.8	36.8	5300.0	38.1	2022.4
EC 1075909	68.5	110.5	316.5	93.0	9.0	18.0	50.1	44.7	5650.0	34.8	1959.2
EC 1075910	70.0	112.5	388.5	103.5	9.8	18.0	52.0	45.4	5750.0	34.6	1972.0
EC 1075911	70.5	109.5	314.5	100.0	6.0	19.0	52.0	36.3	5500.0	36.1	1991.2
EC 1075912	69.0	112.5	316.5	101.0	9.0	17.0	54.0	37.5	5900.0	36.0	2119.2
EC 1075913	68.5	111.5	372.0	106.5	9.8	19.5	54.6	39.7	5700.0	38.4	2193.6
EC 1075914	69.5	110.5	347.5	115.0	9.8	19.0	52.0	39.1	5300.0	39.0	2059.2
EC 1075915	69.5	112.5	288.5	99.0	8.3	18.0	48.1	48.0	4900.0	34.4	1678.4
EC 1075916	70.5	109.5	315.0	93.0	9.0	16.0	54.6	40.4	4900.0	35.7	1748.8
EC 1075917	69.5	110.5	331.0	99.0	8.8	16.0	43.0	39.5	4600.0	39.0	1810.4
EC 1075918	69.5	110.5	308.0	112.5	8.8	16.0	40.5	40.9	4150.0	37.3	1552.0
EC 1075919	68.5	110.5	360.0	90.0	8.8	16.0	40.5	37.2	4600.0	38.4	1780.0
EC 1075920	68.5	111.0	294.5	84.0	8.5	17.0	41.0	47.5	4900.0	34.9	1712.0
EC 1075921	69.5	113.0	333.5	101.0	9.8	18.0	54.0	40.4	6200.0	37.1	2284.8
EC 1075922	70.5	112.0	318.0	102.0	9.5	19.0	51.4	38.0	6550.0	34.8	2292.0
EC 1075923	69.5	112.5	331.0	90.0	10.8	21.0	52.0	42.6	6350.0	36.9	2334.4
EC 1075924	68.5	111.5	381.5	106.5	9.8	19.0	54.6	41.8	5900.0	38.3	2267.2
EC 1075925	69.5	110.5	344.0	96.0	10.0	19.0	52.7	38.7	5350.0	38.3	2052.8
EC 1075926	71.5	111.0	349.0	112.5	9.5	18.0	53.3	40.1	6200.0	39.0	2412.8
EC 1075927	69.5	111.5	376.5	93.0	9.3	19.0	54.0	42.9	6100.0	38.6	2363.2
EC 1075928	69.5	110.5	317.5	96.0	9.5	18.0	52.7	44.3	6450.0	36.7	2347.2
EC 1075929	69.0	112.0	297.0	93.0	8.3	16.0	42.0	42.9	5300.0	35.0	1848.0
EC 1075930	68.5	110.5	299.0	90.0	9.0	19.0	52.7	39.7	5550.0	36.9	2060.0
EC 1075931	70.5	112.0	310.0	87.5	9.0	18.0	51.4	39.6	6150.0	35.1	2158.4
EC 1075932	68.5	111.0	354.5	99.0	10.8	20.0	75.4	42.2	7000.0	38.6	2697.2
EC 1075933	69.5	112.5	327.5	97.0	10.8	21.0	52.7	37.1	6000.0	38.3	2301.6
EC 1075934	67.5	110.0	342.0	99.0	10.3	20.0	51.4	37.2	5100.0	39.4	2007.2
EC 1075935	67.5	112.0	353.5	100.0	9.8	19.0	54.0	41.6	5600.0	35.6	1992.0
EC 1075936	70.5	113.5	332.0	93.0	9.3	17.0	52.0	45.9	5450.0	36.1	1966.4
EC 1075937	67.5	111.5	309.0	93.0	10.0	19.0	54.0	40.0	5400.0	38.7	2096.8
EC 1075938	68.5	113.5	366.0	95.5	10.8	17.0	52.7	43.2	6400.0	36.4	2327.2
EC 1075939	70.5	112.5	316.5	90.0	9.3	17.0	47.0	46.6	5350.0	36.0	1924.8
EC 1075940	69.5	112.5	376.0	111.0	9.0	18.0	61.8	41.5	6350.0	36.7	2326.4
EC 1075941	70.5	112.5	356.0	107.5	11.3	21.0	67.0	44.7	6900.0	38.4	2633.6
Koshan	69.5	109.5	283.5	102.5	9.8	18.0	55.0	40.3	6450.0	34.3	2220.0
Mazar#00	69.0	112.5	286.0	90.0	11.3	22.0	54.0	36.3	6650.0	36.5	2440.0
Dehdadi	69.5	112.5	315.0	93.0	10.8	18.0	52.7	40.0	6250.0	36.8	2290.0
Ghori#96	70.5	112.5	318.5	101.0	11.3	19.0	60.5	43.5	5250.0	35.1	1848.0
Mean	69.4	111.8	321.1	96.6	9.5	18.2	52.8	41.3	5637.0	36.6	2063.8
Maximum	72.5	114.5	388.5	115.0	11.3	22.0	75.4	48.0	7000.0	39.4	2697.2
Minimum	65.5	109.5	242.0	84.0	6.0	16.0	40.5	36.0	4150.0	32.0	1512.0
C.D. at 5%	1.3	1.6	45.2	5.2	1.9	2.0	4.3	3.4	291.2	3.1	122.3
C.V. (%)	0.9	0.7	7.1	2.7	9.7	5.5	4.0	4.1	3.0	4.2	3.0

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

Accordingly the study showed lower grain yield expressed under E₄. Hence, in E₅ the maximum grain yield was obtained in genotype EC 1075912 (2713.5g), genotype EC 1075914 (2631.6g) and EC 1075926 (2860.2) with the minimum yield expression in genotype Koshan (1570). While the average performance of the yield was 2271g that revealed the higher yield potential in E₅ among all the environments. In E₆ the yield performance was noted out from 1512g to 2697.2 with average yield performance of 2063.8g. The yield maximum yield performance was took for genotypes EC 1075932 (2697g), EC 1075923 (2334.4) and EC 1075927 (2363.2g) with lower yield performance for genotype EC 1075896 (1512g).

4.3 Mean performance of Wheat genotypes for quality traits

- 4.3.1 Wet gluten (%)
- 4.3.2 Dry Gluten (%)
- 4.3.3 Crude protein content (%)
- 4.3.4 β -carotene (ppm)
- 4.3.5 Iron content (ppm)
- 4.3.6 Zinc content (ppm)
- 4.3.7 Copper content (ppm)
- 4.3.8 Magnesium content (ppm)
- 4.3.9 Sedimentation value (ml)
- 4.3.10 Hectolitre weight (kg/hectolitre)
- 4.3.11 Grain density (cc)

(i) Wet gluten (%)

The estimated value of this trait ranged from 13% to 27.8% with an average ratio of 20.7%. The genotype with high value was noted for genotype EC 1075896 (27.8%) and lower value for genotype EC 1075902 (13%). As regard to the E₂ the average value was rated 20.3% with range of 9.3% to 27.8% that the maximum range was observed for genotype EC 1075896 (27.8%) and minimum rate took by genotype EC 1075936 (9.6%). From the estimation of E₃ it's observed that the average ratio of wet gluten was obtained 19.7% and the maximum was took place by genotype WH1024 (29.8%) with least value through genotype EC 1075911 (10.7%). Under E₄ the highest value was noted by genotype WH1024 (30%) to the lower value for genotype EC 1075941 (13%) with an average ratio of 20.1%. that indicated wide range of variation among the genotypes. The study of E₅ was showed a significant variation among the genotype that noted from 17.9% to 43% with an average ratio of 28%. The maximum ration is noted by genotype EC 1075927 (43.3%). And lower value was observed by genotype EC 1075916 (17.9%). Hence, on the base E₆ from the study of wet gluten percentage was revealed the average value 28.7 with the range of 18.7% to 44%, while the maximum range was point out for genotype EC 1075938 (43.8%) and the least value was obtained for genotype EC 1075916 (18.7%).

(ii) Dry Gluten (%)

In the study of E_1 , the average dry gluten was noted 7.8 with the range of 5.8% to 10.8% that highest value noted for genotype EC 1075912 (10.8%) and minimum ratio was obtained by genotype EC 1075922 (5.8%). Under study of E_2 the maximum value was ranged from 5.3% in genotype 45 and maximum value was noted for genotype EC 1075912 (10.8%). Similarly, under E_3 genotype EC 1075912 was ranged maximum (11%) with minimum range recorded in genotype EC 1075941 (4.7%) and the average yield was noted 6.9%. In the same manner under E_4 the genotype EC 1075935 (5%) was noted minimum value with higher value noted in genotype EC 1075912 (11%) and average ratio of 7%. Hence under E_5 the average value indicated 8.9% and maximum value expressed in genotype WH1021 (14.5%) while the minimum ratio was obtained from genotype EC 1075916 (5.5%). Wherein, under E_6 higher rate was obtained from genotype WH1021 (14.95) while the less value was obtained from genotype EC 1075916 (5.9%) and the average value was 9.3%.

(iii) Crude protein content (%)

From the study of crude protein under E_1 indicated the average value was trended 11% and it was ranged from 8.8 to 14%, while the maximum range is noted for genotype EC 1075905 and the less value is took place in genotype EC 1075937 (8.8%). Under the E_2 crude protein was ranged from 8.3% to 14.7% with the mean of 7.5%. While the higher magnitude of crude protein took place in genotype EC 1075907 and EC 1075912 (14.7%) and less value was noted for genotype EC 1075936 (8.3%). Similarly under E_3 the maximum range obtained by genotype EC 1075908 (13.6%) with the least value was noted for genotype EC 1075924 (8.9%) and the average yield of 11.2% among whole individual. The estimation of crude protein under E_4 was rated from 8.5e% to 16% with the average performance of 12.5%. The maximum ratio obtained from genotype EC 1075892 and EC 1075893 (16%) but the lower rate was depend to genotype EC 1075936 (8.55). In E_5 the maximum frequency of crude protein indicated from genotype EC 1075914 (16.4%) to the lower magnitude expressed in genotype EC 1075894 (10.4%) with average yield of 12.8% respectively. Hence, genotype EC 1075893 (15.2) was at the first range and the lower value was noted for genotype EC 1075933 (10.4%) with mean of the 12.7% under E_6 .

(iv) β -carotene (ppm)

The study of beta-carotene under E_1 was ranged from 2.4 ppm to 5.3 ppm with mean of 3.5 ppm. In the same way from the estimation of E_2 results higher range was noted for genotype EC 1075934 (4.9 ppm) with a lower value in genotype EC 1075925 (2.0 ppm) with the mean of 3.2 ppm. On the base of E_3 the greater value of beta-carotene noted for genotype EC 1075908 (4.3 ppm) with a lower yield of 2.00 ppm in genotype EC 1075913 and the mean value performance obtained 3 ppm. From the estimation under E_4 the greater magnitude was obtained from genotype EC 1075905 (4.5 ppm) and EC 1075934 (5.5 ppm) but the lower

expression was noted for genotype EC 1075919 and EC 1075920 (2.5 ppm). In E₅ it's observed that genotype EC 1075911 (5.7 ppm) and genotype EC 1075931 (5.3 ppm) got the higher yield, and the lower yield was noted for genotype EC 1075903 and EC 1075904 (2.00 ppm) while the mean expression was obtained 3.4 ppm out of 54 genotypes. The study out from E₆ was noted higher ratio for genotype EC 1075921 (4.3 ppm), that lower yield of individual EC 1075919 (0.7 ppm) and mean yield noted 2.7 ppm exhibited higher variation among the individual with a significant difference.

(v) Iron content (ppm)

The study of Fe content under E₁ was showed a significant variation observed among the genotype. It was ranged from 16.5 ppm to 45.5 ppm with an average yield expression of 21.9 ppm. The highest ratio of Fe noted for genotype EC 1075908 (45.5 ppm) and lower was obtained from individual EC 1075941 (16.5 ppm). In E₂ the genotype EC 1075909 (46.5 ppm) was ranged in higher concentration and the lower concentration was noted for genotype EC 1075897 (16.4 ppm) with average concentration of 23.2 ppm. In E₃ the lower concentration observes as regards to E₁ and E₂. The highest range of Fe concentration was noted for genotype EC 1075911 (28.8 ppm) and less value for genotype EC 1075894 (10.8 ppm) with the mean of 19 ppm due to E₄. Genotype WH1105 (38 ppm) took place in high range, but the minimum concentration was obtained from genotype EC 1075933 (9 ppm) with average value of 17.4 ppm. Similarly under E₅ genotype EC 1075922 (54.9 ppm) was ranged the highest value and genotype EC 1075924 (11.8 ppm) with an average rate of 20.1 ppm. The concentration of Fe in E₆ was ranged from

(vi) Zinc content (ppm)

From the study of E₁ the highest concentration was obtained from genotype EC 1075902 (37.5 ppm) with less concentration in genotype EC 1075912 (10 ppm) and the average value 21.9 ppm. On the base of the E₂ the higher concentration was obtained from genotype EC 1075902 (38.6 ppm) and genotype EC 1075912 took the minimum ratio of concentration (10.3 ppm) with average concentration ratio of 22.1 ppm. In E₃ the concentration of the Zn ranged from 9.4 to 59.1 with the mean concentration of 16 ppm. The maximum value observed for genotype EC 1075893 (59.1 ppm) and lower concentration was trended for genotype EC 1075929 (10.8 ppm) under E₄ the ratio of concentration averaged (16.5 ppm) with higher concentration in genotype EC 1075922 (35 ppm). Under E₅ the mean value was noted out 19.1 ppm and lower was 7.7 ppm in genotype EC 1075935 while a higher concentration was expressed in genotype 68.9 ppm. The value Zn under E₆ noted out the highest among all environments with a maximum concentration range of 60.9 ppm for genotype EC 1075903 and average range of 28.7 ppm but the less value of 12.5 ppm in genotype EC 1075933.

(vii) Copper content (ppm)

Cu concentration ratio was narrow under E₁ that rated from 2 ppm to 5 ppm with mean concentration 3.5 ppm. The higher value depicted from genotype WH1024 (5 ppm) and lower rate was observed in genotype EC 1075897 (2.2 ppm). Under E₂ the concentration was similar to E₁ at all with the average concentration 2.2 ppm and higher frequency in genotype WH1024 (4.9 ppm) while the minimum concentration was noted for genotype EC 1075931 (3.4 ppm). Under E₃ the also no different significant concentration was observed among the individual. Wherein, the maximum concentration was noted for genotype EC 1075892 and lower value was obtained from genotype EC 1075894 (2.8 ppm) with mean concentration of 3.00 ppm. Same to the other environment Cu concentration was constant in E₅ with a mean range of 2.6 ppm and high rate from genotype EC 1075938 (5.9 ppm) and less concentration in genotype EC 1075936 (2.6 ppm). As regards to the E₆ a wide range of variation appeared that ranged from 2.3 ppm to 14.8 ppm with mean of 5.00 ppm. The high concentrated genotype is EC 1075936 (14.8 ppm) and lower is observed in genotype EC 1075933 (2.3 ppm).

(viii) Magnesium content (ppm)

The estimation of Mg under E₁ was observed as average 30.9 ppm with the higher range for genotype EC 1075903 (52.9 ppm) and lower range from genotype EC 1075904 (21.00 ppm). The study under E₂ notified the average Mg concentration was obtained 30.2 ppm and higher concentration was noted for genotype EC 1075903 (51.3 ppm) while the lower value was expressed EC 1075904 ppm. Similarly in E₃ the maximum ratio of Mg was obtained from genotype EC 1075912 (63.2 ppm) with less quantity in genotype EC 1075899 (23.1 ppm) while the mean of 51.4 ppm. A high variation observed in E₄ that ranged from 11.5 ppm to 66.5 ppm with mean of 29.4 ppm. The high ratio was expressed in genotype EC 1075915 (66.5 ppm) and lower was noted for genotype 11.5 ppm. The investigation under E₅ estimated maximum range was 80.3 ppm for in genotype EC 1075894 with a minimum concentration obtained from genotype EC 1075925 (29.6 ppm). While the average yield was recorded 51.9 ppm. The estimated indicated a wide variation among the genotype from the analysis this trait. Concentration of Mg from one environment to other and among the genotype was showed a high range that estimated from 1.6 ppm to 74.5 ppm with average concentration 43.1 ppm. It conclude that genotype EC 1075934 was noted at first range and genotype EC 1075933 was took place at lower concentrated genotype.

(ix) Sedimentation value (ml)

The investigation test was revealed ratio of sedimentation value among 54 genotypes under E₁ ranged from 32.5 ml to 58.6 ml with mean concentration of 30.9 ml. While the higher concentration was noted for genotype EC 1075928 (58.6 ml) and lower cost for genotype WH1021 (32.5 ml). In E₂ the maximum rate was noted in genotype EC 1075921 (55.1 ml) and low cost of 31.2 ml in genotype WH1021 with a mean range 43.8 ml. The test

of E₃ revealed high concentration of sedimentation value ranged 58.3 ml in genotype EC 1075928 with minimum range for genotype WH1021 (34.00 ml) and mean range of 46.3 ml. It also revealed the significant variation was observed among the genotype that rated from 30.5 to 55 ml with an average concentrated value of EC 1075934 ml. the minimum range of sedimentation value noted for genotype 28.4 with maximum range of 54.4 and average yield 38.4 ml in E₅. Hence, the study indicated higher value was expressed in genotype EC 1075918 (54.5 ml) and EC 1075919 (55 ml) with average value of 38.9 ml and the lower value was recorded in genotype 29.5 ml in E₆.

(x) Hectolitre weight (kg/hectolitre)

Under the study of E₁ hectolitre weight was noted higher for genotype EC 1075936 (77.4 kg/hectolitre) and lower value was noted for genotype EC 1075940 (66.9 kg/hectolitre) with a medium range of 73.9 kg/hectolitre. The investigation from E₂ was showed a narrow variation among the genotype similar to E₁. It indicated the higher value was taken by genotype EC 1075938 (79.1 kg/hectolitre), while the average value was noted 75.6 kg/hectolitre under the study of E₃ the ratio of hectolitre weight is looking similar among the genotype with a high value noted for genotype EC 1075938 (79.7 kg/hectolitre) and lower weight for genotype EC 1075909 (70.7 kg/hectolitre). The result point out from E₄ was indicated genotypes EC 1075938 and EC 1075939 was noted higher weight and the lower weight was expressed in genotype EC 1075933 (71.5 kg/hectolitre) but the average was ranged 75 kg/hectolitre as regards the E₅ higher weight was expressed by genotype koshan (83.6 kg/hectolitre) and lower weight in genotype EC 1075907 (74.6 kg/hectolitre). In E₆ similar to the other environments the similar value is obtained among the genotype with a narrow range of variation. The higher weight was obtained from genotype koshan (85.9 kg/hectolitre) and lower ratio in genotype EC 1075939 (75.1 kg/hectolitre).

(xi) Total Soluble Sugar (TSS)

From the study of genotypes under E₁ resulted higher value of total soluble sugar concentration ranged in genotype EC 1075931 (92 ppm) and the lower concentrated genotype was EC 1075910 (34.5 ppm) with an average value of 64.1 ppm. The study under E₂ showed a significant difference among the genotypes that rated at higher concentration for genotype EC 1075938 (104.6 ppm) while the lower concentration was obtained from genotype EC 1075929 (35.9 ppm) and mean concentration of 61 ppm. The maximum concentrated genotype under E₃ noted for genotype EC 1075904 (188 ppm) and lower value depicted from genotype EC 1075910 (44.6 ppm) while the average concentration was indicated 105.8 ppm. In E₄ same to the above environments higher concentration was noted out for genotype EC 1075938 (172 ppm) and lower concentrated genotype was recorded genotype EC 1075919 (53 ppm) while the mean value was estimated 101 ppm.

Table 4.11 Performance of Wheat genotypes for quality traits in E₁

Characters	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
EC 1075892	15.3	6.3	9.6	3.1	16.8	31.9	2.6	33.9	53.5	75.0	49.9	15.0
EC 1075893	18.0	8.3	11.1	2.9	17.0	31.9	2.4	33.2	53.5	73.7	71.4	14.0
EC 1075894	25.6	7.9	11.0	4.2	17.8	31.4	2.5	37.0	50.5	76.3	68.1	14.5
EC 1075895	22.6	8.0	11.4	3.2	17.2	33.0	2.4	35.6	43.2	74.1	49.2	15.5
EC 1075896	27.8	9.4	10.7	3.1	17.2	34.2	2.6	33.8	43.5	72.3	65.7	14.5
EC 1075897	25.5	9.3	11.1	2.8	17.1	31.0	2.2	38.0	42.5	73.5	82.4	15.5
EC 1075898	24.1	9.4	11.7	2.9	22.4	35.8	2.8	32.2	42.8	74.7	76.3	15.5
EC 1075899	22.7	7.0	11.3	4.5	27.1	36.9	2.7	33.0	44.0	72.0	70.0	15.0
EC 1075900	20.0	8.0	12.3	3.4	17.7	35.7	2.4	34.4	40.0	74.0	65.3	15.5
EC 1075901	18.7	7.4	10.8	3.4	19.2	36.5	2.5	35.3	41.5	73.1	64.4	15.0
EC 1075902	13.0	6.6	10.1	3.4	19.4	37.5	2.4	36.2	53.0	73.5	73.0	15.0
EC 1075903	18.5	7.2	12.0	3.9	20.1	26.7	2.8	52.9	52.5	71.3	67.0	15.5
EC 1075904	24.0	7.5	11.7	3.5	29.4	18.4	3.1	21.0	40.0	75.3	74.5	15.5
EC 1075905	20.5	7.7	12.7	4.3	16.6	18.6	3.2	26.7	41.5	72.3	68.4	14.5
EC 1075906	23.5	10.1	12.7	4.1	21.0	16.9	3.9	34.7	52.5	71.8	66.3	15.0
EC 1075907	21.4	8.0	10.0	2.8	18.6	16.6	3.8	34.5	46.0	73.5	69.1	14.5
EC 1075908	21.6	7.9	14.0	3.7	45.5	16.3	3.5	34.1	44.0	76.7	62.7	14.5
EC 1075909	22.3	7.3	11.3	3.2	20.9	18.2	3.3	38.3	42.5	77.0	49.6	14.5
EC 1075910	18.7	6.6	13.2	3.2	26.0	16.8	4.1	36.6	42.5	76.0	34.5	15.0
EC 1075911	15.0	7.9	9.7	3.2	21.4	18.7	4.1	31.2	41.5	76.3	55.4	15.0
EC 1075912	25.9	10.8	11.3	2.9	27.8	10.0	4.3	29.6	43.0	73.5	66.0	16.0
EC 1075913	20.7	8.8	9.8	4.0	25.0	20.4	3.9	28.8	47.0	75.8	42.9	16.0
EC 1075914	18.1	6.8	11.9	3.4	19.7	19.7	3.8	31.4	56.5	75.4	65.7	15.0
EC 1075915	19.7	7.5	8.8	3.5	17.5	15.5	3.2	27.4	50.5	73.2	65.2	15.0
EC 1075916	15.6	7.3	10.4	3.8	20.3	16.5	3.5	27.9	40.0	72.5	51.0	14.5
EC 1075917	19.0	7.3	9.8	3.8	17.1	20.3	3.3	24.9	42.5	74.5	39.1	15.0
EC 1075918	18.6	7.2	9.8	3.7	19.0	11.0	3.3	26.9	52.5	74.8	47.6	14.5
EC 1075919	21.4	7.7	10.1	2.6	26.7	17.9	3.5	27.9	52.5	76.3	39.3	14.5
EC 1075920	20.2	7.1	12.3	2.7	24.9	11.4	3.8	25.8	52.5	74.1	64.8	14.5
EC 1075921	20.3	7.3	11.2	3.2	19.3	11.8	3.6	24.8	54.5	73.0	37.7	14.5
EC 1075922	20.8	5.8	10.0	3.2	18.0	10.4	3.2	26.4	41.5	74.1	64.9	15.0
EC 1075923	21.5	7.9	11.4	2.7	18.2	22.8	3.6	26.5	37.0	70.3	49.1	15.0
EC 1075924	20.9	7.5	12.1	2.7	19.8	26.0	3.8	23.4	37.5	72.6	67.0	15.5
EC 1075925	21.9	6.9	9.9	2.4	20.6	18.4	3.5	29.5	38.5	70.2	65.8	15.0
EC 1075926	20.1	7.8	10.9	4.0	24.7	19.3	3.8	30.0	43.0	71.8	40.9	14.5
EC 1075927	20.4	7.1	11.0	3.8	22.8	19.2	3.5	28.6	46.0	71.0	70.6	14.5
EC 1075928	21.2	7.7	10.3	3.4	20.8	21.2	3.3	26.9	58.6	73.1	86.8	15.0
EC 1075929	21.9	8.2	10.7	3.6	21.0	21.1	3.6	27.4	41.5	74.4	86.0	15.0
EC 1075930	19.4	7.9	11.7	4.2	19.0	11.9	3.8	27.1	36.0	77.2	84.7	14.5
EC 1075931	18.7	7.6	13.0	4.2	20.4	13.0	3.5	30.5	38.0	73.8	92.0	14.5
EC 1075932	20.3	6.6	12.3	4.4	32.4	15.7	4.4	34.6	37.5	74.8	60.8	14.5
EC 1075933	23.9	8.3	11.1	3.8	22.4	16.8	4.1	32.1	36.1	73.2	87.8	14.5
EC 1075934	20.9	6.9	8.8	5.3	18.7	15.5	3.9	28.6	46.5	70.7	70.9	14.0
EC 1075935	24.3	7.5	8.8	4.1	17.9	21.0	4.5	31.3	42.5	74.6	66.3	15.5
EC 1075936	15.7	8.9	9.4	2.5	18.8	24.2	4.3	35.0	42.0	77.4	59.5	15.0
EC 1075937	22.4	7.6	8.8	5.0	21.0	22.5	4.6	31.6	46.0	74.4	67.9	14.6
EC 1075938	22.9	8.5	9.3	3.4	24.1	29.1	4.0	27.8	43.0	73.8	67.7	15.0
EC 1075939	21.9	8.3	10.3	3.4	20.0	19.6	3.9	29.1	39.0	76.8	66.5	14.5
EC 1075940	21.3	7.9	8.8	3.0	20.4	15.9	3.7	33.9	50.0	66.9	64.2	15.0
EC 1075941	24.2	8.1	9.9	3.0	16.5	15.2	3.5	24.9	40.0	76.2	66.5	15.0
WH1105	15.5	7.6	11.2	3.0	19.3	22.9	3.4	24.6	46.0	76.5	73.6	14.5
WH1184	18.9	6.6	12.8	3.5	26.4	23.6	3.6	32.6	44.5	76.5	65.6	14.0
WH1021	21.4	8.3	12.7	4.5	32.1	17.6	4.8	31.3	32.5	72.4	66.8	14.5
WH1024	21.1	7.9	13.7	3.3	41.4	17.5	5.0	29.6	33.0	75.3	65.2	14.5
Mean	20.7	7.8	11.0	3.5	21.9	21.4	3.5	30.9	44.4	73.9	64.1	14.9
Maximum	27.8	10.8	14.0	5.3	45.5	37.5	5.0	52.9	58.6	77.4	92.0	16.0
Minimum	13.0	5.8	8.8	2.4	16.5	10.0	2.2	21.0	32.5	66.9	34.5	14.0
C.D. at 5%	4.3	1.4	1.7	0.5	3.3	4.8	1.0	5.0	5.7	3.6	14.1	0.3
C.V. (%)	8.2	7.6	7.9	7.2	7.5	10.9	14.9	8.1	6.4	2.4	10.9	3.3

Wet gluten (WG %), Dry gluten (DG %), Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

Table 4.12: Performance of Wheat genotypes for quality traits in E₂

Characters	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
EC 1075892	15.3	6.3	12.2	3.1	17.2	32.9	2.5	32.9	51.6	76.1	42.2	12.7
EC 1075893	22.0	8.3	14.5	2.7	17.5	32.8	2.4	32.2	51.0	74.8	71.7	11.6
EC 1075894	25.6	7.9	13.8	3.8	18.4	32.4	2.4	35.9	49.2	75.2	63.4	13.4
EC 1075895	19.6	8.5	13.8	2.8	17.8	34.0	2.3	34.5	44.9	74.1	47.1	13.2
EC 1075896	27.8	9.4	13.1	3.1	17.7	35.2	2.5	32.8	43.8	74.6	63.7	11.8
EC 1075897	25.5	9.3	13.0	3.9	16.4	31.9	2.2	44.0	44.0	73.7	70.0	13.8
EC 1075898	24.1	9.3	12.8	2.8	23.1	36.9	2.7	31.3	44.0	77.0	70.3	11.1
EC 1075899	22.7	7.0	11.2	3.8	27.9	38.0	2.6	32.0	45.7	73.8	59.4	13.0
EC 1075900	20.0	7.9	12.0	2.8	18.2	36.8	2.3	33.4	41.8	75.7	54.6	12.8
EC 1075901	18.6	7.4	13.2	3.1	19.8	37.6	2.5	34.3	40.9	75.3	68.5	12.0
EC 1075902	13.0	5.5	12.0	3.0	20.0	38.6	2.3	35.1	50.4	74.4	73.0	10.8
EC 1075903	18.9	7.2	12.2	3.2	20.8	27.5	2.7	51.3	52.9	73.0	79.1	12.6
EC 1075904	24.0	8.9	11.5	3.1	30.3	18.9	3.0	20.4	39.8	78.1	68.8	13.7
EC 1075905	16.5	7.2	12.2	4.0	17.1	19.2	3.1	25.9	38.8	75.2	66.2	13.2
EC 1075906	23.5	10.1	14.3	3.6	21.6	17.4	3.8	33.7	52.7	73.5	59.0	13.3
EC 1075907	21.4	7.9	14.7	3.0	19.1	17.1	3.7	33.5	42.8	78.3	58.6	10.4
EC 1075908	21.6	7.8	11.7	3.2	46.5	16.8	3.4	33.1	43.0	73.7	72.5	12.1
EC 1075909	22.8	5.8	14.4	2.5	21.6	18.8	3.2	37.1	43.2	74.4	47.4	12.5
EC 1075910	20.2	6.6	13.7	2.9	26.8	17.3	4.0	35.5	45.2	77.6	40.1	12.6
EC 1075911	16.5	5.4	13.1	3.5	22.1	19.3	4.0	30.3	38.8	77.2	49.6	12.4
EC 1075912	24.4	10.8	14.7	3.1	28.6	10.3	4.1	28.7	41.7	76.1	58.7	12.2
EC 1075913	16.7	8.2	14.1	3.4	25.7	21.0	3.8	27.9	48.2	75.0	44.5	12.3
EC 1075914	18.6	7.3	13.6	3.1	21.2	20.3	3.7	30.5	55.5	75.3	52.9	13.8
EC 1075915	15.7	7.5	13.8	4.5	18.9	16.0	3.1	26.6	50.4	73.1	61.9	12.0
EC 1075916	15.6	5.3	11.8	3.1	22.0	17.0	3.4	27.0	38.4	75.9	43.1	11.7
EC 1075917	19.0	6.7	9.6	3.2	18.5	21.0	3.2	24.1	39.0	77.7	60.7	12.6
EC 1075918	18.5	7.2	11.2	3.2	20.5	11.3	3.2	26.0	52.5	77.6	40.2	13.5
EC 1075919	21.4	7.2	11.8	2.3	28.8	18.5	3.4	27.1	52.4	75.8	35.9	12.3
EC 1075920	20.2	7.0	11.6	2.2	26.8	11.8	3.7	25.0	51.1	74.5	57.7	12.4
EC 1075921	20.3	7.3	12.2	2.7	20.8	12.2	3.5	24.1	55.1	73.2	61.4	11.6
EC 1075922	20.8	6.3	11.1	2.8	19.4	10.7	3.1	25.6	41.0	75.7	60.5	11.9
EC 1075923	22.5	7.9	12.6	2.3	19.7	23.5	3.5	25.7	33.8	73.2	44.3	11.5
EC 1075924	20.9	7.5	11.9	2.2	21.4	26.8	3.7	22.7	36.7	75.1	65.1	15.3
EC 1075925	14.9	6.9	12.1	2.0	22.3	18.9	3.4	28.6	36.6	73.6	66.9	13.4
EC 1075926	20.0	7.2	12.0	3.5	26.6	19.9	3.7	29.1	44.0	75.0	42.7	13.8
EC 1075927	20.3	7.1	11.9	3.3	24.7	19.8	3.4	27.7	45.3	76.8	62.7	14.6
EC 1075928	21.2	7.7	12.5	3.0	22.5	21.9	3.2	26.1	54.4	75.5	68.3	12.4
EC 1075929	17.4	8.2	11.9	3.1	22.7	21.7	3.4	26.5	40.6	77.8	70.3	11.2
EC 1075930	19.4	7.4	13.1	3.8	20.5	12.3	3.6	26.3	34.7	76.4	69.6	13.8
EC 1075931	17.6	7.6	13.1	3.8	22.0	13.4	3.4	29.6	37.7	77.1	69.0	13.7
EC 1075932	20.3	6.6	12.2	4.0	35.0	16.2	4.3	33.5	37.2	74.0	69.3	13.9
EC 1075933	23.9	8.3	13.0	4.2	24.2	17.3	4.0	31.1	36.0	72.3	69.4	12.8
EC 1075934	20.4	6.9	12.9	4.9	20.2	16.0	3.8	27.8	46.9	74.3	69.0	13.0
EC 1075935	24.2	7.5	11.7	3.6	19.3	21.7	4.3	30.4	43.6	77.2	67.3	13.5
EC 1075936	9.6	5.4	8.3	2.2	20.3	24.9	4.2	33.9	39.9	76.5	50.4	11.9
EC 1075937	22.4	7.5	10.8	4.6	22.7	23.1	4.5	30.6	46.3	75.4	57.6	12.1
EC 1075938	22.9	8.4	14.5	3.3	26.0	29.9	3.8	27.0	43.8	79.1	104.6	12.5
EC 1075939	22.9	8.3	12.1	2.9	21.5	20.2	3.8	28.2	35.6	78.7	70.3	11.8
EC 1075940	21.3	7.9	11.9	2.6	22.0	16.3	3.6	32.9	48.9	76.5	68.3	11.4
EC 1075941	25.2	8.1	12.6	2.5	17.8	15.7	3.4	24.1	39.2	76.0	56.4	12.8
WH1105	15.5	7.6	13.0	2.6	20.9	23.5	3.3	23.8	45.3	78.1	64.7	12.2
WH1184	18.8	6.6	13.1	3.1	28.5	24.4	3.5	31.6	41.9	78.2	61.1	12.9
WH1021	22.8	8.2	14.1	4.0	34.7	18.2	4.7	30.4	31.2	76.9	64.9	10.9
WH1024	21.1	7.9	13.7	2.9	44.7	18.0	4.9	28.7	34.3	75.8	60.8	14.2
Mean	20.3	7.5	12.6	3.2	23.2	22.1	3.4	30.2	43.8	75.6	61.0	12.6
Maximum	27.8	10.8	14.7	4.9	46.5	38.6	4.9	51.3	55.5	79.1	104.6	15.3
Minimum	9.6	5.3	8.3	2.0	16.4	10.3	2.2	20.4	31.2	72.3	35.9	10.4
C.D. at 5%	5.3	1.5	1.1	0.5	4.8	4.5	1.0	4.3	4.1	3.5	6.6	1.5
C.V. (%)	7.4	7.7	4.3	7.2	9.9	9.9	14.9	7.1	4.7	2.3	5.4	5.8

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

Table 4.13: Performance of Wheat genotypes for quality traits in E₃

Characters	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
EC 1075892	20.0	6.4	12.0	4.0	21.0	47.0	4.3	47.0	54.0	75.0	60.0	20.0
EC 1075893	17.0	6.4	11.0	4.0	28.0	59.0	3.6	47.0	53.0	75.0	127.0	17.0
EC 1075894	26.0	8.0	12.0	3.0	11.0	26.0	2.8	24.0	50.0	75.0	123.0	26.0
EC 1075895	15.0	6.1	12.0	4.0	13.0	42.0	2.9	29.0	48.0	74.0	66.0	15.0
EC 1075896	24.0	8.1	12.0	4.0	13.0	30.0	2.9	25.0	46.0	74.0	119.0	24.0
EC 1075897	26.0	8.5	11.0	3.0	16.0	36.0	3.2	28.0	47.0	72.0	113.0	26.0
EC 1075898	25.0	9.0	11.0	3.0	15.0	28.0	3.0	29.0	47.0	76.0	106.0	25.0
EC 1075899	23.0	7.2	12.0	3.0	13.0	26.0	2.9	23.0	48.0	74.0	98.0	23.0
EC 1075900	20.0	8.1	11.0	3.0	13.0	25.0	2.9	25.0	43.0	75.0	76.0	20.0
EC 1075901	19.0	7.6	12.0	3.0	16.0	25.0	3.0	31.0	44.0	74.0	141.0	19.0
EC 1075902	16.0	5.6	11.0	3.0	22.0	14.0	3.0	61.0	54.0	73.0	147.0	16.0
EC 1075903	24.0	8.3	11.0	3.0	24.0	12.0	3.0	61.0	53.0	72.0	154.0	24.0
EC 1075904	23.0	7.2	13.0	3.0	22.0	13.0	3.0	60.0	43.0	78.0	189.0	23.0
EC 1075905	17.0	6.8	12.0	4.0	22.0	12.0	3.0	63.0	42.0	78.0	145.0	17.0
EC 1075906	27.0	9.3	13.0	3.0	24.0	12.0	3.1	61.0	55.0	75.0	88.0	27.0
EC 1075907	18.0	7.6	11.0	3.0	20.0	12.0	3.0	62.0	48.0	78.0	92.0	18.0
EC 1075908	21.0	8.5	14.0	4.0	22.0	12.0	3.1	63.0	46.0	74.0	133.0	21.0
EC 1075909	15.0	5.4	13.0	3.0	22.0	12.0	3.1	62.0	46.0	71.0	57.0	15.0
EC 1075910	21.0	6.7	13.0	4.0	23.0	12.0	3.1	62.0	48.0	77.0	45.0	21.0
EC 1075911	11.0	5.1	13.0	3.0	29.0	12.0	3.1	63.0	42.0	77.0	85.0	11.0
EC 1075912	26.0	11.0	13.0	3.0	25.0	12.0	3.0	63.0	45.0	75.0	115.0	26.0
EC 1075913	17.0	6.9	12.0	2.0	22.0	12.0	3.0	63.0	51.0	75.0	60.0	17.0
EC 1075914	18.0	6.4	13.0	3.0	22.0	10.0	3.0	52.0	58.0	74.0	81.0	18.0
EC 1075915	17.0	6.1	11.0	3.0	19.0	11.0	3.0	55.0	53.0	72.0	141.0	17.0
EC 1075916	16.0	5.9	11.0	3.0	21.0	11.0	2.9	57.0	41.0	76.0	71.0	16.0
EC 1075917	15.0	5.3	10.0	3.0	19.0	11.0	2.9	56.0	42.0	78.0	113.0	15.0
EC 1075918	19.0	7.4	12.0	3.0	19.0	11.0	2.9	55.0	55.0	76.0	59.0	19.0
EC 1075919	23.0	7.9	11.0	2.0	19.0	11.0	2.9	56.0	55.0	76.0	60.0	23.0
EC 1075920	17.0	5.1	12.0	3.0	19.0	11.0	2.9	54.0	54.0	74.0	95.0	17.0
EC 1075921	20.0	7.4	12.0	3.0	19.0	11.0	2.9	56.0	57.0	74.0	90.0	20.0
EC 1075922	21.0	6.9	9.0	3.0	20.0	11.0	2.9	55.0	43.0	77.0	95.0	21.0
EC 1075923	14.0	5.0	10.0	3.0	19.0	11.0	2.9	55.0	37.0	72.0	75.0	14.0
EC 1075924	20.0	5.6	9.0	3.0	20.0	11.0	2.9	52.0	40.0	75.0	106.0	20.0
EC 1075925	21.0	6.5	10.0	3.0	19.0	11.0	2.9	55.0	39.0	76.0	166.0	21.0
EC 1075926	21.0	6.8	10.0	3.0	19.0	11.0	2.9	55.0	47.0	74.0	78.0	21.0
EC 1075927	21.0	7.2	10.0	3.0	16.0	10.0	2.9	50.0	48.0	76.0	78.0	21.0
EC 1075928	14.0	4.8	11.0	2.0	16.0	10.0	2.9	48.0	58.0	75.0	156.0	14.0
EC 1075929	15.0	4.8	12.0	3.0	16.0	9.0	2.9	46.0	44.0	77.0	133.0	15.0
EC 1075930	20.0	7.5	11.0	3.0	19.0	11.0	2.9	56.0	38.0	77.0	142.0	20.0
EC 1075931	25.0	8.7	11.0	4.0	19.0	11.0	2.9	54.0	38.0	77.0	137.0	25.0
EC 1075932	21.0	6.7	12.0	3.0	20.0	11.0	2.9	55.0	40.0	74.0	72.0	21.0
EC 1075933	19.0	6.4	10.0	4.0	19.0	11.0	2.9	53.0	39.0	71.0	132.0	19.0
EC 1075934	17.0	6.0	10.0	3.0	20.0	11.0	2.9	54.0	50.0	74.0	94.0	17.0
EC 1075935	18.0	5.0	10.0	3.0	19.0	11.0	2.9	55.0	46.0	76.0	153.0	18.0
EC 1075936	18.0	7.5	9.0	3.0	19.0	11.0	2.9	53.0	43.0	79.0	79.0	18.0
EC 1075937	21.0	5.6	10.0	3.0	18.0	11.0	2.9	54.0	48.0	74.0	95.0	21.0
EC 1075938	19.0	5.5	10.0	3.0	18.0	11.0	2.9	52.0	45.0	80.0	138.0	19.0
EC 1075939	19.0	6.6	10.0	3.0	15.0	10.0	2.9	48.0	38.0	78.0	135.0	19.0
EC 1075940	19.0	6.6	12.0	2.0	19.0	11.0	2.9	57.0	52.0	76.0	139.0	19.0
EC 1075941	13.0	4.7	12.0	2.0	18.0	11.0	2.9	56.0	41.0	76.0	87.0	13.0
WH1105	15.0	5.2	10.0	2.0	15.0	10.0	2.9	51.0	48.0	77.0	109.0	15.0
WH1184	27.0	9.2	10.0	3.0	17.0	10.0	2.9	53.0	45.0	76.0	75.0	27.0
WH1021	22.0	6.9	10.0	4.0	20.0	11.0	2.9	59.0	34.0	79.0	104.0	22.0
WH1024	30.0	10.0	11.0	3.0	20.0	11.0	2.9	59.0	36.0	76.0	87.0	30.0
Mean	20.0	6.9	11.0	3.0	19.0	16.0	3.0	51.0	46.0	75.0	106.0	20.0
Maximum	30.0	11.0	14.0	4.0	29.0	59.0	4.3	63.0	58.0	80.0	189.0	30.0
Minimum	11.0	4.7	9.0	2.0	11.0	9.0	2.8	23.0	34.0	71.0	45.0	11.0
C.D. at 5%	3.7	1.2	1.5	0.4	3.6	6.7	0.0	4.5	3.3	2.1	15.2	1.6
C.V. (%)	6.5	6.5	6.5	6.0	9.9	18.2	0.3	5.0	3.5	1.4	7.1	5.6

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

Table 4.14: Performance of Wheat genotypes for quality traits in E₄

Characters	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
EC 1075892	21.0	6.5	16.0	4.0	19.0	6.0	2.0	22.0	50.0	76.0	59.0	21.0
EC 1075893	17.0	6.0	16.0	3.0	19.0	32.0	2.0	17.0	51.0	75.0	108.0	17.0
EC 1075894	26.0	8.0	15.0	4.0	19.0	25.0	2.0	17.0	48.0	75.0	113.0	26.0
EC 1075895	16.0	6.0	14.0	3.0	19.0	16.0	2.0	19.0	44.0	74.0	76.0	16.0
EC 1075896	25.0	8.0	14.0	4.0	18.0	16.0	2.0	16.0	43.0	74.0	106.0	25.0
EC 1075897	26.0	8.5	13.0	4.0	18.0	12.0	3.0	26.0	44.0	73.0	115.0	26.0
EC 1075898	25.0	8.5	11.0	3.0	19.0	15.0	2.0	14.0	43.0	77.0	115.0	25.0
EC 1075899	23.0	7.5	12.0	5.0	12.0	14.0	2.0	22.0	45.0	73.0	97.0	23.0
EC 1075900	21.0	8.0	11.0	3.0	20.0	14.0	2.0	16.0	40.0	75.0	85.0	21.0
EC 1075901	19.0	7.5	13.0	4.0	21.0	11.0	2.0	12.0	41.0	75.0	108.0	19.0
EC 1075902	19.0	6.0	11.0	4.0	20.0	11.0	2.0	12.0	51.0	74.0	124.0	19.0
EC 1075903	25.0	8.5	12.0	4.0	21.0	14.0	2.0	14.0	51.0	73.0	120.0	25.0
EC 1075904	23.0	7.0	12.0	4.0	20.0	17.0	3.0	28.0	40.0	78.0	140.0	23.0
EC 1075905	20.0	7.5	12.0	5.0	21.0	13.0	2.0	17.0	39.0	75.0	104.0	20.0
EC 1075906	25.0	9.5	14.0	4.0	21.0	11.0	2.0	18.0	51.0	73.0	96.0	25.0
EC 1075907	18.0	7.5	13.0	3.0	11.0	12.0	2.0	13.0	45.0	78.0	95.0	18.0
EC 1075908	21.0	8.5	12.0	4.0	12.0	14.0	2.0	22.0	43.0	73.0	109.0	21.0
EC 1075909	18.0	6.0	14.0	3.0	20.0	12.0	3.0	23.0	43.0	74.0	72.0	18.0
EC 1075910	21.0	7.0	13.0	3.0	20.0	12.0	3.0	30.0	45.0	77.0	65.0	21.0
EC 1075911	14.0	6.0	13.0	4.0	22.0	13.0	3.0	31.0	39.0	77.0	81.0	14.0
EC 1075912	26.0	11.0	13.0	4.0	19.0	19.0	3.0	27.0	42.0	76.0	104.0	26.0
EC 1075913	18.0	7.0	13.0	4.0	19.0	12.0	3.0	29.0	48.0	75.0	67.0	18.0
EC 1075914	20.0	7.0	13.0	4.0	20.0	15.0	3.0	29.0	55.0	75.0	86.0	20.0
EC 1075915	18.0	6.0	13.0	5.0	12.0	23.0	4.0	67.0	50.0	73.0	111.0	18.0
EC 1075916	17.0	6.0	11.0	4.0	18.0	24.0	5.0	63.0	38.0	75.0	70.0	17.0
EC 1075917	19.0	6.0	10.0	4.0	17.0	22.0	5.0	58.0	39.0	77.0	80.0	19.0
EC 1075918	19.0	7.0	12.0	4.0	18.0	21.0	2.5	49.0	51.0	77.0	65.0	19.0
EC 1075919	24.0	8.0	12.0	3.0	18.0	20.0	4.0	43.0	52.0	75.0	53.0	24.0
EC 1075920	16.0	6.0	11.0	3.0	20.0	22.0	4.0	42.0	50.0	74.0	76.0	16.0
EC 1075921	21.0	7.0	12.0	3.0	20.0	17.0	3.5	41.0	54.0	73.0	69.0	21.0
EC 1075922	22.0	7.0	11.0	3.0	29.0	35.0	3.5	28.0	41.0	76.0	69.0	22.0
EC 1075923	14.0	5.5	12.0	3.0	12.0	14.0	4.0	29.0	34.0	72.0	71.0	14.0
EC 1075924	19.0	6.0	11.0	3.0	11.0	14.0	3.0	34.0	36.0	75.0	88.0	19.0
EC 1075925	21.0	6.5	12.0	3.0	20.0	12.0	3.0	30.0	36.0	74.0	119.0	21.0
EC 1075926	21.0	7.0	11.0	4.0	21.0	12.0	3.0	37.0	44.0	75.0	65.0	21.0
EC 1075927	21.0	7.5	12.0	4.0	19.0	11.0	3.5	31.0	45.0	76.0	102.0	21.0
EC 1075928	16.0	7.0	12.0	4.0	11.0	13.0	4.0	32.0	55.0	75.0	171.0	16.0
EC 1075929	18.0	6.0	12.0	4.0	20.0	19.0	4.0	37.0	41.0	77.0	143.0	18.0
EC 1075930	20.0	7.5	13.0	4.0	20.0	14.0	3.0	27.0	34.0	78.0	167.0	20.0
EC 1075931	25.0	9.0	14.0	4.0	20.0	14.0	3.5	32.0	37.0	76.0	135.0	25.0
EC 1075932	21.0	6.5	13.0	4.0	11.0	29.0	3.5	33.0	36.0	73.0	121.0	21.0
EC 1075933	21.0	6.5	13.0	5.0	9.0	15.0	3.0	27.0	36.0	72.0	149.0	21.0
EC 1075934	18.0	6.0	13.0	6.0	15.0	21.0	4.0	37.0	46.0	74.0	136.0	18.0
EC 1075935	18.0	5.0	12.0	4.0	10.0	13.0	4.0	33.0	43.0	77.0	115.0	18.0
EC 1075936	18.0	7.0	9.0	3.0	11.0	32.0	4.0	34.0	40.0	76.0	82.0	18.0
EC 1075937	21.0	6.0	10.0	5.0	15.0	16.0	3.0	31.0	46.0	75.0	94.0	21.0
EC 1075938	19.0	5.5	14.0	4.0	22.0	18.0	3.0	37.0	42.0	78.0	172.0	19.0
EC 1075939	19.0	6.5	12.0	4.0	10.0	11.0	3.0	31.0	35.0	78.0	116.0	19.0
EC 1075940	21.0	7.0	13.0	3.0	11.0	13.0	3.0	32.0	48.0	76.0	144.0	21.0
EC 1075941	13.0	5.5	13.0	3.0	11.0	15.0	4.0	32.0	39.0	76.0	92.0	13.0
WH1105	15.0	5.0	13.0	3.0	38.0	26.0	6.5	31.0	45.0	78.0	106.0	15.0
WH1184	25.0	9.5	13.0	4.0	17.0	24.0	4.0	34.0	42.0	78.0	91.0	25.0
WH1021	22.0	6.5	14.0	4.0	23.0	17.0	3.5	28.0	31.0	76.0	97.0	22.0
WH1024	30.0	10.0	15.0	3.0	21.0	15.0	4.0	32.0	34.0	75.0	99.0	30.0
Mean	20.0	7.5	13.0	4.0	17.0	16.5	3.1	29.0	43.0	75.0	102.0	20.0
Maximum	30.0	11.0	16.0	6.0	38.0	35.0	6.5	67.0	55.0	78.0	172.0	30.0
Minimum	13.0	5.0	9.0	3.0	9.0	6.0	2.0	12.0	31.0	72.0	53.0	13.0
C.D. at 5%	1.67	0.67	0.60	0.75	4.41	6.23	0.51	5.33	3.39	3.21	17.71	1.73
C.V. (%)	2.86	3.25	2.40	10.33	12.41	17.97	8.1	6.34	3.93	2.14	8.67	6.97

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

Table 4.15: Performance of Wheat genotypes for quality traits in E₅

Characters	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
EC 1075892	33.1	10.8	13.1	2.3	22.2	18.4	3.1	78.4	30.9	80.9	91.0	14.8
EC 1075893	25.5	8.5	12.9	2.4	17.6	18.5	3.1	80.3	34.9	81.0	86.8	14.2
EC 1075894	25.6	9.4	10.4	2.7	16.3	17.9	3.1	75.8	34.9	81.1	49.2	15.1
EC 1075895	32.9	10.9	12.0	2.6	16.8	18.1	3.1	75.7	30.4	79.3	93.3	15.8
EC 1075896	36.6	11.0	12.5	2.8	16.1	17.3	3.0	74.1	28.9	80.9	61.6	15.1
EC 1075897	19.7	6.8	11.2	2.2	13.5	15.9	3.0	69.5	28.9	81.2	104.3	16.0
EC 1075898	20.4	7.1	12.9	2.7	14.8	16.8	3.0	72.3	36.9	81.5	57.3	13.8
EC 1075899	27.5	8.9	12.4	2.7	13.8	14.9	3.0	70.9	36.4	82.1	105.9	14.4
EC 1075900	21.4	7.6	13.2	2.8	14.2	15.7	2.9	66.2	33.9	82.0	61.6	14.9
EC 1075901	26.2	9.4	12.9	2.5	25.6	13.7	2.9	65.0	35.4	79.7	106.1	15.0
EC 1075902	25.5	7.9	12.1	2.7	26.2	13.8	2.9	62.3	45.9	81.0	92.3	14.0
EC 1075903	34.8	10.7	13.0	2.0	23.2	13.6	2.9	57.1	33.9	82.2	116.8	15.4
EC 1075904	32.0	9.3	11.8	2.0	25.7	15.5	2.9	69.1	31.9	80.6	97.5	14.8
EC 1075905	22.8	7.4	13.5	3.1	26.5	15.4	3.0	68.3	36.9	82.7	115.3	14.7
EC 1075906	22.1	6.5	12.6	3.0	26.4	14.3	2.9	67.8	37.4	81.6	53.6	14.6
EC 1075907	27.3	8.8	12.8	2.9	23.4	14.5	2.9	60.8	36.9	74.6	42.5	14.8
EC 1075908	19.9	5.9	12.7	2.6	23.8	14.8	2.9	61.4	31.9	82.2	94.3	15.6
EC 1075909	26.4	8.5	11.8	3.5	21.8	13.2	2.9	56.8	38.9	81.7	92.2	15.4
EC 1075910	21.9	6.7	13.4	3.2	21.5	13.1	3.0	59.0	39.9	81.2	105.7	15.8
EC 1075911	23.3	8.1	11.5	5.7	19.9	13.0	2.9	55.3	37.9	83.5	110.8	14.6
EC 1075912	19.0	5.6	12.7	2.7	21.6	14.3	2.8	54.2	33.9	81.8	94.4	15.4
EC 1075913	21.4	7.3	14.3	3.5	18.3	12.2	2.8	50.3	28.9	82.4	85.9	16.1
EC 1075914	28.6	9.2	16.4	2.8	18.2	12.8	2.7	49.8	43.9	81.7	98.8	15.9
EC 1075915	27.2	8.1	15.7	2.4	18.1	11.8	2.8	48.0	44.9	80.9	91.4	15.1
EC 1075916	17.9	5.5	10.7	3.1	20.0	13.2	2.9	56.9	46.4	80.4	91.7	14.0
EC 1075917	21.0	7.3	10.9	3.2	17.9	12.3	2.9	52.5	54.4	80.7	98.4	14.5
EC 1075918	22.9	7.2	12.1	4.2	16.3	13.1	2.8	50.2	54.4	79.4	103.2	15.2
EC 1075919	28.5	8.9	11.5	4.7	17.4	13.4	2.8	45.8	35.9	80.9	111.6	14.0
EC 1075920	32.3	10.3	11.5	2.2	13.6	14.9	2.7	42.1	44.9	81.1	110.9	14.1
EC 1075921	23.8	7.1	12.2	2.7	20.9	19.7	2.7	42.2	52.9	81.1	95.4	13.2
EC 1075922	24.3	7.6	13.0	3.6	54.9	58.2	3.0	44.2	44.9	79.3	109.3	13.6
EC 1075923	21.4	6.4	11.6	2.3	16.0	10.2	2.9	42.7	42.9	81.0	117.2	13.1
EC 1075924	22.2	7.6	12.6	2.5	11.8	11.4	2.7	40.8	38.9	82.2	119.4	17.0
EC 1075925	32.2	9.4	12.2	4.0	19.0	8.9	2.6	29.6	35.4	81.5	97.3	15.1
EC 1075926	22.3	7.5	11.2	3.6	19.8	10.3	2.7	32.3	37.9	82.1	113.5	15.6
EC 1075927	43.3	13.2	13.0	4.4	15.5	11.0	2.8	32.6	41.4	82.0	92.8	16.4
EC 1075928	20.4	6.5	12.3	4.4	18.9	10.6	2.8	39.2	30.4	80.6	103.8	14.1
EC 1075929	29.4	9.5	12.9	4.1	19.8	11.7	2.6	34.3	37.9	81.0	114.9	14.4
EC 1075930	22.7	7.1	13.5	4.1	19.2	13.1	2.8	33.8	41.9	82.2	108.1	15.6
EC 1075931	34.7	9.1	13.7	5.3	19.7	8.7	2.7	30.6	42.9	80.7	118.2	15.4
EC 1075932	30.9	10.1	11.4	4.6	19.6	11.3	2.6	37.1	33.4	82.7	118.0	15.6
EC 1075933	41.1	11.7	15.0	4.3	18.7	9.3	2.6	34.5	30.9	81.6	111.3	14.5
EC 1075934	37.2	11.7	13.7	4.6	19.1	11.6	2.7	38.8	34.4	77.4	114.7	14.7
EC 1075935	29.1	9.2	12.5	4.8	16.2	7.7	2.6	38.5	41.4	82.7	103.1	15.2
EC 1075936	24.9	7.2	13.8	3.4	24.9	48.4	3.0	48.9	37.4	81.7	107.6	13.6
EC 1075937	26.2	8.6	13.1	3.2	23.6	33.4	2.7	39.1	42.9	81.1	95.4	13.8
EC 1075938	43.0	13.7	13.6	3.8	27.3	57.6	5.9	61.7	42.4	80.6	88.8	14.2
EC 1075939	40.2	12.4	15.3	3.6	23.2	51.5	2.8	43.0	38.9	82.4	95.4	13.5
EC 1075940	25.3	8.2	12.2	4.1	19.3	10.1	2.8	39.9	42.9	81.4	117.7	14.6
EC 1075941	43.0	13.8	14.8	4.3	19.1	16.1	2.8	43.3	37.9	83.4	81.6	14.5
Koshan	35.5	12.2	14.0	4.0	12.2	37.8	2.8	53.4	28.4	83.6	80.3	13.9
Mazar#00	20.6	7.7	11.1	3.6	19.1	48.0	3.0	41.0	38.9	82.7	91.4	14.6
Dehdadi	40.5	14.5	16.0	4.8	16.9	68.9	2.7	42.1	46.9	81.4	114.3	12.6
Ghori#96	32.6	8.7	13.8	3.0	18.8	19.5	3.0	40.4	38.9	83.4	130.9	15.4
Mean	28.0	8.9	12.8	3.4	20.1	19.1	2.9	51.9	38.4	81.3	97.5	14.8
Maximum	43.3	14.5	16.4	5.7	54.9	68.9	5.9	80.3	54.4	83.6	130.9	17.0
Minimum	17.9	5.5	10.4	2.0	11.8	7.7	2.6	29.6	28.4	74.6	42.5	12.6
C.D. at 5%	3.0	1.6	1.2	0.7	3.4	3.6	0.2	6.0	3.7	2.7	10.9	1.7
C.V. (%)	5.3	8.7	4.7	10.6	9.6	10.3	3.5	6.4	4.9	1.6	5.6	5.8

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

Table 4.16: Performance of Wheat genotypes for quality traits in E₆

Characters	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
EC 1075892	33.9	11.2	12.7	3.0	21.8	21.7	2.3	53.0	31.5	79.9	89.2	14.8
EC 1075893	26.3	8.9	15.2	2.4	18.0	14.3	2.4	50.8	35.5	80.6	82.2	13.6
EC 1075894	26.3	9.8	12.3	3.1	39.1	27.0	2.9	65.9	35.5	83.5	66.1	15.7
EC 1075895	33.6	11.3	13.7	3.1	26.9	17.5	2.9	61.8	31.0	84.2	79.1	15.6
EC 1075896	37.4	11.4	13.9	3.6	26.2	13.6	2.9	59.7	29.5	83.0	90.8	13.9
EC 1075897	20.4	7.2	14.6	2.1	23.5	13.1	2.9	60.9	29.5	83.9	117.5	15.8
EC 1075898	21.2	7.5	11.8	1.5	16.2	55.8	2.9	44.6	37.5	85.8	68.4	13.3
EC 1075899	29.3	9.3	11.9	2.6	15.8	48.5	2.8	40.9	36.5	81.8	113.0	15.0
EC 1075900	22.1	8.5	11.7	2.7	15.9	39.8	3.3	40.5	34.5	80.7	77.5	14.9
EC 1075901	27.0	9.8	12.8	2.0	26.6	44.0	2.9	45.3	36.0	85.0	90.3	14.3
EC 1075902	26.3	8.3	12.2	2.7	26.6	40.5	2.9	42.8	46.5	82.6	85.2	13.3
EC 1075903	35.6	11.1	12.5	2.8	26.5	60.9	3.0	45.5	34.5	84.9	121.2	16.3
EC 1075904	32.8	9.7	12.3	2.6	26.0	40.1	2.9	42.0	32.5	82.5	98.2	15.8
EC 1075905	23.5	8.8	13.7	2.5	26.5	37.8	2.9	34.1	37.5	81.5	89.9	15.6
EC 1075906	22.8	8.4	14.2	2.6	26.3	39.0	3.0	40.5	38.0	83.4	92.2	15.7
EC 1075907	28.0	9.2	12.5	3.0	26.4	39.4	3.0	39.9	37.5	82.7	50.2	12.3
EC 1075908	20.6	6.3	12.7	2.7	27.1	49.2	2.9	46.5	32.5	85.1	90.2	15.7
EC 1075909	27.1	8.9	13.0	2.7	26.7	38.9	3.0	56.8	39.5	83.0	98.0	14.7
EC 1075910	22.6	7.1	11.8	2.1	26.1	41.7	2.9	50.0	40.0	82.7	96.4	14.8
EC 1075911	24.1	8.5	14.0	2.3	25.6	37.3	2.7	47.0	38.0	83.0	65.2	14.7
EC 1075912	19.7	6.0	12.9	2.2	26.1	46.7	3.3	49.9	34.5	85.2	104.4	15.9
EC 1075913	22.2	7.7	14.2	2.7	16.2	40.2	2.9	46.5	29.0	85.2	84.4	15.9
EC 1075914	29.4	9.6	14.8	1.9	15.7	39.3	2.8	49.7	44.5	79.7	118.5	15.8
EC 1075915	28.0	8.5	14.1	1.8	15.8	32.4	2.9	48.2	45.5	84.2	103.6	13.9
EC 1075916	18.7	5.9	13.4	1.9	15.9	35.7	2.8	43.3	47.0	85.0	99.9	13.9
EC 1075917	21.8	7.7	12.7	2.1	15.5	39.5	2.9	46.2	54.5	84.2	83.5	14.7
EC 1075918	23.7	7.6	12.7	3.1	15.0	32.5	2.9	46.8	55.0	83.9	103.9	15.7
EC 1075919	29.2	9.3	13.1	0.7	16.4	32.4	3.0	47.4	36.5	84.0	118.9	14.3
EC 1075920	33.0	10.7	12.3	3.0	17.5	26.4	3.0	35.1	45.5	84.9	133.7	14.7
EC 1075921	24.6	7.5	11.7	4.3	15.6	22.9	2.8	35.2	53.0	85.3	85.6	13.6
EC 1075922	25.1	8.0	11.8	2.8	18.3	19.0	2.8	38.7	45.5	82.4	97.1	14.3
EC 1075923	22.2	7.8	12.6	2.0	13.6	16.9	2.5	10.9	43.5	84.9	83.8	13.7
EC 1075924	22.9	8.0	12.0	2.0	3.0	15.5	2.4	10.4	39.5	83.4	101.6	17.8
EC 1075925	33.0	9.8	11.5	2.9	11.7	13.3	2.4	3.7	36.0	82.4	89.2	15.7
EC 1075926	23.0	7.9	13.1	2.8	12.1	14.4	2.4	6.1	38.5	83.0	110.4	16.0
EC 1075927	44.0	12.6	12.4	2.6	3.3	19.6	2.5	13.4	42.0	85.9	91.4	17.0
EC 1075928	21.2	6.9	12.2	2.5	2.2	15.1	2.4	7.8	31.0	81.6	109.0	14.7
EC 1075929	30.2	9.9	13.3	2.6	22.5	15.1	2.4	8.2	38.5	80.6	121.6	14.9
EC 1075930	23.4	7.5	11.4	3.1	22.1	13.9	2.4	5.2	42.5	81.8	109.7	15.9
EC 1075931	35.5	9.5	13.6	3.2	1.5	13.1	2.3	3.2	43.5	81.1	113.4	15.8
EC 1075932	31.6	10.5	11.5	2.9	9.8	20.0	2.7	54.6	34.0	82.3	99.8	16.0
EC 1075933	41.9	12.1	10.4	3.0	19.8	12.5	2.3	1.6	31.5	79.5	119.4	14.9
EC 1075934	37.9	12.1	11.7	3.4	25.4	13.3	12.1	74.5	35.0	81.7	117.1	15.0
EC 1075935	29.9	9.6	11.3	3.3	22.5	13.2	12.8	61.4	42.0	80.6	115.7	15.1
EC 1075936	25.7	7.6	12.9	2.8	24.2	13.3	14.8	59.7	38.0	81.2	94.7	14.0
EC 1075937	27.0	9.0	13.5	3.5	21.1	13.2	12.6	60.3	43.5	78.8	89.5	14.3
EC 1075938	43.8	14.1	13.0	2.8	22.1	13.2	12.7	61.1	43.0	78.9	96.8	14.7
EC 1075939	40.9	12.8	10.6	3.3	22.2	13.2	12.9	60.2	39.5	75.1	91.3	13.9
EC 1075940	26.1	8.6	14.1	2.8	22.3	13.2	12.6	61.9	43.5	76.2	132.7	14.6
EC 1075941	43.8	14.2	14.8	3.1	22.1	13.2	12.1	60.5	38.5	78.8	90.5	14.8
Koshan	36.3	12.6	13.1	3.0	22.4	33.7	12.4	60.4	29.0	85.2	100.7	14.3
Mazar#00	21.3	8.1	12.4	2.7	21.7	47.1	13.0	61.9	39.0	81.8	100.3	15.0
Dehdadi	41.2	14.9	12.0	2.3	21.5	52.2	12.9	61.5	47.0	78.8	113.5	13.3
Ghori#96	33.3	9.1	10.9	2.1	23.2	54.3	12.3	61.6	39.5	83.2	83.2	16.0
Mean	28.7	9.3	12.7	2.7	19.9	28.7	5.0	43.1	38.9	82.4	97.6	14.9
Maximum	44.0	14.9	15.2	4.3	39.1	60.9	14.8	74.5	55.0	85.9	133.7	17.8
Minimum	18.7	5.9	10.4	0.7	1.5	12.5	2.3	1.6	29.0	75.1	50.2	12.3
C.D. at 5%	4.0	1.7	1.1	0.4	1.5	4.1	0.4	5.6	4.0	4.0	26.5	0.7
C.V. (%)	7.0	9.0	4.2	7.8	3.7	10.9	4.1	6.4	5.1	2.4	13.5	2.4

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

The study in E₅ declared, a high range of concentration placed in genotype Ghor#96 (130.9 ppm) and less concentration showed in genotype EC 1075907 (42.5 ppm) with mean range of 97.5 ppm. The mean value due to E₆ was 97.6 ppm, while the maximum range was noted for genotype EC 1075940 (132.7 ppm) and minimum concentration ratio recorded for genotype EC 1075907 (50.2 ppm). The study of total soluble sugar under total six environment showed wide variation among the genotype that E₃ was noted as higher concentrated genotype for total soluble sugar.

(xii) Grain Density (cc)

From the study of E₁ resulted higher grain density noted for genotype EC 1075912 and EC 1075913 (16 cc) and lower density was noted for genotype EC 1075934 and WH1184 (14 cc) with the overall mean of 14.9 cc. Under E₂ grain density was ranged from 10.4 cc to 15.3 cc and mean of 12.6 cc. the maximum range was noted for genotype EC 1075926 (15.3 cc) and lower ratio of genotype EC 1075907 (10.4 cc). In E₃ the higher value was noted for genotype EC 1075924 (16.8 cc) with a lower value of genotype WH1021 (12.3 cc) and the average value was obtained from genotype 14.3 cc. similarly under the E₄ higher value recorded for genotype EC 1075924 (15 cc) with the less value in genotype WH1021 (10.5 cc) while the mean value was depicted 12.4 cc. Under E₅ maximum ratio is noted for genotype EC 1075924 (17 cc) and less value obtained for genotype WH1021 (12.6 cc) while the overall mean was noted 14.8 cc that showed a higher ration as compare to the other four above environments. Higher ratio of grain density under E₆ placed for genotype EC 1075927 (17 cc) and EC 1075924 (17.8 cc) and least record for genotype EC 1075907 (12.3 cc) with the mean of 14.9 cc as regards to the six deferent environmental test its revealed E₁, E₅ and E₆ recorded higher mass per volume at all.

The Grain hardness test was identified in Table 4.17 on the base of hard, semi-hard and soft that showed the difference among the genotypes. Grain appearance was observed only on the base grain morphology for identification of the color that mostly showed whitish color and amber color but few of them showed reddish color also respectively.

Table 4.17: Studies of grain hardness and grain appearance of wheat genotypes

Grain appearance analysis					Grain appearance analysis					Grain appearance analysis				
Characters	Hardness	Score	Appearance	Score	Characters	Hardness	Score	Appearance	Score	Characters	Hardness	Score	Appearance	Score
EC 1075892	semi hard	5	Whitish	1	EC 1075910	semi hard	5	Amber	2	EC 1075928	semi hard	5	Whitish	1
EC 1075893	semi hard	5	Whitish	1	EC 1075911	semi hard	5	Amber	2	EC 1075929	semi hard	5	Whitish	1
EC 1075894	semi hard	5	Whitish	1	EC 1075912	hard	7	Amber	2	EC 1075930	semi hard	5	Amber	2
EC 1075895	semi hard	5	Whitish	1	EC 1075913	hard	5	Red	3	EC 1075931	semi hard	5	Amber	2
EC 1075896	semi hard	5	Whitish	1	EC 1075914	semi hard	5	Whitish	1	EC 1075932	semi hard	5	Whitish	1
EC 1075897	semi hard	5	Whitish	1	EC 1075915	semi hard	5	Whitish	1	EC 1075933	semi hard	5	Whitish	1
EC 1075898	semi hard	5	Whitish	1	EC 1075916	soft	3	Whitish	1	EC 1075934	hard	7	Amber	2
EC 1075899	semi hard	5	Whitish	1	EC 1075917	semi hard	5	Whitish	1	EC 1075935	semi hard	5	Whitish	1
EC 1075900	semi hard	5	Whitish	1	EC 1075918	semi hard	5	Amber	2	EC 1075936	hard	7	Amber	2
EC 1075901	hard	7	Amber	2	EC 1075919	semi hard	5	Whitish	1	EC 1075937	semi hard	5	Whitish	1
EC 1075902	semi hard	5	whitish	1	EC 1075920	semi hard	5	Whitish	1	EC 1075938	semi hard	5	Whitish	1
EC 1075903	semi hard	5	Whitish	1	EC 1075921	semi hard	5	Amber	2	EC 1075939	semi hard	5	Amber	2
EC 1075904	semi hard	5	Whitish	1	EC 1075922	semi hard	5	Amber	2	EC 1075940	semi hard	5	Whitish	1
EC 1075905	semi hard	5	Whitish	1	EC 1075923	semi hard	5	Amber	2	EC 1075941	semi hard	5	Amber	2
EC 1075906	soft	3	Whitish	1	EC 1075924	hard	7	Amber	2	WH1105	semi hard	5	Amber	2
EC 1075907	semi hard	5	Whitish	1	EC 1075925	semi hard	5	Amber	2	WH1184	semi hard	5	Amber	2
EC 1075908	semi hard	5	Amber	2	EC 1075926	semi hard	5	Amber	2	WH1021	semi hard	5	Amber	2
EC 1075909	semi hard	5	Whitish	1	EC 1075927	semi hard	5	Whitish	1	WH1024	hard	7	Amber	2

The grain color is scored on the base of color which white color was scored number 1, amber was in second grade and red was placed in 3 respectively. Similarly grain hardness was scored from (3-7), that hard grain was scored number 7, semi-hard number 5 and soft was scored number 3 respectively.

4.4 Genetic variability parameters

The genetic variability is to estimate the tendency of individuals in a population, to find out the variation among the individual from one another. It revealed variability is different from genetic variation, which is the actual amount of phenotypic variation seen in a particular population. Genetic variability in a population is very important because, without variability, it becomes difficult a population to adapt to environmental changes and plays a very important role in any crop breeding program. The estimates of genetic traits for different morphological traits for all the six environments presented in Table 4.21

Days to maturity, was exhibited moderate magnitude of variation at all and higher heritability was recorded in E₆ ($h^2=86.80$) and followed by E₅ ($h^2 =73$), number of effective tillers meter⁻² was showed highly heritable in all environments but was computed higher ($h^2 = 92.1\%$) in E₂. Plant height (cm), recorded high magnitude of heritable in E₆ ($h^2= 88\%$) and followed by E₅ ($h^2 =87\%$), but the least heritability was observed in E₄ ($h^2 = 59.10\%$). Spike length (cm), was higher in E₁ ($h^2 = 83.1\%$) and moderate was studied among in E₃ ($h^2 = 77.60\%$) and E₅ ($h^2 = 68.86\%$). No. of spikelets spike⁻¹ was studied higher in E₆ ($h^2 = 65.77\%$), but at all similar and low heritability was studied in rest of environments. No. of grains per spike exhibited high heritability in most of the environments, among all least was recorded in E₅ ($h^2 = 64.77\%$). 1000 grain weight (g) was showed moderated variation at all except in E₃ least heritable magnitude was revealed ($h^2 = 63.90\%$). Biological yield per plot (kg), heritability was varied at all and higher magnitude was recorded in E₆ ($h^2 =87.30\%$) with least heritability in E₁ ($h^2 = 58.37\%$). Harvest index was showed low variation and respectively least magnitude of heritability was studied at all. Therefore, grain yield was studied high magnitude of heritability in E₆ ($h^2 =95.19\%$ and E₂ ($h^2 = 86.50\%$) with least ($h^2 = 56.30\%$) in E₁.

The magnitude of coefficient of variation estimated from error mean squares was below 10 per cent for all character in all environment but for grain yield in E₁ and E₄ the coefficient of variation recorded higher than rest of the environments, biological yield showed high coefficient of variation in E₂, E₃, and E₄ while harvest index exhibited moderate and similar coefficient of variation at all environments except in E₂ was recorded higher respectively in Table 4.21. The tendency of coefficient variation for remaining traits was below 10 percent that suggesting a higher component of experimental error arising due to environmental variation.

The genotypic and phenotypic coefficients of variation (GCV & PCV) for all the characters studied in six test environments along with the estimates of heritability (h^2) in broad sense, and genetic advance as % of mean are given in Table 4.18.

From the studies it revealed, the estimates of PCV were larger in magnitude than GCV. Least and respectively similar GCV was recorded for all environment for days to heading, E1 ($g^2=2.67$) was recorded higher than others. Days to maturity was estimated low in all environments and similar GCV was recorded. Effective tiller meter⁻² magnitude was moderate in all environments for GCV, while higher was exhibited in E1 ($g^2 = 13.25$), E3 and E4 was respectively estimated as same to E1. Moderated GCV was recorded with moderate heritability for effective tiller m⁻² among all environments except under E₂ ($h^2 = 92.13$).

From the study of Table 4.18, plant height was recorded low for GCV in all environments except in E₆ ($g^2 = 7.42$) and in the same environments PCV was recorded higher value than GCV, while estimated high heritability in E₁ ($h^2 = 82.10$), E₅ ($h^2 = 87.50$) and E₆ ($h^2 = 88.36$). Spike length was recorded moderate for GCV and PCV but the heritability was recorded varied among all environments from low E₄ ($h^2 = 53.90$) to high in E₁ ($h^2 = 83.50$). Number of spikelet spike⁻¹ was showed varied for GCV and PCV with lows heritability. Number of grain spiken⁻¹ was estimated lower value for GCV and PCV with less heritability in most of the environments. 1000 grain weight was estimated moderate for GCV and PCV with varied heritability from low to higher. The higher GCV was exhibited in E₃ ($g^2 = 7.79$ and $p^2 = 11.76$). Harvest index was estimated varied for GCV and PCV that pointed out from ($g^2 = 3.64$ and $p^2 = 5.58$) in E₆ to the maximum value of ($g^2 = 10.32$ and $p^2 = 14.24$) in E₁ with low heritability.

Grain yield was computed high in GCV and PCV in all the environments that higher GCV and PCV was respectively recorded in E₂ ($g^2 = 14.14$ and $p^2 = 15.20$) with varied heritability among 6 environments. The results of the present investigation and variability analysis indicated that the environmental influence was comparatively more pronounced for these characters in expressing the phenotypic performance of different genotypes in the respective to the environmental test.

The genetics advance as % of mean estimated low in days to heading and days to maturity, while the magnitude for effective tiller m⁻² was high in all environments respectively and the highest was computed E₁ (26.33). E₃ (26.33) and E₄ (25.31), with highly heritability,

Plant height was recorded low to moderate, but least genetics advance as % of mean was exhibited in E₄ (5.60) and higher magnitude was estimated in E₆ (14.37) similarly Spike length was also recorded low to moderate, that higher was computed in E₁ (17.21) and least was recorded in E₅ (6.52). No of grain spike⁻¹ was exhibited moderate respectively except in E₃ (22.09) was exhibited higher. Estimated value of 1000 grain weight for genetic advance as % of mean was showed moderate at all. Biological yield was studied low to high for genetic

advance as % of mean that highest was recorded in E₄ (24.51) and low was exhibited in E₁ (10.27) harvest index was exhibited low for genetic advance as % of mean. But it was recorded high value grain yield in all environments except in E₄ (18.28) and E₁ (13.72) respectively.

However, from the study of Table 4.18, the high PCV or the GCV did not provide a clear picture for some of the characters to the extent of genetic gain to be achieved from investigated traits, for the phenotypic traits unless the heritable fraction of the trait was known (Kumar et al., 2017). According to Singh (2001), heritability of a trait was assigned as high when the estimated value is 80% or when between 40-80% ranged, is called moderate and once the percentage tend to less than 40%, the low heritability is being known. Deshmukh *et al.* (1986) classified genetic advance as percent of mean is low when it follow (<10%), while moderate is being consider (10-20%) and high (>20%). In our study, low to moderate is being popular but high value of heritability were also estimated for few characters studied. High heritability was showed close coupled with high genetic advance as percent of mean (36%) observed for the grain yield and high heritability (0.96%), in E₆, similarly genetic advance as % of mean biological yield showed (33.8 %) and higher heritability (0.92%) was observed as the same. The conclusion indicated that the environmental factors expression influenced more in these characters than the genetic factors, suggesting the limited scope for expression of these characters by direct selection of high performing genotypes.

The genotypes in different environmental condition and various quality test was therefore, assessed for variability analysis. The existence of wide variation in case of quality traits among the constituent genotypes with regard to characters under study was confirmed through various statistical parameters. The basic materials, therefore, provide the positive opportunities for further investigation of the aforesaid objectives. The PCV was generally higher than the GCV for all the characters, indicating the influence of the growing season and environmental effects. The general mean, coefficient of variation along with genotypic and phenotypic coefficient of variation, heritability and genetic advance as % of mean for the grain yield with its component characters and some quality traits in the total six environments generations are presented in Table 4.21

The higher (h^2) was estimated in E₅ ($h^2 = 95.64$) and E₆ ($h^2 = 92.09$), while the rest of 4 other environments were tended to moderate for WG. DG was showed similar tendency of WG except in E₃ ($h^2 = 84.07$) expressed high heritability. CP tendency was recorded high to moderate, high heritability was recorded for E₂, ($h^2 = 83.17$) E₄ ($h^2 = 95.50$) and E₅ ($h^2 = 81.42$). Beta carotene was computed higher in all environments that indicate the outside effect was less influenced in regards to the genotypic effects respectively. As presented in table 4.19 highest (h^2) was trended for all elements Fe, Zn, Cu and Mg along with SV in all environments that revealed the environmental and side effects was highly under control and the genotype expression was

influences respectively. HW (kg/hectolitre) was recorded from lower to moderate that least h^2 was showed in E_5 ($h^2 = 42.04$) and E_6 ($h^2 = 48.39$), and rest of the environment was tended to moderate. TSS was estimated from moderate to highest, that highest heritability was in E_2 ($h^2 = 92.74$) E_3 ($h^2 = 94.90$), E_4 ($h^2 = 91.07$), and E_5 ($h^2 = 92.22$). GD was recorded from least to high which E_3 ($h^2 = 38.60$), E_4 ($h^2 = 32.82$) and E_5 ($h^2 = 36.11$) and E_1 ($h^2 = 88.89$) E_6 ($h^2 = 88.67$) while E_2 ($h^2 = 57.40$) was recorded moderate. The GCV and PCV was closely coupled with each other and heritability. Through trended h^2 the higher GCV and PCV was also raised up. While tendency of the heritability tended to low and moderate, the GCV and PCV respectively followed the same manner in computing that result came out in the Table 4.19.

The study of genetic advance as % of mean, was revealed that, WG was computed from moderate to highest value that expressed highest in E_5 (95.64) and E_6 (92.09) and the rest of environments was recorded moderate. The study of dry gluten showed higher heritability under E_5 (87.93) and E_6 (84.75) with higher GCV in E_5 (23.59) and E_6 (21.31) along with higher PCV in E_5 (25.15) and E_6 (23.14). Similarly, the genetic advance as % of mean was increased in the same E_5 (58.41) and E_6 (51.83). Irrespectively CP was showed higher heritability in E_4 (95.50) and rest of the environment recorded least but in same manner close coupled to each other. Highest Genetic advance as % of mean was computed for β -C, four elements like Fe, Zn, Cu and Mg along with SV and TSS in all the environment, that indicate the better opportunity for selection and boost the crop improvements due to more expression of the genotypic potential. The HW (kg/hectolitre) was recorded low genetic advance as % of mean in all environments. For GD the study of genetic advance as % of mean was showed low to moderate.

Through the evaluation of the Table 4.19. It revealed that environmental influence was less effective for most of the characters in all the environments. In opposite to the quality characters, the results for morphological characters indicated that, the environmental influence was comparatively more pronounced for these characters in expressing the phenotypic performance of different genotypes in the respective test environments, while for quality characters the genotypic expression was more pronounced for a better selection of the genotypes. In other word it indicates the genotypic expression was expressed well for the selection of the genotype with high genotypic variability values due to the quality characters in compare to the morphological characters that indicates less genetic variability and was mainly influenced by environmental effects. In general, the variation in six environmental populations for grain yield and quality traits indicated that selection for these traits might be effective.

Table 4.18: Estimation of genetic parameter for different characters of bread wheat genotypes under six different environments

Parameters	Environments	DH	DM	No. ET	PH (cm)	SL(cm)	NSS	NGS	TSW(g)	BY(g)	HI%	GY(g)
Heritability (broad sense)	1	75.90	82.22	73.50	82.10	83.50	56.70	82.10	89.90	50.20	66.45	76.86
	2	75.02	75.83	92.13	57.90	60.86	66.08	82.73	91.49	71.15	58.70	86.50
	3	70.36	86.10	70.90	59.40	77.60	59.90	81.80	63.90	68.50	76.39	86.10
	4	73.14	79.53	76.99	59.10	53.90	52.20	71.60	78.70	81.60	78.81	66.60
	5	78.20	73.00	74.99	87.50	54.86	52.13	64.77	85.09	84.14	65.19	85.91
	6	76.80	86.80	75.74	88.36	58.79	60.77	87.73	71.76	87.30	42.67	95.19
GCV	1	2.67	0.76	13.25	5.21	9.14	6.32	10.91	10.33	6.53	8.44	8.88
	2	1.02	0.56	12.04	4.55	4.84	8.54	9.95	10.26	12.29	5.29	14.14
	3	1.35	0.90	12.25	4.72	7.65	7.28	11.86	7.79	10.42	6.26	13.34
	4	1.57	0.99	11.25	3.88	6.46	5.40	10.99	7.80	13.17	6.77	10.88
	5	1.37	0.58	8.04	6.56	4.53	5.62	8.31	7.52	11.08	4.57	13.26
	6	1.65	1.00	8.88	7.42	6.19	6.81	10.80	6.56	11.50	3.64	13.14
PCV	1	3.07	1.09	13.90	5.75	10.00	8.40	12.05	10.89	8.54	10.32	11.83
	2	1.99	1.04	14.29	5.99	6.21	9.93	10.94	10.73	14.57	8.21	15.20
	3	1.84	1.11	13.90	6.72	8.68	10.41	13.11	11.76	12.59	7.49	14.37
	4	2.06	1.23	13.90	5.54	9.75	8.32	12.98	8.78	14.58	8.36	13.33
	5	2.57	0.88	13.29	7.01	6.47	7.78	10.32	8.16	12.07	5.66	14.31
	6	1.89	1.23	10.20	7.89	11.55	8.73	11.53	7.74	12.31	5.58	13.47
Genetic advance as % of mean	1	4.80	4.08	24.03	9.72	17.21	9.81	20.37	20.17	10.27	14.24	13.72
	2	5.07	15.63	26.29	7.14	7.78	12.73	18.65	20.21	21.36	7.02	26.40
	3	4.05	13.51	23.03	6.84	13.88	11.62	22.09	10.63	17.77	10.79	25.50
	4	5.45	8.64	21.27	5.60	8.82	7.22	19.15	14.25	24.51	11.28	18.28
	5	5.50	7.78	17.35	12.64	6.52	8.35	13.77	14.29	20.93	7.61	25.33
	6	4.99	14.69	19.22	14.37	6.85	10.93	20.84	11.44	22.13	4.90	27.08

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m⁻²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

Table 4.19: Estimation of genetic parameter for quality characters in bread wheat genotypes for six different environments

Parameters	Environments	WG (%)	DG (%)	CP (%)	β -C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
Heritability (broad sense)	1	66.20	75.92	64.73	84.70	93.77	91.95	52.70	70.00	80.54	56.95	79.35	88.89
	2	54.96	65.61	83.17	87.85	87.44	92.76	52.75	84.80	89.34	53.59	92.74	57.40
	3	74.95	84.07	68.53	88.15	76.73	85.42	96.88	93.40	93.11	76.09	94.90	38.60
	4	65.30	66.40	95.50	73.67	80.42	86.87	93.15	88.90	92.46	57.87	91.07	32.82
	5	95.64	87.93	81.42	85.30	78.22	97.84	94.82	84.10	91.47	42.04	92.22	36.11
	6	92.09	84.75	78.83	88.49	91.02	86.61	95.76	84.20	90.15	48.39	53.61	88.67
GCV	1	11.42	13.52	10.70	17.00	20.45	25.93	15.73	12.29	12.95	4.26	21.36	9.22
	2	8.18	10.64	9.47	19.25	18.46	24.58	15.74	12.13	13.58	1.50	19.17	6.78
	3	18.91	19.63	9.61	16.32	12.70	16.85	7.54	18.79	12.87	6.52	30.92	4.46
	4	15.71	15.71	10.80	17.00	17.77	21.18	31.43	17.98	13.78	4.66	27.69	5.19
	5	24.71	23.59	9.74	25.54	12.84	14.20	14.87	14.76	15.87	1.38	19.10	4.33
	6	23.82	21.31	8.01	21.63	23.62	19.50	44.45	14.75	15.50	2.33	14.53	6.64
PCV	1	14.03	15.51	13.30	18.47	21.11	27.04	21.66	14.69	14.43	5.30	23.97	9.78
	2	11.03	13.13	10.39	20.54	19.75	23.77	21.67	14.03	14.36	2.76	19.91	8.95
	3	21.84	21.41	11.61	17.38	14.50	18.23	7.54	19.44	13.33	8.89	31.74	7.18
	4	19.06	19.11	11.21	17.99	19.82	22.72	31.52	19.06	14.30	5.66	29.03	8.35
	5	25.27	25.15	10.80	27.56	14.75	147.00	15.18	16.08	16.59	2.14	19.89	7.22
	6	24.82	23.14	9.06	22.97	24.52	21.01	84.56	16.07	16.32	3.35	19.84	7.05
Genetic advance as % of mean	1	19.13	24.27	17.73	32.23	40.79	51.23	23.52	21.18	23.94	8.19	39.19	17.90
	2	12.49	17.75	17.80	37.17	35.57	49.76	23.55	21.61	26.44	1.68	38.03	10.50
	3	43.23	47.54	21.00	40.45	22.92	32.00	19.93	37.42	32.77	10.82	59.55	7.33
	4	34.20	34.10	27.85	32.44	32.84	40.60	53.02	34.92	35.06	8.73	49.71	8.52
	5	33.80	58.41	23.21	42.12	23.40	38.40	38.12	27.91	40.08	2.36	48.43	6.85
	6	32.35	51.83	18.73	53.79	46.42	37.49	52.69	27.89	38.85	4.28	28.11	16.56

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β -C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

4.5 Correlation coefficient of variation

4.5.1 Genotypic correlation for morphological traits of pooled environments

In general aspect, the phenotypic correlation consider a genotypic and environmental effect, which give evidence about total association among the observable characters. The phenotypic correlations were normally happened due to the genetic and environmental interaction which provided information about the association between two or more characters. In plant breeding, various yield components character are handled together by the plant breeders, because most of the traits are correlated with each other. Grain yield, is referred as major traits in most of the crops, that results from either additive action or the multiplicative interactions from several components traits that are termed as yield attributing traits

The degree of mutual relationship among the yield and its attributing characters in pooled environments were computed by estimating the correlation coefficient at the genotypic and phenotypic levels using 11 characters in 54 genotypes. The estimated result are presented in Table 4.20. In general, the magnitude of genotypic correlation coefficients were higher than their corresponding correlation coefficients at phenotypic level. Days to heading had genotypic positive and significant correlation with days to maturity (0.653**), number of spikelets spike⁻¹ (0.281**) and number of grain spike⁻¹ (0.321**), but with other all traits association was non-significant correlation. Days to maturity was contributed significant negative correlation with effective tiller (-2.228*) and significant correlation with number of grain spike⁻¹ (0.359**) but with all other traits associated non-significant.

Number of effective tillers m⁻² calculated positive significant correlation with spike length (0.243**), biological yield (0.456**), harvest index (0.338**) and grain yield plot⁻¹ (0.568**) respectively, while with other traits the association was observed non-significant.

Plant height showed significant positive correlation with number of spikelets spike⁻¹ (0.417**), number of spikelets spike⁻¹ (0.494**), number of grain spike⁻¹ (0.422**), negative significant correlation with 1000 grain weight (-0.221*), positive significant correlation with biological yield (0.444**), non-significant correlation with harvest index (-0.271**), while positive significant correlation was showed with grain yield (0.258**).

Spike length was showed positive significant correlation with number of spikelets spike⁻¹ (0.700**), number of grain spike⁻¹ (0.563**), biological yield (0.645**) and grain yield (0.469**). Number of spikelets spike⁻¹ was associated with number of grain spike⁻¹ (0.493**), biological yield (0.473**) and grain yield (0.380**) respectively. Number of grain spike⁻¹ was associated positive correlation with biological yield (0.278**) and non-significant correlation with other traits respectively. 1000 grain weight was correlated positively with harvest index (0.473**) while biological yield was positively correlated with grain yield plot⁻¹ (0.880**) and harvest index (0.519**) respectively.

Therefore, the association between yield and its attributed traits was significantly positive with effective tiller m⁻² (0.568**), plant height (0.258**), spike length (0.469**)

number of spikelets spike⁻¹ (0.380**), biological yield (0.880**) and harvest index (0.519**), but with rest of the characters the result was non-significant respectively.

4.5.2 Phenotypic correlation for morphological traits

Phenotypic correlation was estimated in Table 4.20, grain yield association was showed significant positive correlation with effective tiller m⁻² (0.493**), plant height (0.235**), spike length (0.430**), number of spikelet spike⁻¹ (0.237**), biological yield (0.841**) and harvest index (0.358**).

Days to heading was associated positively with day to maturity (0.523**), and number of grain spike⁻¹ (0.238*) but negative significant correlation was estimated with effective tiller m⁻² respectively. The contribution of day to maturity was correlated positively with number of grain spike⁻¹ (0.295**) and was showed non-significant with other traits.

Effective tiller m⁻² showed positive correlation with spike length (0.236**), biological yield (0.425**) and grain yield (0.493**) while with other traits the non-significant correlation was estimated respectively. Plant height associated positive correlation with spike length (0.332**), number of spikelets spike⁻¹ (0.375**), number of grain spike⁻¹ (0.340**), biological yield (0.390**), grain yield (0.235*) and negative e significant was observed with harvest index (-0.219*) while with other traits non-significant correlation was observed respectively.

From table 4.20 revealed, Spike length was associated positive significant correlation with effective tiller m⁻² (0.236**), and plant height (0.332**), Number of grain spike⁻¹ was contributed positively correlation with plant height (375**) and spike length (0.603**) but non-significant correlation was contributed with the rest of traits respectively days to heading (0.157) and days to maturity (0.078).

Number of grain per spike showed positive significant correlation with days to heading (0.238**), days to maturity (0.259**), plant height (0.340**), spike length (0.532**) and number of spikelets per spike (0.491**) while with other traits the contribution was non-significant. 1000 grain was negatively significant contributed with plant height (-0.205*) and with all other the correlation was non-significant.

Biological yield was contributed significant positive correlation with effective number of tiller (0.425**), plant height (0.340**), spike length (0.547**), number of spikelets per spike (0.344**) and number of grain per spike (0.246**) respectively and with remain of the traits non-significant contribution was calculated. Harvest index had significant positive correlation with 1000 grain weight (0.346**) and non-significant was contributed with all other traits.

Grain yield was contributed significantly positive correlation with effective tiller per m², plant height (0.235**), spike length (0.430**), number of spikelets per spike (0.237**), biological yield (0.841**) and harvest index (0.358**).

Table 4.20: Pooled genotypic (above diagonal) and phenotypic (below diagonal) correlation among yield and its attributing traits for morphological characters of pooled environments

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
DH	1.00	0.653**	-0.320**	0.092	0.152	0.281**	0.321**	-0.174	-0.062	-0.051	-0.085
DM	0.523**	1.00	-0.228*	0.084	0.144	0.143	0.359**	-0.094	-0.102	-0.053	-0.134
ET	-0.295**	-0.185	1.00	-0.005	0.243*	0.105	-0.243*	0.031	0.456**	0.338**	0.568**
PH	0.080	0.009	-0.001	1.00	0.417**	0.494**	0.422**	-0.221*	0.444**	-0.271**	0.258**
SL	0.080	0.080	0.236*	0.332**	1.00	0.700**	0.563**	-0.050	0.645**	0.150	0.469**
NSS	0.157	0.078	0.129	0.375**	0.603**	1.00	0.493**	-0.177	0.499**	-0.085	0.380**
NGS	0.238*	0.259**	-0.127	0.340**	0.532**	0.491**	1.00	0.102	0.278**	-0.036	0.184
TSW	-0.140	-0.084	0.060	-0.205*	-0.018	-0.131	0.078	1.00	-0.106	0.473**	0.103
BY	-0.044	-0.132	0.425**	0.390**	0.547**	0.344**	0.246*	-0.076	1.00	0.160	0.880**
HI	-0.016	-0.005	0.134	-0.219*	0.119	-0.100	-0.074	0.346**	-0.082	1.00	0.519**
GY	-0.069	-0.136	0.493**	0.235*	0.430**	0.237*	0.155	0.111	0.841**	0.358**	1.00

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m⁻²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

4.5.3 Genotypic correlation for Quality traits of pooled environments.

The analysis of variance showed highly significant differences among the genotypes for all the morphological characters presented in the Table 4.21, thereby, present considerable amount of variability among the 54 different genotype of wheat evaluated in the present study. The study of inter-relationship among several traits in the form of correlation is, in fact, one of the most important aspects in the presence of the significant correlation for the breeder to make an effective selection based on the correlated and uncorrelated response. Therefore, in the bellow table 4.21, several quality characters associated with each other to show the magnitude of correlation among the individuals.

From the Table 4.21 exhibited above the diagonal, wet gluten was showed genotypic positive contribution with dry gluten (0.912**), crude protein (0.483**), beta carotene (0.232**) Fe (0.248**), copper (0.206**) total soluble sugar (0.208**) but non-significant correlation was in correspondence to the sedimentation value (-0.229*) respectively.

The magnitude of dry gluten was exhibited positive significant correlation with crude protein (0.483**), beta carotene (0.244**), Fe (0.293**), while rest of the traits correspondence was non-significant correlation respectively. Crude protein was showed positive correlation with Fe (0.348**) and grain yield (0.362**). Beta carotene was showed positive association with copper (0.201*) and total soluble sugar (0.294**) respectively, while the correspondence of other traits was non-significant correlation.

Fe was associated positive correlation with copper (0.256**), magnesium (0.481**) hectolitre weight (0.254*) and grain yield (0.202*), but with other traits non-significant correlation was exhibited except for sedimentation value there was negative positive correlation (-0.265*). Zinc was associated negatively significant correlation (-0.530**) with mg and the correspondence was non-significant correlation with other traits respectively. Magnesium association along with sedimentation value was non-significant with all the traits, while hectolitre weight was associated negative significant with total soluble sugar (-0.193*) and negative significant correlation was corresponded with grain yield (-0.266*).

Total soluble sugar correlation was non-significant with grain yield and grain density was correlated positively with grain yield (0.219*). Therefore, grain yield was correlated significantly positive with crude protein (0.362**), Fe (0.202*) and grain density (0.219*), while negative significant correlation with copper (-0.266**), hectolitre weight (-0.266) respectively.

4.5.4 Phenotypic correlation for Quality traits

The result from the below diagonal of Table 4.21 was studied, wet gluten estimation was showed positive significant correlation with dry gluten (0.872**), crude protein (0.476**), beta carotene (0.216**) Cu (0.200**) total soluble sugar (0.192*) respectively and

Table 4.21: Pooled genotypic (above diagonal) and phenotypic (below diagonal) correlation among yield and its quality traits for morphological characters

Characters	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg(ppm)	SV (ml)	HW (kghectolitre)	TSS (ppm)	GD (cc)	GY
WG (%)	1.00	0.912**	0.483**	0.232*	0.248**	-0.087	0.206*	0.045	-0.229*	-0.121	0.208*	0.043	0.135
DG (%)	0.872**	1.00	0.656**	0.244*	0.293**	0.074	0.104	-0.056	-0.178	-0.071	0.096	0.003	0.110
CP (%)	0.476**	0.649**	1.00	0.059	0.384**	-0.112	-0.170	0.042	-0.046	-0.032	-0.037	0.137	0.362**
β-C (ppm)	0.216*	0.220*	0.045	1.00	0.154	-0.093	0.201*	0.141	-0.107	-0.180	0.294**	0.061	-0.083
Fe(ppm)	0.241*	0.304**	0.355**	0.143NS	1.00	-0.034	0.265**	0.481**	-0.265**	0.254**	-0.026	-0.071	0.202*
Zn(ppm)	-0.058	0.081	-0.051	-0.094	-0.026	1.00	-0.026	-0.530**	0.038	0.051	-0.125	-0.164	-0.072
Cu (ppm)	0.200*	0.109	-0.149	0.193*	0.260**	-0.001	1.00	0.426**	-0.156	0.303**	0.122	-0.201*	-0.254**
Mg (ppm)	0.024	-0.057	0.045	0.127	0.435**	-0.419**	0.393**	1.00	0.065	0.071	0.042	-0.013	0.142
SV (ml)	-0.213*	-0.175	-0.046	-0.086	-0.248**	0.050	-0.141	0.051	1.00	-0.168	-0.187	-0.166	0.008
HW (kg/hectolitre)	-0.092	-0.056	-0.025	-0.124NS	0.199*	0.026	0.246*	0.033	-0.149	1.00	-0.193*	0.054	-0.266**
TSS (ppm)	0.192*	0.099	-0.028	0.283**	-0.024	-0.103	0.118NS	0.038	-0.176	-0.149	1.00	0.092	-0.077
GD (cc)	0.034	-0.004	0.132	0.043	-0.064	-0.153	-0.197*	-0.010	-0.172	0.051	0.091	1.00	0.219*
GY	0.101	0.054	0.262**	-0.065	0.159	-0.051	-0.229*	0.130	0.010	-0.187	-0.090	0.205*	1.00

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), Copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

non-significant correlation was associated with other traits, but in some traits exhibited negative significant association like, sedimentation value (-0.213**) and hectolitre weight (-0.092) respectively. Dry gluten was associated positive significant traits with crude protein (0.649**), beta carotene 0.220**) Fe (0.304**) respectively but with other traits was tend to associate negative and positive non-significant correlation.

Crude protein association was showed positive significant with Fe (0.355**), and grain yield (0.262**) respectively, while with other traits the association was resulted positive and negative non-significant correlation. Beta carotene was tend to have positive significant correlation with copper (0.197*), and total soluble sugar (0.283**) respectively and non-significant correlation was revealed with other traits.

Iron (Fe) was associated positive significant correlation with copper (0.260**), hectolitre weight (0.199*) respectively, while with other traits the association was exhibited non-significant correlation. Zinc correlation was mainly non-significant with all traits except negative significant correlation was exhibited with magnesium (-0.419**) respectively, while copper was showed positive significant correlation with magnesium (0.394**), hectolitre weight (0.246**) and negative significant correlation with grain density (-0.197*) and grain yield (-0.299**) respectively. Magnesium association along with sedimentation value, hectolitre and total soluble sugar was resulted non-significant correlation respectively.

Therefore, grain density had positive significant correlation with grain yield (0.205**) and grain yield was contributed positively significant correlation with crude protein (0.262**) and negative significant with copper (-0.299**) but positive significant correlation was contributed with grain density (0.205*) respectively.

4.6 Path coefficient analysis.

Path coefficient analysis is one of the statistical important tool for using the partitioning of correlation coefficients into direct and indirect effects of an independent variables on the dependent variable. Path analysis is the three correlation demonstration as they are associated with a common third one. Thus, it is needs to employ a method that respectively considers the true relationship between the variables. Additionally, to the extent of such relationships, path coefficient analysis estimates the direct effect of one variable upon the other and allows separation of correlation coefficients into components of direct and indirect effects.

With the inclusion of more variables in correlation study, their indirect association becomes more complex. Two characters may show correlation, just because they are correlated with a common third one. In such circumstances, path coefficient analysis provides an effective means of a critical examination of specific forces action to produce a given correlation and measure the relative importance of each factor.

In this study, the grain yield was taken as dependent variable and other yield attributed characters were considered as independent variables. The path coefficient analysis

makes able to splits total correlation coefficient of various characters into direct and indirect effects on grain yield plot⁻¹ in such a way, sum of direct and indirect effects being equal to total genotypic correlation

Therefore, path coefficient analysis was performed to assess the direct and indirect effects of different characters on grain yield. The direct and indirect effect of different characters on grain yield are presented in Table 4.22. In the study, grain yield was taken as dependent variable where as other yield attributed traits viz., days to heading, days to maturity, plant height, effective tiller m⁻², spike length, number of spikelet spike⁻¹, number of grain spike⁻¹, 1000-grain weight, biological yield per plot and harvest index.

The residual effect (0.084) in path coefficient analysis was considerably low for phenotypic path analysis of morphological traits.

4.6.1 Direct Effect

Form the pooled analysis of morphological characters revealed maximum positive direct effect on grain yield plot⁻¹ was exhibited by biological yield (0.9378) followed by harvest index (0.45196)), and negative effect on spike length (-0.21501)

4.6.2 Indirect Effect

The indirect effect on grain yield analysed at phenotypic level *via* different characters are presented in Table 4.22. The maximum positive indirect effect were noted through spike length (0.505), followed by plant height (0.360) and effective tiller m⁻² (0.392), 1000 grain weight *via* harvest index (0.156), negative of spike length *via* number of spikelets spike⁻¹ (-0.0129) and number of grain spike⁻¹ (-0.114) respectively.

Path coefficient analysis for grain yield plot⁻¹ analysed for 11 traits at phenotypic level out of them here only those traits are explained which showed significant and positive correlation to grain yield traits viz., effective tiller m⁻², plant height, spike length, number of spikelets spike⁻¹, number of grain spike⁻¹, biological yield and harvest index.

Effective tiller m⁻² had a significant direct effect (0.089) on grain yield. It was showed positive indirect effect through number of spikelets spike⁻¹ (0.007), 1000 grain weight (0.012), biological yield (0.392) and harvest index (0.060). Negative indirect effect was showed through days to heading (-0.013), days to maturity (-0.099), plant height (-0.001), spike length (-0.071) and number of grain spike⁻¹ (-0.006).

Plant height had a significant and positive direct effect (0.010) on the grain yield and it was showed indirect positive effect through days to heading (0.004), days to maturity (0.005), number of spikelets spike⁻¹ (0.020), number of grain spike⁻¹ (0.018), and biological yield (0.360) respectively. Indirect negative effect was showed through effective of tiller m⁻² (-0.001), spike length (-0.071), 1000 grain weight (-0.043) and harvest index (-0.099).

Spike length had negative significant effect (-0.215) on grain yield. Spike length was showed positive indirect effect through days to heading (0.004), days to maturity (0.043), effective tiller m⁻² (0.021), plant height (0.003), number of spikelets spike⁻¹ (0.033), number

of grain spike⁻¹ (0.028). Negative indirect effect was showed through 1000 grain weight respectively.

Number of spikelets spike⁻¹ had positive significant direct effect (0.055) on grain yield. It was showed indirect positive effect through days to heading (0.007), days to maturity (0.041), plant height (0.003) number of spiklets spike⁻¹ (0.026) and biological yield (0.317) respectively. Negative indirect effect was showed through 1000 grain weight (-0.27) and harvest index (-0.045).

Biological yield had positive significant direct effect (0.923) on grain yield. It was showed positive indirect effect through effective tiller m⁻² (0.038), plant height (0.003), number of spikelets spike⁻¹ (0.019), number of grain spike⁻¹ (0.013), while negative indirect effect was showed through days to heading (-0.002), day s to maturity (-0.007), spike length (-0.117), 1000 grain weight (-0.016) and harvest index (-0.037) respectively.

Harvest index had positive significant direct effect (0.451) on grain yield. Though, harvest index was showed positive indirect effect on effective tiller m⁻² (0.012) and 1000 grain weight (0.073). Negative indirect effect was showed through days to heading (-0.001), days to maturity (-0.003), plant height (-0.002), spike length (-0.025), number of spikelets spike⁻¹ (-0.005), number of grain spike⁻¹ (-0.003), biological yield plot⁻¹ (-0.076) respectively.

In addition, grain yield was considered as dependant variable for the quality traits viz., wet gluten (WG %), dry gluten (DG %) crude protein (CP %) beta carotene (β-C ppm), iron(Fe ppm), Zn (Zn ppm), copper (Cu ppm), magnesium (Mg ppm), sedimentation value (SV ml), hectolitre weight (HW kg/hectolitre) total soluble sugar (TSS ppm) and grain density (GD cc) were considered as independent variables that presented in Table 4.23.

Crude protein had positive significant direct effect (0.271) on grain yield. It was showed indirect positive effect through wet gluten (0.212) Fe (0.053), copper (0.034), and magnesium (0.007) sedimentation value (0.003) hectolitre weight (0.004), and total soluble sugar (0.002) grain density (0.020). Negative indirect effect was showed through dry gluten (-0.338), beta carotene (-0.002), and Zn (-0.006) respectively.

Copper had significant negative direct effect (-0.230) on grain yield. While positive indirect effect was showed through wet gluten (0.089), Fe (0.039) magnesium (0.066) sedimentation value (0.009). Negative indirect effect was showed through dry gluten (-0.056), copper (-0.040), beta carotene (-0.008), hectolitre weight (-0.044), total soluble sugar (-0.018) and grain density (-0.030) respectively.

Grain density had positive significant direct effect (0.156) on grain yield. Though, positive indirect effect was showed through wet gluten (0.014), dry gluten (0.018), crude protein (0.035), and copper (0.045) sedimentation value (0.001). Negative indirect effect was showed through beta carotene (-0.019), Fe (-0.009) Zn (-0.018), magnesium (-0.001), hectolitre weight (-0.092) and total soluble sugar (-0.009) respectively.

Table 4.22: Path coefficients for grain yield per plot and its attributing traits of pooled environments

Characters	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
DH	0.044	0.0278	-0.026	0.008	-0.017	0.008	0.012	-0.029	-0.040	-0.007	-0.069
DM	0.023	0.052	-0.016	0.009	-0.017	0.0043	0.013	-0.018	-0.121	-0.002	-0.136
ET	-0.013	-0.099	0.089	-0.001	-0.050	0.007	-0.006	0.012	0.392	0.060	0.493**
PH	0.004	0.005	-0.001	0.010	-0.071	0.020	0.018	-0.043	0.360	-0.099	0.235*
SL	0.004	0.043	0.021	0.003	-0.215	0.033	0.028	-0.003	0.505	0.053	0.430**
NSS	0.007	0.041	0.011	0.003	-0.129	0.055	0.026	-0.027	0.317	-0.045	0.237*
NGS	0.011	0.017	-0.011	0.003	-0.114	0.027	0.053	0.016	0.226	-0.033	0.155
TSW	-0.006	-0.0045	0.005	-0.002	0.003	-0.007	0.004	0.021	-0.070	0.156	0.111
BY	-0.002	-0.007	0.038	0.003	-0.117	0.019	0.013	-0.016	0.923	-0.037	0.841**
HI	-0.001	-0.003	0.012	-0.002	-0.025	-0.005	-0.003	0.073	-0.076	0.451	0.358**

The residual effect (0.084)

Table 4.23: Path coefficients for grain yield per plot and its quality traits of pooled environments

Characters	WG (%)	DG (%)	CP (%)	β -C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS	GD (cc)	GY
WG (%)	0.445	-0.454	0.129	-0.009	0.036	-0.006	-0.046	0.004	0.001	0.016	-0.020	0.005	0.101
DG (%)	0.388	-0.521	0.176	-0.010	0.045	0.009	-0.025	-0.009	0.001	0.010	-0.010	-0.005	0.054
CP (%)	0.212	-0.338	0.271	-0.002	0.053	-0.006	0.034	0.007	0.003	0.004	0.002	0.020	0.262**
β -C (ppm)	0.096	-0.114	0.012	-0.045	0.021	-0.011	-0.044	0.021	0.005	0.022	-0.030	0.006	-0.065
Fe(ppm)	0.107	-0.158	0.096	-0.006	0.151	-0.003	-0.059	0.073	0.001	-0.035	0.002	-0.010	0.159
Zn (ppm)	-0.025	-0.042	-0.013	0.004	-0.003	0.118	0.003	-0.070	-0.003	-0.004	0.011	-0.023	-0.051
Cu (ppm)	0.089	-0.056	-0.040	-0.008	0.039	-0.001	-0.230	0.066	0.009	-0.044	-0.018	-0.030	-0.229*
Mg (ppm)	0.010	0.029	0.012	-0.005	0.065	-0.049	-0.090	0.168	-0.003	-0.006	-0.004	-0.001	0.13
SV(ml)	-0.095	0.091	-0.012	0.003	-0.037	0.005	0.032	0.008	-0.006	0.026	0.019	-0.026	0.01
HW (kg/hectolitre)	-0.041	0.029	-0.006	0.005	0.030	0.003	-0.056	0.005	0.009	-0.181	0.016	0.008	-0.187
TSS (ppm)	0.085	-0.051	-0.007	-0.013	-0.003	-0.012	-0.027	0.006	0.001	0.026	-0.108	0.014	-0.09
GD (cc)	0.014	0.018	0.035	-0.019	-0.009	-0.018	0.045	-0.001	0.001	-0.092	-0.009	0.156	0.205*

The residual effect (0.740)

4.7 G x E interaction and stability analysis

The experimental data recorded on wheat genotypes in different environments for various characters under investigation were pooled and a joint regression analysis was carried out. The pooled variance and joint regression analysis for G x E interaction for all the characters have been presented in Table 4.24. The mean sum of squares due to genotypes were found significant for days to heading, days to maturity, number of effective tillers per m⁻², plant height, , number of spikelets spike⁻¹, number of grains per spike, 1000 grain weight, , harvest index, while non-significant were found for spike length, biological yield and grain yield. Though the G x E interactions were observed significant for most of the characters except for spike length and biological yield. The mean squares due to these interactions were further splitted into linear and non-linear components observed significant for all the characters whereas, for pooled deviation for regression. It was observed that the mean square due to environment (linear) and pooled deviation from regression were significant for all the characters except for spike length number of spikelets spike⁻¹ and biological yield, which non-significant were found in pooled deviation, while the G x E interaction (linear) was significant for all the characters except for spike length.

The stability behaviour of all wheat genotypes for all the characters studies were estimated individually and results further supported by the trend of environmental indexes estimated for different characters and presented in Table 4.25 and Table 4.27. These indices were taken under estimation to the linearity and the deviation from the linearity components of response of individual genotypes representing their stability parameters over the test environment.

Table 4.24: Joint regression analysis of G x E interaction for various characters in wheat

Characters	Mean sum of squares							
	Genotype (G)	Env (E)	G x E	Env+ G x E	Env (Linear)	Gx E (Linear)	PD*	PE*
	48	5	240	245	1	48	196	288
DH	7.312**	8057.74*	2.127**	151.3	40288.7*	4.319**	1.55*	1.59
DM	2.655**	13815.0*	1.264*	257	69075.3*	3.022**	0.809	0.87
ET	4801.5**	33211.6*	1226.3*	1818	166058.4*	273.05*	1437**	176
PH	116.69*	2292.7*	20.1**	62.1	11464.8*	23.83**	18.8**	11.78
SL	1.259	13.48**	0.487	0.72	67.4**	0.827	0.394	0.33
NSS	3.793**	64.042**	1.459*	2.61	320.21**	2.769**	1.111	1.18
NGS	67.103	558.768**	32.013**	41.7	2793.8**	42.954**	28.7**	9.044
TSW	23.432**	308.978**	11.549**	17.05	1544.8**	6.279**	12.6**	3.814
BY	0.525	35.572**	0.388	1.03	177.8**	0.37	0.385	0.112
HI	5.86	336.858**	5.326*	11.4	1684.2**	6.924**	4.835**	2.74
GY	0.086**	4.09**	0.059	0.13	20.45**	0.081	0.053	0.012

Table 4.25: The environmental indexes (*I_j*) estimated as deviation from the grand mean of genotypes for various characters in different environments

Characters	Environmental indexes (<i>I_j</i>) in test environments						
	E1	E2	E3	E4	E5	E6	Grand Mean
DH	15.86	-1.44	13.50	-3.83	-10.69	-13.43	82.84
DM	23.16	-5.54	17.31	-9.98	-11.36	-13.59	125.34
ET	31.16	11.36	-26.08	-7.03	19.85	-29.21	350.34
PH	12.94	-4.86	-0.67	-2.89	-1.51	-3.06	99.66
SL	0.96	-0.04	0.00	-0.35	-0.34	-0.33	9.84
NSS	1.24	0.14	-0.49	-1.49	1.18	-0.64	18.86
NGS	3.69	1.29	-1.81	-4.15	3.27	-2.30	55.11
TSW	1.20	-0.80	0.12	-4.33	2.52	1.23	40.10
BY	1.11	-0.39	-0.11	-1.26	0.61	0.04	5.59
HI	-4.62	0.08	-0.17	0.25	2.25	2.18	34.42
GY	0.04	-0.11	-0.02	-0.44	0.37	0.17	1.90

Days to heading (DH), Days to maturity (DM), Number of effective tillers per m²(ET), Plant height(PH), Spike length (SL), Number of spikelets spike⁻¹(NSS), Number of grains per spike (NGS), 1000 grain weight (TSW), Biological yield per plot (BY), Harvest index(HI) and Grain yield per plot(GY)

The pooled variance and joint regression analysis for G x E interaction of all the characters have been presented in Table 4.26 the mean sum of squares due to genotypes were found significant for most of the quality traits such as wet gluten, dry gluten, crude protein beta carotene, iron, Zn, copper, sedimentation value, hectolitre weight, total soluble sugar and grain density except for magnesium the mean square was found non-significant. Though the G x E interactions were observed significant for 10 characters out of 11 characters observed, and only for grain yield the mean squares was found non-significant. Due to these G x E interactions were further splitted into linear and non-linear components for all eleven traits. The mean square due to environment (linear) and pooled deviation were found significant for all characters except for total soluble sugar in environment (linear) and hectolitre weight in pooled deviation was observed non-significant from regression. Therefore the G x E interaction (linear) was not found significant for all characters. Since, the remainder or mean sum of squares of pooled deviation were highly significant for most of the characters except for hectolitre weight and grain density. The stability behaviour of genotypes of wheat for all the characters investigation was calculated separately and results are presented through following Tables. Therefore, the indices were used for estimation of the linearity and the deviation from the linearity components of response of each genotypes representing their stability parameters over the environments under studies.

Table 4.26: Joint regression analysis of G x E interaction for various quality characters in wheat.

Characters	Genotype (G)	Env (E)	G x E	Env+G x E	Env (Linear)	G x E (Linear)	PD*	PE*
	48	5	240	245	1	48	196	288
WG %	48.18**	508.86**	18.46**	27.55	2544.29**	10.14	20.17**	3.63
DG %	5.08**	16.97**	1.85**	2.13	84.84**	1.65	1.87**	0.46
CP (%)	3.31**	37.32**	1.25**	1.92	186.59**	1.83	1.09**	0.39
β-C (ppm)	1.06**	6.65**	0.31**	0.43	33.26**	0.36	0.29**	0.06
Fe(ppm)	35.98	340.49**	17.16**	23.14	1702.45**	24.15	15.12**	3.3
Zn (ppm)	67.60**	297.35**	13.41**	18.67	1486.74**	58.56	2.08**	6.49
Cu (ppm)	5.03**	32.38**	2.95**	3.49	161.88**	12.7	0.50**	0.1
Mg (ppm)	154.63	6161.40*	148.20*	259.56	30806.98*	92.45	159.14*	1.63
SV (ml)	125.34**	530.23**	19.91**	29.36	2651.16**	85.4	3.47	4.16
HW (kg/hectolitre)	6.60**	709.03**	3.08	16.15	3545.12**	6.54**	2.17	2.59
TSS	1361.74**	21219.7*	315.68**	702.79	106098.8	216.47	334.18**	66.56
GD (cc)	3.27**	779.56**	0.24	14.68	3897.80**	0.60**	0.15	0.45

Table 4.27: The environmental indexes (*I_j*) estimated as deviation from the grand mean of genotypes for various characters in different environments

Characters	Environmental indexes (<i>I_j</i>) in test environments						
	E1	E2	E3	E4	E5	E6	Grand Mean
DG (%)	-2.2	-2.7	-3.3	-2.8	5.0	-13.6	22.9
CP (%)	-0.2	-0.4	-1.1	-0.9	1.0	4.8	7.9
β-C (ppm)	-1.2	0.5	-0.9	0.4	0.7	-9.5	12.1
Fe(ppm)	0.3	0.0	-0.2	0.4	0.1	16.7	3.2
Zn (ppm)	0.7	2.0	-2.1	-3.8	2.0	7.5	21.2
Cu (ppm)	-1.7	-1.1	-7.7	1.5	1.3	-18.2	23.2
Mg (ppm)	0.0	-0.1	-0.5	-0.4	-0.6	39.5	3.5
SV (ml)	-9.3	-10.2	11.9	-10.1	12.3	-0.6	39.5
HW (kg/hectolitre)	2.0	1.3	3.8	0.6	-4.1	40.0	42.5
TSS (ppm)	-3.4	-1.7	-2.0	-2.3	4.0	20.3	77.3
GD (cc)	-23.0	-26.6	18.2	14.2	9.9	-72.7	87.6

Wet gluten (WG %), Dry gluten (DG %) Crude protein (CP %) Beta carotene (β-C ppm), Iron (Fe ppm), Zinc (Zn ppm), copper (Cu ppm), magnesium (Mg ppm), Sedimentation value (SV ml), Hectolitre weight (HW kg/hectolitre) Total soluble sugar (TSS ppm) and Grain density (GD cc)

4.7.1 Days to heading

The estimates of stability parameters for days to heading, days to maturity and effective tiller m⁻² are included in Table 4.28. The genotypes exhibited a range of days to heading from 80.667 to 85.750 where genotypes number EC 1075894, EC 1075897, EC 1075934, and EC 1075938 were earliest for days to heading while, genotypes number EC 1075905 and EC 1075906 were found late in days to heading. With regression coefficient higher than unity the genotypes number EC 1075894, EC 1075921, EC 1075925, EC 1075932, EC 1075939 adapted to and responsive for better environments. Genotypes number EC 1075893, EC 1075904, EC 1075912, EC 1075915 and EC 1075937 were observed *bi* value

close to zero and remaining genotypes were close to unity in response and responsive and adaptive to poor and average environments, respectively. The S^2di values for most of the genotypes except EC 1075905 genotypes, such as genotypes number EC 1075892, EC 1075893, EC 1075902, EC 1075903, EC 1075904, EC 1075905, EC 1075907, EC 1075911, EC 1075927, EC 1075930, EC 1075932, EC 1075933, EC 1075939 were not significant indicating their stability in days to heading.

4.7.2 Days to maturity

As regards days to maturity, the range varied from 123cm to 126cm where, genotypes EC 1075905, EC 1075906, EC 1075930, EC 1075936 and EC 1075940 were latest and genotypes number EC 1075892, EC 1075902 and EC 1075903 were earliest, respectively. The regression coefficients of the genotypes were varied from 0.032 to 6.24 it meant the high variation was observed among the genotypes that indices different response to the environments. $bi > 1$ was showed for most of the genotypes which indicated the favourable environments responsive and $bi < 1$ or close to zero was responsive for poor environments among all genotypes while few genotypes like genotypes number EC 1075914, EC 1075929 was favourable for all environments ($bi = 1$ or non-significant). The non-significant S^2di value recorded for EC 1075931 genotypes that was observed stable for different specific environment.

4.7.3 Effective tiller m^{-2}

The estimation of stability for effective tiller m^{-2} was observed, that highly variation was showed under different environments, ranged from 280 to 381, which the genotype EC 1075903 was noted highest and genotype EC 1075930 was recorded least number of effective tiller m^{-2} . The regression was showed higher than unity for 14 genotypes and the more number of genotypes was showed non-significant or close to zero that indices stable for poor environments and regression higher from the unity was observed for better environments. S^2di significant for 21 genotypes, which was showed non stable condition in all environments for effective tiller m^{-2} respectively.

Table 4.28: Estimates of stability parameters for days to heading, days to maturity and effective tiller m⁻² of wheat genotypes

Characters	Days to heading			Days to maturity			Effective tiller m ⁻²		
	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>
EC 1075893	83.25	0.96	3.62**	125.18	1.76	3.83**	336.40	-0.33	12.89
EC 1075894	81.67	3.83	14.48	125.34	0.76	0.87	344.35	-1.31	3.14**
EC 1075895	82.08	0.13	2.03	124.69	-3.73	1.14	378.01	1.64	2.40
EC 1075896	81.67	-0.35	0.02	125.18	-2.83	3.28**	356.43	-1.02	4.92**
EC 1075897	80.67	-2.48	1.56	124.77	-5.20	0.31	361.99	-2.40	14.25**
EC 1075898	82.25	-2.94	1.59	125.18	-3.09	6.28	369.32	-0.25	4.73**
EC 1075899	82.00	-3.83	2.21	125.27	-4.62	7.66	349.76	0.19	5.36
EC 1075900	83.08	-1.85	0.24	125.35	-3.08	1.34	351.51	0.25	2.50
EC 1075901	83.25	3.40	1.53	125.25	5.84	1.06	322.00	-1.23	2.03
EC 1075902	81.67	-4.31	3.96**	123.94	-1.41	13.14	313.99	1.08	0.28
EC 1075903	81.50	-4.41	3.24**	123.86	-2.48	0.62	381.55	-1.85	1.10
EC 1075904	83.42	0.93	3.53**	124.68	-0.72	1.83	339.75	4.04	0.62
EC 1075905	85.75	2.93	5.43**	127.00	0.82	4.35**	340.04	-0.52	1.45
EC 1075906	85.25	2.47	13.52	126.09	0.56	1.91	342.70	0.03	0.59
EC 1075907	83.00	1.46	3.98*	125.10	-3.70	0.37	327.95	0.32	0.25
EC 1075908	83.50	1.75	2.06	125.10	-0.57	2.84**	351.93	1.52	2.86**
EC 1075909	82.92	1.08	0.87	125.01	-0.29	1.57	368.20	3.17	1.16
EC 1075910	83.17	-1.96	0.57	125.35	-3.05	0.33	362.53	-3.09	0.80
EC 1075911	81.83	-4.67	2.52*	124.77	-0.80	4.18**	325.27	0.48	0.08
EC 1075912	82.33	-0.68	0.22	125.18	-1.08	1.09	313.99	0.96	1.62
EC 1075913	82.58	-0.78	2.42	125.33	2.13	0.58	362.50	0.67	2.02
EC 1075914	82.75	0.35	0.11	125.01	1.21	0.88	335.28	-0.75	2.78*
EC 1075915	82.42	0.56	0.57	124.85	-2.19	5.10**	324.22	-1.74	1.88
EC 1075916	84.42	1.25	1.42	125.91	6.90	2.96**	325.13	-0.81	0.17
EC 1075917	83.50	2.26	1.24	125.42	2.41	4.09	315.84	1.34	7.31
EC 1075918	83.00	2.28	2.19	125.17	3.49	0.28	292.08	1.03	1.92
EC 1075919	81.58	-2.34	1.35	125.17	2.26	1.57	357.60	-2.66	8.37**
EC 1075920	81.75	-0.79	0.42	124.27	0.03	0.32	347.95	0.50	2.42
EC 1075921	84.75	3.06	1.24	125.84	-0.11	0.82	358.20	-3.42	2.10
EC 1075922	81.50	-4.62	2.20	125.35	-1.63	0.47	372.80	-0.64	3.65**
EC 1075923	81.33	-1.71	2.02	124.85	-1.74	4.88**	343.37	-3.85	4.35**
EC 1075924	83.25	2.54	0.97	124.68	-0.84	1.04	347.70	-0.91	5.12**
EC 1075925	84.42	3.50	0.08	125.58	3.68	1.10	302.98	-0.71	3.62**
EC 1075926	82.75	-2.62	1.98	125.33	3.99	2.30	338.50	0.17	2.58**
EC 1075927	81.75	-3.34	4.16*	124.69	-2.50	0.72	338.11	-0.06	6.84**
EC 1075928	83.25	1.15	1.26	125.75	3.46	1.60	313.74	-0.36	0.48
EC 1075929	82.75	-1.80	1.16	125.42	1.12	1.06	291.36	-0.55	0.80
EC 1075930	83.33	1.10	3.76*	126.24	6.25	3.08**	280.50	-0.78	2.60
EC 1075931	82.58	-2.45	0.31	125.76	0.00	1.17	325.36	1.11	2.67*
EC 1075932	83.17	3.59	2.38*	126.32	5.84	1.19	345.56	2.90	5.85**
EC 1075933	84.00	3.18	3.78*	125.35	-3.05	0.33	342.17	1.78	1.17
EC 1075934	81.83	1.62	0.27	125.43	0.11	3.85**	352.66	0.70	0.47
EC 1075935	82.33	2.17	0.51	125.10	-2.15	0.70	306.85	-1.60	10.71**
EC 1075936	83.33	0.03	1.29	126.58	1.99	1.98	317.83	0.80	3.03
EC 1075937	82.25	0.59	1.48	125.50	-1.78	3.94**	314.41	0.68	4.19**
EC 1075938	81.25	-1.35	0.65	125.42	-1.09	4.18**	344.44	0.01	4.97**
EC 1075939	84.75	4.63	6.29	125.93	-1.65	3.81**	319.15	0.35	1.05
EC 1075940	82.83	1.05	2.41*	126.57	7.81	1.71	374.20	0.25	1.07
EC 1075941	82.17	-1.72	1.33	125.58	-0.17	6.67	353.15	2.48	3.44**
P Mean	82.78	-	-	125.28	-	-	337.02	-	-
S.E(mean)	0.57	1.00	-	0.42	1.00	-	16.25	1	-
S.E. of b	0.047	-	-	0.026	-	-	0.851	-	-

**Significant at 1% probability level, * Significant at 5% probability level

b1 = Regression coefficient, s2d1 = Deviation from regression coefficient.

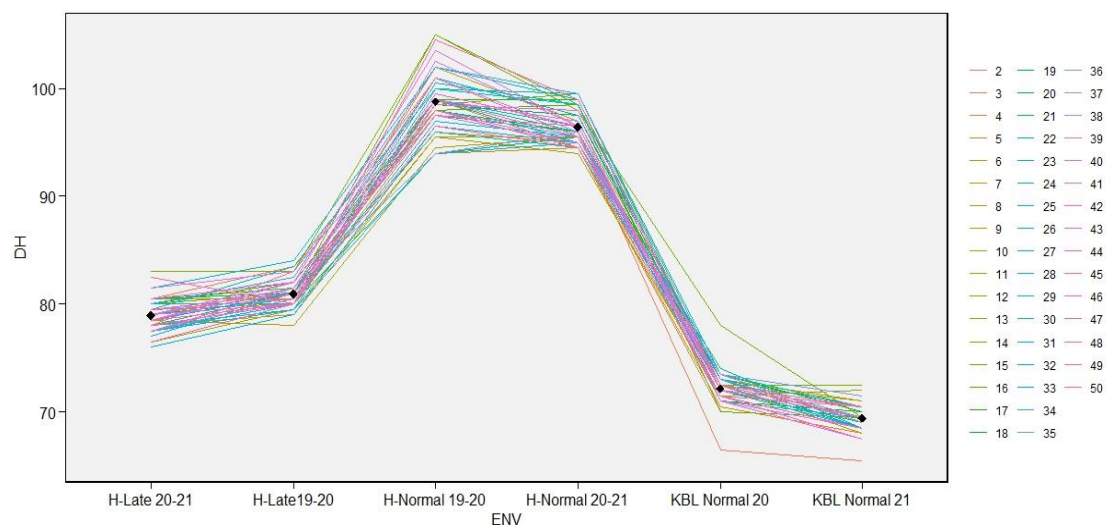


Figure 4.1: Scatter plot of wheat genotypes based on stability parameters (Mean, b_i , S^2d_i) of days to heading

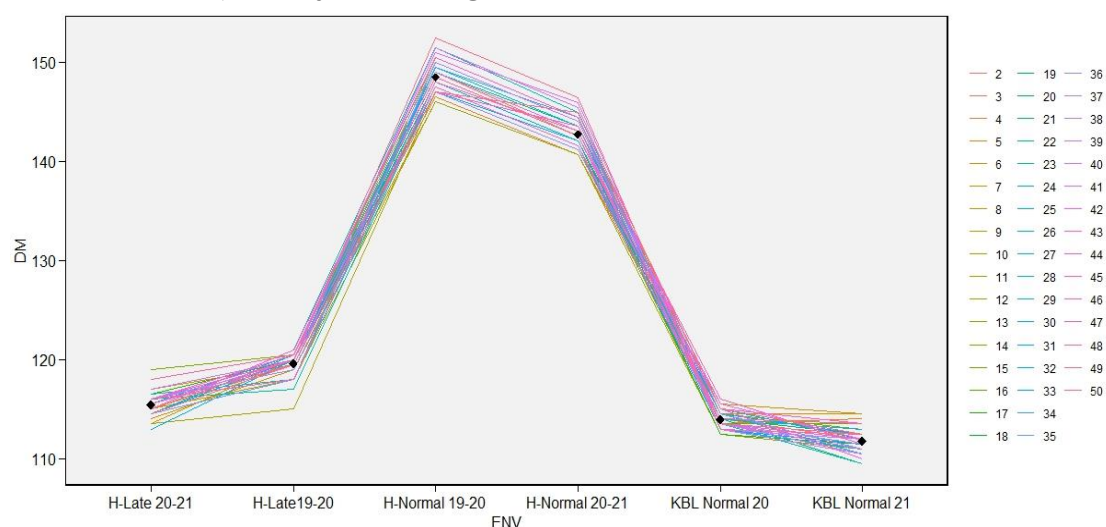


Figure 4.3: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of days to maturity

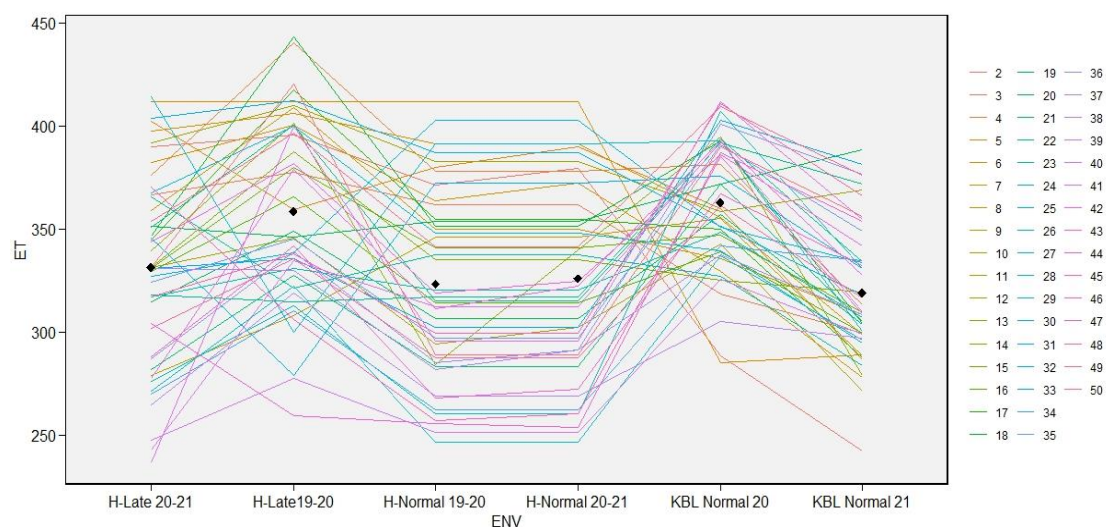


Figure 4.2: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of effective tiller m^{-2}

4.7.4 Plant height

The estimates of stability parameters for plant height, spike length and number of spikelets spike⁻¹ are presented in the table 4.29. The genotypes were showed range of plant height from 86cm to 108cm that the genotype number EC 1075894, and EC 1075940 was noted tallest and the genotype number EC 1075905 was recorded semi-dwarf, with regression coefficient higher than unity the genotypes number EC 1075921, EC 1075924, EC 1075925, EC 1075928, EC 1075931 and were stable with mean of height for all environments. More number of genotypes were observe close to zero which indices favoured under poor environments, while few number of genotypes were indices $b_i > 1$ favoured for best environments. Deviation from regression was observe non-significant for genotypes number EC 1075900, EC 1075904, EC 1075913, EC 1075915, EC 1075919, EC 1075924, EC 1075929, EC 1075931, EC 1075936, EC 1075938, EC 1075939, EC 1075940, and WH1184 respectively.

4.7.5 Spike length

With respect to the mean, stability parameter of genotypes for spike length is ranged from the 8.9cm to 11cm. The variation is moderate that genotype EC 1075915 was noted the shortest and genotype number EC 1075941 was recorded with highest length for spike length. With regression coefficient close to zero for genotypes number EC 1075941, EC 1075902, EC 1075904, EC 1075922, EC 1075928 and EC 1075930 respectively showed responsive under poor environments. While few genotypes was observed higher than the unity which is favourable for better environments. The S^2di was studied significant for 20 genotypes that is not stable for all environments respectively.

4.7.6 Number of spikelets spike⁻¹

Moderate variation was observed for mean of number of spikelets spike⁻¹, ranged from 17 to 20 that least number of spikelet spike⁻¹ was noted for 6 genotypes and more number of spikelets were recorded for genotype EC 1075894, EC 1075895 and EC 1075933. The smaller regression coefficient of variation determination is evaluating due to quit different location and the higher determination of coefficient of variation showed stable with higher pooled mean. With regression coefficient of variation equal to the unity was estimated for 5 genotypes that adaptive to intermediate environment and the regression close to zero was observed for 4 genotypes that showed responsive to the poor environments respectively. Deviation from regression was significant for 10 genotypes among the genotypes that indicated except 10 genotypes all other genotypes were stable under each specific environment or in favourable and intermediate environments.

Table 4.29: Estimates of stability parameters for plant height, spike length and number of spikelets per spikes genotypes

Characters	Plant height			Spike length			Number of spikelet per spike		
	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>Bi</i>	<i>S²di</i>
EC 1075893	96.92	0.53	1.89	9.83	3.92	4.78**	18.42	4.62	1.85
EC 1075894	108.08	0.55	0.99	9.96	-0.27	1.53	20.75	0.22	13.17
EC 1075895	100.75	-0.60	1.09	10.21	1.52	2.45*	20.00	-0.62	2.61
EC 1075896	94.08	0.36	0.84	9.71	0.98	1.64	17.83	1.09	1.75
EC 1075897	94.92	-1.36	1.97	10.13	0.44	0.05	18.50	0.60	0.47
EC 1075898	94.83	-0.43	2.44	9.46	-0.79	1.73	17.67	2.10	1.24
EC 1075899	94.33	-0.90	1.87	9.58	-1.12	0.96	19.50	-0.75	0.86
EC 1075900	99.92	1.92	2.58**	9.71	0.61	1.37	18.83	2.00	0.45
EC 1075901	96.08	1.61	1.36	9.92	0.10	1.27	19.50	2.80	2.74
EC 1075902	95.75	0.34	2.34	9.33	-0.45	0.69	18.33	-4.35	1.91
EC 1075903	96.42	1.71	0.64	9.75	-0.40	1.98	18.67	2.04	2.24
EC 1075904	99.08	-1.71	5.85**	10.21	-0.60	0.62	19.83	2.12	0.98
EC 1075905	86.33	-3.53	0.88	9.50	-2.17	1.77	19.00	1.11	0.51
EC 1075906	102.08	3.45	1.59	10.04	-0.06	1.08	19.75	1.88	1.19
EC 1075907	101.00	-1.06	1.26	9.50	2.18	1.02	18.33	0.94	0.58
EC 1075908	98.75	0.59	2.97	9.54	-1.36	4.90*	19.25	1.50	2.13
EC 1075909	100.92	-0.45	1.56	9.88	1.47	1.65	19.50	1.85	1.96
EC 1075910	106.33	-0.17	1.96	9.88	-0.07	0.42	18.50	-1.24	0.55
EC 1075911	101.92	-1.84	1.57	9.46	3.74	14.74	18.83	-0.95	0.81
EC 1075912	101.25	-0.49	0.68	9.38	-1.13	3.19**	17.50	0.21	1.18
EC 1075913	105.17	-2.04	3.112**	10.50	-3.08	3.65**	19.25	-4.47	0.79
EC 1075914	106.83	-3.99	10.76	9.88	-3.59	0.32	19.50	0.60	0.47
EC 1075915	104.33	-0.54	4.45**	8.96	0.63	0.79	18.92	-0.20	3.39**
EC 1075916	102.67	3.22	1.35	9.75	3.09	1.35	18.58	1.87	2.22
EC 1075917	105.58	-0.33	1.94	9.88	1.67	1.42	18.83	2.42	1.87
EC 1075918	103.75	-2.10	8.83	9.79	0.76	3.14**	18.33	-1.89	2.70**
EC 1075919	96.83	-2.76	4.39**	9.29	-1.13	3.13**	18.17	4.53	1.63
EC 1075920	93.58	-1.02	7.79	9.34	-1.23	2.58**	17.25	-1.73	1.97
EC 1075921	99.92	-3.61	0.91	10.04	-2.52	0.62	19.50	1.02	1.34
EC 1075922	101.33	1.34	1.49	9.58	-1.49	0.48	19.00	-3.23	0.85
EC 1075923	94.92	-2.00	2.28	10.00	-2.13	3.41**	19.50	-1.74	1.82
EC 1075924	103.75	1.09	5.82**	9.50	-3.12	4.19**	18.42	-1.99	2.71**
EC 1075925	101.17	1.33	1.38	9.58	-2.01	2.39**	18.67	-0.09	1.59
EC 1075926	103.42	-0.77	10.88	9.83	-0.26	0.65	18.33	0.45	0.68
EC 1075927	100.33	4.02	0.81	10.04	-0.76	1.89	19.33	-1.93	1.03
EC 1075928	98.67	1.36	1.85	9.96	2.01	0.22	19.17	0.93	1.24
EC 1075929	96.75	3.01	3.11**	9.04	-0.43	1.35	18.00	-0.30	1.33
EC 1075930	98.17	1.81	1.87	9.67	0.77	0.78	19.50	0.27	0.23
EC 1075931	93.33	1.11	5.47**	9.42	-4.12	1.29	17.33	-5.26	0.32
EC 1075932	102.33	-1.37	0.13	10.63	2.15	4.55**	19.00	-0.26	2.97**
EC 1075933	104.75	0.78	1.77	11.04	2.39	2.42**	20.83	0.20	2.60**
EC 1075934	101.42	0.52	6.24	9.54	2.70	6.01**	17.83	-3.90	5.30**
EC 1075935	100.92	0.21	1.83	9.50	-2.03	1.36	19.17	-0.50	1.11
EC 1075936	92.58	0.01	5.15**	9.29	-2.17	3.14	18.00	-2.42	2.40**
EC 1075937	94.58	-1.23	0.52	9.75	-0.07	1.20	18.33	-0.86	1.77
EC 1075938	96.25	3.39	4.78**	9.54	-2.89	3.75**	18.00	1.66	0.10
EC 1075939	99.08	4.22	5.04**	9.42	-0.30	1.61	18.17	-1.17	1.05
EC 1075940	108.33	-2.68	5.26**	10.18	2.20	1.18	19.50	3.59	0.22
EC 1075941	102.50	-1.77	6.61	11.04	0.95	2.62**	19.83	0.48	2.96
P Mean	99.66	-	-	9.83	-	-	18.86	-	-
S.E(mean)	1.94	1	-	0.28	1	-	0.47	1	-
S.E. of b	0.298	-	-	0.562	-	-	0.433	-	-

**Significant at 1% probability level, * Significant at 5% probability level

bi = Regression coefficient, *s²di* = Deviation from regression coefficient.

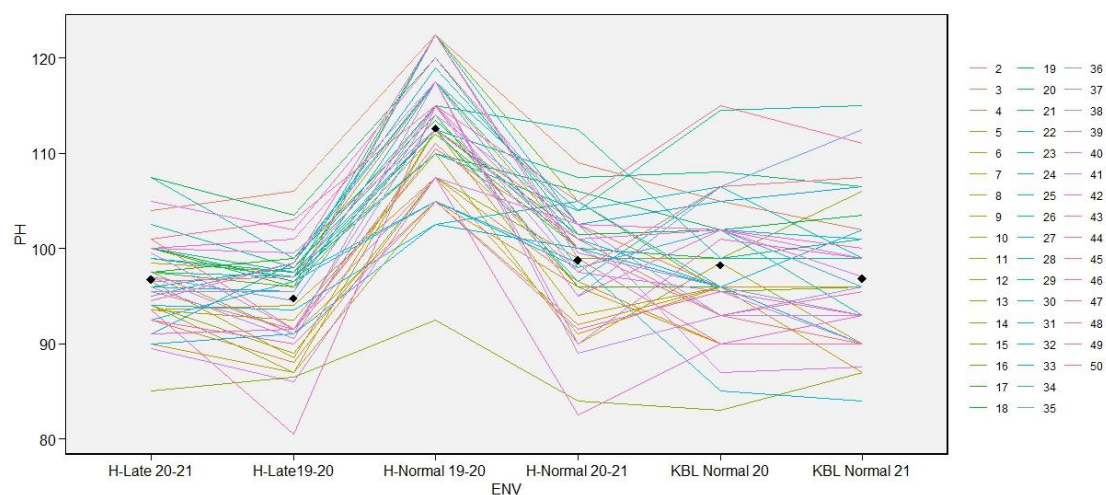


Figure 4.4: Scatter plot of wheat genotype based on three stability parameters (Mean, b_i , S^2d_i) of plant height

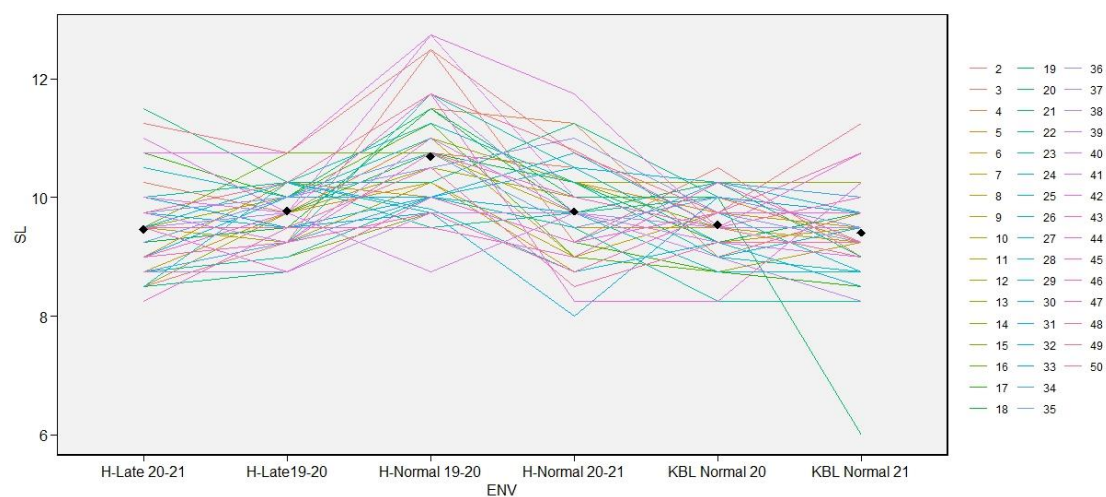


Figure 4.5: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) spike length

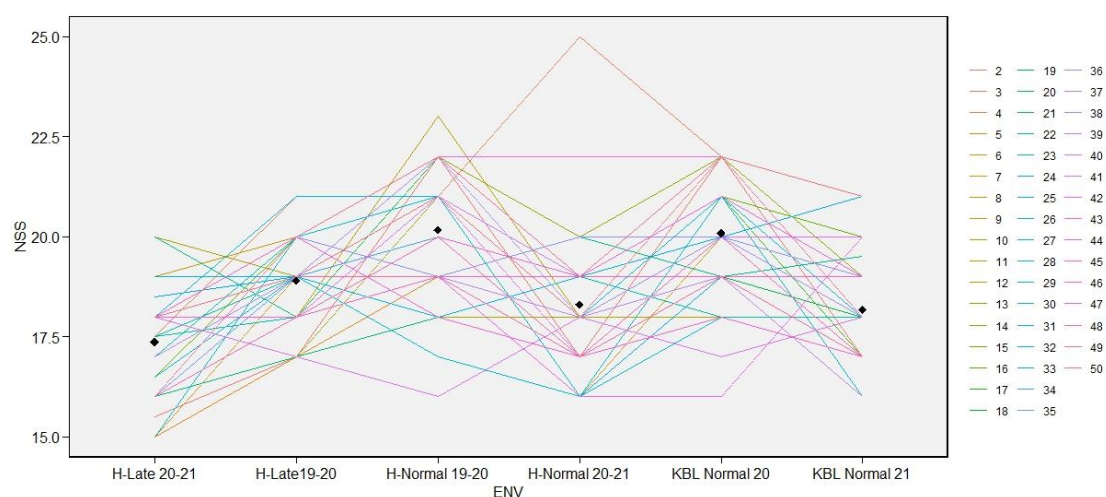


Figure 4.6: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) number spikelets spike⁻¹

4.7.7 Number of grain spike⁻¹

The analysis of variation in joint regression was showed non-significant due to the genotypes for number of grain spike⁻¹ and significant for G x E, but non-significant in pooled deviation except for genotype number EC 1075896, EC 1075936 and WH1105 that indicated non-significant due to pooled deviation for all genotypes was stable in at least specific environments with greater value of regression from the unity for 7 genotypes. The mean value among the genotypes were ranged from 48 to 65 that observed highly variation in number of grain spike⁻¹ due to the mean. Higher mean was noted for genotype number EC 1075941, 3EC 10759309, EC 1075906and EC 1075901. The regression variation was noted intermediate, ranged from -0.016 to 5.934. It indicated that higher regression value is noted with stable genotypes. The deviation from regression indices non-significant genotypes got stable and the genotypes with higher value than unity or close to zero is recorded adaptive under favored environments with high mean.

4.7.8 1000 grain weight

Estimate from the mean value for 1000 grain weight, was ranged from 36.7 to 45.24 indices wide variation among the genotypes due to mean where the higher mean was evaluated for genotypes number EC 1075898, EC 1075904, and EC 1075909 respectively with regression above the unity was showed for 5 genotypes that was responsive for better environment, while 4 genotypes was recorded close to zero or below the unity which is adaptive under poor environments. The regression with high value determine the stable of the genotypes and deviation from regression was estimated significant for 37 genotypes among all 54 genotypes. It evaluate most of the genotypes is not stable in different environments due to the 1000 grain weight. Pooled deviation was should for 35 genotypes among all genotypes that indices most of the genotypes was not stable with high regression in few genotypes evaluated stable under favored environments. The high mean was noted for genotypes EC 1075913and EC 1075941respectively.

4.7.9 Biological yield

Estimate from the biological yield pooled mean was ranged from 5712 to 7701 with regression coefficient of variation above the unity was showed for 3 genotypes that is responsive in better environments and $bi < 1$ or close to zero was observed for 6 genotypes indicated responsive in poor environment. Regression was varied from -0.1 to -14.1 and 6.77 which wide variation is estimated among all genotypes for regression. Deviation from regression was significant for 31 genotypes indicating most of the genotypes was not stable due to the biological yield among all genotypes.

Table 4.30: Estimates of stability parameters for number grain spik^{-1} , 1000 grain weight and biological yield of wheat genotypes.

Characters	Number of grain per spike			1000 seed weight			Biological yield		
	Mean	bi	S^2di	Mean	bi	S^2di	Mean	bi	S^2di
EC 1075893	56.10	1.83	5.46	41.11	2.10	1.96	6577.86	-1.69	4.56**
EC 1075894	56.55	-0.61	1.24	37.94	1.50	1.85	6860.40	-5.41	7.10**
EC 1075895	57.46	0.29	0.35	39.17	1.74	2.91**	6922.30	0.53	0.57
EC 1075896	51.96	0.22	2.80**	41.59	0.08	5.05**	6275.00	-7.49	6.31**
EC 1075897	55.69	-2.45	1.19	42.51	3.22	5.30**	6939.37	-1.78	2.70**
EC 1075898	52.57	-0.86	1.81	44.38	-0.92	1.72	7193.25	1.79	2.51**
EC 1075899	56.44	-1.05	0.13	41.73	1.43	2.56**	6312.22	1.78	18.53**
EC 1075900	59.33	1.25	2.27	43.61	2.50	5.33**	6817.46	1.44	1.16
EC 1075901	60.52	1.17	0.83	40.30	2.48	0.14	6887.86	0.20	3.01**
EC 1075902	52.19	-2.81	1.94	40.41	0.25	4.59**	6979.05	0.23	2.43**
EC 1075903	53.96	1.97	2.11	40.07	-1.89	1.70	7161.98	1.55	1.64
EC 1075904	54.19	-1.14	0.21	44.31	-0.70	1.52	7557.70	5.49	1.24
EC 1075905	54.27	1.40	1.97	36.94	2.23	7.98	6960.71	4.61	5.95**
EC 1075906	62.03	-0.02	0.29	37.66	0.47	4.01**	7032.46	-0.39	0.39
EC 1075907	57.69	2.90	0.56	40.68	-1.76	8.88**	6762.94	1.28	3.57**
EC 1075908	50.46	1.59	0.75	40.86	-4.20	31.91**	6588.25	-3.97	3.21**
EC 1075909	58.32	2.86	1.16	44.28	0.64	5.83**	7086.19	1.02	3.21**
EC 1075910	57.23	0.49	3.23	39.88	0.50	12.43**	7091.67	-0.16	2.14
EC 1075911	55.09	0.16	0.03	37.56	-2.93	1.70	6890.56	-0.39	0.61
EC 1075912	53.57	-0.66	1.29	38.95	-3.25	4.08**	7229.84	5.75	0.22
EC 1075913	56.86	-5.31	3.35	40.55	-2.17	0.76	7509.37	3.65	2.71**
EC 1075914	52.57	-1.52	1.08	39.04	2.97	9.16**	7004.05	-1.33	1.62
EC 1075915	51.83	-0.68	1.08	39.00	3.50	13.76**	6397.58	-4.07	9.91**
EC 1075916	59.37	0.59	0.16	39.09	-0.30	5.11**	6466.19	-2.37	3.31**
EC 1075917	50.81	-0.75	1.99	38.05	-0.43	2.22**	6528.33	0.93	6.36**
EC 1075918	57.56	1.50	12.92	39.00	1.19	2.67**	6148.02	-6.03	4.99**
EC 1075919	53.05	5.93	0.80	38.53	-2.15	10.29**	6716.67	4.09	0.85
EC 1075920	50.18	0.49	4.95	38.83	0.13	36.95**	6840.87	-2.26	7.60**
EC 1075921	55.66	-1.60	0.20	37.73	1.35	7.77**	7439.21	6.78	5.22**
EC 1075922	53.52	1.19	5.28	38.56	-1.59	1.97	6948.02	2.36	1.37
EC 1075923	48.44	-2.44	3.77	37.18	3.43	7.03**	7002.14	2.68	2.38
EC 1075924	56.31	2.70	3.12	35.31	0.22	30.76**	6867.54	3.38	2.15
EC 1075925	55.92	0.95	1.72	38.43	-0.41	6.06**	6819.76	0.76	2.39
EC 1075926	56.94	0.31	11.23	40.02	-0.35	1.29	7169.76	5.64	3.20**
EC 1075927	57.62	-0.55	6.76	41.76	-0.09	2.32**	6879.05	5.76	4.28**
EC 1075928	61.83	4.36	1.44	40.62	-1.47	5.00**	6714.47	0.78	6.42**
EC 1075929	56.53	3.66	5.11	42.01	-1.85	10.63	6218.65	-4.44	3.51**
EC 1075930	61.04	-0.46	5.12	41.01	-0.62	10.75**	6620.64	4.22	3.23**
EC 1075931	49.61	-2.65	3.75	38.92	0.47	1.20	6467.62	4.36	3.77**
EC 1075932	58.40	-3.94	11.73	41.72	0.85	0.20	7632.74	6.34	8.49**
EC 1075933	57.47	-2.33	2.18	38.69	1.63	8.66**	7200.24	3.03	1.23
EC 1075934	54.36	-0.67	0.21	40.76	-1.11	7.18**	7117.54	0.63	1.56
EC 1075935	54.08	-2.45	0.21	43.12	0.81	4.10**	6475.00	-0.14	0.62
EC 1075936	54.12	-1.00	4.29**	41.56	-0.18	7.32**	6337.06	2.36	7.37**
EC 1075937	54.53	-1.59	0.90	39.50	-0.95	0.88	6691.98	0.56	6.25**
EC 1075938	55.02	-0.21	0.13	41.12	-3.30	2.71*	6644.68	5.95	7.48**
EC 1075939	53.10	1.26	0.23	42.62	-3.02	15.70*	5712.41	-3.73	3.48**
EC 1075940	57.45	-0.38	2.59	38.63	-1.10	3.24*	7513.25	2.72	1.08
EC 1075941	65.63	-0.26	1.10	40.23	-0.40	11.80*	7701.83	4.62	10.06**
P Mean	55.11	-	-	40.1	-	-	4,357.76	-	-
S.E(mean)	2.4	1	-	1.59	1	-	285.73	1	-
S.E. of b	0.745	-	-	0.664	-	-	0.129	-	-

**Significant at 1% probability level, * Significant at 5% probability level

bi = Regression coefficient, s^2di = Deviation from regression coefficient.

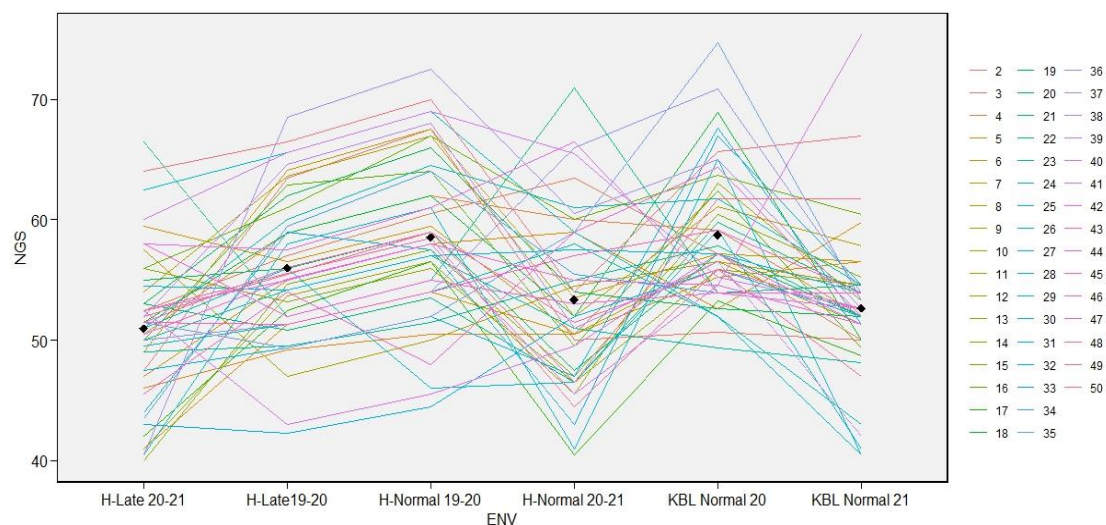


Figure. 4.7: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of number of grain spike⁻¹

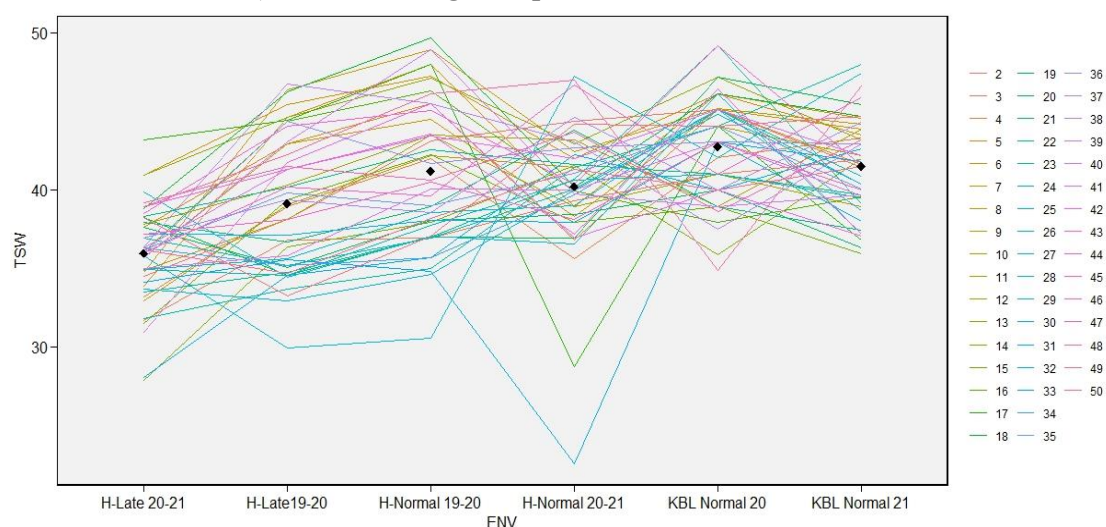


Figure. 4.8: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of 1000 grain weight

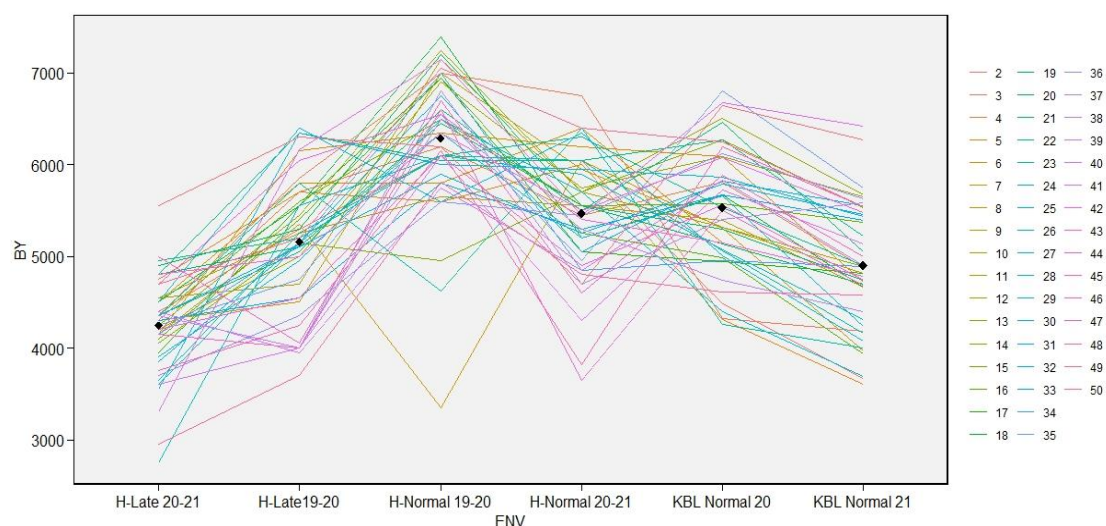


Figure. 4.9: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of biological yield

4.7.10 Harvest index

The estimate of stability parameters for harvest index was observed in close range of performance that, only genotypes number EC 1075892, EC 1075894, EC 1075897, and EC 1075912 were noted higher mean than the general mean over environments. It was ranged from the 32% to 36% with regression coefficient of variation was above the unity for three genotypes, was adapted in better environment and for six genotype deviation from regression close to zero, responsive in poor environment. As regards to deviation from regression, the non-linear component expressed as deviation from regression observed significant for 18 genotypes were not adapted over all environment and the remaining of them are rated stable respectively. The regression coefficient of variation was recorded narrow range from -0.1 to the high value 3.6 due to the harvest index, indicated the wide variation is disappear due to the regression coefficient variation observation.

4.7.11 Grain yield

The estimates of stability parameter for grain yield as regards to the mean performance wide range of variation were found, from 2076g to 2777g. The higher mean value over the all genotypes were observed for genotypes number EC 1075898, EC 1075904, EC 1075913, EC 1075927, and EC 1075932 respectively with regression coefficient of variation over the unity for EC 1075906 genotype and close to zero was depicted for genotype EC 1075895, EC 1075900, EC 1075906, EC 1075912, EC 1075935 genotypes adapted to the poor environment. A wide range of regression coefficient of variation was observed from -0.4 to 12.3, indices the wide responsive of the genotypes over the environments. Deviation from regression was depicted significantly difference performance for 33 genotypes among the genotypes, was noted unstable performance and the remaining of them are rated stable.

These results are depicted through the Table (4.34). Thus, in the results mentioned in foregoing paragraphs ample efforts were made to categories genotypes with regard to their performance, variability components, environmental response and stability behaviour for the grain yield investigated on them and explanations have been pointed out instantly.

Table 4.31: Estimates of stability parameters for harvest index and grain yield for wheat genotypes

Characters	Harvest index			Grain yield		
	Mean	bi	S^2di	Mean	bi	S^2di
EC 1075893	35.08	-4.90	1.47	2302.84	-8.53	9.57**
EC 1075894	32.39	-1.09	1.82	2289.07	-9.70	6.60
EC 1075895	36.02	1.05	1.05	2552.22	2.64	0.72
EC 1075896	34.65	-2.69	0.99	2237.60	-9.86	6.38*
EC 1075897	36.33	-1.85	0.46	2536.39	-3.98	3.43*
EC 1075898	35.84	-0.17	2.68**	2661.35	4.32	3.18*
EC 1075899	35.21	-4.99	3.13**	2285.16	-0.23	13.17**
EC 1075900	34.65	-3.28	1.43	2438.85	-0.43	0.60
EC 1075901	35.40	0.59	3.75	2468.97	-1.49	0.98
EC 1075902	33.16	3.45	7.96	2355.75	-0.41	1.29
EC 1075903	35.16	2.19	0.73	2614.78	5.22	1.51
EC 1075904	35.38	3.01	2.93**	2757.38	7.78	0.87
EC 1075905	35.49	-4.75	10.87	2570.31	7.56	1.51
EC 1075906	33.92	0.24	0.88	2498.04	1.10	0.99
EC 1075907	33.17	-0.79	3.69**	2305.78	-3.49	3.28**
EC 1075908	34.98	2.05	1.50	2349.23	-4.04	3.26**
EC 1075909	35.12	-0.64	1.54	2569.69	1.00	5.26**
EC 1075910	34.51	-2.57	2.18	2500.91	-3.66	3.08**
EC 1075911	34.44	-1.20	2.58**	2439.01	-1.49	1.46
EC 1075912	36.24	0.32	2.19	2694.57	7.77	0.98
EC 1075913	35.94	1.69	1.39	2756.97	5.01	6.53
EC 1075914	34.96	2.00	6.67	2519.39	0.28	7.43
EC 1075915	34.13	-6.00	2.62**	2193.07	-9.70	3.41**
EC 1075916	33.12	2.23	0.55	2232.22	-1.61	2.91**
EC 1075917	34.09	1.03	3.40**	2232.92	-1.21	4.23**
EC 1075918	35.83	1.52	6.49	2203.31	-8.45	5.60**
EC 1075919	34.19	0.69	3.96**	2330.62	3.38	1.57
EC 1075920	33.91	-2.40	4.41**	2390.23	-3.83	10.82**
EC 1075921	34.60	-3.12	4.06**	2589.39	3.37	1.87
EC 1075922	35.18	-0.18	2.31	2536.05	2.66	1.57
EC 1075923	33.52	2.38	1.61	2443.47	4.18	4.31**
EC 1075924	32.74	3.53	2.21	2331.40	3.69	4.57**
EC 1075925	32.81	2.83	3.43	2244.61	-2.93	1.32
EC 1075926	34.82	3.66	1.41	2629.63	12.35	3.06**
EC 1075927	34.46	0.36	3.23**	2452.88	7.22	5.32**
EC 1075928	34.34	0.79	1.17	2377.41	0.47	9.26**
EC 1075929	34.47	-0.56	3.83**	2223.25	-4.72	4.23**
EC 1075930	34.61	-0.03	2.23	2367.44	4.69	7.36**
EC 1075931	34.42	-0.49	0.26	2314.93	4.54	3.78*
EC 1075932	35.51	3.07	2.08	2777.65	9.87	5.72*
EC 1075933	34.94	1.15	0.45	2594.63	5.00	1.49
EC 1075934	34.43	0.91	5.18**	2438.11	-3.19	1.84
EC 1075935	34.39	2.12	6.56	2336.88	2.54	0.78
EC 1075936	35.20	-1.63	1.35	2299.22	2.19	8.79**
EC 1075937	34.64	3.11	2.30	2418.93	4.52	11.05**
EC 1075938	34.28	0.49	2.79**	2398.24	8.44	11.57**
EC 1075939	35.41	-1.65	1.51	2076.81	-4.27	4.51**
EC 1075940	34.89	2.69	1.59	2707.44	5.54	1.44
EC 1075941	33.82	2.29	2.54**	2664.83	10.50	9.99**
P Mean	34.66	-	-	2419.53	-	-
S.E(mean)	1	1	-	101.55	1	-
S.E. of b	0.516	-	-	0.132	-	-

**Significant at 1% probability level, * Significant at 5% probability level

bi = Regression coefficient, S^2di = Deviation from regression coefficient.

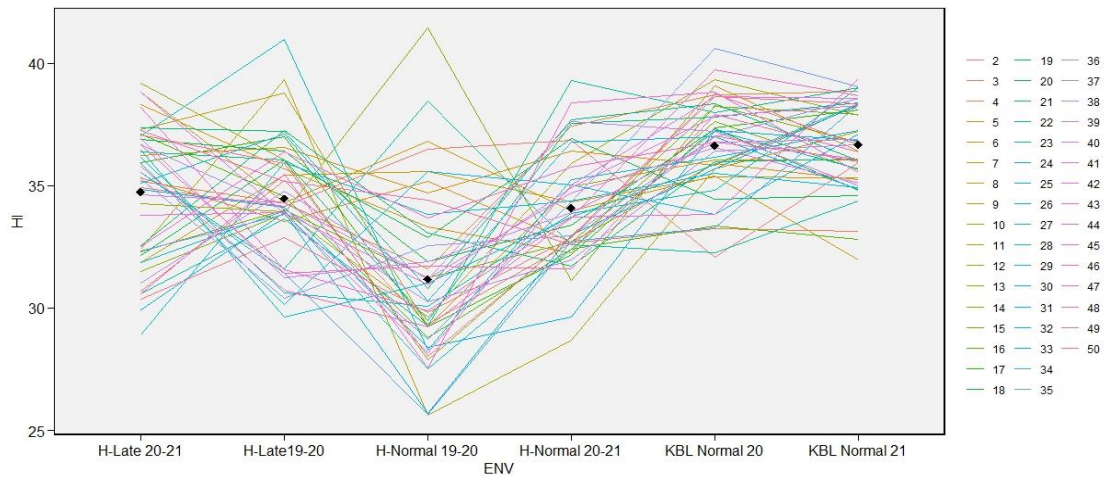


Figure. 4.10: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of harvest index

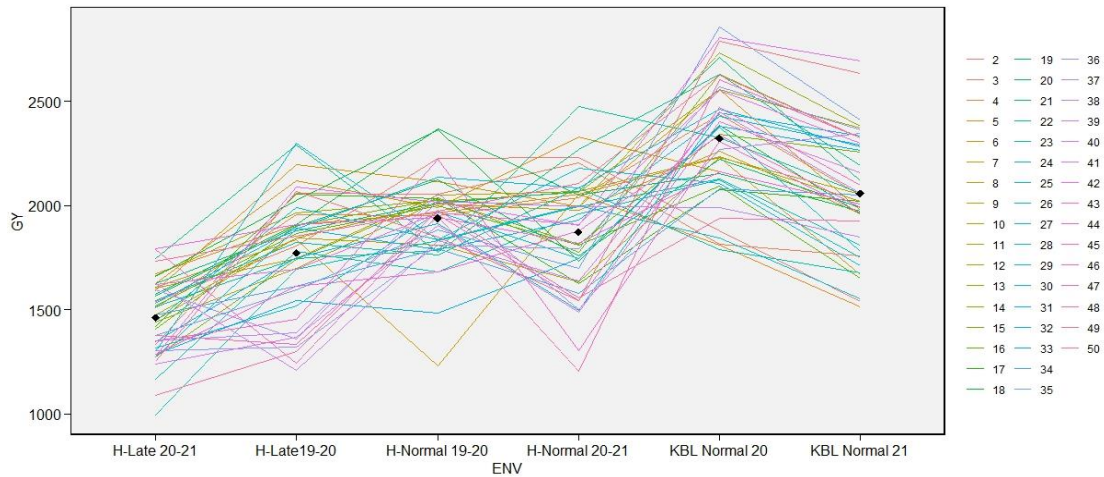


Figure. 4.11: Scattering pattern of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of grain yield

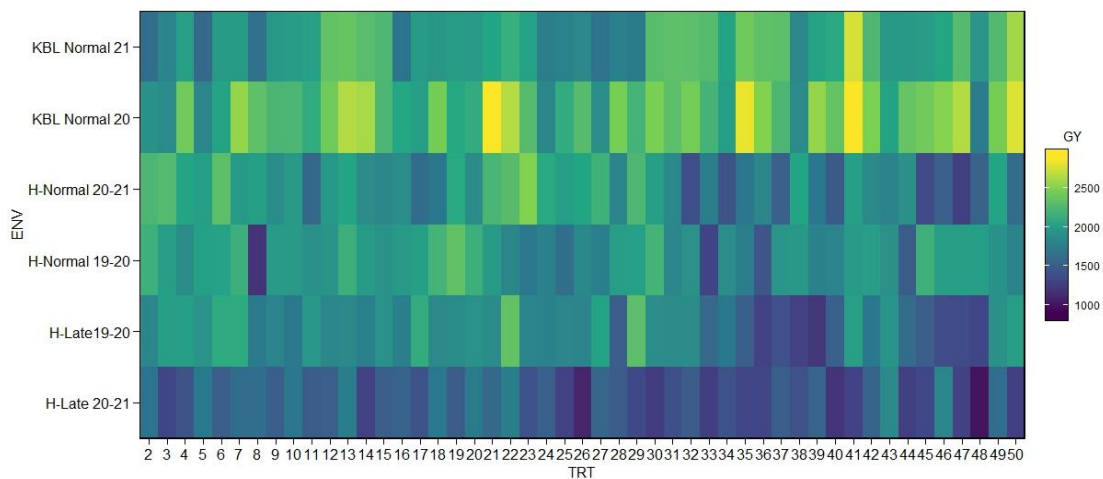


Figure. 4.12: Heat map of wheat genotypes for grain yield of six environment

4.8 Stability analysis for quality traits

4.8.1 Wet gluten

The stability parameters for wet gluten ranged from the 22.81% (EC 1075926) to 35.73% (EC 1075941) indicated significant variation, with mean of 29.34, in this investigation, prediction of performance was possible only for 8 genotypes having non-signification non-linear component (S^2_{di}) that total 26 genotypes having low mean value. The regression coefficient of variation was found above than the unity for genotype EC 1075908, that favoured to better environments and genotypes showed lower the unity is favourable in poor environments. While genotypes EC 1075895, EC 1075899, EC 1075900, EC 1075901, EC 1075907, EC 1075919, EC 1075929, EC 1075932 was found non-significant and all other was found significant due to deviation from regression. It indicates all genotypes only 8 genotypes were stable. Deviation from regression was found significant for 48 genotypes that noted stable in none of the environments.

4.8.2 Dry gluten

It estimated due to the mean, rated from 7.36% (EC 1075936) with mean of 29.34% and 17 genotypes showed lower mean with regression coefficient of variation higher than the unity for none of the genotypes and lower the unity was noted for EC 1075906, EC 1075914, EC 1075921 that is stable under poor environments. The deviation from regression rated close to zero for genotypes EC 1075901, EC 1075902, EC 1075917, EC 1075922, EC 1075926, EC 1075929 and EC 1075936, along with 10 other genotypes showed non-significant. It revealed these genotypes are stable under favourite environments. 37 genotypes were significantly different due to deviation from regression was significant or in addition, close to zero was noted for the none of the genotypes were found unstable in all the environments and the genotypes with higher mean non-significant from zero due to deviation from regression with regression equal to the unity is stable under all environments.

4.8.3 Crude protein

Estimated the mean of the crude protein was ranged from 10.29% (EC 1075936) to 13.77% (EC 1075914) with mean of the 12.13 %. The minimum rang of crude protein was rated for genotypes EC 1075914 genotypes. And the rest of them were rated higher mean with regression coefficient of variation above the unity for genotype number EC 1075896, EC 1075936 and equal to the unity was recorded for genotype (EC 1075925). The genotype with bi above the unity was stable for better environments and equal to the unity is stable for favourable environments. The bi below the unity was noted for 6 genotypes that adapted to poor environment. Deviation from regression was significant for 35 genotypes and other was non-significant or close to zero is stable.

Table 4.32: Estimates of stability parameters for wet gluten, dry gluten, and crude protein in wheat genotypes

Characters	Wet gluten (%)			Dry gluten (%)			Crude protein (%)		
	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>
EC 1075893	30.27	0.92	10.32**	10.31	5.25	9.27**	13.39	4.62	9.67**
EC 1075894	30.88	-0.14	9.18**	10.60	2.10	3.07**	12.36	-0.98	18.18**
EC 1075895	31.86	-3.78	1.30	10.62	-0.99	2.00	12.76	-0.68	3.39**
EC 1075896	33.59	-2.14	7.15**	10.50	-0.86	3.03**	12.57	1.17	2.46*
EC 1075897	27.87	0.67	20.63**	8.84	3.36	4.96**	12.45	0.16	8.24**
EC 1075898	27.33	0.73	16.79**	8.75	-0.07	5.66**	11.96	-2.26	2.48**
EC 1075899	29.75	-1.60	2.12	9.34	-1.59	1.27	11.73	-3.71	1.38
EC 1075900	26.38	0.65	6.30	9.26	-1.85	5.52**	11.96	-3.50	3.25**
EC 1075901	28.18	-1.62	2.38	9.93	-0.65	0.08	12.41	0.07	0.73
EC 1075902	25.90	2.53	4.87**	8.67	-0.51	0.56	11.36	0.00	0.46
EC 1075903	30.26	-2.75	13.21**	9.78	-3.55	4.48**	12.05	-1.68	1.59
EC 1075904	32.93	0.68	3.54**	9.86	-1.74	1.83	12.05	-5.13	1.61
EC 1075905	27.56	-0.46	6.54**	9.18	-0.54	6.06**	12.72	-2.77	3.00**
EC 1075906	30.35	2.22	18.77**	10.37	0.80	30.21**	13.55	-2.45	3.01**
EC 1075907	30.07	2.83	1.21	9.90	-0.47	4.31**	12.27	3.06	4.81**
EC 1075908	27.92	1.49	21.90**	9.20	-0.13	33.96**	12.79	-7.88	1.62
EC 1075909	31.69	3.24	4.92**	10.10	2.59	2.83**	12.90	-1.44	7.99**
EC 1075910	28.56	4.08	11.85*	9.07	3.24	10.47**	13.01	-4.80	2.54**
EC 1075911	28.01	4.69	8.93**	9.28	3.59	3.02**	12.36	0.52	9.29**
EC 1075912	29.50	3.07	35.16**	8.98	4.44	23.23**	12.93	-1.16	5.27*
EC 1075913	28.41	3.16	11.18**	9.22	4.74	7.38**	12.93	4.34	2.20
EC 1075914	30.12	0.76	3.68**	10.15	0.97	2.67**	13.77	2.06	6.90**
EC 1075915	27.25	-0.01	5.11**	8.70	4.24	4.11**	12.64	7.85	3.89**
EC 1075916	22.81	-1.58	9.98**	7.76	2.75	9.33**	11.38	-1.24	5.68**
EC 1075917	24.78	0.38	3.29*	7.77	-0.25	0.68	10.51	-1.37	6.45**
EC 1075918	26.52	-0.82	3.69**	8.33	2.60	2.54*	11.53	-0.43	2.83**
EC 1075919	29.39	0.13	1.16	8.94	-0.16	1.39	11.50	-0.30	2.38
EC 1075920	30.24	-1.64	5.14**	9.64	-3.59	3.40*	11.74	-4.90	1.06
EC 1075921	28.03	0.07	4.59**	8.84	0.43	7.62*	11.92	-3.23	0.84
EC 1075922	26.83	1.02	2.97**	7.98	-0.10	0.59	11.03	1.64	2.62**
EC 1075923	27.26	2.93	8.27**	8.49	1.61	4.15*	11.73	-0.91	2.32**
EC 1075924	25.99	1.62	5.47*	8.52	-1.97	4.17*	11.44	-0.77	8.47**
EC 1075925	29.57	-4.45	5.32*	9.14	-1.77	2.38	11.30	1.00	0.61
EC 1075926	26.15	0.73	3.18*	8.35	-0.24	0.48	11.41	-0.96	4.01**
EC 1075927	33.52	-3.59	48.54*	10.30	-5.73	21.07*	11.71	0.73	1.64
EC 1075928	26.62	1.81	9.62*	8.27	2.36	3.94*	11.63	0.73	0.16
EC 1075929	29.32	-4.96	1.27	9.80	-1.72	0.74	12.14	-0.96	3.06**
EC 1075930	26.93	-0.11	4.32**	8.76	2.79	2.66*	12.24	-0.54	3.99*
EC 1075931	30.92	-4.51	11.74*	9.90	0.63	1.21	13.10	-0.91	2.64*
EC 1075932	30.12	-1.34	1.65	9.78	-1.32	2.09	11.86	-4.72	1.14
EC 1075933	34.34	-2.21	28.95**	9.98	-0.78	17.82*	12.08	1.61	13.81**
EC 1075934	31.49	-1.83	21.89**	9.93	-1.05	19.19**	11.59	5.48	3.02**
EC 1075935	28.76	2.27	2.49**	9.01	-0.68	1.58	11.02	2.66	1.14
EC 1075936	23.75	-0.77	4.37**	7.36	-3.62	0.57	10.29	1.29	30.73*
EC 1075937	28.09	1.75	6.61**	8.66	-4.30	2.01	11.00	3.75	7.09*
EC 1075938	34.69	-0.55	42.20**	10.92	-2.00	38.68*	12.34	6.08	2.86*
EC 1075939	33.56	-0.76	29.87**	10.14	-3.08	22.42**	11.70	2.67	14.09*
EC 1075940	29.41	0.28	3.58**	9.05	2.64	2.67**	12.03	1.84	10.82**
EC 1075941	35.73	-2.14	30.55**	11.06	-4.41	31.40**	12.86	3.43	6.73**
P Mean	29.01	-	-	9.42	-	-	12.13	-	-
S.E(mean)	2.01	1.00	-	0.61	1.00	-	0.47	1.00	-
S.E. of b	0.654	-	-	1.09	-	-	0.561		

*, ** = Significant at 5 and 1% level of significance, respectively.

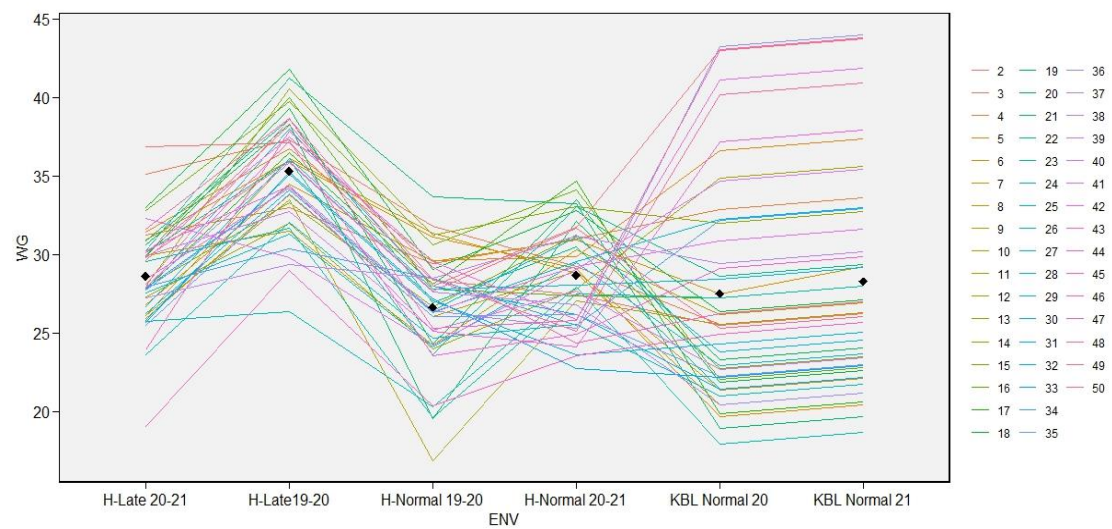


Figure. 4.13: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Wet Gluten

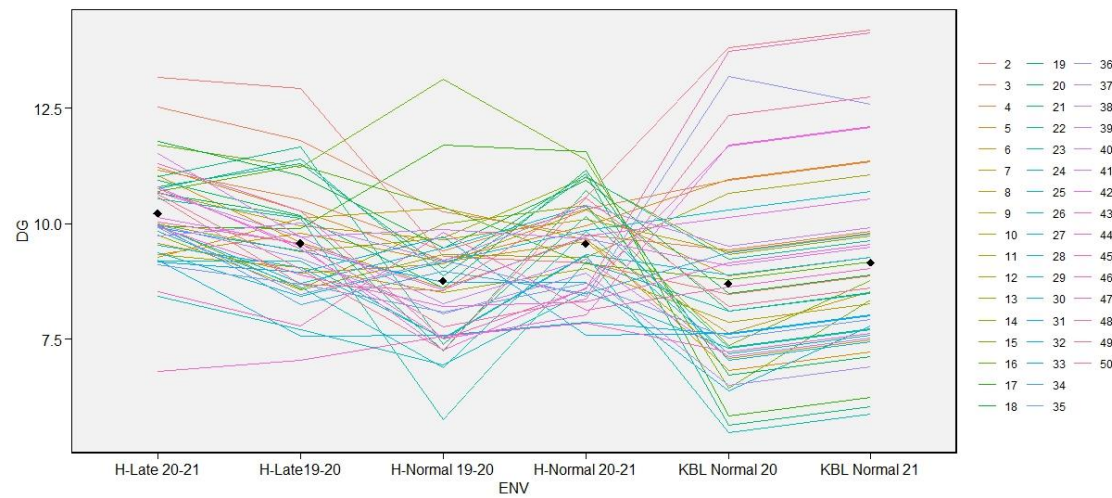


Figure 4.14: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Dry Gluten

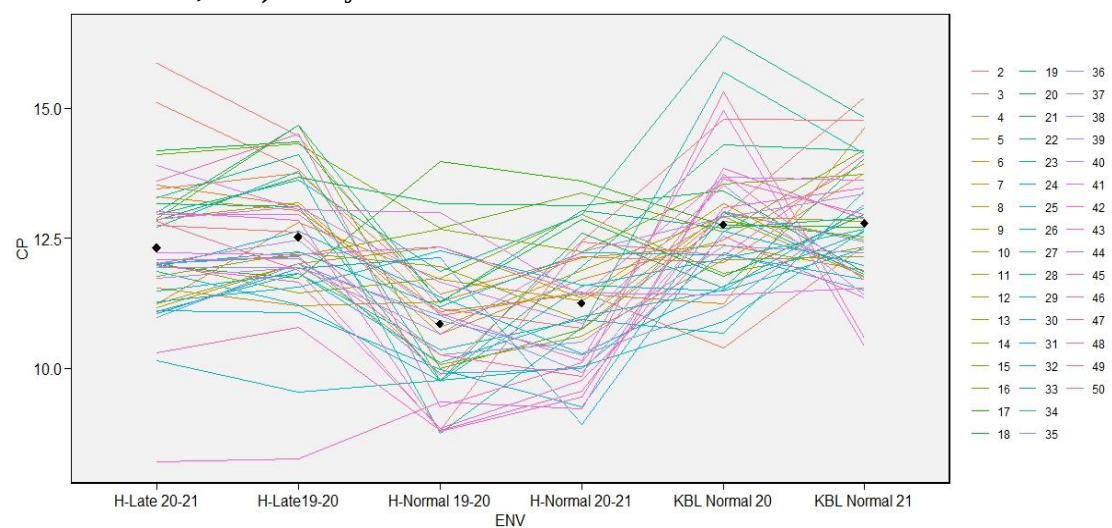


Figure 4.15: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Crude Protein

4.8.4 Beta-carotene

From the study observed beta-carotene is another important quality parameter which is highly influenced by environment. The stability parameters for grain beta-carotene content due to the mean were illustrated from 2.46 (EC 1075924) to 4.42 (EC 1075934) with the mean 3.22 and 17 genotypes noted least mean value while other were showed higher mean. The regression coefficient of variation exhibited above the unity for genotype EC 1075901, EC 1075935, WH1024 adapted to the better environment and bellow the unity for genotypes EC 1075910, EC 1075912, EC 1075918 that rated stable for poor environments. Deviation from regression was recorded significant for 43 genotypes from zero and rest of them were estimated non-significant or close to the zero adapted to favoured environments. The greater mean with regression above the unity and non-significant from zero due to deviation from regression was adapted genotypes to favourable environments.

4.8.5 Iron (Fe)

The stability parameters for Fe in mean was rated from 15.31 (EC 1075928) to 25.98 (EC 1075908) with the mean of 19.89. Least mean value were depicted for 23 genotypes and the rest were rated above mean or in range of the mean. From the exhibition of the mean value it showed high variation among the genotypes. With regression coefficient of variation above the unity is rated for genotype EC 1075926, EC 1075928, EC 1075929, EC 1075933, EC 1075938 adapted to the better environment and bellow the unity was depicted for genotypes EC 1075898, EC 1075924 and EC 1075939 adapted to the poor environments. Deviation from regression was significant for 35 genotypes out of all genotypes and rest of them was non-significant or close to the zero, was stable.

4.8.6 Zinc (Zn)

The stability parameter for Zn as regards to the mean variation was depicted varied among all genotypes that ranged from the 14.78 (EC 1075925) to 29.15 (EC 1075893) with the mean of 19.36 ppm. The lowest mean was noted for 34 genotypes and the remaining was above the range. The regression coefficient of variation was above the unity for genotypes EC 1075925, EC 1075926, EC 1075929 stable in better environments, while equal to the unity was only noted for genotype EC 1075894 which adapted favourable environments and below the unity was noted for genotypes EC 1075909, EC 1075910, EC 1075911, EC 1075914, EC 1075927, EC 1075928, and EC 1075937 adapted to the poor environment. The deviation from regression was illustrated significant for none of the genotypes or noted close to the zero among all genotypes adapted to the environment.

Table 4.33: Estimates of stability parameters for beta carotene, iron, and zinc of wheat genotypes

Characters	β -Carotene (ppm)			Fe (ppm)			Zn (ppm)		
	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>
EC 1075892	3.13	-4.85	10.41**	19.87	-6.47	5.33**	27.26	-0.14	0.03
EC 1075893	2.95	-4.19	18.01**	20.36	-8.16	5.45**	29.15	-1.77	1.74
EC 1075894	3.56	-0.67	10.17**	20.89	-1.74	61.38**	25.65	1.00	0.28
EC 1075895	3.09	-5.03	4.96**	18.15	-1.02	15.09**	23.18	5.09	0.36
EC 1075896	3.32	-6.54	4.83**	19.05	-2.41	9.50**	23.32	5.01	0.60
EC 1075897	3.06	1.82	25.60**	18.52	-4.16	5.31**	18.94	6.03	1.66
EC 1075898	2.66	2.46	3.56**	18.69	0.52	2.25**	22.95	6.98	0.75
EC 1075899	3.48	2.53	12.62**	18.39	5.17	3.30**	22.61	8.46	0.54
EC 1075900	3.01	-1.85	1.33	16.74	-1.63	2.08	21.89	8.25	0.57
EC 1075901	2.90	1.09	4.71**	20.49	-2.32	8.08**	21.23	9.36	0.57
EC 1075902	3.11	-1.84	3.30**	20.47	-1.14	6.77**	20.85	10.18	2.56
EC 1075903	3.11	-1.39	15.61**	21.83	-3.22	4.53**	19.17	5.36	1.05
EC 1075904	2.95	-1.45	11.09**	22.51	2.82	3.13**	19.12	-2.65	0.29
EC 1075905	3.76	2.65	11.45**	20.35	-5.32	7.61**	17.46	-0.37	0.07
EC 1075906	3.39	2.32	4.71**	22.05	-3.21	6.19**	15.71	1.05	0.78
EC 1075907	2.99	-3.57	2.17	18.92	-1.65	11.97**	16.79	-0.44	0.37
EC 1075908	3.38	-1.91	16.24**	25.98	9.88	4.70**	16.43	-1.74	0.51
EC 1075909	2.95	-2.22	3.98**	20.81	-1.31	6.59**	15.15	0.87	0.13
EC 1075910	3.09	0.06	8.95**	23.36	1.31	1.60	15.82	0.18	0.10
EC 1075911	3.63	3.93	35.30**	24.36	-4.94	3.51**	17.87	0.11	0.68
EC 1075912	2.86	0.04	2.51**	23.44	3.07	2.05	19.47	-4.86	0.30
EC 1075913	3.25	3.25	9.58**	19.90	4.23	2.63**	16.93	2.09	0.23
EC 1075914	3.02	2.17	4.76**	18.32	-0.66	2.44**	18.84	0.11	0.70
EC 1075915	3.30	6.84	33.95**	17.03	-0.51	1.48	19.40	-4.45	0.43
EC 1075916	3.16	2.64	4.46*	18.97	-1.09	1.82	19.08	-3.75	1.41
EC 1075917	3.22	2.54	3.56*	17.20	-1.78	2.32**	19.46	-0.47	0.54
EC 1075918	3.41	0.18	7.27*	17.78	-1.35	1.62	17.86	-5.62	0.19
EC 1075919	2.55	6.23	38.28*	19.35	4.24	5.12**	18.21	-2.33	0.53
EC 1075920	2.60	-6.15	3.48*	19.59	2.52	2.20	20.31	-6.88	2.19
EC 1075921	3.13	-8.78	12.10*	18.75	-0.50	3.46	16.56	-4.93	1.22
EC 1075922	3.05	-1.67	2.85*	19.50	-3.33	13.16**	17.55	-4.18	0.19
EC 1075923	2.52	-2.18	6.23*	17.54	-0.55	3.45**	17.43	2.38	0.58
EC 1075924	2.46	-1.56	0.78	15.88	0.78	36.65**	18.81	4.13	1.12
EC 1075925	2.84	-6.06	21.79*	19.10	-2.16	9.99**	14.78	1.36	0.30
EC 1075926	3.46	1.65	0.61**	20.96	1.04	14.85**	16.65	1.09	0.11
EC 1075927	3.43	2.48	6.65**	17.01	2.48	35.14**	17.13	0.79	0.22
EC 1075928	3.18	2.12	11.03**	15.31	1.08	33.35**	17.81	0.81	0.09
EC 1075929	3.26	1.77	5.31**	18.91	1.10	7.01**	17.78	1.07	0.92
EC 1075930	3.66	2.70	6.50**	19.69	-2.17	1.52	16.77	-4.09	2.40
EC 1075931	4.02	2.14	11.32**	16.45	-1.26	43.98**	16.11	-4.88	0.61
EC 1075932	3.84	4.03	7.42**	21.04	8.45	28.89**	24.11	-8.85	0.84
EC 1075933	3.91	2.18	4.45**	19.96	1.11	2.53**	16.65	-2.27	0.42
EC 1075934	4.42	6.06	11.71**	19.59	-2.58	8.00**	21.84	-4.56	1.07
EC 1075935	3.81	1.22	8.76**	18.80	-3.35	3.21**	17.98	-0.35	0.51
EC 1075936	2.67	-4.64	6.34**	18.83	-1.07	6.91**	28.14	-5.63	0.85
EC 1075937	4.09	2.64	22.46**	20.33	-0.63	0.26	18.68	0.99	0.20
EC 1075938	3.37	-0.70	1.04	21.53	1.49	0.20	22.03	3.55	0.68
EC 1075939	3.30	-3.83	1.83	19.03	0.95	4.23	16.31	1.73	0.43
EC 1075940	2.99	-1.89	12.16	18.74	2.11	3.34	16.48	-2.00	0.45
EC 1075941	3.00	-2.14	23.53	18.13	-1.01	5.08	15.68	-1.95	0.24
P Mean	3.23	-	-	19.89	-	-	19.36	-	-
S.E(mean)	0.24	1.00	-	1.74	1.00	-	0.64	1.00	-
S.E. of b	0.687	-	-	0.693	-	-	0.275	-	-

*, ** = Significant at 5 and 1% level of significance, respectively.

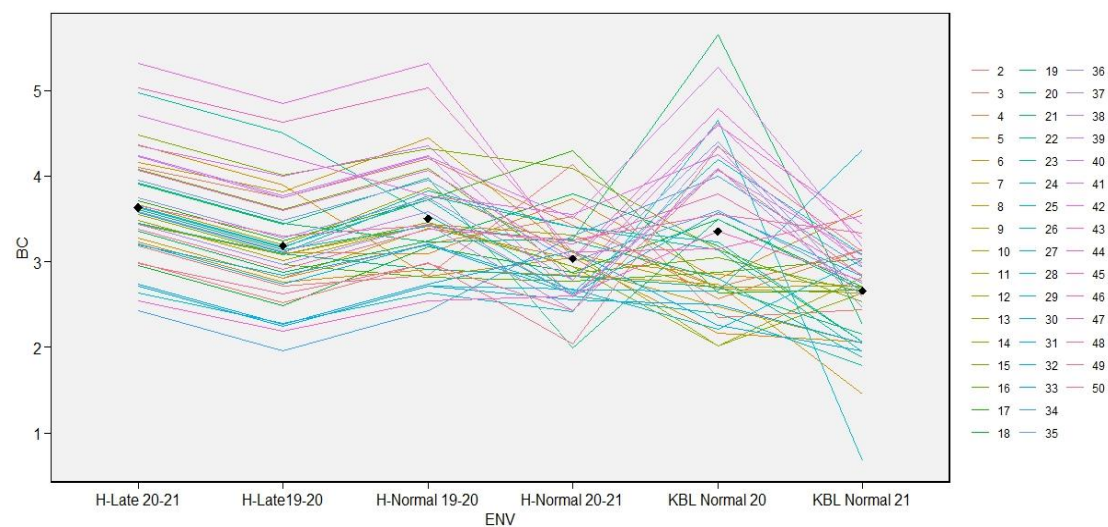


Figure. 4.16: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Beta Carotene

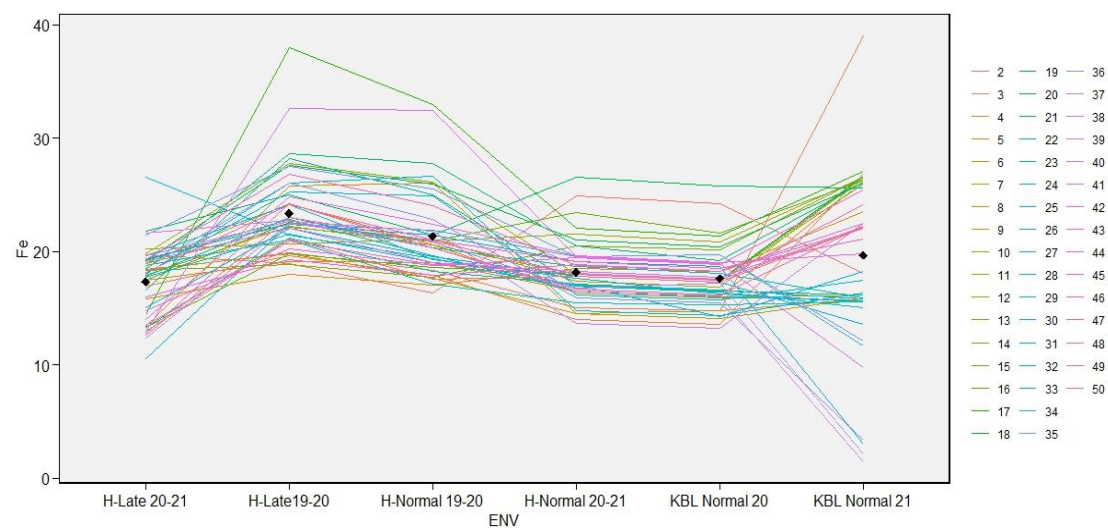


Figure 4.17: Scatter plot of wheat genotypes on three stability parameters (Mean, b_i , S^2d_i) of Fe based

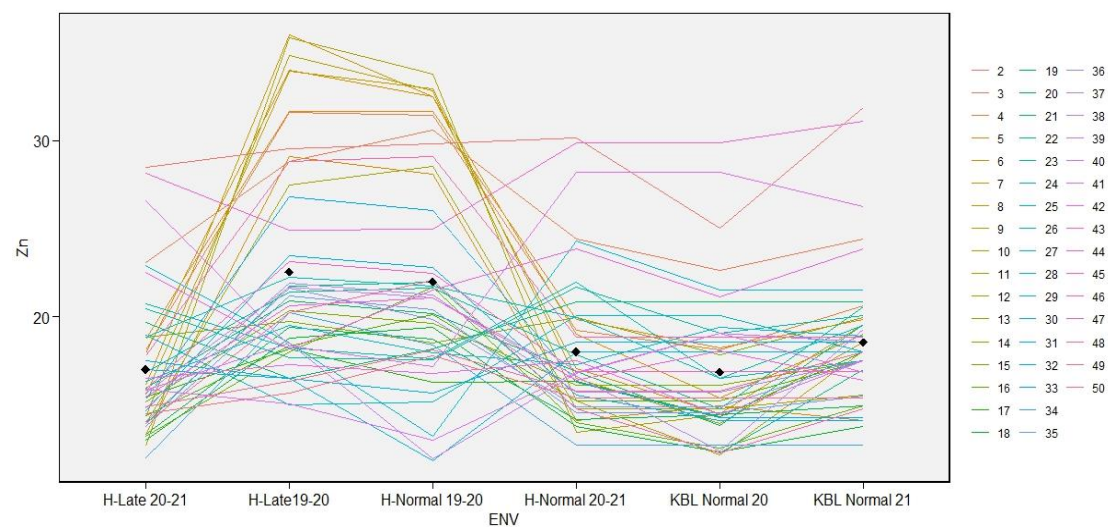


Figure 4.18: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Zn

4.8.7 Copper (Cu)

The estimation of the stability parameters for Cu was rated from 2.56 (11) to 5.48 (EC 1075936) with mean 3.47. The variation among the genotypes in mean were close to each other with regression above the unity was observed for none of the genotypes while equal and below the unity was also not exhibited for all the genotypes. Deviation from regression close to zero observed for EC 1075904, EC 1075909, EC 1075909, was adapted to be stable. With regression, above the unity noted for none of the genotypes as well below the unity and equal to the unity no genotypes were depicted. The deviation from regression was significant for 43 genotypes and 6 genotypes were noted non-significant.

4.8.8 Magnesium (Mg)

The estimation parameters of stability for Mg from the mean was noted from 29.13 (EC 1075930) to 46.98 (EC 1075903) with the mean of 39.45. The least mean was recorded for genotypes EC 1075925, EC 1075930, EC 1075931, and EC 1075933 while the wide variation among the genotypes were illustrated with higher mean value for most of the genotypes. With regression coefficient of variation above the unity was noted for genotype EC 1075922 adapted better environment. Below the unity was exhibited for genotype EC 1075914 adapted to the poor environments, while below the unity was exhibited for genotype EC 1075914 adapted to the poor environments. The variation due to *bi* was high, that ranged from 0.2 to 23, sensitive to the environment. Deviation of regression from the zero was significant for genotypes EC 1075910, EC 1075911, EC 1075912, EC 1075914, and EC 1075922 and the remaining were non-significant or close to the zero are stable.

4.8.9 Sedimentation Value

The estimation of stability parameters for sedimentation value was ranged from the 34.77 (EC 1075933) to 54.44 (EC 1075921) with mean 42.44. The least mean was observed for 30 genotypes and remaining was higher than mean. It revealed, the wide variation was observed among all genotypes. With regression coefficient of variation above the unity was observed for none of the genotypes and below the unity was estimated for genotypes EC 1075898, EC 1075900, EC 1075901, EC 1075902, EC 1075920, EC 1075926 and EC 1075940 adapted to the poor environments. Deviation from regression was close to zero or non-significant for most of the genotypes, observed stable. While 9 genotypes were exhibited significant, adapted to none of the environments.

Table 4.34: Estimates of stability parameters for Cu, Mg and sedimentation value of wheat genotypes

Characters	Cu (ppm)			Mg (ppm)			Sedimentation value (ml)		
	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>
EC 1075893	2.65	-10.26	8.07**	43.38	18.91	205.40	46.46	8.19	3.77**
EC 1075894	2.62	-6.89	3.83**	42.41	3.33	628.84	44.59	6.18	2.13**
EC 1075895	2.57	-6.89	5.70**	42.64	5.76	448.47	40.19	6.41	2.00
EC 1075896	2.59	-6.75	6.35*	40.23	4.78	504.90	39.18	6.97	1.76
EC 1075897	2.68	-7.83	4.85**	43.24	-4.07	371.36	39.11	6.89	2.10
EC 1075898	2.65	-6.82	7.33*	37.18	6.28	339.45	41.82	0.95	0.37
EC 1075899	2.74	-7.71	1.00	36.87	-2.98	366.89	42.43	2.44	0.64
EC 1075900	2.60	-4.84	6.22**	35.85	-3.06	319.07	38.63	0.64	0.46
EC 1075901	2.58	-6.85	5.00**	37.05	1.62	282.21	39.57	0.12	0.00
EC 1075902	2.55	-6.98	5.03**	41.39	15.29	112.52	50.00	0.10	0.24
EC 1075903	2.71	-6.44	4.47**	46.98	-1.74	299.11	46.34	9.15	4.47**
EC 1075904	2.96	-8.03	0.58	40.07	23.35	36.86	37.63	1.88	0.13
EC 1075905	2.89	-7.16	4.66**	39.02	23.56	68.12	39.06	-2.11	0.56
EC 1075906	3.14	-7.35	9.92**	42.50	16.50	76.01	47.75	7.02	1.87
EC 1075907	3.05	-6.67	12.30**	40.57	15.35	94.05	42.59	1.97	0.54
EC 1075908	2.98	-7.53	6.11**	43.10	13.47	26.28	39.85	4.37	0.62
EC 1075909	3.02	-7.62	0.92	45.67	8.21	58.77	42.06	-1.02	0.23
EC 1075910	3.33	-8.41	8.42**	45.46	6.73	8.25	43.27	-0.54	1.02
EC 1075911	3.32	-9.11	9.03**	42.99	7.88	10.73	39.31	-2.69	0.66
EC 1075912	3.37	-6.37	11.21**	41.98	11.64	17.67	40.08	2.43	0.20
EC 1075913	3.26	-8.40	5.10**	40.79	8.22	27.04	41.84	10.22	4.10**
EC 1075914	3.24	-8.95	5.35**	40.38	0.27	13.56	52.13	4.67	0.75
EC 1075915	3.16	-9.06	5.08**	45.22	-13.97	338.49	48.95	-0.02	0.03
EC 1075916	3.46	-10.83	21.41**	45.73	-6.72	271.26	41.74	-9.77	3.77**
EC 1075917	3.36	-9.87	14.56**	43.51	-4.99	241.33	45.08	-14.72	8.88**
EC 1075918	2.95	-7.31	1.90	42.23	-4.28	116.14	53.39	-5.63	1.48
EC 1075919	3.27	-8.81	5.27**	41.27	-4.15	77.98	47.25	8.18	2.36
EC 1075920	3.32	-8.46	6.11**	37.24	-7.41	92.09	49.60	0.71	0.07
EC 1075921	3.18	-8.67	3.97**	37.29	-4.86	105.90	54.44	-2.68	0.23
EC 1075922	3.06	-9.16	1.10	36.30	1.28	21.89	42.72	-7.10	1.58
EC 1075923	3.25	-10.70	6.26**	31.57	-4.88	238.56	37.81	-10.24	4.68**
EC 1075924	3.09	-9.81	6.20**	30.62	-7.19	248.62	38.00	-5.56	1.24
EC 1075925	2.97	-9.69	3.75**	29.38	-16.50	375.40	36.97	-2.78	0.45
EC 1075926	3.13	-10.07	7.05**	31.50	-18.30	357.36	42.20	0.25	0.26
EC 1075927	3.07	-9.85	3.18**	30.58	-15.43	183.68	44.51	-1.07	0.06
EC 1075928	3.04	-10.46	3.46**	29.96	-12.67	237.89	47.94	15.22	8.11**
EC 1075929	3.08	-10.25	5.63**	29.99	-19.47	242.58	40.42	-1.70	0.20
EC 1075930	3.07	-10.07	6.13**	29.13	-9.87	335.51	37.77	-9.18	3.30**
EC 1075931	3.06	-10.36	4.71**	29.84	-18.16	376.48	39.58	-8.66	1.29
EC 1075932	3.39	-8.78	15.96**	41.38	-8.94	97.02	36.43	-1.15	0.10
EC 1075933	3.15	-9.91	13.19**	29.81	-15.56	392.98	34.77	-0.21	0.06
EC 1075934	4.93	27.47	14.72**	43.36	-2.22	346.42	43.03	5.12	0.99
EC 1075935	5.14	30.70	6.25**	41.59	-4.23	153.05	43.10	-2.66	0.59
EC 1075936	5.48	37.95	18.18**	44.08	-3.06	61.85	39.85	-1.79	0.32
EC 1075937	5.08	30.18	3.23	41.03	-4.56	133.56	45.35	-2.01	0.06
EC 1075938	5.42	25.95	70.55**	44.43	8.25	90.34	43.10	-3.86	0.60
EC 1075939	4.88	31.47	14.05**	39.94	-3.34	117.03	37.71	-5.86	2.06
EC 1075940	4.80	30.33	17.19**	42.94	-4.24	142.84	47.54	0.74	0.01
EC 1075941	4.74	27.50	22.24**	40.05	4.81	139.14	39.23	-3.15	0.27
P Mean	3.47	-	-	39.46	-	-	42.45	-	-
S.E(mean)	0.32	1.00	-	5.64	1.00	-	0.83	1.00	-
S.E. of b	0.408	-	-	0.528	-	-	0.266	-	-

*, ** = Significant at 5 and 1% level of significance, respectively.

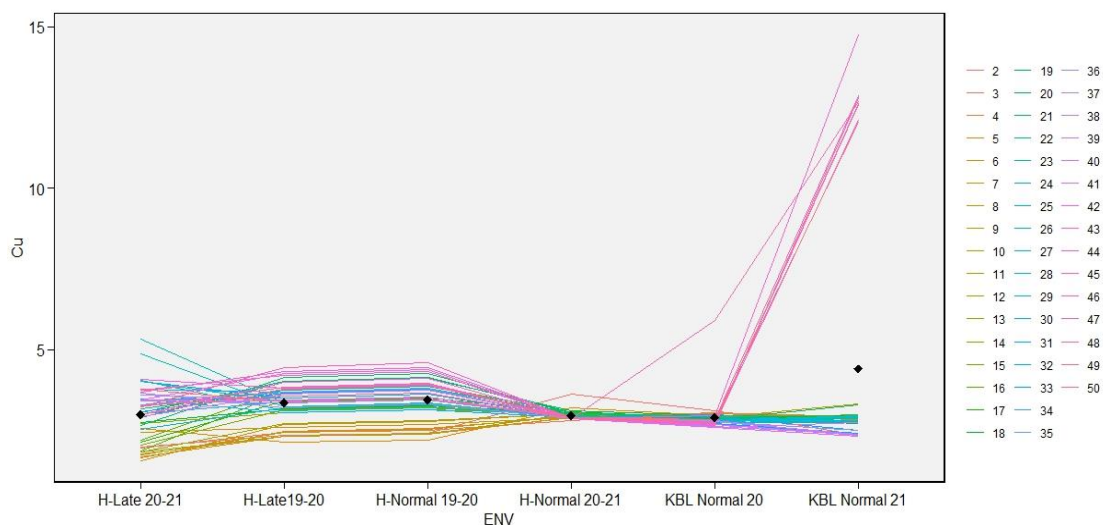


Figure 4.19: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Cu

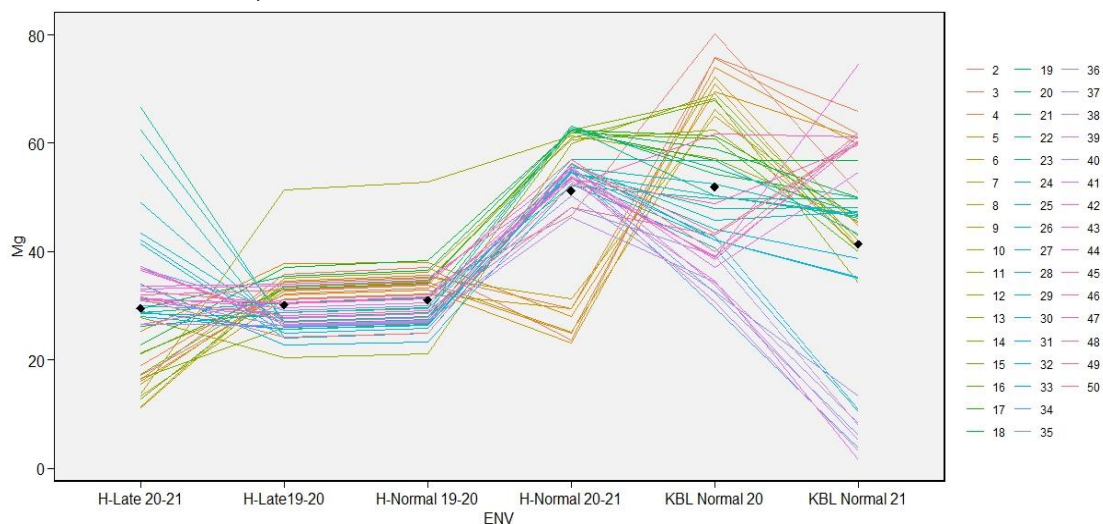


Figure 4.20: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Mg

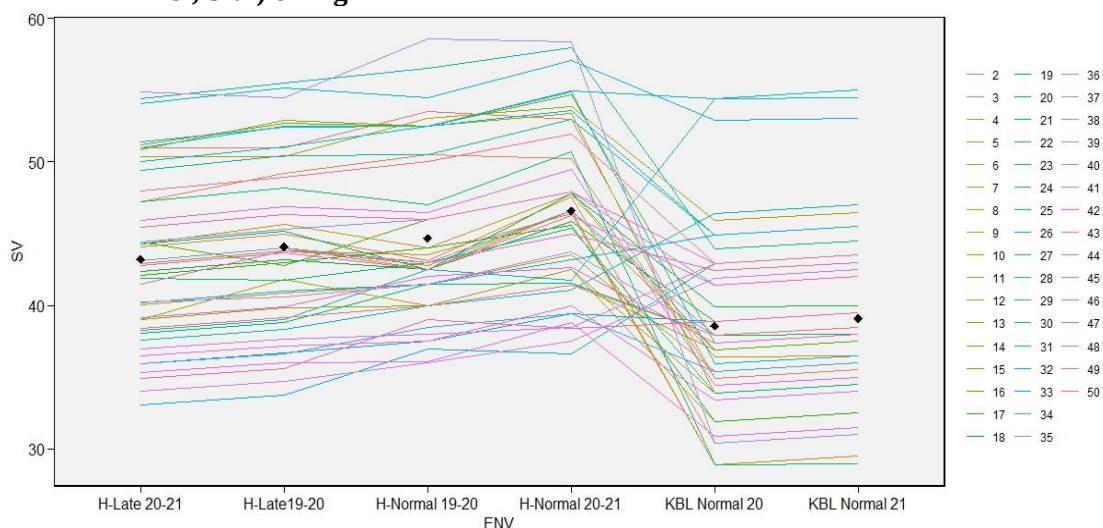


Figure. 4.21: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of sedimentation value

4.8.10 Hectolitre weight

The estimates of stability parameters due to hectolitre weight (kg/hectolitre) for mean was ranged from 74.83 (EC 1075933) to 78.89 (EC 1075911) with population mean 77.26. Based on mean performance, 39 genotypes exhibited least mean and the remaining was observed high mean performance. Regression coefficient of variation above the unity were observed for genotype EC 1075895, EC 1075901, EC 1075902, EC 1075915, EC 1075917, EC 1075919, EC 1075921, and EC 1075932 adapted to better or genotype is suitable for favourable for this character environments. *bi* equal to the unity was observed for none of the genotypes, but below the unity were observed for genotype EC 1075899, EC 1075905, EC 1075909, WH1105, and WH1024 adapted to poor environments. from the study revealed narrow variation were depicted on the base of mean performance while except genotypes EC 1075933, EC 1075941 and WH1021, all other were non-significant on the base of deviation from regression were indicated their stability.

4.8.11 Total Soluble Sugar (TSS)

The estimate of stability parameter for Total Soluble Sugar (TSS) was observed from 64.21 ppm (EC 1075913) to 115.7 ppm (EC 1075928) along with mean performance of 88.04 ppm. The wide variation of mean performance was observed with regression coefficient above the unity observed for genotype EC 1075902, EC 1075917, EC 1075926 and EC 1075939 adapted to rich environments. Regression coefficient of variation was indicated below the unity for genotypes EC 1075908, EC 1075912, EC 1075919, EC 1075920, EC 1075934, EC 1075938, and WH1021 indices poor environment for this characters while *bi* was observe equal to the unity for none of the genotypes. Deviation from regression were non-significant for EC 1075897, EC 1075900, EC 1075912, EC 1075937, EC 1075940 and EC 1075941, while the remaining were indicated significant that is unstable in all environments.

4.8.12 Grain density

Estimate of the stability parameter on the base of mean performance for grain density was ranged from 12 (WH1021) to 16 (EC 1075924) along the mean population performance 13.94. Narrow variation was expressed among the genotypes on the base of mean performance. Regression coefficient of variation above the unity was noted for genotypes EC 1075902, EC 1075929 and EC 1075940 adapted to greater environments, the *bi* lower the unity was noted for 22 genotypes, indicated poor environments. Deviation from regression was non-significant for all genotypes except genotypes EC 1075898, EC 1075927 and WH1021 was showed significant.

Table 4.35 Estimates of stability parameters for hectolitre weight, total soluble sugar, and grain density of wheat genotypes

Characters	HW (kg/hectolitre)			Total soluble sugar (ppm)			Grain density (cc)		
	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>	Mean	<i>bi</i>	<i>S²di</i>
EC 1075893	76.66	-0.75	0.26	91.09	-0.94	6.79**	13.01	0.05	0.32
EC 1075894	77.60	-0.08	1.23	80.35	-1.77	24.71**	14.19	-0.30	1.09
EC 1075895	76.49	1.06	1.81	68.53	-2.08	4.34*	14.69	0.20	0.13
EC 1075896	76.38	1.63	0.10	84.37	-0.86	10.64**	13.64	0.01	1.48
EC 1075897	76.22	2.51	1.35	100.22	-0.42	1.13	14.93	-0.35	0.23
EC 1075898	78.61	0.89	0.90	82.16	-3.93	16.08**	12.96	1.57	3.26**
EC 1075899	76.05	1.88	0.28	90.50	-0.24	2.89**	13.77	0.22	1.00
EC 1075900	77.06	-0.65	0.51	70.03	-4.43	2.25	14.03	0.53	0.47
EC 1075901	76.95	1.48	1.70	96.21	2.00	6.86*	13.78	0.54	0.76
EC 1075902	76.31	1.22	0.55	99.12	1.38	13.60**	12.91	1.40	2.11
EC 1075903	75.90	4.61	0.41	109.59	3.76	4.74*	14.51	1.50	0.59
EC 1075904	78.58	-2.22	0.47	111.29	6.11	30.16*	14.31	0.24	1.86
EC 1075905	77.28	0.42	2.04	98.12	2.31	8.98*	13.97	-0.02	1.23
EC 1075906	76.34	2.43	0.50	75.82	-3.31	7.92**	14.04	0.30	1.59
EC 1075907	77.33	-4.15	7.83	67.96	-5.26	16.45**	12.98	0.49	7.29
EC 1075908	77.40	2.10	3.95	93.67	0.86	5.90**	14.26	0.82	1.76
EC 1075909	76.72	0.91	6.20	69.33	-2.37	10.80**	14.06	-0.30	0.84
EC 1075910	78.59	-1.89	0.06	64.30	-1.02	23.50**	14.35	-0.06	1.19
EC 1075911	78.89	-0.50	0.32	74.44	-1.24	8.69**	13.70	0.55	0.23
EC 1075912	77.88	1.73	0.42	90.28	0.96	0.66	14.47	1.98	0.62
EC 1075913	78.00	1.65	1.20	64.21	-2.20	5.58*	14.81	1.61	1.12
EC 1075914	76.83	-1.47	1.32	83.73	-1.04	9.43*	14.79	-0.67	0.66
EC 1075915	75.94	2.88	1.41	95.60	2.75	5.80*	13.74	0.22	1.48
EC 1075916	77.52	1.31	1.51	70.95	-1.16	7.77*	13.26	0.02	0.35
EC 1075917	78.74	-0.95	1.40	79.10	1.21	6.31*	13.87	-0.15	0.11
EC 1075918	78.10	-1.26	1.54	69.79	-1.02	17.30*	14.46	-1.03	0.85
EC 1075919	77.95	-0.27	1.01	69.81	0.50	32.95*	13.41	-0.29	0.15
EC 1075920	77.03	2.01	0.99	89.63	0.01	17.22*	13.57	-0.21	0.14
EC 1075921	76.51	3.17	1.25	73.09	-1.00	6.29*	12.79	0.27	0.96
EC 1075922	77.24	-1.32	0.65	82.61	-2.07	7.79*	13.23	0.65	1.12
EC 1075923	75.57	4.38	0.47	73.45	-0.37	12.67*	12.83	0.85	2.11
EC 1075924	77.19	1.64	0.13	91.17	-0.42	4.92*	16.18	-1.33	3.11
EC 1075925	76.22	1.97	1.69	100.53	3.99	18.77*	14.48	-0.53	0.27
EC 1075926	76.73	1.96	0.17	74.91	1.21	18.32**	14.75	-1.32	1.44
EC 1075927	77.97	2.68	2.35	82.93	-3.05	3.06**	15.44	-1.72	3.96**
EC 1075928	76.71	-0.25	0.08	115.70	5.01	18.89*	13.62	0.23	0.45
EC 1075929	77.99	-2.61	0.80	111.33	2.64	2.42**	13.64	1.47	1.13
EC 1075930	78.73	-2.36	0.54	113.42	4.07	13.66*	14.73	-1.39	1.34
EC 1075931	77.70	-1.96	0.75	115.32	-0.66	10.30**	14.62	-1.25	1.10
EC 1075932	76.80	1.25	1.35	90.10	-1.00	14.40**	14.78	-1.39	1.50
EC 1075933	74.83	1.08	2.71**	111.38	2.64	4.75**	13.87	-0.63	0.12
EC 1075934	75.19	0.07	1.47	100.31	0.97	8.49**	13.90	-1.13	0.67
EC 1075935	77.95	-1.43	1.04	103.29	4.00	6.36**	14.54	-0.73	0.16
EC 1075936	78.55	-2.84	1.26	78.76	-1.10	6.23**	13.18	0.42	1.20
EC 1075937	76.42	-1.90	1.16	83.25	-1.49	0.42	13.32	-0.04	0.27
EC 1075938	78.38	-4.56	3.95	111.29	0.76	35.14**	13.72	0.01	0.31
EC 1075939	78.13	-6.46	5.66	95.75	1.33	5.79**	13.01	0.13	0.58
EC 1075940	75.42	-1.33	12.97	111.00	5.92	1.94	13.69	1.03	1.16
EC 1075941	77.73	-2.40	3.07**	78.97	-2.38	0.71	13.94	-0.34	0.13
P Mean	77.26	-	-	88.05	-	-	12.28	-	-
S.E(mean)	0.66	1.00	-	8.18	1.00	-	0.17	1.00	-
S.E. of b	0.182	-	-	0.412	-	-	0.046	-	-

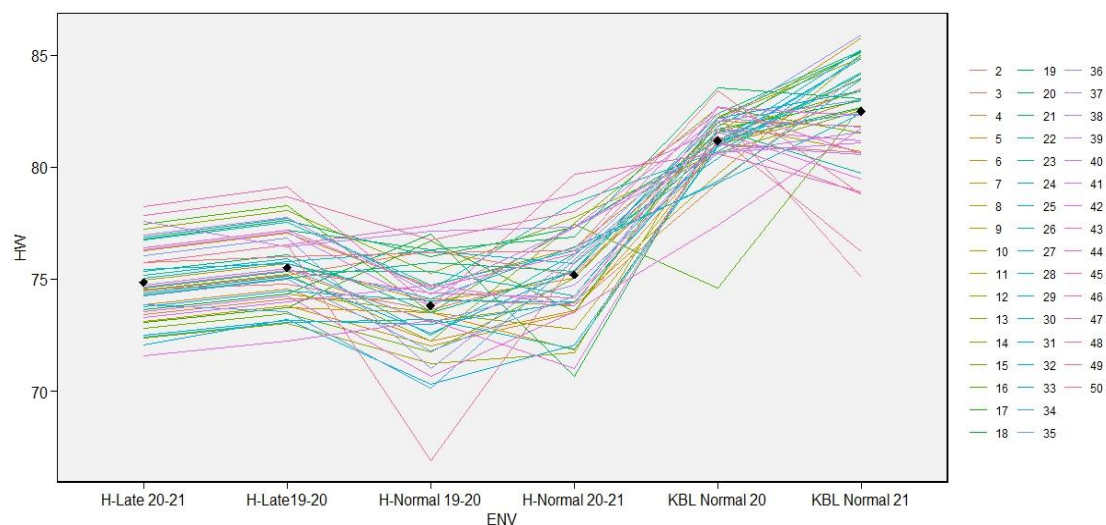


Figure4.22: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of Hectolitre weight (kg/hectolitre)

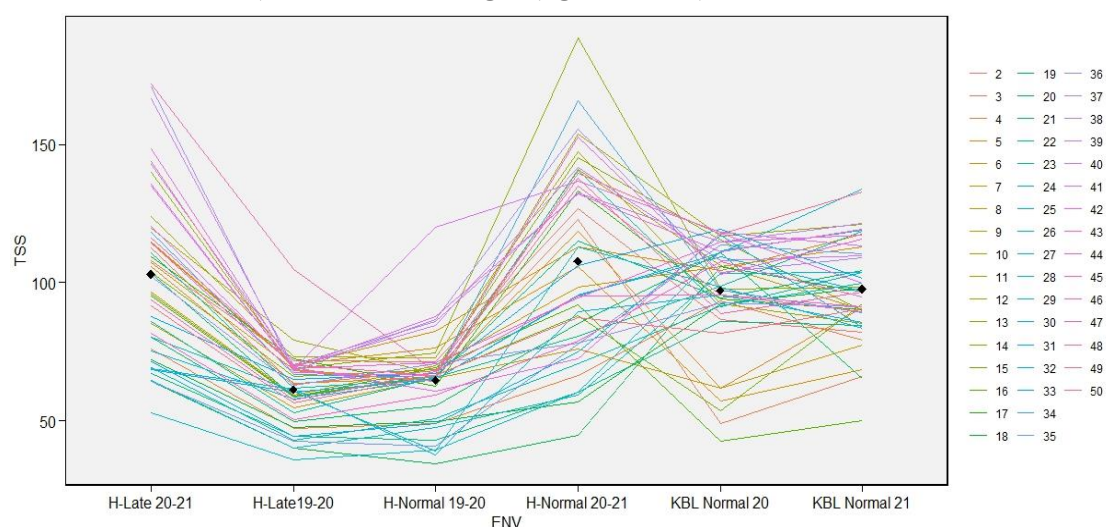


Figure 4.21: Scatter plot of wheat genotypes for based on three stability parameters (Mean, b_i , S^2d_i) of total soluble sugar (TSS)

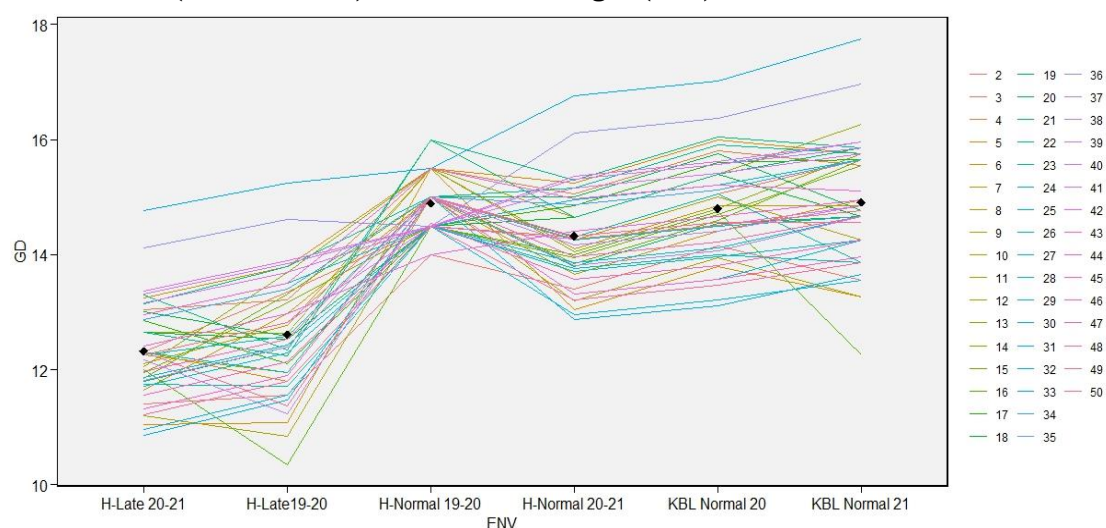


Figure. 4.21: Scatter plot of wheat genotypes based on three stability parameters (Mean, b_i , S^2d_i) of grain density

Wheat (*Triticum aestivum* L.) is one of the world's leading cereal crops for human food and animal feeding and the largest cultivated crop of the worldwide. Because of its wider adaptability, it's the most popular cereal crop among for farmers and ecological suitability. It provides highest nutrition to the human as compare to the other cereals. According to the USDA (2014), about 65% of the wheat crop is used for human food, 17% for animal feed and 12% for industrial applications Total food grain production is estimated around 305.44 million tonnes (2020-21)

India is the second largest wheat producing country back to China, currently occupied an area nearly 31.76 million hectares. Production of 109.52 million tons (13% of the globally wheat production) (Anonymous, 2021). Haryana, Uttar Pradesh, Punjab, Madhya Pradesh, Rajasthan and Bihar are the major wheat producer of India. Uttar Pradesh is reported the highest area and production of wheat and Punjab is ranked first in productivity.

Because of its wider adaptability, it attains an important place in Indian economy. It is a world-wide staple cereal food. So, it is important to enhance the production and productivity of wheat by developing the high yielding varieties and better crop management. Grain yield in wheat is a complex character and it depends on various component traits. The presence of ample amount of genetic variability between genotypes is the prime object to develop an effective breeding selection programme. The experimental results are presented under the following sub heads:

- 5.1 Mean performance of genotypes**
- 5.2 Genetic variability parameters**
- 5.3 Correlation coefficient of variation.**
- 5.4 Path coefficient analysis**
 - 5.4.1 Direct Effect**
 - 5.4.2 Indirect Effect**
- 5.5 Joint regression analysis**
- 5.6 Stability parameters of genotypes**

5.1 Mean performance of genotypes

The variable performances among the genotypes for each elements and characters are because of the genotypes performance, soil fertility along with the temperature effects or environmental influences. The environment wise analysis of variance of observations recorded for 23 different characters in bread wheat carried out and expressed highly significant genotypic differences for all the characters in six test environments (Table 5.1 & Table 5.2).

The results indicated wide differences among genotypes for the yield contributing as well as quality characters over the environments and that these could be used for further work to select the superior genotypes for breeding programme. Hence phenotypic values observed for all the characters, which similar findings for such yield related traits have been reported by Baye *et al.* (2020), Bhushan *et al.* (2018), Kumar *et al.* (2019) and Kumar *et al.* (2017) and respectively. The environment wise mean performance over all genotypes for different characters showed that, days to heading was delayed in E₁, and E₃ but days to heading in E₅ and E₆ was earliest. While, E₂ and E₄, showed moderate duration of days to heading. The earliest days to maturity showed in E₆ and E₅ while in the E₁ and E₃ recorded the delayed maturity days but moderate days to maturity showed in E₂, and E₃. Whereas, genotypes attained minimum height in E₅ and E₆ and the maximum height were expressed in E₁, followed by E₃. The effective tiller m⁻² was more in E₂, E₅ and E₄ but plant number were recorded maximum in E₂ and E₅ with overall mean performance of the genotypes investigated along with the maximum of mean of performance, and minimum mean performance were exhibited in E₆, Spike length showed tallest in E₁ followed by E₃ and E₄, but the shortest were recorded in E₆ with moderate coefficient of variation in all environments.

The performance of genotypes for spikelets spike⁻¹ was highest in E₁ and E₃ followed by E₂, E₅ and E₆ respectively. Number of grain spike⁻¹ was higher in E₁, E₅ and E₆ respectively and on the base of mean performance, moderate was computed in environments E₃ and E₄. Significant differences were reported for major traits in bread wheat in different environments by previous workers (Shashikala, 2006; Kalimullah *et al.*, 2012; Naik *et al.*, 2015). The test weight was highest under E₁ followed by E₅ and E₆, the least test weight was recorded in E₃ and E₄ with moderate magnitude of coefficient of variation were estimated in E₄ and E₆. Biological yield, was estimated highest in E₁ and E₅ that least was recorded in E₃ and E₄. The report is in agreements with Rahman *et al.*, 2016. Grain yield plot⁻¹ was maximum in E₅, followed by E₆. Liwani *et al.*, (2019) observed reduction in grain yield in poor yielding environments. In our study the environment E₅ and E₆ are good environmental conditions that exhibited normal growth rate which leads to good performance of the genotypes.

The mean performance for different quality characters showed that genotypes exhibited variation among the environments for each of the characters. It indicates that the environment and soil fertility between two different countries are mainly different, that the exhibition of the genotypes were affected from temperature and soil fertility both. Therefore, for wet gluten the high amount was recorded in E₅, and E₆, and the rest of the environments showed moderate. Similarly dry gluten was exhibited high in E₅, and E₆, but in rest of the environments the test was moderate as same to wet gluten. Crude protein estimation was moderate for all the environments and narrow variation was exhibited. The result for the beta-carotene showed moderate for all environments except E₆. The least amount recorded in E₆ in

respect to others. The environment E₅, and E₆ observed higher wet gluten whereas, similarly for dry gluten, environment E₅ & E₆ was found higher than other environments. The rest of the other traits in all the environments was appeared similarly moderate. The elements mean analysis showed high variation among the element, like Mg was high concentration, followed by Fe and Zn which the magnitude were moderate, but Cu was tended to least concentration and similar results revealed among the environments. Wide range in within population for micronutrient has also been reported for numerous other crops, for instance in sorghum (Reddy *et al.*, 2005) and maize (Banziger and Long, 2000). Sedimentation value trended high in E₃, followed by E₁ and least was recorded in E₆ with least and similar coefficient of variation between all environments. The report coincided with Rahul *et al.*, (2017) mean performance of RIL population for grain iron and zinc was significantly different over all six environments, whereas except E₂ and E₅ for zinc, the mean performances of RILs for grain iron and zinc was non-significant. Hectolitre weight was trended highest in E₅, E₆, respectively.

Table 5.1: Overall mean performance for phenotypic characters of genotypes in 6 different environments

Parameters	Environment	DH	DM	No. ET	PH (cm)	SL(cm)	NSS	NGS	TSW(g)	BY(g)	HI%	GY(g)
Mean	E ₁	99	149	380	113	11	20	59	41	6630	29	1950
	E ₂	81	120	362	95	10	19	56	39	5207	35	1784
	E ₃	96	143	324	99	10	18	53	40	5478	34	1876
	E ₄	79	115	343	97	10	17	51	36	4336	35	1454
	E ₅	72	114	370	98	10	20	58	43	6198	37	2271
	E ₆	69	112	321	97	10	18	53	41	5637	37	2064
Maximum	E ₁	105	153	485	123	15	23	73	50	7800	37	2368
	E ₂	85	122	444	106	11	22	69	47	6400	41	2300
	E ₃	100	146	412	113	12	25	71	47	6750	39	2475
	E ₄	83	119	437	108	12	20	67	43	5785	40	1795
	E ₅	78	116	419	115	11	22	75	49	7300	41	2860
	E ₆	73	115	389	115	11	22	75	48	7000	39	2697
Minimum	E ₁	94	146	296	93	9	16	45	31	4500	25	1483
	E ₂	79	116	260	81	9	17	42	30	3700	30	1210
	E ₃	94	140	251	83	8	16	41	23	3650	29	1205
	E ₄	76	110	266	85	8	15	40	28	2750	29	995
	E ₅	67	113	293	83	8	16	49	35	4300	32	1570
	E ₆	66	110	242	84	6	16	41	36	4150	32	1512

Table 5.2: Overall mean performance for quality characters of genotypes in 6 different environments

Parameters	Environments	WG%	DG%	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV(ml)	HW(kg ha ⁻¹)	TSS	GD
Mean	E ₁	21	8	11	4	22	21	4	31	44	74	64	15
	E ₂	20	8	13	3	23	22	3	30	44	76	61	13
	E ₃	20	7	11	3	19	16	3	51	46	75	106	20
	E ₄	20	8	13	4	17	17	3	29	43	75	102	20
	E ₅	28	9	13	3	20	19	3	52	38	81	98	15
	E ₆	29	9	13	3	20	29	5	43	39	82	98	15
Maximum	E ₁	28	11	14	5	46	38	5	53	59	77	92	16
	E ₂	28	11	15	5	47	39	5	51	56	79	105	15
	E ₃	30	11	14	4	29	59	4	63	58	80	189	30
	E ₄	30	11	16	6	38	35	7	67	55	78	172	30
	E ₅	43	15	16	6	55	69	6	80	54	84	131	17
	E ₆	44	15	15	4	39	61	15	75	55	86	134	18
Minimum	E ₁	13	6	9	2	17	10	2	21	33	67	35	14
	E ₂	10	5	8	2	16	10	2	20	31	72	36	10
	E ₃	11	5	9	2	11	9	3	23	34	71	45	11
	E ₄	13	5	9	3	9	6	2	12	31	72	53	13
	E ₅	18	6	10	2	12	8	3	30	28	75	43	13
	E ₆	19	6	10	1	2	13	2	2	29	75	50	12

Total soluble sugar test was exhibited high concentration in E₃, and E₄. Supportive findings was reported by Rahul *et al.*, (2017) the mean performances results indicated the existence of sufficient variability between parents in overall individual environments and greater opportunities for recovering desirable recombinants by using them in crossing programs. Grain density test was higher in E₃, and E₄, from the mean of all environments resulted, higher wet gluten was estimated for genotypes EC 1075938. Dry gluten concentration was exhibited higher value for the genotype Dehdadi. Crude protein test was higher in genotype EC 1075914 and genotype EC 1075933 was showed high concentration for beta-carotene. Respectively Fe was higher in E₅ for genotype EC 1075922 with concentration of (55ppm), Zn (69 ppm) for genotype Dehdadi, Cu (15.12ppm) for genotype EC 1075936 in E₆ and Mg (80.3ppm) for genotype EC 1075893 in E₅. Grain density was recorded very less difference between genotype that highest was recorded for genotype WH1024 and least was for genotype EC 1075907 respectively. Supportive findings were reported by (Wosene *et al.*, 2015; Wolde *et al.*, 2016) and Zewdu *et al.* (2021).

5.2 Genetic variability parameters

The knowledge about genetic variability, heritability and genetic advance is pre-requisite for crop breeding programme. The presence of higher genetic variability among genotypes is useful for better selection in crop improvements. Developing of a systematic breeding improvement programme, is necessity of genetic variability parameters for a breeder to study the exhibition of all the individual in subsequent generations for various characters. Hence to get a clear picture of variability among the genotypes, variability was further partitioned into phenotypic coefficient of variance (PCV) and genotypic coefficient of variance (GCV). In the present investigation, wide range of variation was noted for most of the yield contributing traits.

Presence of high heritability is an important aspect for choosing the suitable trait for selection. High heritability was observed for most of the characters under study indicating the strong genetic base. High heritability coupled with moderate to high genetic advance as per cent of mean (genetic gain) provide an effective mean of directional selection in a breeding improvement programme. High heritability coupled with high genetic gain were observed for the traits viz., sedimentation value, grain yield per plant and biological yield per plant. These observations are in agreement with earlier reports of Bhusan *et al.* (2013), Kumar *et al.* (2017), Islam *et al.*, 2020; Vanisri *et al.*, (2020)

Days to maturity, performance was moderate magnitude of variation at all and higher heritability was recorded in E₃ and E₆, followed by E₁, number of effective tillers meter⁻² was showed highly heritable in all environments but was computed higher in E₂. Plant height, recorded high magnitude of heritable in E₆ and followed by E₅, but the least heritability was observed in E₄. Spike length (cm), was higher in E₁ and moderate was studied among in E₃. No. of spikelets spike⁻¹ was studied higher in E₆, but at all similar and low heritability was studied in rest of environments. No. of grains per spike exhibited high heritability in most of the environments, among all least was recorded in E₅. 1000 grain weight (g) was showed moderated variation at all except in E₃ least heritable magnitude was revealed. Biological yield (g), heritability was varied at all and higher magnitude was recorded in E₆ with least heritability in E₁. Harvest index was showed low variation and respectively least magnitude of heritability was studied at all. Therefore, grain yield was studied high magnitude of heritability in E₆ and E₂ with least in E₁. Similar results were reported by Bhushan *et al.* (2013), Kumar *et al.* (2019, hence comparable outcomes have been accounted in wheat and different oats particularly for yield attributes (Tuhina-Khatun *et al.*, 2015; Islam *et al.*, 2020; Vanisri *et al.*, (2020), Sorour *et al.*, (2021).

The magnitude of coefficient of variation estimated from error mean squares was below 10 per cent for all character in all environment but for grain yield in E₁ and E₄ the coefficient of variation recorded higher than rest of the environments, biological yield showed

high coefficient of variation in E_2 , E_3 , and E_4 while harvest index exhibited moderate and similar coefficient of variation at all environments except in E_2 was recorded higher respectively. The tendency of coefficient variation for remaining traits was below 10 percent that suggesting a higher component of experimental error arising due to environmental variation presented in table (4.21)

From the studies it revealed, the estimates of PCV were larger in magnitude than GCV. Least and respectively similar GCV was recorded for all environment for days to heading. Higher value of GCV and PCV was computed for grain yield in all the environments and the heritability value were varied (low to higher value) among all environments respectively. While the higher heritability exhibited least influence of the environmental affect that gave the better chance of selection for desirable genotypes to the breeders for next generation and the better genotypes can also utilized in their breeding programme.

The investigation and variability analysis indicated that the environmental influence was comparatively more pronounced for these characters in expressing the phenotypic performance of different genotypes in the respective to the test environments. From the analysed characters observed, the phenotypic coefficient of variation was greater than the genotypic coefficient of variation. Phenotypic variance usually exceeds their corresponding genotypical variance, but obtaining of minimum variance make sure greater heritability. However, the variable performances of the genotypes give the ideas to the breeder for better selection of the superior genotypes which showed less influence through the environments. Similar result was found by (Abinasa *et al.*, 2011) and (Bhushan, *et al.*, 2013).

As revealed from Table (4.21) the genetic advance as % of mean estimated low in days to heading and days to maturity, while the magnitude for effective tiller m^{-2} was high in all environments respectively. Plant height was recorded low to moderate, but least genetic advance as % of mean was exhibited in E_4 and higher magnitude was estimated in E_6 , similarly Spike length was also recorded low to moderate, that higher was computed in E_1 and least was recorded in E_5 . No of grain spike $^{-1}$ was exhibited moderate respectively except in E_3 was exhibited higher. Estimated value of 1000 grain weight for genetic advance as % of mean was showed moderate at all. Biological yield was studied low to high for genetic advance as % of mean that highest was recorded in E_4 and low was exhibited in E_1 harvest index was exhibited low for genetic advance as % of mean. But it was recorded high value grain yield in all environments except in E_4 and E_1 respectively. Hence, Johnson *et al.* (1955) reported the genetic advance estimation is more useful in a selection tool when considered jointly along with the estimates of heritability. It means the heritability value as regard to itself cannot provide the amount of genetic progress which have been resulted from a selection of the best individuals. The study showed first, variability for grain quality traits are different, second, to know the environmental influences for these traits; third, association between grain quality

traits and other yield component traits and fourth, to identify environments and genotypes for studied traits and based on all results to decide the efficiency of genetic variability population for concentration of elements and other quality traits of wheat grain. Present study showed that genotypes have substantial differences for both micronutrients elements like Fe, Zn, Cu and Mg along the other quality traits in all environments. Similar results were obtained by Vreugdenhil *et al.* (2004) who reported that nutrient content of plant seeds depends on environment factors. It is being not essential that direct high estimates of heritability is always been associated with high genetic gain (Ghuttai *et al.*, 2015). Singh and Upadhyay (2013) reported a high magnitude of heritability and high genetic advance as percentage of mean. The appearance of high variability for grain yield per plant and component traits has also been studied by Aslani *et al.* (2012) and Jaiswal *et al.* (2020).

5.3 Correlation coefficient of variation.

Correlation is the most important statistical measures which enable breeders to identify the degree of correlation and magnitude among various traits (Sabit *et al.* 2017). It is necessary to a plant breeder to handle several yield contributing characters together in crop breeding programmes. Two or more genetically positively correlated characters can be ameliorated by improving one of them by direct selection then the other one improve indirectly. Correlation between traits may be due to linkage, pleiotropy and physiological inter-relationship. The correlation among the characters are the result of overall effect of segregating genes, out of all genes that govern specific characters some genes may improve all the correlated traits have been tend to show positive correlation, oppositely, the other genes may enhance the effect of one and decrease the others that result to the negative correlation. Hence, the knowledge about correlation between the traits is important in selecting the promised and positively correlated traits can help the selection based on attributed traits could be strongly effective in grain yield improvement programme. Similar results were found by Chaturvedi and Gupta (1995), Okuyama *et al.* (2004). In the present investigation, the degree of mutual relationship among the yield and its attributing characters in pooled environments were computed by estimating the correlation coefficient at the genotypic and phenotypic levels using 11 morphological traits along with 12 quality characters among all 54 genotypes as regards to the association between yield and its attributed traits was significantly positive with effective tiller m^{-2} , plant height, spike length number of spikelets $spike^{-1}$, biological yield and harvest index, but with rest of the characters the result was non-significant respectively, presented in Table 23.

On the other hand phenotypic correlation was estimated that grain yield association was showed significant positive correlation with effective tiller m^{-2} (0.493**), plant height (0.235**), spike length (0.430**), number of spikelet $spike^{-1}$ (0.237**), biological yield (0.841**) and harvest index (0.358**), while Rahul *et al.*, (2017) reported, though the

correlation of grain iron and zinc densities with days to 50% flowering and plant height showed significant negative and positive correlation respectively, but the lower magnitude of correlation suggests near-independence of crop growth traits and grain micronutrient traits. The correlation coefficient analysed for all the traits with grain yield at both genotypic and phenotypic levels to examine the degree of association and nature of relationship among yield and yield contributing characters. The research result showed that the estimates of genotypic correlation coefficient were higher than the respective phenotypic correlation coefficient. This indicated that how much of phenotypic correlation coefficient are influenced by environment Upadhyay *et al.* (2020) and Sharma *et al.* (2018). Similar results also reported by Baye *et al.* (2020), Dabi *et al.* (2016), Ayer *et al.* (2017) and Ahmed *et al.* (2018). On behalf of the quality traits the grain yield was correlated significantly positive with crude protein (0.362**), Fe (0.202*) and grain density (0.219*), while negatively significant correlation with copper (-0.266**), hectolitre weight (-0.266) respectively. The report is in agreement with Reddy *et al.*, (2005) the association of grain iron and zinc with grain yield was significantly negative in most of the environment as well as across the environments, but the magnitude of association was low. Such patterns of relationships of grain iron and zinc densities with grain yield are not unexpected considering the high positive correlation between iron and zinc densities and larger $G \times E$ interaction effect relative to genotypic effect. But in regards to the phenotypic correlation, the magnitude of association was mainly non-significant for more number of traits except in case of crude protein, Cu and grain density the positive significant correlation was estimate. Development of wheat cultivars with high levels of grain major elements like Fe, Zn, Cu and Mg with high concentration of other quality traits such as crude protein, beta carotene etc., can make significant contribution to reducing widespread deficiencies of these micronutrients and protein contents in populations heavily dependent on wheat for their dietary energy and the requirements of quality traits. Similar results were obtained by Kaya & Akcura *et al.* (2014), Saint *et al.* (2008). Also a similar finding was reported by Barnard *et al.* (2002), Yagdi & Sozen (2009) and Ayed *et al.* (2018).

5.4 Path coefficient analysis

Path analysis is a regression model extension that is used to evaluate the matrix fit to two or more causal models to compare a researcher. For agronomic traits, it was determine to evaluate the direct and indirect effects of traits on path analysis. A simple correlation coefficient among all characters obtained were determine partial regression coefficient (direct effects) of the characters. The indirect effects were identified by a simple coefficient regression by multiplying the direct effects. The correlation coefficient provides the incomplete information, in the sense that they do not through light underlying causes that are operative for the various inter-relationship. Through breaking of the correlation coefficient by path coefficient analysis into direct and indirect effects and thus provides the causal basis of

various inter-relationships. Path coefficient analysis was performed to assess the direct and indirect effects of different characters on grain yield. In the study, grain yield was taken as dependent variable where as other yield attributed traits viz., days to heading, days to maturity, plant height, effective tiller m^{-2} , spike length, number of spikelet $spike^{-1}$, number of grain $spike^{-1}$, 1000-grain weight, biological yield and harvest index.

The residual effect (0.084) in path coefficient analysis was considerably low for phenotypic path analysis of morphological traits.

5.4.1 Direct Effect

From the pooled analysis of morphological characters revealed maximum positive direct effect on grain yield $plot^{-1}$ was exhibited by biological yield, followed by harvest index, and negative effect on spike length. The result was similar to that reported by Jain *et al.* (1975).

5.4.2 Indirect Effect

The indirect effect on grain yield analysed at phenotypic level via different characters are presented in Table 4.24. The maximum positive indirect effect were noted through biological yield via spike length (0.505), followed by plant height (0.360) and effective tiller m^{-2} (0.392), 1000 grain weight via harvest index (0.156), negative of spike length via number of spikelets $spike^{-1}$ (-0.129) and number of grain $spike^{-1}$ (-0.114) respectively..

Path coefficient analysis for grain yield analysed for 11 traits at phenotypic level out of them here only those traits are named which showed significant and positive correlation to grain yield $plot^{-1}$ traits viz., effective tiller m^{-2} , plant height, spike length, number of spikelets $spike^{-1}$, number of grain $spike^{-1}$, biological yield and harvest index. Plant height had positive association with grain yield, this is in agreement with Safeer-ul-Hassan *et al.* (2004). Positive relationship of grain yield was found with spike length, plant height, grains per spike, and harvest index and similar findings had also been reported by Tabassum *et al.* (2018) and Kumar *et al.* (2014) for 1000-grain weight.

In addition, grain yield was considered as dependant variable for the quality traits viz., wet gluten (WG %), dry gluten (DG %) crude protein (CP %) beta carotene (β -C ppm), iron (Fe ppm), Zn (Zn ppm), copper (Cu ppm), magnesium (Mg ppm), sedimentation value (SV ml), hectolitre weight (HW kg/hectolitre) total soluble sugar (TSS ppm) and grain density (GD cc) were considered as independent variables.

Crude protein had positive significant direct effect on grain yield. It was showed indirect positive effect through wet gluten, Fe, copper, and magnesium, sedimentation value, hectolitre weight, and total soluble sugar, grain density respectively. Negative indirect effect was showed through dry gluten, beta carotene, and Zn respectively. While positive indirect effect was showed through wet gluten, Fe magnesium sedimentation value.

Grain density had positive significant direct effect on grain yield. Though, positive indirect effect was showed through wet gluten, dry gluten, crude protein, copper, and sedimentation value. Comparatively study was shown the spike length had positive direct effect on grain yield noticed by Jaleel *et al.* (2009). The study is in agreement with Iftikhar *et al.* (2012) under drought condition.

5.5 Joint regression analysis

Results summarized in Table 4.24 represented that mean squares due to genotypes are significant for all the characters except spike length, biological yield and harvest index, and the mean squares due to environments were showed significant for all the characters. The G x E interaction were significant for total eight characters and non-significant for spike length biological yield and grain yield. Env + G x E interaction were non-significant for all characters. While environment (linear) was significant for all the characters that tend to wide variation and with regards to unstable situation among the all genotypes of wheat. G x E (Linear) components were significant for most of the characters and non-significant for spike length, biological yield and grain yield that suggested presence of wide variability in wheat genotypes as well as the test environments and demonstrated strong G x E interaction for days to heading, days to maturity, effective tiller m^{-2} , plant height, number of spikelets $spke^{-1}$, number of grain $spike^{-1}$, and harvest index. The present results are in agreement with those of previous reports of Patel *et al.* (2014), Verman *et al.* (2015). Thus, the pooled variance and joint regression analysis due to genotypes and environments and G x E were significant for all characters except for Fe due to genotypes and grain density due to G x E and Env + G x E were significant for none of the characters respectively, while due to Env (linear) components were significant for all characters except for total soluble sugar and the pooled deviation showed significant for 10 characters out of 12 that only non-significant was observed for sedimentation value and hectolitre weight. Genotype x environment (G x E) interaction are of major concern to plant breeders for developing improved cultivars. For a variety to be commercially successful, it must perform well across the range of environments in which the cultivar may be grown. One of the important advances in biometrical genetics during last several decades was the investigations, and understanding of genotype x environment interaction. This may demonstrate for G x E interaction for most of the characters over the environments and genotypes and none stability of the genotypes. Therefore, it is well known that yield is quantitatively inherited character while considerably there is interaction between genotypes and environments. Some of the crop varieties are widely adapted, and others are not. The estimate of a genotype gets biased if GxE interaction is present and this results when a crop is grown in a single environment. But in multi environmental test it's consequently removing this basis. The knowledge about the extent of yield fluctuation and yield attributed traits over environments is very important for identification of the genotypes which are widely

adapted. The multi environmental testing of genotypes can give the opportunity to the plant breeders for identification of the adaptability of a genotype to a particular environment and also the stability of the genotype over different locations or environments. The information on genotype x environment interaction is of major importance to the plant breeder in developing an improved stable variety. The analysis of variance as per the Eberhart and Russell (1966) model showed a very significant difference between the genotypes for all characters. Similar results were reported for grain yield by Singh *et al.* (2018), Mekuria *et al.* (2018), Gulzar *et al.* (2015). Due to environments the variance was also found highly significant for all the studied characters, indicating that for evaluation of the material wide variation was observed. Thakur *et al.* (2019), Krupal *et al.* (2018), Mut *et al.* (2010) and Singh *et al.* (2018) had observed similar results.

5.6 Stability parameters of genotypes

Finlay and Wilkinson (1963) considered linear regression slope as a parameter for measurement of stability. Therefore, Eberhart and Russell (1966) emphasized the need of estimating both linear (bi) and nonlinear (S^2di) components of $G \times E$ interaction to be judged the stability of genotype. The promised genotype is determined as, one possessing high mean performance, with regression coefficient around unity ($bi=1$) and deviation from regression (S^2di) close to zero. The linear regression is regarded as the measure of linear response of a particular genotype to the changing environments. If the regression coefficient (bi) is greater than unity, the genotype is being tend to highly sensitive to environmental fluctuations, but adapted to high yielding environments i.e. it exhibits below average stability. If the regression coefficient (bi) being said equal to unity, it considered the average sensitivity to environmental variation and adaptable to all kinds of environments i.e. it exhibits average stability. If the regression coefficient (bi) is less than unity, it indicates less sensitivity to environmental fluctuation and if this is accompanied by a high mean value, then the genotype is considered better adapted for poor condition i.e. it exhibits above average stability. In the present study, stability parameters such as mean ($\bar{X}$), regression coefficient (bi) and deviation from regression (S^2di) as suggested by Eberhart and Russell (1966) were said to explain and discuss the stability of different genotypes for various characters under consideration. In present investigation on the basis of days to heading parameters, three genotypes expressed a range of days to heading from 80.667 to 85.750 and genotypes number EC 1075894, EC 1075897, EC 1075934, EC 1075938, and WH1021, were earliest for days to heading while, genotypes EC 1075905 and EC 1075906 were found late in days to heading as regards to the mean performance. The regression coefficients of the 54 genotypes were varied from 0.032 to 6.24 it meant the high variation was observed among the genotypes that indicate different response to the environments. $bi>1$ was showed for most of the genotypes which indicated the favourable environments responsive and $bi<1$ or close to zero was responsive for poor

environments among all genotypes. The of stability for effective tiller m^{-2} was observed highly variation was showed under different environments, ranged from 280 to 381, which the genotype number EC 1075903 was noted highest and genotype EC 1075930 was recorded least number of effective tiller m^{-2} . The regression was showed higher than unity for 14 genotypes and the more number of genotypes was showed non-significant or close to zero that indices stable for poor environments and regression higher from the unity was observed for better environments. S^2di significant for 21 genotypes, which was showed unstable in all environments for effective tiller m^{-2} respectively. Due to plant height, genotypes were showed range of plant height from 86cm to 108 cm that the genotype number EC 1075894, and EC 1075940 was noted tallest and the genotype number EC 1075905 was recorded dwarf, with regression coefficient higher than unity the genotypes number EC 1075921, EC 1075924, EC 1075925, EC 1075928, EC 1075931 and WH1184 were stable with mean of height for all environments. The report is coincide with (Arulselvi, S and Selvi, 2010) average plant height was 94.51 cm over the three locations and two seasons and across the locations and seasons, performed stable for plant height. Deviation from regression was observe non-significant for 13 genotypes. Genotypes for spike length is ranged from the 8.9cm to 11cm. The variation is moderate that genotype 24 was noted the shortest and genotype EC 1075941 was recorded with highest length for spike length. With regression coefficient close to zero for genotypes number EC 1075899, EC 1075902, EC 1075904, EC 1075922, EC 1075928 and EC 1075930 respectively showed responsive under poor environments. The S^2di was studied significant for 20 genotypes that is not stable for all environments respectively.

Moderate variation was observed for mean of number of spikelets spike $^{-1}$, ranged from 17 to 20 that least number of spikelet spike $^{-1}$ was noted for 6 genotypes and more number of spikelets were recorded for genotype EC 1075894, EC 1075895 and EC 1075933 with regression coefficient of variation equal to the unity was estimated for 5 genotypes that adaptive to intermediate environment and the regression close to zero was observed for 4 genotypes that showed responsive to the poor environments respectively. Deviation from regression was significant for 10 genotypes among the genotypes that indicated except 10 genotypes Similar results reported for days to heading and days to maturity and effective tiller m^{-2} by Thakur *et al.* 2019, Pansuriya *et al.*(2014), Verman *et al.*, (2015), Gulzar *et al.* (2015), and Kamal *et al.* (2011). Higher mean was noted for genotype number EC 1075941, EC 1075930, EC 1075906 and EC 1075901. The regression variation was noted intermediate, ranged from -0.016 to 5.934. It indicated that higher regression value is noted with stable genotypes. records from the mean value for 1000 grain weight, was ranged from 36.7 to 45.24 with regression above the unity was showed for 5 genotypes that was responsive for better environment, while 4 genotypes was recorded close to zero or below the unity which is adaptive under poor environments. Mean value for 1000 grain weight, was ranged from 36.7

to 45.24 indices wide variation with regression above the unity was showed for 5 genotypes that was responsive for better environment, while 4 genotypes was recorded close to zero or below the unity which is adaptive under poor environments and deviation from regression was estimated significant for 37 genotypes among all 54 genotypes. Higher mean, regression value near to one and non-significant deviation from regression (Wasala *et al.*, 2013). Biological pooled mean was ranged from 5712g to 7701g with regression coefficient of variation above the unity was showed for 4 genotypes that is responsive in better environments and $b_i < 1$ or close to zero was observed for six genotypes indicated responsive in poor environment. Regression was varied from -0.1 to -14.1 and 6.77 which wide variation is estimated among all 54 genotypes for regression. Similar results were obtained by Pujer *et al.* (2020), Haydar *et al.* (2018) Singh *et al.* (2018), Jhinjer *et al.* (2017). Deviation from regression was significant for 34 genotypes indicating most of the genotypes was not stable due to the biological yield among all 54 genotypes. Such kind of differential performance of various yield contributing characters by the stable genotypes were also reported by Ashraf *et al.* 2001, Gupta *et al.* 2004, Kumar *et al.* 2005, and Yadav *et al.* 2008. Gohil and Jadeja (2009) performed stability analysis and reported that none of the genotype was stable for evaluated traits.

From the range of mean performance of harvest index rated that, only genotypes number EC 1075892, EC 1075894, EC 1075897 and EC 1075912 were noted higher mean than the general mean over environments with regression coefficient of variation was above the unity for three genotypes, was adapted in better environment and deviation from regression was close to zero for six genotype, responsive in poor environment. The non-linear component expressed as deviation from regression significant for 18 genotypes were not adapted over all environment and the remaining of them are rated stable respectively.

As regards to the yield mean performance wide range of variation showed, from 2076g to 2777g. The higher mean value over the genotypes noted for genotypes number EC 1075898, EC 1075904, EC 1075913, EC 1075927, and EC 1075932 with regression coefficient of variation over the unity for two genotype and close to zero was depicted for five genotypes adapted to the poor environment. A wide range of regression coefficient of variation was rated them from -0.4 to 12.3, indices the wide responsive of the genotypes over the environments. The main purpose of this investigation was to identify high yielding stable genotypes and its attributed traits that would further be tested for their general and specific adaptability depending on their magnitude performance, that need to be used in next generation or desirable genotypes this is the key point that breeding programmes and farmers, stable yields are provide the sustainable food supplies. Even though the importance of genotype environment interaction was recognised well and these were known to be heritable (Jinks and Mather, 1955). The main efforts made by the researches were aimed to measure this interaction. It indicates that genotypes react in different ways if environmental conditions

change and is of significance for breeders, and growers. Estimation of the genotype x environment interaction is considerably important in plant breeding programmes because it otherwise reduces the progress from selection in the target environment (Hill, 1975). Significant G x E interaction results from the change in the magnitude of different environments or changes in relative ranking of the genotypes. These results were in harmony with those obtained by *Shah et al* (2009). Deviation from regression was depicted significantly difference performance for 33 genotypes among the genotypes, was noted unstable performance and the remaining of them are rated stable. Deviations from regression (S^2_{di}) exhibited a positive and highly significant. These findings agree with other researchers (Letta 2007 and *Shah et al*, 2009). Similar results were further confirmed by Verma and Singh (2021), Adil, N *et al.* (2022), Oral, *et al.* (2018) and Shojaei *et al.* (2022). Hence, present work validates the genotypes exhibiting stability for each character was given a score of I and total score obtained by each genotype across quality traits were found to be stable for none of the genotypes over all characters. Each of the genotypes deserve a special consideration. Whereas the mean for dry gluten ranged from 7.36 % (EC 1075936) to 11.06 (EC 1075941) with mean of 9.34% with regression coefficient of variation higher than the unity. Deviation from regression was found significant from zero for 48 genotypes that rated stable in none of the environments. As regard to the regression coefficient of variation no genotype were estimated higher than the unity and genotypes EC 1075906, EC 1075914, EC 1075921 is stable under poor environments. The mean of the crude protein was ranged from 10.29% (EC 1075936) to 13.77% (EC 1075914) with mean of the 12.13 %. Along with the regression coefficient of variation above the unity for genotype number EC 1075896 and EC 1075936 equal to the unity was recorded for genotype (EC 1075925). Deviation from regression was significant for 39 genotypes and other was non-significant or close to zero is stable. Different stability parameters such as phenotypic stability bi residual mean variance S^2_{di} and phenotypic index p_i are available to test the stability of genotypes. Among the test entries, stability parameters for grain beta-carotene content due to the mean were illustrated from 2.46 (EC 1075924) to 4.42 (EC 1075934) with the mean 3.22. The regression coefficient of variation depicted above the unity for genotype EC 1075901, EC 1075935, WH1024 adapted to the better environment and bellow the unity for genotypes EC 1075910, EC 1075912, EC 1075918 that rated stable for poor environments. Deviation from the regression was significant for most of the genotypes were found unstable expression. Fe mean were rated from 15.31 (EC 1075928) to 25.98 (EC 1075908) with the mean of 19.89. Deviation from regression was found significant for 42 genotypes and reaming of them was non-significant or close to the zero, was stable. The Zn concentration was ranged from the 14.78 (EC 1075925) to 29.15 (EC 1075893) with the mean of 19.36 ppm. While, deviation from regression was illustrated significant for none of the genotypes or noted close to the zero among all genotypes adapted to the environment.

As regard to Cu, pooled environments mean, was ranged from 2.56 (EC 1075902) to 5.48 (EC 1075936) with mean 3.47. Mean performance stability parameter for Mg was ranged from 29.13 (EC 1075930) to 46.98 (EC 1075903) with the mean of 39.45. The regression coefficient of variation above the unity was noted for genotype EC 1075922 adapted better environment. From deviation regression, 11 genotypes out of all individuals were exhibited significant, adapted to none of the environments. Hectolitre weight (kg/hectolitre) for mean was ranged from 74.83 (EC 1075933) to 78.89 (EC 1075911). Regression coefficient of variation above the unity were identified for genotype EC 1075895, EC 1075901, EC 1075902, EC 1075915, EC 1075917, EC 1075919, EC 1075921, and EC 1075932 adapted to better environments. These findings agree with support of other researcher. Genotypes selected according to stability of grain micronutrients and grain yield in present study verified the possibility of combining both stable and high performances Ramandeep *et al.*, (2017). Gomaa, *et al.*, (2018). Therefore, Eberhart and Russel (1966) from the actual experiments carried out the average response to varying environments, the genotype x environment (liner) sum of squares was not a large proportion of the G x E interaction. Hence, the S^2di parameter appeared to be very important. Since variance of S^2di is function of number of environments with minimum replications per environment so several environments with minimum replications per environments were advocated to be necessary to obtain reliable estimates of S^2di . For identification of the stable genotypes it needs to have wide adaptability over a wide range of agro-climatic conditions and it's of major significance in crop improvement, the study is in agreement with (Khalil, 2013) that found stable as indicated by their higher mean yield, statistically unit regression and non- significant S^2di value.

CHAPTER–VI

SUMMARY AND CONCLUSION

The present investigation entitled "Stability analysis of genotypes with concern to yield performance and quality traits in bread wheat (*Triticum aestivum* L.)" was conducted with an objective to know the effect of different characters for imparting the genetic variability, their correlation studies along with path analysis and the stability to analysis over diverse environments. The experiment comprises 54 genotypes including four checks. The experiments were conducted in India and Afghanistan during 2019-2020 and 2020-2021. In India the experiment was conducted at Wheat and Barley section, Department of Genetics and Plant Breeding, CCS HAU, Hisar in two different sowing conditions *i.e.* timely sown and late sown conditions, while in Afghanistan it was conducted at Central Research Farm, Agricultural Research Institute of Afghanistan (ARIA), in timely sown condition only, using randomized block design with two replications. Observations were recorded on randomly selected plants in each treatment for 11 for morphological traits *viz.*, Days to heading, Days to maturity, Number of effective tillers per m², Plant height (cm), Spike length, Number of spikelets per spike, Number of grains per spike, 1000 grain weight, Biological yield per plot (g), Harvest index and Grain yield per plot (g) and Quality characters *viz.*, Gluten content (%), Crude protein content (%), β -carotene (ppm), Fe content (ppm), Zn content (ppm), Copper content (ppm), Magnesium content (ppm), Sedimentation value (ml), Hectolitre weight (kg/hectolitre), Total Soluble Sugar (ppm), Grain hardness (Hard, Semi-hard & Soft) and Grain density (cc).

On the basis of results obtained, the major findings of the study are given below:

- The analysis of variance for all the morphological and quality characters was carried out to partition the total variance into variance due to genotypes and other sources, which revealed that all the mean sum of squares due to genotypes were highly significant for all the traits under study under all environmental conditions, which indicated the presence of sufficient genetic variability among the genotypes for these traits.
- On the basis of the pooled mean data of all the environment for morphological traits revealed that the genotype EC 1075905, EC 1075906, EC 1075916 were observed late in heading whereas, the genotypes EC 1075905, EC 1075906, EC 1075916 and EC 1075897 observed early in heading. The maximum days to maturity was observed for genotypes EC 1075905, EC 1075932, EC 1075936 and EC 1075940. Maximum effective tiller per m² was observed for genotype EC 1075903, EC 1075921 and EC 1075922. The higher plant height was observed for genotypes EC 1075940 and EC 1075894. Maximum spike length observed for genotype EC 1075933 whereas maximum number of spikelets per spike was observed for genotype EC 1075894. More number of grains per spike was

received for genotypes EC 1075941 and EC 1075930. The highest 1000 grain weight was recorded for genotypes EC 1075898, EC 1075904 and EC 1075904.

- Maximum biological yield per plot was observed for genotypes EC 1075913, EC 1075941 and EC 1075940 whereas, for the grain yields per plot the genotypes EC 1075913, EC 1075904 and EC 1075932 were observed superior than the other genotypes.
- From pooled mean performance on the basis of quality traits genotypes recorded better quality characters were EC 1075896, EC 1075910, EC 1075914, EC 1075927, EC 1075931, EC 1075938, EC 1075939 and EC 1075941
- The evaluation of the genotypes in six different environments for morphological and quality characters, revealed that heritability was high for effective tiller m^{-2} , 1000 grain weight in environment E_2 along with higher genetic advance for the same environments. Higher heritability with higher genetic advance as percent of mean was observed for grain yield in environment E_6 .
- Genotypic and phenotypic correlation study revealed the grain yield was significantly correlated with effective tiller m^{-2} , plant height, spike length, number of spikelets per spike, number of grain per spike, biological yield and harvest index. The path coefficient analysis revealed that the maximum positive direct effect on grain yield was exerted by biological yield followed by harvest index and negative effect of spike length. The positive indirect effect noted *via* effective tiller per m^2 , plant height, number of spikelets per spike, number of grain per spike, but negative indirect was noted *via* spike length. The quality traits contributed to crude protein had high positive direct effect on grain yield and it was showed indirect positive effect through wet gluten, Fe, Cu and Mg.
- The G x E interaction was observed significant for most of the morphological characters except for spike length and biological yield. The mean squares due to these interactions were further split into linear and non-linear components for all the characters, while G x E interaction (linear) was found significant for the characters, namely, days to heading, days to maturity, effective tiller m^{-2} , plant height, number of spikelets per spike, number of grains per spikelet, 1000 grain weight and harvest index. For quality traits the mean square due to environment (linear) and pooled deviation were found significant for all characters except for total soluble sugar in environment (linear) and hectolitre weight in pooled deviation was observed non-significant.
- The genotypes investigated have shown variable performance, stability behaviour and response for different environments, whereby no single genotype was found stable and outstanding for all the characters studied. Stability analyses of variance showed significant differences for environments, genotypes and environment (linear). The genotypes EC 1075893 and EC 1075904 for days to maturity, EC 1075912 for effective tillers per square

meter, EC 1075896 and 1075941 for spike length, EC 1075907 and 1075928 for number of spikelets per spike, EC 1075925 for number of grains per spike, EC 1075909 and EC 1075917 for biological yield, EC 1075917 for harvest index EC 1075909 for grain yield have regression coefficient (b_i) values close to unity and thus possessed fair stability and wider adaptation over different environment.

- Estimation of stability for different quality traits observed that S^2di was significant in most of the genotypes except in case of Zn. Therefore, instability was predicted for all the traits of the genotypes that the S^2di showed significant over the genotypes traits except for Zn. The regression coefficient (b_i) was differ in all the traits, revealing that the genotypes were varied in performance and were either better or poorly adapted or in most of the case instability to these environments.
- The maximum grain yield performance (2860g) was found for E_5 in genotype EC 1075926 and least grain yield (900g) was exhibited for genotype EC 1075899 in E_4 .
- However, from the study of the experiment in several environments of two different countries concluded that the stable genotypes can select by breeders and farmers which already mentioned in summary part, at both the countries as genetic materials for breeding purpose and stable varieties against climate resilience.

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APPENDIX-1

Pooled mean of 6 environment for phenotypic traits

Genotypes	DH	DM	ET	PH	SL	NSS	NGS	TSW	BY	HI	GY
EC 1075892	81.7	123.4	363.0	94.5	9.8	18.3	51.2	40.5	5400.0	35.6	1889.3
EC 1075893	83.3	125.1	360.2	96.9	9.8	18.4	54.9	41.1	5533.3	34.2	1870.0
EC 1075894	81.7	125.3	364.4	108.1	10.0	20.8	56.8	38.0	5808.3	32.3	1871.5
EC 1075895	82.1	124.7	392.4	100.8	10.2	20.0	57.1	39.2	5650.0	35.4	1990.9
EC 1075896	82.1	125.2	383.0	94.1	9.7	17.8	51.3	41.6	5500.0	33.5	1821.2
EC 1075897	80.7	124.9	387.3	94.9	10.1	18.5	55.2	42.5	5716.7	35.8	2038.8
EC 1075898	82.3	125.2	391.3	94.8	9.5	17.7	51.4	44.4	5825.0	35.7	2072.4
EC 1075899	82.2	125.3	372.0	94.3	9.6	19.5	56.2	41.7	5266.7	33.7	1771.7
EC 1075900	83.1	125.4	369.0	99.9	9.7	18.8	58.0	43.6	5666.7	34.0	1918.0
EC 1075901	83.3	125.3	305.6	96.1	9.9	19.5	59.3	40.3	5591.7	35.4	1954.6
EC 1075902	82.0	124.0	321.9	95.8	9.4	18.3	52.8	40.4	5650.0	33.1	1842.0
EC 1075903	81.5	123.9	402.2	96.4	9.8	18.7	52.2	40.1	5766.7	35.1	2026.1
EC 1075904	83.4	124.7	366.3	99.1	10.2	19.8	53.7	44.3	6033.3	35.7	2127.9
EC 1075905	85.9	127.3	353.0	86.3	9.5	19.0	52.5	37.0	5616.7	34.8	1964.4
EC 1075906	85.4	126.1	359.1	102.1	10.1	19.8	61.4	37.7	5900.0	33.4	1959.0
EC 1075907	83.0	125.0	343.4	101.0	9.5	18.3	56.4	40.7	5516.7	33.6	1824.0
EC 1075908	83.7	125.1	368.9	98.8	9.5	19.3	48.9	40.9	5416.7	34.9	1871.7
EC 1075909	82.9	125.1	362.7	100.9	9.9	19.5	57.2	44.3	5791.7	35.1	2021.0
EC 1075910	83.2	125.4	376.9	106.3	9.9	18.5	56.6	39.9	5825.0	34.5	2004.9
EC 1075911	81.8	124.8	336.6	101.9	9.5	18.8	54.5	37.6	5675.0	34.1	1927.4
EC 1075912	82.5	125.2	322.2	101.3	9.4	17.5	52.9	39.0	5758.3	36.2	2070.0
EC 1075913	82.3	125.2	367.6	105.2	10.5	19.3	58.8	40.6	6191.7	35.2	2151.3
EC 1075914	82.8	125.0	346.6	106.8	9.9	19.5	52.5	39.0	5658.3	35.0	1984.1
EC 1075915	82.4	125.1	344.4	104.3	9.0	18.9	51.6	39.0	5608.3	32.2	1781.3
EC 1075916	84.4	125.7	341.9	102.7	9.8	18.6	58.8	39.1	5291.7	33.1	1743.1
EC 1075917	83.8	125.7	315.6	105.6	9.9	18.8	51.3	38.1	5183.3	34.0	1742.6
EC 1075918	83.2	125.2	311.6	103.8	9.8	18.3	58.1	39.0	5058.3	35.8	1778.7
EC 1075919	81.6	125.2	389.3	96.8	9.3	18.2	51.0	38.5	5275.0	34.1	1783.9
EC 1075920	81.8	124.4	361.8	93.6	9.4	17.3	49.9	38.8	5850.0	32.7	1905.8
EC 1075921	84.8	126.1	397.4	99.9	10.0	19.5	55.7	37.7	5900.0	34.5	2022.1
EC 1075922	81.5	125.4	397.9	101.3	9.6	19.0	52.5	38.6	5625.0	35.2	1976.9
EC 1075923	81.3	125.0	358.2	94.9	10.0	19.5	48.3	37.2	5641.7	33.5	1880.7
EC 1075924	83.3	124.7	346.7	103.8	9.5	18.4	54.2	35.3	5425.0	32.7	1783.7
EC 1075925	84.4	125.8	310.5	101.2	9.6	18.7	54.9	38.5	5466.7	32.8	1765.9
EC 1075926	82.8	125.5	342.5	103.4	9.8	18.3	56.7	40.0	5641.7	34.7	1971.3
EC 1075927	81.8	124.9	343.1	100.3	10.0	19.3	57.7	41.8	5558.3	33.5	1861.4
EC 1075928	83.3	125.8	321.2	98.7	10.0	19.2	59.9	40.6	5591.7	34.4	1905.0
EC 1075929	82.8	125.4	298.6	96.8	9.1	18.0	55.7	42.0	5141.7	34.5	1765.1
EC 1075930	83.3	126.2	285.8	98.2	9.7	19.5	61.3	41.0	5216.7	34.6	1803.2
EC 1075931	82.6	125.8	341.3	93.3	9.4	17.3	49.8	38.9	5125.0	34.4	1761.4
EC 1075932	83.2	126.5	353.7	102.3	10.6	19.0	56.8	41.7	6075.0	35.5	2131.8
EC 1075933	84.2	125.4	357.0	104.8	11.1	20.8	58.3	38.7	5741.7	34.9	2007.3
EC 1075934	82.2	125.4	360.1	101.4	9.6	17.8	54.1	40.8	5716.7	34.4	1940.1
EC 1075935	82.6	125.1	304.8	100.9	9.5	19.2	54.3	43.1	5233.3	34.4	1798.5
EC 1075936	83.4	126.6	321.0	92.6	9.3	18.0	53.8	41.6	5025.0	35.2	1767.9
EC 1075937	82.3	125.8	306.9	94.6	9.8	18.3	54.5	39.5	5333.3	34.6	1850.1
EC 1075938	81.2	125.8	347.2	96.3	9.6	18.0	54.4	41.1	5225.0	34.3	1798.9
EC 1075939	85.1	125.9	324.2	99.1	9.4	18.2	52.3	42.6	4808.3	34.5	1630.8
EC 1075940	83.1	126.6	384.7	108.3	10.2	19.5	56.1	38.6	6091.7	34.9	2103.2
EC 1075941	82.3	125.9	355.9	102.5	11.1	19.8	64.5	40.2	6141.7	33.8	2022.7
WH1105	82.9	124.8	326.0	100.7	10.3	19.3	58.4	40.5	5475.0	34.2	1811.3
WH1184	84.3	125.4	330.6	100.4	10.6	19.8	58.1	38.5	5866.7	33.6	1860.4
WH1021	81.9	125.7	350.0	102.4	10.8	19.7	55.6	38.5	5583.3	32.9	1770.4
WH1024	83.4	125.7	372.9	100.8	10.5	18.5	55.6	41.9	5697.5	34.3	1812.4
mean	82.8	125.3	350.3	99.7	9.8	18.9	55.1	40.1	5581.0	34.3	1898.3
max	85.9	127.3	402.2	108.3	11.1	20.8	64.5	44.4	6191.7	36.2	2151.3
min	80.7	123.4	285.8	86.3	9.0	17.3	48.3	35.3	4808.3	32.2	1630.8

APPENDIX-1I
Pooled mean of 6 environment for quality traits

Genotypes	WG (%)	DG (%)	CP (%)	β-C (ppm)	Fe (ppm)	Zn (ppm)	Cu (ppm)	Mg (ppm)	SV (ml)	HW (kg/hectolitre)	TSS (ppm)	GD (cc)
EC 1075892	19.7	6.8	10.8	2.7	16.8	22.5	2.4	38.0	38.7	66.0	55.9	11.9
EC 1075893	17.9	6.6	11.5	2.5	16.6	26.9	2.3	37.2	39.8	65.8	78.0	11.2
EC 1075894	22.2	7.3	10.6	3.0	17.3	22.7	2.3	36.4	38.3	66.5	68.9	12.2
EC 1075895	20.0	7.3	10.9	2.6	15.8	22.9	2.2	36.5	34.4	65.6	58.7	12.6
EC 1075896	25.5	8.2	10.8	2.9	15.4	20.9	2.3	34.5	33.6	65.5	72.3	11.7
EC 1075897	20.4	7.1	10.6	2.6	15.0	19.9	2.4	38.0	33.6	65.3	85.9	12.8
EC 1075898	19.8	7.3	10.2	2.2	15.7	26.9	2.3	31.9	35.8	67.4	70.4	11.2
EC 1075899	21.2	6.7	10.1	3.0	15.6	25.4	2.3	31.6	36.4	65.2	77.6	11.8
EC 1075900	17.8	6.9	10.2	2.5	14.0	23.8	2.3	30.7	33.2	66.1	60.0	12.0
EC 1075901	18.3	7.0	10.7	2.5	18.2	24.0	2.2	31.8	34.0	65.9	82.5	11.9
EC 1075902	16.1	5.7	9.7	2.7	19.1	22.1	2.2	35.5	42.9	65.4	85.0	11.1
EC 1075903	22.4	7.5	10.4	2.7	19.2	22.1	2.3	40.2	39.7	65.1	94.0	12.5
EC 1075904	22.5	7.1	10.3	2.6	21.8	17.4	2.6	34.4	32.3	67.4	95.4	12.3
EC 1075905	17.2	6.5	10.9	3.2	18.4	16.6	2.5	33.4	33.5	66.2	84.1	12.0
EC 1075906	20.5	7.7	11.6	2.9	20.0	15.8	2.7	36.4	40.9	65.5	64.9	12.1
EC 1075907	19.2	7.0	10.5	2.5	17.0	15.9	2.6	34.7	36.5	66.3	58.2	11.2
EC 1075908	17.8	6.4	11.0	2.9	25.2	17.5	2.5	37.0	34.2	66.3	80.3	12.2
EC 1075909	18.7	6.0	11.0	2.5	18.9	16.1	2.6	39.1	36.1	65.7	59.4	12.0
EC 1075910	17.8	5.8	11.2	2.6	20.3	16.2	2.9	39.0	37.1	67.3	55.1	12.3
EC 1075911	14.8	5.9	10.6	3.1	20.0	16.2	2.8	36.8	33.8	67.6	63.8	11.8
EC 1075912	20.2	7.9	11.1	2.5	21.1	16.0	2.9	36.0	34.4	66.8	77.4	12.4
EC 1075913	16.5	6.6	11.0	2.8	17.9	16.8	2.8	35.0	35.9	66.9	55.0	12.7
EC 1075914	18.9	6.6	11.8	2.6	16.6	16.7	2.7	34.6	44.7	65.8	71.8	12.7
EC 1075915	17.9	6.2	10.9	2.8	14.4	15.6	2.7	38.7	42.0	65.1	82.0	11.8
EC 1075916	14.4	5.1	9.7	2.8	16.6	16.7	2.9	39.2	35.8	66.4	60.8	11.3
EC 1075917	16.3	5.8	9.0	2.8	15.0	17.9	2.9	37.2	38.7	67.4	67.8	11.9
EC 1075918	17.4	6.2	9.9	3.0	15.4	14.2	2.5	36.2	45.8	67.0	59.8	12.4

EC 1075919	21.0	7.0	9.9	2.2	18.1	16.1	2.8	35.3	40.5	66.8	59.9	11.5
EC 1075920	19.8	6.6	10.0	2.2	17.3	13.8	2.9	31.9	42.5	66.1	76.9	11.7
EC 1075921	18.5	6.2	10.2	2.7	16.4	13.5	2.7	31.9	46.7	65.6	62.6	11.0
EC 1075922	19.1	5.9	9.4	2.6	22.7	20.6	2.6	31.1	36.7	66.2	70.8	11.4
EC 1075923	16.5	5.8	10.1	2.2	14.0	14.0	2.8	27.1	32.5	64.8	62.9	11.0
EC 1075924	17.9	6.0	9.8	2.2	12.3	15.0	2.6	26.2	32.5	66.2	78.1	13.9
EC 1075925	20.4	6.6	9.7	2.4	16.0	11.8	2.5	25.2	31.6	65.4	86.2	12.4
EC 1075926	18.1	6.3	9.8	3.0	17.5	12.3	2.6	27.0	36.2	65.8	64.3	12.6
EC 1075927	24.2	7.8	10.0	3.0	14.4	12.9	2.6	26.2	38.2	66.8	71.1	13.2
EC 1075928	16.2	5.8	10.0	2.7	13.0	13.0	2.7	25.7	41.1	65.8	99.2	11.7
EC 1075929	18.8	6.7	10.4	2.9	17.3	13.9	2.7	25.7	34.7	66.9	95.4	11.7
EC 1075930	17.8	6.4	10.5	3.1	17.0	10.8	2.6	25.0	32.4	67.5	97.2	12.7
EC 1075931	22.3	7.3	11.2	3.4	14.5	10.4	2.6	25.6	33.9	66.6	94.9	12.5
EC 1075932	20.7	6.7	10.2	3.2	18.1	14.8	2.9	35.5	31.2	65.8	77.2	12.7
EC 1075933	24.3	7.6	10.4	3.4	16.1	11.6	2.7	25.5	29.8	64.1	95.5	11.9
EC 1075934	21.6	7.1	9.9	3.8	16.9	12.5	4.2	37.2	36.9	64.4	86.0	11.9
EC 1075935	20.4	6.2	9.5	3.3	14.9	12.5	4.4	35.6	37.0	66.8	88.5	12.5
EC 1075936	16.0	6.2	8.9	2.3	16.8	21.9	4.7	37.8	34.2	67.3	67.5	11.2
EC 1075937	20.0	6.3	9.4	3.5	17.3	17.0	4.3	35.2	38.9	65.6	71.4	11.5
EC 1075938	24.2	8.0	10.6	2.9	19.8	22.6	4.6	38.1	36.9	67.2	95.4	11.8
EC 1075939	23.3	7.8	10.0	2.8	16.0	18.0	4.2	34.2	32.3	67.0	82.1	11.1
EC 1075940	19.2	6.6	10.3	2.6	16.2	11.3	4.1	36.8	40.8	64.7	95.1	11.8
EC 1075941	23.2	7.8	11.1	2.6	14.9	12.2	4.1	34.4	33.6	66.7	67.7	12.0
WH1105	18.9	7.2	10.6	2.5	18.3	21.9	4.5	34.9	34.4	68.2	76.2	11.5
WH1184	18.7	6.8	10.3	2.7	18.4	25.3	4.3	36.2	35.8	67.5	69.1	11.9
WH1021	24.2	8.5	11.3	3.3	21.2	26.4	4.5	36.0	31.7	66.3	80.0	10.6
WH1024	24.0	7.6	11.1	2.5	24.1	19.3	4.6	35.9	30.7	67.0	75.2	12.8
mean	19.6	6.8	10.4	2.8	17.4	17.6	3.0	33.8	36.4	66.2	75.4	12.0
max	25.5	8.5	11.8	3.8	25.2	26.9	4.7	40.2	46.7	68.2	99.2	13.9
min	14.4	5.1	8.9	2.2	12.3	10.4	2.2	25.0	29.8	64.1	55.0	10.6

ABSTRACT

Title of thesis	:	Stability analysis of genotypes with concern to yield performance and quality traits in bread wheat (<i>Triticum aestivum</i> L.)
Full name of degree holder	:	Ibrahim Hassani
Admission Number	:	2018A59D
Title of the degree	:	Doctor of Science
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Year of award of degree	:	2022
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Keywords: Stability Analysis, Correlation, PCV, GCV, Path analysis, Wheat, *Triticum aestivum*

The present investigation entitled, "Stability analysis of genotypes with concern to yield performance and quality traits in bread wheat (*Triticum aestivum* L.)" was carried out in in RBD using 54 bread wheat genotypes at research farm of Genetic & Plant Breeding Deptt. College of Agriculture, CCS HAU Hisar, Haryana (India) during Rabi 2019-2020 and 2020-2021 and research farm of Agricultural Research Institute of Afghanistan in Kabul during 2020 and 2021 in spring season. Observations were recorded for morphological characters viz., Days to heading, Days to maturity, Number of effective tillers per m² and Quality characters viz., Sedimentation value (ml), Hectolitre weight (kg/ ha), Grain density, Grain hardness, Gluten content (%), Crude protein content (%), β -carotene (ppm), Fe content (ppm), Zn content (ppm), Copper content (ppm), Magnesium content (ppm), Total Soluble Sugar (ppm). Analysis of variance revealed significant difference among the genotypes for most of the characters suggesting sufficient amount of variability in the experimental material under study.

The analysis of variance for all the morphological and quality characters was carried out to partition the total variance into variance due to genotypes and other sources, which revealed that all the mean sum of squares due to genotypes were highly significant for all the traits under study under all environmental conditions, which indicated the presence of sufficient genetic variability among the genotypes for these traits. GCV and PCV study revealed the grain yield was significantly correlated with effective tiller m⁻², plant height, spike length, number of spikelets per spike, number of grain per spike, biological yield and harvest index. The path coefficient analysis revealed that the maximum positive direct effect on grain yield was exerted by biological yield followed by harvest index and negative effect of spike length. The quality traits contributed to crude protein had high positive direct effect on grain yield and it was showed indirect positive effect through wet gluten, Fe, Cu and Mg.

Stability analyses of variance showed significant differences for environments, genotypes and environment (linear). The genotypes EC 1075893 and EC 1075904 for days to maturity, EC 1075912 for effective tillers per square meter, EC 1075896 and 1075941 for spike length, Ec 1075907 and 1075928 for number of spikelets per spike, EC 1075925 for number of grains per spike, EC 1075909 and EC 1075917 for biological yield, EC 1075917 for harvest index EC 1075909 for grain yield have regression coefficient (b_i) values close to unity and thus possessed fair stability and wider adaptation over different environment.

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Hassani I, Nimbal S, and Singh V. Genetic variability analysis and correlation studies of bread wheat (*Triticumaestivum* L.) genotypes 2022 *Ekin Journal of genetics and plant breeding*

Sayedpoor S, Hassani I., and Attifullah Shinwari 2019 Assessment of genetic variability among bread wheat (*Triticumaestivium* L.) *Journal of Pharomacognosy and Phytochemistry* 8(6): 1036-1041

Hassani, I., Shailesh, M., and Lal, G, M., 2017. Inter-relationship studies among grain yield and its components characters in wheat (*Triticum aestivum* L.). *Journal of Pharomacognosy and Phytochemistry*. 6(4): 186-19.

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UNDERTAKING OF COPYRIGHT

I, **Ibrahim Hassani**, Admission No. **2018A59D**, undertakes that I give copyright to the **Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana)** of my thesis entitled, “**Stability analysis of genotypes with concern to yield performance and quality traits in bread wheat (*Triticum aestivum* L.)**”.

I also undertake that patent, if any, arising out of the research work conducted during the program shall be filed by me only with due permission of the competent authority of **Chaudhary Charan Singh Haryana Agricultural University, Hisar (Haryana)**.

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