AN ASSESSMENT OF GENETIC VARIABILITY FOR DROUGHT TOLERANCE AND OTHER ASSOCIATED TRAITS IN WHEAT (*Triticum aestivum* L.)

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THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE AWARD OF THE DEGREE OF

Master of Science (Agriculture) in GENETICS AND PLANT BREEDING

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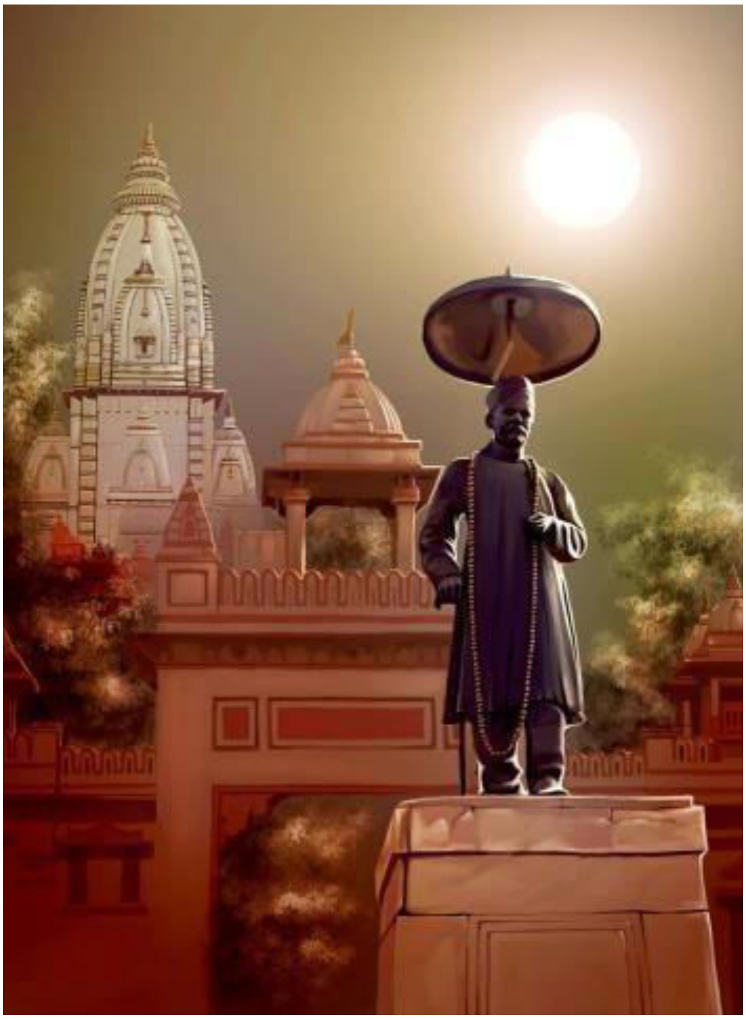

Dedicated to

My Parents

Mr. Sanal Kumar N.

Mrs. Sujaya Sanal

&

Advisor

Prof. J.P. Lal

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CERTIFICATE

To,

The Registrar (Academic),

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Through: The Head, Department of Genetics and Plant Breeding, Institute of Agricultural Sciences, B.H.U, Varanasi.

Dear Sir,

I have great pleasure in forwarding the thesis entitled **"AN ASSESSMENT OF GENETIC VARIABILITY FOR DROUGHT TOLERANCE AND OTHER ASSOCIATED TRAITS IN WHEAT (*Triticum aestivum* L.)"** submitted by **Ms. DARSHNA SANAL, I.D. No. 19412GPB005, Enrolment Number-416822,** in partial fulfillment of the requirements for the award of degree of **Master of Science (Agriculture)** in **Genetics and Plant Breeding** of the Institute of Agricultural Sciences, Banaras Hindu University, Varanasi (U.P).

I certify that the entire work reported herein, was planned and carried out by the candidate under my guidance and supervision and to the best of my knowledge and belief, the data presented in the thesis are genuine and original.

Forwarded by Yours faithfully,

(Prof. B. Sinha) **(Prof. J.P.Lal)**

Head of Department Supervisor/Advisor

AN ASSESSMENT OF GENETIC VARIABILITY FOR DROUGHT TOLERANCE AND OTHER ASSOCIATED TRAITS IN WHEAT

(*Triticum aestivum* L.)

काशी हिन्दू विश्वविद्यालय
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By

DARSHNA SANAL

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Date:

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LIST OF ABBREVIATIONS

%	Percentage
^{O}C	Degree Celsius
cm	Centimeter
CV	Coefficient of variation
et al.	And co worker
GCV	Genotypic coefficient of variation
gm	Gram
h^2	Heritability
i.e.	In other words
Mha	Million Hectare
MT	Million Tonnes
PCV	Phenotypic coefficient of variation

CHAPTER-1

INTRODUCTION

Wheat is one of the most important staple food crops grown worldwide. It belongs to family Poaceae. As per the archaeological records, this cereal grain was first cultivated in the regions of the Fertile Cresent around 9699 BC. Genetic analysis of einkorn wheat suggest that it was grown in Karacadag Mount, Turkey. The cultivated emmer wheat reached Indian subcontinent by 6500 BC. Identifiable bread wheat that dated back to 1350 BC was found using the DNA analysis of samples from old granaries at Macedonia.

Wheat (*Triticum aestivum* L.) is a bisexual self-pollinated crop. The inflorescence of wheat is botanically known as spike which consists of smaller units called Spikelet. The florets comprise of bracts called lemma (external) and palea (internal) which enclose the reproductive parts androecium and gynoecium. The opening of flowers and anthers are regulated by lodicules. Each of the florets consists of three stamens bearing anthers and a pistil with feathery bifid stigma. Wheat flowers are incomplete and zygomorphic. Wheat stamens can produce approximately 1000 to 3800 pollen grains per anther **(McMaster, 1997).** Anthesis of florets begin at the middle of the inflorescence and continues in both directions. The anthesis is complete in about 2-3 days. Anthesis leads to grain formation and botanically the fruit type of wheat is caryopsis.

Wheat is an allohexaploid crop which arose as a result of two wide hybridization event that occurred 0.5- 3.0 million years ago. This occurred between two diploid (2n=14) ancestors namely *Triticum monococcum* var. *urartu* (AA genome) and an unknown species (BB genome). After chromosome doubling it finally formed the wild tetraploid wheat *Triticum turgidum* ssp. *dicoccoides* having AABB genome (2n=28). This particular species was domesticated to cultivated *Triticum turgidum* ssp. *dicoccum* which is also known as the emmer wheat. About 9000 years ago a second hybridization occurred between the cultivated emmer wheat and diploid *Aegilops tauschii* (DD genome) to form allohexaploid wheat *Triticum aestivum* having genome AABBDD (2n=42) **(Walkowiak *et al.,* 2020).** Wheat has a very large genome size of about 16 gigabases with each subgenome size approximately being 5.5 gigabases and >85% being the repetitive sequences. A group of breeders and scientists in 2005 initiated the International Wheat Genome Sequencing Consortium (IWGSC) which aimed to decode and unravel the mystery of the wheat genome to expedite the molecular breeding techniques in wheat. At present all the chromosome arms of Chinese Spring variety of wheat have been sorted and the construction of their physical maps are completed successfully **(Xioli Shi *et al.,* 2018).**

India is blessed with a diversified agroecological conditions which helps in ensuring a steady production of wheat. It is mainly cultivated in the rabi (winter) season and mostly grown in the flat fertile alluvial plains of Northern India. The optimum temperature for its germination is 20-25℃. Wheat crop require cool and moist weather (10-15℃) during the vegetative phase and dry and warm weather (21-26℃) during reproductive phase At the time of ripening, the crop requires an average temperature of around 30℃ **(McMaster, 1997).** It has a wide range of adaptability and can be grown at an altitude as high as 3300 meters from the sea level. The crop is successfully grown in places with an annual mean rainfall of 750 mm. In India it is even cultivated in areas receiving below 500 mm rainfall due to the availability of sophisticated irrigation facilities. Wheat is successfully grown not only in the tropical and sub-tropical zones but also in the temperate zone. It is capable of tolerating severe cold and then resuming its growth with the setting in of warm weather. However, excessive high or low temperature and drought during its reproductive phase (heading and flowering) are harmful and have adverse effects on yield.

The wheat production during 1950-51 was merely 6.46 million tons and the productivity was only 663 kg per hectare. Our country was a major importer of food grains (including wheat) for domestic consumption due to insufficient production to meet the growing population. The situation became more worse after the China war during 1962. Due to the challenges like malnutrition, hunger and increasing pressure of population, the Government took decision to establish "The All India Coordinated Wheat Improvement Project (AICWIP)" in the year 1965 which was one of the largest multidisciplinary and multilocational crop improvement project. It played a pivotal role in setting the dawn for the "Green Revolution" in 1966-1967. The impact of inception of AICWIP (now known as the AICRP on Wheat and Barley Research) was substantial and contributed significantly leading to green revolution. Thus, it helped nation in progressing closer to its food security mission and to achieve surplus food production **(Ramadas *et al.,* 2019).**

Wheat is the 2nd most important food crop cultivated in India after rice. It is globally grown in an area of 217 million hectares with the annual production of 772 million metric tons in 2020-21 (Anonymous, 2021). It has the highest acreage among all crops. In India wheat covers an area of approximately 29.8 million hectares with Uttar Pradesh having the largest share in area accounting to 9.75 million hectare (32%), followed by Madhya Pradesh (18.75%), Punjab (11.48%) and Rajasthan (9.74%). China holds the position of highest wheat grain production of 133.6 million metric tons. India ranks 2nd with an annual production of 108.0 million metric tons (2020-2021) with a growth of 0.13% amidst the COVID-19 pandemic (Anonymous, 2021)**.** World trade in this crop is much more than all other crops combined. During the year of 2019-2020, India has exported 2,17,354.22 million tons of wheat to the world for the worth of Rs.439.16 crores.

Wheat is an important staple diet for around 2.5 billion consumers worldwide. Wheat contains 78.10% carbohydrates, 14.7% protein, 2.10% fat and 2.10% minerals. It is also a good source of vitamins (thiamine) and dietary fiber and traces of magnesium. The characteristic quality of gluten protein helps to make bread dough stick and provides the ability to retain gas. Thus, it is extensively used in bread, biscuit, cake and chapatti. The wheat grain/germ is rich in pantothenic acid, riboflavin, essential vitamin E and minerals such as copper, zinc and iron, though vit. E is removed in the process of refining. The whole wheat including bran and germ has great medicinal value and helps in preventing diseases like ischaemic, constipation, heart attack and diabetes **(Kumar *et al.,* 2011).**

In general wheat is taken in the form of wheat flour which is the protein rich grinded powder of wheat endosperm and used for human consumption. Wheat flour containing low gluten content is known as “soft” or “weak” whereas if the gluten content is high (12-14%) it is known as “hard” or “strong” flour. Hard flour is used for bread making and its dough has enough elastic toughness. Soft flour is used for making cake. There are mainly three types of flour on the basis of part of grain used for flour making.

i) White flour- It is made only from the endosperm.

ii) Brown flour- It is made from grain’s bran and germ

iii) Whole meal flour- It is made from grain’s germ, bran and the endosperm

iv) Germ flour- It is made from germ and endosperm (excluding bran)

Drastic climate changes and increased scarcity of water are big challenges to global food and nutritional security, which might be further complicated due to the pressing need to feed an increasing global population. It is predicted that the global temperature, which is expected to increase by 2 °C by 2050, will cause approximately 50 million people to experience malnutrition and hunger risk due to agricultural effects. Estimates state that global food and agricultural production might need to be increased by 60–110% to keep in pace with the increasing demands. However, the rates of Indian as well as the global food production are far below the amounts required to meet expected demands by 2050 **(Yerlikaya *et al.,* 2020)**. Crop productivity and yield are affected by various agronomic and environmental factors amongst which water availability and temperature are the most important. There is extensive crop yield variability present in many semi-arid regions, which are owed to water limitation and year-to-year fluctuations in climatic and meteorological conditions. Drought has been one of the most important limiting factors for crop productivity and nutritional security worldwide. Although an increase in the optimum temperature is beneficial for some crop productivity in few cooler regions of the world, drought still significantly reduces national cereal crop production by 9–10% on a global scale via its negative effects on plant growth, physiology, reproduction and grain development

Qaseem *et al.,* (2021) have reported that a yield reduction of 27.5% was observed due to drought in wheat. Yield reduction has been attributed to the decrease in photosynthetic activity and lower supply of carbon assimilates that are important for reproductive development and seed growth. Wheat can adapt to drought conditions through high osmotic adjustment followed by recovery after stress. Plant such as wheat is capable of shedding their old leaves and maintaining the carbon assimilation in their new, young leaves. Molecular genetics combined with genomics have discovered many quantitative trait loci (QTLs) that affect yield under drought conditions.

The most important component in wheat which is responsible for reduction in plant biomass is the decrease in grain yield, which is followed by a decrease in the plant height. The yield loss under drought conditions attributed to the decreases in yield components (e.g., weight of grains/spike and biological yield). Plant height and number of grains per spike were the two most important components responsible to yield reduction in wheat. Drought has an extremely adverse effect on cell division (meiosis) and anthesis, which directly affects fertilization and grain formation. This result in a substantial reduction in grain yield. When drought occurs during the early stage of microsporogenesis, pollen development is affected and pollen becomes sterile which would reduce the grain number. It is suggested that grain filling is damaged the most by drought over the complete crop growth cycle **(Zhang *et al.,* 2018).**

Hence, it becomes very necessary to understand the gravity of the problem and to come up with selection criteria which enable to increase biomass production and economic yield under the conditions constrained by climate and water availability.

Therefore, the present research entitled "An Assessment of Genetic Variability for Drought Tolerance and other associated traits in Wheat (*Triticum aestivum* L.)" was carried out with thirty genotypes. The objectives of the experiment under study were set in accordance with the present as well as future needs of the global population. The objectives were as follows-

1) To study genetic variability present in a set of 30 wheat varieties.

2) To determine characters associated with drought tolerance.

3) To estimate direct and indirect effects on grain yield.

4) To select drought tolerant genotypes based on Drought Tolerance Indices.

CHAPTER-2

REVIEW OF LITERATURE

Review of literature helps in evaluation of the currently available literature and identifying the problems and their solutions by choosing a proper methodology for research work. It provides the students and researchers with an opportunity to correlate the results with the existing knowledge and to recommend further research in the area under study.

The available literatures are reviewed and studied in accordance with the objectives under the following sub-headings.

2.1 Analysis of genetic variability parameters such as Genotypic coefficient of variation (GCV) and Phenotypic coefficient of variation (PCV), heritability (broad sense), Genetic Advance (as a percent mean)

2.2 Character association studies

2.3 Analysis of Path Coefficient

2.4 Study of Drought Tolerance Indices using Principal Component Analysis

2.1 Analysis of genetic variability parameters-

Study of genetic variability parameters are of great importance as a plant's phenotypic expression is determined by the genotype, environment and the GE interaction. It becomes a challenging task for the breeders to select the plants with desirable traits that are conferred by the genotype rather than the environment. Estimation of heritability helps in selection of the plants with higher magnitude of genotypic variance and lower environmental variance.

Therefore, the parameters like GCV, PCV, broad sense heritability, narrow sense heritability, genetic advance (percent of mean) helps to increase the efficiency of selection for quantitative as well as qualitative characters and to predict the variability present in the germplasm.

Panwar *et al.,* (2000) evaluated 30 cultivars of wheat under agro-c1imatic conditions of Uttar Pradesh (western) and reported higher values of variability for number of effective tillers per plant, plant height, spike length, test weight (1000 grain weight) and grain yield per plant.

Korkut *et al.,* (2001) conducted experiments in randomised block design (RBD) with three replications in the field of Tekirda đ Agricultural Faculty at Thrace University. The data showed that the highest genotypic variability was exhibited by yield per hectare and the highest values for phenotypic variability were obtained for test weight (1000 kernel weight), plant height and grain yield. The broad sense heritability (H_b) was found to be the highest for characters such as plant height and test weight, whereas it was low for number of spikelets per spike and spike length.

Khan *et al.,* (2003) studied the F2 population of six crosses of wheat namely WLRG-3×LU26S, WLRG-4 × 5039, WLRG-3 × 5039, WLRG-5 × 5039, WLRG-6 × 5039, WLRG-6 × LU26S to determine the genetic advance and broad-sense heritability of traits like number of productive tillers per plant, peduncle length, plant height, flag leaf area and grain yield/ plant. The broad sense heritability for grain yield per plant ranged from 65.58% to 90.01%. The excellent cross which gave promising segregating material for selecting high yielding lines of wheat was WLRG-3 × 5039.

Sial *et al.,* (2007) evaluated 8 parental lines and their F3 progenies for the genetic parameters in 7 yield associated traits. All the genotypes exhibited highly significant differences ($p \leq 0.01$) for the traits like plant height, number of kernels per spike and seed index. Progeny of cross Khirman×RWM-9313 showed high heritability combined with higher genetic advance for number of grains per spike and number of spikelets per spike. Outstanding performance was shown by the drought tolerant variety- Khirman as it had higher number of tillers per plant and higher grain yield per plant.

Eid (2009) evaluated four lines of wheat namely, Sakha8, Sids1, line1, line3 and their crosses Line1×Sakha8, Line3×Sakha8, Line1× Sids1 and Line3×Sids1. Experiment was conducted under both drought stress and irrigated conditions to estimate heritability and genetic advance for yield traits. Plant height, number of grains per spike, spike length and test weight revealed significant differences among genotypes and crosses under both the conditions. Greater magnitude of heritability and genetic advances in few traits showed that they were under the control of additive genetic effects. Selection could be effective for genetic improvement of such traits.

Gashaw *et al.,* (2010) conducted experiment using 44 durum wheat accessions and reported medium genotypic coefficient of variation for spike length (12.5%) and kernel yield per plant (12.3%). High broad sense heritability for spike length (89.2%), plant height (87.1%) and test weight (80%) were observed. Maximum broad sense heritability combined with high genetic advance were observed for plant height, ear length and test weight.

Talebi (2012) evaluated 24 genotypes of bread wheat for 2 years under constructing water regime and observed that number of seeds per m^2, plant height and yield showed highest environmental variances. Harvest index showed lowest GCV values (2%) whereas highest GCV value (12%) was shown by number of seeds per spike, plant height and grain yield per plant. Number of seeds per spike and plant height showed high broad sense heritability under both water stress and control condition, whereas a significant decrease in seed weight, number of seeds per plant and harvest index was seen under water stress condition.

Pokharel *et al.,* (2013) reported significant variance among the wheat cultivars for most of the traits. Variability was seen for water use efficiency, plant height, days to anthesis, biomass yield and number of tillers under both moisture-stressed (drought condition) and non-moisture stressed environment. Genotype Gautam showed superiority among rest of the cultivars for drought adaptive physiological traits.

Amin *et al.*, (2015) did experiment on 50 wheat lines to study heritability, genetic advance (GA), genotypic coefficient of variation (GCV) and phenotypic coefficient of variation (PCV). A total of 14 different morphological traits were considered for the genetic analysis. GCV and PCV were high for the traits like grain filling duration and grain yield. High heritability (broad sense) coupled with high genetic advance (GA) was observed for days to heading, days to anthesis, days to physiological maturity, plant height and yield per hectare.

Guo *et al.,* (2015) conducted a variance component analysis to determine the heritability of size of anther and ovary at various positions within a spikelet at 7 different floral developmental stages under field and greenhouse conditions. The 3rd and 4th floret from the spikelet base showed more sensitivity to the environment as compared to the 1st floret.

Choudhary *et al.,* (2015) raised eight genotypes of wheat at Pusa farm, Bihar under both normal and stressed environment to evaluate genetic variability and heritability of four traits namely, spikelet fertility, pollen sterility, number of effective tillers per plant and number of grains per spike. The GCV and PCV both were high for number of grains per spike, spikelet fertility and pollen sterility while it was moderate for number of tillers per plant. The heritability and GA (genetic advance over mean) was found to be high for all the four traits under study.

Kumar *et al.,* (2017) evaluated eighteen characters in 10 diverse parents along with their 45 F1 progeny of bread wheat. The studies showed highly significant differences which indicated high amount of genetic variability. High yield per plant was seen for cross DBW 14×K0424 followed by cross K9162×K9423. High PCV and GCV was observed for canopy temperature and grain yield per plant. High heritability and high genetic advance were shown by protein content and grain yield per plant respectively.

Farooq *et al.,* (2019) conducted the line × tester analysis of 10 parents and its F1 progeny to assess the combining ability effects for yield using randomized complete block design. Significant differences were observed among line, tester and their F1 progenies. Their study showed more than 80% heritability for most of the yield contributing traits.

Jaiswal *et al.,* (2019) investigated 32 genotypes of wheat to assess the genetic variability, heritability and genetic advance. Moderate heritability was observed in traits like 75% anthesis, ear length and test weight. High GCV and PCV was seen in yield per plot, canopy temperature and biological yield. Extremely low GCV and PCV were observed in traits days to 75% heading, days to 75% flowering, SPAD meter reading (chlorophyll content). Genetic advance was high for plant height while moderate for character such as harvest index, chlorophyll content and grains per spike.

Gerema (2020) conducted an experiment to study seven metric characters in 12 genotypes of durum wheat at Oromia. The estimates of GCV and PCV were found to be high for test weight, number of grains per spike and also grain yield per plant. The broad sense heritability ranged from 31.6% to 80.8% for maturity and grain yield, respectively. Phenotype based selection was expected to be effective due to high heritability coupled with high genetic advance for the characters such as height of plant, test weight and number of grains per spike.

Malbhage *et al.,* (2020) did experiment on 40 varieties of durum wheat (*Triticum durum* L.) and found significant differences among MSS (mean sum of square) due to genotypes. High estimates of both GCV and PCV were observed for grain yield/plant. High heritability along with moderate to high genetic advance (as percent of mean) were observed for the characters such as days to 50% flowering, plant height, number of tillers per plant, spike length and biological yield per plant which indicated high selective value due to higher additive gene action.

Heidari *et al.,* (2020) evaluated 16 advanced durum wheat breeding lines under supplementary and rainfed irrigation conditions. It was revealed in the study that PCV of traits was more than GCV. High heritability along with high genetic advance (GA) was observed for most of the traits which indicated that the heritability is mainly due to additive gene effects.

Biru (2020) conducted an experiment on 49 genotypes of bread wheat at three locations of southwestern Ethiopia under rainfed conditions. The studies revealed highly significant differences ($p<0.01$) between various genotypes for all traits except number of tillers per plant at Chena and biomass yield at Masha. Non-significant differences between genotypes were observed for number of spikelets per spike at Shey Bench. At all the three locations, it was observed that most of traits showed phenotypic coefficient of variation greater than the genotypic coefficient of variation. Characters like days to heading, spike length, days to maturity and grain filling period showed high heritability along with moderate genetic advance.

Nizamani *et al.*, (2020) evaluated 8 F3 populations along with their six parents in a Randomized Complete Block Design with four replications. The ANOVA (analysis of variance) exhibited significant differences among genotypes for the traits such as tillers per plant, plant height, spikelets per spike, spike length, number of grains per spike and harvest index. The genetic parameters revealed that cross TJ-83 x TD-1 showed higher heritability coupled with high genetic advance for spike length, plant height, spikelets per spike and grains/ spike; TJ-83 x Sarsabz for number of tillers per plant; TJ-83 x Moomal for harvest index and grain yield per plant and Moomal x TD-1 for seed index.

2.2) CHARACTER ASSOCIATION-

The literature of scientific research studies conducted by various workers on correlation in wheat are presented below.

Esmail (2001) conducted an experiment with 21 wheat crosses at the Experimental Research Station of Shebin El-Korn, Menofiya University to determine the association of grain yield and other related traits. Genotypic and phenotypic correlations, between all possible pairs of characters studied showed difference in magnitudes when estimated from the Parents, Fl and F2 generations due to different genetic constitution of the 3 populations studied (parents, F1 and F2). Grain yield per plant exhibited positive correlation with plant height, number of spikes per plant, and days to heading but negative correlation was observed for grain weight per spike in the parents, Fl and F2 generations at both the genotypic and phenotypic levels. In all the three populations, the largest negative phenotypic and genotypic correlation was observed between number of spikes per plant and grain weight per spike. Thus, number of spikes per plant and grain weight per spike could be used as a reliable selection criterion in wheat breeding programmes.

Okuyama *et al.,* (2004) studied correlation in wheat genotypes under both moisture-stress and non-stress environments Positive phenotypic correlation was observed between grain yield and number of grains per spike and biomass yield. Results clearly revealed that number of grains per spike and number of spikes per plant were related to higher yield.

Khan *et al.,* (2005) reported a positive correlation between plant height and spikelets per spike whereas all other traits were negatively correlated with plant height. Tillers per plant was also found to be positively correlated with all other characters excepts number of spikelets per spike. Spike length was positively correlated with grain yield and spikelets per spike. Significant positive correlation was seen between test weight and grain yield per hectare.

Gashaw *et al.,* (2010) conducted an experiment using 44 durum wheat accessions and reported strong positive genetic correlation between grain yield with kernel yield per plant (r=0.89), plant height (r=0.84%), test weight (r=0.82%), number of grains per plant (r=0.78%). On the contrary, a significant negative correlation was observed between grain yield and days to heading.

Khan (2012) did experiment with 13 genotypes under two different water regimes (irrigated and non-irrigated condition). The studies showed that under irrigated condition traits like number of spikelets, number of grains had a direct positive contribution to the grain yield. To increase the grain yield, traits such as number of spikes, spike length, number of spikelets, number of grains per spike could be taken into consideration.

Mohammadi *et al.,* (2012) observed that grain yield had a positive correlation with test weight and plant height under supplemental irrigation condition. In dryland environment also a positive correlation was seen between grain yield and spike length, test weight, plant height, days to maturity. Under dryland environment the grain yield of bread wheat mainly depended on plant height, 1000 kernel weight and days to maturity, whereas under supplemental irrigation grain yield was depended on spike length, plant height and test weight. Test weight of wheat was thus reported as a promising character for increasing grain yield under stress condition.

Farshadfar *et al.,* (2012) reported highly significant differences among GE interaction. According to the environmental component of GE interaction, the absolute value of first environmental component (r1) in all the environments was higher than the r2 and r3 components. It was also observed that the variation of r1 was higher than r2 and r3, and that of r2 was more than r3. Much variation was seen for yield contributing traits indicating possibility of selection for drought- tolerant genotypes.

Talebi (2012) evaluated 24 genotypes of bread wheat for 2 years under constructing water regime and observed significant and positive correlation between number of grains per spike, number of seeds per m^2 and harvest index with yield at both phenotypic and genotypic level in both environments. Studies suggested that wheat cultivars can be improved through direct selection for grain yield and indirect selection for yield components.

Yani (2012) did experiment to determine the traits responsible for grain yield under drought stress. A high correlation was observed between grain yield and biological yield. Thus, grain yield could be increased by obtaining maximum expression of biological yield.

Ata *et al.,* (2014) studied the morphological traits under both irrigated and drought conditions in 25 genotypes of wheat. Correlation studies and path coefficient indicated that the spike density, spike length and 1000 grain weight were the main traits that contributed towards grain yield under both the conditions. In irrigated condition maximum correlation was observed for number of grains per spike followed by weight of grains/ spike, whereas in drought condition the maximum value of correlation was seen between number of grains per spike and grain yield.

Guo *et al.,* (2015) conducted experiment which revealed a good correlation between spike dry weight and ovary and anther size under both field and greenhouse condition. However, size of the ovary depicted much closer relationship with spike dry weight.

Mecha *et al.,* (2017) tested 64 wheat genotypes to assess the yield contributing traits. They observed that at both phenotypic and genotypic levels grain yield had a positive correlation with number of productive tillers per plant, number of spikelets per spike, spike length and test weight.

Ojha *et al.,* (2018) studied 20 diverse genotypes of wheat and reported a significant and positive correlation (r=0.663) between number of spikes per m^2 and grain yield. A positive phenotypic correlation was observed between grain yield and spike weight, plant height, spike length, number of grains per spike and test weight.

Barman *et al.,* (2020) evaluated 30 wheat cultivars using fifteen quantitative parameters. A positive correlation was observed between number of tillers per plant, days to 50% flowering, spike length, flag leaf area, plant height chlorophyll content, test weight and harvest index with grain yield per plant at both genotypic and phenotypic levels whereas canopy temperature and grain yield exhibited a significant negative correlation.

Gerema (2020) conducted an experiment at Oromia to study seven quantitative characters in 12 cultivars of durum wheat. A strong correlation of grain yield with test weight, number of grains per spike and plant height were established providing an opportunity for indirect selection.

Upadhyay (2020) observed that grain yield had a significant positive phenotypic and genotypic correlation with number of grains per spike, test weight, weight of grains/ spike, days to maturity and harvest index of wheat. For all the traits studied, the genotypic correlation was higher in magnitude than phenotypic correlation.

Ajmalud Din *et al.,* (2020) reported significant differences among mean sum of squares for all traits under normal and moisture stress environmental conditions. High variability was observed for osmotic adjustment and relative water content suggesting that they could be used as selection criterion for drought tolerance. Significant association was seen between proline content and chlorophyll content. Osmotic adjustment was significantly correlated with cell membrane stability and relative water content.

2.3) Path coefficient analysis-

Esmail (2001) conducted an experiment with 21 wheat crosses at the Experimental Research Station of Shebin El-Korn, Menofiya University. Parents, F1 and F2 population were evaluated to study path analysis which showed that traits exhibiting highest correlation to yield also had the maximum direct effects on yield at genotypic and phenotypic levels. Number of spikes per plant showed highest direct effect on grain yield per plant followed by weight of grains per spike and plant height in the three populations but at the genotypic level, plant height exhibited a negative direct effect in the parental lines. Grain weight per spike and number of spikes per plant had the highest contribution to grain yield, either through its direct or indirect effects with other traits.

Okuyama *et al.,* (2004) studied path coefficient in wheat genotypes in both moisture-stress and non-stress environments. Based on path coefficient analysis, grain yield was the dependent variable and the independent variables included number of grains per spike, days to anthesis, kernel weight and plant height. Path analysis indicated direct positive effect and moderate correlation between grain yield with number of grains per spike and number of spikes per plant.

Khan *et al.,* (2005) evaluated ten elite breeding lines of wheat under rainfed condition at Peshwar for yield contributing traits**.** They reported that path analysis revealed highest positive direct effect of number of tillers per plant on yield of plant followed by test weight and spikelets per spike.

Aycicek *et al.,* (2006) conducted experiment with twenty bread wheat genotypes to estimate the direct and indirect effects of traits contributing to yield. Positive direct effect of grain weight per spike and plant height with grain yield was observed, whereas negative direct effect of days to heading was observed with grain yield. Thus, it indicated that these yield contributing traits could be used as a good selection criterion to enhance yield of wheat cultivars.

Khan ***et al.,*** **(2010)** reported that the magnitude of positive direct effect on grain yield was highest through number of spikelets per plant, followed by number of grains per spike and 100-seed weight; whereas high negative direct effect on grain yield per plant was observed due to protein content followed by number of grains per spikelet and number of effective tillers.

Farshadfar ***et al.,*** **(2012)** reported that path coefficient studies showed more contribution of test weight in the phenotypic stability of grain yield than the number of seeds per spike and number of spikes per plant.

Yani (2012) did experiment to determine the traits responsible for grain yield under drought stress. Path analysis revealed that under drought stress condition, straw yield and plant height had a positive and significant role in increasing grain yield.

Ayer ***et al.,*** **(2017)** reported biological yield and harvest index showed the highest positive direct effect on grain yield, whereas other yield contributing characters showed significant but indirect effect on the grain yield through biological yield and harvest index. This indicated that harvest index and biological yield had significant positive correlation and high direct effect on grain yield. Therefore, direct selection of the wheat genotypes through these characters could be effective for improving yield potentiality.

Mecha ***et al.,*** **(2017)** tested 64 wheat genotypes to assess the yield contributing traits. Path coefficient analysis revealed that there was a positive direct effect of test weight (thousand kernel weight), harvest index, number of kernels per spike on grain yield.

Zare ***et al.,*** **(2017)** reported the direct effects of spike weight per plant and harvest index on grain yield were positive and highest under non-stress conditions, suggesting that direct selection could be effective to improve grain yield with these traits.

Ojha ***et al.,*** **(2018)** studies in 20 diverse genotypes of bread wheat. The path coefficient studies showed that the positive direct effect on grain yield was highest via number of grains per spike, test weight and days to flowering.

Sharma *et al.,* (2018) The high positive direct effects for the grain yield per plant (dependent variable) was recorded for number of effective tillers per plant followed by number of grains per spike, and 100 grain weight. It was observed that in general, there was a low indirect effect of the traits towards grain yield per plant.

Barman *et al.,* (2020) evaluated 30 wheat cultivars using fifteen quantitative parameters. Path coefficient analysis showed that number of grains per spike, plant height and relative water content had the maximum direct effect (positive) on grain yield.

Upadhyay (2020) reported that path coefficient analysis of genotypic correlation revealed a high positive direct effect of spike length (0.43), plant height (0.75) on grain yield of wheat.

2.4) Effect of drought on wheat-

Kilic *et al.,* (2010) did experiment on fourteen cultivars of *Triticum turgidum* ssp. *durum* to evaluate yield components and some quality traits. The studies showed a negative association between the number of days to maturity and Drought Susceptibility Index (DSI), while a positive association was seen between spike length and DSI under drought condition. A high degree of variation in relative yield (RY) and DSI within genotypes were observed. Values of DSI ranged from 0.83 to 1.07. The mean RY values were 0.82 and 0.87 for well-watered and water stressed plots respectively.

Kulkarni *et al.,* (2017) studied ERECTA gene which is a classical example of a gene regulating transcription efficiency in Arabidopsis. TaER1 and TaER2 are two homologues of ERECTA in wheat which had a negative correlation with transcription rate and a positive correlation with flag leaf area and biomass. Thus, suggesting their involvement in transcription efficiency related traits in *Triticum* spp. Overexpression of TaERF3 in bread wheat resulted in increased drought tolerance.

Huiqian Yu *et al.,* (2018) did a dynamic monitoring of effects of drought in winter wheat in five provinces of eastern China by studying the drought severity index (DSI), based on normalized difference vegetative index (NDVI) and the potential evapotranspiration. Spatial and temporal patterns of DSI based droughts helped to study the correlation coefficient between the stress affected crop area and the winter wheat yield. The incipient drought during wintering, greening and jointing period had a promoting effect on the wheat yield. But the mild drought during the grain filling and maturity significantly reduced the grain yield. The severe to extreme droughts at the seeding period also affected the production of winter wheat.

Muhammad *et al.,* (2018) studied two tolerance mechanisms in response to drought stress. The first mechanism being the upregulation in genes which produced antioxidant enzymes like SOD (superoxide mutase), CAT (catalase), APX (ascorbate peroxidase) and production of non- enzymatic antioxidants e.g., GSH and carotenoids whereas second mechanism involves accumulation of proline, free amino acids and soluble salts which were responsible for osmotic adjustment. Antioxidant enzyme activity were higher under severe stress than moderate stress without any significant difference ($P<=0.05$) between the various growth stages; whereas APX enzyme which showed a higher activity during tillering stage than the jointing stage. Drought tolerance attribute of certain cultivars were due to combined effect of increased ability to scavenge ROS and osmotic adjustment which ultimately resulted in increased photosynthetic stability during drought periods and rapid recovery following drought.

Schmidt *et al*., (2020) conducted X-ray computed tomographic analysis of over 203 diverse wheat accessions which was either exposed to drought or combined drought and heat stress. They successfully established a pipeline which had a higher throughput with a scanning time of 7min per ear and had an accuracy of 95-99% in evaluating the grain set. The seed weight and seed number per ear showed a significant reduction under drought stress condition. The pipeline could be used for high throughput, high resolution phenotyping of thousands of genotypes, thus greatly accelerating the abiotic stress breeding program.

2.5) Study of Drought Tolerance Indices using Principal Component Analysis-

Drought Tolerance Indices provide a means for comparison between the yields of various genotypes under stress and non-stress environments. The literatures reviewed the scientific studies on Drought Tolerance Indices conducted by different workers are presented below.

Boussen *et al.,* (2010) conducted experiment with 249 F7 RILs and studied their yield ability under irrigated (Yi) and rainfed (Yp) environment. 6 drought tolerance indices including- STI, SSI, MP, GMP, YSI and TOL were used to identify high yielding as well as drought tolerant RILs. Higher values of indices - GMP, STI and MP indicated higher yielding RILs under both growing conditions. Higher values SSI and TOL were associated with significant reduction in grain yield under moisture stress environment. Significant positive associations between the indices MP, STI and GMP with yield were observed whereas negative correlation between YSI and SSI were seen with grain yield.

Anwar *et al.,* (2011) studied grain yield which was recorded in both experiments under stress (Ys) and irrigated (Yp). Drought tolerance/resistance indices such as tolerance index (TOL), mean productivity (MP), stress susceptibility index (SSI), harmonic mean (HM), geometric mean productivity (GMP), Yield Index (YI), Stress Tolerance Index (STI), Yield stability index (YSI) and modified stress tolerance index (k1STI & k2STI) were calculated. Significant differences were seen among cultivars for Yp, Ys and all other indices. Moderate to high genetic advance and heritability were observed for Yp, Ys and all other drought tolerance indices. Grain yield under non-stress irrigated environment (Yp) was observed to be positively and significantly correlated with HM, MP, GMP, STI and k1STI. Significant positive association was observed between Ys (grain yield under stress condition) and the indices such as MP, GMP, HM, YI, STI and k2STI.

Ilker *et al.,* (2011) evaluated 7 wheat cultivars based on tolerance indices in 4 years field experiments which differed in rainfall quantity. Six selection indices including Stress Tolerance Index (TOL), Relative Decrease in Yield (RDY), Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Tolerance Index (STI) and Stress Susceptibility Index (SSI) were estimated based on grain yield under both dry and wet conditions. From the undertaken studies it was clearly concluded that MP, GMP and STI values were reliable parameters to efficiently select high yielding wheat cultivars in both dry and wet environment whereas values of RDY, TOL and SSI were better indices to estimate tolerance levels.

Ghobadi *et al.,* (2012) did research which included two different experiments (one with rain-fed condition and other with supplemental irrigation) containing 20 dryland bread wheat genotypes which were sown in a randomized block design with three replications each. Various Drought Tolerance Indices including TOL, MP, GMP, SSI, STI, HAM, YI and YSI were determined based on grain yield under rain-fed and supplemental irrigation conditions. GMP, STI and MP indices revealed high correlation with grain yield per plant under both rain-fed and supplementary irrigation conditions and were recognized as appropriate indices to identify genotypes under drought stress environments**.**

Mollasadeghi (2013) conducted investigation with 12 wheat genotypes in RBD and found that drought tolerance indices indicated that indices such as GMP and MP were highly correlated with Yp and Ys, and were thus designated as the most efficient indices for screening for drought conditions. Based on the indices two main components accounted for 99.54% of the variations.

Karimi *et al.,* (2013) studied 79 RILs under different moisture regimes- normal and water deficit conditions. Analysis of variance depicted that there was significant difference among genotypes for grain yield under non-stressed and normal conditions. Different drought tolerance indices include MP, GMP, TOL, SSI and STI were calculated based on the grain yield under rain-fed (Ys) and normally irrigated (Yp) environments. MP, GMP and STI had the highest correlation with grain yield in both the conditions and therefore was selected as the best indices.

Nouraein ***et al.,*** **(2013)** did experiment with 149 RILs and calculated 8 drought tolerance indices including STI, TOL, MP, GMP, SSI, RDI, YSI, and DI in order to identify high yielding, drought tolerant RILs. Significant positive correlation was found between Ys (grain yield under stress condition) and STI, GMP, MP, SSI, YSI, DI and RDI showing the efficiency of the following indices for screening and identification of drought tolerant genotypes. Decrease in plant height under water stress condition was negatively correlated with biomass, grain yield, spike length, grain no. per spike and 1000 grain weight. The biplot analysis based on components indicated that the most appropriate drought indices were MP, GMP and STI. GMP also showed highest correlation with grain yield. The wheat genotypes with high scores for PC1 and low scores for PC2 were high yielding or stable genotypes whereas genotypes having low PC1 and high PC2 scores were low yielding or unstable genotypes.

Ali ***et al.,*** **(2016)** studied several drought indices to identify drought-tolerant lines among 49 wheat lines in Egypt under irrigated and non-irrigated condition. Results revealed that grain yield under non-stress and stress environments were highly correlated with the mean productivity, the geometric mean productivity, stress tolerance index, yield index and drought resistance index. It was found that MP, GMP and STI were considered the best indices for the selection of the tolerant lines. PCA indicated that the first two components or factors accounted for more than 98% of the total variations for drought tolerant indices. TOL SSI SSPI had low PC1 and high PC2. MP, GMP, STI, Ys and Yp had both high PC1 and PC2 values. DI and YSI had high PC1 and low PC2.

Patel ***et al.,*** **(2019)** studied thirteen indices which were compared based on grain yield of 20 wheat genotypes. Highly significant differences were seen for yield (Yp and Ys) and almost all other indices except Tolerance Index (TOL). The average of grain yield under non-stress(irrigated) condition (Yp) values ranged between 4.60 to 20.53 (gm per plant), while the range of yield under stress condition (Ys) was found between 2.32 to 8.67 gm per plant. There was significant reduction in grain yield under drought stress condition. To identify drought stress tolerant lines moderate drought stress environments were more useful as compared to severe drought stress. Significant high positive correlation was found between grain yield and GMP, MP and YI indices under both stress and favourable environment. Ys and Yp showed significant positive correlation with GMP, MP, YI and STI. Selection of genotypes that had high PCA1 and low PCA2 were suitable for both rain-fed and irrigated conditions.

Hooshmandi (2019) evaluated 15 wheat cultivars in RCBD for 2 years and observed that results from analysis of variance showed a significant difference at 1% level of significance among genotypes in terms of grain yield. Stress Tolerance Index (STI), Geometric Mean Productivity (GMP) and Mean Productivity (MP) showed highest correlation with grain yield under both drought stress and non-stress environment.

Aboughadareh *et al.*, (2020) conducted the research to study the effect of drought on various agro-morphological and physiological traits in 17 genotypes of durum wheat for over two years under both control and drought conditions. As per the yield-based drought and susceptibility indices, the geometric mean productivity (GMP), stress tolerance index (STI), mean productivity (MP) and harmonic mean (HM) showed significant positive correlation with grain yields in both conditions.

Anwaar *et al.*, (2020) observed that grain yield showed negative correlations with Drought Index (DI), Tolerance Index (TOL) and Drought Susceptibility Index (DSI) whereas positive correlation was seen for mean productivity (MP) and geometric mean productivity (GMP) under drought condition.

CHAPTER-3

MATERIALS AND METHODS

3.1 Experimental site-

The present experiment- **"An Assessment of Genetic Variability for Drought tolerance and other associated traits in wheat (*Triticum aestivum* L.)"** was conducted at the Agricultural Research Farm of Institute of Agricultural Sciences of Banaras Hindu University which is the largest residential university of Asia spreading over 1300 acres of land. The Agriculture Research Farm encompasses an area of 65 hectares. It is situated in the Varanasi district of north- eastern plain zone of Uttar Pradesh extending between 25°10′30" to 25°35′15" N latitude and 82°40′50"to 83°12′18" E longitudes. It is located at an elevation of 80.71 meters (264.8ft) from the sea level and is situated in the center of the Ganges valley.

3.2 Soil and climate-

Varanasi in general and Banaras Hindu University in particular is physiographically located in the middle of Indo-Gangetic plains. The soil is very fertile as it is continually replenished by the low-level floods. The area is mainly underlain by the alluvial deposits of Quaternary age. The soil is rich in phosphorus, potassium and lime but deficient in nitrogen. The soil texture is sandy loam to sandy clay loam with organic carbon ranging from 0.5-0.6%.

This area experiences a warm humid subtropical climate with temperature as high as 46°C in summers. The cold Himalayan waves causes a fall in temperature to even 4°C in winters. The average annual temperature of Varanasi is 26.8°C and the mean annual rainfall of the district is about 1100 mm.

3.3 Experimental material-

A total of 30 different genotypes of bread wheat (*Triticum aestivum* L.) were received from Dr. V. K. Mishra, Professor of the Department of Genetics and Plant Breeding for the assessment of drought tolerance. 10 out of the 30 genotypes were lines evaluated in the All India Coordinated Research Project (AICRP) advance varietal trial (AVT-IR-TS-TAS-NEPZ) of the year 2018- 2019.

TABLE 3.1- List of genotypes under investigation-

S.no.	**Genotype name**	**Description**
1)	**MACS 6222**	MACs 6222 variety is one of the widely cultivated wheat variety in the Peninsular zone of India. It was developed by the Maharashtra Association for the Cultivation of Science in the year 2011. The pedigree of MACS 6222 is HD-2189*2/MACS-2496. It has a yield potential of 6-7 tonnes/ha.
2)	**HD 3249**	Pusa wheat 3249 (HD 3249) is a new variety developed by ICAR-Indian Agricultural Research Institute. It has a semi-spreading growth habitat, dark green color foliage with non-pigmented auricle. It even has slow rusting genes for brown rust. It is also resistant to Karnal Bunt and Powdery Mildew. It has an average yield of 6.57 tonnes/ha.
3)	**HD 2733**	Pusa wheat 2733 (HD 2733) is also a new variety developed by ICAR- Indian Agricultural Research Institute. It has an average potential yield of 50 q/ha.
4)	**PBW 781**	Genotype PBW 781 had an average yield of 43q/ha. It is resistant to leaf rust, strip rust and powdery mildew. It has a sedimentation value greater than 65ml.
5)	**DBW 257**	It was developed by ICAR-Indian Institute of Wheat & Barley Research, Karnal. This genotype is powdery mildew resistant. It has an iron content of 40 ppm and a sedimentation value greater than 65ml.
6)	**DBW 39**	DBW 39 is a new high yielding variety developed by ICAR-Indian Institute of Wheat & Barley Research, Karnal. It was developed from the cross Attila/Hui. It is recommended for both timely and late sown condition. It has a medium maturity duration of 120 days and has a yield potential of 55.2 q/ha.

7)	**HD 3277**	Pusa wheat 3277 (HD 3277) was developed by ICAR-Indian Agricultural Research Institute. It is resistant to leaf rust and powdery mildew. It had an average yield of 42.7 q/ha.
8)	**RAJ 4529**	RAJ 4529 was developed by the Rajasthan Agricultural Research Institute, Jaipur. It had an average yield of 40.5 q/ha.
9)	**DBW 187 (Karan Vandana)**	It is a high yielding wheat variety developed by ICAR-Indian Institute of Wheat & Barley Research, Karnal. It performs well under timely, irrigated and North-Eastern plain zone. It is resistant to prevalent pathotypes of brown rust. It has a yield potential of 64.7 q/ha.
10)	**WH 1239**	Genotype WH 1239 performed well under timely, irrigated condition of Northern plain zone. It had an average yield of 44.3q/ha.
11)	**K 0307**	K 0307 is a high yielding wheat variety with high number of tillers and grain yield under irrigated condition. It is recommended mainly for north eastern plain zone. It has an average yield of 45.50 q/ha.
12)	**DBW 88**	This bread wheat variety was released in the year 2014 for commercial cultivation in Punjab, Uttarakhand and Uttar Pradesh regions of Northern India. This variety has a yield potential of 70q/ha. It has seedling resistance against brown and yellow rust pathotypes. It has also shown considerable tolerance to karnal bunt.
13)	**GW 322-**	This variety is suitable to be sown in all states of India. It gives an average yield of 60-62 quintal per hectare. This is suitable for chapati making and is tolerant to almost all the diseases.
14)	**BHU 35**	This is a new high zinc containing wheat variety developed Banaras Hindu University. This variety underwent genetic bio-fortification technology for enhancing the zinc content under the HarvestPlus project of CIMMYT and the International Center for Tropical Agriculture funded by the Bill & Melinda Gates Foundation.

15)	**HD 2967**	The variety was released in the year 2011. It is a double dwarf early maturing (125-135 days) variety of bread wheat having an average plant height of 101cm. It has medium dense ears with tapering white glumes and profuse tillering seen. Grain is medium bold, lustrous and amber colored. Average yield is estimated around 45-50 q/ha.
16)	**HD 3215**	HD 3215 developed by ICAR- Indian Agricultural Research Institute, New Delhi. It has high sedimentation value of (72-75 ml) which provides opportunity for this genotype to be used as a potential donor.
17)	**HD 3241-**	HD 3241 was developed by ICAR- Indian Agricultural Research Institute, New Delhi. It performs well under North Western Plain zone.
18)	**HD 3304**	HD 3304 was developed by ICAR- Indian Agricultural Research Institute, New Delhi. It has a high protein content of (11.5%) and an average yield of 43.7 q/ha.
19)	**HD 3310**	HD 3310 was developed by ICAR- Indian Agricultural Research Institute, New Delhi. It performs well under North Western Plain zone. It has good quality parameters of high sedimentation value and average zinc content (35.2ppm)
20)	**HS 490-**	It is a medium height genotype suitable for limited irrigation in the lower mountain regions. It has thick white semi hard grains and is suitable for biscuit making. This variety has an average yield of 30q/ha.
21)	**HUW 234 (Malviya Wheat 234)**	This bread wheat variety was developed by Banaras Hindu University. It was released in the year 1986. HUW 234 has a parentage of HUW 12*2/CPAN 1666. It has Lr 14a+, Sr 9b+11+, Yr 2 genes for leaf, stem and yellow rust resistance respectively. This genotype has white ear heads with slightly circular bright colored grain. The variety can grow up to a height of 100 to 105 cm and takes 125 to 130 days to attain maturity. It is expected to give an average yield of 40-45 quintals per hectare.

22)	**HUW 468 (Malviya Wheat 468)**	This high yielding variety was also developed by Banaras Hindu University. It was released in the year 1999 and is well adapted to the North Eastern Plains Zone. It has Lr13+, Sr2+ rust resistant genes. It has excellent chapatti making quality and an average grain yield of 55 to 60 quintals per hectare.
23)	**HUW 510 (Malviya Wheat 510)**	This bread wheat variety was developed by Banaras Hindu University. It was released in the year 2000 and is mainly adapted to the peninsular zone. HUW 510 has a parentage of HD 2278/HUW234//DL 230-16. It has Lr 24+, Sr 2+24+ genes for leaf and stem rust resistance respectively. It is suitable for general cultivation, surface seeding and zero tillage. It consists of bold grain that are very good for chapatti making. It has an average yield of 45 to 50 quintals per hectare.
24)	**HUW 669 (Malviya Wheat 669)**	It has been developed by BHU, Varanasi. It is suitable for cultivation under timely sown and restricted irrigation condition. The parentage being ALTAR84/HUW206/MILAN. It has a yield potential of 43.2 quintal/hectare under timely sown, rainfed conditions. It is resistant against the pathotypes for yellow and brown rust of wheat. (Gupta, 2019)
25)	**HUW 712 (Malviya Wheat 712)**	This is a wheat variety developed by Banaras Hindu University. It is leaf and stem rust resistant variety of wheat. It is recommended for timely sown irrigated condition of North-Eastern plain zone with an average yield of 44 q/ha.
26)	**QLD 98**	QLD 98 is a medium plant height, smut resistant variety of wheat. It is a quick maturing variety with an average yield of 46 q/ha.
27)	**QLD 102**	QLD 102 is a high yielding variety of wheat with amber colored, good grain quality. It has an average yield of 47.4 q/ha.
28)	**QLD 107**	QLD 107 is a sprouting resistant variety of wheat with an average yield of 47 q/ha.
29)	**UP 2672**	UP 2672 is a local variety of wheat grown mainly in regions of Uttar Pradesh and Western Bihar. It is a wheat germplasm with high protein content of 14.1%.

30)	**Lok 1**	Lok 1 is grown in semi-irrigated condition. It has a maturity duration of 105-110 days. It has an average yield of 42- 45 q/ha.

3.4 Experimental layout & sowing-

The sowing of each 30 genotype was done on the 30th of December 2019 (*rabi* season). The experiment was conducted in two different environments i.e., irrigated (non-stressed) and non-irrigated (stressed) conditions. Randomized block design with three replications was adopted for sowing the 30 varieties of wheat. Each genotype was sown in three rows of 2.5 m in length with a spacing of 0.25m between the rows.

3.5 Fertilizer and nutrients-

Standard agronomic practices such as basal application of fertilizers i.e., 120 kg/ha of nitrogen, 60 kg/ha of phosphorus and 60 kg/ha of potassium were applied

3.6 Intercultural practices-

Time to time intercultural practices were followed to clean the plots from grasses, weeds and other inert materials.

3.7 Irrigation-

Three irrigations to non-stress plot were given on the following days-

1) 1st irrigation was given around the most critical stage, Crown Root Initiation stage- 22nd of January 2020

2) 2nd irrigation -10th of February 2020

3) 3rd irrigation -3rd March 2020

The non-irrigated block containing three replication was not given any irrigation.

3.8 Harvesting-

Harvesting was done on the 28th of April 2020 when the plants attained physiological maturity. The tagged 10 plants from every genotype were harvested manually. Only the spikes along with the tags were harvested and kept separately in cloth bags for drying and recording of post-harvest data.

3.9 Observations taken for quantitative characters under investigation-

To take the precise phenotypic data on following quantitative traits, a total of 10 competitive plants were randomly selected and tagged from each genotype in every replication. Observations on the following 11 traits were taken from the tagged plants at appropriate plant growth stages.

Pre-harvest characteristics:

1) Germination%-

The number of seeds germinated were counted and percentage was determined on the basis of total number of seeds sown on a plot basis.

2) Days to heading-

The number of days from the date of sowing to the date of initiation of heading was noted.

3) Days to 50% spike initiation-

The number of days from the date of sowing to the date of 50% flowering in each genotype was noted.

4) Canopy temperature (degree celsius)-

Canopy temperature was measured with the help of infrared thermometer. Four readings were taken on every alternate day at flowering stage. Care was taken that the readings were taken on normal sunny days at around 2p.m. Cloudy and excess windy weather was avoided.

5) Chlorophyll content-

Leaf chlorophyll concentration was measured instantly and in a non-destructive manner after spike initiation. It was done using the Soil Plant Analysis Development (SPAD) chlorophyll meter by pressing the intact flag leaf in between the sensor. The measurement was taken at a position 2/3rd of the distance between the leaf base and leaf apex.

6) Plant height-

Plant height in cm was taken from base to the tip of the plant using a meter scale. The height of all 10 plants from each genotype was taken at maturity and their mean was calculated.

7) Number of effective tillers per plant-

Total number of effective tillers was counted at the time of maturity. The mean of all the 10 plants was calculated**.**

Post-harvest characters:

8) Spike length (cm)-

The length of main spike from the base of spike to the tip was measured after harvesting. The average of 10 spikes were calculated.

9) Number of grains per spike-

Total number of filled grains per spike was counted and mean was calculated.

10) Test weight (gm)-

1000 grains were randomly counted and its weight in grams was recorded.

11) Yield per plant (gm)-

The grain yield of individual plants was weighed and recorded in grams. Mean yield/plant of all the 10 plants were calculated.

3.10 Statistical analysis-

Statistical analysis for each quantitative trait was done on the mean calculated from the tagged 10 plants in all the three replications.

1) Analysis of variance (ANOVA)-

The experiment was laid out in Randomized Block Design (RCBD) with three replications under both irrigated and non-irrigated (stressed) conditions.

Table-3.2 ANOVA TABLE for Randomized block design:

Source of variation	Degree of freedom	Sum of squares	Mean sum of square	F-cal
Treatment	t-1	Trss	MStr	$\frac{MStr}{MSe}$
Replication	r-1	Rss	MSr	$\frac{MSr}{MSe}$
Error	(t-1) (r-1)	Erss	MSe	
Total	rt-1	Tss		

Where,

t= total number of treatments

r= total number of replications

MStr=Treatment mean sum of square

MStr= Trss/t-1

MSr=Replication mean sum of square

MSr= Rss/r-1

MSe=Error mean sum of square

MSe= Erss/(t-1) (r-1)

Mean, range, variance, standard deviation, coefficient of variation and critical difference were determined for every trait using their standard formulas.

3.11 ESTIMATION OF GENETIC PARAMETERS-

To study the genetic variability the following parameters were calculated.

3.11.1. Mean and Range:

Mean:

The mean value of each character was determined by summing up all the observations and dividing them by corresponding number of observations.

$$\overline{X} = \frac{\sum_{i=1}^{N} X_i}{N}$$

Where,

$\overline{X}$ = mean

$\sum_{i=1}^{N} X_i$ = sum of observations

N = No. of observations

Range:

In statistics, the range of a set of data is the difference between the largest and smallest values. It is measured in the same units as the data. Since it only depends on two of the observations, it is most useful in representing the dispersion of small data sets.

3.11.2 Coefficient of variation:

Estimates of phenotypic, genotypic and environment variances were determined by analysis of variance. They were used for the estimation of respective coefficients of variation. The phenotypic, genotypic and environment coefficients of variation were computed as follows-

Phenotypic coefficient of variation = $\frac{\textbf{Phenotypic standard deviation}}{\textbf{General mean}} \times 100$

$$= \frac{\sqrt{\sigma_p^2}}{X} \times 100$$

Genotypic coefficient of variation = $\frac{\textbf{Genotypic standard deviation}}{\textbf{General mean}} \times 100$

$$= \frac{\sqrt{\sigma_g^2}}{X} \times 100$$

Environmental coefficient of variation $= \frac{\textbf{Environmental standard deviation}}{\textbf{General mean}} \times 100$

$$= \frac{\sqrt{\sigma_e^2}}{X} \times 100$$

Where,

σ_p^2 = Phenotypic variance or total variance

σ_g^2 = Genotypic variance

σ_e^2 = Environmental variance

X = Mean of the trait

Table 3.3 PCV and GCV were classified according to Robinson *et al*., (1966) as follows:

S. NO.	Value of GCV and PCV%	Rate or scale
1	0-10	Low
2	10-20	Moderate
3	>20	High

3.11.3 Heritability-

It is the proportion of genetic variance to the phenotypic variance an expressed in percentage. It was calculated by the formula given by Allard (1960) which is given below:

$$\textbf{Heritability (broad sense)} = \frac{\sigma_g^2}{\sigma_p^2} = \frac{\sigma_g^2}{\sigma_g^2+\sigma_e^2}$$

Where,

H= Heritability in broad sense

σ_g^2=genotypic variance= $\frac{MSt-MSe}{r}$

σ_p^2= Phenotypic variance= $\sigma^2 g + \sigma^2 e$

Table 3.4 Heritability percentage was categorized as follows Robinson *et al*., (1966)

S.No.	Heritability%	Scale
1	0-30	Low
2	30-60	Moderate
3	>60	High

3.11.4 Genetic advance-

The improvement in the performance of selected lines over the original population is called genetic advance. The genetic advance i.e., expected genetic gain resulting from selecting five per cent superior plants was estimated by the following formula suggested by Allard (1960):

$$\mathbf{Gs= K \times \sigma p \times H_b = K \times \frac{\sigma_g^2}{\sqrt{\sigma_p^2}}}$$

σp = phenotypic standard deviation

K =Selection differential

H_b =heritability in broad sense

GAM $=\frac{GA}{X} \times 100$

Table 3.5 The GA as per cent mean was classified (Johnson *et al.*, 1955) as given below:

S.No.	GA as percent of mean	Scale
1	0-10	Low
2	10-20	Moderate
3	>20	High

3.11.5 <u>Correlation coefficient-</u>

The simple phenotypic correlation coefficients among pairs of characters were calculated according to the formula suggested by Searle (1961). The software used for analysis was WINDOSTAT version 9.3.

$$\mathbf{r=Cov.(XY)/\sqrt{\sigma_x^2 \times \sigma_y^2}}$$

Cov. (XY)= co-variance between variable x and y

σ_x^2= variance of variable x

σ_y^2= variance of variable y

In the estimation of phenotypic correlation coefficients, phenotypic covariance and variance were considered for calculation. The statistical significance of correlation coefficients was tested against table “r” values at (n-2) d.f. (degree of freedom), where n refers to pair of observation. (Statistical table by Fisher and Yates, 1963) at 5% and 1% levels of significance.

Table 3.6 Scales of correlation coefficients (Searle ,1965)

S.No.	Correlation coefficient	Scale
1	>0.64	Strong
2	0.50-0.64	Moderately strong
3	0.30-0.49	Moderately Weak
4	0-0.30	Weak

3.11.6 Path coefficient analysis:

Path-coefficient analysis was done to partition the total correlation into direct and indirect effects due to the dependent variable. Wright (1934) suggested thisanalysis and it was further elaborated by Dewey and Lu (1959).

Path-coefficient is the ratio of standard deviation of the effect due to a given cause to the total standard deviation of the effect i.e., if grain yield per plant (Y) is the function of the causal factor X1, then path co-efficient for the path from causal factor X1 to the effect Y is σ X1/ σ Y.

In other words, it is a standardized partial regression coefficient, which individually provides a measure of direct effect of the causal factor or independent variables on the dependent variable. These permit partitioning of the correlation between the casual factors and the effect of variable into components of direct, indirect and residual effects.

rX1Y= PX1Y + PX2YrX1X2 + ...+ PXnYrX1Xn

rX2Y= PX2Y + PX1YrX2X1 + ...+ PXnYrX2Xn

rXnY= PXnY + PX1YrXnX2 + …………………………. + PXn-1 YrXnXn-1

Where,

P_{X1Y} to P_{XnY} are the direct path coefficients of characters X1 to Xn on the dependent character Y.

r_{X1X2} to r_{Xn-1Xn} are possible correlation coefficients between various independent variables and r_{X1Y} to r_{XnY} are the correlations between dependent and independent variables.

Indirect effect = $r_{ij} . P_{ij}$

Where, i=1……n

j=1…..n

P_{ij}= P1Y, P2Y, P3Y ….. Pny.

The residual factor (P_{RY}) i.e., the variation in yield unaccounted for causal effects under consideration or the path values for residual effect was calculated as follows:

Residual factor (P_{RY}) = $\sqrt{1 - R^2}$

$$(R^2) = \sum_{i=1}^{5} P_{X_iY} r_{X_5Y} = \sqrt{1 - (P_{1Y} r_{1Y} + P_{2Y} r_{2Y} + ... + P_{iY} r_{iY})}$$

Where,

P_{RY} = Residual effect

P_{iY} = Direct effect of X_i on Y

r_{iY} = Correlation coefficient of X_i and Y.

R^2 is the coefficient of determination, and is the amount of variation in yield that can be accounted for the yield component trait.

Table 3.7 Scales for Path Coefficients (Lenka and Mishra, 1973)

S.No.	Values of Path Coefficients	Scale
1.	0.00 - 0.09	Negligible
2.	0.10 -0.19	Low
3.	0.20 -0.29	Moderate
4.	0.30 -0.99	High
5.	>1.00	Very high

3.11.7. DROUGHT TOLERANCE INDICES:

Drought stress is one of the most significant environmental factors which has an impact on yield of crops and it affects about 40 to 60% of the world's agricultural lands. To evaluate response of plant genotypes to drought stress, some selection indices has been proposed based on a mathematical relation between stress and non-stress conditions. Drought indices which provide a measure of drought based on loss of yield under drought conditions in comparison to normal conditions have been used for screening drought tolerant genotypes. These indices are either based on drought resistance or susceptibility of genotypes.

"Drought resistance is defined as the relative yield of genotype compared to other genotypes subjected to the same drought stress" **Hall (1993)**. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress.

1) Stress susceptibility index (SSI) (Fisher & Maurer, 1978):

SSI = 1 – (Ys / Yp) / SI

while Stress Index (SI) = 1 – (Ŷ s / Ŷ p)

Ys= Mean grain yield of each genotype under stress condition

Yp=Mean grain yield of each genotype under non-stress(irrigated) conditions

Ŷ s=mean yield of all genotypes under stress conditions

$\hat{Y}$ p=mean yield of all genotypes under non- stress (irrigated)conditions

2) Tolerance index (TOL) (Rosielle and Hamblin, 1981):

TOL = (Yp – Ys)

3) Mean productivity (MP) (Rosielle and Hamblin, 1981)

(MP) = (Ys + Yp) / 2

Ys= Mean grain yield of each genotype under stress condition

Yp= Mean grain yield of each genotype under non-stressed(irrigated)condition.

4) Yield Stability Index (YSI) (Bouslama & Schapaugh, 1984):

YSI = Ys / Yp

5) Stress Tolerance index (STI) (Fernandez, 1992)

STI= (Yp x Ys) / ($\hat{Y}$ p)^2

Ys= Mean grain yield of each genotype under stressed;

Yp= Mean grain yield of each genotype under non-stress conditions.

$\hat{Y}$ s=mean yield of all genotypes under stress conditions

$\hat{Y}$ p=mean yield of all genotypes under non- stress (irrigated) conditions

6) Geometric Mean Productivity (GMP) (Fernandez, 1992; Kristin *et al.,* 1997):

GMP = $\sqrt{\text{Yp} \times \text{Ys}}$

7) Relative Drought Index (RDI) (Fischer, 1979)

RDI= (Ys / Yp) / ($\hat{Y}$ s / $\hat{Y}$ p)

8) Drought Resistance Index (DI) (Lan, 1998)

DI= Ys × (Ys / Yp) / $\hat{Y}$ s

9) Stress non-stress production index (SNPI) (Moosavi *et al.,* 2008)

$$\text{SNPI}=\sqrt[3]{\frac{Y_p+Y_s}{Y_p-Y_s}} \times \sqrt[3]{Y_p \times Y_s \times Y_s}$$

10) Stress susceptibility percentage index (SSPI)

SSPI=$\left[(\mathrm{Yp}-\mathrm{Ys}/2(\widehat{\mathrm{Yp}})\right]\times 100$

CHAPTER 4

EXPERIMENTAL FINDINGS

The results and experimental findings obtained after the analysis of data for the 30 genotypes of wheat (*Triticum aestivum* L.) under irrigated (non-stress) and non-irrigated (stress) condition are presented in this chapter under the following sub-heads:

4.1 Analysis of variance (ANOVA)-

The data for eleven characters of the thirty genotypes sown under both the irrigated and non-irrigated conditions were subjected to analysis of variance to determine whether the variation present among the genotypes for each trait were significant or not.

Under irrigated condition the mean sum of square for treatment exhibited significant differences for the traits such as germination percent (205.37**), days to heading (20.615*), days to 50% spike initiation (21.069**), canopy temperature (1.311**), chlorophyll content (16.196**), plant height (117.32**), number of tillers per plant (1.577**), spike length (1.774**), number of grains per spike (118.564**), test weight (51.065**) and yield per plant (14.439**).

Under non-irrigated condition the mean sum of square for treatment exhibited significant differences for the traits such as germination percent (52.362**), days to heading (13.636**), days to 50% spike initiation (14.908**), canopy temperature (1.61**), chlorophyll content (24.202**), plant height (326.782**), number of tillers per plant (2.092**), spike length (2.188**), number of grains per spike (127.911**), test weight (51.342**) and yield per plant (17.787**).

Table 4.1 ANOVA for 11 traits of 30 genotypes of wheat under irrigated condiion.

Sl.No.	Source	Replication	Treatment	Error
	Degrees of freedom	2	29	58
1	Germination%	90.1330	205.37**	73.731
2	Day to heading	31.1950	20.615*	10.048
3	Days to 50% spike initiation	6.1780	21.069**	2.488
4	Canopy temperature (℃)	1.6880	1.311**	0.563
5	Chlorophyll content	2.1870	16.196**	7.645
6	Plant height(cm)	80.1990	117.32**	57.131
7	Number of tillers/plant	0.3610	1.577**	0.368
8	Spike length(cm)	0.8520	1.774**	0.432
9	No. of grains per spike	51.5250	118.564**	17.206
10	Test weight(g)	1.7890	51.065**	10.629
11	Yield per plant(g)	0.9430	14.439**	0.58

Significant at 1% level of significance (**)

Significant at 5% level of significance (*)

Table 4.2 ANOVA table for 11 traits of 30 genotypes of wheat under non-irrigated condition.

Sl.No.	Source	Replication	Treatment	Error
	Degrees of freedom	2	29	58
1	Germination%	33.5440	52.362**	21.97
2	Days to heading	2.6330	13.636**	5.679
3	Days to 50% spike initiation	2.3440	14.908**	5.264
4	Canopy temperature (°C)	2.3520	1.61**	0.784
5	Chlorophyll content	35.2570	24.202**	11.79
6	Plant height(cm)	1.2850	326.782**	12.781
7	No. of tillers/plant	1.110	2.092**	0.37
8	Spike length(cm)	1.3620	2.188**	0.454
9	No.of grains per spike	16.1850	127.911**	18.277
10	Test weight(g)	1.1140	51.342**	10.988
11	Yield per plant(g)	2.7950	17.787**	0.933

Significant at 1% level of significance (**)

Significant at 5% level of significance (*)

4.2 Analysis of genetic variability parameters under non-stress and stress condition-

4.2.1 Germination percent-

The mean for germination percent under irrigated (non-stress) condition was 70.53% while it was 71.16% under non-irrigated (stress) condition. The germination percent varied from 47.67% to 84.67% under irrigated condition (i.e., with a range of 37) while it varied from 63.33% to 79.33% under non-irrigated condition (i.e., with a range of 16). The genotypes with the highest and lowest germination percent under irrigated condition was HD 2967 and HD 3215 respectively, whereas under non-irrigated condition it was KO 307 and HUW 510 respectively.

Moderate PCV (15.375%) and low GCV (9.392%) was observed under irrigated condition whereas low PCV (7.962%) and low GCV (4.473%) was observed under non-irrigated condition. PCV was higher than GCV indicating higher environmental effect. Moderate broad sense heritability of 37.309% and moderate genetic advance (as percent of mean) of 11.817% was observed under irrigated condition whereas moderate broad sense heritability of 31.559% and genetic advance (as percent of mean) of low 5.177% was observed under non-irrigated condition.

4.2.2. Days to heading-

The mean for days to heading under irrigated (non-stress) condition was 71.49 days while it was 72.23 days under non-irrigated (stress) condition. The days to heading varied from 66.67 to 76.33 days under irrigated condition (i.e., with a range of 9.66) while it varied from 68.67 to 79.33 days under non-irrigated condition (i.e., with a range of 7.66). The genotypes with the highest and lowest days to heading under irrigated condition was HUW 669 and Lok1 respectively, whereas under non-irrigated condition it was DBW 257 and BHU 35 respectively.

Low PCV (5.153%) and low GCV (2.625%) was observed under irrigated condition while low PCV (3.996%) and low GCV (2.255%) was observed under non-irrigated condition. Broad sense heritability of 25.955% and low genetic advance (as percent of mean) of 2.755% was observed under irrigated condition whereas broad sense heritability of 31.833% and low genetic advance as percent of mean of 2.62% was observed under non-irrigated condition.

4.2.3. Days to 50% spike initiation-

The mean for days to 50% spike initiation under irrigated (non-stress) condition was 75.32 days while it was 75.54 days under non-irrigated (stress) condition. The days to 50% spike initiation varied from 70.67 to 79.33 days under irrigated condition (i.e., with a range of 8.66) while it varied from 72.33 to 80.67 days under non-irrigated condition (i.e., with a range of 8.34). The genotypes with the highest and lowest number of days to 50% spike initiation under irrigated condition was HD 2733 and HUW 234 respectively, whereas under non-irrigated condition it was HD 2733 and BHU 35 respectively.

Low PCV (3.912%) and low GCV (3.304%) was observed under irrigated condition whereas low PCV (3.854%) and low GCV (2.373%) was observed under non-irrigated condition. High broad sense heritability of 71.34% and low genetic advance (as percent of mean) of 5.749% was observed under irrigated condition whereas moderate broad sense heritability of 37.914 % and low genetic advance as percent of mean 3.01% was observed under non-irrigated condition.

4.2.4 Canopy temperature-

The mean for canopy temperature under irrigated (non-stress) condition was 26.21 °C while it was 26.24 °C under non-irrigated (stress) condition. The canopy temperature varied from 25.10°C to 27.70°C under irrigated condition (i.e., with a range of 2.6) while it varied from 24.9°C to 27.53°C under non-irrigated condition (i.e., with a range of 2.63). The genotypes with the highest and lowest canopy temperature under irrigated condition was PBW 781 and Lok 1 respectively, whereas under non-irrigated condition it was GW 322 and DBW 187 respectively.

Low PCV (3.438%) and low GCV (1.904%) was observed under irrigated condition whereas low PCV (3.924%) and low GCV (2%) was observed under non-irrigated condition. Broad sense heritability of 30.688% and low genetic advance as percent of mean was 2.173% was observed under irrigated condition whereas broad sense heritability of 25.973% and low genetic advance as percent of mean of 2.099% was observed under non-irrigated condition.

4.2.5 Chlorophyll content-

The mean for chlorophyll content under irrigated (non-stress) condition was 39.93 while it was 38.69 under non-irrigated (stress) condition. The chlorophyll content varied from 35.60 to 43.90 under irrigated condition (i.e., with a range of 8.3) while it varied from 33.37 to 46.43 under non-irrigated condition (i.e., with a range of 13.6). The genotypes with the highest and lowest chlorophyll content under irrigated condition was MACS6222 and WH1239 respectively, whereas under non-irrigated condition it was KO 307 and UP 2672 respectively.

Low PCV (8.114%) and low GCV (4.228%) was observed under irrigated condition whereas moderate PCV (10.315%) and low GCV (5.257%) was observed under non-irrigated condition. PCV was higher than GCV indicating higher environmental effect. Broad sense heritability of 27.159% and low genetic advance (as percent of mean) of 4.539% was observed under irrigated condition whereas broad sense heritability of 25.976% and low genetic advance (as percent of mean) of 5.52% was observed under non-irrigated condition.

4.2.6 Plant height-

The mean for plant height under irrigated (non-stress) condition was 62.07 cm while it was 59.29 cm under non-irrigated (stress) condition. The plant height varied from 49.61 cm to 71.20 cm under irrigated condition (i.e., with a range of 21.59) while it varied from 45.8 cm to 84.35 cm under non-irrigated condition (i.e., with a range of

38.55). The genotypes with the highest and lowest plant height under irrigated condition was DBW 257 and HD 2733 respectively, whereas under non-irrigated condition it was UP 2672 and HD 3277 respectively.

Moderate PCV (14.154%) and low GCV (7.216%) was observed under irrigated condition whereas moderate PCV (18.278%) and moderate GCV (17.255%) was observed under non-irrigated condition. Broad sense heritability of 25.99% and low genetic advance (as percent of mean) of 7.578% was observed under irrigated condition whereas high broad sense heritability of 89.117% and high genetic advance (as percent of mean) of 33.556% was observed under non-irrigated condition.

4.2.7 Number of tillers per plant-

The mean for number of tillers per plant under irrigated (non-stress) condition was 5.51 while it was 5.18 under non-irrigated (stress) condition. The number of tillers per plant varied from 4.23 to 7.2 under irrigated condition (i.e., with a range of 2.97) while it varied from 3.67 to 6.57 under non-irrigated condition (i.e., with a range of 2.9). The genotypes with the highest and lowest number of tillers per plant under irrigated condition was HUW 234 and HD 3241 respectively, whereas under non-irrigated condition it was DBW 88 and QLD 102 respectively.

Moderate PCV (15.922%) and moderate GCV (11.515%) was observed under irrigated condition whereas moderate PCV (18.758%) and moderate GCV (14.623%) was observed under non-irrigated condition. Moderate broad sense heritability of 52.299% and moderate genetic advance (as percent of mean) of 17.154% was observed under irrigated condition whereas high broad sense heritability of 60.767% and high genetic advance (as percent of mean) 23.482% was observed under non-irrigated condition.

4.2.8 Spike length-

The mean for spike length under irrigated (non-stress) condition was 9.26 cm while it was 8.96 cm under non-irrigated (stress) condition. The spike length varied from 7.12 cm to 10.78 cm under irrigated condition (i.e., with a range of 3.66) while it varied from 6.66 cm to 10.53 cm under non-irrigated condition (i.e., with a range of 3.87). The genotypes with the highest and lowest spike length under irrigated condition was HD 3277 and HUW 510 respectively, whereas under non-irrigated condition it was HD 3277 and QLD 102 respectively.

Moderate PCV (10.129%) and low GCV (7.225%) was observed under irrigated condition whereas moderate PCV (11.339%) and low GCV (8.486%) was observed under non-irrigated condition. Moderate broad sense heritability of 50.878% and moderate genetic advance (as percent of mean) of 10.616% was observed under irrigated condition whereas moderate broad sense heritability of 56.005% and moderate genetic advance (as percent of mean) of 13.082% was observed under non-irrigated condition.

4.2.9 Number of grains per spike-

The mean for number of grains per spike under irrigated (non-stress) condition was 42.38 while it was 39.52 under non-irrigated (stress) condition. The number of grains per spike varied from 28.13 to 52.43 under irrigated condition (i.e., with a range of 24.3) while it varied from 25.8 to 52.77 under non-irrigated condition (i.e., with a range of 26.97). The genotypes with the highest and lowest germination percent under irrigated condition was HD 2967 and QLD 102 respectively, whereas under non-irrigated condition it was DBW 88 and QLD 102 respectively.

Moderate PCV (16.848%) and moderate GCV (13.714%) was observed under irrigated condition whereas moderate PCV (18.735%) and moderate GCV (15.297%) was observed non-irrigated condition. High broad sense heritability of 66.257% and high genetic advance (as percent of mean) of 22.996% was observed under irrigated condition whereas high broad sense heritability of 66.661% and high genetic advance (as percent of mean) of 25.727% was observed under non-irrigated condition.

4.2.10 Test weight-

The mean for test weight under irrigated (non-stress) condition was 33.25 g while it was 32.79 g under non-irrigated (stress) condition. The test weight varied from

25.66 g to 40.87 g under irrigated condition (i.e., with a range of 15.21) while it varied from 25.06 g to 39.99 g under non-irrigated condition (i.e., with a range of 14.93). The genotypes with the highest and lowest test weight under irrigated condition was HUW 234 and HUW 712 respectively, whereas under non-irrigated condition it was Lok 1 and HUW 712 respectively.

Moderate PCV (14.767%) and moderate GCV (11.042%) was observed under irrigated condition whereas moderate PCV (15.075%) and moderate GCV (11.184%) was observed under non-irrigated condition. Moderate broad sense heritability of 55.909% and moderate genetic advance (as percent of mean) of 17.008% was observed under irrigated condition whereas moderate broad sense heritability of 55.041% and moderate genetic advance (as percent of mean) was 17.093% observed under non-irrigated condition.

4.2.11 Yield per plant-

The mean for grain yield per plant under irrigated (non-stress) condition was 8.56 g while it was 7.68 g under non-irrigated (stress) condition. The grain yield per plant varied from 5.40 g to 12.35 g under irrigated condition (i.e., with a range of 6.95) while it varied from 3.72 g to 12.5 g under non-irrigated condition (i.e., with a range of 8.78). The genotypes with the highest and lowest test weight under irrigated condition was DBW 88 and HD 3241 respectively, whereas under non-irrigated condition it was DBW 88 and HUW 712 respectively.

High PCV (26.625%) and high GCV (25.095%) was observed under irrigated condition whereas high PCV (33.33%) and high GCV (30.868%) was observed under non-irrigated condition. Moderate broad sense heritability of 88.836% and high genetic advance (as percent of mean) of 48.724% was observed under irrigated condition whereas high broad sense heritability of 85.754% and high genetic advance (as percent of mean) of 58.884% observed under non-irrigated condition

TABLE 4.3- Range, mean, C.V., C.D. for the 11 traits of 30 wheat genotypes under irrigated condition

Sl. No.	Genotypes	Germination%	Day to heading	Days to 50% spike initiation	Canopy temperature(degree celcius)	Chlorophyll content	Plant height (cm)	Number of tillers	Spike length(cm)	No.of grains per spike	Test weight(gm)	Yield per plant(gm)
1	MACS6222	70.333	71.667	75	26.333	43.9	66.463	5.3	9.61	45.033	30.507	7.957
2	HD 3249	72.333	67.333	71.333	26.6	37.567	60.703	5.833	9.907	48.333	35.4	10.523
3	HD2733	75.667	74.333	79.333	25.5	39.467	49.613	5.767	9.103	46.933	32.217	9.247
4	PBW 781	76	73.667	78.667	27.7	40.467	60.11	4.833	8.667	34.467	31.607	6.97
5	DBW 257	77	74	78.667	25.267	40.667	71.203	6.133	9.417	39.067	34.697	8.637
6	DBW 39	77.667	71.667	75.333	26.4	40.267	60.62	5	9.313	48.367	31.573	9.653
7	HD 3277	76.333	72	77	25.467	39.167	71.117	6.667	10.777	50.433	33.96	11.797
8	RAJ 4529	69.333	67.333	72	25.267	41.3	68.24	4.967	9.54	46.367	36.387	9.477

9	DBW 187	77	71.333	76.667	25.667	35.667	61.127	5.8	9.45	41.8	27.693	7.637
10	WH 1239	70.667	70	74.333	26.733	35.6	64.513	5.433	9.477	44.867	34.987	8.907
11	K 0307	78.333	73	77.333	25.733	41.9	64.343	5.6	9.817	43.7	34.543	8.49
12	DBW 88	60.333	72.333	75	26.967	42.333	60.447	5.967	10.247	52.333	38.37	12.347
13	GW 322	65.667	74.667	78	26.867	36.833	55.453	4.567	9.09	43.067	30.803	7.463
14	BHU 35	75	71	74.333	25.967	37.367	55.96	5.067	8.233	40.833	30.027	7.153
15	HD 2967	84.667	71	74.333	26.2	43.367	68.153	6.667	10.14	52.433	33.363	12.07
16	HD 3215	47.667	72.333	78.333	26.933	41.333	55.54	5.433	9.22	37.3	28.883	6.46
17	HD 3241	72	68.333	72.333	26.8	39	59.433	4.233	9.177	40.3	30.24	5.397
18	HD 3304	68	74	78.333	25.867	39.267	54.843	4.6	9.05	37.7	27.503	6.313
19	HD 3310	74.333	68	71.333	25.833	42.5	64.173	5.6	9.323	35.133	34.967	7.217

20	HS 490	67.667	74.333	77.667	26.467	38	68.07	6.167	9.31	43.7	38.12	10.407
21	HUW 234	69.333	67	70.667	26.9	37.1	58.333	7.2	9.9	50.567	40.867	12.017
22	HUW 468	74.667	68.667	72	26	38.167	57.74	5.333	8.537	34	27.433	5.4
23	HUW510	48	73.333	76	26.367	38.4	49.697	5.067	7.123	32.433	39.907	7.207
24	HUW 669	76.667	76.333	78.667	25.533	41.667	62.607	5.867	9.6	43.5	34.543	9.07
25	HUW 712	62.667	73.333	76.333	25.733	41.1	69.883	5.567	8.96	34.467	25.657	5.47
26	QLD 98	69.333	74.333	76.667	27.1	41.9	66.463	6.733	10.027	44.833	38.603	12.07
27	QLD 102	75.333	71	74.333	27.2	43.8	52.693	4.833	7.257	28.133	28.757	5.45
28	QLD 107	73.667	71.667	75.333	26	41.7	69.97	5.5	8.897	37.5	32.387	7.01
29	UP 2672	59	70	73.333	25.933	40	66.51	4.3	9.043	46.633	33.07	8.088
30	Lok1	71.333	66.667	71	25.1	38.033	68.15	5.367	9.5	47.3	40.417	11.04

Mean	70.53	71.49	75.32	26.21	39.93	62.07	5.51	9.26	42.38	33.25	8.56
CV	12.17	4.43	2.09	2.86	6.92	12.18	11	7.1	9.79	9.81	8.9
SEm	4.96	1.83	0.91	0.43	1.6	4.36	0.35	0.38	2.39	1.88	0.44
CD at 5%	14.03	5.18	2.58	1.23	4.52	12.35	0.99	1.07	6.78	5.33	1.25
CD at 1%	18.67	6.89	3.43	1.63	6.01	16.44	1.32	1.43	9.02	7.09	1.66
Minimum	47.67	66.67	70.67	25.1	35.6	49.61	4.23	7.12	28.13	25.66	5.4
Maximum	84.67	76.33	79.33	27.7	43.9	71.2	7.2	10.78	52.43	40.87	12.35
Range	37	9.66	8.66	2.6	8.3	21.59	2.97	3.66	24.3	15.21	6.95
Replication	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment	S	S	S	S	S	S	S	S	S	S	S

TABLE 4.4- Range, mean, C.V., C.D. for the 11 traits of 30 wheat genotypes under non- irrigated condition

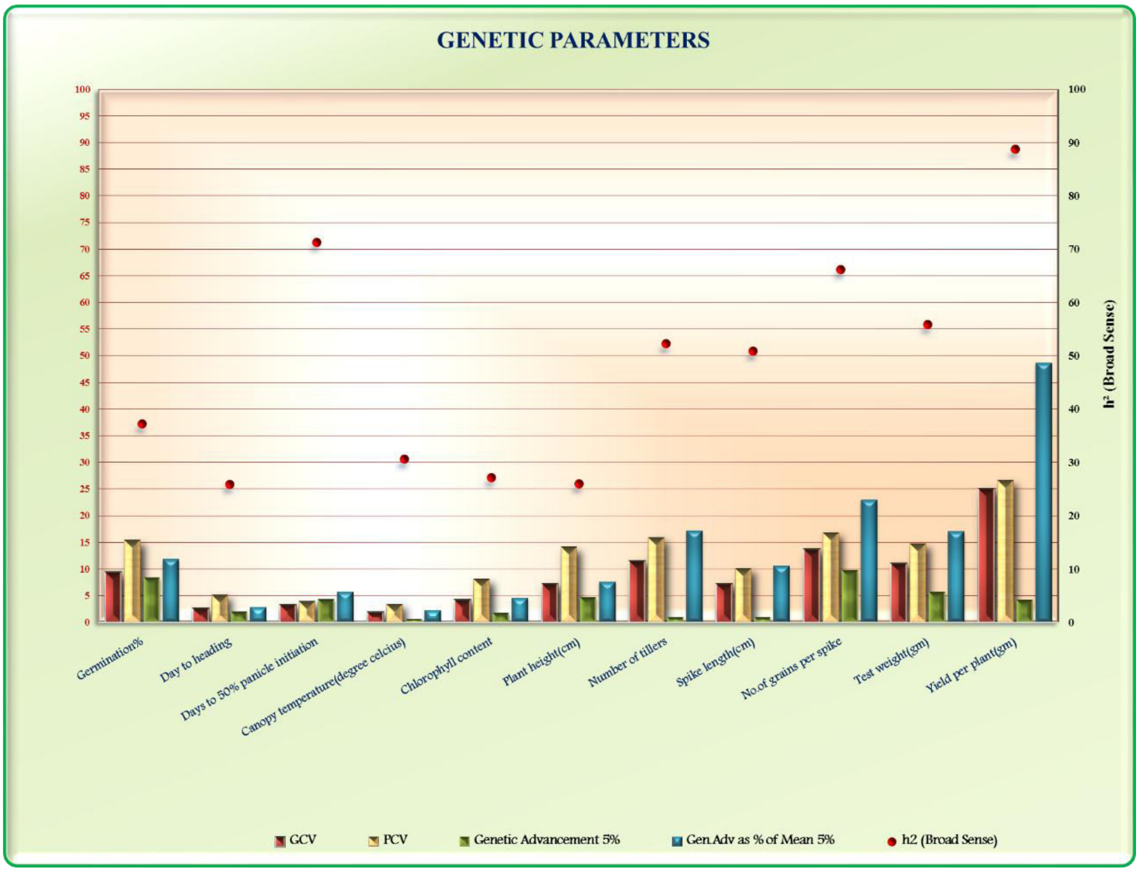
Sl. No.	Genotypes	Germin-ation%	Days to heading	Days to 50% spike initiation	Canopy temperature	Chlorophyll content	Plant height(cm)	No.of tillers	Spike length (cm)	No.of grains per spike	Test weight(gm)	Yield per plant (gm)
1	MACS6222	71.333	71	74.333	25.133	37.433	54.083	4.8	9.407	42	30.813	6.853
2	HD 3249	70.667	70	73.667	25.1	37.467	61.39	6.067	9.59	47.767	35.973	11.213
3	HD2733	70	76	80.667	25.5	34.5	54.607	5.133	9.207	39.233	31.137	7.113
4	PBW 781	70	75.333	79	26.9	39.267	59.263	4.067	8.22	35.667	31.693	6.127
5	DBW 257	74.667	76.333	80	25.967	37.2	59.857	6	8.807	37.5	34.247	8.293
6	DBW 39	76	73	76.333	25.967	37.9	66.287	5.233	9.243	39	31.033	8.003
7	HD 3277	72	75	78.333	25.933	40.133	45.8	5.967	10.527	41.867	32.773	9.157
8	RAJ 4529	70	71	74	25.533	35.3	66.883	5.6	8.6	40.3	35.423	8.763

9	DBW 187	73.333	74.333	78	24.9	36.633	54.69	5.033	9.11	33.667	26.523	5.553
10	WH 1239	64.667	72.667	76	26.767	39.133	64.26	5.433	9.203	40.167	34.463	8.21
11	K 0307	79.333	69.333	72.667	26.433	46.433	67.05	3.767	9.27	43.533	34.323	5.777
12	DBW 88	73	70.667	74.667	26	39.867	62.393	6.567	9.49	52.767	37.85	12.497
13	GW 322	67.667	71	74	27.533	38.033	49.357	5.233	9.287	38.533	31.597	6.827
14	BHU 35	74	68.667	72.333	26.833	38	56.637	4.367	8.06	37.433	29.317	5.643
15	HD 2967	78	75	78.333	26.9	43.033	70.437	6.3	9.597	49.367	32.287	10.617
16	HD 3215	65	72.333	75.667	27.133	40.667	50.45	4.3	9.003	35.9	28.883	5.623
17	HD 3241	67	70	73.333	26.667	38.233	48.923	5.5	9.46	42.633	30.16	7.697
18	HD 3304	70.667	69.333	72.667	26.333	39.1	55.717	4.067	8.67	38.6	26.91	4.48
19	HD 3310	67.667	73.333	76	27.2	38.8	49.02	5.767	7.997	37.467	33.46	7.733
20	HS 490	76.333	74.333	77	26.167	38.8	63.007	6.067	9.647	40.467	37.933	10.083
21	HUW 234	71	74.333	77.333	27.1	37.5	62.987	6.067	10.153	51.267	39.79	12.373

22	HUW 468	67	72.667	76	24.933	42.7	63.487	4.8	7.353	27.367	27.05	4.287
23	HUW510	63.333	70.333	73.667	26.9	33.6	46.567	4.2	7.577	29.1	39.983	5.207
24	HUW 669	73.667	70	74	26.7	38.633	67.9	4.767	9.567	41.9	33.957	8.417
25	HUW 712	73.333	70.667	74.667	25.967	40.733	63.16	3.967	8.217	28.933	25.057	3.723
26	QLD 98	69.333	72	74	25.9	41.6	71.963	6.2	9.85	45.4	38.027	11.517
27	QLD 102	75	71.333	74.333	25.9	42.6	49.86	3.667	6.66	25.8	27.89	4.013
28	QLD 107	64.333	73.333	76.667	25.3	37.867	62.38	5.567	8.433	37.733	32.1	7.153
29	UP 2672	69.667	72.333	75	26.733	33.367	84.347	5.1	8.873	45.867	33.12	8.233
30	Lok 1	76.667	71.333	73.667	26.733	36.167	65.953	5.8	9.69	38.367	39.993	9.17
Mean		71.16	72.23	75.54	26.24	38.69	59.29	5.18	8.96	39.52	32.79	7.68
CV		6.59	3.3	3.04	3.38	8.87	6.03	11.75	7.52	10.82	10.11	12.58
SEm		2.71	1.38	1.32	0.51	1.98	2.06	0.35	0.39	2.47	1.91	0.56
CD at 5%		7.66	3.89	3.75	1.45	5.61	5.84	0.99	1.1	6.99	5.42	1.58

CD at 1%	10.19	5.18	4.99	1.93	7.47	7.77	1.32	1.47	9.3	7.21	2.1
Minimum	63.33	68.67	72.33	24.9	33.37	45.8	3.67	6.66	25.8	25.06	3.72
Maximum	79.33	76.33	80.67	27.53	46.43	84.35	6.57	10.53	52.77	39.99	12.5
Range	16	7.66	8.34	2.63	13.06	38.55	2.9	3.87	26.97	14.93	8.78
Replication	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
Treatment	S	S	S	S	S	S	S	S	S	S	S

Graph 4.1- Graph depicting GCV, PCV, broad sense heritability, Genetic Advance at 5% and Genetic Advance as percent of mean for 11 traits of 30 wheat genotypes under irrigated condition.



Graph 4.2- Graph depicting GCV, PCV, broad sense heritability, Genetic Advance at 5% and Genetic Advance as percent of mean for 11 traits of 30 wheat genotypes under non- irrigated condition.

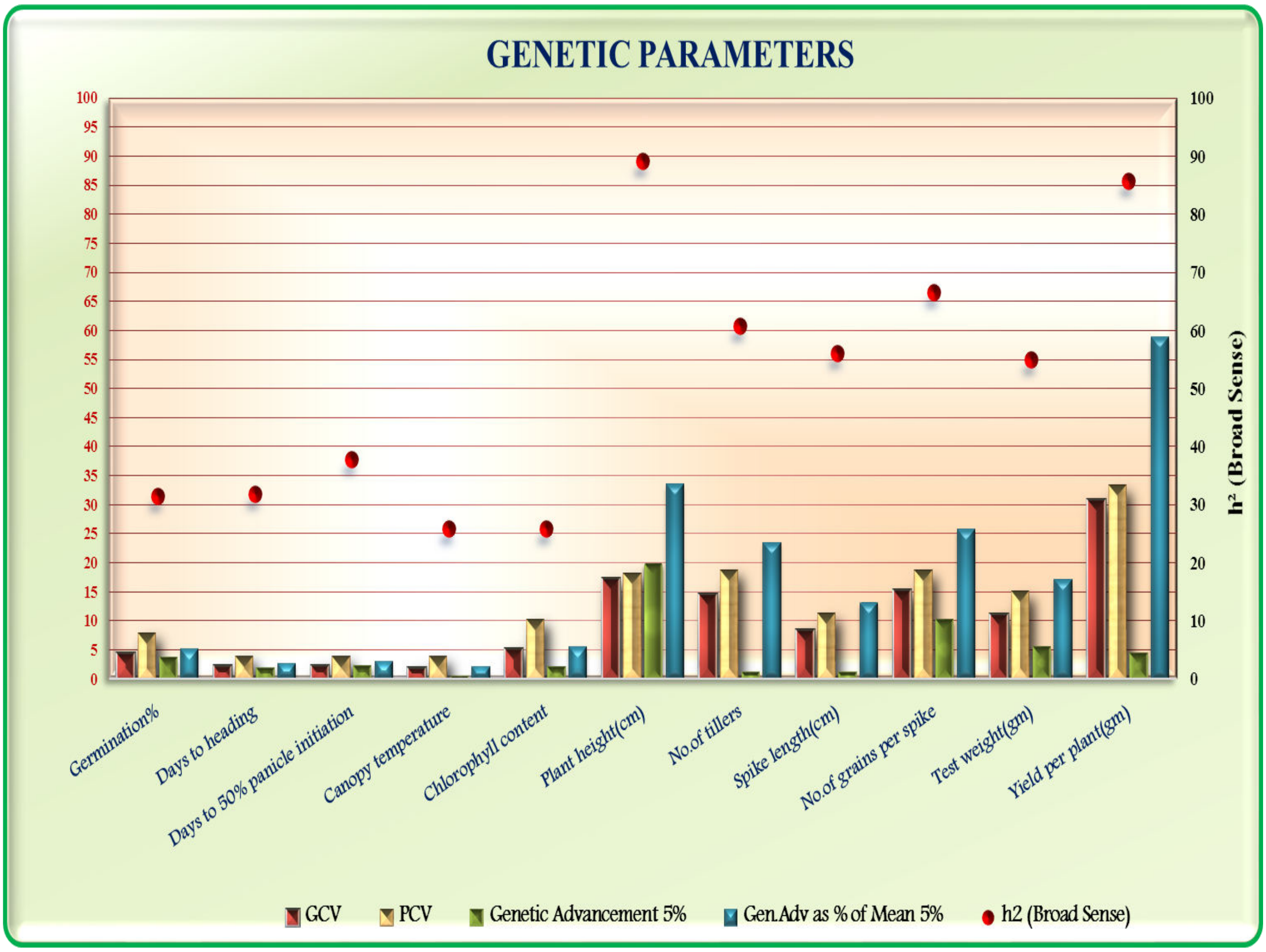


TABLE4.5- Different genetic parameters calculated for various characters of 30 wheat genotypes under irrigated (non-stress) condition.

	Germination%	Day to heading	Days to 50%spike initiation	Canopy temperature	Chlorophyll content	Plant height(cm)	Number of tillers/plant	Spike length(cm)	Number of grains per spike	Test weight(gm)	Yield per plant(gm)
GCV	9.392	2.625	3.304	1.904	4.228	7.216	11.515	7.225	13.714	11.042	25.095
PCV	15.375	5.153	3.912	3.438	8.114	14.154	15.922	10.129	16.848	14.767	26.625
h2 (Broad Sense)	37.309	25.955	71.34	30.688	27.159	25.99	52.299	50.878	66.257	55.909	88.836
Genetic Advancement 5%	8.335	1.97	4.33	0.57	1.812	4.704	0.946	0.983	9.747	5.655	4.173
Gen.Adv as % of Mean 5%	11.817	2.755	5.749	2.173	4.539	7.578	17.154	10.616	22.996	17.008	48.724

TABLE 4.6- Different genetic parameters calculated for various characters of 30 wheat genotypes under non-irrigated (stress) condition.

	Germination%	Days to heading	Days to 50% spike initiation	Canopy temperature	Chlorophyll content	Plant height(cm)	Number of tillers/plant	Spike length(cm)	Number of grains per spike	Test weight(gm)	Yield per plant(gm)
GCV	4.473	2.255	2.373	2	5.257	17.255	14.623	8.486	15.297	11.184	30.868
PCV	7.962	3.996	3.854	3.924	10.315	18.278	18.758	11.339	18.735	15.075	33.333
h2 (Broad Sense)	31.559	31.833	37.914	25.973	25.976	89.117	60.767	56.005	66.661	55.041	85.754
Genetic Advancement 5%	3.683	1.893	2.274	0.551	2.136	19.895	1.216	1.172	10.168	5.605	4.521
Gen.Adv as % of Mean 5%	5.177	2.62	3.01	2.099	5.52	33.556	23.482	13.082	25.727	17.093	58.884

4.3. Correlation between traits under irrigated (non-stress) condition and non-irrigated (stress) condition:

The analysis for correlation was done using WINDOSTAT version 9.3. Under irrigated (non-stress) condition, grain yield per plant exhibited significant strong positive correlation with no. of grains per spike (0.7868**), no. of tillers per plant (0.6426**), spike length (0.6132**), test weight (0.6067**). It showed non-significant positive correlation with germination percent (0.1390), and chlorophyll content (0.0328) whereas it showed negative correlation with days to 50% spike initiation (-0.0929), days to heading (-0.0406) and canopy temperature (-0.0177). The correlations between the various traits under irrigated (non-stress) condition are depicted in the (Table 4.7, Fig. 4.1 and Fig 4.2).

Under non irrigated (stress) condition, grain yield per plant exhibited strong significant phenotypic correlation with no. of tillers per plant (0.8222**), no. of grains per spike (0.7613**), test weight (0.6136**), spike length (0.5859**) and plant height (0.2388*). It showed non- significant positive correlation with germination perecnt (0.0907), days to heading (0.1914), days to 50% spike initiation (0.1612) and canopy temperature (0.0130) whereas a negative correlation was seen with chlorophyll content (-0.0766). The correlations between the various traits are shown in the (Table 4.8, Fig 4.3 and Fig 4.4)

4.3.1 Germination percent

Germination percent showed positive significant correlation with plant height (0.3241**) and spike length (0.2576*) under irrigated condition.

4.3.2 Days to heading

Days to heading showed positive significant correlation with days to 50% spike initiation (0.8083**) under irrigated condition whereas days to heading showed positive significant correlation with the traits such as days to 50% spike initiation (0.9678**) followed by number of tillers per plant (0.3052**) under non-irrigated condition.

4.3.3 Days to 50% spike initiation

Days to 50% spike initiation showed positive significant correlation with days to heading (0.8083**) and it showed negative significant correlation with test weight (-0.2465*) under irrigated condition whereas days to 50% spike initiation showed positive significant correlation with the days to heading (0.9678**) followed by number of tillers per plant (0.2856**) under non-irrigated condition.

4.3.4 Canopy temperature

Canopy temperature (℃) showed significant negative correlation with plant height (-0.3106**) under irrigated condition whereas canopy temperature (℃)did not show significant correlation with any the traits under study under non-irrigated condition.

4.3.5 Chlorophyll content

Chlorophyll content showed positive significant correlation with plant height (0.2602*) under irrigated condition whereas, chlorophyll content did not show significant correlation with any the traits under study under non-irrigated conditio

4.3.6 Plant height

Plant height showed significant positive correlation with germination percent (0.3241**) followed by chlorophyll content (0.2602*), spike length (0.2600*), yield per plant (0.2492*) and test weight (0.2434*) and it showed negative significant correlation with canopy temperature (-0.3106**) under irrigated condition whereas plant height showed positive significant correlation with the number of grains per spike (0.2677*) under non-irrigated condition.

4.3.7 Number of effective tillers per plant

Number of tillers per plant showed positive significant correlation with grain yield per plant (0.6426**) followed by spike length (0.4451**), test weight (0.3270**) and number of grains per spike (0.3035**) under irrigated condition whereas number of tillers per plant showed positive significant correlation with grain yield per plant (0.8222**) followed by number of grains per spike (0.4625**), test weight (0.4082**), spike length (0.3812**), days to heading (0.3052**) and days to 50% spike initiation (0.2856**) under non-irrigated condition.

4.3.8 Spike length

Spike length showed significant positive correlation with the number of grains per spike (0.6711**) followed by grain yield per plant (0.6132**), number of tillers per plant (0.4451**), plant height (0.2600*) and germination percent (0.2576*) under irrigated condition whereas spike length showed positive significant correlation with number of grains per spike (0.6781**) followed by grain yield per plant (0.5859**), number of tillers per plant (0.3812**) and test weight (0.3572**) under non-irrigated condition.

4.3.9 Number of grains per spike

Number of grains per spike showed significant positive correlation with grain yield per plant (0.7868**) followed by spike length (0.6711**), test weight (0.3360**) and number of tillers per plant (0.3035**) under irrigated condition whereas number of grains per spike showed positive significant correlation with grain yield per plant (0.7613**), spike length (0.6781**), no. of tillers per plant (0.4625**), test weight (0.4214**) and plant height (0.2677*) under non-irrigated condition.

4.3.10 Test weight

Test weight showed positive significant correlation with grain yield per plant (0.6067**) followed by number of grains per spike (0.3360**), number of tillers per plant (0.3270**) and plant height (0.2434*) and test weight showed negative significant correlation with days to 50% spike initiation (-0.2465*) under irrigated condition whereas test weight showed positive significant correlation with grain yield per plant (0.6136**), number of grains per spike (0.4214**), number of tillers per plant (0.4082**) and spike length (0.3572**) under non-irrigated condition

Table 4.7- Phenotypic correlations between traits of 30 wheat genotypes under irrigated (non-stress) condition.

	Germination%	Day to heading	Day to 50% spike initiation	Canopy temperature	Chlorophyll content	Plant height(cm)	Number of tillers/plant	Spike length(cm)	No. of grains per spike	Test weight(gm)
Germination%	1	-0.1559	-0.1506	-0.1224	0.0536	0.3241 **	0.1316	0.2576 *	0.1226	-0.0402
Day to heading	-0.1559	1	0.8083 **	0.0523	0.0493	-0.1244	0.0403	-0.0029	-0.1310	-0.0847
Days to 50% spike initiation	-0.1506	0.8083**	1	0.0521	0.0436	-0.1766	0.0315	0.0013	-0.1263	-0.2465 *
Canopy temperature	-0.1224	0.0523	0.0521	1	-0.1308	-0.3106 **	-0.0207	-0.0944	-0.1132	-0.0078
Chlorophyll content	0.0536	0.0493	0.0436	-0.1308	1	0.2602 *	0.0727	0.0240	-0.0253	0.0267
Plant height (cm)	0.3241 **	-0.1244	-0.1766	-0.3106 **	0.2602 *	1	0.1778	0.2600 *	0.1764	0.2434 *
Number of tillers/plant	0.1316	0.0403	0.0315	-0.0207	0.0727	0.1778	1	0.4451 **	0.3035 **	0.3270 **
Spike length (cm)	0.2576 *	-0.0029	0.0013	-0.0944	0.0240	0.2600 *	0.4451 **	1	0.6711 **	0.1994
No.of grains per spike	0.1226	-0.1310	-0.1263	-0.1132	-0.0253	0.1764	0.3035 **	0.6711 **	1	0.3360 **
Test weight (gm)	-0.0402	-0.0847	-0.2465 *	-0.0078	0.0267	0.2434 *	0.3270 **	0.1994	0.3360 **	1
Yield per plant (gm)	0.139	-0.0406	-0.0929	-0.0177	0.0328	0.2492*	0.6426**	0.6132**	0.7868**	0.6067**

Significant at 1% level of significance (**)

Significant at 5% level of significance (*)

Fig 4.1- Shaded correlation matrix between traits of 30 wheat genotypes under irrigated (non-stress) condition.

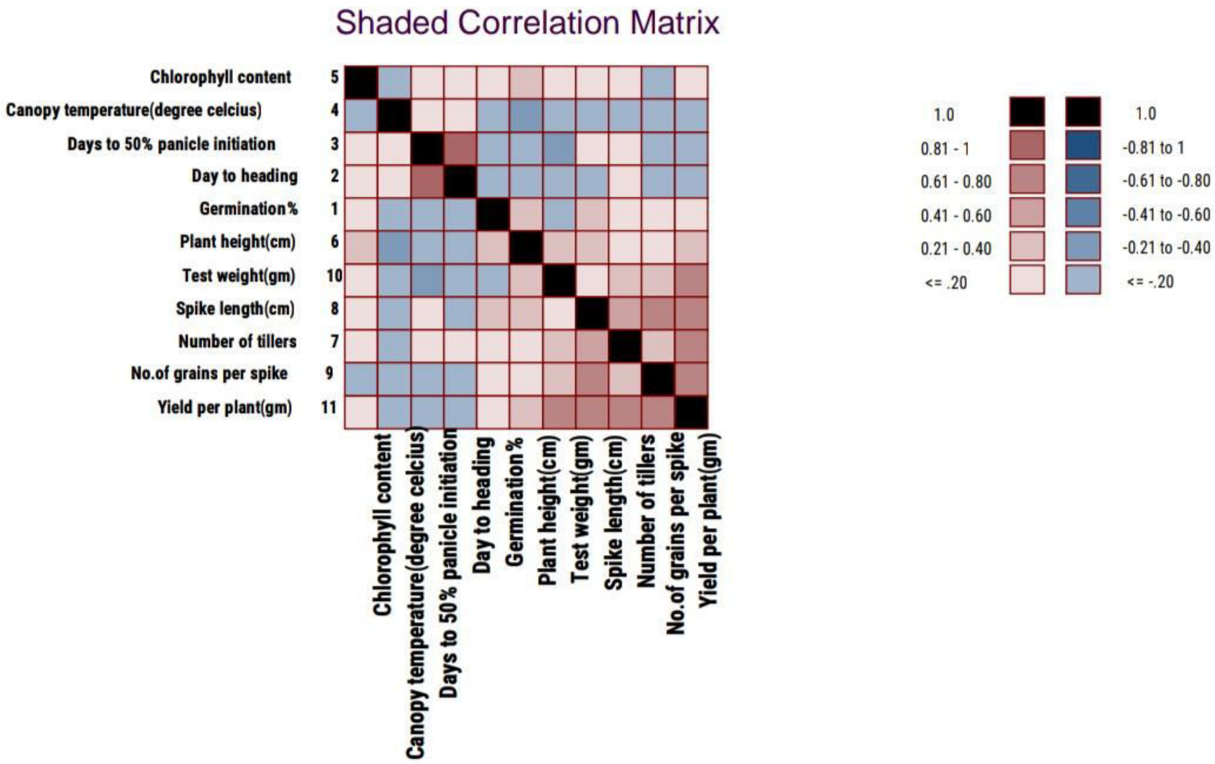


Fig 4.2- Phenotypic correlations between traits of 30 wheat genotypes under irrigated (non-stress) condition.

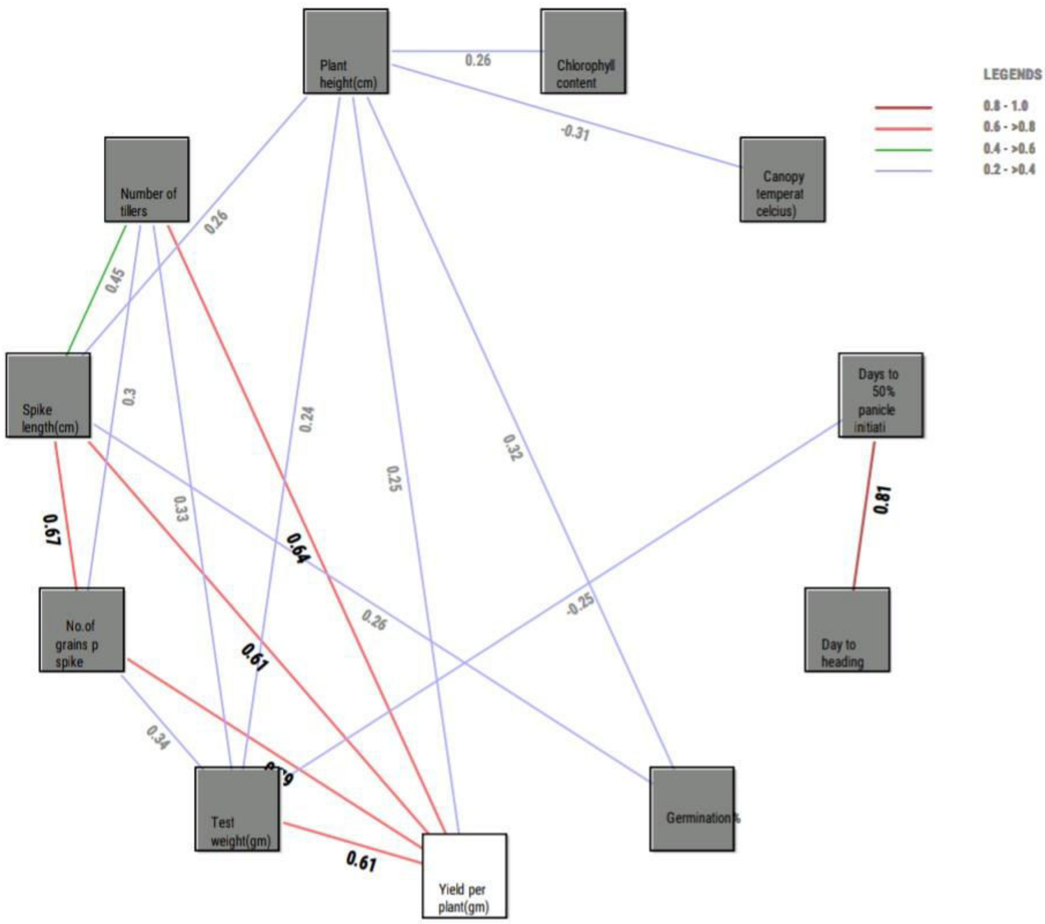


Table 4.8- Phenotypic correlations between traits of 30 wheat genotypes under non-irrigated (stress) condition

	Germination%	Days to heading	Days to 50% spike initiation	Canopy temperature	Chlorophyll content	Plant height(cm)	No. of tillers/plant	Spike length(cm)	No. of grains per spike	Test weight(gm)
Germination%	1	0.0316	0.0127	-0.0347	0.1211	0.1545	0.0578	0.0743	0.0873	-0.0654
Days to heading	0.0316	1	0.9678 **	-0.0141	-0.1216	-0.1105	0.3052 **	0.1448	-0.0117	-0.0224
Days to 50% spike initiation	0.0127	0.9678 **	1	-0.0397	-0.1261	-0.1440	0.2856 **	0.1012	-0.0151	-0.0810
Canopy temperature	-0.0347	-0.0141	-0.0397	1	-0.0463	-0.0085	-0.1262	0.0780	0.0999	0.0751
Chlorophyll content	0.1211	-0.1216	-0.1261	-0.0463	1	0.0071	-0.0964	-0.0399	-0.0196	-0.1809
Plant height(cm)	0.1545	-0.1105	-0.1440	-0.0085	0.0071	1	0.0980	0.0459	0.2677 *	0.1886
No.of tillers/plant	0.0578	0.3052 **	0.2856 **	-0.1262	-0.0964	0.0980	1	0.3812 **	0.4625 **	0.4082 **
Spike length(cm)	0.0743	0.1448	0.1012	0.0780	-0.0399	0.0459	0.3812 **	1	0.6781 **	0.3572 **
No.of grains per spike	0.0873	-0.0117	-0.0151	0.0999	-0.0196	0.2677 *	0.4625 **	0.6781 **	1	0.4214 **
Test weight(gm)	-0.0654	-0.0224	-0.0810	0.0751	-0.1809	0.1886	0.4082 **	0.3572 **	0.4214 **	1
Yield per plant(gm	0.0907	0.1941	0.1612	0.013	-0.0766	0.2388*	0.8222 **	0.5859**	0.7613**	0.6136**

Significant at 1% level of significance (**)

Significant at 5% level of significance (*)

Fig 4.3- Shaded correlation matrix between traits of 30 wheat genotypes under non-irrigated (stress) condition.

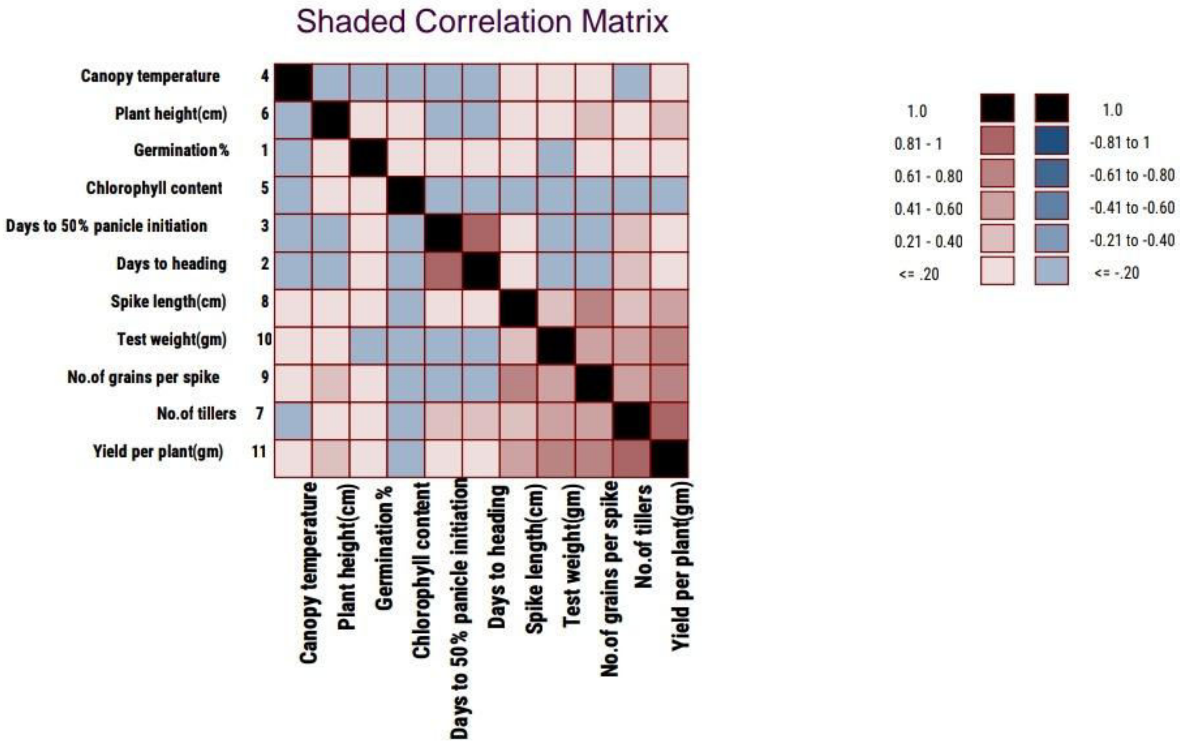
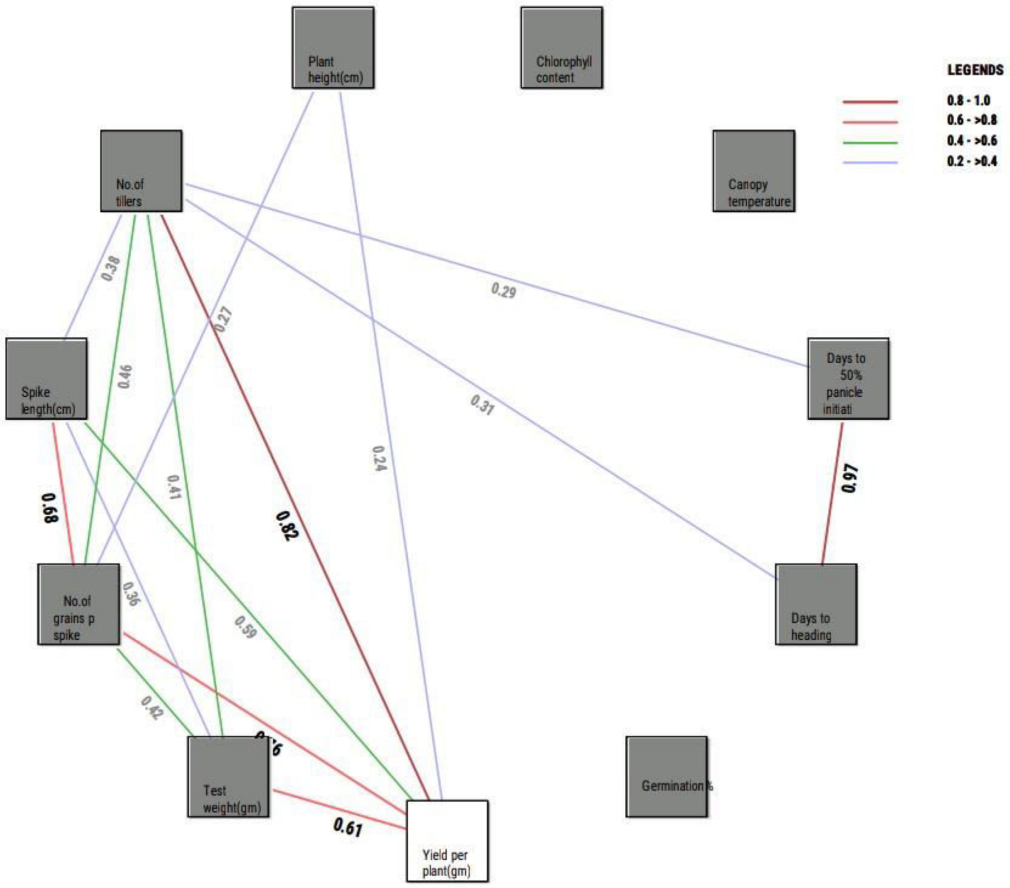


Fig 4.4- Phenotypic correlations between traits of 30 wheat genotypes under non- irrigated (stress) condition.



4.4. <u>Path coefficient analysis under irrigated (non-stress) and non-irrigated (stress) condition</u>-

Phenotypic path coefficient analysis was done by considering grain yield per plant (g) as dependent variable and other yield contributing traits as independent variables. The phenotypic correlations were partitioned into direct, indirect and residual effects on yield per plant (g). The data of phenotypic path coefficient analysis is presented in (Table 4.9 for irrigated condition) and (Table 4.10 for non-irrigated condition)

4.4.1 Germination percent-

Under irrigated condition, germination percent exhibited a positive correlation of 0.1390 on yield along with a positive direct effect of 0.0436 on yield. It also showed a positive indirect effect via chlorophyll content (0.0006), plant height (0.0082), number of tillers per plant (0.0475) and no. of grains per spike (0.0730) and negative indirect effect via days to heading (-0.0056), spike length (-0.0045), days to 50% spike initiation (-0.0033), canopy temperature (-0.0085) and test weight (-0.0119) whereas under non-irrigated condition, germination percent exhibited a positive correlation of 0.0907 on yield along with a positive direct effect of 0.0277 on yield. It also showed a positive indirect effect via days to heading (0.0030), chlorophyll content (0.0030), plant height (0.0059), number of tillers per plant (0.0304), spike length (0.0020), number of grains per spike (0.0343) and negative indirect effect via days to 50% spike initiation (-0.0007) canopy temperature (-0.0008) and test weight (-0.0143)

4.4.2 Days to heading

Under irrigated condition, days to heading exhibited a negative correlation of -0.0406 on yield along with a positive direct effect of 0.0361 on yield. It also showed a positive indirect effect via days to 50% spike initiation (0.0176), canopy temperature (0.0036), chlorophyll content (0.0006), number of tillers per plant (0.0145), spike length (0.0001) and negative indirect effect via germination percent (-0.0068), plant height (-0.0031), number of grains per spike (-0.0780) and test weight (-0.0251) whereas under non-irrigated condition, days to heading exhibited a positive correlation of 0.1941 on yield along with a positive direct effect of 0.0956 on yield. It also showed a positive indirect effect through germination percent (0.0009), number of tillers per plant (0.1606), spike length (0.0040) and negative indirect effect via days to 50% spike initiation (-0.0498), canopy temperature (-0.0003), chlorophyll content (-0.0030), plant height (-0.0042), number of grains/ spike (-0.0046) and test weight (-0.0049)

4.4.3 Day to 50% spike initiation

Under irrigated condition, days to 50 percent spike initiation exhibited a negative correlation of -0.0929 on yield along with a positive direct effect of 0.0217 on yield. It also showed a positive indirect effect via days to heading (0.0292), canopy temperature (0.0036), chlorophyll content (0.0005), no. of tillers per plant (0.0114) and negative indirect effect via germination % (-0.0066), plant height (-0.0044), number of grains/ spike (-0.0752) and test weight (-0.0731) whereas under non-irrigated condition, days to 50% spike initiation exhibited a positive correlation of 0.1612 on yield along with a negative direct effect of -0.0515 on yield. It also showed a positive indirect effect via germination % (0.0004), days to heading (0.0926), number of tillers per plant (0.1503), spike length (0.0028) and negative indirect effect via canopy temperature (-0.0009), chlorophyll content (-0.0032), plant height (-0.0055), number of grains per spike (-0.0059) and test weight (-0.0177)

4.4.4 Canopy temperature

Canopy temperature exhibited a negative correlation of - 0.0177 on yield along with a positive direct effect of 0.0695 on yield under irrigated condition. It also showed a positive indirect effect via days to heading (0.0019), days to 50% spike initiation (0.0011), spike length (0.0017) and negative indirect effect through germination percent (-0.0053), chlorophyll content (-0.0015), plant height (-0.0078), number of tillers per plant (-0.0075), number of grains per spike (-0.0674) and test weight (-0.0023) whereas under non-irrigated condition, canopy temperature exhibited a positive correlation of 0.0130 on yield along with a positive direct effect of 0.0233 on yield. It also showed a positive indirect effect via days to 50% spike initiation (0.0020), spike length (0.0021), number of grains per spike (0.0393), test weight (0.0164) and negative indirect effect via germination % (-0.0010), days to heading (-0.0013), chlorophyll content (-0.0012), plant height (-0.0003) and number of tillers per plant (-0.0664).

4.4.5 Chlorophyll content

Under irrigated condition, chlorophyll content exhibited a positive correlation of 0.0328 on yield along with a positive direct effect of 0.0116 on yield. It also showed a positive indirect effect via germination percent (0.0023), days to heading (0.0018), days to 50% spike initiation (0.0009), plant height (0.0065), number of tillers per plant (0.0262), test weight (0.0079) and negative indirect effect via canopy temperature (-0.0091), spike length (-0.0004) and number of grains per spike (-0.0151) whereas under non-irrigated condition, chlorophyll content exhibited a negative correlation of -0.0766 on yield along with a positive direct effect of 0.0251 on yield. It also showed a positive indirect effect via germination percent (0.0034), days to 50% spike initiation (0.0065), plant height (0.0003) and negative indirect effect via days to heading (-0.0116), canopy temperature (-0.0011), number of effective tillers per plant (-0.0508), spike length (-0.0011), number of grains per spike (-0.0077) and test weight (-0.0396).

4.4.6 Plant height

Under irrigated condition, plant height exhibited a positive correlation of 0.2492 on yield along with a positive direct effect of 0.0252 on yield. It also showed a positive indirect effect via germination percent (0.0141), chlorophyll content (0.0030), number of effective tillers per plant (0.0642), number of grains per spike (0.1050), test weight (0.0079) and negative indirect effect via days to heading (-0.0045), days to 50% spike initiation (-0.0038), canopy temperature (-0.0216) and spike length (-0.0046) whereas under non-irrigated condition, plant height exhibited a positive correlation of 0.2388 on yield along with a positive direct effect of 0.0384 on yield. It also showed a positive indirect effect via germination percent (0.0043), days to 50% spike initiation (0.0074), chlorophyll content (0.0002), number of tillers per plant (0.0516), spike length (0.0013), number of grains per spike (0.1052), test weight (0.0413) and negative indirect effect via days to heading (-0.0106) and canopy temperature (-0.0002).

4.4.7 Number of effective tillers per plant

Under irrigated condition, number of tillers per plant exhibited a positive correlation of 0.6426 on yield along with a positive direct effect of 0.3610 on yield. It also showed a positive indirect effect via germination percent (0.0057), days to heading

(0.0015), days to 50% spike initiation (0.0007), chlorophyll content (0.0008), plant height (0.0045), number of grains per spike (0.1807), test weight (0.0969) and negative indirect effect via canopy temperature (-0.0014) and spike length (-0.0078) whereas under non-irrigated condition, number of tillers per plant exhibited a positive correlation of 0.8222 on yield along with a positive direct effect of 0.5262 on yield. It also showed a positive indirect effect via germination percent (0.0016), days to heading (0.0292), plant height (0.0038), spike length (0.0104), number of grains per spike (0.1818), test weight (0.0893) and negative indirect effect via days to 50 percent spike initiation (-0.0147), canopy temperature (-0.0029) and chlorophyll content (-0.0024)

4.4.8 Spike length

Under irrigated condition, spike length exhibited a positive correlation of 0.6132 on yield along with a negative direct effect of -0.0176 on yield. It also showed a positive indirect effect via germination percent (0.0112), chlorophyll content (0.0003), plant height (0.0065), no. of tillers per plant (0.1607), number of grains per spike (0.3995), test weight (0.0591) and negative indirect effect via days to heading (-0.0001) and canopy temperature (-0.0066) whereas under non-irrigated condition, spike length exhibited a positive correlation of 0.5859 on yield and along with a positive direct effect of 0.0273 on yield. It also showed a positive indirect effect via germination percent (0.0021), days to heading (0.0139), canopy temperature (0.0018), plant height (0.0018), number of tillers per plant (0.2006), number of grains per spike (0.2666), test weight (0.0781) and negative indirect effect via days to 50 percent spike initiation (-0.0052) and chlorophyll content (-0.0010)

4.4.9 Number of grains per spike

Under irrigated condition, number of grains per spike exhibited a positive correlation of 0.7868 on yield along with a positive direct effect of 0.5953 on yield. It also showed a positive indirect effect via germination percent (0.0053), plant height (0.0044), no. of effective tillers per plant (0.1096), test weight (0.0996) and negative indirect effect via days to heading (-0.0047), days to 50% spike initiation (-0.0027), canopy temperature (-0.0079), chlorophyll content (-0.0003) and spike length (-0.0118) whereas under non-irrigated condition, number of grains per spike exhibited a positive correlation of 0.7613 on yield along with a positive direct effect of 0.3931 on yield. It also showed a positive indirect effect via germination percent (0.0024), days to 50% spike initiation (0.0008), canopy temperature (0.0023), plant height (0.0103), number of tillers per plant (0.2434), spike length (0.0185), test weight (0.0922) and negative indirect effect via days to heading (-0.0011) and chlorophyll content (-0.0005).

4.4.10 Test weight

Under irrigated condition, test weight exhibited a positive correlation of 0.6067 on yield along with a positive direct effect of 0.2964 on yield. It also showed a positive indirect effect via chlorophyll content (0.0003), plant height (0.0061), number of tillers per plant (0.1181), number of grains/spike (0.2000) and negative indirect effect via germination percent (-0.0018), days to heading (-0.0031), days to 50% spike initiation (-0.0054), canopy temperature (-0.0005) and spike length (-0.0035) whereas under non-irrigated condition, test weight exhibited a positive correlation of 0.6136 on yield along with a positive direct effect of 0.2187 on yield. It also showed a positive indirect effect via days to 50% spike initiation (0.0042), canopy temperature (0.0017), plant height (0.0072), number of tillers per plant (0.2148), spike length (0.0097), number of grains/spike (0.1656) and negative indirect effect via germination percent (-0.0018), days to heading (-0.0021) and chlorophyll content (-0.0045).

The residual effect of other independent variables on yield under irrigated condition was 0.3500 while under non-irrigated condition was 0.3123. The lesser value for residual effect indicated that most of the yield contributing traits have been included in the study and fewer possible independent variables which contributed towards yield were left out.

Table 4.9- Path matrix of yield per plant (g) of 30 wheat genotypes under irrigated (non-stress) condition

	Germination%	Day to heading	Days to 50% spike initiation	Canopy temperature	Chlorophyll content	Plant height(cm)	No. of tillers/plant	Spike length(cm)	No. of grains per spike	Test weight(gm)
Germination%	0.0436	-0.0068	-0.0066	-0.0053	0.0023	0.0141	0.0057	0.0112	0.0053	-0.0018
Day to heading	-0.0056	0.0361	0.0292	0.0019	0.0018	-0.0045	0.0015	-0.0001	-0.0047	-0.0031
Days to 50% spike initiation	-0.0033	0.0176	0.0217	0.0011	0.0009	-0.0038	0.0007	0	-0.0027	-0.0054
Canopy temperature	-0.0085	0.0036	0.0036	0.0695	-0.0091	-0.0216	-0.0014	-0.0066	-0.0079	-0.0005
Chlorophyll content	0.0006	0.0006	0.0005	-0.0015	0.0116	0.003	0.0008	0.0003	-0.0003	0.0003
Plant height(cm)	0.0082	-0.0031	-0.0044	-0.0078	0.0065	0.0252	0.0045	0.0065	0.0044	0.0061
Number of tillers/plant	0.0475	0.0145	0.0114	-0.0075	0.0262	0.0642	0.361	0.1607	0.1096	0.1181
Spike length(cm)	-0.0045	0.0001	0	0.0017	-0.0004	-0.0046	-0.0078	-0.0176	-0.0118	-0.0035
No. of grains per spike	0.073	-0.078	-0.0752	-0.0674	-0.0151	0.105	0.1807	0.3995	0.5953	0.2
Test weight(gm)	-0.0119	-0.0251	-0.0731	-0.0023	0.0079	0.0721	0.0969	0.0591	0.0996	0.2964
Yield per plant(gm	0.139	-0.0406	-0.0929	-0.0177	0.0328	0.2492	0.6426	0.6132	0.7868	0.6067
Partial R^2	0.0061	-0.0015	-0.002	-0.0012	0.0004	0.0063	0.232	-0.0108	0.4684	0.1799
R SQUARE = 0.8775 RESIDUAL EFFECT = 0.3500										

Fig 4.5- Phenotypic Path Diagram for yield per plant (gm) of 30 wheat genotypes under irrigated (non-stress) condition

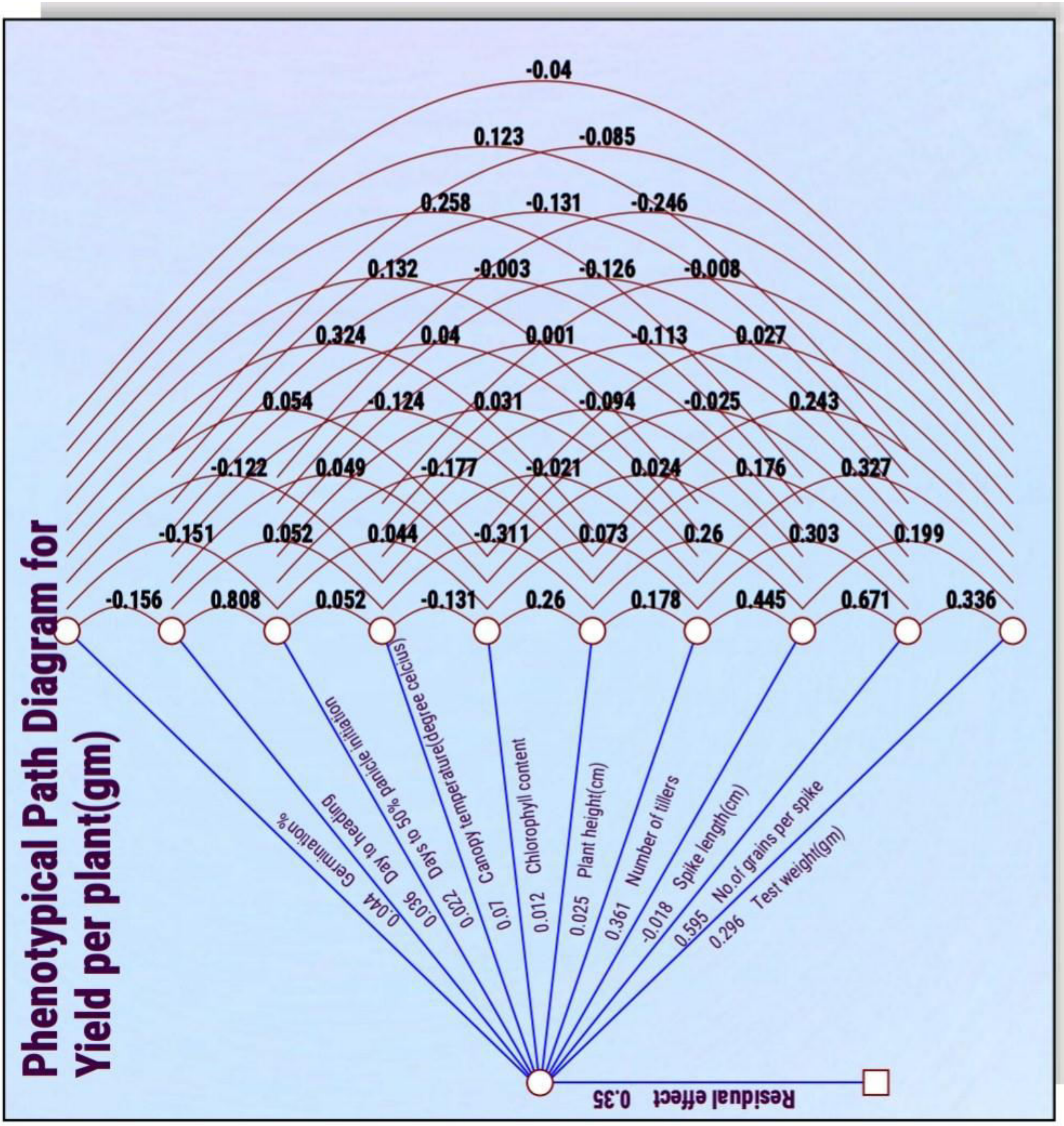
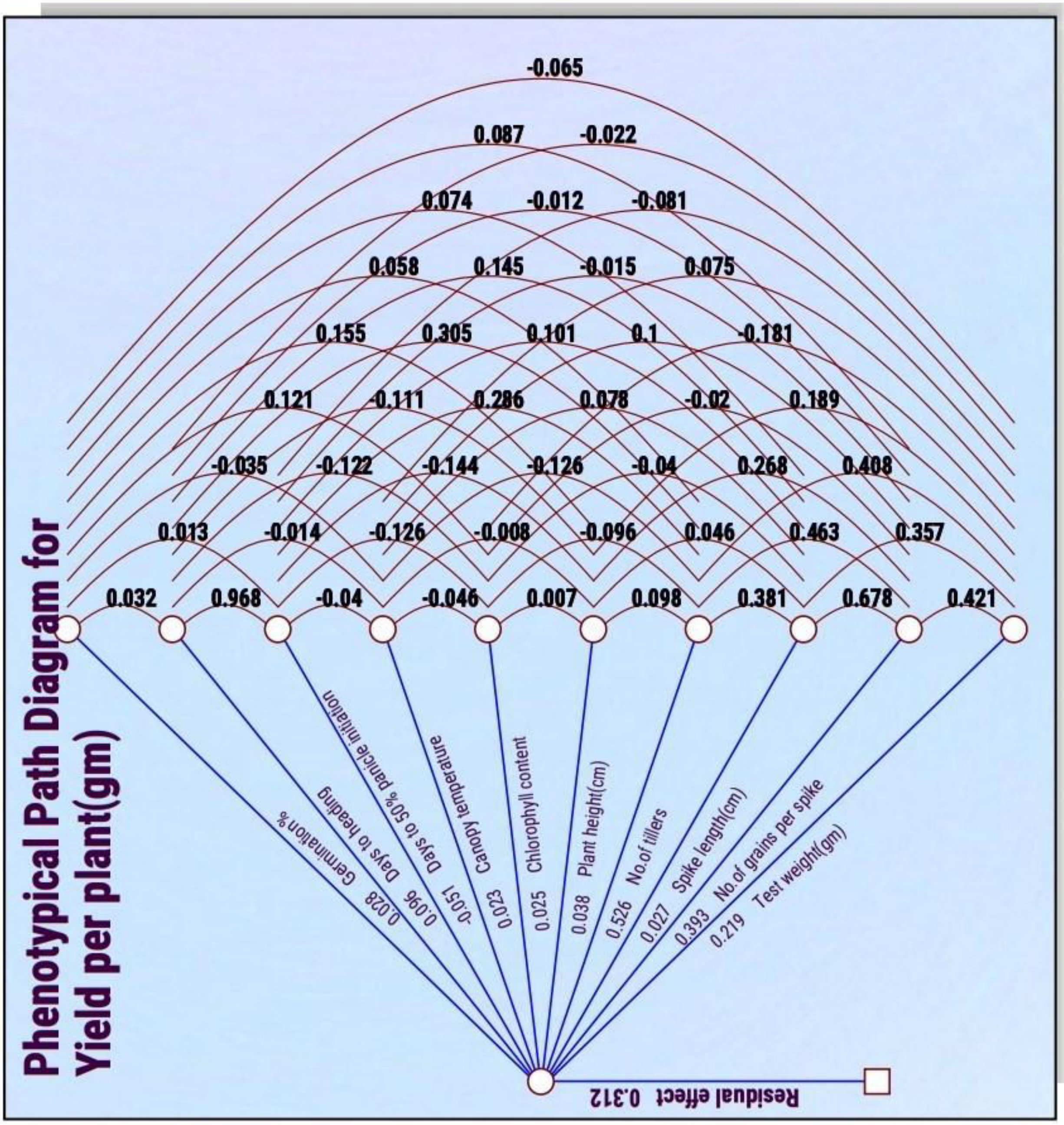


Table 4.10- Path matrix of yield per plant (gm) of 30 wheat genotypes under non-irrigated (stress) condition

	Germination%	Days to heading	Days to 50% spike initiation	Canopy temperature	Chlorophyll content	Plant height(cm)	No. of tillers/plant	Spike length(cm)	No. of grains per spike	Test weight(gm)
Germination percent	0.0277	0.0009	0.0004	-0.001	0.0034	0.0043	0.0016	0.0021	0.0024	-0.0018
Days to heading	0.003	0.0956	0.0926	-0.0013	-0.0116	-0.0106	0.0292	0.0139	-0.0011	-0.0021
Days to 50% spike initiation	-0.0007	-0.0498	-0.0515	0.002	0.0065	0.0074	-0.0147	-0.0052	0.0008	0.0042
Canopy temperature	-0.0008	-0.0003	-0.0009	0.0233	-0.0011	-0.0002	-0.0029	0.0018	0.0023	0.0017
Chlorophyll content	0.003	-0.003	-0.0032	-0.0012	0.0251	0.0002	-0.0024	-0.001	-0.0005	-0.0045
Plant height(cm)	0.0059	-0.0042	-0.0055	-0.0003	0.0003	0.0384	0.0038	0.0018	0.0103	0.0072
No.of tillers per plant	0.0304	0.1606	0.1503	-0.0664	-0.0508	0.0516	0.5262	0.2006	0.2434	0.2148
Spike length(cm)	0.002	0.004	0.0028	0.0021	-0.0011	0.0013	0.0104	0.0273	0.0185	0.0097
No.of grains per spike	0.0343	-0.0046	-0.0059	0.0393	-0.0077	0.1052	0.1818	0.2666	0.3931	0.1656
Test weight(gm)	-0.0143	-0.0049	-0.0177	0.0164	-0.0396	0.0413	0.0893	0.0781	0.0922	0.2187
Yield per plant (gm)	0.0907	0.1941	0.1612	0.013	-0.0766	0.2388	0.8222	0.5859	0.7613	0.6136
Partial R^2	0.0025	0.0186	-0.0083	0.0003	-0.0019	0.0092	0.4327	0.016	0.2993	0.1342
R SQUARE = 0.9025 RESIDUAL EFFECT = 0.3123										

Fig 4.6-Phenotypic path diagram for yield per plant (gm) of 30 wheat genotypes under non-irrigated (stress) condition



4.5 Study of Drought Tolerance Indices using Principal Component Analysis (PCA)-

Multivariate statistical principal component analysis (PCA) was performed to study all the drought tolerant indices simultaneously. PCA is a type of factor analysis that helped in simplifying and reducing the dimensions of huge data sets. The interrelationships, similarities and dissimilarities were studied using correlation matrix between Drought Tolerant Indices (DTIs) and Principal Components using XLSTAT version 2020. The 10 DTIs used in the study include Stress Susceptible Index (SSI), Mean Productivity (MP), Tolerance Index (TOL), Yield Susceptible Index (YSI), Geometric Mean Productivity (GMP), Drought Resistance Index (DI), Stress Non-stress Production Index (SNPI), Stress Susceptibility Percentage Index (SSPI) Stress Tolerance Index (STI) and Relative Drought Index (RDI).

Only the first two factors or principal components out of the seven factors showed an Eigen value of more than unity (Table 4.11). PC1 or F1 exhibited an Eigen value of 7.617 and PC2 or F2 exhibited an Eigen value of 3.581. PC1 and PC2 together accounted for 93.32 % of the total variance in the database. The first principal component accounted for 63.477 % of the total variance followed by the second PC (29.843).

The findings depicted a higher loading of Eigen value of PC1 for DI (0.360), yield under non-irrigated condition (0.328), YSI and RDI (0.304), GPM (0.288), MP (0.287) and STI (0.285) whereas a negative loading was seen for SSI (0.304), TOL and SSPI (-0.277) and SNPI (-0.184). PC2 showed highest value for TOL and SSPI (0.330) followed by MP (0.322), STI (0.321), GMP (0.319), SSI (0.271), SNPI (0.172), DI (0.055) whereas negative values were observed for RDI and YSI (-0.271) as presented in (Table 4.12).

Table 4.11- Eigen values, variability and cumulative variability % of seven Principal Components or factors.

Eigenvalues:

	F1	F2	F3	F4	F5	F6	F7
Eigenvalue	7.617	3.581	0.694	0.096	0.009	0.002	0.000
Variability (%)	63.477	29.843	5.786	0.803	0.072	0.018	0.000
Cumulative %	63.477	93.320	99.107	99.910	99.982	100.000	100.000

Graph 4.3- Bar graph showing relationship between Eigen values, seven PCs (Principal Components) and their respective cumulative variability% of 7 Principal components in 30 wheat genotypes.

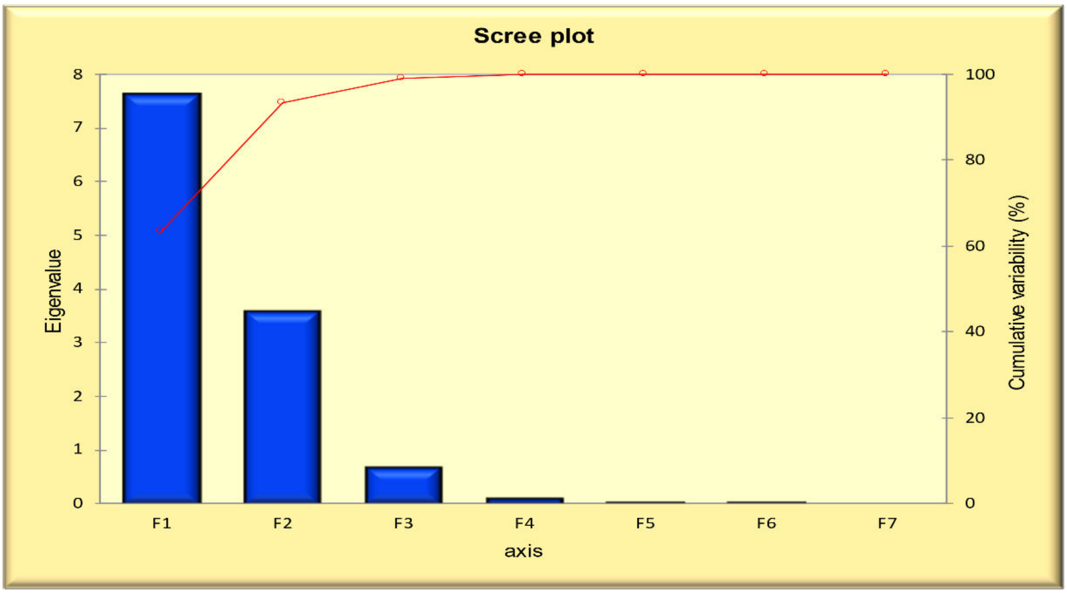


Table 4.12- Eigen vectors for the Drought Tolerant Indices of seven Principal Components in 30 wheat genotypes

	F1	F2	F3	F4	F5	F6	F7
Yield per plant(gm)-Irrigated	0.225	0.413	-0.001	0.159	-0.205	0.002	-0.316
Yield per plant(gm)-Non irrigated	0.328	0.223	0.016	-0.084	-0.250	-0.043	-0.304
TOL	-0.277	0.330	-0.036	0.504	0.144	0.099	0.044
MP	0.287	0.322	0.008	0.032	-0.235	-0.022	-0.318
GMP	0.288	0.319	0.010	0.004	-0.310	-0.193	0.825
STI	0.285	0.321	-0.050	-0.216	0.799	-0.357	-0.005
SSI	-0.304	0.271	-0.166	-0.356	-0.066	0.092	0.002
RDI	0.304	-0.271	0.166	0.356	0.066	-0.092	-0.002
SSPI	-0.277	0.330	-0.036	0.504	0.144	0.099	0.044
SNPI	-0.184	0.172	0.955	-0.155	0.022	0.017	-0.001
YSI	0.304	-0.271	0.166	0.356	0.066	-0.092	-0.002
DI	0.360	0.055	0.024	-0.089	0.224	0.888	0.145

Factor loadings or correlation between the variables (DTIs) and first two Principal Components-

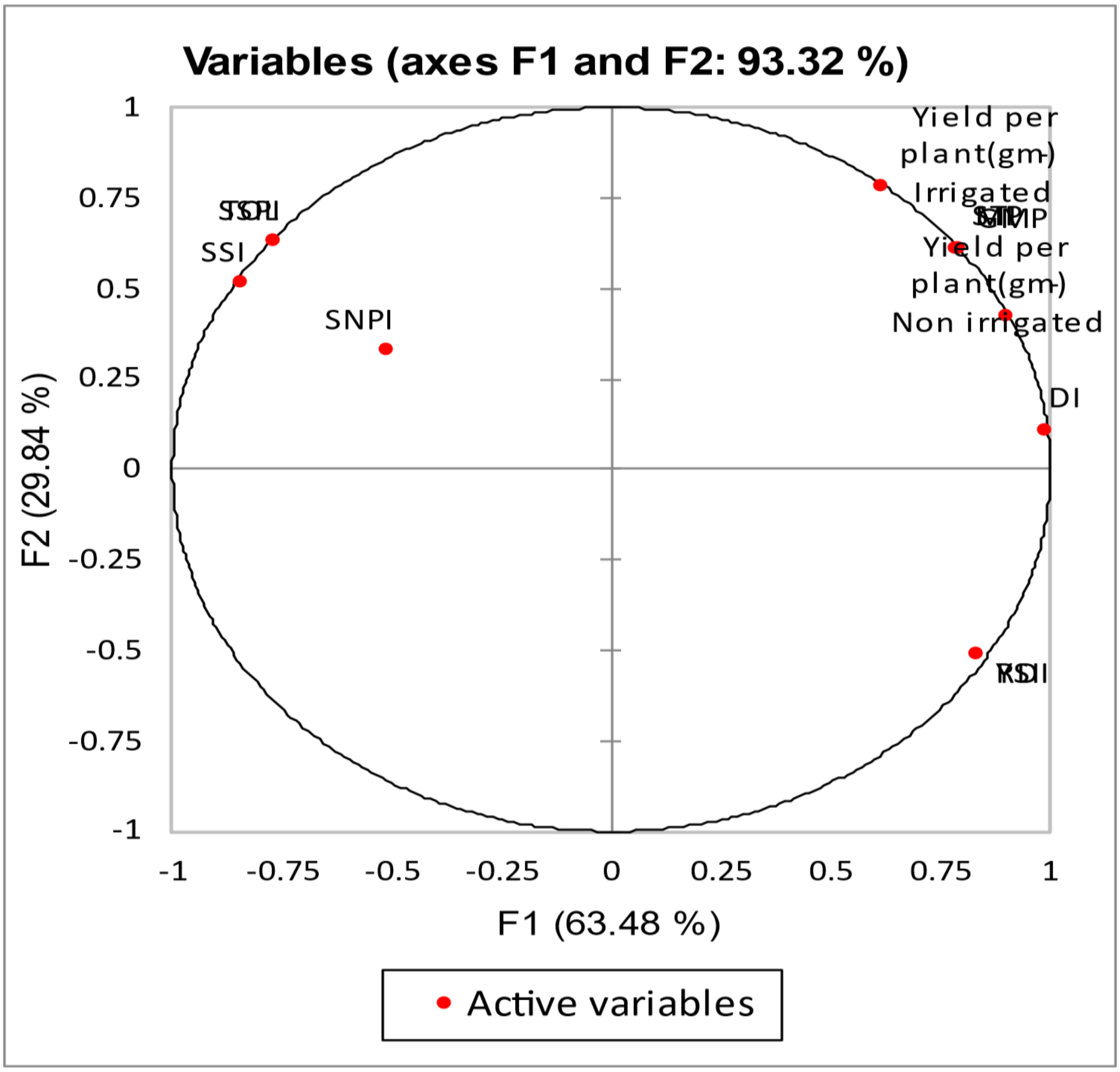
DI showed highest positive correlation with PC1 (0.993) followed by YSI and RDI (0.840), GMP (0.796), MP (0.793), STI (0.787) whereas negative correlation was observed for the indices SSI (-0.840), TOL and SSPI (-0.765) and SNPI (-0.508) with PC1.

TOL and SSPI showed positive correlation with PC2 (0.624), MP (0.609), STI (0.608), GMP (0.604), SSI (0.513), SNPI (0.326) and DI (0.105) whereas negative correlation was observed for RDI and YSI (-0.513) with PC2 as depicted in (Table 4.13).

Table 4.13- Correlation between the variables (DTIs and yield per plant under both the conditions) and factors (Principal Components) of 30 genotypes of wheat.

	F1	F2
Yield per plant(gm)-Irrigated	0.622	0.781
Yield per plant(gm)-Non irrigated	0.906	0.422
TOL	-0.765	0.624
MP	0.793	0.609
GMP	0.796	0.604
STI	0.787	0.608
SSI	-0.840	0.513
RDI	0.840	-0.513
SSPI	-0.765	0.624
SNPI	-0.508	0.326
YSI	0.840	-0.513
DI	0.993	0.105

Graph 4.4- The biplot depicting correlation between DTIs and the first two Principal Components (F1 and F2)



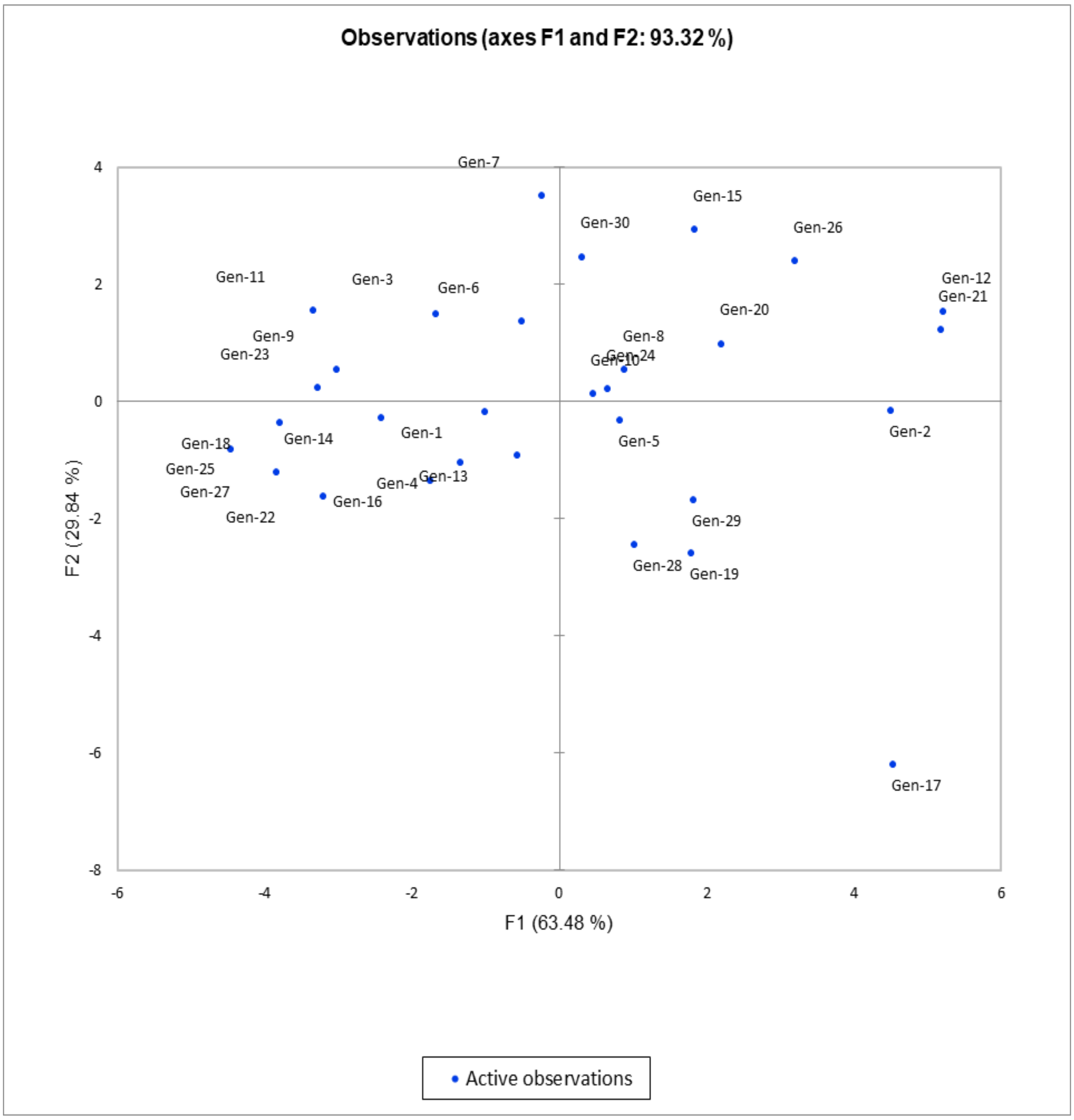
Biplot method of analysis-

The relationship between various Drought Tolerant Indices was graphically represented in a biplot of F1 (PC1) and F2 (PC2) principal component analysis for 30 genotypes.

The two axes representing F1 and F2 justified 93.32 % (63.48% and 29.84% for F1 and F2, respectively) of the total variance for the ten drought tolerant indices along with the yield per plant under both irrigated and non-irrigated condition. It distinguished the twelve variables into three different groups (DTIs with acute angle and high correlations were placed in the same group). Indices TOL, SSPI, SSI and SNPI were placed in group 1(G1). The PCs axes separated STI, GMP, MP and DI into group 2(G2). The third group (G3) consisted of indices YSI and RDI as depicted in (Fig.3). Mostly, the indices (DTIs) in the same group distinguishes the drought tolerant varieties in the same manner. The indices in group 2 were positively correlated with the indices in group 3 since the angle formed between them was acute whereas indices in group 1 were negatively correlated with group 2 indices since the angle formed between them was obtuse which is clearly depicted in (Graph 4.6).

One of the important interpretations of this biplot is that the cosine of the angle between the vectors of two Drought Tolerant Indices approximates the correlation coefficient between the two. The cosine of the angles between indices does not relatively translate into correlation coefficients, since the biplot of principal components analysis (PCA) does not explain most of the variation present in a data set. Even though the cosine angles help in understanding the interrelationship among the various indices.

Graph 4.5- Biplot analysis of 30 genotypes with respect to F1(PC1) and F2 (PC2)



Graph 4.6- Biplot analysis based on first two principal components F1(PC1) and F2 (PC2) of Drought Tolerant Indices for the 30 genotypes of wheat.

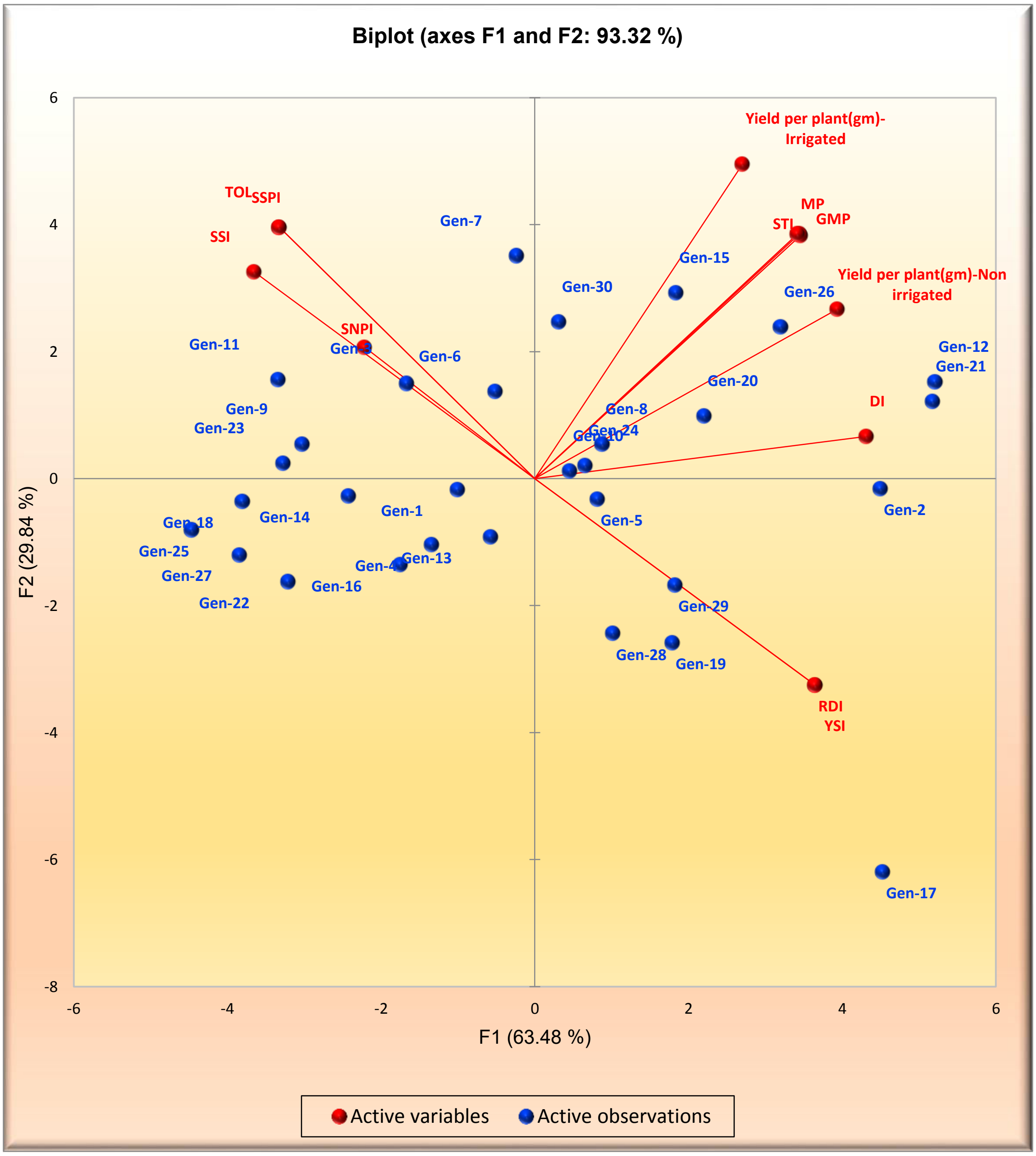


Table 4.14- Factor scores between the 30 genotypes of wheat and first two principal components i.e., PC1 and PC2

GENOTYPES		F1(PC1)	F2(PC2)
MACS6222	Gen-1	-1.005	-0.174
HD 3249	Gen-2	4.500	-0.156
HD2733	Gen-3	-1.667	1.500
PBW 781	Gen-4	-1.342	-1.040
DBW 257	Gen-5	0.817	-0.326
DBW 39	Gen-6	-0.512	1.374
HD 3277	Gen-7	-0.236	3.510
RAJ 4529	Gen-8	0.881	0.542
DBW 187	Gen-9	-3.026	0.543
WH 1239	Gen-10	0.457	0.125
K 0307	Gen-11	-3.334	1.559
DBW 88	Gen-12	5.212	1.528
GW 322	Gen-13	-0.575	-0.916
BHU 35	Gen-14	-2.420	-0.273
HD 2967	Gen-15	1.841	2.930
HD 3215	Gen-16	-1.746	-1.358
HD 3241	Gen-17	4.531	-6.193
HD 3304	Gen-18	-3.801	-0.360
HD 3310	Gen-19	1.792	-2.583
HS 490	Gen-20	2.208	0.985
HUW 234	Gen-21	5.177	1.220
HUW 468	Gen-22	-3.207	-1.624

HUW510	Gen-23	-3.271	0.241
HUW 669	Gen-24	0.658	0.207
HUW 712	Gen-25	-4.462	-0.807
QLD 98	Gen-26	3.203	2.392
QLD 102	Gen-27	-3.837	-1.200
QLD 107	Gen-28	1.018	-2.440
UP 2672	Gen-29	1.828	-1.675
Lok 1	Gen-30	0.315	2.469

Table 4.15- The values of 10 DTIs and yield per plant under irrigated and non- irrigated condition for 30 wheat genotypes.

	Genotype	Yield per plant(gm)-Irrigated	Yield per plant(gm)-Non irrigated	TOL	MP	GMP	STI	SSI	RDI	SSPI	SNPI	YSI	DI
1	MACS6222	7.96	6.85	1.10	7.41	7.38	0.74	1.34	0.96	6.44	4.59	0.86	0.77
2	HD 3249	10.52	11.21	-0.69	10.87	10.86	1.61	-0.63	1.19	-4.03	-7.02	1.07	1.56
3	HD2733	9.25	7.11	2.13	8.18	8.11	0.90	2.23	0.86	12.46	3.90	0.77	0.71
4	PBW 781	6.97	6.13	0.84	6.55	6.53	0.58	1.17	0.98	4.92	4.63	0.88	0.70
5	DBW 257	8.64	8.29	0.34	8.47	8.46	0.98	0.38	1.07	2.01	7.45	0.96	1.04
6	DBW 39	9.65	8.00	1.65	8.83	8.79	1.05	1.65	0.92	9.63	4.50	0.83	0.86
7	HD 3277	11.80	9.16	2.64	10.48	10.39	1.47	2.16	0.87	15.41	4.29	0.78	0.93
8	RAJ 4529	9.48	8.76	0.71	9.12	9.11	1.13	0.73	1.03	4.17	6.13	0.92	1.06
9	DBW 187	7.64	5.55	2.08	6.60	6.51	0.58	2.64	0.81	12.17	3.39	0.73	0.53
10	WH 1239	8.91	8.21	0.70	8.56	8.55	1.00	0.76	1.03	4.07	5.92	0.92	0.99
11	K 0307	8.49	5.78	2.71	7.13	7.00	0.67	3.09	0.76	15.84	3.26	0.68	0.51
12	DBW 88	12.35	12.50	-0.15	12.42	12.42	2.10	-0.12	1.13	-0.88	-12.73	1.01	1.65

13	GW 322	7.46	6.83	0.64	7.15	7.14	0.69	0.82	1.02	3.71	5.41	0.91	0.81
14	BHU 35	7.15	5.64	1.51	6.40	6.35	0.55	2.04	0.88	8.82	3.73	0.79	0.58
15	HD 2967	12.07	10.62	1.45	11.34	11.32	1.75	1.16	0.98	8.48	5.57	0.88	1.22
16	HD 3215	6.46	5.62	0.84	6.04	6.03	0.50	1.25	0.97	4.89	4.40	0.87	0.64
17	HD 3241	5.40	7.70	-2.30	6.55	6.45	0.57	-4.12	1.59	-13.43	-3.39	1.43	1.43
18	HD 3304	6.31	4.48	1.83	5.40	5.32	0.39	2.81	0.79	10.70	3.09	0.71	0.41
19	HD 3310	7.22	7.73	-0.52	7.48	7.47	0.76	-0.69	1.20	-3.01	-6.03	1.07	1.08
20	HS 490	10.41	10.08	0.32	10.25	10.24	1.43	0.30	1.08	1.89	8.64	0.97	1.27
21	HUW 234	12.02	12.37	-0.36	12.20	12.19	2.03	-0.29	1.15	-2.08	-9.43	1.03	1.66
22	HUW 468	5.40	4.29	1.11	4.84	4.81	0.32	1.99	0.89	6.50	3.43	0.79	0.44
23	HUW510	7.21	5.21	2.00	6.21	6.13	0.51	2.68	0.81	11.68	3.30	0.72	0.49
24	HUW 669	9.07	8.42	0.65	8.74	8.74	1.04	0.70	1.04	3.81	6.14	0.93	1.02
25	HUW 712	5.47	3.72	1.75	4.60	4.51	0.28	3.09	0.76	10.20	2.81	0.68	0.33
26	QLD 98	12.07	11.52	0.55	11.79	11.79	1.90	0.44	1.06	3.23	7.93	0.95	1.43
27	QLD 102	5.45	4.01	1.44	4.73	4.68	0.30	2.55	0.82	8.39	3.08	0.74	0.38
28	QLD 107	7.01	7.15	-0.14	7.08	7.08	0.68	-0.20	1.14	-0.83	-8.89	1.02	0.95
29	UP 2672	8.09	8.23	-0.15	8.16	8.16	0.91	-0.17	1.14	-0.85	-9.73	1.02	1.09
30	Lok1	11.04	9.17	1.87	10.11	10.06	1.38	1.64	0.93	10.92	4.72	0.83	0.99

The values of F1(PC1) and F2(PC2) of the 30 genotypes are presented in (Table 4.14). The positive factor score with respect to PC1 were exhibited by genotypes namely, DBW 88 (5.212) followed by HUW 234 (5.177), HD 3241 (4.531), HD 3249 (4.500), QLD 98 (3.203), HS 490(2.208), UP 2672 (1.828), QLD 107 (1.018), HD 3310 (1.792), HD 2967 (1.841), RAJ 4529 (0.881), DBW 257 (0.817), HUW 669 (0.658), WH 1239 (0.457) and Lok 1 (0.315) whereas positive factor score with respect to PC2 were observed for genotypes HD 3277 (3.510), HD 2967 (2.930), Lok 1 (2.469), QLD 98 (2.392), K 0307 (1.559), DBW 88 (1.528), HD 2733(1.500), DBW 39 (1.374), HUW 234 (1.220), HS (0.985), DBW 187 (0.543), RAJ 4529 (0.542), HUW 510 (0.241), HUW 669 (0.207) and WH 1239 (0.125).

Selection of genotypes that possess high PC1 and low PC2 factor score were suitable for both non-irrigated (stress) and irrigated (non-stress) conditions. Among the various genotypes under study, genotype DBW 88 has the highest factor score of 5.212 with respect to PC1 and a low PC2 value of 1.528 followed by genotype HUW 234 which has a PC1 factor score of 5.177 and PC2 score of 1.220, genotype HD 3249 with a PC1 and PC2 score of 4.500 and -0.156 respectively and genotype QLD 98 with PC1 value of 3.203 and PC2 value of 2.392.

According to the Drought Tolerant Indices (Table-4.15) the genotype DBW 88 had the highest values for yield per plant under irrigated (12.35g) and non-irrigated (12.50g) condition. It had the highest value for STI (2.10), GMP (12.42) and MP (12.42). It had a value of 1.01 for YSI, 1.65 for DI and 1.13 for RDI. It exhibited a value of (-0.12) for SSI.

Genotype HUW 234 had the values of 12.02 g yield per plant under irrigated and 12.37 g under non-irrigated condition. It had the value of 2.03 for STI, 12.19 for GMP and 12.20 for MP. It had a value of 1.03 for YSI, 1.15 for RDI and highest value of 1.66 for DI. It exhibited a value of (-0.29) for SSI.

Genotype QLD 98 had the values of 12.07 g yield per plant under irrigated and 11.52 g under non-irrigated condition. It had the value of 1.90 for STI, 11.79 for both GMP and MP. It had a value of 0.95 for YSI, 1.06 for RDI and 1.43 for DI. It exhibited a value of (0.44) for SSI.

Genotype HD 3249 had the values of 10.52 g yield per plant under irrigated and 11.21 g under non-irrigated condition. It had the value of 1.61 for STI, 10.86 for GMP and 10.87 for MP. It had the highest values of 1.07 and 1.19 for YSI and RDI respectively. It had a value of 1.56 for DI. It exhibited the lowest value of (-0.63) for SSI.

Plate 1 - Sowing on 30th of December 2019

Plate 2-First irrigation given to the three replications in the irrigated block

Plate 3-Measuring chlorophyll content using SPAD meter

Plate 4-Measuring plant height at physiological maturity using scale

CHAPTER-5

DISCUSSIONS

5.1 Analysis of variance

Analysis of variance of the eleven traits for thirty genotypes indicated high significant variation among the characters such as germination percent, days to heading, days to 50% spike initiation, canopy temperature, chlorophyll content, plant height, number of tillers per plant, spike length, Number of grains per spike, test weight and yield per plant under irrigated condition. High significant variation among the characters such as germination percent, days to heading, days to 50% spike initiation, canopy temperature, chlorophyll content, plant height, number of tillers per plant, spike length, Number of grains per spike, test weight and yield per plant were observed under non-irrigated condition. This implied high amount of variability was present among the genotypes and it could be used for breeding programmes.

The observations showed similarities with the results of the studies done by **Eid (2009), Kumar *et al.,* (2017), Biru (2020), Ajmalud Din *et al.,* (2020), Malbhage *et al.,* (2020) and Nizamani *et al.,* (2020).**

5.2 Genetic parameters-

Different genetic parameters such as range, mean, coefficient of variation, phenotypic coefficient of variation, genotypic coefficient of variation, broad sense heritability and genetic advance were used to assess the genetic variability present in a set of 30 wheat varieties under moisture stress and non-stress condition.

5.2.1 Range, mean and CV under irrigated (non-stress) and non-irrigated (stress) condition-

Germination percent-

Germination percent was highest in the genotype HD 2967 and lowest in the genotype HD 3215 with a general mean of 70.53 percent under irrigated condition whereas germination percent was highest in the genotype K 0307 and lowest in the genotype HUW 510 with a general mean of 71.16% under non-irrigated condition. The coefficient of variation was observed to be 12.17% and 6.59% under non-stress and stress condition respectively.

Number of days to heading-

Number of days to heading was highest in the genotype HUW 669 and it was lowest in the genotype Lok 1 with a mean of 71.49 days under irrigated condition whereas number of days to heading was highest in the genotype DBW 257 and it was lowest in the genotype BHU 35 with a mean of 72.23 days under non-irrigated condition. The coefficient of variation was observed to be 4.43% and 3.30% under non-stress and stress condition respectively.

Days to 50% spike initiation-

Number of days required for 50% spike initiation was highest in the genotype HD 2733 and lowest in the genotype HUW 234 with an average value of 75.32 days under irrigated condition whereas number of days required for 50% spike initiation was highest in the genotype HD 2733 and lowest in the genotype BHU 35 with an average value of 75.54 days under non-irrigated condition. The coefficient of variation was observed to be 2.09% and 3.04% under non-stress and stress condition respectively.

Canopy temperature-

The canopy temperature was recorded to be highest in genotype the PBW 781 and lowest in the genotype Lok 1 with a mean of 26.21°C under irrigated condition whereas the canopy temperature was recorded to be highest in genotype GW 322 and lowest in genotype DBW 187 with a mean of 26.24°C under non-irrigated condition. The coefficient of variation was observed to be 2.86% and 3.38% under non-stress and stress condition respectively.

Chlorophyll content-

The chlorophyll content was highest in the genotype MACS 6222 and lowest in the genotype WH 1239 with a general mean of 39.93 under irrigated condition whereas chlorophyll content was highest in the genotype K 0307 and lowest in the genotype UP 2672 with a general mean of 38.69 under non-irrigated condition. The coefficient of variation was observed to be 6.92% and 8.87% under non-stress and stress condition respectively.

Plant height-

Plant height was recorded to be maximum in the genotype DBW 257 and minimum in HD 2733 with an average value of 62.07 cm under irrigated condition whereas plant height was recorded to be maximum in the genotype UP 2672 and minimum in the genotype HD 3277 with an average value of 59.29 cm under non-irrigated condition. The coefficient of variation was observed to be 12.18% and 6.03% under non-stress and stress condition respectively.

Number of effective tillers per plant-

The number of effective tillers per plant was highest in the genotype HUW 234 and lowest in the genotype HD 3241 with a mean of 5.51 under irrigated condition whereas the number of effective tillers per plant was highest in the DBW 88 and lowest in the genotype QLD 102 with a mean of 5.18 under non-irrigated condition. The coefficient of variation was observed to be 11% and 11.75% under non-stress and stress condition respectively.

Spike length-

Spike length was observed to be highest in the genotype HD 3277 a and lowest in the genotype HD 510 with an average of 9.26 cm under irrigated condition whereas spike length was observed to be highest in genotype HD 3277 a and lowest in QLD 102 with an average of 8.96cm under non-irrigated condition. The coefficient of variation was observed to be 7.10% and 7.52% under non-stress and stress condition respectively.

Number of grains per spike-

Number of grains per spike was highest in the genotype HD 2967 and lowest in the genotype QLD 102 with a mean of 42.38 under irrigated condition whereas number of grains per spike was highest in the genotype DBW 88 and lowest in genotype QLD 102 with a mean of 39.52 under non-irrigated condition. The coefficient of variation was observed to be 9.79% and 10.82% under non-stress and stress condition respectively.

Test weight-

The test weight (1000 seed weight) was found to be highest in the genotype HUW 234 and lowest in the genotype HUW 712 with a mean value of 33.25g under irrigated condition whereas the test weight (1000 seed weight) was found to be highest in the genotype Lok 1 and lowest in the genotype HUW 712 with a mean value of 32.79g under non-irrigated condition. The coefficient of variation was observed to be 9.81% and 10.11% under non-stress and stress condition respectively.

Grain yield per plant-

Grain yield per plant was highest in the genotype DBW 88 and lowest in the genotype HD 3241 with a mean yield of 8.56g under irrigated condition whereas grain yield per plant was highest in the genotype DBW 88 and lowest in the genotype HUW 712 with a mean yield of 7.68g under non-irrigated condition. The coefficient of variation was observed to be 8.9% and 12.58% under non-stress and stress condition respectively.

5.2.2 Genotypic and phenotypic coefficients of variation under irrigated (non-stress) and non-irrigated (stress) condition-

The phenotypic coefficient of variance was more than the genotypic coefficient of variance for all the traits studied under both irrigated and non-irrigated condition. It was also seen in studies done by **Biru (2020)** and **Heidari *et al.,* (2020).**

Germination percent exhibited moderate phenotypic coefficient of variation and low genotypic coefficient of variation under irrigated condition whereas germination percent exhibited low phenotypic coefficient of variation and low genotypic coefficient of variation under non-irrigated condition. Number of days to heading had both low phenotypic and genotypic coefficients of variation under irrigated as well as non-irrigated condition. Number of days to 50% spike initiation also had low phenotypic and genotypic coefficients of variation under both the irrigated and non-irrigated condition. This was in accordance with studies done by **Jaiswal *et al.,* (2019)**. The canopy temperature had low phenotypic and low genotypic coefficients of variation under both the irrigated and non-irrigated conditions. Under irrigated condition chlorophyll content had low phenotypic and low genotypic coefficients of variation as observed in studies of **Jaiswal *et al.,* (2019)** whereas chlorophyll content had moderate phenotypic and low genotypic coefficients of variation under non-irrigated condition. Plant height had moderate phenotypic coefficient of variation and low genotypic coefficient of variation under irrigated condition whereas plant height exhibited moderate phenotypic coefficient of variation and moderate genotypic coefficient of variation under non-irrigated condition which is supported by the findings of **Talebi *et al.,* (2012).** Number of effective tillers per plant showed moderate genotypic and phenotypic coefficient of variation under both the irrigated and non-irrigated conditions. This was in confirmation with the results of **Choudhary *et al.,* (2015).** Spike length had moderate phenotypic and low genotypic coefficients of variation under irrigated as well as non-irrigated condition. Under both the irrigated and non-irrigated conditions number of grains per spike had both moderate phenotypic as well as moderate genotypic coefficients of variation. Similar results were also observed by **Talebi *et al.,* (2012).** Test weight had both moderate phenotypic and genotypic coefficients of variation under irrigated as well as non-irrigated condition. Grain yield per plant exhibited both high phenotypic and genotypic coefficients of variation under irrigated condition and non-irrigated condition. High GCV and PCV for grain yield per plant was in accordance with the studies done by **Talebi *et al.,* (2012), Amin *et al.,***

(2015), Kumar *et al.,* (2017), Jaiswal *et al.,* (2019), Gerema *et al.,* (2020), and Malbhage *et al.,* (2020)

5.2.3 Heritability and genetic advance under irrigated (non-stress) and non-irrigated (stress) condition-

Under irrigated condition highest broad sense heritability was observed for grain yield per plant which was followed by 50% spike initiation and number of grains per spike. High broad sense heritability for grain yield per plant was reported by **Khan *et al.,* (2003) and Gerema (2020),** high broad sense heritability (h^2) for number of grains per spike was reported by **Talelebi (2012).** Moderate heritability was recorded for test weight followed by number of tillers per plant, spike length, germination percent and canopy temperature. Moderate broad sense heritability (h^2) for spike length was reported by **Jaiswal *et al.,* (2019).**

Under non-irrigated condition highest broad sense heritability was recorded for the trait plant height followed by grain yield per plant, number of grains per spike and number of tillers per plant. High broad sense heritability for grain yield per plant was reported by **Khan *et al.,* (2003)** and **Gerema (2020),** for no. of grains per spike by **Talebi (2012),** for plant height by **Gashaw *et al.,* (2010)** and **Talebi (2012).** Moderate heritability was observed for spike length followed by test weight, days to 50% spike initiation, days to heading and germination percent. Moderate broad sense heritability (h^2) for spike length was reported by **Jaiswal *et al.,* (2019).**

Under irrigated condition highest GA as a percent of mean was observed for grain yield per plant followed by no. of grains per spike. Moderate GA was recorded for no. of tiller per plant followed by test weight, germination percent and spike length. Moderate GA for number of tillers per plant and spike length was reported by **Malbhage *et al.,* (2020)**.

Under non-irrigated condition highest GA as a percent of mean was observed for grain yield per plant followed by plant height, number of grains per spike and number of tillers per plant. Moderate GA was recorded for characters spike length and test weight. Moderate GA for spike length was reported by **Malbhage *et al.,* (2020)** and **Biru (2020).**

Under irrigated condition high heritability coupled with high GA was recorded for number of grains per spike and grain yield per plant**.** High heritability combined with high GA for number of grains per spike was in accordance with the studies done by **Memon *et al.,* (2007), Choudhary *et al.,* (2015), Gerema (2020) and Nizamani *et al.,* (2020).** High heritability combined with high GA for grain yield per plant was reported by **Kumar *et al.,* (2017**). Higher heritability indicates that the trait is less influenced by the environment and high GA indicates higher additive gene action. High heritability but low genetic advance was observed for number of days to 50% spike initiation indicating non- additive gene action whereas high heritability could be a result of favourable environmental condition rather than genotype. Moderate heritability coupled with moderate genetic advance was observed for the characters such as germination percent, number of productive tillers per plant, spike length and test weight. Moderate heritability along with low genetic advance was recorded for canopy temperature indicating non-additive gene action. Both low heritability with low genetic advance was recorded for the traits days to heading, chlorophyll content and plant height. Low heritability suggests higher influence of environment on the development of traits and low GA suggests non- additive gene action.

Under non-irrigated condition high heritability coupled with high genetic advance was recorded plant height, number of tillers per plant, number of grains per spike and grain yield per plant indicating more of additive gene action. High heritability combined with high GA for number of tillers per plant was in accordance with the studies done by **Choudhary *et al.,* (2015),** for number of grains per spike by **Memon *et al.,* (2007), Choudhary *et al.,* (2015), Gerema (2020) and Nizamani *et al.,* (2020),** for grain yield per plant by **Kumar *et al.,* (2017),** for plant height by **Gashaw *et al.,* (2010), Gerema (2020) and Nizamani *et al.,* (2020).** Moderate heritability coupled with moderate genetic advance was observed for the characters spike length and test weight. Moderate heritability along with low genetic advance was recorded for the traits such as germination percent, days to heading, days to 50% spike initiation. Both low heritability with low genetic advance was recorded for the traits canopy temperature and chlorophyll content suggesting non- additive gene action.

5.3 Correlation between traits under irrigated (non-stress) and non-irrigated (stress) condition-

Under irrigated condition, germination percent showed significant positive but moderately weak phenotypic correlation with plant height and weak correlation with spike length.

Days to heading exhibited very strong and significant phenotypic positive correlation with days to 50% spike initiation under irrigated condition. Similarly, under non- irrigated condition days to heading exhibited very strong positive correlation with days to 50% spike initiation and significant positive but moderately weak correlation with no. of tillers per plant.

Days to 50% spike initiation showed very strong and positive phenotypic correlation with days to heading and significantly but negative weak correlation with test weight under irrigated condition and days to 50% spike initiation showed significant positive and very strong correlation with days to heading and significant positive but weak correlation with number of tillers per spike under non- irrigated condition.

Canopy temperature showed significantly negative but moderately weak correlation with plant height under irrigated condition.

Chlorophyll content showed significant positive but weak correlation with plant height under irrigated condition.

Under irrigated condition, plant height exhibited significant positive but moderately weak phenotypic correlation with germination percent, weak correlation with yield per plant, chlorophyll content, spike length and test weight. It also exhibited significantly negative but moderately weak correlation with canopy temperature whereas under non- irrigated condition, plant height showed significantly positive but weak correlation with number of grains per spike.

Under irrigated condition, number of tillers per plant showed significantly positive and moderately strong correlation with yield per plant and moderately weak correlation with spike length, number of grains per spike and test weight whereas under non- irrigated condition, no. of tillers per plant showed significantly positive and very strong correlation with yield per plant, moderately weak correlation with no. of grains per spike, test weight, spike length and days to heading, weak correlation with days to 50% spike initiation.

Under irrigated condition, spike length showed significantly positive and very strong phenotypic correlation with no. of grains per spike, moderately strong correlation with yield per plant, moderately weak correlation with number of tillers per plant, weak correlation with plant height and germination percent whereas under non-irrigated condition, spike length exhibited significant positive and very strong correlation with number of grains per spike, moderately strong correlation with grain yield per plant, moderately weak correlation with number of tillers per plant and test weight.

Under irrigated condition, number of grains per spike exhibited significantly positive and very strong phenotypic correlation with grain yield per plant and spike length, moderately weak correlation with test weight and weak correlation with number of tillers per plant whereas under non- irrigated condition, number of grains per spike exhibited significant positive and very strong correlation with yield per plant and spike length, moderately weak correlation with number of tillers per plant and test weight, weak correlation with plant height.

Under irrigated condition, test weight showed significant positive and moderately strong phenotypic correlation with yield per plant, moderately weak correlation with no. of grains per spike and no. of tillers per plant, test weight and significant negative and weak correlation with days to 50% spike initiation whereas under non-irrigated condition, test weight showed significantly positive and moderately strong correlation with yield per plant, moderately weak correlation with number of grains per spike, number of tillers per plant and spike length.

Similar results were also observed by **Esmail (2001)** which showed grain yield per plant exhibited positive correlation with plant height and no. of spikes per plant; **Okuyama *et al.,* (2004)** reported positive correlation between no. of grains per spike and grain yield per plant. **Khan *et al.,* (2005)** observed positive correlation of grain yield with spike length and test weight. **Mohammadi *et al.,* (2012)** got positive correlation between grain yield with spike length, test weight and plant height under both dryland and supplemental irrigation condition. Under both the irrigated and non-irrigated condition positive correlation of grain yield with spike length and test weight were observed. Similar results were reported by **Ata *et al.,* (2014).** Number of grains per spike also exhibited maximum correlation with grain yield under irrigated condition. **Mecha *et al.,* (2017)** reported positive phenotypic correlation between grain yield and productive tillers per plant, spike length and test weight; **Ojha *et al.,* (2018)** between grain yield and plant height, spike length, no. of grains per spike and test weight. **Barman *et al.,* (2020)** observed positive correlation between grain yield and number of tillers per plant, spike length, plant height and test weight at phenotypic level. A significant negative correlation was also seen between canopy temperature and grain yield. **Upadhyay (2020)** also observed a significant positive correlation of grain yield with number of grains per spike and test weight.

5.4 Path coefficient analysis under irrigated (non-stress) and non-irrigated (stress) condition-

Under irrigated condition, all the traits showed positive direct effects on yield except spike length. Number of grains per spike exhibited maximum positive direct effect on yield followed by no. of tillers per plant, test weight, canopy temperature, germination percent, days to heading, plant height, days to 50% spike initiation and chlorophyll content whereas spike length exhibited negative direct effect on yield.

Under non- irrigated condition, all the traits exhibited positive direct effect on yield except no. of days to 50% spike initiation. Number of tillers per plant exhibited maximum positive direct effect on yield followed by number of grains per spike, test weight, days to heading, plant height, germination percent, spike length, chlorophyll content and canopy temperature whereas days to 50% spike initiation exhibited negative direct effect on yield.

Okuyama *et al.,* (2004) and Mecha et al., (2017) reported that path analysis indicated direct positive effect of number of grains per spike on grain yield. Under non-irrigated condition the highest positive direct effect of number of tillers per plant on yield was reported by **Khan *et al.,* (2005).** Positive direct effect of test weight on grain yield was reported by **Mecha *et al.,* (2017)** and **Ojha *et al.,* (2018).** Under irrigated condition the path coefficient studies done by **Ojha *et al.,* (2018)** and **Barman *et al.,* (2020)** showed that the positive direct effect on grain yield was highest through number of grains per spike.

5.5 Study of Drought Tolerant Indices using principal component analysis-

The principal components with Eigen value greater than unity is considered as major components as they are responsible for higher magnitude of variance in the data set. In the present study PC1 and PC2 were taken into consideration.

Drought Tolerant Indices which showed positive correlation with the first factor or principal component were expected to contribute to the yield under both irrigated and non-irrigated condition. In the present study the indices which exhibited positive correlation included DI (Drought Resistance Index), YSI (Yield Stability Index), RDI (Relative Drought Index), GMP (Geometric Mean Productivity), MP (Mean Productivity) and STI (Stress Tolerance Index). Therefore, these could be used for selection. Indices such as TOL, SSI, SSPI and SNPI showed negative correlation with first PC which is presented in (Table-11)

The results are in confirmation with the studies of **Ilker *et al.,* (2011), Ghobadi *et al.,* (2012), Mollasadeghi (2013), Karimi *et al.,* (2013), Nouraein *et al.,* (2013), Hooshmandi *et al.,* (2019), Anwaar *et al.,* (2020). Boussen *et al.,* (2010)** observed a positive correlation between MP (Mean Productivity), STI (Stress Tolerance Index) and GMP (Geometric Mean Productivity) whereas they reported a negative correlation between SSI (Stress Susceptibility Index) and yield.

According to the biplot graph of PCA, the different Drought Tolerance Indices were divides into three groups. Indices TOI, SSPI, SSI and SNPI were placed in group 1(G1) having low PC1 but high PC2. The PCs axes separated STI (Stress Tolerance Index), GMP (Geometric Mean Productivity), MP (Mean Productivity) and DI (Drought Tolerance Index) into group 2 (G2) having both high PC1 and PC2. The third group (G3) consisted of indices YSI (Yield Stability Index) and RDI (Relative Drought Index) possessing high values of PC1 and low values of PC2 as depicted in (Fig.3). This result was in accordance with the findings reported by **Ali *et al.,* (2016).**

The genotype which showed high positive factor score for PC1 and low factor score for PC2 were expected to perform well in both the irrigated and non- irrigated conditions whereas genotypes with low factor score for PC1 and high Factor score for PC2 were reported to be low yielding by **Nouraein *et al.,* (2013) and Patel *et al.,* (2019).**

As per the biplot analysis (Fig-3) of the various genotypes studied, genotype DBW 88 had the highest factor score with respect to PC1 and a low PC2 value followed by genotype HUW 234 which also had a high PC1 factor score and low PC2 score, genotype QLD 98 and genotype HD 3249.

According to the Drought Tolerant Indices (Table 4.15), the genotype DBW 88 had the highest value for yield per plant under both the irrigated and non-irrigated condition. It also exhibited highest value for STI (Stress Tolerance Index), GMP (Geometric Mean Productivity) and MP (Mean Productivity) followed by the genotype HUW 234. Higher value of STI (Stress Tolerance Index) suggested that the genotype was more tolerant to stress. Similarly, higher values of GMP (Geometric Mean

Productivity) and MP (Mean Productivity) indicated higher yield of the respective genotypes under stress condition. Genotype HUW 234 had the highest value for DI (Drought Resistance Index). Higher values of DI indicated that the variety was more resistant to drought environment. QLD 98 showed high value for STI (Stress Tolerance Index) and low value for SSI (Stress Susceptibility Index). Genotype HD 3249 exhibited the highest value for RDI (Relative Drought Index) as well as the lowest value for SSI. Lower values of SSI suggested that the genotype is less susceptible and more tolerant to the stress environment. Thus, genotypes with higher values of STI, DI, RDI, YSI, GMP, MP and lower values of SSI could be selected.

Therefore, on the basis of both Drought Tolerant Indices and the biplot analysis DBW 88, HUW 234, QLD 98 and HD 3249 were selected as the superior genotypes under both the irrigated and drought conditions.

CHAPTER 6

SUMMARY AND CONCLUSION

The present study **"An Assessment of Genetic variability for Drought Tolerance and other associated traits in wheat (*Triticum aestivum* L.)"** involved an assessment of thirty genotypes of wheat for genetic parameters, phenotypic correlation and path coefficient analyses for yield and other yield contributing traits. The study also aimed to isolate drought tolerant/resistant genotypes with the help of Drought Tolerance Indices using Principal Component Analysis. The 30 genotypes including two checks viz. DBW 187 and DBW 39 were sown in Randomised Block Design (RBD) with three replications in irrigated (non-stress) and non-irrigated (stress) blocks at the Agricultural Research Farm of Institute of Agricultural Sciences, Banaras Hindu University, Varanasi during *Rabi* season 2019-20. All standard agronomic practices were followed to raise a good crop.

The data were recorded on 10 randomly selected plants from each 30 genotypes and from each replication. The mean formed the basis of computation and analysis of data for 11 quantitative traits of wheat genotypes.

Under irrigated condition, the genotype HUW 234 exhibited maximum number of effective tillers per plant and the highest test weight. Genotype DBW 88 had the highest yield per plant. Plant height was observed to be highest in genotype DBW 257 while spike length was maximum in the genotype HD 3277. Number of grains per spike was highest in HD 2967.

Under non- irrigated condition, the genotype DBW 88 showed highest values for the traits such as maximum number of effective tillers, number of grains per spike and yield per plant. Plant height was highest in the genotype UP 2672. Spike length was maximum in genotype HD 3277. Test weight was maximum in the genotype Lok1.

Thus, it may be concluded that the wheat varieties DBW 88 and HD 3277 are the promising genotypes in both the environments which may be utilized in further breeding programmes.

Under both stress and non- stress environments, grain yield per plant showed high values for both genotypic and phenotypic coefficients of variation. The traits such as number of productive tillers per plant, number of grains per spike and 1000 grain weight exhibited moderate genotypic as well as phenotypic coefficients of variation. Under irrigated condition, days to 50% spike initiation, spike length, number of grains per spike, test weight and grain yield per plant and under non-irrigated condition, days to heading, days to 50% spike initiation, canopy temperature, plant height, spike length, yield per plant showed less difference between PCV and GCV indicating that phenotypic selection could be effective. Therefore, on the basis of genotypic and phenotypic coefficients of variation the traits such as grain yield per plant, number of grains per spike and number of tillers per plant could be used for selection under both the environments.

Under both the irrigated and non-irrigated conditions, high heritability coupled with high genetic advance as a percent of mean was recorded for number of grains per spike and grain yield per plant. High heritability along with high genetic advance was also recorded for plant height, no. of tillers per plant under non-irrigated condition. Higher heritability indicates that genotypic contribution to the development of the trait is more than the environment (i.e., the trait is less influenced by the environment) and high genetic advance indicates higher additive gene action. Thus, it may be concluded that according to heritability and genetic advance, selection based on number of grains per spike and grain yield per plant could be rewarding and effective for the wheat breeders.

The studies on correlation coefficients revealed that yield per plant showed positive significant correlations with number of grains per spike followed by number of tillers per plant, spike length and test weight under irrigated conditions while yield per plant showed positive significant correlation with number of tillers per plant followed by number of grains per spike, test weight and spike length under non-irrigated conditions. Therefore, number of grains per spike and number of tillers per plant could be used by the breeders for direct selection in wheat breeding programmes that aims at developing drought tolerant varieties.

Similarly, the studies on path coefficients showed that number of grains per spike, number of tillers per plant and test weight showed significant positive correlation as well as direct positive effect on yield per plant under irrigated condition while no. of tillers per plant followed by no. of grains per spike, test weight and spike length exhibited significant positive direct effects on yield per plant under non-irrigated condition. Thus, number of grains per spike and number tillers per plant could be reliably used for the purpose of direct selection in breeding programmes.

On the basis of overall observations for genetic variability, correlations and path coefficients it might be suggested that number of grains per spike, number of productive tillers per plant and grain yield per plant may be utilized for the selection of plants for their yield improvement.

In the present study the indices which exhibited positive correlation with PC1 included DI (Drought Resistance Index), YSI (Yield Stability Index), RDI (Relative Drought Index), GMP (Geometric Mean Productivity), MP (Mean Productivity) and STI (Stress Tolerance Index). Therefore, according to the biplot analysis it can be concluded that these indices could be used for selection of high yielding varieties under both the drought and irrigated conditions.

According to the Drought Tolerant Indices (Table 4.15), the genotype DBW 88 had the highest value for yield per plant under both the irrigated and non-irrigated condition. It also exhibited highest value for STI (Stress Tolerance Index), GMP (Geometric Mean Productivity) and MP (Mean Productivity) followed by the genotype HUW 234. Genotype HUW 234 also had the highest value for DI. QLD 98 showed high value for STI and low value for SSI. Genotype HD 3249 exhibited the highest value for RDI (Relative Drought Index) and lowest value for SSI. Higher value of STI (Stress Tolerance Index) and DI (Drought Resistance Index) suggested that the genotype was more tolerant to stress. Similarly, higher values of GMP (Geometric

Mean Productivity) and MP (Mean Productivity) indicated higher yield of the respective genotypes under stress condition. Lower values of SSI suggested that the genotype is less susceptible and more tolerant to the stress environment. Thus, genotypes with higher values of STI, DI, RDI, YSI, GMP, MP and lower values of SSI could be selected.

As per the biplot analysis (Fig-3) of the various genotypes studied, genotype DBW 88 had the highest factor score with respect to PC1 (Principal Component 1) and a low PC2 (Principal Component 2) values followed by genotypes HUW 234 which also had a high PC1 factor score and low PC2 score, QLD 98 and HD 3249.

Therefore, on the basis of both Drought Tolerant Indices and the biplot analysis the genotypes DBW 88, HUW 234, QLD 98 and HD 3249 were selected as the superior genotypes under both the irrigated (non-stress) and drought (stress) conditions which might be utilized in further breeding for wheat yield improvement programmes.

BIBLIOGRAPHY

Abid, M., Ali, S., Qi, L. K., Zahoor, R., Tian, Z., Jiang, D., & Dai, T. (2018). Physiological and biochemical changes during drought and recovery periods at tillering and jointing stages in wheat (*Triticum aestivum* L.). *Scientific reports*, *8*(1), 1-15.

Ali, M. B., & El-Sadek, A. N. (2016). Evaluation of drought tolerance indices for wheat (*Triticum aestivum* L.) under irrigated and rainfed conditions. *Communications in Biometry and Crop Science*, *11*(1), 77-89.

Amin, M. F., Hasan, M., Barma, N. C. D., Rahman, M. M., & Hasan, M. M. (2015). Variability and heritability analysis in spring wheat (*Triticum aestivum* L.) Genotypes. *Bangladesh Journal of Agricultural Research*, *40*(3), 435-450.

Anonymous (2021), *Third Advance Estimates of Production of Food grains for 2020-21*, Directorate of Economics and Statistics, Ministry of Agriculture and Farmers Welfare, Government of India.

Anwaar, H. A., Perveen, R., Mansha, M. Z., Abid, M., Sarwar, Z. M., Aatif, H. M., & Khan, K. A. (2020). Assessment of grain yield indices in response to drought stress in wheat (*Triticum aestivum* L.). *Saudi journal of biological sciences*, *27*(7), 1818-1823.

Anwar, J., Subhani, G. M., Hussain, M., Ahmad, J., Hussain, M., & Munir, M. (2011). Drought tolerance indices and their correlation with yield in exotic wheat genotypes. *Pakistan Journal of Botany*, *43*(3), 1527-1530.

Ata, A., Yousaf, B., Khan, A. S., Subhani, G. M., Asadullah, H. M., & Yousaf, A. (2014). Correlation and path coefficient analysis for important plant attributes of spring wheat under normal and drought stress conditions. *Journal of Natural Sciences Research*, *4*(8), 66-73

Aycicek, M., & Yildirim, T. (2006). Path coefficient analysis of yield and yield components in bread wheat (*Triticum aestivum* L.) genotypes. *Pakistan Journal of Botany*, *38*(2), 417.

Ayer, D. K., Sharma, A., Ojha, B. R., Paudel, A., & Dhakal, K. (2017). Correlation and path coefficient analysis in advanced wheat genotypes. *South Asian Association for Regional Cooperation Journal of Agriculture*, *15*(1), 1-12.

Biru, T., & Negash, H. (2021). Genotypic variation, inheritance and genetic advance in bread wheat (*Triticum aestivum* L.) genotypes in Ethiopia. *Applied Biological Research, 23*(1), 87-94

Boussen, H., Ben Salem, M., Slama, A., Mallek-Maalej, E., & Rezgui, S. (2010). Evaluation of drought tolerance indices in durum wheat recombinant inbred lines. *Proceeding of Second International Conference on Drought Management, Istanbul, Turkey, 6*(4), 4-6.

Choudhary, R. C., Sharma, N. K., Kumar, R., & Kumar, M. (2015). Genetic variability, heritability and genetic advance in wheat under different normal and heat stressed environments. *Electronic Journal of Plant Breeding*, *6*(4), 1082-1087.

Din, A., Ahmad, M., Watto, F. M., Ahmed, S., Ali, I., & Shah, M. K. N. (2020). Drought tolerance screening in thirty common wheat (*Triticum aestivum* L.) genotypes. *Sarhad Journal of Agriculture, 36*(1), 168-177.

Eid, M. H. (2009). Estimation of heritability and genetic advance of yield traits in wheat (*Triticum aestivum* L.) under drought condition. *International Journal of Genetics and Molecular Biology*, *1*(7), 115-120.

Esmail, R. M. (2001). Correlation and path coefficient analysis of some quantitative traits with grain yield in bread wheat (*Triticum aestivum* L.). *Bulletin of the national Centre, Cairo*, *26*(3), 395-408.

Fard, A. K., & Sedaghat, S. (2013). Evaluation of drought tolerance indices in bread wheat recombinant inbred lines. *European Journal of Experimental Biology 3*(2), 201-204.

Farooq, M. U., Ishaaq, I., Maqbool, R., Aslam, I., Naqvi, S. M. T. A., & e Mustafa, S. (2019). Heritability, genetic gain and detection of gene action in hexaploid wheat for yield and its related attributes. *Agriculture and Food*, *4*(1), 56-72.

Farshadfar, E., Rasoli, V., Mohammadi, R., & Veisi, Z. (2012). Path analysis of phenotypic stability and drought tolerance in bread wheat (*Triticum aestivum* L.). *International Journal of Plant Breeding*, *6*(2), 106-112.

Gashaw, A., Hussein, M., & Singh, H. (2010). Genotypic variability, heritability, genetic advance and associations among characters in Ethiopian durum wheat (*Triticum durum* L.) accessions. *East African Journal of Sciences*, *4*(1), 27-33.

Gerema, G. (2020). Evaluation of durum wheat (*Triticum turgidum* L.) genotypes for genetic variability, heritability, genetic advance and correlation studies. *Journal of Agriculture and Natural Resources*, *3*(2), 150-159.

Ghobadi, M., Ghobadi, M. E., Kahrizi, D., Zebarjadi, A., & Geravandi, M. (2012). Evaluation of drought tolerance indices in dryland bread wheat genotypes under post-anthesis drought stress. *International Journal of Agricultural and Biosystems Engineering*, *6*(7), 528-532.

Guo, Z., Chen, D., & Schnurbusch, T. (2015). Variance components, heritability and correlation analysis of anther and ovary size during the floral development of bread wheat. *Journal of experimental botany*, *66*(11), 3099-3111.

Gupta, A., Charan, S., Vishnu, K., Gyanendra, S., & Singh, G. P. (2019). Special features of newly released wheat and barley varieties for cultivation in India. *Wheat and Barley Research*, *11*(2), 168-171.

Heidari, S., Heidari, P., Azizinezhad, R., Etminan, A., & Khosroshahli, M. (2020). assessment of genetic variability, heritability and genetic advance for agro-morphological and some in-vitro related traits in durum wheat. *Bulgarian Journal of Agricultural Science*, *26*(1), 120-127.

Hooshmandi, B. (2019). Evaluation of tolerance to drought stress in wheat genotypes. *Idesia*, *37*(2), 37-43.

Ilker, E., Tatar, Ö., Tonk, F. A., & Tosun, M. (2011). Determination of tolerance level of some wheat genotypes to post-anthesis drought. *Turkish Journal of Field Crops*, *16*(1), 59-63.

Jaiwal, J. P., Singh, A., & Gahatyari, N. C. (2019). Assessment of genetic diversity for terminal heat tolerance in bread wheat (*Triticum aestivum* L.). *Journal of Pharmacognosy and Phytochemistry*, *8*(1), 2572-2579.

Khan, A. J., Azam, F., Ali, A., Tariq, M., & Amin, M. (2005). Inter-relationship and path coefficient analysis for biometric traits in drought tolerant wheat (*Triticum aestivum* L.). *Asian Journal of Plant Sciences*, *4*(5), 540-543.

Khan, A.S., Ishtiaq, S., & Zulfiqar, A. (2003). Heritability of various morphological traits in wheat. *International Journal of Agriculture & Biology, 5*(2), 138-140.

Khan, M. H., & Dar, A. N. (2010). Correlation and path coefficient analysis of some quantitative traits in wheat. *African Crop Science Journal*, *18*(1), 112-122

Khan, N., & Naqvi, F. N. (2012). Correlation and path coefficient analysis in wheat genotypes under irrigated and non-irrigated conditions. *Asian Journal of Agricultural Sciences*, *4*(5), 346-351.

Kilic, H., & Yagbasanlar, T. (2010). The effect of drought stress on grain yield, yield components and some quality traits of durum wheat (*Triticum turgidum* ssp. *durum*) cultivars. *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *38*(1), 164-170.

Korkut, K. Z., Baş er, I., & Bilgin, O. (2001). Genotypic and phenotypic variability, heritability and phenotypic correlation for yield and yield components in bread wheat varieties. *Acta Agronomica Hungarica*, *49*(3), 237-242.

Kulkarni, M., Soolanayakanahally, R., Ogawa, S., Uga, Y., Selvaraj, M. G., & Kagale, S. (2017). Drought response in wheat: key genes and regulatory mechanisms controlling root system architecture and transpiration efficiency. *Frontiers in chemistry*, *5*(2), 106.

Kumar, J., Kumar, M., Kumar, A., Singh, S. K., & Singh, L. (2017). Estimation of genetic variability and heritability in bread wheat under abiotic stress. *International Journal of Pure & Applied Bioscience* *5*(1), 156-163.

Kumar, P., Yadava, R. K., Gollen, B., Kumar, S., Verma, R. K., & Yadav, S. (2011). Nutritional contents and medicinal properties of wheat: a review. *Life Sciences and Medicine Research*, *22*(1), 1-10.

Malbhage, A. B., Talpada, M. M., Shekhawat, V. S., & Mehta, D. R. (2020). Genetic variability, heritability and genetic advance in durum wheat (*Triticum durum* L.). *Journal of Pharmacognosy and Phytochemistry*, *9*(4), 3233-3236.

McMaster, G. S. (1997). Phenology, development, and growth of the wheat (*Triticum aestivum* L.) shoot apex: a review. *Advances in agronomy*, *59*(2), 63-118.

Mecha, B., Alamerew, S., Assefa, A., Dutamo, D., & Assefa, E. (2017). Correlation and path coefficient studies of yield and yield associated traits in bread wheat (*Triticum aestivum* L.) genotypes. *Advances in Plants & Agriculture Research*, *6*(5), 1-10.

Mohammadi, M., Sharifi, P., Karimizadeh, R., & Shefazadeh, M. K. (2012). Relationships between grain yield and yield components in bread wheat under different water availability (dryland and supplemental irrigation conditions). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *40*(1), 195-200.

Mollasadeghi, V. (2012). Evaluation of drought tolerance indices bread wheat genotypes in end-season drought stress conditions. *Journal of Biology*, *1*(2), 99-107.

Nizamani, M. M., Nizamani, F. G., Rind, R. A., Khokhar, A. A., Mehmood, A., & Nizamani, M. (2020). 36. Heritability and genetic variability estimates in F3 populations of bread wheat (*Triticum aestivum* L.). *Pure and Applied Biology*, *9*(1), 352-368.

Nouraein, M., Mohammadi, S. A., Aharizad, S., Moghaddam, M., & Sadeghzadeh, B. (2013). Evaluation of drought tolerance indices in wheat recombinant inbred line population. *Annals of Biological Research*, *4*(3), 113-122.

Ojha, R., Sarkar, A., Aryal, A., Rahul, K. C., Tiwari, S., Poudel, M., & Shrestha, J. (2018). Correlation and path coefficient analysis of wheat (*Triticum aestivum* L.) genotypes. *Farming and Management*, *3*(2), 136-141.

Okuyama, L. A., Federizzi, L. C., & Barbosa, J. F. (2004). Correlation and path analysis of yield and its components and plant traits in wheat. *Ciência Rural*, *34*(6), 1701-1708.

Panwar, B. S., & Singh, D. (2000). Genetic variability and correlation studies in wheat (*Triticum aestivum* L). *Indian Journal of Plant Genetic Resources*, *13*(3), 286-289.

Patel, J. M., Patel, A. S., Patel, C. R., Mamrutha, H. M., Pradeep, S., & Pachchigar, K. P. (2019). Evaluation of selection indices in screening durum wheat genotypes combining drought tolerance and high yield potential. *International Journal of Current Microbiology and Applied Sciences*, *8*(4), 1165-1178.

Pokhrel, D., Baral, K., Ojha, B. R., Ghimirey, S. K., & Pandey, M. P. (2013). Screening Wheat Genotypes for Drought Tolerance and Co-relation Study among Morpho-physiological Traits. *Journal of Agriculture and Environment*, *14*(2), 65-77.

Poudel, M. R., Poudel, P. B., Puri, R. R., & Paudel, H. K. (2021). Variability, Correlation and Path Coefficient Analysis for Agro-morphological Traits in Wheat Genotypes (*Triticum aestivum* L.) under Normal and Heat Stress Conditions. *International Journal of Applied Sciences and Biotechnology*, *9*(1), 65-74.

Pour-Aboughadareh, A., Mohammadi, R., Etminan, A., Shooshtari, L., Maleki-Tabrizi, N., & Poczai, P. (2020). Effects of drought stress on some agronomic and morpho-physiological traits in durum wheat genotypes. *Sustainability*, *12*(14), 5610.

Qaseem, M.F., Qureshi,R., Shaheen, H., & Waheed, A. (2021). Multivariate analysis for yield and proline content in wheat under lab and field conditions. *Pakistan Journal of Botany, 53*(1), 227-239.

Ramadas, S., Kumar, T. K., & Singh, G. P. (2019). Wheat production in India: Trends and prospects. *Recent Advances in Grain Crops Research*, *66*(2), 24-37

Schmidt, J., Claussen, J., Wörlein, N., Eggert, A., Fleury, D., Garnett, T., & Gerth, S. (2020). Drought and heat stress tolerance screening in wheat using computed tomography. *Plant Methods*, *16*(1), 1-12.

Sharma, P., Kamboj, M. C., Singh, N., Chand, M., & Yadava, R. K. (2018). Path coefficient and correlation studies of yield and yield associated traits in advanced homozygous lines of bread wheat germplasm. *International Journal of Current Microbiology and Applied Sciences*, *7*(2), 51-63.

Shi, X., & Ling, H. Q. (2018). Current advances in genome sequencing of common wheat and its ancestral species. *The Crop Journal*, *6*(1), 15-21.

Sial, M. A. (2007). Genetic heritability for grain yield and its related characters in spring wheat (*Triticum aestivum* L.). *Pakistan Journal of Botany, 39*(5), 1503-1509.

Talebi, R., & Fayyaz, F. (2012). Estimation of heritability and genetic parameters associated with agronomic traits of bread wheat (*Triticum aestivum* L.) under two constructing water regimes. *Journal of Applied Biological Sciences*, *6*(3), 35-39.

Upadhyay, K. (2020). Correlation and path coefficient analysis among yield and yield attributing traits of wheat (*Triticum aestivum* L.) genotypes. *Archives of Agriculture and Environmental Science*, *5*(2), 196-199.

Walkowiak, S., Gao, L., Monat, C., Haberer, G., Kassa, M. T., Brinton, J., Kolodziej, M.C., & Pozniak, C. J. (2020). Multiple wheat genomes reveal global variation in modern breeding. *Nature*, *588*(7837), 277-283.

Yani, S. C., & Rashidi, V. (2012). Selection indices in the improvement of wheat grain yield on drought stress conditions. *African Journal of Agricultural Research*, *7*(7), 1177-1183.

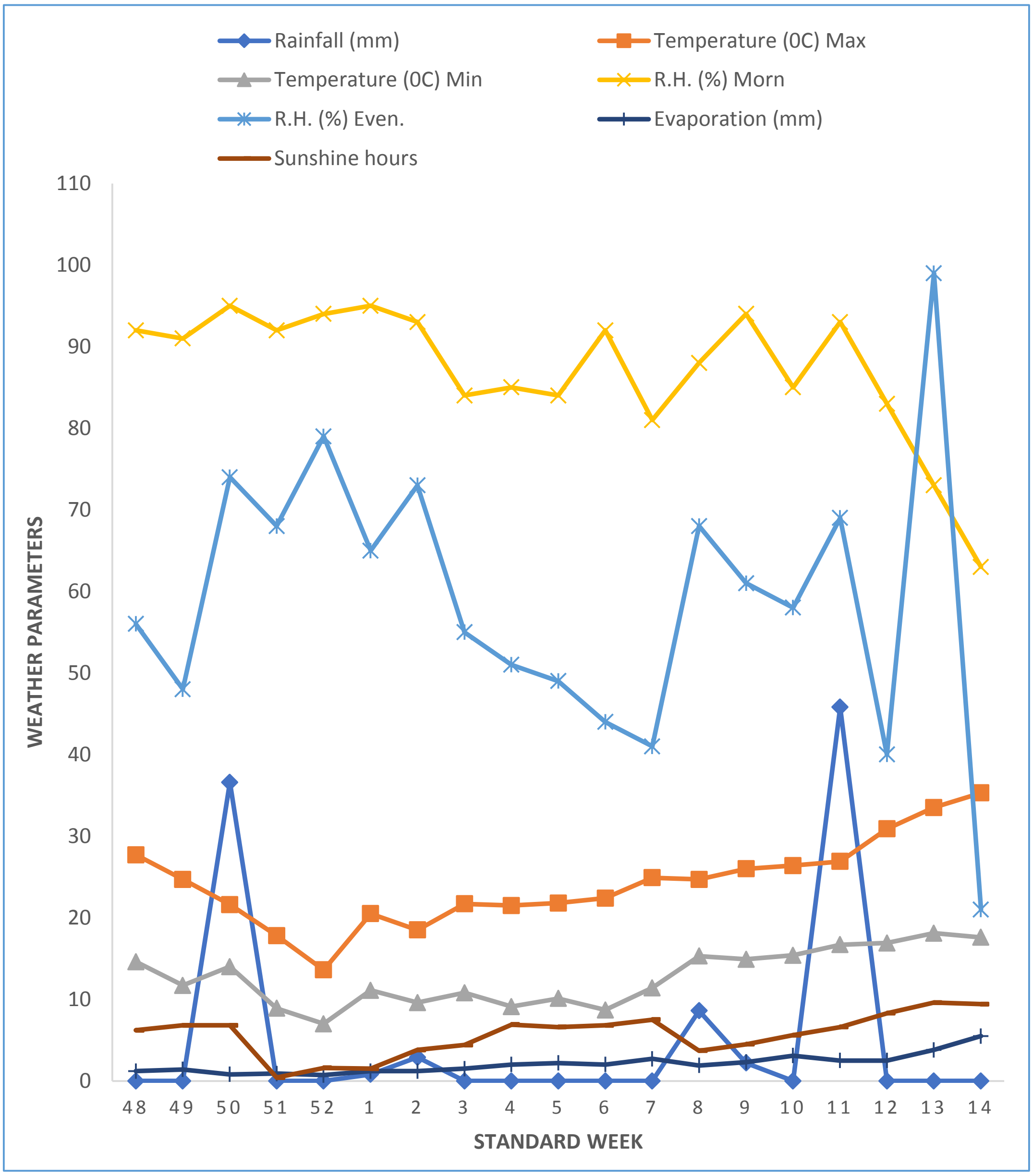
Yerlikaya, B. A., Omezli, S., & Aydogan, N. (2020). Climate change forecasting and modeling for the year of 2050. *Environment, Climate, Plant and Vegetation Growth, 3*(4) 109-122.

Yu, H., Zhang, Q., Sun, P., & Song, C. (2018). Impact of droughts on winter wheat yield in different growth stages during 2001–2016 in Eastern China. *International Journal of Disaster Risk Science*, *9*(3), 376-391.

Zare, M., Shokrpour, M., & Nejad, S. E. H. (2017). Correlation and path coefficient analysis in wheat (*Triticum aestivum* L.) under various drought stress conditions. *Bangladesh Journal of Botany*, *46*(4), 1309-1315.

Zhang, J., Zhang, S., Cheng, M., Jiang, H., Zhang, X., Peng, C., & Jin, J. (2018). Effect of drought on agronomic traits of rice and wheat: A meta-analysis. *International journal of environmental research and public health*, *15*(5), 839.

Appendix I- Weather parameters for the *rabi* season 2019-20



Appendix-II Meteorological observations (standard week wise) during crop season (2019-20)

Week No.	Month & Date	Rainfall (mm)	Temperature (^0C)		R.H. (%)		Sunshine hours	Evaporation (mm)
			Max	Min	Morning	Evening		
48	Nov 26-02	0.0	27.7	14.6	92	56	6.2	1.2
49	Dec 03-09	0.0	24.7	11.7	91	48	6.8	1.4
50	10-16	36.6	21.6	14.0	95	74	6.8	0.8
51	17-23	0.0	17.8	8.9	92	68	0.4	0.9
52	24-31	0.0	13.6	7.0	94	79	1.6	0.7
1	Jan 01-07	0.8	20.5	11.1	95	65	1.5	1.2
2	8-14	2.9	18.5	9.6	93	73	3.8	1.2
3	15-21	0.0	21.7	10.8	84	55	4.4	1.5
4	22-28	0.0	21.5	9.1	85	51	6.9	2.0
5	29-04	0.0	21.8	10.1	84	49	6.6	2.2
6	Feb 05-11	0.0	22.4	8.7	92	44	6.8	2.0
7	12-18	0.0	24.9	11.4	81	41	7.5	2.7
8	19-25	8.6	24.7	15.3	88	68	3.7	1.9
9	26-04	2.2	26.0	14.9	94	61	4.5	2.3
10	Mar 05-11	0.0	26.4	15.4	85	58	5.6	3.1
11	12-18	45.8	26.9	16.7	93	69	6.6	2.5
12	19-25	0.0	30.9	16.9	83	40	8.3	2.5
13	26-01	0.0	33.5	18.1	73	99	9.6	3.8
14	Apr 02-08	0.0	35.3	17.6	63	21	9.4	5.5

Appendix III- Physical and Chemical Characteristics of Soils-Agricultural Research Farm, Institute of Agricultural Sciences, BHU, Varanasi

Particulars	**Characteristics**
Soil Texture	Sandy Clay Loam
Topography	Levelled
Bulk Density	1.35 to 1.75 g cc^{-1}
EC	0.15 to 0.33 dS m^{-1} of $25^{o}C$
Nutrient Status	
Available Nitrogen	: Low
Available Phosphorus	: 23.6 to 34.2 kg ha^{-1}
Available Potassium	: 185 to 252 kg ha^{-1}
Available Zinc (ppm)	: 6.4

Source: Department of Agronomy, Institute of Agricultural Sciences, BHU, Varanasi

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