

PERFORMANCE OF ADVANCE WHEAT GENOTYPES UNDER TERAJ ZONE OF WEST BENGAL

Thesis submitted to the
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Degree of Master of Science (Agriculture)*

In
GENETICS AND PLANT BREEDING

By
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2013

Dedicated
To
My Beloved
Parents



UTTAR BANGA KRISHI VISWAVIDYALAYA
FACULTY OF AGRICULTURE
APPROVAL OF EXAMINERS FOR THE DEGREE OF MASTER OF
SCIENCE (AGRICULTURE) IN GENETICS AND PLANT BREEDING

We, the undersigned, having been satisfied with the performance of Mr. Manmatha Hansda, In the viva-voce examination, conducted today the 16th September 2013, recommended that the thesis entitled “**Performance of advance wheat genotypes under Terai Zone of West Bengal** ” be accepted for the of the **Degree of Master of Science (Agriculture) in Genetics and Plant Breeding of Uttar Banga Krishi Viswavidyalaya.**

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This is to certify that thesis entitled “Performance of advance wheat genotypes under Terai Zone of West Bengal” submitted in partial fulfillment of the requirements for the degree of Master of Science (Agriculture) in Genetics and Plant Breeding of Uttar Banga Krishi Viswavidyalaya, is a genuine record of bonafide research work carried out by Manmatha Hansda under my guidance and supervision. The results of the investigation reported in this thesis have not so far been submitted for any other degree or diploma.

The assistance and help received from various source during the course of investigation have duly acknowledged.

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CHAPTER I

Introduction

Introduction

1.1. Economic importance and taxonomy of the wheat

Wheat (*Triticum aestivum* L.) is the most important cereal crop for the majority of world's populations. It is the most important staple food of about two billion people (36% of the world population). Worldwide, wheat provides nearly 55% of the carbohydrates and 20% of the food calories consumed globally (Breiman and Graur, 1995). Wheat is cultivated over a wide range of climatic conditions and therefore understanding of genetics is of great value for genetics and plant breeding purposes.

Wheat belongs to family *Poaceae* (*Gramineae*) which includes major crop plants such as wheat (*Triticum spp.* L.), barley (*Hordeum vulgare* L.), oat (*Avena sativa* L.), rye (*Secale cereale* L.), maize (*Zea mays* L.) and rice (*Oryza sativa* L.). *Triticeae* is one of the tribes containing more than 15 genera and 300 species including wheat and barley.

Linnaeus in 1753 first classified wheat. In 1918, Sakamura reported the chromosome number sets (genomes) for each commonly recognized type. He separated wheat into three groups viz. diploids ($2n=14$), tetraploids ($2n=28$) and hexaploids ($2n=42$) chromosomes.

1.2. Wheat cultivation in India

The world acreage under wheat crop is 215.26 million ha with production of 584.76 million-tonnes with an average yield of 2717 kg per hectare. In India, wheat is the second most important crop after rice occupying 26.69 million ha, with production of 93.9 million tonnes with an average productivity of 2713 kg per hectare (Project Directors report, DWR, 2012). Area under wheat accounts for 14 per cent of the total gross cropped area, 18% of the net cropped area, 21 % of the area under food grains and 26% of the total area under cereals in the country. The area under wheat cultivation has increased from 97.46 lakh hectare in 1950-51 to 274 lakh hectares in 1999- 2000 showing a net increase of 181 % during the last 49 years. Wheat also contributed 34.2% of total production of food grains and 36.5% of the cereals in the country (2002-03). Over 86 per cent of the India's wheat production comes from 5 states of Uttar Pradesh, Punjab, Haryana, Rajasthan and Madhya Pradesh while three northern states of Uttar Pradesh, Punjab and Haryana together supply about 72 per cent of the country's wheat output. On the basis of agro climatic diversity wheat cultivation in India has been divided in to six mega zones (fig 1.1).

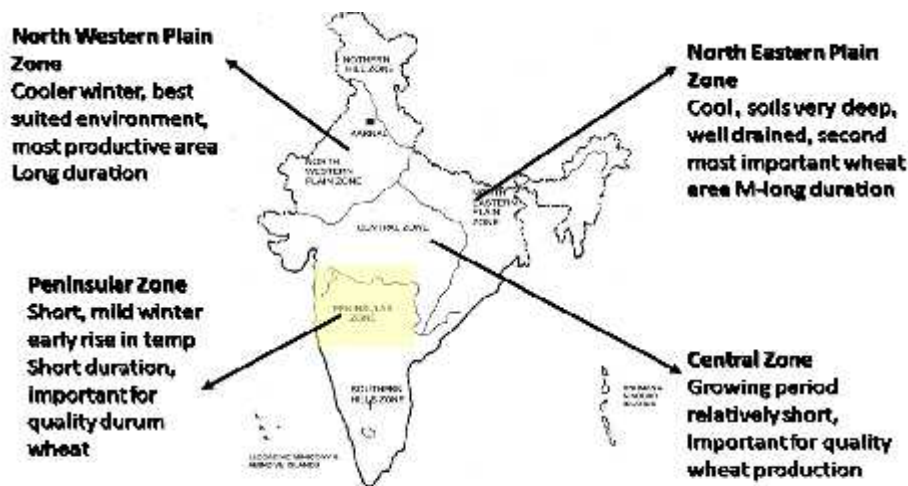


Fig 1.1: Different Wheat growing zones in India

Only 13% area of wheat cultivation is rainfed. Major Rainfed wheat areas are in Madhya Pradesh, Gujarat, Maharashtra, West Bengal and Karnataka. All India basis only 1/3 irrigated wheat receives desired irrigations and remaining is limited irrigation only. Breeding programmes are generally aimed for rainfed and irrigated environments and there is need to develop varieties which are responsive to limited irrigation conditions.

1.3. Drought and heat stress

Drought and high temperature (heat) stress are considered to be the two major environmental factors limiting crop growth and yield. The impacts of environmental stress, particularly those of drought and heat, have been studied independently. However, under field conditions, both of these stresses often occur in combination. Simultaneous occurrence of multiple stresses increases the deleterious effect, such that the effect considerably exceeds the simple additive effects of the action alone (cross-synergism). Similarly, a plant subjected to a single stress can be capable of increasing its resistance to subsequent or other stress (cross-adaptation). Crop performance in terms of growth, development, biomass accumulation, and yield depends on the crop's ability to withstand, acclimate, or recover from the stress. Both stress tolerance and recovery often involve a complex network of molecular and biochemical processes that integrate together to achieve a specific response of the whole crop. These aspects are even more important when we consider future climate change scenarios where seasonal changes in temperature and drought and occurrences of extreme weather events are highly expected.

About one third of the developing world's wheat (*Triticum aestivum* L.) area is located in environments that are regarded as marginal for wheat production because of drought, heat and edaphic factors. Despite these limitations, the world's dry and difficult cropping environments are increasingly crucial to food security in the developing world. For example, it has been reported that 32% of the 99 million hectares of wheat grown in developing countries experiences varying levels of drought stress (Rajaram et al., 1996). Wheat production suffers from variability in yield from year to year and from location to location. One of the main environmental abiotic stress responsible for yield instability is drought stress, which may occur early in the season or terminally at grain filling and grain development stages.

Wheat may experience water stress in any environment. CIMMYT has defined 12 mega environments (ME) as irrigated region, high rainfall areas, acid soils, semi arid zones tropical areas and winter wheat zones on the basis of water availability, soil type, temperature regime, production system and associated biotic and abiotic stress (Rajaram et al., 1995). Taking into account all these factors India comes under ME4C. In this mega environment wheat crop suffers from continuous or subcontinent type of drought which is associated with stored moisture after monsoon rain that is rain-fed condition. Thus to increase the productivity of this region different physiological techniques need to be adopted, for improving water use efficiency and breeding wheat genotypes tolerant to water stress and heat.

1.4. State scenario

Wheat is one of the important winter cereals in West Bengal. The area covered by this crop in this state during 2010-11 is around 316.8 thousand hectares providing 874.4 thousand tonnes of production which is less than 1% of the total production in the country. Productivity of wheat in this state is only 2760 kg/ha which is also much below the national level. In West Bengal, major wheat growing districts are Murshidabad, Nadia, Malda, Uttar Dinajpur, Jalpaiguri, Coochbehar and Birbhum. These districts contribute about 87% production from 88% wheat area in the State. Around 90% area under wheat is cultivated under either rainfed or restricted irrigated condition.

Annual average receipt of rainfall is around 1762 mm in West Bengal of this 76% is received in the monsoon months and the rest in the non monsoon period. 21% of the rain fall infiltrates through the soils and recharges the ground water and 49% goes back to the atmosphere as evapo-transpiration. The net annual water resource generated from rainfall in West Bengal amounts to 51.02 bcm (WBPCB, 2009). About 60% of the water resource is available in the North and South Bengal has 40% of the resources. The water received as precipitation in the northern areas flows away due to the gradient towards the plains as well as to the neighbouring country Bangladesh.

Considering the impacts of climate change in terms of changes in rain fall, temperature and water storage, it was found that the northern part of West Bengal might face water stress condition during wheat growing period. In winter and pre monsoon seasons the rain fall has decreased in the southern region by -14.5 mm and -6.7 mm respectively between 1901-2003. In the northern region an increase in rain fall in the pre-monsoon season by +10.5 mm has been observed during the same period, whereas a decrease in rainfall by -1.7 mm in the winter season has been observed. Post monsoon season show drastic decrease in rain fall in the northern region (-5mm). The post monsoon rain fall during October-November is likely to experience no change but will decrease in January-February period with respect to the base line [1970s] (West Bengal Action Plan on Climate Change, 2010).

Keeping these things in view, an effort has been made in the present study to evaluate a set of fourty nine wheat genotypes with the following objectives:

1. To assess the mean performance of wheat genotypes under both drought and irrigated conditions.
2. To estimate the variability, heritability and genetic advance for yield, yield components of these genotypes under both drought and irrigated conditions.
3. To estimate genotypic and phenotypic correlation with yield and path analysis under both drought and irrigated conditions.
4. To estimate different drought tolerant indices based on grain yield under drought and irrigated conditions.
5. To identify drought tolerant wheat genotypes based on these indices.

CHAPTER II

Review of Literature

Review of Literature

A thorough understanding of the genetic diversity, extent of variation, genetic architecture of the plant and heritability of characters, among the genotypes would help in developing sound plant improvement programme. Genetic variability is the gift of nature and its fruitful utilization in any crop species calls for systematic collection, evaluation, description and grouping based on economic descriptors. A brief review of available information on the above aspects in wheat is presented in this section.

2.1 Variability, Heritability and Genetic Advance

Possibility of achieving improvement in any crop plants depends heavily on the magnitude of genetic variability. The phenotypic variability expressed by a genotype or a group of genotypes in any species can be partitioned into genotypic and phenotypic components. The genotypic component being the heritable part of the total variability, its magnitude on yield and its component characters influences the selection strategies to be adopted by the breeders.

A comprehensive character wise review on phenotypic coefficient of variation (PCV), genotypic coefficient of variation (GCV), broad sense heritability (H) and genetic advance (GA) as per cent over mean is presented in Table 2.1.

2.2 Character association

Grain yield is a complex trait, which is influenced by a number of contributing characters. The estimates of the inter relationship between grain yield and other yield attributes and among themselves would facilitate effective selection schemes to improve the yield. Thus, the review pertaining to the correlation between yield, yield contributing traits and among them in wheat is summarized in Table 2.2.

2.3 Path analysis

Assuming yield is a contribution of several characters which are correlated among themselves and to the yield, path co-efficient analysis was developed (Wright, 1921; Dewey and Lu, 1959). Unlike the correlation coefficient which measures the extent of relationship, path coefficient measures the magnitude of direct and indirect contribution of the component characters to a complex character and it has been defined as a standardized, regression coefficient which splits the correlation coefficient into direct and indirect effects. The review of literature on contribution of different traits on yield is documented in Table 2.3.

Table 2.1: Review of literature on variability, heritability and genetic advance

Sl. No	Material used for the study	H	GA	PCV	GCV	References
1.	Days to 50% flowering					
1.	Durum wheat	97.7	28.68	-	14.8	Dixit (1990)
2.	F ₃ population	High	-	-	-	Tiwari and Rawat (1993)
3.	6 x 6 diallel crosses	High	-	-	-	Senapathi <i>et al.</i> (1994)
4.	50 hill wheat along with standard varieties	49.44	3.09	3.04	2.13	Chaturvedi and Gupta (1995)
5.	44 diverse strains of spring wheat	87.6	5.3	2.9	2.7	Jagshoran (1995)
6.	9 generation from- HD2329 x Kalyansona HD2009 x Sonalika	58.99 74.17	3.37 3.65	3.73 1.87	3.54 1.61	Jitendrakumar and Lutra(1995)
7.	1844 accessions of <i>T. monococcum</i>	-	-	High	High	Empilli <i>et al.</i> (1995)
8.	6 parents x their 15 F ₁ 's of bread wheat	44.63	18.44	5.46	5.29	Singh <i>et al.</i> (1996)
9.	Inter varietal crosses of bread wheat	High	-	-	-	Nirmala and Jha (1998)
10.	52 Aegilops accessions	-	-	High	High	Zaharieva <i>et al.</i> (2003)
2.	Number of effective tillers per meter	H	GA	PCV	GCV	References
1.	Durum wheat	Low	High	-	High	Shivkumar (1994)
2.	F ₂ wheat lines	High	High	High	High	Raha and Ramgiru (1998)
3.	300 genotypes of bread and durum	-	-	High	High	Sharma <i>et al.</i> (1998)
4.	wheat	High	High	High	High	Thakur <i>et al.</i> (1999)
7.	F ₂ wheat lines	57.70	19.95	21.07	16.01	Mahesh <i>et al.</i> (2001)
8.	Late sown wheat genotypes	98.84	42.94	-	-	Nayeem <i>et al.</i> (2003)
9.	Durum wheat Six cultivars/ liens of bread wheat	69.28-90.64	3.26-7.18	-	-	Ali-Firouzian <i>et al.</i> (2003)

Contd....

Sl. No	Material used for the study	H	GA	PCV	GCV	References
3.	Plant height					
1	Durum wheat	96.00	32.93	-	16.4	Dixit (1990)
2	11 parents and 9 F ₁ hybrids	High	High	-	-	Mahamood and Shahd (1991)
3	40 strains	High	High	-	-	Mandal <i>et al.</i> (1991)
4	F ₁ from diallel crosses	82.6	-	-	-	Pradanoric (1993)
5	F ₂ generation of wheat	High	-	-	-	Collakua (1994)
6	44 diverse strain of spring wheat	63.5	10.51	8.04	6.40	Chaturvedi and Gupta (1995)
7	Wide range of lines and varieties	High	-	-	-	Dachev (1995)
8	1844 accessions of <i>T. monococcum</i>	-	-	High	High	Empilli <i>et al.</i> (1995)
9	50 hill wheat along with checks	95.1	23.3	11.9	11.0	Jag Shoran (1995)
10	6 parents and their 15 F ₁ 's of bread wheat	41.66	80.00	9.12	8.64	Singh <i>et al.</i> (1996)
11	44 bread wheat lines	High	High	-	High	Shah (1998)
12	300 genotypes of bread and durum wheat	-	-	Low	Low	Sharma <i>et al.</i> (1998)
13	F ₂ 's of 20 wheat crosses	High	-	-	-	Wang <i>et al.</i> (1998)
14	Semi-dwarf wheat	68.78	Moderate	-	-	Rebetzke (1999)
15	21 F ₂ wheat lines	High	High	High	High	Thakur <i>et al.</i> (1999)
16	42 genetics stocks of durum wheat	High	-	-	-	Saiprasad and Pandey (2000)
17	50 bread wheat cultivars	-	-	High	High	Bergale <i>et al.</i> (2001)
18	50 wheat cultivars	High	High	High	High	Pawara <i>et al.</i> (2002)
19	52 Aegilops accessions	-	-	High	High	Zaharieva <i>et al.</i> (2003)
20	15 genotypes of foxtail millet	84.17	21.73	11.49	12.53	Muhammed and Hussain (2004)

Contd....

Sl. No	Material used for the study	H	GA	PCV	GCV	References
4.	Days to maturity					
1	Durum wheat	93.96	12.02	High	6.07	Dixit (1990)
2	47 tibetans wheat varieties	> 60%	-	-	Low	Lu <i>et al.</i> (1991)
3	Intermating of F ₂	High	High	High	Low	Subhash <i>et al.</i> (1993)
4	50 genotypes of winter wheat	High	High	Low	-	Jag Shoran (1995)
5	44 strains of bread wheat	Moderate	-	High	-	Chaturvedi and Gupta (1995)
6	50 hill wheat along with std. varieties	57.10	0.70	0.99	-	Jagshoran (1995)
7	F ₁ s and their parents	High NS	-	-	0.50	
8	F ₁ of 15 crosses from 6 half diallels and their 6 parents	heritability	-	-	-	Wang and Weichun (1996)
9	F ₁ , F ₂ , F ₃ , BC ₁ , BC ₂ , selfed BC ₁ , selfed BC ₂	Lower	High	-	-	Hassan <i>et al.</i> (1996)
10	6 parents and their 15 F ₁ 's of bread wheat	High	20.89	3.73	3.63	Dhanda and Sethi (1996)
11	15 genotypes of foxtail millet	26.26	10.26	5.37	5.17	Singh <i>et al.</i> (1996)
		92.71				Muhammed and Hussain (2004)
5.	Spike length	H	GA	PCV	GCV	References
1.	40 strains	High	High	-	-	Mandal <i>et al.</i> (1991)
2	21 genotypes	65	-	-	-	Zaheer Ahmed (1991)
3	F ₁ 's from diallel	94	-	-	-	Prodanoric (1993)
4	Wide range of lines and varieties	High	-	-	-	Dachev (1995)
5	44 bread wheat lines	High	High	-	High	Shah (1998)
6	11 F ₂ wheat lines	High	High	High	High	Thakur <i>et al.</i> (1999)
7	6 cultivars of bread wheat	49.93-66.05	1.28-2.25	-	-	Ali-Firouzian <i>et al.</i> (2003)
6.	Grain per spike	H	GA	PCV	GCV	References
1.	21 wheat genotypes	42	-	-	-	Zaheer Ahmad (1991)
2.	F ₃ family from Giza 155 and west bread	High	-	-	-	Khiralla (1993)
3.	25 genotypes	73-91	27.53	17.97	15-45	Bahadur <i>et al.</i> (1994)
4.	F ₅ generation	High	-	-	-	Collakua (1994)
5.	6 x 6 diallel	Moderate	-	-	-	Senapathi <i>et al.</i> (1994)
6.	50 hill wheat along with 3 checks	88.00	31.90	17.50	16.5	Jagshoran (1995)
7.	Generation from HD2329 x Kalyanasona	68.15	3.36	7.19	6.81	Jitendra Kumar and Lutra (1995)
	HD2009 x Sonalika	41.11	2.29	14.02	9.07	
8.	F ₂ wheat generation	High				Ozkan <i>et al.</i> (1997)
9.	21 bread wheat varieties	Moderate	Moderate	-	-	Uddin <i>et al.</i> (1997)
10.	Inter varietal crosses of bread wheat	Low	-	-	High	Nirmala and Jha (1998)

Contd..

Sl. No	Material used for the study	H	GA	PCV	GCV	References
7.	1000 grain weight					
1	11 parents and 9 F ₂ population	High	High	-	-	Mahamood and Shahd (1991)
2	F ₃ family from Giza 155 x West bread	High	-	-	-	Khiralla (1993)
3	1844 accessions of <i>T. monococcum</i>	-	-	High	High	Empilli <i>et al.</i> (1995)
4	6 parents and their 15 F ₁ 's of bread wheat	28.81	2.22	8.79	1.33	Singh <i>et al.</i> (1996)
5	300 genotypes of bread and durum wheat	-	-	Moderate	Moderate	Sharma <i>et al.</i> (1998)
6	44 bread wheat lines	High	High	-	High	Shah (1998)
7	F ₂ 's of 20 wheat crosses	High	-	-	-	Wang <i>et al.</i> (1998)
8	F ₂ population of wheat intermediate cross	Moderate	-	-	-	Kamboj <i>et al.</i> (2000)
9	in NC-1	-	-	High	High	Bergale <i>et al.</i> (2001)
10	50 bread wheat cultivars	-	-	-	-	
	52 Aegilops accessions			High	High	Zaharieva <i>et al.</i> (2003)
8.	Grain yield per plot					
1.	Durum wheat	55.98	40.10	-	27.30	Dixit (1990)
2.	6 variety of half diallel	High	-	-	-	Khiralla <i>et al.</i> (1993)
3.	25 genotypes	39.31	18.23	22.51	14.11	Bahadur <i>et al.</i> (1994)
4.	F ₅ generations	-	High	-	-	Collakua (1994)
5.	10 spring genotypes	Low	High	-	High	Liu and Ma (1994)
6.	6 x 5 diallel	Moderate	-	-	-	Senapathi <i>et al.</i> (1994)
7.	44 strains with Kaj3077 and K78 as checks	4.17	2.44	28.15	5.75	Chaturvedi and Gupta (1995)
8.	50 hill wheat along with 3 checks	82.50	58.90	34.60	-	Jagshoran (1995)
9.	6 parents and their 15 F ₁ 's of bread wheat	7.47	1.93	14.19	12.54	Singh <i>et al.</i> (1996)
10.	F ₂ 's of 20 wheat crosses	High	-	-	-	Wang <i>et al.</i> (1998)
11.	300 genotypes of bread and durum wheat	-	-	High	High	Sharma <i>et al.</i> (1998)
12.	F ₂ population of wheat cross in NC-1	High	-	-	-	Kamboj <i>et al.</i> (2000)
13.	design	-	-	High	High	Bergale <i>et al.</i> (2001)
	50 bread wheat cultivars					

Contd..

Table 2.2. Review of literature on correlation studies in wheat

Sl. No	Material used for the Study	Correlation with grain yield	References
1.	Days to 50% flowering		
1	F ₁ of crosses and parents	Positive and significant	Khan <i>et al.</i> (1999)
2	Advanced wheat lines	Negative	Narwal <i>et al.</i> (1999)
3	F ₁ and F ₂ generations of 5 half diallel crosses	Positive	Tammam <i>et al.</i> (2000)
4	F ₆ and F ₇ of triticale x wheat crosses	Negative	Gautam & Sethi (2002)
5	76 genotypes of durum wheat	Positive	Nayeem <i>et al.</i> (2003)
2.	Tillers per meter	Correlation with grain yield	References
1	Wheat genotypes	Positive	Saini <i>et al.</i> (1990)
2	<i>T. aestivum</i>	Positive	Dawari and Lutra (1991)
3	Bread wheat	Positive	Deshpande (1992)
4	257 land races of durum wheat	Significant positive	Al-Ajlouni and Jordat (1997)
5	Advanced wheat lines	Positive and significant	Narwal <i>et al.</i> (1999)
6	49 elite genotypes of wheat	Significant positive association with yield	Mahesh <i>et al.</i> (2001)
7	4 wheat cultivars	Positive and significant	Jat and Dhakar (2003)
3.	Plant height	Correlation with grain yield	References
1	Wheat	Positive	Szunics <i>et al.</i> (1982)
2	F ₂ population of eight parent diallel crosses of wheat	Positive and significant	Bhullar (1984)
3	70 Ethiopian durum wheat genotypes	Strong positive	Getachew <i>et al.</i> (1993)
4	Winter x spring nursery	Positive and significant	Sharma <i>et al.</i> (1995)
5	15 F ₂ populations from 6 x 6 half diallel	Significant	Abdel-Sabour <i>et al.</i> (1996)
6	F ₁ of 15 crosses from 6 half diallels and their 6 parents	Significant	Hassan <i>et al.</i> (1996)
7	F ₂ of crosses and parents	Positive & highly significant	Khan <i>et al.</i> (1999)
8	200 genotypes of durum and dicoccum wheat	Significantly positive	Naik (2000)
9	16 wheat breeding lines	Strong negative	Mohammad Shahid <i>et al.</i> (2002)

Contd..

Sl. No	Material used for the Study	Correlation with grain yield	References
4.	Days to maturity		
1	Wheat	Positive and significant	Jadhav (1994)
2	23 segregating population	Positive	Nirmala and Jha (1996)
5.	Spike length	Correlation with grain yield	References
1	<i>T. aestivum</i>	Positive	Dawari & Lutra (1991)
2	Bread wheat	Positive	Deshpande (1992)
3	15 F ₁ population from 6 x 6 half diallel	Significant	Abdel-Sabour <i>et al.</i> (1996)
4	40 advanced F ₈ lines of wheat along with 11 checks	Positive and significant	Narwal <i>et al.</i> (1999)
5	Advanced wheat lines	Positive	Satish kumar <i>et al.</i> (2001)
6	50 hexaploid triticales	Positive	Gautam & Sethi (2002)
7	F ₆ and F ₇ of triticales x wheat cross 40 F ₁ 's	Strong and positive	Sudesh <i>et al.</i> (2002)
8	16 wheat breeding lines	Positive and significant	Mohammad Shahid <i>et al.</i> (2002)
6.	Grains per spike	Correlation with grain yield	References
1	32 bread wheat genotypes	Positive	Raut <i>et al.</i> (1995)
2	15 F ₂ populations from 6 x 5 half diallel	Significant	Abdel-Sabour <i>et al.</i> (1996)
3	Wheat genotypes	Positive and significant	Paul and Ganguli (1996)
4	F ₂ population derived from intercultivar crosses involving KAUZ "S" and 84 CZT04	Significant	Ozkan <i>et al.</i> (1997)
5	257 land races of durum wheat	Significant positive	Al-Ajlouni and Jaradat (1997)
6	Wheat genotypes	Significant	Wang <i>et al.</i> (1998)
7	22 common wheat cultivars	Positive	Dokuyucu and Akkaya (1999)
8	advanced wheat lines	Positive and significant	Narwal <i>et al.</i> (1999)
9	Pure line	Negative	Singh & Sharma (1999)
10	200 genotypes of durum & dicoccum wheat	Significantly positive	Naik (2000)
11	F ₁ and F ₂ generations of 5 half diallel crosses	Positive	Tammam <i>et al.</i> (2000)
12	Fifty bread wheat cultivars	Positive	Bergale <i>et al.</i> (2001)
13	F ₆ and F ₇ of triticales x wheat cross	Positive	Gautam & Sethi (2002)

Contd..

Sl. No	Material used for the Study	Correlation with grain yield	References
7.	1000 grain weight		
1	Pure line	Negative and significant	Yadav and Singh (1991) and Rao
2	70 Ethiopian durum wheat genotypes	Strong positive	Getachew <i>et al.</i> (1993)
3	F ₁ of 15 crosses from 6 half diallel and their 6 parents	Strong positive	Getachew <i>et al.</i> (1993)
4	15 F ₂ populations from 6 x 6 half diallel	Significant	Hassan <i>et al.</i> (1996)
5	Wheat genotypes	Significant	Abdel-Sabour <i>et al.</i> (1996)
6	257 land races of durum wheat	Positive and significant	Paul and Ganguli (1996)
7	22 common wheat cultivars	Significant positive	Al-Ajlouni and Jaradat (1997)
8	F ₁ of crosses and parents	Negative and significant	Khan <i>et al.</i> (1999)
9	Advanced wheat lines	Positive and significant	Narwal <i>et al.</i> (1999)
10	and F ₂ generation of 5 half diallel crosses	Positive	Tammam <i>et al.</i> (2000)
11	and F ₇ of triticale x wheat cross	Positive	Gautam and Sethi (2002)
12	76 genotypes of durum wheat	Positive	Nayeem <i>et al.</i> (2003)
13	4 wheat cultivars	Positive and significant	Jat and Dhakar (2003)
8.	Grain yield/plot	Correlation with grain yield	References
1	Pure line	Significant	Chaturvedi and Gupta (1995)
2	50 genotypes of winter wheat	Positively significant	Shorun (1995)
3	Wheat genotypes	Positive and significant	Paul and Ganguli (1996)
4	F ₂ population derived from intercultivar crosses involving KAUZ“S” and 84 CZT04	Significant	Ozkan <i>et al.</i> (1997)
5	Wheat genotypes	Significant	Wang <i>et al.</i> (1998)
6	22 common wheat cultivars	Positive and significant	Dokuyucu and Akkaya (1999)

Table 2.3. Review of literature on path analysis for yield attributing traits on grain yield in wheat

Characters studied	Material used for the study	Effect on grain yield	References
Plant height	1. 44 strains of spring wheat 2. F ₃ and F ₄ genotypes of tetraploid wheat 3. 200 genotypes of durum and dicoccum wheat	Direct positive Direct effect Maximum indirect positive effect via total biomass and harvest index	Chaturvedi and Gupta (1995) Halloli (1997) Naik (2000)
Days to 50% flowering	1. 44 Strains of spring wheat 2. F ₃ and F ₄ genotypes of tetraploid wheat	Direct positive Direct	Chaturvedi and Gupta (1995) Halloli (1997)
Number of tillers/meter	1. 44 strains of spring wheat 2. Advanced wheat lines	Direct positive Positive and large direct effect	Chaturvedi and Gupta (1995) Narwal <i>et al.</i> (1999)
Spike length	1. Advanced wheat lines	Positive and large direct effect	Narwal <i>et al.</i> (1999)
Grains per spike	1. 15 F ₁ hybrids and parents 2. 44 strains of spring 3. F ₃ and F ₄ genotypes of tetraploid wheat Advanced wheat lines 5. 22 common wheat cultivars 6. 200 genotypes of durum and dicoccum wheat	Positive direct effect Positive direct effectp Positive direct effect Positive and large direct effect Direct via grain weight Maximum indirect positive effect via total biomass and harvest index	Ibrahim (1994) Chaturvedi and Gupta (1995) Halloli (1997) Narwal <i>et al.</i> (1999) Dokuyucu <i>et al.</i> (1999) Naik (2000)
1000 grain weight	1. Durum wheat 15 F ₁ hybrids and parents F ₃ and F ₄ genotypes of tetraploid wheat	Positive direct effect Positive direct effect Positive direct effect	Deshmukh <i>et al.</i> (1990) Ibrahim (1994) Halloli (1997)
Grain yield/plot	1. Durum wheat 2. F ₃ and F ₄ genotypes of teraploid wheat	Direct positive effect Positive direct effect	Ehdaie and Waines (1989) Halloli (1997)

2.4 Drought stress in wheat

World food production is limited primarily by environmental stresses. It is very difficult to find 'stress free' areas where crops may approach their potential yield. Abiotic environmental factors are considered to be the main source (71%) of yield reductions (Boyer, 1982). Drought is one of the most common environmental stresses that affects growth and development of plants through alterations in metabolism and gene expression (Leopold, 1990). It is a permanent constraint to agricultural production in many developing countries (Ceccarelli and Grando, 1996).

Water stress is of common and wide occurrence in nature. It occurs whenever water absorption by the crop is lower than the evaporative demand of the atmosphere. There are two major processes involved in that i) water absorption by the crop which is controlled by root characteristics and soil properties. ii) Crop evapotranspiration (ET) which depends on atmospheric properties like net radiation, vapour pressure deficit (VPD) and crop characteristics (Allen *et al.*, 1998).

All stages of crop growth are not uniformly susceptible to water scarcity. On the other hand, some stages can cope-up with water shortage very well, while others are more susceptible and water shortages at such stages may result in distinct yield losses. Moisture stress is known to reduce biomass, tillering ability, grains per spike and grain size at any stage when it occurs. So, the overall effect of moisture stress depends on intensity and length of stress (Bukhat, 2005). Water stress imposed during later stages might additionally cause a reduction in number of kernels/ear and kernel weight (Gupta *et al.*, 2001; Dencic *et al.*, 2000).

Water stress experienced by a wheat crop during growth is known to have cumulative effects expressed as a reduction in total biomass compared to the well watered potential (Legg *et al.*, 1979). Better performance of the crop depends upon availability of water during Tillering, Anthesis and Grain formation stages. Water stress at anthesis reduces pollination and thus less grains spike-1 which results in the reduction of grain yield (Nazir *et al.*, 1987). Adequate water at or after anthesis period not only allows the plant to increase photosynthetic rate but also increases grain filling duration (Zhang *et al.*, 1998), thus enhancing grain size and ultimately cause higher grain yield (Gallagher and Biscoe, 1978).

2.5 Drought tolerance mechanism

Drought tolerance in wild plant species is often defined as survival, but in crop species it is defined in terms of productivity (Passioura, 1983). Rosielle and Hamblin (1981) defined drought tolerance as the difference in yield between stress and nonstress environments, while productivity is the average yield in stress and non-stress. A different definition regards drought tolerance as minimization of reduction in yield caused by stress compared to yield under non-stress environments (Fischer and Maurer, 1978;; Blum, 1983a; Blum, 1988). Also, it is defined as the relative yield of a genotype compared to

other genotypes subjected to the same drought stress (Hall,1993). Drought tolerance comprises drought escape, dehydration avoidance and dehydration tolerance mechanisms (Blum, 1988).

2.5.1 Drought escape

Drought escape through early flowering and/or short growth duration is advantageous in environments with terminal drought stress and where physical or chemical barriers inhibited root growth (Turner, 1986; Blum, 1988; Blum *et al.*, 1989). On the other hand, late flowering can be beneficial in escaping early-season drought, if drought is followed by rains (Ludlow and Muchow, 1990). Under non-stress conditions, late flowering varieties tend to yield higher than early-flowering varieties (Turner, 1986; Ludlow and Muchow, 1990). This is because the early-flowering varieties are likely to leave the yield potential unutilized (Muchow and Sinclair, 1986).

2.5.2 Dehydration avoidance

Dehydration avoidance can be defined as the plant's ability to retain a relatively higher level of 'hydration' under conditions of soil or atmospheric water stress (Blum, 1988). Levitt (1980) identified two plant types with respect to dehydration avoidance i.e. 'water savers' and 'water spenders'. Important features of these plants are root characteristics (increased water uptake), leaf and stomatal characteristics (reduced water loss) and osmotic adjustment to lower the osmotic potential (Blum, 1988; Acevedo and Fereres, 1993).

2.5.3 Dehydration tolerance

Dehydration tolerance describes the ability of plants to continue metabolizing at low leaf water potential and to maintain growth despite of dehydration of the tissue. According to Hsiao (1973) and Boyer (1976), translocation is one of the more dehydration tolerant processes in plants. It would proceed at levels of water deficit sufficient to inhibit photosynthesis. When water stress occurs and the current photosynthetic source is inhibited, the role of stem reserves as a source for grain filling increases. Stem reserves may therefore be considered as a powerful resource for grain filling in stress-affected plants during the grain filling stage.

2.5.4 Model for drought tolerance

The conceptual model was described by Reynolds *et al.*, (2000). This model includes following traits:

➤ **Large seed size**

Helps in emergence, early ground cover and initial biomass.

- **Long coleoptiles**

Helps for emergence from deep sowing (Radford, 1987). This enables to help seedlings to reach the receding moisture profile and to avoid high soil surface temperatures which inhibit germination.
- **Early ground cover**

Thinner, wider leaves (i.e. with a relatively low specific leaf weight) and a more prostrate growth habit help to increase ground cover, thus conserving soil moisture and potentially increasing radiation use efficiency (Richards, 1996).
- **High pre-anthesis biomass**

Up to 40% of available water may be lost by evaporation directly from the soil surface in Mediterranean types of environments (Loss and Siddique, 1994), so early ground cover and biomass production may be useful to permit a more efficient use of soil water.
- **Good capacity for stem reserves and remobilization**

Stored fructans can contribute substantially to grain filling especially when canopy photosynthesis is inhibited by drought (Rawson and Evans, 1971). Traits that may contribute include long and thick stem internodes, with extra storage tissue perhaps in the form of solid stems.
- **High spike photosynthetic capacity**

Spikes have higher WUE than leaves and have been shown to contribute up to 40% of total carbon fixation under moisture stress (Evans *et al.*, 1972). Awns contribute substantially to spike photosynthesis and longer awns are a possible selection criterion.
- **High RLWC/CTD during grain filling to indicate ability to extract water**

A root system that can extract whatever water is available in the soil profile is clearly drought adaptive (Hurd, 1968), but that is difficult to measure. Traits affected by the water relations of the plant, such as relative leaf water content (RLWC) , canopy temperature depression (CTD) during the day and C13 discrimination or ash content of grain or other tissues, can give indications of water extraction patterns.
- **Osmotic adjustment**

Osmotic adjustment will help to maintain leaf metabolism and root growth at relatively low leaf water potentials by maintaining turgor pressure in the cells (Morgan and Condon, 1986).

➤ **Accumulation of abscisic acid (ABA)**

It appears that plants can be pre adapted to stress by reducing stomatal conductance, rates of cell division, organ size and increasing development rate. The benefit of ABA accumulation under drought has been demonstrated (Innes *et al.*, 1984). However, high ABA can also result in sterility problems since high ABA levels may abort developing florets.

➤ **Leaf anatomy: waxiness, pubescence, rolling and thickness**

These traits decrease radiation load to the leaf surface (Richards, 1996). Benefits include a lower evapotranspiration rate and reduced risk of irreversible photo-inhibition.

➤ **High tiller survival**

Comparison of old and new varieties have shown that under drought older varieties over-produce tillers many of which fail to set grain while modern drought tolerant lines produce fewer tillers most of which survive (Loss and Siddique, 1994).

➤ **Heat tolerance**

The contribution of heat tolerance to performance under moisture stress needs to be quantified, but it is relatively easy to screen (Reynolds *et al.*, 1998).

➤ **Stay green**

The trait may indicate the presence of drought avoidance mechanisms, but probably does not contribute to yield. If there is no water left in the soil profile by the end of the cycle to support leaf gas exchange, it may be detrimental if it indicates lack of ability to remobilize stem reserves (Blum, 1998). However, research in sorghum has indicated that stay green is associated with higher leaf chlorophyll content at all stages of development and both were associated with improved yield and transpiration efficiency under drought (Borrell *et al.*, 2000).

2.6 Genetics for drought tolerance

Drought resistance is a complex trait, expression of which depends on action and interaction of different morphological (earliness, reduced leaf area, leaf rolling, wax content, efficient rooting system, awn, stability in yield and reduced tillering), physiological (reduced transpiration, high water-use efficiency, stomatal closure and osmotic adjustment) and biochemical (accumulation of proline, polyamine, trehalose, etc, increased nitrate reductase activity and increased storage of carbohydrate) characters.

The identification of genes responsible for morphological and physiological traits and their location on chromosome have not been possible, but their inheritance pattern and nature of gene action have been reported. Polygenic inheritance of root characters is reported by Ekanayake *et al* (1985). The long root and high root numbers are controlled by dominant alleles and thick root tip by recessive

alleles (1983). However, leaf rolling and osmotic adjustment (1991) have shown monogenic inheritance Tomnar and Prasad (1996) reported a drought resistance gene, *Drt1* in rice, which is linked with genes for plant height, pigmentation, hull colour and awn, and has pleiotropic effect on the root system. Similarly, in cowpea drought resistance is reported to be controlled by a single dominant gene (1999).

2.7 Breeding approach

Three breeding approaches for drought resistance have been evolved. The first is to breed for high yield under optimum (water stress free) condition. As the maximum genetic potential of yield is expected to be realized under optimum condition and a high positive correlation exists between performance in optimum and stress conditions (1967), a genotype superior under optimum level will also yield relatively well under drought condition. This is the basic philosophy of this approach.

However, the concept of expression of maximum genetic potential in optimum condition is debated (1973) as genotype environment interaction may restrict the high yielding genotype to perform well under drought. Thus, the second approach, i.e. to breed under actual drought condition has been suggested (1971). The second approach suffers from the problem that the intensity of drought is highly variable from year to year and as a consequence environmental selection pressure on breeding materials changes drastically from generation to generation. This problem compounded with low heritability of yield (1970) makes the breeding programme complicated and slow.

An alternative approach to the above two would be to improve drought resistance in high-yielding genotypes through incorporation of morphological and physiological mechanisms of drought resistance. However, transferring drought resistance in high-yielding genotypes is complicated due to lack of understanding of the physiological and genetic basis of adaptation in drought condition. In contrast, improving the yield potential of an already resistant material may be a more promising approach, provided there is genetic variation within such material (1995). Simultaneous selection for yield in stress free environment and for stability in drought condition may be done to achieve the desired goal of devolving drought-resistant genotype with high yield.

As such, the breeding methodology to be applied for drought resistance is the same as that applied for other purposes. In general, pedigree and bulk method could be used for self- pollinated crops and recurrent selection for cross-pollinated crops. However, if transfer of few traits relation to drought resistance to high-yielding genotypes is the aim, then backcross is the appropriate Methodology.

On the other hand, biparental mating (half sib and full sib) maintains the broad genetic base as well as provides the scope to evolve the desired genotype of drought resistance. The success of any breeding programme depends on the availability of the screening technique, especially for drought resistance (1982).

2.7.1 Screening techniques

As loss of yield is the main concern for the crop plant from agricultural point of view, plant breeders emphasize on yield performance under moisture stress condition. As per Clarke *et al.*(1995) and Bruckner and Frohberg (1987) different drought indices which provide a measure of drought based on loss of yield under drought-condition in comparison to moist condition have been used for screening drought-resistant genotypes. Visual scoring or measurement for maturity leaf rolling, leaf length, angle, root morphology and other morphological characters of direct relevance to drought resistance are also taken into consideration.

2.7.2 Drought tolerance indices

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 (Mitra 2001). These indices are either based on drought resistance or susceptibility of genotypes (Fernandez 1992). Drought resistance is defined by Hall (1993) as the relative yield of genotype compared to other genotypes subjected to the same drought stress. Drought susceptibility of a genotype is often measured as a function of the reduction in yield under drought stress (Blum 1988). Rosielle and Hamblin (1981) defined stress tolerance (TOL) as the differences in yield between the stress and non-stress environments and mean productivity (MP) as the average yield under stress and non stress environments (Hamblin1981). Fischer and Maurer (1978) proposed a stress susceptibility index (SSI) of the cultivar. Fernandez (1992) defined a new advanced index (STI = Stress tolerance index), which can be used to identify genotypes that produce high yield under both stress and non-stress conditions. Other yield based estimates of drought resistance are geometric mean (GM), Mean productivity (MP) and TOL. The Geometric mean is often used by breeders interested in relative performance since drought stress can vary in severity in field environment over years (Kelly 1988).

CHAPTER III

Materials and Methods

Materials and Methods

3.1 Experimental site

The present investigation was conducted during *rabi* season of 2011-2012 crop season at the University Farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar. The farm is situated at 26° 19' 86" N latitude, 89° 23' 53" E longitude with an altitude of 43 m above the mean sea level.

3.2 Meteorological features of the experimental site

3.2.1 Climatic condition

The experimental site falls under sub Himalayan terai agro-climatic condition. The average annual rainfall is 3000 mm and most of which is received during June to September. The temperature begins to rise from the end of February reaching maximum towards the April-May. The relative humidity remains high throughout the year. The late monsoon rain during October helps in better germination while early rain during April hampers the matured crop.

3.2.2 Temperature

During the experimental period the temperature was lower at the beginning and then gradually increases. The maximum temperature varied from 20.0°C during January to 30.7°C during March while minimum temperature varied from 7.5°C to 19.5°C during April. Mean maximum temperature faced by crop before anthesis (75%) was 23.4°C while mean minimum temperature was 11.5°C. After anthesis mean maximum temperature raised up to 27.3°C and minimum temperature upto 13.8°C. Overall crop faces mild temperature throughout the crop growth period.

3.2.3 Rainfall

During the experimentation period crop faces mild rainfall during germination which is congenial for the crop germination but huge rain during maturity adversely affected matured crop (Table 3.1).

3.2.4 Humidity

Humidity was very high throughout the experimentation period. In many cases it reached up to 99.00%. In November to April the maximum humidity was 99.00 % and the minimum was 43.1 %.

Table 3.1: Meteorological data pertaining to the period of experimentation

Weeks	Temperature, °c		RH (%)		Rainfall	Wind Speed	No. of rainy days
	Max.	Min	Max	Min	mm	km/hr	
12-18 Nov	24.1	15.8	98.7	67.1	4.1	3.8	4
19-25 Nov	28.5	13.9	99.0	43.1	0.0	3.3	0
26-02 Dec	27.9	14.2	99.0	46.1	0.0	2.4	0
03-09 Dec	26.6	15.4	98.3	56.0	3.3	3.4	3
10-16 Dec	20.5	12.0	99.0	68.0	0.0	3.0	0
17-23 Dec	20.7	10.2	99.0	65.7	0.3	4.0	1
24-31 Dec	25.9	9.1	99.0	39.9	0.0	2.8	0
01-07 Jan	21.0	11.3	99.0	63.4	1.6	2.8	2
08-14 Jan	21.2	9.7	98.6	56.6	0.0	3.9	0
15-21 Jan	20.0	9.7	98.9	60.6	0.0	3.2	0
22-28 Jan	21.3	8.5	99.0	54.4	0.0	2.1	0
29-04 Feb	24.1	7.5	99.0	40.9	0.0	2.5	0
05-11 Feb	23.7	10.1	99.0	53.0	8.5	3.7	1
12-18 Feb	25.2	10.6	99.0	42.4	0.0	2.6	0
19-25 Feb	26.3	13.3	99.0	50.0	1.4	2.5	2
26-04 Mar	26.1	12.0	96.1	39.9	0.0	4.8	0
05-11 Mar	28.4	13.2	91.7	31.6	0.0	5.6	0
12-18 Mar	26.9	13.7	96.3	42.3	15.7	4.2	2
19-25 Mar	30.7	16.9	97.0	38.7	0.0	3.7	0
126-01 Apr	32.8	19.5	90.3	35.4	0.0	5.4	0
02-08 Apr	28.5	19.0	98.7	58.9	48.8	6.8	5
09-15 Apr	26.77	18.93	98.86	69.86	20.64	1.7	6

Source: Integrated Agromet Advisory Services, Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar

3.3 Experimental soil

The soil of the experimental field was from Teesta alluvial plain group which is sandy loam in texture with poor water holding capacity and moderate fertility status. The pH value was acidic in nature (Table 3.2).

Table 3.2: Soil characteristics of the experimental field

CHARACTERISTICS	CONTENT	CHARACTERISTICS	CONTENT
Sand	65.9	Field capacity (%)	44.04
Slit	18	Permanent wilting point (%)	3.81
Clay	16.1	Organic Carbon (%)	0.76
Bulk density (mg/m ³)	1.25	EC, dSm ⁻¹	0.08
Available Nutrients, kg/ha		pH	5.3
Nitrogen	117.6		
Phosphorous	14.98		
Potassium	121.33		

3.4 Experimental details/plan of work

The experiment was undertaken under normal sowing condition with one set of genotypes having normal rate of irrigation and another without any irrigation (i.e under drought stress). The experimental detail is as follows:

Date of sowing	: 15 th November, 2011
Design of the experiment	: Randomized block design
No. of genotypes	: 49
No. of replication	: 2
Type of sowing	: Line Sowing
Length of the row	: 2.0 m
Distance between rows	: 30 cm
Plot size (length x breadth)	: 2.0 m x 0.6 m
Irrigation	: One set with full irrigation and another without any irrigation
Fertilizer	: N-120 Kg ha ⁻¹ , P-60 Kg ha ⁻¹ , K-40 Kg ha ⁻¹ (basal)
Date of harvesting	: 10 th April, 2012

Table 3.3 List of genotypes along with their description

Sl. No.	Genotypes	Sl. No.	Genotypes
1.	AKAW 3717	26	KLY 1086
2	AKAW 4705	27	KYP 0826
3	AKAW 4730	28	NI 5439
4	AKAW 473	29	NIAW 1689
5	C 306	30	NIAW 656
6	GW-09-260	31	NWL-9-15
7	GW 2010-343	32	RAJ 4083
8	GW-2010-345	33	RAJ 4128
9	Gw-09-262	34	GW-09-264
10	GW-09-264	35	RAJ 4168
11	GW-09-269	36	RAJ 4169
12	GW-09-270	37	RAJ 4254
13	HI 1564	38	RAJ 4257
14	HI 1579	39	RAJ 4258
15	HI 1580	40	RS 1002
16	HI 1581	41	RS 1017
17	K 0624	42	VL 950
18	KLP 1032	43	VL 952
19	KLP 1042	44	WH 1022
20	KLP 1043	45	WS 902
21	KLP 1045	46	WS 903
22	KLP 3077	47	WS 904
23	KLP 3105	48	WS 905
24	KLP 3129	49	WSM 1472
25	KLY 1081		

All the genotypes were collected and stored under All India Coordinated Wheat and Barley Improvement project, Coochbehar centre, UBKV.

3.5 Method of recording observation

Ten randomly selected plants were taken per replication and per entry /lines for recording data for the following plant characters:

1. Germination %

It was calculated by counting the number of plants per meter after two weeks of sowing and percentage was calculated by comparing with the control.

2. Days to heading (75%)

Average days of heading of 75% plants of each line were recorded. The duration from date of sowing to date of heading was counted and recorded as days to heading.

3. Days to maturity

The physiological maturity of each line was recorded by judging the toughness of the grains. The duration from date of sowing to date of maturity was counted and recorded as days to maturity.



**Wheat genotypes grown under
Irrigated condition**



**Wheat genotypes grown under
Drought condition**

4. Plant height(cm)

Plant height (cm) was measured from the base to the tip of the panicle of the plant after harvesting the plant at the ground level.

5. Tiller per meter

All the tillers arising from the plant of per meter square were counted and expressed as the no. of tiller per plant.

6. Grain per spike

Total number of grains was counted from each spike and then calculated their average.

7. Spike length(cm)

Length of the spike (cm) was measured from neck node to the tip of the spike.

8. Test weight(g)

Thousand grains were counted from harvested bulk grains of ten plants and then their weight was recorded in grains by correct to two decimal points by an electric balance.

9. Grain yield(g):

The total number of grain found after harvesting of wheat was calculated in gram.

3.6. Statistical analysis

Statistical analysis was performed on the mean values of each character was compared for each replication and then used for statistical analysis. The Design of experiment was randomized block design which described below:

3.6.1. Analysis of Randomize block design

Model for RBD: $Y_{ij} = \mu + t_i + r_j + e_{ij}$

Where, Y_{ij} = Responses obtained due to the i^{th} treatment and j^{th} replication

μ = Grand mean

t_i = i^{th} treatment effect

r_j = j^{th} replication effect

e_{ij} = error term

Analysis of variance (ANOVA):

The analysis of variance was compared in the following table

Table 3.4: Estimation of different components in the analysis of variance

Sources of variance	df	Sun of squares	Mean sum squares	F _{cal}	F _{tab}
Replication	r-1	RSS	RMS	RMS/E	
Treatment	t-1	TSS	TMS	MS	
Error	(r-1) (t-1)	ESS	EMS	TMS/E	
Total	Rt-1	Total SS		MS	

Where, r = number of replications
 t = number of treatments
 df = degrees of freedom
 RSS = replication sum of square
 TSS = treatment sum of square
 ESS = Error sum of square
 RMS = replication mean sum of square
 TMS = treatment mean sum of square
 EMS = error mean sum of square

3.6.2 Critical difference

To compare the means of varieties, we have to calculate the difference (CD) by the following formula:

$$CD = S.E_D \times t$$

Where, $S.E_D$ (standard error of difference of the treatment means to be compared)

$$= \frac{\sqrt{2I}}{r}$$

and t is the table value at 5% level of significance for the error df

$$\text{Thus } CD = \frac{\sqrt{2I}}{r} \times t_{0.05}$$

3.6.3 Coefficient of variation

The coefficient of variation (C.V) being a unit less measurement is a good basis comparing the extent of variation between characters with different scales.

$$C.V = \frac{S.D}{\bar{X}} \times 100$$

Where, $S.D$ = Standard deviation = \sqrt{MES}

\bar{X} = Grand mean

3.6.4 Components of variance

Considering that all the varieties tested here were genetically uniform, the expected error mean sum of squares or E (MSE) i.e. will be purely a random environmental variance. The mean sum of between varieties will consist of variances.

- (i) Attributable to varietal difference (i.e. genotypic differences) and
- (ii) Due to environmental variation among individuals of each genotype. Thus the expected mean sum of square are as follow:

$$E(MST) = \frac{1}{r} \sum_{i=1}^r \sigma^2_g \quad (r = \text{no. of replication})$$

$$E(MSE) = \sigma^2_e$$

Therefore,

$$\sigma^2_g = \frac{M - M}{r}$$

Now, the genotypic variance being σ^2_g and environmental variance being σ^2_e . The phenotypic variance i.e. σ^2_p will be equal to

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

Phenotypic coefficient of variation (PCV)

$$PCV = \frac{\sqrt{\sigma^2_p}}{\bar{X}} \times 100 = \frac{P}{G} \frac{s_d}{m} \times 100$$

Genotypic coefficient of variation (GCV)

$$GCV = \frac{\sqrt{\sigma^2_g}}{\bar{X}} \times 100 = \frac{G}{G} \frac{s_d}{m} \times 100$$

3.6.5 Heritability (Broad sense)

The heritability is the ratio of genotypic variance to phenotypic variance.

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p} \times 100 = \frac{G}{P} \frac{v}{v} \times 100$$

3.6.6 Genetic advance (GA)

$$\text{Genetic advance (GA)} = k \times h^2 \times \sigma_p$$

Where,

K = a constant (The value equal to 2.06 at 5 % selection intensity)

h^2 = heritability in broad sense

σ_p = phenotypic standard deviation

3.6.7 Correlation coefficient (r)

It is the degree of association between any two variables. Correlation coefficients are calculated using the following formula:

$$R(X_1, X_2) = \frac{C(X_1, X_2)}{\sqrt{v(X_1) \cdot v(X_2)}}$$

Where, $R (X_1, X_2) =$ correlation coefficient between X_1, X_2

$Cov (X_1, X_2) =$ covariance of X_1, X_2

$v (X_1) =$ variance of X_1

$v (X_2) =$ variance of X_2

3.6.8 Path co-efficient analysis

The concept of path coefficient analysis was originally developed by Wright in 1921. But the technique was first used for plant selection by Dewey and Ln in 1959. Path analysis is simply standardized partial regression coefficient which splits the correlation coefficient into the measure of direct and indirect effects of a set of independent variables.

Path coefficient : Direct and Indirect effect

$$\begin{array}{c} \mathbf{A} \end{array} \quad \begin{array}{c} \mathbf{B} \end{array} \quad \begin{array}{c} \mathbf{C} \end{array}$$

$$\begin{bmatrix} r_{y1} \\ r_{y2} \\ \dots \\ r_{yn} \end{bmatrix} = \begin{bmatrix} r_{11} \ r_{12} \ \dots \ r_{1n} \\ r_{21} \ r_{22} \ \dots \ r_{2n} \\ \dots \\ r_{n1} \ r_{n2} \ \dots \ r_{nn} \end{bmatrix} \begin{bmatrix} P_1 \\ P_2 \\ \dots \\ P_n \end{bmatrix}$$

Or, $A = B.C$

$C = B^{-1}.A$

Here, $r_{11}, \dots, r_{nn} =$ Correlation coefficients among independent variable

r_{y1}, \dots, r_{yn} Correlation coefficients of dependent variable with independent variables

$P_1, P_2, P_3, \dots, P_n$ are direct paths

Indirect paths for the first variable are

$r_{11} \times P_1, r_{12} \times P_2, \dots, r_{1n} \times P_n$

Residual effect $= (1 - P_1 \times r_{y1} - \dots - P_n \times r_{yn}) \frac{1}{2}$

3.6.9 Drought tolerance indices:

Different drought tolerance indices include Stress Tolerance (Tol), Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Susceptibility Index (SSI), Stress Tolerance Index (STI), Harmonic Mean (HAM), Yield Index (YI) and Yield Stability Index (YSI) were evaluated based on grain yield under drought (Y_s) and irrigated condition (Y_p).

Table 3.5: Estimation of different drought tolerant indices along with their formula

Index	Formula	Reference
Stress Tolerance	$TOL = Y_p - Y_s$	Rosielle and Hamblin [1981]
Mean Productivity	$MP = (Y_p + Y_s) / 2$	Rosielle and Hamblin [1981]
Geometric Mean Productivity	$GMP = (Y_p * Y_s)^{0.5}$	Fernandez [1992]
Stress Susceptibility Index	$SSI = [(1 - (Y_s / Y_p)) / SI]$	Fischer and Maurer [1978]
(Stress Index)	$SI = 1 - (s / p)$	
Stress Tolerance Index	$STI = (Y_p * Y_s) / (p)^2$	Fernandez [1992]
Harmonic Mean	$HAM = [2 * (Y_p * Y_s)] / (y_p + Y_s)$	Kristin <i>et al.</i> , [1997]
Yield Index	$YI = Y_s / s$	Lin <i>et al.</i> , [1986]
	$YSI = Y_s / Y_p$	Bousslama and Schapaugh [1984]

Y_p and Y_s : Grain yield of each genotype under non-stress and stress conditions, respectively

p and s : Mean grain yield of all genotypes under non-stress and stress conditions, respectively

Genotypes may be further grouped into four categories based on their production in irrigated and drought conditions (Fernandez, 1992). The first group consists of genotypes with high production under both conditions (Group A), second group having genotypes with high production only under non stress conditions (Group B), third group containing genotypes with high production only under stress condition (Group C) and fourth group having genotypes with weak production under both conditions (Group D).

CHAPTER IV

Results and Discussion

Results and Discussion

4.1 Variability, Heritability and Genetic Advance

4.1.1 Studies on variability

Variability of the genotypes under study was measured under drought and irrigated condition separately (Table 4.1 & 4.2 respectively). Polled variability was also measured (Table 4.3). The genotypes varied significantly for the traits like germination (%), days to heading (75%), days to maturity, plant height, tillers per meter, grains per spike, and yield per plot, etc. under both drought, irrigated and pooled conditions. It revealed that genotypes had enough variability for the concerned traits. But traits like test weight and spike length did not show significant variation either in drought condition or in both.

Difference between two environments (i.e. drought and irrigated) was found significant for most of the traits germination (%). Genotype and environmental interaction was also significant for all traits barring test weight, germination (%) and spike length.

4.1.2 Studies on mean values

Mean performance of the genotypes were calculated and presented in Table 4.4 and 4.5. Overall mean and variation (%) were also presented in Table 4.6. Variation (%) was calculated using following formula:

Variation (%) = (Mean of genotypes under stress condition - Mean of genotypes under irrigated condition) / Mean of genotypes under irrigated condition.

- 1. Germination (%):** Germination (%) varied from 49.95 (HI 1579) to 94.91(RAJ 4257) under drought condition and 58.28 (HI 1579) to 94.91(AKAW 473) under irrigated condition. Overall mean value of germination was 81.52% in case of irrigated condition while it was 70.44% in case of drought stress condition. The variation (%) was -13.50 showing minor variation between drought and irrigated condition..
- 2. Days to heading (75%):** Days to heading (75%) varied from 63.00 (GW-09-264) to 86.00 (KLY 1086) under drought condition and 69.50 (GW-2010-345) to 101.00 (VL 950) under irrigated condition. Overall mean value of heading was 82.60 in case of irrigated condition while it was 71.65 in case of drought stress condition. The variation (%) was -13.25 revealing shorter duration of flowering under drought condition.

Table 4.1: Analysis of variance for growth and reproductive characters of wheat genotypes in drought condition

Sources	df	Mean Square								
		Germination (%)	Days to heading (50%)	Days to maturity	Plant height (cm)	Tillers per meter	Grains per spike	Spike length (cm)	Test weight (g)	Grain yield per plot (g)
Replication	1	393.88*	21.59**	4.50	74.94	284.58**	2.00	0.29	33.86	637.76
Genotype	48	161.99*	71.59**	55.36**	91.13**	78.01**	45.27**	3.32**	15.79	6023.77**
Error	48	93.32	2.76	4.27	20.27	15.71	3.73	0.53	16.24	1673.17
CV		13.71	2.32	1.74	5.53	7.72	4.27	9.53	8.10	16.34

*, **= Significant at 5% and 1% levels respectively

Table 4. 2: Analysis of variance for growth and reproductive characters of wheat genotypes in irrigated condition

Sources	df	Mean Square								
		Germination (%)	Days to heading (50%)	Days to maturity	Plant height (cm)	Tillers per meter	Grains per spike	Spike length (cm)	Test weight (g)	Grain yield per plot (g)
Replication	1	670.87**	15.52	19.76	10.51	112.50**	0.65	34.17	2.24	2159.18
Genotype	48	155.93*	161.33**	121.07**	223.46**	226.10**	56.05**	23.88	1.87	9881.76**
Error	48	98.18	4.91	7.80	27.31	7.77	5.26	20.75	1.70	2127.93
CV		12.16	2.68	2.19	5.54	3.89	4.30	14.05	9.54	14.22

*, **= Significant at 5% and 1% levels respectively

Table. 4.3: Pooled analysis of variance for growth and reproductive characters of wheat genotypes

Sources	Df	Mean Square								
		Germination (%)	Days to heading (50%)	Days to maturity	Plant height (cm)	Tillers per meter	Grains per spike	Spike length (cm)	Test weight (g)	Grain yield per plot (g)
Environment	1	6012.67	5874.12**	3405.55**	8172.16**	20245.22**	3200.33**	73572.30**	53318.76**	269657.65**
Error	2	532.38	18.55	12.12	42.72	198.54	1.32	17.23	18.04	1398.47
Genotype	48	239.19**	162.15**	138.98**	205.44**	207.92**	72.75**	10.88	8.11	14617.67**
GxE	48	78.72	70.76**	37.45**	109.14**	96.19**	28.58**	16.31	9.56	1287.86**
Error	96	95.75	3.83	6.03	23.78	11.73	4.49	10.64	8.91	1900.55
CV		12.88	2.54	1.99	5.55	5.57	4.30	11.62	11.50	15.17

*, **= Significant at 5% and 1% levels respectively

Table 4.4: Mean performance of 49 genotypes of wheat under drought and irrigated condition for different growth attributes

Sl. No.	Genotypes	Germination(%)		Days to flowering (75%)		Days to maturity (75%)		Plant height	
		Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated
1.	AKAW 3717	79.92	81.59	71.50	82.50	115.50	120.50	87.10	96.25
2	AKAW 4705	64.94	69.93	72.50	73.50	130.50	135.00	84.80	84.15
3	AKAW 4730	63.27	66.60	70.00	90.00	117.00	141.50	83.00	88.40
4	AKAW 473	71.60	94.91	80.00	82.50	116.50	125.50	76.00	78.90
5	C 306	59.94	86.58	69.50	86.00	128.00	140.00	70.00	85.10
6	GW-09-260	68.27	78.26	66.50	67.00	116.00	117.00	72.40	109.00
7	GW 2010-343	66.60	81.59	71.00	79.50	127.00	131.00	90.80	114.00
8	GW-2010-345	64.94	84.92	67.00	69.50	117.00	131.00	72.50	89.80
9	Gw-09-262	71.60	84.92	73.50	85.00	118.00	123.00	74.10	86.40
10	GW-09-264	61.61	64.94	63.50	73.50	121.00	128.50	75.20	93.80
11	GW-09-269	68.27	74.93	68.50	71.00	117.50	123.50	67.00	95.60
12	GW-09-270	74.93	76.59	82.50	87.00	128.00	134.50	78.35	95.00
13	HI 1564	56.61	86.58	73.50	94.00	118.00	121.00	81.90	90.50
14	HI 1579	49.95	58.28	73.50	92.00	122.00	134.50	80.75	94.50
15	HI 1580	66.60	94.91	68.00	98.50	116.50	117.50	79.10	91.50
16	HI 1581	63.27	81.59	74.00	91.00	120.00	133.00	82.20	85.00
17	K 0624	54.95	68.27	66.50	67.00	116.00	117.00	75.80	90.80
18	KLP 1032	76.59	84.92	73.00	77.50	117.50	127.50	83.90	91.20
19	KLP 1042	73.26	91.58	71.00	73.50	116.00	121.50	89.00	122.30
20	KLP 1043	81.59	93.24	75.00	82.00	117.50	124.00	73.10	107.50
21	KLP 1045	71.60	78.26	70.00	90.50	116.50	136.00	88.00	110.60
22	KLP 3077	86.58	93.24	72.50	82.00	120.50	127.50	85.70	84.50
23	KLP 3105	59.94	88.25	85.50	89.50	108.50	121.50	84.50	100.30
24	KLP 3129	68.27	86.58	74.50	89.00	130.50	135.50	85.20	111.85
25	KLY 1081	63.27	66.60	83.00	95.00	120.00	138.00	92.10	95.30
26	KLY 1086	78.26	93.24	86.00	87.50	117.50	119.50	95.10	108.80
27	KYP 0826	63.27	84.92	82.00	82.00	125.50	132.50	90.00	95.20
28	NI 5439	61.61	84.92	73.50	80.50	118.00	131.50	82.70	101.50
29	NIAW 1689	76.59	78.26	67.00	67.50	116.00	127.50	80.00	84.30
30	NIAW 656	59.94	81.59	71.50	82.00	117.00	118.00	84.40	94.40
31	NWL-9-15	64.94	78.26	66.50	87.00	112.50	118.00	78.80	118.50
32	RAJ 4083	69.93	73.26	68.50	71.00	116.00	119.00	75.65	80.60
33	RAJ 4128	76.59	83.25	69.50	74.50	116.50	116.50	89.20	93.00
34	GW-09-264	83.25	91.58	63.00	90.00	117.50	120.50	89.00	96.40
35	RAJ 4168	79.92	78.26	65.50	67.50	120.00	125.00	67.60	73.30
36	RAJ 4169	68.27	84.92	67.00	72.50	117.00	118.00	73.50	88.90
37	RAJ 4254	73.26	83.25	65.00	84.50	118.00	131.00	75.40	102.60
38	RAJ 4257	94.91	91.58	69.00	82.00	116.00	118.50	85.30	101.75
39	RAJ 4258	66.60	63.27	71.50	91.50	120.00	127.00	82.50	87.00
40	RS 1002	68.27	73.26	77.50	79.50	105.50	116.00	78.70	82.50
41	RS 1017	69.93	78.26	64.50	83.00	129.50	136.50	82.80	80.60
42	VL 950	79.92	83.25	85.50	101.00	116.50	141.00	82.80	92.90
43	VL 952	78.26	84.92	70.50	97.00	116.50	129.00	85.90	85.05
44	WH 1022	83.25	88.25	65.50	70.00	117.00	127.00	74.60	86.30
45	WS 902	78.26	86.58	69.00	91.00	118.50	137.50	86.20	105.30
46	WS 903	74.93	76.59	74.00	92.50	128.50	138.00	75.10	92.85
47	WS 904	83.25	91.58	62.50	83.50	116.00	116.50	93.20	90.00
48	WS 905	61.61	88.25	67.50	84.00	115.50	132.50	87.10	94.35
49	WSM 1472	68.27	74.93	73.00	77.50	128.00	137.00	79.70	92.20

Table 4.5: Mean performance of 49 genotypes of Wheat under drought and irrigated condition for different reproductive traits

Sl. No.	Genotypes	Tillers per meter		Grains per spike		Spike length (cm)		Test weight (g)		Grain yield per plot (g)	
		Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated
1.	AKAW 3717	56.50	75.50	45.00	47.00	7.90	8.55	41.68	45.72	395.00	425.00
2	AKAW 4705	56.00	62.50	40.00	59.50	7.35	7.75	42.74	46.65	190.00	210.00
3	AKAW 4730	51.50	75.50	46.00	52.00	10.35	8.85	42.52	45.92	315.00	385.00
4	AKAW 473	39.50	73.50	49.50	55.50	9.35	10.25	44.54	47.80	200.00	275.00
5	C 306	52.50	79.50	51.00	56.00	8.85	10.55	46.36	51.50	215.00	290.00
6	GW-09-260	57.00	69.00	45.00	61.50	8.00	9.30	49.38	47.64	275.00	390.00
7	GW 2010-343	49.50	84.50	42.00	49.50	6.65	7.20	43.80	52.68	290.00	340.00
8	GW-2010-345	47.00	62.50	39.00	59.00	8.10	8.95	44.74	52.62	230.00	310.00
9	Gw-09-262	48.00	76.00	41.00	51.00	8.95	9.55	41.38	46.64	275.00	325.00
10	GW-09-264	52.00	65.50	50.50	55.50	7.70	8.95	40.58	53.74	290.00	325.00
11	GW-09-269	47.00	63.50	48.00	62.50	9.50	9.90	45.38	53.32	210.00	290.00
12	GW-09-270	49.00	60.50	45.50	48.00	7.70	7.20	39.88	48.06	155.00	215.00
13	HI 1564	43.50	63.50	51.50	59.00	8.75	10.45	38.00	46.62	275.00	310.00
14	HI 1579	41.50	53.00	51.50	54.50	10.85	10.20	43.90	44.18	300.00	500.00
15	HI 1580	48.50	71.00	51.00	57.00	8.75	9.05	36.62	47.00	265.00	310.00
16	HI 1581	55.50	93.00	38.50	53.50	9.30	10.95	40.60	46.12	325.00	380.00
17	K 0624	46.50	65.00	46.50	61.50	9.85	8.60	41.72	40.78	235.00	325.00
18	KLP 1032	55.00	92.50	52.50	60.50	9.55	8.90	43.80	55.34	200.00	250.00
19	KLP 1042	42.50	59.00	44.50	50.00	10.95	10.95	41.42	50.98	275.00	305.00
20	KLP 1043	50.00	58.00	49.50	54.00	11.30	10.20	47.46	45.28	330.00	425.00
21	KLP 1045	55.00	73.50	42.00	49.50	9.50	9.75	39.76	45.92	310.00	350.00
22	KLP 3077	50.00	60.00	49.50	61.00	9.60	8.95	41.76	47.40	190.00	225.00
23	KLP 3105	51.50	65.50	49.00	58.50	11.20	9.60	47.10	45.04	240.00	350.00
24	KLP 3129	52.50	60.50	50.00	54.00	9.35	10.65	40.74	50.20	335.00	475.00
25	KLY 1081	57.50	95.50	50.50	52.50	10.70	8.90	38.94	46.90	245.00	300.00
26	KLY 1086	53.50	79.50	43.50	43.50	7.00	8.35	41.92	44.02	225.00	280.00
27	KYP 0826	56.00	67.00	43.00	58.00	7.35	9.00	40.08	49.96	300.00	450.00
28	NI 5439	44.50	72.00	49.00	56.00	8.00	9.60	39.32	45.42	230.00	255.00
29	NIAW 1689	40.50	64.00	51.50	55.50	8.60	9.65	40.62	55.22	270.00	375.00
30	NIAW 656	55.00	72.00	49.00	52.00	6.00	7.35	43.18	47.78	325.00	455.00
31	NWL-9-15	39.50	60.00	39.00	39.00	9.35	9.25	41.46	50.68	210.00	275.00
32	RAJ 4083	43.00	55.50	43.00	48.50	9.15	8.45	43.38	45.28	180.00	210.00
33	RAJ 4128	60.50	69.50	42.00	56.00	8.15	8.75	48.14	51.48	200.00	275.00
34	GW-09-264	55.00	66.50	36.00	48.00	7.75	9.65	43.78	49.22	180.00	250.00
35	RAJ 4168	50.00	76.50	40.00	52.50	8.45	8.65	44.52	46.10	165.00	230.00
36	RAJ 4169	58.50	69.50	36.00	45.00	8.00	10.10	39.72	47.32	185.00	260.00
37	RAJ 4254	56.50	64.00	47.50	52.50	8.95	8.10	42.32	47.66	190.00	310.00
38	RAJ 4257	61.00	80.00	40.50	58.50	9.50	9.20	39.96	52.70	325.00	375.00
39	RAJ 4258	45.00	66.00	37.50	53.50	10.40	10.30	38.52	49.36	250.00	325.00
40	RS 1002	53.00	65.50	38.00	44.50	9.85	9.05	42.56	45.60	200.00	265.00
41	RS 1017	54.50	81.00	47.50	55.50	7.60	9.40	42.38	50.12	245.00	350.00
42	VL 950	66.00	85.00	43.50	46.50	12.10	10.85	39.94	43.44	260.00	350.00
43	VL 952	59.50	64.50	40.50	47.00	8.45	9.20	38.16	43.52	340.00	425.00
44	WH 1022	49.00	92.00	44.00	59.50	8.45	9.05	41.50	47.94	250.00	350.00
45	WS 902	45.50	67.50	52.00	56.00	10.45	9.05	43.54	44.22	200.00	275.00
46	WS 903	64.00	85.00	49.50	51.00	10.50	9.95	38.78	40.48	250.00	350.00
47	WS 904	51.50	84.50	48.50	49.00	9.45	9.35	41.88	42.88	200.00	300.00
48	WS 905	47.00	87.50	43.00	51.50	8.55	7.50	47.16	47.44	220.00	275.00
49	WSM 1472	51.00	78.00	44.00	51.50	8.95	10.85	43.54	47.86	300.00	350.00

Table 4.6: Mean values and variation of traits in wheat genotypes under irrigated and drought stress

Sources	Germination (%)	Days to heading (75%)	Days to maturity	Plant height (cm)	Tillers per meter	Grains per spike	Spike length (cm)	Test weight (g)	Grain yield per plot (g)
Irrigated condition	81.52	82.60	127.33	94.30	71.64	53.33	9.28	47.75	324.49
Drought stress	70.44	71.65	118.99	81.38	51.32	45.24	9.00	42.27	250.31
Variation %	-13.59	-13.25	-6.55	-13.69	-28.37	-15.15	-3.02	-11.48	-22.87

[Variation (%) = (Mean of genotypes under stress conditions – Mean of genotypes under normal conditions)/ Mean of genotypes under normal conditions]

1. **Days to maturity:** Days to maturity varied from 105.00 (RS 1002) to 130.00 (KLP 3129) under drought condition and 116.00 (WS 904) to 138.00 (WS 903) under irrigated condition. Overall mean value of maturity was 127.33 in case of irrigated condition while it was 118.99 in case of drought stress condition. The variation (%) was -6.55 confirming shorter duration of maturity under drought condition.
2. **Plant height:** Plant height varied from 67.00 (GW-09-269) to 93.20 (WS 904) under drought condition and 79.90 to 122.30 under irrigated condition. Overall mean value of plant height was 94.30 in case of irrigated condition while it was 81.38 in case of drought stress condition. The variation (%) was -13.69 revealing higher plant height under irrigated condition.
3. **Tillers per meter:** Tillers per meter varied from 39.50 (AKAW 473) to 61.00 (RAJ 4257) under drought condition and 53.00 (HI 1579) to 87.50 (WS 905) under irrigated condition. Overall mean value of tillers per meter was 71.64 in case of irrigated condition while it was 51.32 in case of drought stress condition. The variation (%) was -28.37 showing highest variation between drought and irrigated conditions.
4. **Grains per spike:** Grains per spike varied from 38.00 (RS 1002) to 52.00 (WS 902) under drought condition and 39.00 (NWL-9-15) to 62.50 (GW-09-269) under irrigated condition. Overall mean value was 53.33 in case of irrigated condition while it was 45.25 in case of drought stress condition. The variation (%) was -15.15.
5. **Spike length:** Spike length varied from 6.00 (NIAW 656) to 12.10 (VL 950) under drought condition and 7.20 (GW-2010-343) to 10.85 (VL 950) under irrigated condition. Overall mean value of spike length was 9.28 in case of irrigated condition while it was 9.00 in case of drought stress condition. The variation (%) was -3.02 showing least variation between drought and irrigated conditions.
6. **Test weight:** Test weight varied from 36.62 (HI 1580) to 49.38 (GW-09-260) under drought condition and 45.28 (KLP 1043) to 52.70 (RAJ 4257) under irrigated condition. Overall mean value of test weight was 47.75 in case of irrigated condition while it was 42.27 in case of drought stress condition. The variation (%) was -11.48.
7. **Grain yield:** Grain yield varied from 155.00 (GW-09-270) to 395.00 (AKAW 3717) under drought condition and 210.00 (AKAW 4705) to 500.00 (HI 1579) under irrigated condition. Overall mean value of yield was 324.49 in case of irrigated condition while it was 250.31 in case of drought stress condition. The variation (%) between drought and irrigated conditions was -22.87 in case of grain yield.

All the genotypes performed poorly under drought stress condition than irrigated condition for all the characters under study. Highest variation (%) among the genotypes between drought and irrigated

conditions were found for tillers per meter (-28.37%) and yield per plot (-22.87%) which indicated that these two traits were greatly affected by drought stress.

4.1.3 Studies on GCV, PCV, genetic advance and heritability

Genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), genetic advance and heritability under broad sense and genetic advance were measured under drought and irrigated condition (Table 4.7). Genotypic coefficient of variation (GCV) was poor for traits like germination (%), days to heading, days to maturity, plant height, grains per spike, spike length and test weight under both the conditions while it was moderate in case of yield per plot and tillers per meter. Similar result was found by Chaturvedi and Gupta (1995), Jag Shoran (1995), Singh *et al.* (1996).

Phenotypic coefficient of variation (PCV) was also poor for most of these traits. High PCV was found in case of germination (%), grain yield per plot (g) and tillers per meter under both conditions and for test weight in drought condition. This was in conformity with earlier findings of Shivkumar (1994), Sharma *et al.*(1998), Thakur *et al.*(1999), Nayeem *et al.*(2003), Liu and ma (1994), Bahadur *et al.*(1994).

Heritability under broad sense value was poor for traits like germination (%), plant height, spike length, test weight and yield per plot. Characters like days to heading, days to maturity, tillers per meter and grains per spike showed good heritability value. Similar findings was found by Dixit *et al.*(1990), Senapathi *et al.*(1994), Raha and Ramguru (1998), Khiralla (1993), Kamboj *et al.*(2000).

In case of genetic advance, traits like days to heading, plant height, tillers per meter and grains per spike showed promising values. This has conformity with findings of Mandal *et al.*(1991), Pawara *et al.*(2002), Bahadur *et al.*(1994).

If we consider both heritability under broad sense and genetic advance together, then characters like days to heading, tillers per meter and grains per spike showed some promise towards selection for onward transmission to next generation.

4.1.4 Studies on character association

4.1.4.1 Drought condition

Among the characters, germination (%) had positive and significant association with plant height; tillers per meter and spike length at genotypic level under drought condition (Table 4.8) whereas significantly negative association was found with grains per spike. At phenotypic level it was only positively correlated with tillers per meter.

Table 4.7: GCV, PCV, Genetic advance and heritability of different traits under drought and irrigated conditions

Parameter	Germination (%)		Days to heading (75%)		Days to maturity		Plant height (cm)		Tillers per meter		Grains per spike		Spike length (cm)		Test weight(g)		Grain yield per plot (g)	
	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated	Drought	Irrigated
PCV	16.040	13.828	8.509	11.038	4.589	6.304	9.171	11.875	13.340	15.094	10.940	10.383	9.468	14.403	15.409	9.893	24.784	23.881
GCV	8.318	6.592	8.187	10.706	4.248	5.911	7.314	10.502	10.877	14.584	10.073	9.451	1.121	3.153	13.106	2.622	18.633	19.189
h²(B.S)	0.269	0.227	0.926	0.941	0.857	0.879	0.636	0.782	0.665	0.934	0.848	0.829	-0.014	0.048	0.724	0.070	0.565	0.646
GA (%)	11.388	8.296	20.797	27.416	10.380	14.630	15.400	24.521	23.413	37.200	24.486	22.709	-0.350	1.822	29.432	1.834	36.983	40.704

Table.4.8: Genotypic and phenotypic correlation coefficients among different characters under Drought condition

Characters		2	3	4	5	6	7	8	Grain yield/plot (g)
1. Germination (%)	r_g	-0.14	-0.093	0.296**	0.515**	-0.347**	0.348	0.0551	-0.257 *
	r_p	-0.079	-0.121	0.09	0.248 *	-0.092	-0.023	0.058	-0.023
2. Days to heading (75%)	r_g		0.027	0.352**	0.167	0.124	0.961**	0.305**	0.119
	r_p		0.037	0.234 *	0.151	0.113	-0.051	0.216*	0.067
3. Days to maturity	r_g			0.004	0.169	0.204*	0.816**	-0.306 **	0.089
	r_p			0.002	0.147	0.13	-0.083	-0.242 *	0.037
4. Plant height(cm)	r_g				0.296 **	-0.074	0.768 **	-0.094	0.218 **
	r_p				0.14	0.004	-0.197	-0.073	0.199
5. Tillers per meter	r_g					-0.228*	0.169	-0.149	0.229 *
	r_p					-0.192	-0.082	-0.017	0.153
6. Grains per spike	r_g						-0.465**	-0.149	0.065
	r_p						-0.012	0.191	0.117
7. Spike length(cm)	r_g							-0.207 *	0.670 **
	r_p							-0.053	-0.144
8. Test weight(g)	r_g								-0.022
	r_p								0.0768

*, **= Significant at 5% and 1% levels respectively

[r_g = Genotypic correlation; r_p = Phenotypic correlation]

Days to heading was found positively correlated with plant height, spike length and test weight at genotypic level whereas phenotypically it was only correlated with plant height and test weight.

Days to maturity was positively correlated with tillers per meter and spike length genotypically while it had negative association with test weight both genotypic and phenotypic level.

Plant height had significantly positive association with tillers per meter and spike length at genotypic level only.

Among the reproductive traits, tillers per meter were positively correlated with yield per plot while negatively correlated with grains per spike at genotypic level only. Spike length was negatively correlated with grains per spike and test weight genotypically.

Yield per plot was found positively correlated with plant height, tillers per meter and spike length at genotypic level only. It indicates these traits may be used as drought stress tolerance indicator which has direct impact on yield. The results had conformity with the findings of Saini *et al.* (1990), Mahesh *et al.* (2001), Khan *et al.* (1999), Naik (2000), Gautam and Sethi (2002) and Sudesh *et al.* (2002).

4.1.4.2 Irrigated condition:

Under irrigated condition, significant and positive association was found between germination(%) and plant height, days to heading and days to maturity, days to heading and grains per spike, days to heading and tillers per meter while negative association was found between germination(%) and days to maturity, days to heading and test weight, grains per spike and test weight (Table 4.9).

Yield was found positively correlated with days to heading, days to maturity, plant height and spike length while it was negatively correlated with test weight. It has similarity with findings of Tammam *et al.* (2000), Nayeem *et al.* (2003), Jadhav *et al.* (1994), Nirmala and Jha (1996), Yadav and Singh (1991), Khan *et al.* (1999).

4.1.5 Path coefficient analysis

4.1.5.1 Direct effect

Positive and high direct effect was found with days to heading, days to maturity, plant height and spike length on grain yield under drought condition (table 4.10) while under irrigated condition high direct effect was found with germination (%), plant height, grains per spike and test weight only (Table 4.11). This result has conformity with earlier findings of Chaturvedi and Gupta (1995), Halloli (1997), Narwal *et al.* (1999), Ibrahim (1994), Deshmukh *et al.* (1990).

Table.4.9: Genotypic and phenotypic correlation coefficients among different characters under Irrigated condition

Characters		2	3	4	5	6	7	8	Grain yield/plot (g)
1. Germination(%)	r_g	0.197	-0.493**	0.351**	0.236*	0.01	0.678**	0.124	-0.21*
	r_p	0.067	-0.208 *	0.1363	0.1	0.006	0.0352	-0.082	-0.076
2.Days to heading (75%)	r_g		0.367**	0.119	0.167	0.343**	0.682**	-0.421**	0.269**
	r_p		0.345**	0.134	0.162	0.302**	0.173	-0.298**	0.21
3.Days to maturity	r_g			-0.075	0.167	0.089	0.582**	-0.018	0.221*
	r_p			-0.061	0.247 *	0.058	0.069	-0.032	0.097
4.Plant height(cm)	r_g				-0.18	-0.222*	0.375**	0.316**	0.239*
	r_p				-0.143	-0.184	-0.045	0.082	0.217
5.Tillers per meter	r_g					-0.033	-0.188	-0.109	0.003
	r_p					-0.031	-0.010	-0.018	-0.038
6.Grain per spike	r_g						0.224*	-0.482**	0.072
	r_p						0.02	0.147	0.063
7.Spike length(cm)	r_g							0.193	0.593**
	r_p							-0.042	0.14
8.Test weight(g)	r_g								-0.355**
	r_p								-0.010

*, **= Significant at 5% and 1% levels respectively

[r_g = Genotypic correlation; r_p = Phenotypic correlation]

Table 4.10: Genotypic and phenotypic path of different yield components on grain yield under Drought condition

Characters		1	2	3	4	5	6	7	8
1.Germination(%)	G	-0.132	0.019	0.012	-0.039	-0.068	0.046	-0.046	-0.007
	P	-0.088	0.007	0.011	-0.008	-0.022	0.008	0.002	-0.005
2.Days to heading (75%)	G	-0.098	0.695	0.018	0.245	0.116	0.086	0.668	0.212
	P	0.004	-0.044	-0.002	-0.010	-0.007	-0.005	0.002	-0.010
3.Days to maturity	G	-0.081	0.023	0.874	0.003	0.148	0.178	0.714	-0.267
	P	0.001	0.000	-0.004	0.000	-0.001	-0.001	0.000	0.001
4.Plant height(cm)	G	0.183	0.218	0.002	0.619	0.183	-0.046	0.475	-0.058
	P	0.016	0.042	0.000	0.180	0.025	0.001	-0.036	-0.013
5.Tillers per meter	G	-0.075	-0.024	-0.025	-0.043	-0.145	0.033	-0.025	0.022
	P	0.044	0.027	0.026	0.025	0.176	-0.034	-0.015	-0.003
6.Grain per spike	G	0.215	-0.077	-0.126	0.046	0.141	-0.619	0.288	-0.164
	P	-0.012	0.015	0.017	0.001	-0.025	0.132	-0.002	0.025
7.Spike length(cm)	G	-0.275	-0.758	-0.644	-0.605	-0.134	0.367	0.789	0.164
	P	0.002	0.005	0.008	0.018	0.008	0.001	0.093	0.005
8.Test weight(g)	G	0.004	0.024	-0.024	-0.007	-0.012	0.021	-0.016	0.078
	P	0.004	0.017	-0.019	-0.006	-0.001	0.015	-0.004	0.076

Residual effect (Genotypic): 0.322; Residual effect (Phenotypic): 0.75

[G= Genotypic path; P= Phenotypic path] 1% levels

Table 4.11: Genotypic and phenotypic path of different yield components on grain yield under Irrigated condition

Characters		1	2	3	4	5	6	7	8
1. Germination (%)	G	0.588	0.116	-0.290	0.206	0.139	0.006	0.399	0.661
	P	-0.128	-0.009	0.027	-0.017	-0.013	-0.001	-0.005	0.011
2. Days to heading (75%)	G	0.446	0.261	0.829	0.269	0.378	-0.775	0.541	-0.883
	P	0.015	0.226	0.078	0.030	0.037	-0.068	0.039	-0.067
3. Days to maturity	G	-0.596	0.444	0.209	-0.091	0.321	0.108	0.704	-0.022
	P	0.001	-0.002	-0.006	0.000	-0.002	0.000	0.000	0.000
4. Plant height(cm)	G	0.110	0.037	-0.024	0.314	-0.056	-0.070	0.118	0.099
	P	0.032	0.032	-0.014	0.237	-0.034	-0.044	-0.011	0.020
5. Tillers per meter	G	-0.252	-0.179	-0.284	0.193	-0.071	0.036	0.201	0.117
	P	-0.002	-0.003	-0.005	0.003	-0.020	0.001	0.000	0.000
6. Grain per spike	G	0.005	-0.174	0.045	-0.112	-0.017	0.506	0.113	0.447
	P	0.001	-0.052	0.010	-0.032	-0.005	0.172	0.004	0.025
7. Spike length(cm)	G	-0.454	-0.462	-0.249	-0.804	0.403	-0.480	-0.145	-0.413
	P	0.004	0.020	0.008	-0.005	-0.001	0.002	0.113	-0.005
8. Test weight(g)	G	0.944	-0.774	-0.015	0.266	-0.092	0.741	0.162	0.840
	P	-0.001	-0.002	0.000	0.001	0.000	0.001	0.000	0.006

Residual effect (Genotypic): 0.67; Residual effect (Phenotypic): 0.83

[G= Genotypic path; P= Phenotypic path] 1% levels

4.1.5.2 Indirect effect

Indirect effect of days to heading was high through germination (%), days to maturity, tillers per meter and spike length under irrigated condition while under drought condition it was only high through spike length only.

Among the reproductive traits, indirect effect of grains per spike was high through test weight under irrigated condition only. Spike length had high negative indirect effect through plant height, grains per spike and test weight but positive effect through tillers per meter under irrigated condition.

Genotypic residual effect was low (0.322) while phenotypic residual effect was high (0.75) under drought condition. But under irrigated both the effects are quite high (0.67 & 0.83).

4.1.6 Drought tolerance indices

Different drought tolerance indices include Stress Tolerance (Tol), Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Susceptibility Index (SSI), Stress Tolerance Index (STI), Harmonic Mean (HAM), Yield Index (YI) and Yield Stability Index (YSI) were evaluated based on grain yield under drought (Y_s) and irrigated condition (Y_p) and presented in Table.4.12.

Calculation of tolerance indices showed that highest Stress tolerance (TOL) and Stress Susceptibility Index (SSI) value were related to genotypes HI 1579, KYP 0826, KLP 3129, NIAW 656, RAJ 4254 indicating that these genotypes had higher grain yield reduction under rainfed condition and highest drought sensitivity (Table 4.12 & 4.13). AKAW 3717, AKAW 4705, NI 5439, KLP 1042 were the most tolerant genotypes based on TOL and SSI values with their low quantity as indication towards tolerant genotypes.

AKAW 3717, HI 1579, KLP 3129, NIAW 656, VL 952 were found to be the tolerant genotypes based on Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Tolerance Index (STI), Harmonic Mean (HAM) and Yield Index (YI) with their high value as indication towards tolerance (Table 4.12 & 4.13). Based on these current indices GW-09-270, RAJ 4083, RAJ 4168 and AKAW 4705 were the most sensitive genotypes. In terms of Yield Stability Index (YSI) genotype AKAW 3717 and AKAW 4705 were having the highest value while genotype HI 1579 and RAJ 4254 had lowest value indicating highest and lowest stability respectively.

Ranking of genotypes in respect to all drought tolerance indices revealed that genotype KLP 3129, NIAW 656 and HI 1579 had the best mean rank (Table 4.13).

Table 4.12: Different drought indices of wheat genotypes calculated on the basis of yield per plot in drought and irrigated conditions

Sl. No.	Genotypes	Irrigated (Y _p)	Drought (Y _s)	TOL	MP	GMP	SSI	STI	HAM	YI	YSI
1.	AKAW 3717	425.00	395.00	30	410.00	409.72	0.31	1.59	409.45	1.58	0.93
2	AKAW 4705	210.00	190.00	20	200.00	199.75	0.42	0.38	199.50	0.76	0.90
3	AKAW 4730	385.00	315.00	70	350.00	348.24	0.80	1.15	346.50	1.26	0.82
4	AKAW 473	275.00	200.00	75	237.50	234.52	1.19	0.52	231.58	0.80	0.73
5	C 306	290.00	215.00	75	252.50	249.70	1.13	0.59	246.93	0.86	0.74
6	GW-09-260	390.00	275.00	115	332.50	327.49	1.29	1.02	322.56	1.10	0.71
7	GW 2010-343	340.00	290.00	50	315.00	314.01	0.64	0.94	313.02	1.16	0.85
8	GW-2010 345	310.00	230.00	80	270.00	267.02	1.13	0.68	264.07	0.92	0.74
9	Gw-09-262	325.00	275.00	50	300.00	298.96	0.67	0.85	297.92	1.10	0.85
10	GW-09-264	325.00	290.00	35	307.50	307.00	0.47	0.90	306.50	1.16	0.89
11	GW-09-269	290.00	210.00	80	250.00	246.78	1.21	0.58	243.60	0.84	0.72
12	GW-09-270	215.00	155.00	60	185.00	182.55	1.22	0.32	180.13	0.62	0.72
13	HI 1564	310.00	275.00	35	292.50	291.98	0.49	0.80	291.45	1.10	0.89
14	HI 1579	500.00	300.00	200	400.00	387.30	1.75	1.42	375.00	1.20	0.60
15	HI 1580	310.00	265.00	45	287.50	286.62	0.63	0.78	285.74	1.06	0.85
16	HI 1581	380.00	325.00	55	352.50	351.45	0.63	1.17	282.64	1.30	0.85
17	K 0624	325.00	235.00	90	280.00	276.36	1.21	0.72	272.77	0.94	0.70
18	KLP 1032	250.00	200.00	50	225.00	223.61	0.87	0.47	222.22	0.80	0.80
19	KLP 1042	305.00	275.00	30	290.00	289.61	0.43	0.80	289.22	1.10	0.90
20	KLP 1043	425.00	330.00	95	377.50	374.50	0.98	1.33	371.52	1.32	0.77
21	KLP 1045	350.00	310.00	40	330.00	329.39	0.50	1.03	328.79	1.24	0.89
22	KLP 3077	225.00	190.00	35	207.50	206.76	0.68	0.40	206.02	0.76	0.84
23	KLP 3105	350.00	240.00	110	295.00	289.83	1.37	0.80	284.74	0.96	0.68
24	KLP 3129	475.00	335.00	140	405.00	398.90	1.29	1.51	392.90	1.34	0.70
25	KLY 1081	300.00	245.00	55	272.50	271.10	0.80	0.70	269.72	0.98	0.82
26	KLY 1086	280.00	225.00	55	252.50	250.99	0.86	0.60	249.50	0.90	0.80
27	KYP 0826	450.00	300.00	150	375.00	367.42	1.46	1.28	360.00	1.20	0.67
28	NI 5439	255.00	230.00	25	242.50	242.18	0.43	0.56	241.85	0.92	0.90
29	NIAW 1689	375.00	270.00	105	322.50	318.20	1.22	0.96	313.95	1.08	0.72
30	NIAW 656	455.00	325.00	130	390.00	384.54	1.25	1.40	379.17	1.30	0.71
31	NWL-9-15	275.00	210.00	65	242.50	240.31	1.03	0.55	238.14	0.84	0.76
32	RAJ 4083	210.00	180.00	30	195.00	194.42	0.62	0.36	193.84	0.72	0.85
33	RAJ 4128	275.00	200.00	75	237.50	234.52	1.19	0.52	231.58	0.80	0.72
34	GW-09-264	250.00	180.00	70	215.00	212.13	1.22	0.43	209.30	0.72	0.72
35	RAJ 4168	230.00	165.00	65	197.50	194.81	1.24	0.36	192.15	0.66	0.71
36	RAJ 4169	260.00	185.00	75	222.50	219.32	1.26	0.46	216.18	0.74	0.71
37	RAJ 4254	310.00	190.00	120	250.00	242.69	1.69	0.56	235.60	0.76	0.61
38	RAJ 4257	375.00	325.00	50	350.00	349.10	0.58	1.16	348.21	1.30	0.87
39	RAJ 4258	325.00	250.00	75	287.50	285.04	1.01	0.77	282.61	1.00	0.77
40	RS 1002	265.00	200.00	65	232.50	230.21	1.07	0.50	227.95	0.80	0.75
41	RS 1017	350.00	245.00	105	297.50	292.83	1.31	0.81	288.23	0.98	0.7
42	VL 950	350.00	260.00	90	305.00	301.66	1.12	0.86	298.36	1.04	0.74
43	VL 952	425.00	340.00	85	382.50	380.13	0.87	1.37	377.78	1.36	0.80
44	WH 1022	350.00	250.00	100	300.00	295.80	1.25	0.83	291.67	1.00	0.71
45	WS 902	275.00	200.00	75	237.50	234.52	1.19	0.52	231.58	0.80	0.73
46	WS 903	350.00	250.00	100	300.00	295.80	1.25	0.83	291.66	1.00	0.71
47	WS 904	300.00	200.00	100	250.00	244.94	1.46	0.57	240.00	0.80	0.66
48	WS 905	275.00	220.00	55	247.50	245.97	0.87	0.57	244.44	0.88	0.80
49	WSM 1472	350.00	300.00	50	325.00	324.03	0.62	0.99	323.08	1.20	0.85

Table 4.13: Mean rank of the genotypes in respect of different drought tolerance indices

Sl. No.	Genotypes	TOL	MP	GMP	SSI	STI	HAM	YI	YSI	Mean
1.	AKAW 3717	45	1	1	49	1	1	1	1	13
2	AKAW 4705	49	46	46	48	46	46	42	2	41
3	AKAW 4730	25	09	10	32	10	10	8	16	15
4	AKAW 473	19	38	38	19	38	38	36	29	32
5	C 306	19	30	31	24	31	31	36	26	29
6	GW-09-260	6	11	12	7	12	13	15	37	14
7	GW 2010-343	35	15	15	37	15	15	13	12	20
8	GW-2010 345	17	29	29	22	29	29	29	26	26
9	GW-09-262	35	18	18	36	18	18	15	12	21
10	GW-09-264	42	16	16	45	16	16	13	5	21
11	GW-09-269	17	32	32	18	32	33	34	32	29
12	GW-09-270	30	49	49	16	49	49	49	32	40
13	HI 1564	42	23	22	44	23	21	15	5	24
14	HI 1579	1	3	3	1	3	5	10	49	9
15	HI 1580	40	25	25	39	25	24	20	12	26
16	HI 1581	31	8	8	40	8	26	4	12	17
17	K 0624	14	27	27	17	27	27	28	37	26
18	KLP 1032	35	42	42	29	42	42	36	19	36
19	KLP 1042	45	24	23	47	23	22	15	2	25
20	KLP 1043	13	6	6	28	6	6	4	22	11
21	KLP 1045	41	12	11	43	11	11	9	5	18
22	KLP 3077	42	45	45	35	45	45	42	14	39
23	KLP 3105	7	22	23	5	24	25	27	45	22
24	KLP 3129	3	2	2	7	2	2	2	37	7
25	KLY 1081	31	28	28	34	27	28	25	16	27
26	KLY 1086	31	30	30	32	31	30	31	19	29
27	KYP 0826	2	7	7	4	7	7	10	46	11
28	NI 5439	48	37	36	46	36	34	29	2	34
29	NIAW 1689	8	14	14	16	14	14	19	32	16
30	NIAW 656	4	4	4	10	4	3	3	37	9
31	NWL-9-15	27	36	37	26	37	36	34	24	32
32	RAJ 4083	45	48	48	40	47	47	46	12	42
33	RAJ 4128	19	39	38	19	38	38	36	32	32
34	GW-09-264	25	44	44	14	44	44	46	32	37
35	RAJ 4168	27	47	47	13	47	48	48	37	39
36	RAJ 4169	19	43	43	9	43	43	45	37	35
37	RAJ 4254	5	32	35	2	35	37	42	48	30
38	RAJ 4257	35	9	9	42	9	9	4	8	16
39	RAJ 4258	19	25	26	27	26	26	21	22	24
40	RS 1002	27	41	41	25	41	41	36	25	35
41	RS 1017	8	21	21	6	22	23	25	37	20
42	VL 950	14	17	17	24	17	17	21	26	19
43	VL 952	16	5	5	29	5	4	2	19	11
44	WH 1022	10	18	19	10	19	19	22	37	19
45	WS 902	19	38	40	19	38	38	36	29	32
46	WS 903	10	18	19	10	19	19	22	37	19
47	WS 904	10	32	34	3	34	35	36	46	29
48	WS 905	31	35	33	30	34	32	32	19	31
49	WSM 1472	35	13	13	41	13	12	10	12	19

Table 4.14: Correlation coefficient among gran yield under irrigated and drought condition and different drought tolerance indices in 49 wheat genotypes

Sl. No.	Indices	1	2	3	4	5	6	7	8	9	10
1.	Y _p	1.00									
2.	Y _s	0.86**	1.00								
3.	TOL	0.64**	0.16	1.00							
4.	MP	0.97**	0.96**	0.44**	1.00						
5.	GMP	0.96**	0.97**	0.41**	1.00**	1.00					
6.	SSI	0.21	-0.30*	0.86**	-0.02	-0.05	1.00				
7.	STI	0.96**	0.96**	0.42**	0.99**	0.99**	-0.05	1.00			
8.	HAM	0.95**	0.96**	0.40**	0.99**	0.99**	-0.06	0.98**	1.00		
9.	YI	0.86**	1.00**	0.16	0.96**	0.97**	-0.30*	0.96**	0.96**	1.00	
10.	YSI	-0.19	0.31*	-0.86**	0.03	0.06	-1.00**	0.06	0.08	0.31*	1.00

*, **= Significant at 5% and 1% levels respectively

Evaluation of correlation coefficients showed that there was a positive and significant correlation coefficient ($r = 0.86$) between grain yield under irrigated (Y_p) and drought stress (Y_s) environments (Table 4.14). Significantly positive correlation with Y_p and Y_s was found among the indices like MP, GMP, STI, HAM and YI. The highest correlation ($r = 1.00$) was observed between Y_s and YI. The correlation of SSI with Y_s ($r = -0.30$) and YSI with Y_p ($r = -0.19$) were found to be negative. There was a positive and significant correlation between TOL and SSI ($r = 0.86$). There were also positive and significant correlation among MP, GMP, STI, HAM and YI.

The result also demonstrated that most appropriate index to select drought tolerant genotypes were STI, MP, GMP, HAM, YI which had a high correlation with grain yield under both irrigated and drought condition. Similar results were reported by Zeynali et al, (2004), Karimizadeh and Mohammadi (2011) and Ghobadi et al (2012).

Genotypes were further grouped into four categories based on their production in irrigated and drought condition (Fernandez, 1992). The first group consists of genotypes with high production under both conditions (Group A), second group having genotypes with high production only under non stress condition (Group B), third group containing genotypes with high production only under stress condition (Group C) and fourth group having genotypes with weak production under both conditions (Group D) [Table 4.15].

Table 4.15: Grouping of genotypes based on their performance in irrigated and drought conditions

Groups	Characteristics	Genotypes
Group A	Genotypes with high production under both conditions	AKAW 3717, NIAW 656, VL 952, KLP 1043
Group B	Genotypes with high production only under non stress condition	HI 1579, KYP 826, KLP 3129
Group C	Genotypes with high production only under stress condition	KLP 1045, AKAW 4730
Group D	Genotypes with weak production under both conditions	GW-09-270, RAJ 4083, RAJ 4168, AKAW 4705, KLP 3077

CHAPTER V

Summary and Conclusion

Summary & Conclusion

Wheat may experience water stress in any environment. In India wheat may suffer from continuous or subcontinent type of drought which is associated with stored moisture after monsoon rain. In our state also due to climate change and changes in rainfall pattern, temperature and water storage, it was reported that the northern part of West Bengal might face water stress condition during wheat growing period.

In this present experiment, forty nine genotypes of wheat were grown in two environments viz. one in drought condition and another in irrigated condition for evaluation of drought tolerant genotypes suitable for this environment.

Genotypes showed enough variability for characters like germination (%), days to heading (75%), days to maturity, plant height, tillers per meter, grains per spike, and yield per plot but poor for test weight and spike length.

Difference between two environments (i.e. drought and irrigated) was found significant for most of the traits except germination %. This may be due to presence of residual moisture during sowing time. Genotype and environmental interaction was also significant for all traits barring test weight, germination% and spike length.

All the genotypes performed poorly under drought stress condition than irrigated condition for all the characters under study. Highest variation (%) among the genotypes between drought and irrigated condition was found for tillers per meter (-28.37%) and yield per plot (-22.87%) which indicated that these two traits were greatly affected by drought stress.

Genotypic coefficient of variation (GCV) was found poor for traits like germination (%), days to heading, days to maturity, plant height, grains per spike, spike length and test weight under both the conditions while it was moderate in case of yield per plot and tillers per meter. Phenotypic coefficient of variation (PCV) was also poor for most of these traits. High PCV was found in case of germination (%), grain yield per plot (g) and tillers per meter under both conditions and for test weight in drought condition.

Heritability under broad sense value was also poor for traits like germination (%), plant height, spike length, test weight and yield per plot. Characters like days to heading, days to maturity, tillers per meter and grains per spike showed good heritability value. In case of genetic advance, traits like days to heading, plant height, tillers per meter and grains per spike showed promising values. If we consider both heritability under broad sense and genetic advance together, then characters like days to heading, tillers

per meter and grains per spike showed some promise towards selection for onward transmission to next generation.

In case of character association, under drought condition, days to heading was found positively correlated with plant height, spike length and test weight at genotypic level whereas phenotypically it was only correlated with plant height and test weight. Days to maturity was positively correlated with tillers per meter and spike length genotypically while it had negative association with test weight both genotypic and phenotypic level.

Among the reproductive traits, tillers per meter was positively correlated with yield per plot while negatively correlated with grains per spike at genotypic level only. Spike length was negatively correlated with grains per spike and test weight genotypically. Yield per plot was found positively correlated with plant height, tillers per meter and spike length at genotypic level only. It indicates these traits may be used as drought stress tolerance indicator which has direct association with yield.

Under irrigated condition, characters like germination(%) and plant height, days to heading and days to maturity, days to heading and grains per spike, days to heading and tillers per meter were positively correlated while negative association was found between germination(%) and days to maturity, days to heading and test weight, grains per spike and test weight. Yield was found positively correlated with days to heading, days to maturity, plant height and spike length while it was negatively correlated with test weight.

Path analysis revealed, positive and high direct effect with days to heading , days to maturity, plant height and spike length on grain yield under drought condition while under irrigated condition high direct effect was found with germination (%), plant height, grains per spike and test weight. Indirect effect of days to heading was high through germination (%), days to maturity, tillers per meter and spike length under irrigated condition while under drought condition it was only high through spike length only.

Genotypic residual effect was low (0.322) while phenotypic residual effect was high (0.75) under drought condition. But under irrigated both the effects are quite high (0.67 & 0.83). It indicates that no character can be used as marker trait to predict suitable genotypes under drought condition.

Calculation of different tolerance indices showed that highest Stress tolerance (TOL) and Stress Susceptibility Index (SSI) value were related to genotypes HI 1579, KYP 0826, KLP 3129, NIAW 656, RAJ 4254 indicating that these genotypes had higher grain yield reduction under rainfed condition and highest drought sensitivity. AKAW 3717, AKAW 4705, NI 5439, KLP 1042 were the most tolerant genotypes based on TOL and SSI values with their low quantity as indication towards tolerant genotypes.

AKAW 3717, HI 1579, KLP 3129, NIAW 656, VL 952 were found to be the tolerant genotypes based on Mean Productivity (MP), Geometric Mean Productivity (GMP), Stress Tolerance Index (STI), Harmonic Mean(HAM) and Yield Index (YI) with their high value as indication towards tolerance. Based on these current indices GW-09-270, RAJ 4083, RAJ 4168 and AKAW 4705 were the most sensitive genotypes. In terms of Yield Stability Index (YSI) genotype AKAW 3717 and AKAW 4705 were having the highest value while genotype HI 1579 and RAJ 4254 had lowest value indicating highest and lowest stability respectively. Ranking of genotypes in respect to all drought tolerance indices revealed that genotype KLP 3129, NIAW 656 and HI 1579 had the best mean rank.

Evaluation of correlation coefficients showed that there was a positive and significant correlation coefficient ($r = 0.86$) between grain yield under irrigated (Y_p) and drought stress (Y_s) environments. Significantly positive correlation with Y_p and Y_s was found among the indices like MP, GMP, STI, HAM and YI. The highest correlation ($r = 1.00$) was observed between Y_s and YI. The correlation of SSI with Y_s ($r = -0.30$) and YSI with Y_p ($r = -0.19$) were found to be negative. There was a positive and significant correlation between TOL and SSI($r = 0.86$). There were also positive and significant correlation among MP, GMP, STI, HAM and YI.

The result also demonstrated that most appropriate index to select drought tolerant genotypes were STI, MP, GMP, HAM, YI which had a high correlation with grain yield under both irrigated and drought conditions.

When genotypes were grouped into four categories based on their production under irrigated and drought condition, it was found that genotypes like AKAW 3717, NIAW 656, VL 952 and KLP 1043 had high production potential under both drought and irrigated condition while genotypes like HI 1579, KYP 826, KLP 3129 were suitable for only irrigated condition. Similarly, genotypes like KLP 1045 and AKAW 4730 had a high production potential only under drought stress condition. So, these genotypes may be used in future breeding programme depending upon the suitability of environmental condition.

Genotypes like GW-09-270, RAJ 4083, RAJ 4168, AKAW 4705 and KLP 3077 had poor production potential under both condition. So these lines are not suitable for any of these environments.

CHAPTER VI

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