INFLUENCE OF MOISTURE AND TEMPERATURE STRESS IN TOLERANT AND SUSCEPTIBLE WHEAT GENOTYPES

by

KONIJETI BHANU PRAKASH

A Thesis
submitted to the Faculty of the Post-Graduate School,
Indian Agricultural Research Institute, New Delhi
in partial fulfilment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY
IN
PLANT PHYSIOLOGY

1997

Approved by :

Chairman :

(Dr. P. S. Deshmukh)

Members :

(Dr. R. K. Sairam)

(Dr. S. R. Chatterjee)

(Dr. Srinivasan)

(Dr. S. R. Singh)

DIVISION OF PLANT PHYSIOLOGY
INDIAN AGRICULTURAL RESEARCH INSTITUTE
NEW DELHI-110012

DR. P.S. DESHMUKH
Sr. Scientist

CERTIFICATE

This is to certify that the thesis entitled "**INFLUENCE OF MOISTURE AND TEMPERATURE STRESS IN TOLERANT AND SUSCEPTIBLE WHEAT GENOTYPES**" submitted in partial fulfillment of the requirements for the award of the degree of **DOCTOR OF PHILOSOPHY** in **Plant Physiology** of the Post-Graduate School, Indian Agricultural Research Institute, New Delhi, is a record of the bonafide research work conducted by **Mr. Konijeti Bhanu Prakash** under my guidance and supervision. No part of the thesis has been submitted for any other degree or diploma. The assistance received during the course of this investigation has been duly acknowledged.

IARI, New Delhi-110012
Dated : 21.08.1997

(Dr. P. S. DESHMUKH)
Chairman
Advisory Committee

ACKNOWLEDGEMENT

I deem it great previlege to express my deep sense of gratitude to the chairman of my Advisory committee, Dr. P.S. Deshmukh, Sr. Scientist, Division of Plant Physiology, Indian Agricultural Research Institute, New Delhi for his counsel, constructive suggestions, constant encouragement and meticulous guidance coupled with his personal charm and warmth during the course of my research work.

I take this opportunity as a previlege to extol my profound etiquette and sincere feelings of gratitude to Dr. D.S. Shukla, Dr. R.K. Sairam, Dr. S.R. Chatterjee, Dr. Srinivasan and Dr. S.R. Singh, members of my Advisory committee for their valuable advises and constant encouragement during my investigation.

I place on record my esteem regards and sincere thanks to Dr. G.C. Srivatsava, Head, Divison of Plant Physiology and Dr. U.K. Sengupta, Professor, Divison of Plant Physiology for providing facilities required from time to time.

I am also extremely thankful to all teachers, staff members and students of Divison of Plant Physiology for their help.I owe my gratitude to Dr. Sitaram for helping me in statistical analysis of the data. I wish to express my profound debt of gratitude to Radhi, Lakshmi, Murali and Padma (Likhita Computers) for their companionship and help in neat execution of thesis.

It will be injustice to me if I don't mention my heart felt thanks to my best friends Anil, Satya and others for their moral support during this work. I humbly express my sincere thanks to Mrs. Rekha Deshmukh for her moral support during course of study.

Diction is not enough to express my unbound gratitude and profound love to my beloved parents , brothers and sister-in-laws for their constant love, inspiration, affection and encouragement all the time.

Finally I am thankful to IARI authorities for granting me fellowship and contingent grant.

(K. BHANUPRAKASH)

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Name : Konijeti Bhanu Prakash
Roll No : 7735
Degree : Ph.D.
Date of joining : 14th Sept. 1992
Major field : Plant Physiology
Minor fields : Biochemistry, Molecular Biology
Name of the Chairman : Dr. P.S.Deshmukh
Title of the thesis : **Influence of moisture and temperature stress in tolerant and susceptible wheat genotypes**

ABSTRACT

When wheat is growing under rainfed conditions, it is generally grown in advance date (October) to gain the advantage of mositure already present in the soil during preceeding monsoon. Early sown wheat under rainfed conditions will be exposed to two major stresses *viz.*, moisture and high temperature stress and so needs suitable plant type. Hence the present study is choosen with an attempt to screen the genotypes *viz.*, C-306, PBW-175, HD-2329 and WH-542 for their drought/ thermo tolerance and to identify the factors contributing to it.

Among the genotypes tested, C-306 followed by PBW-175 are relatively drought/ thermo tolerant compared to HD-2329 and WH-542, as they have better water retention capacity, nitrogen uptake, photosynthetic efficiency, biomass production with large sink coupled with better partitioning coefficient even under stress conditions. High percent relative water content and less per cent ion leakage in C-306 and PBW-175 enabled them to take up more nitrogen, synthesis of more chlorophyll necessary for efficient photosynthetic process. The tolerance mechanism of these varieties is also reflected in total crop duration. C-306 and PBW-175 have taken more days to anthesis and maturity when compared to other varieties to accumulate more biomass. Besides accumulating more biomass, these varieties also showed better partitioning ability and hence showed higher grain yields. Temperature studies under controlled conditions also justified that C-306 and PBW-175 are thermotolerant as they have high germination percentage, shoot vigour index, catalase and peroxidase activities, even under supra - optimal temperatures.

INTROUDUCTION

Wheat is the second important staple food crop in India and it is grown in different parts of the country either as rainfed wheat or irrigated wheat depending upon the availability of irrigation sources. Even today, considerable portion of wheat is still grown under rainfed conditions thereby loosing 40 - 50 per cent of its productivity compared to irrigated conditions. As per the recent estimates given by Agricultural Situation in India (1996-97) about 25 m ha is under wheat cultivation contributing 62.6 m ton. However, at global level scenario, wheat yield increases in some of the most productive environments have begun to level off and mere expanding the land under cultivation to fulfill the demand for more production is no longer possible. Hence, we need more suitable and resource efficient varieties that produce higher and more stable yields in any environment (CIMMYT report, 1996). To meet this challenge, it may be necessary to analyse physiological processes to help identify oppurtunities for further breeding aimed at breaking the barriers (Slafer *et al.*, 1996).

In central parts of India, wheat is grown in October under rainfed condition when land is available immediately after harvesting of *kharif* crops like short duration varieties of rice and mungbean to make better use of soil moisture under rainfed conditions (Bagga *et al.*, 1987). Early sown (mid-Oct) crop in unirrigated area is able to use soil moisture conserved during the preceeding monsoon (Winter and Musick, 1993) but exhibits poor crop stand due to high soil and air temperature at early stages and so yeild losses occur (Abrol *et al.*, 1991). Early wheat sowings in rainfed area therefore needs suitable plant types (Bagga *et al.*, 1987) The possibility of increasing wheat productivity by utilizing early seedling vigour under relatively high temperature conditions is an aspect that has not been worked extensively by the researchers.

Drought, under rainfed condition, is a common problem and its ill-effects on wheat crop growth and yeild are many. Although we are still far from a complete understanding of damages caused by drought or the plant tolerance mechanism in various wheat genotypes, much work has been collected over the past few years (Asana, 1968; Sinha and Rajgopal, 1981; Bagga *et al.*, 1987; Abrol, 1991; Blum, 1996; Deshmukh *et al.*, 1996). However, the current knowledge of regulatory network governing drought stress response in the genotypes taken for present study is fragmentary. Despite the ill effects of high temperature under early planting and drought under rainfed conditions, exposing wheat to these situations has become a common practice due to various reasons. Hence a proper understanding of the effect of temperature and drought on growth and development of wheat is essential in case an increase in wheat production has to be looked over in our country.

Drought and thermotolerance of a variety depends upon its endurance or its adaptation through manipulation of morpho-physiological traits. Traits like ion-leakage(or) membrane stability index (Deshmukh *et al.*, 1991, 1996; Navari-Izzo *et al.*, 1993; Gupta, 1996), Nitrate reductase activitiy (Bate *et al.*, 1978; Deshmukh *et al.*, 1985), relative water content (Misra, 1990; Tahara *et al.*, 1990), total chlorophyll content (Ritchi *et al.*, 1990), total biomass accumulation (Austin, 1994; Sharma, 1993) and grain mumber (Slafer *et al.*, 1994) contributing drought / thermotolerance are considered for screening large number of wheat genotypes under stress environments. There is almost a consensus among cereal breeders that future yield increases will be possible primarily through mainpulation of morpho-physiological traits including biomass yield (Sharma, 1993). High biomass accumulation under unfavourable conditions may be a factor contributing tolerance. Wheat cultivars exhibiting drought/thermo tolerance accumulated more biomass over sensitive cultivars (Gummuluru *et al.* 1989; Ashraf *et al.*, 1994). Moreover biomass yield in wheat had positive genotypic correlation with grain yield (Asana, 1975; Aggarwal and Sinha, 1987; Bansal and Sinha,1991; He Zhong-hu and Rajaram, 1994), effective tiller number and number of kernels per spike. So, biomass yield may be a useful selection trait for yield improvement in wheat. Helsel (1985) reported low to high heritability estimates for biomass yield and suggested a combined selection for biomass yield and harvest index to improve grain yield.

Thus, the above information reveals that there is need to investigate the suitability of various genotypes under stress environments. Studies are conducted at cellular, physiological and morphological levels to assess the behaviour of genotypes chosen (C-306, PBW-175, HD-2329 and WH-542) for study under early and normal plantings of irrigated and rainfed conditions. Genotypes which showed stability in this environments are compared with less stable genotypes (sensitive) to identify parametres contributing tolerance mechanism. These investigations were further extended to identify the sensitive stages during reproductive phase. Attempt was also made to suggest some parametres for screening genotypes under early high temperature and rainfed conditions.

The present investigation was carried out with the following objectives :

(1) To understand the mechanism of tolerance to moisture and temperature stress in contrasting wheat genotypes.

(2) To identify the stages sensitive to stresses and the extent of their effect on yield and yield components.

REVIEW OF LITERATURE

Water stress and high temperature stress are the two major important factors limiting crop growth and yield. Several efforts have been made to analyse the effects of water and high temperature stress on various plant processes at cellular, morphological and physiological levels. In the present chapter, work done on wheat and other related crops in the above mentioned aspects is critically reviewed under different sections.

2.1. HIGH TEMPERATURE STRESS

2.1.1. INFLUENCE OF HIGH TEMPERATURE STRESS ON SEED GERMINATION

Seed germination is subjected to very precise regulation in which various environmental factors play an important part (Alka, 1990). Temperature had strong effect on median germination. Wheat seeds are known to germinate between 4 and 37°C with 20 and 25°C being optimum. Temperature above optimum delays or inhibit germination. In maize, germination was significantly delayed above 35°C and was completely prevented at 39°C (Riley, 1981). Upadhyaya and Ruwali (1984) in wheat observed defective germination due to high temperatures at sowing time in Bhal tracts of Gujrat where soil temperatures between October and December may reach 35 to 39°C maximum and 22 to 25°C minimum. For 26.5°C average temperature, the germination per cent was 84 where as for 30.2°C, it was only 56 per cent. In similarity to this, Acevedo *et al.* (1991) also reported a decrease in germination per cent from 81.62 to 71.7 for increase in soil temperature from 33.7 to 42.2°C. The effect of temperature on germination percentage varies with genotypes also. Laford and Baker (1986) studied the germination of 9 spring wheat cultivars at 5, 8, 12, 20 and 30°C and observed significant effects among cultivars. Pictic 62, Potam and NB 402 took the shortest germination time while other cultivars required more time to germinate. More recently Helms *et al.* (1996) also reported the importance and basic role of initial soil moisture content and temperature in soybean seed imbibition and germination. And in addition to germination percentage, Nayeem and Mahajan (1991) further studied shoot length, root length and shoot vigour index in various wheat genotypes. All these parameters were decreased progressively with increase in temperature from 25 to 35°C. However, thermotolerant varieties showed higher values for these parametres when compared to susceptible varieties. Differences and interrelation among these parametres, variation in wheat genotypes for these characters were also observed by Chaudhary *et al.* (1984). Gupta *et al.* (1987) observed that the inhibition in plumule growth recorded at 72 hours post heat shock of 40°C for 2 hours was about 30 per cent in cultivar WH 147 (Sensitive), while it was less than 9% in its thermotolerant mutant WH 147M. Likewise, reduction in radicle growth was about 36 per cent in WH 147 and 25 per cent in WH 147M.

2.1.2. INFLUENCE OF HIGH TEMPERATURE STRESS ON α-AMYLASE, CATALASE AND PEROXIDASE

Amylases are those enzymes involved in the degradation of endosperm starch (Akazawa *et al.*, 1982). In wheat and barely, alpha amylase is synthesized in aleurone tissue and secreted into the starchy endosperm in response to the hormone gibberellin from the embryo (Paleg, 1960). Degradation of starch produces a mixture of maltose and glucose which is absorbed through the scutellum into the developing seedling. The energy for the rapidly growing embryonic axis is derived from the process of respiration which is at its maximum efficiency in a fully imbibed seed. Seedling vigour is often related to the respiration rate (Sinha and Khanna, 1975). Environmental factors influence the synthesis and activity of amylase. Alpha amylase synthesis has been found to be temperature dependent by Groat and Briggs (1969) and Ching (1975). Williams and Peterson (1973) suggested that low alpha amylase activity levels in certain rice cultivars could limit their early seedling development. There were differences in the alpha amylase activity depending upon cultivar and temperature. Luciani *et al.* (1984) and Reddy *et al.* (1984) working with wheat cultivars noted significant increase in activity upto sixth day and remained constant upto eighth day. Variation in wheat genotypes alpha amylase activity under different temperature exposures was also noticed by Deshmukh *et al.* (1986). These workers further suggested that these differences in alpha amylase activity due to cultivar is useful in breeding wheat genotypes for stress environment as they may posses high seedling vigour. Correlation between alpha amylase activity and seedling vigour in rice was reported by Williams and Peterson (1973) and Karrer *et al.* (1993). Contrary to this, Bhupinder Singh *et al.* (1996) observed no correlation between alpha amylase activity of geminating seeds and seedling emergence.

Catalase and peroxidase are the two important oxidative enzymes which employ a toxic metabolite H_2O_2 as their substrate. Catalase represents one of the important photorespiratory enzymes while peroxidase is an oxidative enzyme involved in secondary metabolism. The activities of both these enzymes showed a marked increase in senescence leaves (Rane and Chavan, 1993). The effect of temperature on the activities of thse enzymes were reported by many. Krans *et al.* (1994) observed increase in Glutathione reductase and peroxidase in wheat seedling upon exposing to high temperature of 50^0C for 2 hours. Analysis of enzyme activity in cabbage leaves showed increased catalase and peroxidase activity during high temperature (Wu *et al.*, 1995). Variation in the activities of these enzymes between thermotolerant and thermosensitive varieties was also observed. Hybrid seedlings were exposed to low and high temperatures and catalase and peroxidase activities were studied in various genotypes. Thermotolerant cultivar Weiyou 287 had more catalase and peroxidase compared to sensitive cultivar Wei you 49 (Fan and Guo, 1992). Similar kind of variation between heat tolerant cultivar 90 - 80 and sensitive cultivar Wumai 74 in wheat was reported by Zhour *et al.* (1995). The tolerance of these cultivars to high temperature is due to their membrane stability as membrane damaging single oxygen radicles were removed by high activities of catalase and peroxidase (Fan and Guo, 1992; Zhour *et al.*, 1995). Increase in activities of these enzymes under water stress was also reported by many in various crops (Song and Tai, 1995; Ashraf *et al.*, 1995).

2.2. MOISTURE AND HIGH TEMPERATURE STRESS

2.2.1. INFLUENCE OF MOISTURE AND HIGH TEMPERATURE STRESS ON VARIOUS BIOCHEMICAL PARAMETRES

2.2.1.A. ION-LEAKAGE

ION LEAKAGE-MOISTURE STRESS

Some of the many noted responses to drought stress include increased leakage of solutes (Leopold *et al.*, 1981). And increased leakage of solutes is an indication of damage to membrane (Chaisompongopan, 1990) A number of important processes namely photosynthesis, respiration (Bjorkman *et al* .,1980) and conversion of sucrose to starch in developing grains of wheat (Bhullar and Jenner, 1986) have been found related to drought tolerance. However stable cell membrane that remains functional during water stress appears central to adaptation to high temperature and found related to heat and drought tolerance (Sullivan and Ross, 1979; Raison *et al.*, 1980). Ion leakage can also be used as a measurement index for screening genotypes against heat and drought stresses, in soybean (Krishnamani *et al.*, 1984) and in maize, sunflower, wheat and barley (Deshmuk *et al.*, 1991).

Premchandra and Shimada (1987) assessed the drought tolerance of 11 spring and 14 winter wheat cultivars by exposure to PEG . Degree of membrane stability was evaluated by measuring ion-leakage. Measurements were significantly affected by plant age, sampling position of leaf, season, degree of drought hardening as well as differences between cultivars. In a study on metabolic changes in wheat plants subjected to water-deficit stress programme, Navari-Izzo *et al.* (1993) have found an increase in ion leakage and decrease in phospholipid and glycolipid content in durum wheat cultivar due to a brief period exposure to water stress. Under severe dehydration, the loss of water leads to crystallization of cellular components,which in sequence damages cellular structures (Ingram and Bartles, 1996).

ION LEAKAGE-HIGH TEMPERATURE STRESS

High temperature can cause considerable damage to crops and is of major concern to physioilogists and breeders working in stress environments. A number of methods and approaches are available to estimate the damages caused by heat and to develop heat - tolerant crop varieties. A heat tolerance test developed for sorghum and soybean (Sullivan and Ross, 1979) and for field grown wheat is based on membrane thermostability test (Blum and Ebercon, 1981 and Tahir and Singh, 1993). Ion-leakage can be taken as criterion for screening large number of genotypes against environmental stresses as these are rapid test and results can be reproducible. Moreover this parameter is most sensitive as its influence can be noted even under mild stress. Thus, it can prove worth while test in breeding for stress tolerant genotypes and breaking barrier of low grain yield under drought prone areas (Deshmukh *et al.*, 1985).

Membrane thermostability is a useful screening procedure for selection of high temperature tolerant genotypes in spring wheat (Saadalla *et al.*, 1990) achieved success in identifying high temperature tolerant lines of wheat by taking membrane thermostability as a screening test. A proportional change in ion-leakage with increasing tempreature in tissues of wheat was reported by Navari-Izzo *et al.* (1993).

IONLEAKAGE-VARIATION IN GENOTYPES AND STAGE OF GROWTH

Exposing leaf discs of two different cultivars WH-147 and WH-147M having difference in thermo tolerance, to 50°C and 55°C for varying periods resulted more ion leakage from WH-147 as compared to thermo tolerant WH-147M leaf discs. At 55°C treatment for 20 minutes, the per centage leakage in WH-147M is 24 per cent less when compared to WH-147 (Kaur *et al.*, 1989). Similar report on two different wheat genotypes was also made by Mehra (1989) in which per cent ion-leakage in HD 2428 was higher than Kalyansona, a variety possessing better adaptability to high temperature stress. Genotypic differences in wheat were observed in cell membrane with respect to injury caused by osmotic shock created with 40% PEG-6000. In general, genotypes with high cell membrane injury also registered much reduction in leaf water potential and osmotic potential. Cell membrane injury measured at 25 days after germination was found to be related with genotypic performance under drought condition in filed. Cell membrane measurements of normal plants even at a very early stage of growth is reported as a criteria for selecting drought tolerant wheat genotypes (Singh *et al.*, 1992).

When different cultivars of cotton were exposed to control (30°C) and high temperatures (48°C) cultivars B-557 and MNH-93 having higher membrane thermostability had lower relative injury and were higher in fresh and drymass production than the other three cultivars. Further, it was also concluded that membrane thermo stability (MT) is a successful measure of heat tolerance in cotton (Ashraf *et al.*, 1994). An increase in ion-leakage with increase in age was also reported in tomato. Ion leakage was more at 50 days stage as compared to 40 days stage which indicates that senescence leaf has less tolerance to high temperature (Savin and Nikalenko, 1977). Studies of Deshmukh *et al.* (1985) with various crops (maize, sunflower, barley and wheat) at various stages of seedling growth have reported that with increase in temperature there was a proportional increase in ion-leakage in the leaf tissue. Results also indicated that the conductivity ratio in maize was more in plants grown at 10°C as compared to those grown at 25°C at 8 and 18 days of growth. And at 40 and 50 days of age increase in temperature increased conductivity ratio. The leaf age played an important role in tolerance to high temperature. Relation between cell memberane damage and leaf age is also reported in barley (Bandusarka *et al.*, 1995).

2.2.1B. RELATIVE WATER CONTENT (RWC)

RWC-MOISTURE AND HIGH TEMPERATURE STRESS

Water is the elixir of life for any biological organism. The function of the metabolic processes and their rate in plants are mostly related with water content. RWC is one of the parameter to measure it and this was first suggested by Barrs and Weatherley (1962). RWC was affected upon imposing stress. Gradual decrease in RWC with increase in stress by with holding water and much reduction afterwards under severe stress were observed in cotton genotypes (Janagoudar *et al.*, 1983). Similar report in maize was given by Patil *et al.* (1984).

RWC, as an indicator of tolerance, is one of the important parameter to be studied in stress experiment. In a green house experiment 5 wheat cultivars were grown at two soil moisture levels (50 and 80 per cent field capacity) Results obtained suggested that leaf water potential during flag leaf stage under moisture stress conditions may be used as an indication of differences in drought tolerance (Janbet, 1987) Similar conclusions were given for wheat and barley and triticale drought tolerance (Aggarwal *et al.*, 1981). High RWC under moisture stress denotes ability of plants to drought tolerance (Uprety and Sirohi, 1987; Misra 1990; Schonfeld *et al.*, 1988; Ritchi *et al* ., 1990). RWC and leaf water potential as related and leaf water potential also an indicator of drought tolerance was suggested by many. Though several works showed that leaf RWC was highly heritable and can be adopted as a screening technique under field drought conditions, but it requires further investigations on relationship between grain yield and RWC. RWC measured during anthesis and grain filling period in high-yield, low yield random selection segregate both traits showed positive relationship with yield in winter wheat. However while using it as a selection criteria, the differences in maturity among genotypes should be considered (Tahara *et al.*, 1990). Wheat cultivar Len was grown in silt-loam soil in a green house until anthesis and subjected to day/night temperature of 15/10, 25/20 or 35/30^0 C. High temperature decreased relative leaf water content (Shah, 1992).

RWC-VARIATION IN GENOTYPES AND STAGE OF GROWTH:

Varieties differ in their RWC content under different stress conditions. In an experiment by Sinha and Rajagopal (1975), sorghum genotypes were tested for their performance under moisture stress conditions by taking various parameters into account including RWC. The RWC of both CSH-1 and 604 showed a reduction of 21.4 per cent and 19.5 per cent respectively over control when subjected to water stress of 10 bars PEG for 24 hours. Similarly, Holday *et al.* (1992) have observed a decrease in RWC both in drought resistant Anza (58%) and drought susceptible Chenab 70 (60 per cent) wheat cultivars due to 12 days water limiting conditions. Ritchie *et al.* (1990) in an experiment with two wheat genotypes differing in drought resistance indicated that the more drought-resistant species *T. kortschyi* delayed its rapid decline in RWC compared with the more drought susceptible sp. Studies with contrasting wheat cultivars by Sairam (1994) revealed the same fact. Findings of all the above had also supported the contention of Schofiled *et al.* (1988) views i.e. that RWC may be used as a selection criteria in breeding for improved drought resistant cultivars.

Reports on stage wise differences in RWC are also many. In a study on effect of water stress on wheat cultivars *viz.* C-306 and Kalyana sona, Aggarwal and Sinha (1984) studied several parameters including leaf water potential in relation to drought tolerance. From the finding, reports were made that leaf water potential during vegetative stage was not significantly different in irrigated and unirrigated plants but at anthesis water potential of the leaves in the unirrigated treatment was 4-5 bars lower in both cultivars. The relative water content was not affected significantly by water stress treatment at pre-anthesis stage. The effect of stress at anthesis stage significantly reduced the RWC content of wheat (24 per cent) and rye (22 per cent). However the reduction was not significant in triticales. At post-anthesis stage also the stress induced reduction in RWC was maximum in wheat (30 per cent) followed by rye (17 per cent) and minimum in triticale (9 per cent).

It was clear that stress effect on the RWC was not apparent at pre-anthesis stage and variability for this character was reflected only at anthesis and post-anthesis period (Uprety and Sirohi, 1987).

2.2.1.C. NITRATE REDUCTASE ACTIVITY (NRA)

NRA-MOISTURE AND HIGH TEMPERATURE STRESS

Nitrogen is mostly taken up as nitrate which is reduced to ammonia before being assimilated into amino acids. Reduction of nitrate to ammonia is catalyzed by two enzymes *viz.*, Nitrate reductase (NR) and nitrite reductase (NiR). Beevers and Hageman(1969) reported that NR is the logical point to affect regulation of input of reduced nitrogen for the organism. NR levels have been shown to fluctuate in response to changes in environmental conditions such as light, temperature, pH, carbondioxide, oxygen tensions, water potential, nitrogen sources and other factors. Bate *et al.* (1978) suggested that NR activity could be used as a selection criteria to increase the crop yields. NRA can be used as an index of protein content. Reports of Singh and Singh (1985) had positive correlation with protein content and its measurement also provides an estimate of current availability of reduced nitrogen in leaves. In the recent reviews, Wilbur and Campbell (1996) critically discussed and asserted the important role of this key enzyme in nitrate assimilation.

Numerous studies have been undertaken by various groups of investigators to examine the behaviour of NO_3 assimilatory enzymes in plants under water-stress conditions. Among these studies, nitrate reductase has recorded maximum attention. Shaner and Boyer (1976) found that NR activity was sensitive to the water potential. Much work has also been done on the effect of moisture stress on nitrogen metabolism. NRA getting influenced by moisture stress has been shown by various workers in various crops (Rajagopal *et al.*, 1976; Nair and Abrol, 1982). While working with various rice genotypes, under drought tolerance conditions, Sairam and Dube (1984) observed a close relation between stability of this enzyme, leaf RWC, grain yield and drought tolerance. Nitrate reductase is very sensitive enzyme. Even under mild water-stress conditions, NR activity declined rapidly compared to other N assimilatory enzymes (Singh and Sawhney, 1989).

Temperature is one of the environmental factors known to affect the distribution of NRA between roots and shoots. (Deane-Drummond *et al.*, 1980). NR is sensitive to higher temperature. Temperatures above a certain optimum affect the level of NR in plants as well as inhibit its activity.The magnitude of inaction or lowering NR levels by higher temperature varies according to the species. Corn seedlings maintained at 15 to 20^{0}C showed six times more NR activity than at 25^{0}C to 30^{0}C (Singh and Sawhney, 1989).

NR ACTIVITY-VARIATION IN GENOTYPES AND STAGE OF GROWTH

NR activity also differs with genotypes. Experiments conducted by Singh and Singh (1985) with twelve wheat cultivars showed significant genotypic variation in NRA. Studies with drought tolerant C-306 and susceptible HD2428 wheat genotypes revealed that under irrigated conditions HD-2428 maintained relatively higher NR activity compared to C-306. Under moisture stress, the tolerant genotype showed higher NR activity than HD-2428 (Sairam, 1994).

Deshmukh *et al.* (1985) measured NR activity in four wheat cultivars and reported that heat tolerant types (C-306 and NI 5439) had less reduction in NR activity as compared to susceptible types (Sonalika and HD - 2329) under temperature stress. It was further noted that the tolerant cultivars had better revival of NR enzyme. From these results it is emphasized that the NR activity can be taken as criterion for screening genotypes against temperature stress. Thus, this parameter may prove worthwhile, in breeding for stress tolerant genotypes and breaking barrier for low grain yield under high temperature conditions. While working with various crops, Chandra and Sirohi (1983) reported that the NR activity changed at different stages of growth and development. Similar investigations were also presented by Sharma and Sirohi (1988).

2.2.1.D. CHLOROPHYLL AND PHOTOSYNTHETIC RATE

CHLOROPHYLL, PHOTOSYNTHETIC RATE AND WATER STRESS

Photosynthesis can be regarded as the most important process in the plant. The response of the photosynthetic process to environmental stress is important for both the survival of the plant and for crop productivity.

Moisture stress influences the synthesis of chlorophyll, possibly through the nutrient availability. Huffaker *et al.* (1970) and Stout *et al.* (1977) reported that water stress reduced chlorophyll content by 21.5 per cent in barley leaves after 4 days of withholding water. The reduction was only 4.2 per cent after 2 days of withholding water. Chlorophyll loss was mainly due to reduction in the lamellar content of the light harvesting chlorophyll a/b protein. The decreased content of this chlorophyll protein accounts for the elevated chlorophyll a/b ratio (2.8 to 4.5) and the reduced photosynthetic unit of the cells in stressed maize plants. Chlorophyll content and photosynthetic rate are related. Investigation in soybean by Buttery *et al.* (1981) revealed that the variability in photosynthetic rate nearly 44 per cent was due to variability in chlorophyll content. This decrease in chlorophyll content was due to decrease in leaf nitrogen percentage. Khanna Chopra *et al.* (1980) observed that water stress resulted in considerable reduction in total, chlorophyll a and chlorophyll b under water stress as compared to non-stressed plants per unit dry weight.

Effect of water stress on organization of chlorophyll content seems to be variable. In *Phaseolus vulgaris* grown at different soil water levels, water stress increased leaf chlorophyll content, delayed flower formation and reduced seed yield (Tabbada and Flores, 1982). Contrary to this, Gummuluru *et al.* (1989) observed decreased net photosynthesis and internal carbondioxide concetration under water stress in various wheat genotypes. This decrease in photosynthesis depends on the severity and duration of drought period (Chaves and Pereira, 1992). Rate of photosynthesis is also related to nitrogen status. Nitrogen limitation decreased photosynthesis rate (Wolfe *et al.*, 1988; John *et al.*, 1996).

CHLOROPHYLL, PHOTOSYNTHETIC RATE AND HIGH TEMPERATURE

High temperature is one of the various kinds of environmental stress reported to cause a reduction in chlorophyll content in various crop plants. Decrease in chlorophyll content due to high temperatures was observed in rye (Feirabend, 1977) and wheat leaves (Liv and Su, 1985).

Photosynthesis is one of the most sensitive processes to heat stress (Blum, 1988) and its rate was declined due to acceleration of senescence during vegetative and reproductive phase (Alkhatib and Paulsen, 1984).

High temperature stress mainly affects thylakoid membrane activities and damages the thermolabile photosystem II reaction centre. Al-khatib and Paulsen (1990) measured net photosynthesis, thylakoid membrane stability, chlorophyll variable fluorescence and productivity in 10 genotypes from major world wheat producing regions under moderate ($22^0/17^0$C day/night) and high ($32^0/27^0$C day/night) tempature for two weeks at seedlings or from anthesis to maturity. They found that heat stress decreased mean photosynthetic rates by 32 and 11 per cent in seedling and mature plants respectively. Decreased photosynthetic rates and diminished productivity of plants were significantly correlated. Similar report of decline in photosynthetic rate due to high temperature was given by Shah (1992) in the same crop. Correlation between photosynthetic rate and yield were investigated by many. Studies of Reyonlds *et al.* (1994) showed signficant correlation among yield , photosynthetic rate and stomatal conductance. This was probably due to premature loss of chlorophyll associated with heat sensivity. Simlar association was also given by Condon *et al.* (1990), Morgan *et al.* (1993) and Amani *et al.* (1996).

CHLOROPHYLL, PHOTOSYNTHETIC RATE-VARIATION IN GENOTYPES AND STAGE OF GROWTH

Chlorophyll content varies with genotypes also. Thermotolerant mutant WH 147M showed a considerable decrease in the rate of photosynthesis as compared to sensitive cultivar WH-147 leaves. Stress of 45^{0}C for 1 hour resulted in 82 and 33 per cent reduction in photosynthetic activity in WH- 147 and WH-147M respectively (Kaur *et al.*, 1989). While studying yield and eight related physiological characters in 20 durum wheat genotypes, Gummuluru *et al.* (1989) have observed that drought tolerant types had higher chlorophyll a & b contents than drought susceptible types. While studying leaf water content and gas exchange parameters of two wheat genotypes differing in drought resistance, Ritchie *et al.* (1990) observed that in drought tolerant genotype TAM W-101, photosynthetic capacity was less effected under water stress compared susceptible genotype Sturdy. Further, these workers concluded that this trait may contribute drought resistance to TAM W-101.

High temperature stress mainly affects thylakoid membrane activities and damages the thermolabile photosystem II reaction centre. Al- Khatib and Paulsen (1990) measured net photosynthesis, thylakoid membrane stabilitiy, chlorophyll variability under moderate (22^0/17^{0}C day/night) and high (32^0/27^{0}C day/night) temperature from two week at seedling or from anthesis to maturity. They found that heat stress decreased mean photosynthetic rates by 32 and 11 per cent.

Differences in chlorophyll content at different growth stages were observed and reported by many in various crops.

Santakumari and Sinha (1972) observed variation in chlorophyll content at different growth stages in chickpea cultivars and also reported the fall in chlorophyll and chlorophyll a/b ratio during pod development. Decrease in leaf chlorophyll content from full expansion to senescence stage was also reported in wheat (Sirohi and Ghildyal, 1975) and in soybean (Buttery and Buzzell, 1971). Investigation on the effect of water stress treatment on the components of photosynthesis by Uprety and Sirohi (1987) in various crops revealed the variation in chlorophyll content in all the stages studied under each treatment. In wheat, the total chlorophyll content was 3.96, 4.14 and 2.03 mg/ g fresh weight at pre-anthesis, anthesis and post anthesis respectively under normal conditions.

2.2.2. INFLUENCE OF MOISTURE AND TEMPERATURE STRESS ON GROWTH AND DEVELOPMENT

2.2.2.A. DAYS TO ANTHESIS AND MATURITY(DAM)

DAM-MOISTURE AND HIGH TEMPERATURE STRESS

Plants try to complete their life cycle early under low moisture conditions in order to make better use of existing moisture. Wheat cultivars subjected to unirrigated treatments showed 50% anthesis 3 days earlier compared to irrigated treatments (Aggarwal and Sinha, 1984).

Bagga and Rawson (1977) studied the response of wheat cultivars to temperature at different stages of development and reported that lower temperature during the floral phase did result in longer duration and larger plants at anthesis. Thus, both temperature and day length are to known to influence these days to ear emergence anthesis and number of spikelets/ spike (Rawson, 1970, 1971; Rawson and Bagga, 1979; Stern and Kirby, 1979; Tongoona and Mostby, 1983). Temperature has a pronounced effect on duration of grain filling. At low temperature, grain development continues for a longer period and this results in higher final grain weight (Warrington *et al.*, 1977). The heat degree days required for wheat grain to attain 95 per cent of the maximum harvest weight from date of anthesis is around 400 heat degree days (HDD) for HD 4502, Kalyanasona and Sonalika. Therefore, high temperatures during this phase will provide 400 HDD in less days and thus the duration of grain development is reduced (Saini and Dadhwal, 1986). Temperature increase from $15/10^0$ to $21/16^0$ reduced the duration of grain filling and from 60 to 36 days (Sofiled *et al*., 1977). The continuous high temperature (30^0C/25^0C) prevailing in central India resulted in the flowering of Kalyanasona within 45 days, which reduced the yield by 60-70 per cent (Upadhyaya and Ruwali, 1984). The most apparent and stiriking effect of high temperatures on wheat growth is the acceleration of plant development and the overwhole reduction in plant size. The reduction in the duration of GS1 (emergence to double ridge) and GS2 (double ridge to anthesis) is associated with reduced spike number per plant and kernel number per spike. The reduction in the duration of GS3 (anthesis to physiological maturity) is often associated with a reduction in kernel weight (Warrington *et al.*, 1977; Behl *et al.*, 1993). These acceleration of phasic development due to high temperature (Waiens, 1994) can be directly or indirectly related to to wheat yield reduction at high temperatures (Shpiler and Blum, 1986). Using days to heading/ anthesis as the key diagnostic character, Singh and Behl (1989) classified wheat genotypes into five groups: Group (1) - high temperature sensitive but photoperiod non responsive; Group (2) - high temperature sensitive and photoperiod responsive; Group (3) - Low temperature responsive but photoperiod non responsive; Group (4) - High temperature and photoperiod tolerant; Group 5 - temperature and photoperiod nonresponsive. For plants experiencing a 3°C increase in day and night temperatures, relative to long term mean temperature, anthesis and end of grain filling were advanced by several days compared to control (Moot *et al* ., 1996).

2.2.2.B. LEAF NUMBER AND LEAF AREA

LEAF NUMBER AND LEAF AREA MOISTURE STRESS

The remarkable effects of water stress are also through the impact on leaf number and leaf area. Field studies conducted by Chaturvedi *et al.* (1981) reported that water deficit 20-25 days after sowing decreased leaf number in each plant group studied (wheat, barley and triticale) when compared with irrigation treatment.

The development of leaf area is another important factor that could effect the crop response to water availability (Rawson and Turner, 1982). Variation in total leaf area may result from changes in leaf number and leaf size. Leaf size is determined by the number and size of the cells of which leaf is built, and influenced by moisture regime and supply of nutrients. It has been observed that, in general there is a rapid, followed by gradual decline in the rate of cell enlargement as water stress develops. Cell enlargement ceases when turgor pressure is negative. Growth of bean plants was reported to stop at leaf water potential of about - 6 bars and solute potential of -10 bars (Boyer, 1970). One of the most important consequence of sensitivity of cell enlargement to water stress is marked decline in leaf area (Boyer, 1970; Hsiao, 1973) and this reduction in leaf area reduces crop growth rate particularly during early stages. Water stress can also affect the leaf area by hastening leaf senescence (Slatyer, 1973). Reports on decrease in leaf area due to water stress are many (Assuncao, 1979; Uprety and Sirohi, 1987; Aggarwal and Koundal, 1988).

The contribution of pre-anthesis photosynthates to grain was higher in unirrigated than irrigated condition. In unirrigated wheat during post-anthesis period, the photosynthetic rate was low due to lesser leaf area (due to early senescence) and low nutrient uptake and utilization which resulted in higher contribution of pre-anthesis reserve photosynthates (Kumar, 1987). Reports regarding correlation between leaf area, yield and yield components were plenty. A direct correlation between leaf area and total dry matter (Evans *et al.*, 1975), spike number (Aggarwal *et al* ., 1981) and seed yield (Rawson and Turner, 1982) was observed. Passioura and Gardner (1990) in wheat seedlings reported that water stress decreased leaf area which may be due to fall in leaf expansion rate.

LEAF NUMBER AND LEAF AREA-HIGH TEMPERATURE STRESS

The leaf development is also influenced by heat stress besides its direct effect on metabolism. Plants time their development based on an accumulation of average daily temperature. The faster the temperature accumulated, the faster the vegetative development progress. Thus the leaf initiation rate will be faster at higher temperatures (Rawson, 1992) but heat stress reduces the duration of vegetative growth (Saini, 1988; Acevedo *et al.*, 1991) and therefore reduces leaf area (Warrington *et al.*, 1977; Shpiler and Blum, 1986) and leaf number (Shpiler and Blum, 1986; Acevedo *et al* ., 1991).

LEAF NUMBER AND LEAF AREA-VARIATION IN GENOTYPES AND STAGE OF GROWTH

Leaf area differences in various genotypes under water stress were also reported. Aggarwal *et al.* (1981) determined the total leaf area of the main shoot at spikelet differentiation stage and observed 18,49 and 52% reduction in leaf area of *T. aestivum*, *T. durum* and triticale respectively under no irrigation treatment as compared with irrigation treatment. Leaves of drought resistant species are generally smaller and have lower surface area volume than species adapted to higher moisture environment (Clarke and Smith, 1984).

In a stress treatment, irrespective of the level of stored soil moisture, C-306 had higher LAI than Kalyanasona which in turn had higher LAI than Moti. However, the difference between C-306 and Kalyanasona were not statistically significant. Application of water during mid-season resulted in increased LAI in all varieties. The recovery from stressed treatments was however, significantly in Rec 75 only. Even after recovery, C-306 and Kalyanasona had higher LAI than Moti (Aggarwal and Sinha, 1987). Similar report that drought tolerant types had higher leaf area compared to drought susceptible types was given by Gummuluru *et al.* (1989) in wheat. Genotypic behaviour in relation to leaf area and photosynthesis was studied by Uprety and Sirohi (1987). These workers observed that though wild genotypes with in a ploidy level had higher rate of photosynthesis than cultivated ones, the leaf area and harvest index were higher in cultivable forms.

Aggarwal and Sinha (1987) studied the performance of three varieties of wheat (C-306, Kalyanasona and Moti) differing in drought resistance under different soil moisture conditions and it was observed that C-306 maintained maximum leaf area index around anthesis relative to other varieties. Cultivars differ in their pre and post anthesis stages in response to water stress. Water stress treatment at pre anthesis stage did not affect the leaf area in wheat and triticale but in rye. At anthesis, water stress treatment significantly reduced the leaf area in rye and wheat only. Whereas, post-anthesis stress treatment caused reduction in leaf area in all the three species (Uprety and Sirohi, 1987). Guinta *et al.* (1995) observed maximum reduction in LAI when drought was imposed between begining of stem elongation and heading. Madhulety and Ved Prakash (1988) observed a sharp decline in leaf area during post-anthesis period in wheat variety C-306 while it was minimum in oligo culm (gias wheat). Thus the maintenance of leaf area during pre and post anthesis in oligoculm could be attributed to the stability of tillering and prolonged photosynthetic surface area which was envisaged as a trait of potential productivity.

2.2.2.C. TILLER NUMBER

TILLER NUMBER-MOISTURE STRESS

Tiller production and survival may depend up on the quantity and stage of water availability either through irrigation or natural precipitation. Production and survival of tillers are also dependent up on prevailing environment, including radiation (Aspinall and Paleg, 1964; Rawson, 1971), Photoperiod (Cannel, 1969). Water stress causes tiller mortality. Turner and Begg (1981) have reported that water deficit in wheat increased the rate of tiller death and also reduced the number of ear bearing tillers by 35 per cent.

Donald (1968) proposed a monoculm ideotype for irrigated regions. It has also been suggested that a similar ideotype would be suitable for unirrigated regions as well (Asana, 1968). However, the production of an optimal number of tillers was found imparting suitability to yield and yield components in plants grown in water-limited environment (Aggarwal *et al* ., 1981; Chaturvedi *et al.*, 1981). The regulation of tillering pattern is therefore an important adaptive mechanism. According to Asana (1968) tillers donot make any contribution to yield under barani conditions Infact ear number per unit area barely exceeds, or is even less than the original plant number, and under such conditions it would be appropriate to select for mother shoot characteristics. Jain (1974) suggested that number of ear bearing tillers at the time of harvest is an important yield component contributing to higher grain yield. The experiments conducted by Keim and Kronstad (1981) with 10 winter wheat cultivars for evaluation of grain yield and yield components under moisture stress conditions revealed that the reason for drought tolerance of Wasner cultivar is due to maintenance of large number of tillers throughout development to harvest.

Tiller production has also correlation with grain yield. Singh and Srivastava (1988) in wheat suggested that grain yield was dependent on tillers per plant during vegetative phase. Under water-limited environments, the importance of tillering as selection index is still unresolved. Hadjichristodoulou (1985) advocated profuse tillering capcity where as Dofing and Karlsson (1993) advocated uniculum ideotype for water limited enviroment. However Simane *et al.* (1993) reported that cultivars with high tillering capacity exhausts limited available soil water and reduces source-sink ratio during grain filling period and resulting ultimately in low harvest index and hence selecting genotypes having two or three tillers would do better under water limited conditions. Bansal and Sinha (1991) reported that maintenance of tillers was considered in maintaining the number of spikes across environment. No significant effect of water availability was observed on tiller mortality in the species like C-306.

TILLER NUMBER - HIGH TEMPERATURE STRESS

Alternation in environmental conditions appear to have comparatively little effect on the initiation of tiller buds at the apex, but have a marked effect on the subsequent growth of these buds. Campbell and Read (1968) could not observe a significant influence on tillering by increasing day temperatures from 21° to 27°C or night temperatures from 13° to 21°C. Nummber of tillers in wheat were reduced both by higher day temperature and low temperature. Post earing temperatures had great effect up on the number of ears/plant through number of tillers and per cent of fertile tillers. Plant given higher day temperatures continued to produce fertile tillers over a longer period (Owen, 1971). Bhardwaj (1978) in his experiment with wheat sown in October observed mean temperature of 25°C and above is always unfavorable for tillering and early vegetative growth. High temperatures during emergence to double ridge decreased number of spike bearing tillers (Shpiler and Blum, 1986; Acevedo *et al* ., 1991). High mean tempreature in early planting compared to normal planting reduced tiller number in various wheat genotypes (Singh *et al.*, 1978; Randhawa *et al.*, 1981). Decrease in tiller number under field condition due to high temperature in wheat was also reported by Walens (1994).

TILLER NUMBER-VARIATION IN GENOTYPES AND STAGE OF GROWTH

The genotypic responses to tillering have been studied by many workers. Semidwarf and dwarf wheat varieties have the advantage over tall varieties in having more effective tillers which make them more productive (Austin *et al*, 1980). Studies conducted by Aggarwal and Sinha (1983) had shown that in C-306 more number of tillers are produced both under irrigated and unirrigated conditions as compared to Kalyanasona. Results also showed that C-306 utilized its tillering habit to maintain stability in grain yield, when the mother shoot had been adversely effected by stress. Where as kalyanasona showed more reduction in yield since it puts greater emphasis on the mother shoot and the yield characters of tillers are more adversely effected. Variety C-306 produced 1200 shoots per m^2 and 800 shoots per m^2 in irrigated and unirrigated treatments respectively. The corresponding figures in kalyanasona were 930 and 650 shoots per m^2. Similarly Uprety and Sirohi (1987) with in genotypes found a reduction in assimilate wastage in terms of significant decrease in tillers/plant in domesticated tetraploids (*Triticum durum* wheat) and Hexaploid (*Triticum aestivum*) compared to their wild forms., The less number of tillers in domesticated forms resulted in increased biomass of individual tillers.

Crop growth resource components like leaf area duration and tillering are determined during GS_1 phase. Sensitivity to heat stress during this phase is expressed as reduction in spike bearing tillers (Shpiler and Blum, 1986).

2.2.2.D.PLANT BIOMASS

PLANT BIOMASS-MOISTURE AND HIGH TEMPERATURE STRESS

Adequate moisture supply is essential to harness fully the advantage of applied fertilizer and for high biological productivity (Singh and Rajatde, 1978). In green house trails, winter wheat plants were grown under three moisture regimes (600,300 or 150 ml water/pot a day) from awn appearance until maturity. Water stressed plants had lower dry weights. Similarly decrease in fresh and dry weights with increasing moisture stress at all growth stages was also reported by Monayeni *et al.* (1984) in wheat and barley and in wheat (Paligham Shah *et al.*, 1996). Water stress may affect growth and yield through disturbances in several morpho physiological processes and nutrient uptake (Ludlow, 1975; Turner and Begg, 1978, 1981). Reduction in dry matter of cowpea and mung due to moisture stress arose from the reduction in leaf area duration, absorption of radiation and the rate of net photosynthesis.Gregory *et al.* (1981) found that the decrease in total biomass was due to decrease in photosynthetic rate which in turn due to decrease in leaf nitrogen per cent. Significant linear relationships of drymatter yield with IPAR, LAI and CGR clearly indicate the interdependence of these characters (Bhatt, 1995).

Al- Khatib and Paulsen (1990) measured various parameters and productivity in 10 genotypes from major world wheat productivity regions under moderate (22°/17°C day/night) and high (32°/27°C day/ night) temperature for two week seedlings or from anthesis to maturity. They found that heat stress decreased mean total biomass by 32 and 15% in seedlings and maturing plants respectively. Wheat plants grown in silty-loam soil in a green house were subjected to day/night temperatures for 15/10, 25/20 or 35/30^{0}C. High temperature exposure decreased shoot dry weight (Shah, 1992). For plants experiencing a 3^{0}C increase in day and night temperatures relative to local-long mean temperatures, dry matter yields were reduced by 18% compared to control in wheat (Moot *et al* ., 1996).

Unfavourable temperatures exposures upon sowing early or late by deviating from recommended time reduced total plant biomass in wheat (Singh *et al.*, 1978; Randhawa *et al.*, 1980; Singh *et al* ., 1985 and Chaturvedi *et al.*, 1985), in corn (Stephan and Wallace, 1996).

BIOMASS-VARIATION IN GENOTYPES AND STAGE OF GROWTH

Studies in twenty durum wheat genotypes grown under irrigated and unirrigated conditions, revealed that reduced water availability decreased shoot weight. It was also observed from the findings that drought tolerant types had higher shoot dry weight than drought susceptible types (Gummuluru *et al.*, 1989). The higher biomass in themotolerant cultivars may be due to less per cent ion leakage or per cent relative injury index or higher membrane thermostability as reported by Ashraf *et al.* (1994) in cotton. Contrary to this, no differences or on par in dry weights upon subjecting to stress in contrasting wheat varieties *viz.*, C-306 and Kalyanasona was reported by Aggarwal and Sinha (1983). Moisture stress at any stage of crop growth and development reduces grain and straw yields. But the rate of crop growth depends on the degree and duration of stress and particularly the stage of crop growth and development at which moisture stress occurs (Talukdar, 1987).

Studies of moisture stress on different growth stages in field grown soybean revealed that stress at flower initiation reduced dry weight by about 50 per cent (Phalwan and Tripathi, 1984). The rate of dry matter accumulation was maximum between 76 and 90 days in C-306 and between 106 and 120 days in Kalyanasona, irrespective of irrigation treatment. The estimated portion of dry matter mobilized to grains increased gradually with the growth stage, reaching a peak between 90 and 105 days in C-306 and between 106 and 120 days in Kalyanasona (Aggarwal and Sinha, 1984). In a field experiments at Allahabad in 1988-89, wheat was given drought stress at two stages. Drought stress at any growth stage reduced yields. Drought stress from heading to maturity gave greater reduction in grain yield than drought stress from emergence to heading (Imtiyaz *et al.*, 1990).

Drought imposed from 2 weeks before anthesis or later reduced biomass production. This was due to a decrease in the amount of radiation intercepted which was mostly associated with more rapid leaf senescence. For the later drought treatments, the radiation use efficiency was stable and near the maximum value for unstresed crops. However, final biomass was sensitive to drought timing and in particular was more sensitive to maximum protential soil moisture deficit for the early than the later drought treatment (Janieson *et al.*, 1995)

In a pot experriment *A.pubescens* was water stressed at the vegetative stage (p1) initiation of reproduction (p2) or the late reproductive (p3) state. Relative to control plants, total dry matter of P1, P2, & P3 plants, harvested after an eight day post - stress recovery period was reduced by 78, 60 and 35 per cent respectively. However, at the end of growing season there was no significant differences in total drymatter accumlation between the stressed and non-stressed palnts. This recovery was explained by the phenotypic plasticty in leaf allocation in stages p1 and p2 and by the increase in the leaf area of p1 and p2 plants following water stress (Moolman *et al* ., 1996). The relation between final grain yield total biomass LAI and days to anthesis and maturity were studied by many (Tompkins *et al.*, 1991; Johnston and Flower 1992). Fossati *et al.* (1993) found no significant correlation of grain yield, total biomass and nitrogen uptake, grain nitrogen per cent, straw nitrogen per cent either with days to heading or days to maturity under normal or controlled conditions in winter triticale.

Biomass in wheat has high economic value yet selection for it is not generally made. In the past, improvement of wheat yields were realized primarily because of the high harvest index of the semidwarf wheats compared to the old tall wheats. There is almost a consensus among cereal breeders that future yield increases will be possible primarily through manipulation of morpho physiological traits including biomass yield (Sharma, 1993). Helsel (1985) reported low to high heritability estimates for biomass yield and suggested a combined selection for biomass yield and harvest index to improve grain yield. Sharma (1993) reported that biomass yield in wheat had positive genotypic correlations with grain yield, effective tiller number, number of kernels per spike but negative correlation with harvest index and so biomass yield may be useful selection trait for yield improvement in wheat.

2.2.2.E. YIELD AND YIELD COMPONENTS

YIELD AND YIELD COMPONENTS - MOISTURE STRESS

Many investigations have shown that grain yield in wheat depends on several grain yield components including grain number, grain weight, pre and post anthesis dry matter and harvest index (Asana, 1975; Sinha and Khanna, 1975; Aggarwal and Sinha, 1987; Bansal and Sinha, 1991). A lot of work on physiological analysis of yield in wheat have been conducted by various workers (Asana, 1975; Evans *et al.*, 1975). Yield is a function of yield components plus the complementing function of vegetative and reproductive growth. So it is essential that the adaptability should be analysed for all these events which influence the final expression of yield (Sinha and Khanna, 1975).

While studying the agronomic performance of wheat as influenced by moisture stress at various growth stages, Hassan *et al.* (1987) have reported that moisture stress reduced the number of ears /m^2; ear length and grain number per ear. Earlier developing yield components could affect later - expressing ones in compensatory pattern during development, particularly when there is shortage of resources, such as water (Fischer, 1985). Reduced productive tillers / plant, fertile spikelets/plant, number of grains/ plant and individual grain weight under stress environment led to yield reduction in wheat (Pal, 1992). Guinta *et al.* (1995) have studied the impact of mild and severe water stress on wheat reproductive behaviour. Severe water stress affected all the grain yield components. Particularly the number of fertile ears per unit area (60 per cent) and grain number per ear (48 per cent). Water stress reduced spike biomass at anthesis to 58-94 per cent that of well watered condition. Stress after terminal spikelet stage reduced the ratio of grain number to anthesis spike weight by 50 per cent suggesting that reduced grain number under stress may not be soley due to restricted assimilate supply (Robert son and Guinta, 1994).

In trails of 1972-73, wheat cultivar Tobari was subjected to two moisture regimes at varying periods and different growth stages. Stress before anthesis decreased the length of ears and weight of individual grains (Hallman, 1975). In a similar type of experiment, Assuncao (1979) found decrease in grain size whereas Monayeni *et al.* (1984) observed decreased grain number/ear and grain weight / plant due to water stress. Ashraf *et al.* (1994) have studied water relation of eight wheat cultivars under control, pre anthesis drought, post anthesis drought and terminal drought. The maximum reduction in all parameters was under terminal drought. The difference between pre and post anthesis drought was not significatnt in the case of yield and RWC but significant in other parameters measured. Grain yield can be analysed in terms of three yield components (number of spikes per unit area of land, number of kernals per spike and mean kernel weight). These components develop sequentially, with later developing components under control of earlier developing ones and interact in compensatory patterns, particularly under stress enviroments (Dofing and Knight, 1992).

Longer grain-filling period, increased number of kernels per spike and limited spike number per meter square can be used as a selection criteria for sustainable yield in water limited environments (Simane *et al.*, 1993).

YIELD AND YIELD COMPONENTS - HIGH TEMPERATURE STRESS

Many investigations have shown that grain yield of wheat depends on several grain yield components including grain number, grain weight, pre and post anthesis dry matter and harvest index (Asana, 1975; Sinha and Khanna, 1975; Aggarwal and Sinha, 1987 and Bansal and Sinha, 1991). Simple phenotypic correlation analysis studied by Hezhonghu and Rajaram (1994) indicated that yield was highly and positively correlated with seeds per spike, biomass and harvest index independent of season and genotypes under high temperature. Moreover, it was further concluded that grains per spike, biomass, harvest index and test weight could be considered as potential selection criteria for yield under high temperature. Shpiler and Blum (1991) in their critical study on yield conponents in wheat under stress reported that kernel number is the most important yield component affecting heat tolerance for yield and that spike number and kernel weight are relatively less important in affecting yield variation among cultivars under heat stress.

Influence on yield components due to changes in sowing dates were also reported. High soil and air temperatures existing under early sowing (October) may be the plausible reason for reduction in total tiller number, number of ears/m^2, spikelets/m^2, grain number/m^2 etc., when compared to normal planting (Singh *et al.*, 1985; Chaturvedi *et al.*, 1985; Abrol *et al.*, 1991; Hunt *et al.*, 1996).

YIELD AND YIELD COMPONENTS - VARIATION IN GENOTYPE AND STAGE OF GROWTH

Moisture stress causes loss in yield depending upon the stage at which the plant was exposed. For many crop plants, moisture stress at flowering period is critical. Even a short period of water stress at anthesis will markedly reduce the number of flowers that set seeds (May and Milthorpe, 1962). Most sensitive stage was between completion of spikelet formation and anthesis, though all the stages were affected (Aspinall and Paleg, 1964 and Henckel, 1964). Different reports regarding the critical time at which the moisture stress cause maximum loss in yield ranging from dough stage (Hutcheon and Renne, 1960) and jointing stage (Day and Intalap, 1990) were given. Fischer (1973) found that the grain filling was reduced most when stress appeared about 10 days before ear emergence and the sensitivity to stress decreased markedly at later stages of development in wheat. Under limited water supply conditions, the dry matter transportation to grain is low or less probably due to low transpiration (Passioura, 1977; Turner and Begg, 1981).

Grain yield of cereals is governed by the duration of grain filling period which is a post anthesis phenomenon. Kumar (1987) in triticale observed a significant reduction in grain yield due to drought treatments given at vegetative, pre-anthesis and post anthesis stages. The effect of drought treatments given at anthesis and post anthesis stages were more related than drought given at vegetative and pre-anthesis stages.

Potential ear number per unit area is largely determined by the extent of tillering before the initiation of inflorescence, while the other major yield components like grain size is determined mainly by the conditions after anthesis. But to take full advantage of favourable conditions during grain filling requires the formation of many spikelets, and relatively slow initial development of inflorescence (Bhinghham, 1967). The adverse weather conditions during the 3 week period prior to anthesis can adversely reduce yield in wheat (Willey and Holliday, 1971). The number of grains per ear is controlled by the number of spikelets present and the number of grains per spikelet. Warrington *et al.* (1977) observed that ear development stage was more critical for temperature effects. Plants grown at low temperature at this stage had long culms, large flag leaves and more potential fertile floret in each spikelet. Temperature prior to floral initiation was not of major important to final weight but it did have an effect on the number of mature ears present at harvest. They have also indicated that higher temperatures during ear development and grain growth stages reduced the duration. Consequently, the number of grains per ear are influenced in the similar order by variation in temperature.

The final yield of wheat depends on the yield components *viz.* ear number per unit area, the number of spikelets per ear, the number of grains per spikelet and individual grain size. The relative magnitudes of these components varies substantially with the sequence of growing conditions, with features or agronomic practices, such as sowing time, plant density and fertilizer application with cultivar used (Evans *et al.*, 1975). After ear emergence, when both final ear number and spikelet number are almost fixed, the grain yield in wheat depends largely on grain number per ear, individual grain size and grain weight per ear.

Grain yield showed a high corrleation with most of its components in all sowing dates from Semptember to February (Saini *et al.*, 1988).

The most apparent and striking effect of high temperatures on wheat growth is the acceleration of plant development and the over whole reduction in plant size. The reduction in the duration of GS1 (emergence to double ridge) and GS2 (double ridge to anthesis) is associated with reduced spike number per plant and kernel number per spike. The reduction in the duration of GS3 (anthesis to physiological maturity) is often associated with a reduction in kernal weight (Warrington *et al.*, 1977; Behl *et al.*, 1993). These accleration of phasic development due to high temperature (Waiens, 1994) can be directly or indirectly related to wheat yield reduction at high temperatures (Shpiler and Blum, 1986). The search for the most important stages in building yield protential is not recent. Hudson (1934) stated that the period between terminal spikelet initiation and anthesis was of paramount importance for yield determination. More recently, others have confirmed this association experimentally (Fisher, 1985; Kirby, 1988; Siddique *et al.*, 1989; Slafer *et al.*, 1990, 1994). While discussing field components and compensation in wheat, Slafer *et al.* (1996) felt that the period around or before anthesis, when the number of grains per square metre is established, is critical.

MATERIALS AND METHODS

The present investigation was carried out at the Division of Plant Physiology, IARI, New Delhi under natural environmental conditions in both field and pot-culture trails during the *rabi* season of 1994-95.

3.1 EXPERIMENT 1

This was carried out under controlled temperature conditions (20°C - 40°C) to study germination per cent, seedling growth and enzyme activity in four different wheat genotypes viz., C-306, PBW-175, HD-2329 and WH-542.

3.1.1. RAISING SEEDLINGS AND TEMPERATURE EXPOSURE

Seeds of all four varieties were made to germinate in petri dishes by placing them over a moistend double walled filter paper. The germinating seds were used to measure amylase activitiy and root and shoot growth at different durations *viz.*, 24, 48, 72, and 96 hours. For studies like catalase and peroxidase, seedlings raised in medium sized plastic pots containing a mixture of soil and FYM (ratio of 1:4) were used. These seedlings were exposed to 4 different temperatures regimes *viz.* 20°C, 30°C , 35°C and 40°C to study the activity of these enzymes under these temperatures.

3.1.2. MORPHOLOGICAL OBSERVATIONS

(a) Percent Germination : Number of sprouted seeds at different temperatures at different durations were counted and percent germination was calculated.

(b) Root and Shoot growth : Root and shoot growth of all 4 varieties exposed to 4 different temperatures were computed in 3 replicates by taking length and dry weights of them.

(c) shoot vigour index : shoot vigour index is calculated by multipling shoot length with germination percent.

3.1.3. BIOCHEMICAL OBSERVATIONS

The procedures followed to estimate α-amylase (in geminating seeds), catalase and peroxidase (in 20 day old seedlings) are described below.

(a) α - amylase activity : The α-amylase acitivity in germinating seeds was estimated according to the method of Shuster and Gifford (1962).

i) Reagents : 0.05 M phosphate buffer (P^H 7.0)

It was prepared by using 2 reagents.

Reagent A: 3.402 g of potassium dihydrogen phosphate was dissolved in distilled water and made to final volume of 500 ml.

Reagent B: 4.35 g of dipotassium hydrogen phosphate was dissolved in distilled water and made to final volume of 100 ml. Buffer solution was prepared by mixing 16 ml of A and 84 ml of B. Final pH.7.0 was adjusted with the help of pH meter.

0.05 M potassium dihydrogen phosphate : 3.4g of KH_2 PO_4 was mixed in 500 ml of distilled water to give 0.05 M KH_2 PO_4

Soluble starch solution: 50 mg of soluble starch was dissolved in 100 ml of boiling 0.05 M KH_2PO_4.

Iodine reagent : Iodine reagent was prepared by dissolving 60 mg potassium iodide and 6 mg of Iodine in 100 ml of 0.05 N HCL.

0.05 N HCL: 0.05 N HCL was prepared by dissolving 2.15 ml of HCl in 500 ml of distilled water.

ii) Assay

Enzyme was extracted by grinding 10 germinating seeds in 10 ml of 0.05 M Potassium Phosphate buffer. The homogenate was passed through four layers of muslin cloth and then centriufuged at 12,000 x g for 10 minutes at 4^{0}C. Supernatant was collected and used as a source of enzyme after diluting it 4/8/10/12 times with cold distilled water. To this diluted enzyme extract, 1ml of starch solution was added and incubated at 25^{0}C for 5 minutes. Immediately after incubation 1 ml of iodine reagent was added to stop the reaction. Finally 5 ml of distilled water was added and the optical density of resulting solution was measured at 620 nm. Blank was prepared by not adding starch solution and control by not adding potassium dihydrogen phosphate. Alpha-amylase activity was expressed as mg. of soluble starch hydrolysed/seed/sec.

iii) Preparation of standard curve:

Standard curve was prepared by preparing stock solutions. Stock solution A was prepared by dissolving 1000 mg of starch in 100 ml of double distilled water. From this 10 ml was taken and stock B solution was made by adding 90 ml of distilled water. From stock B solution 1ml, 2ml, 3ml........ 9ml were taken in series of test tubes and final volume was made to 10 ml by adding double distilled water. From these solutions, series of different starch concentrations were prepared by taking 1ml from each test tube and adding 1 ml of Iodine reagent,1 ml of phosphate buffer and 5 ml of double distilled water. These preparations gave 100,200,.....1000 μgs of starch solutions respectively. Using these solutions, readings were taken at 620 nm. Standard curve was prepared by plotting OD values against different concentrates of starch.

b) Catalase activity :

Enzyme was assayed following the method of Teranashi *et al.* (1974) with the little modification

i) Preparation of reagents : The following reagents were prepared

Phosphate buffer: 0.1 M phosphate buffer ($P^{H}7.5$) was prepared as described in section 3.1.3.a.

H_2O_2 solution: H_2O_2 was prepared by dissolving 10 ml of 30% (8.82 M) of H_2O_2 in water to make the final volume 88.2 ml. This gives approximately 1 M soultion (1 m mol/ml).

Titaninum reagent: One gram of titanium oxide (TiO_2) and 10.0 gms of potassium sulphate (K_2SO_4) were mixed together and digested with 150 ml of concentrated H_2SO_4 for 2 to 3 hours on mantle heater. The digested mixture was then cooled, diluted to 1.5 litres with distilled water and used as titanium reagent.

ii) Extraction of the enzyme :

Leaves from twenty days old seedlings were collected in the ice-bucket, washed with distilled water and wiped out by filter paper. Small pieces of leaves were cut for grinding.Weighed amount of sample (0.5 g) was taken and ground in pre-chilled mortar with 0.1 M phosphate buffer containing EDTA (p^{H} 7.5). Homogenate was centrifuged at 0°C in a refrigerated centrifuge for 20 minutes at 12,000 xg. Supernatant was used as a source of the enzyme.

iii) Assay of enzyme: Assay mix consisted the following

0.1 ml enzyme extract

2.0 ml 1M H_2O_2 (2m mole)

2.9 ml phosphate buffer pH 7.5 (290 μ moles)

A blank with out H_2O_2 in the mixture was used as a control. Incubation was done at 30°C in a water bath for one minute and the reaction was stopped by adding 0.1 ml of 1.0 M zinc acetate which also precipitates the excess of protein. To this, 0.9 ml of distilled water was added and the whole content was centrifuged at 3,000 x g for 10 minutes. 3 ml of the supernatant was taken and mixed with 2.0 ml of titanium reagent to develop the colour. The optical density readings were taken at 410 nm in Bausch and Lomb spectronic -20 spectrophotometer for estimation of residual H_2O_2. All the assays were carried out in triplicate.

iv) Preparation of standard curve for H_2O_2

H_2O_2 was first standardised by using standard soultion of potassium permanganate (1.0 M). From this solution, several concentrations, such as 5,10,15....70 μ moles of H_2O_2 were prepared. To this, 2 ml titanium reagent was added and the final volume was made upto 5ml and OD readings were taken at 410 nm wave length. Standard curve was drawn by plotting OD readings against the respective concentrations.

c) Peroxidase activity

Enzyme was assayed following the method of Castillo *et al.* (1984) with little modifications.

i) Preparations of reagents : The following reagents were prepared.

0.1M Phosphate Buffer : This was prepared as described in section 3.1.3.a

96 mM Guiacol

6 mM H_2O_2 : First 0.15 M H_2O_2 was prepared by adding 1.7 ml of 30% H_2O_2 in 100ml distilled water. From this 4 ml was taken and diluted to 100 ml which gave 6 mM H_2O_2.

Crude extract : The supernatant of enzyme mix was referred as crude extract.

ii) Extraction

Leaf tissue (0.5 g) was homogenised with a mortar & pistle with 10 ml of 0.1 M potassium phosphate buffer (p^H 7.5) containing 0.5 mM EDTA. The brie was filtered with cheese cloth & the filtrate was centrifuged for 10 minutes at 0 °C in refrigerated centrifuge at 20,000 x g. The supernatant collected was used as crude extract.

iii) Assay

0.1 ml of crude extract was taken and to it 1.4 ml of 0.1M phosphate buffer, 0.5 ml of 96 mm Guiacol were added step by step and distilled water was added to see that final volume becomes 3 ml after addition of H_2O_2. 1 ml of 6mM H_2O_2 was added as and when the cuvet was placed in Spectronic- 20 with the help of micropipettee. The change in O.D at 470 nm upon addition of H_2O_2 for every 30 seconds was recorded.

D) Protein estimation :

i) Reagents

2 per cent Na_2 CO_3 in 0.1N NaOH. 20g sodium carbonate and 4g Sodium hydroxide was dissolved in distilled water.

1 per cent $CuSO_4.5H_2O$ solution. 1g of copper sulphate was dissolved in 100ml distilled water.

2 per cent sodium potassium tartarate solution. 2g of sodium potassium tartarate was dissolved in 100 ml distilled water. Working solution of was prepared by mixing 0.5ml of above two solutions.

Carbonate-Cu++solution.

Folin Ciocalteu reagent (1N)

ii) Procedure:

The protein content of seeds was estimated by using alkaline copper and folin reagent (Lowry *et al* .,,1951). Exactly 200 mg of fresh seed material was ground using 10 ml of 0.1M phosphate buffer (7.5 P^H). The extract was centrifuged at 5,000 rpm for 30 minutes. To this supernatant 3 ml of 50 per cent Trichloro acetic acid was added and kept over night. The contents were centrifuged again at 5,000 rpm for 30 minites. The supernatant was discarded and 5ml of 1 N Sodium hydroxide was added to the pillet. One ml of allkaline copper reagent was pipetted out into each test tube containing 0.2ml of protein extract and 0.2ml of folin reagent was added and shaken. After 30 minutes the volume was made up to 5ml using distilled water. The absorbance was read to 500 nm using Spectrophotometer. A blank was run with no proteion extract.The content of the soluble protein was determined by reading from the standard curve. The standrard curve was developed by using BSA. The soluble protein in the sample was expressed as mg/g fresh weight basis.

3.2 EXPERIMENT II

3.2.1 PLANT MATERIAL

Four wheat [*Triticum aestivum L].* varieties *viz.*, C-306 and PBW -175 and H.D-2329 and WH-542 which have almost same differentiation time were used in the study. The seed material of all the varieties was obtained from Division of Genetics, IARI, New Delhi.

a) C-306 : A tall, medium to late maturing variety, developed by crossing (REGENT 1974/3 x CHZ// x 2C 591/3/P19/C281) and released in 1965. Recommended for both North East and North West plain zones and performs well under timely sown, low fertility and rainfed conditions.

b) PBW-175 : One gene dwarf medium maturity variety developed by crossing HD 2160 with WG 1025 and released in 1986. Well suited to North West plains and performs well under timely sown rainfed conditions.

c) HD-2329 : This is a double dwarf variety, released in 1985 and developed from the cross of HD 1962-E 4870 x K 65/HD 1552 x UP.-262. Yields high under timely sown high fertility and irrigated conditions of northern plains

d) WH-542 : Two gene, profusely tillering, medium to late maturing variety developed from JUPATICO/BJYO/URES and released in 1991. Well suited to North West plains and performs well under timely sown, irrigated conditions.

3.2.2 GENERAL CULTURAL OPERATIONS

a) Field preparations :

Forty eight plots, each of 4.5 square metre area, were made. Two irrigations were given prior to sowing and made the soil conducive for proper germination and growth. Out of 48 plots, 24 were used under early sowing and remaining under normal sowing. In each sowing half of the plots were kept unirrigated. The irrigated and non-irrigated plots were separated by 5 metre band to prevent seepage and entry of water.

b) Manures and Fertilizers :

Farm yard manure (FYM) at the rate of 100 kg/ha was applied at the time of pre-sowing irrigation to bring the soil to fine tilth. Nitrogen fertilizer (Urea) was applied in two doses, so that it gives a total of 100 kg N/ha. First dose was given at the time of sowing and remaining dose was applied at crownroot initiation, Uniform doses of phosphorus and potash at the rate of 40 kg P_2O_5/ ha and 40 kg K_2O/ha were also applied at the time of sowing. The amount of fertilizers were calculated on the basis of amount of nutrients (N,.P,.K.) needed for hactare.

c) Sowings :

Sowings were done with the help of fertilizer cum seed driller. Early sowing was on 15th October and normal sowing was on 19th November.

d) Thinning and plant protection

Thinning was done 20 days after sowing and care was taken to maintain optimum number of plants/square metre so as to avoid the competition for light, space and mineral elements.

3.2.3 TOTAL TREATMENTS

The total treatments were a combination of irrigations, plantings, varitics and replications. All the 4 varieties which were replicated thrice, were randomly arranged in both irrigated (12) and unirrigated (12) plots under each date of sowing.

a) Sowing times (2)

(i) Early (15th October)

(ii) Normal (19th November)

b) Irrigations (2)

(i) Irrigated (Control)

(ii)Unirrigated (stress)

c) Varieties (4)

Drought tolerant:-C-306,PBW-175

Drought susceptible; HD-2329,WH-542

d) Number of replications (3)

So the total treatment combinations were :4 x 2x 2x 3=48

3.2.4 DESIGN - SPLIT-SPLIT-PLOT

The performance of all varieties under both irrigated and stress conditions in both early and normal plantings were compared. Irrigations were alloted to main plots and sowings to sub plots and varieties to sub subplots in this design. The effect of all 3 types of treatments and their interaction were studied with the help of this design.

3.2.5 SAMPLING

In each plot, plants in 1 square metre area were kept undisturbed for final harvest data and five of them were tagged to record date of ear emergence and anthesis. Rest of plants in each plot were used for studying various morphological,physiological and biochemical observations during fixed intervals beginning from 45th day after sowing. The sampling procedure for these observations was as follows:

3.2.6 MORPHOLOGICAL OBSERVATIONS

a) Days to anthesis and maturity : The number of days from sowing to 50 percent anthesis and maturity were recorded as days to anthesis and days to maturity.

b) Main shoot studies

i) Leaf area : Leaf area was measured using an automatic area meter (LICOR 3000) The leaves of the whole plant were separated, cleaned. Leaf area of only green portion was measured and expressed as cm^2/plant

ii) Leaf dry weight : Leaves separated were kept in oven at 80°C for 48 hours and then final dry weights were recorded.

iii) Stem dry weight : Main culm was dried after separating the roots and expressed as g/plant.

iv) Shoot height : The lenght of main shoots of four plants was measured from ground level to the base of the ear head, averaged and expressed in centimeters..

v) Ear length : Ear length was considered from neck node to the tip of the top-most spikelet. Ear length of four plants was measured, averaged and expressed in centimetres.

vi) Ear number : The total number of ears for four plants were counted, averaged and expressed as number of ears per main shoot.

vii) Spikelet number : The total number of spikelets from the ears that were used for measuring ear length were counted and the average value was expressed as the number of spikelets per main shoot ear.

viii) Grain number : The total number of grains from the ears that were used for counting number of spikelets per ear were counted and the average value was expressed as the number of grains per main shoot ear.

ix) Grain weight : Grains from dried ears were separated and weighed to obtain total grain weight. It is expressed as g/main shoot

x) Grain density : The grain density was calculated by the method of Chaudhary (1982). The volume of the weighed and counted number of grains was estimated by replacement of spirit in a measuring cylinder after dipping the grains in spirit. The weight per 100 CC of the grains was calculated by dividing the grains weight with the volume of the spirit replaced and multiplied by 100.

xi) 1000-grain weight: A sample of grains from the produce of plants (whose flag leaf was not detached) of each treatment were collected and cleaned. One thousand grains were counted from the sample and their weights were recorded in grams

xii) Harvest Index =

$$\frac{\text{Total Economic Yield}}{\text{Total Biological Yield}} \text{ X } 100$$

c) Tiller shoot studies :

Similar observations as that of main shoot were studied here also .

d) Total plant dry matter accumulation

Total plant weight was recorded as g /plant. This was computed by adding the dry weight of leaves, stems and ears.

e) Total grain yield

The grain yield per plant at harvest was recorded by weighing the total grains obtained after threshing all the ears of plants under observation. The average values were expressed as grain yield (g/plat).

3.2.7 PHYSIOLOGICAL OBSERVATIONS:

a) Growth parameters : Based on the data obtained, the following growth parameters were computed.

Leaf Area Index = Leaf Area/Unit Area

Spelic Leaf Weight = Leaf Weight/Leaf Area

Drought Susceptibility Index = $\frac{1-[Y_r/Y_i]}{1-[\bar{Y}_r/\bar{Y}_i]}$

Where, Y_i =Yield of a specific cultivar under irrigated conditions.

Y_r=Yield of a specific cultivar under rainfed conditions.

$\bar{Y}_i$ =Mean yield of all cultivars under irrigated conditions.

$\bar{Y}_r$=Mean yield of all cultivars under rainfed conditions.

b) Photosynthetic measurements

i) Measurement of rate of photosynthesis

The net photosynthesis in the upper most fully expanded leaf of the mother shoot was measured by the battery operated portable infra-red CO_2 analyser ADC, LCA-2 (Sestak *et al.*, 1971). The observations such as PAR ($\mu\Sigma/m^2/s$), leaf temperature(^0C) RH (per cent)Δ CO_2 (the difference in CO_2 concentration in and out of the leaf chamber)(vpm), recorded from IRGA were used for measuring the net photosynthesis. The flow rate of gas to the analyser was maintained at 150ml/minute. Flow rate was regulated by the metre attached in the gas analyser. The analyser was operated in differential mode. The differences in CO_2 concentration (ΔCO_2) in an air stream before and after it has passed over a leaf. The measurements were made at the saturated light intensity i.e. > 1000 $\mu\Sigma/m^2/s$. Leaf temperature was measured by the thermocouple present in the parkinson Leaf chamber and recorded by the analyser. The PR was measured between 10 a.m and 12a.m on clear sky days.Leaf was inserted into the Parkinson leaf chamber of 5cm x 2 cm area for the measurement of CO_2 assimilation. Leaf area used for photosynthesis measurement was recorded. The CO_2 concentration for the air was estimated before any photosynthetic measurement which was ranging from 313 to 320 vpm.

ii) Calculation of photosynthesis

Net photosynthesis was calculated by the formula

$P(net) = X \times f/A$

Temperature correction was done on the basis of gas equation

$22.4 \times (273 + t)/273 = V$ (volume of the gas)

where $X = \Delta CO_2$

f = flowrate of air

The photosynthesis rate was expressed in μ mol CO_2 $m^{-2}s^{-1}$

3.2.8 BIOCHEMICAL OBSERVATIONS:

a) Nitrate Reductase (NR) activity

The NR activity *in vivo* was assayed by the method of Klepper *et al.* (1971).

i) Preparation of reagents

Phosphate buffer:(0.1M P^H 7.5). Phosphate buffer was prepared by mixing 16ml of 6.8045 g of potassium dihydrogen phosphate in distilled water (final volume of 500 ml) and 84ml of 8.70g g of dipotassium hydrogen phosphate (final volume of 500 ml.) Final pH was adjusted with the help of pH meter.

Potassium nitrate: (0.4 M) Potassium nitrate was prepared by dissolving 4.044 g of potassium nitrate in distilled water and the volume was made upto 100 ml.

Sulphanilamide: One percent soultion was preparedby dissolving 1.0 g of sulphanilamide in 100 ml of IN HCl.

N-(1 Naphthyl) ethylene diamine dihydrochloride (NEDD): (0.02%) Solution was prepared by dissolving 20 mg of the above chemical in 100 ml of distilled water.

ii) Assay of enzyme.

Samples in triplicate from fully emerged flag leaves were taken from each treatment and collected in ice bucket. The leaves were cleaned thoroughly with muslin cloth. 0.3g leaf pieces were taken in 30ml test tube containing, 2.5ml of 0.1 M phosphate buffer (P^H 7.5) and 2.5 ml of 0.4 M potassium nitrate. The blank was run simultaneously using 5ml of 0.1 M phosphate buffer only. Test tubes were kept in a tray with ice in order to prevent denaturation of enzyme protein. The solution was infiltrated in leaf tissue by creating vacuum in the flask using the vacuum pump. The infiltration was performed for one minute and the infiltrated material was kept for incubation at 35°C for an hour. The test tubes were covered with black cloth to prevent from photo-oxidation of nitrite to nitrate. The reaction was stopped by boiling the reaction mixture.

Test tubes were removed from the hot plate immediately after boiling to avoid chlorophyll mixing with the solution. A known volume of reaction mixture (0.2ml) was taken in a test tube and one ml each of sulphanilamide and NEDD were added and kept for 15 minutes. The final volume was made upto 10ml with distilled water. The optical density was recorded in Bausch and Lomb Spectronic 20 Spectrophotometer at 540 nm. The blank readings were deducted from the readings recorded for the samples. The NR activity was calculated and expressed as the amount in µ moles of nitrite formed per gram fresh weight per hour.

ii) Preparation of standard curve

Sodium nitrite was used for the preparation of the standard curve. 69 mg sodium nitrite was dissolved in 10 ml distilled water to made a solution of 10 µ mole/0.1 ml concentration. By successive dilutions, a solution with 0.1 ml containing 10 millimicro moles of nitrite was prepared (10ml of the stock solution diluted to 100 ml). From this, 10,20,30,40..... 100, 120 m µ moles of nitrite soultion were prepared adding 0.1,0.2,0.3, 0.4 ..... 1,2ml of above solution in test tubes. One ml of 1 percent sulfanilamide and 1 ml of 0.02 percent NEDD solution were added to each test tube and the final volume was made upto 10ml. The colour was allowed to develop for 20 minutes. The O.D. was read at 540 nm wave length in spectronic 20 spectrophotometer. The standard curve was plotted by taking concentration against optical density .

b) Estimation of NO_3 content

Nitrate was estimated in the dried samples of leaves of each treatment. Estimation was carried out in two phases (a) extraction of nitrate from the tissue, and (b) estimation of nitrate by converting it into nitrite.

i) Extraction: The dried leaf samples were extracted following the procedure described by Grover *et al.* (1978). Equivalent weights of powdered leaves samples (100mg)and activated charcoal (100 mg) were taken in culture vials of 30 ml capacity. To each tube 10 ml distilled water was added and boiled for 10 minutes. The residue was again extracted with another 25ml of water. The two extracts were then combined and filtered through Whatman No.42 filter paper to obtain a colourless extract.

The extracts were further purified with activated charcoal as followed. One ml of the extract was taken in a 30 ml culture vial and diluted to 3ml with distilled water and heated for a while in a boiling water bath. To each tube 100 ml of activated charcoal was added and tubes were again heated in boiling water bath for 15 minutes. The contents of the tube were then filtered through Whatman No.42 filter paper to obtain colourless solution. Nitrate in these extracts was estimated by the following chemical reduction procedure.

ii) Estimation: The method for the estimation of nitrate was that of modified by Downes (1978). The reagents and the concentrations in which they were, are as follows:

Catalyst solution: 0.0313 g $CuSo_4$. $5H_2O$ + 0.9 g $ZnSo_4$. $7H_2O$ in one litre of distilled water.

Sodium hydroxide solution:40 g in one litre of distilled water.

Hydrazine sulphate solution: 1.529 g in one litre distilled water.

Acetone reagent (10% v/v): 100ml of acetone in one litre of distilled water.

A suitable aliquot of the sample was pipetted into well cleaned incubation vials of 30 ml capacity along with 0.2 ml of the catalyst soultion and 0.2 ml of the Sodium hydroxide solution and then the volume was made upto 1.8 ml with distilled water. To this 0.2 ml of hydrazine sulfate solution was then added and the tubes were stoppered loosely and placed in a water bath at 65°C for 10 minutes. Immediately the tubes were placed in an ice bath for 5 minutes to terminate the reaction. 0.5 ml of acetone was added to remove excess of hydrazine sulfate. Nitrate formed was measured by the method of Snell and Snell (1949). Suitable aliquots from this solution was added into test tubes and 1 ml of 1% sulfanilamide in 1N HC1 was added and shaken thoroughly. To the colourless diazo compound so formed, 1 ml of 0.01 N per cent NEDD in H_2O was added. The colour was allowed to develop for 25 minutes after which the volume was made up to 6 ml with distilled water. The absorbance of the pink coloured solution was recorded at 540 nm using a Spectronic 20 Spectrophotometer. The amount of nitrite was calculated with the help of a calibration curve prepared with standard solutions, ranging from 10 mμ moles to 100 mμ moles concentrations .

c) Estimation of Chlorophyll: For estimation of chlorophyll, the method of Hiscox and Iserelstom (1979) was followed.

i) Procedure: Fifty mg of leaf material from fully emerged flag leaf blades was weighed after cutting into small pieces and put in 10 ml of Dimethyl Sulphoxide (DMSO). The test tubes were then kept in oven at 65 °C for 4 hrs to facilitate the extraction of chlorophyll into the solution. The O.D values were then recorded at 645 nm and 663 nm in a spectronic 20 spectrophotometer.

ii) Calculation : The amount of chlorophyll a, chloropyll b, and total chlorophyll were calculated using the following formulae given by Arnon *et al.* (1949).

Chlorophyll a =12.7 (O.D.663) - 2.69 (O.D.645)
(mg chl a/g fr.wt)
Chlorophyll b = 22.9 (O.D.645)- 4.68 (O.D.663)
(mg chl b/g fr.wt)
Total chlorophyll = 22.2 (O.D.645)+ 8.02(O.D.663)
(mg total chlorophyll/g fr.wt.)

d) Estimation of percent Relative Water Content [RWC]

Relative water content was determined in flag leaf during each stress treatment by the method of Barrs and Weatherley (1962). 100 mg leaf material was taken and was kept in distilled water in a petri dish for 2 hours to make the leaf tissue turgid. The turgid weights of the leaf materials were taken after carefully soaking the tissues between the two filter papers. Subsequently this leaf material was kept in a butter paper bag and dried in oven at 65°C for 24 hrs and their dry weights recorded. The RWC was calculated by using the formula.

$$\text{RWC (per cent)} = \frac{\text{Fresh weight-Dry weight}}{\text{Turgid weight- Dry weight}} \text{ X } 100$$

e) Ion leakage:

Ion leakage studies were carried out by the method given by Onwueme (1979) with slight modifications. Flag leaves were cleaned with muslin cloth to remove dust particles. 100 mg of leaf sample was weighed and put in a test tube containing 10 ml of double distilled water. Three replicates were prepared for each treatment. Tubes were incubated at 45°C for half an hour in a water bath (York scientific Industries). Electrical conductivity of this solution was measured with the help of conductivity bridge (Elico Model CM 82 T). These test tubes were then kept in boiling water at 100°C for 10 minutes, cooled to room temperature and conductivity was measured again .The percent ion leakage was determined in the following way:

$$\text{Percent ion leakage} = \frac{\text{EC } 45^{\circ}\text{C } (C_1)}{\text{EC } 100^{\circ}\text{C } (C_2)} \times 100$$

Where EC= conductivity in mhos.

3.3 EXPERIMENT III

This experiment was carried out under pot culture conditions. The plant material used was same as that of experiment 1.

3.3.1. General Cultural Operation

a) Preparation of pots:

Earthen pots (height 45 cm and diameter 30 cm) containing 10 - 12 kg sandy loam soil were used for this study and these were kept under natural light and atmosphere conditions.

b) Manures and fertilizers

Farm yard manure (FYM) and soil mixed in the ratio of 1:4 was used to fill the pots.Nitrogen fertiliser(as urea) at the rate of 100 kg/ha was applied in two splits. First half dose of N-fertilizer was given at the time of sowing and remaining half dose was applied at crown root initiation (CRI) stage. Uniform doses of phosphorus and potash at the rate of 40 kg P_2O_5 /ha and 40 kg K_2O/ha respectively were also applied at the time of sowing.

c) Sowing

Ten seeds per pot of each variety were sown by dibbling method at 2 to 3cm depth. Thinning was done 20 days after sowing and in each pot four plants were left.

3.3.2 TOTAL TREATMENTS

The total number of treatments were a combination of sowing times. varieties , treatments and replications

a) Sowing times (2)

Early planting -15th October

Normal planting - 19th November

b) Varieties (4)

C-306

PBW-175

HD-2329

WH-542

c) Treatments (4)

Control

Moisture stress at 0-15 days pre anthesis (0-15 DPA)

Moisture stress at 0-15 days after anthesis (0-15 DAA)

Moisture stress at 15-30 days after anthesis (15-30 DAA)

Stress was given by withholding water supply to respective pots and they were re-watered after treatment was over. Out of 8 pots used for each treatment, 4 were used for bio-chemical analysis and rest for final harvest data.

d) Replications (3)

3.3.3. DESIGN -CRD

Plants of all varieties under early planting under each treatment were compared with those grown under normal planting conditions. Individual effects and interaction were studied.

3.3.4. SAMPLING

In each treatment under both dates of sowing, out of 8 pots, 4 pots were marked and kept for observations on growth and yield characters at maturity. And mother shoot of each plant was tagged to record date of anthesis and maturity. Rest of pots were used for various morphological and biochemical observations during specific stress treatments. The sampling procedure for these observations was performed as follows.

3.3.5. MORPHOLOGICAL, PHYSIOLOGICAL AND BIOCHEMICAL OBSERVATIONS

All the observations studied under experiment-II are also studied here. Observations for ear number per plant,spikelet number per plant,grain number per plant and grain weight per plant were taken at the time of harvest to compare the effect of stresses given at different stages around anthesis.Where as observations for rest of the parametres were taken befote termination of respective stresses.

3.4. STATISTICAL ANALYSIS

To find out the various effects, the data were statistically analysed using CRD for pot culture experiment and split-split design for field experiment, following the procedure out lines by Panse and Sukhatme (1985). The treatment mean sum of squares were tested against error mean sum of squares by F-test of significance.

RESULTS

EXPERIMENT I

PER CENT GERMINATION

Per cent germination in all four varieties (C-306,PBW-175 HD-2329 and WH-542) were studied at 96 hours period at various temperatures ranging from 20 to 40° C.(Table-1). Increasing temperature from 20 to 40°C gradually decreased germination in all 4 varieties but significantly much more in V_3 and V_4 (Fig.1). Increasing temperature from (30 to 35° C) decreased germination per cent significantly only incase of V_3 ,V_4 indicating their relative sensitivity to temperature compared to V_1 and V_2. When varietal performance was taken in to account, V_1 and V_2, had higher percent germination at all the temperatures treatments compared to V_3 and V_4. Even though there was no significant differences between varieties at 20 ° C , significant differences between V_1 and V_3, V_4 and V_2 and V_3, V_4 at 30,35° C and 40°C were observed. In all treatment combinations, highest percent germination (meanvalue) was exhibited by V_1 which was 1.04, 13.5 and 14.2 per cent more when compared to V_2, V_3 and V_4 respectively (Table-1).

ROOT GROWTH

Both root length and fresh weight were taken in to account in this study. Maximum root length was observed at 96 hours duration for all temperature treatments. No detectable root length was observed at 24 hours durations of all temperatures treatments. Among the varieties, V_1 and V_2 had maximum root length (meanvalues) significantly over rest of the varieties at 48, 72 and 96 hours durations

TABLE -1.

EFFECT OF TEMPERATURE ON PERCENT GERMINATION (AT 96 hrs) IN VARIOUS WHEAT GENOTYPES

Temp / Variety	V1	V2	V3	V4	M
20°C	98.5	98.0	95.7	95.0	9.68
30°C	94.5	94.5	88.3	88.0	91.3
35°C	92.5	90.0	81.8	81.0	86.3
40°C	24.0	24.0	7.0	7.0	15.5
M	77.4	76.6	68.2	67.8	72.5

V1=C-306 V2= PBW- 175 V3=HD2329 V4=WH542

	CD at 5 %
T	3.7
V	3.7
T x V:	7.5

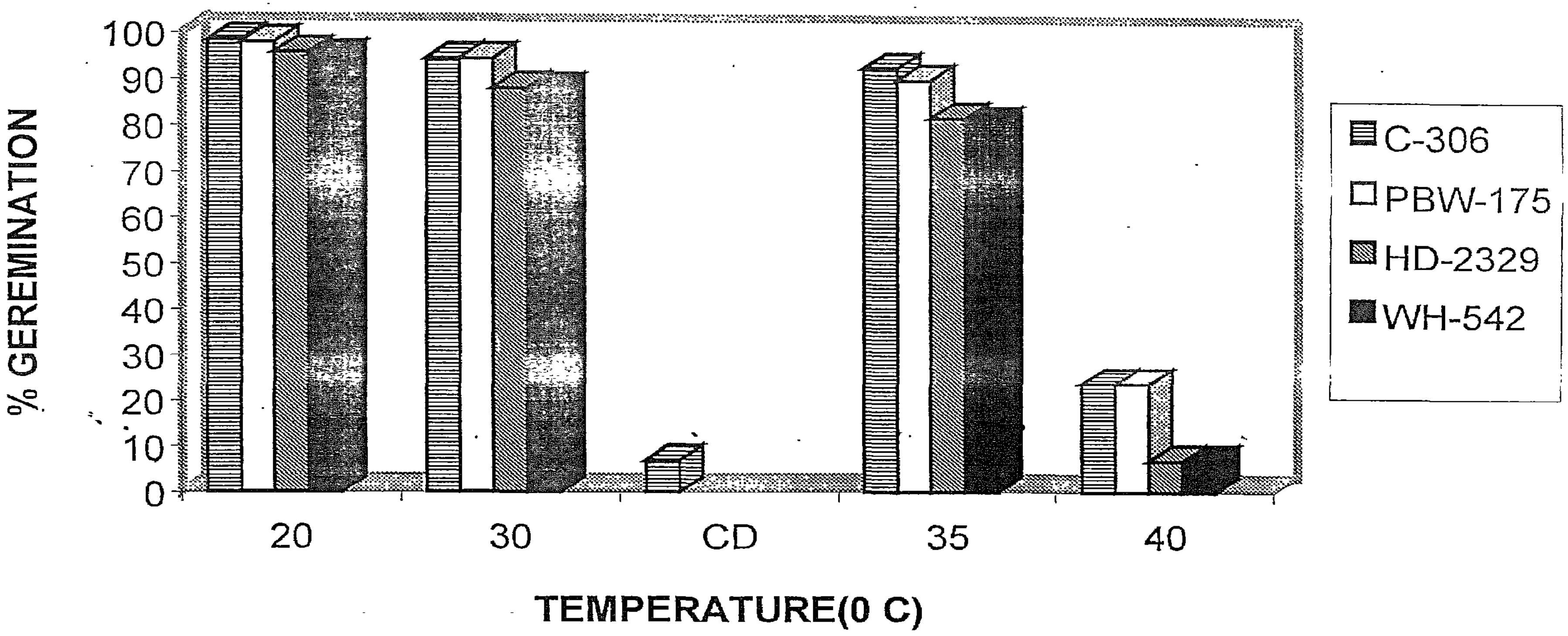


FIG-1. PERCENT GERMINATION AS AFFECTED BY TEMPERATURE IN VARIOUS WHEAT GENOTYPES (appendix-1). When temperature effects were taken in to account, 30°C resulted more root length at all durations. More over, results of appendix-I also shows less per cent reduction in root length in V_1,V_2 compared to V_3, V_4 when temperature was increased from 30 to 35°C compared to V_3, V_4 at 72 and 96 hours duration. Negligable root growth was observed at 40°C.

Fresh wieght of root increased with increase in temperature from 15 to 30°C and thereafter decreased at all durations studied. All the varieties showed maximum root fresh weight for 96 hrs duration of 30°C. Among the varieties, C-306 recorded maximum fresh weight of 55 mg/seedling at 96 hours duration of 30°C. Corresponding values for rest of the varieties are 47, 38 and 38 mg/ seedling inorder. Temperature at 40°C resulted negligable root fresh weight for all varieties at all durations. Significantly more decrease in root fresh weight for V_3 and V_4 compared to V_1 and V_2 due to increase in temperature from 30to 35°C was also observed (Appendix-II).

SHOOT GROWTH

Shoot length was maximum at 30°C temperature in all the varieties at all durations, when compared to rest of the temperature treatments. Further increasing temperature(35°C) inhibited shoot length and resulted lesser values. This inhibition was the tune of 5, 8, 9, and 9 mm in V_1,V_2,V_3 and V_4 respectively at 96 hours duration, which indicates their tolerance to high temperature in descending order. Further increasing in temperature (40°C) resulted negligable values. No detectable Shoot length was observed at 40°C shoot length was increased with increasing duration from 48 to 96 hours at all temperatures condition. However no detectable shoot length was observed at 24 hours (Appendix-III.)

Fresh weight of shoot in response to temperatures for different durations, followed the same pattern as that of shoot length. For 72 and 96 hours durations, maximum fresh weight in all varieties was at 30°C followed by 35°C . All the varieties showed minimum fresh weight at 20°C and resulted maximum with further increase in temperature upto 30°C (Appendix-III).

SHOOT VIGOUR INDEX (SVI)

The effect of temperatures on shoot vigour index at 96 hours duration is represented in Table-2. Irrespective of variety, maximum shoot vigour was observed at 30°C treatment followed by 35°C. Increase in temperature form 20 to 30°C significantly increased shoot vigour index. Further increase in temperature up to 35°C reduced SVI significantly in all the varieties but with less effect on V_1,V_2 compared to V_3 and V_4. When varieties performance was taken in to account, at all temperatures V_1 and V_2 had higher shoot vigour indices significantly over V_3 and V_4 indicating their tolerance to high temperatures (Fig-2). Significant variation in shoot vigour index of genotypes was also seen from Table-2. At 30°C, where maximum shoot vigour index was noticed, variety V_1 had 13.6, 84 and 85 per cent more shoot vigour index significantly compared to V_2, V_3 and V_4.

α-AMYLASE ACTIVITY

α–amylase activity was expressed as μg starch hydrolysed per seed basis per second and this was increased with increase in duration from 24 to 96 hours at all temperatures (Table-3). Fig-3 also shows that this activity was increased with increase in temperature from 20 to 30°C at all durations and decreased later by further increase in temperatures. Maximum values were observed at 30°C for 96 hours duration. At this combination V_1 had highest activity which was

TABLE - 2.

EFFECT OF TEMPERATURE ON SHOOT VIGOUR INDEX (AT 96 hrs) IN VARIOUS WHEAT GENOTYPES

Temp / Variety	V1	V2	V3	V4	M
20°C	1281	1274	957	950	
30°C	4725	4158	2561	2552	
35°C	4163	3420	1636	1620	
M	3390	2951	1718	1703	

	CD at 5 %
T	157
V	182
T x V	316

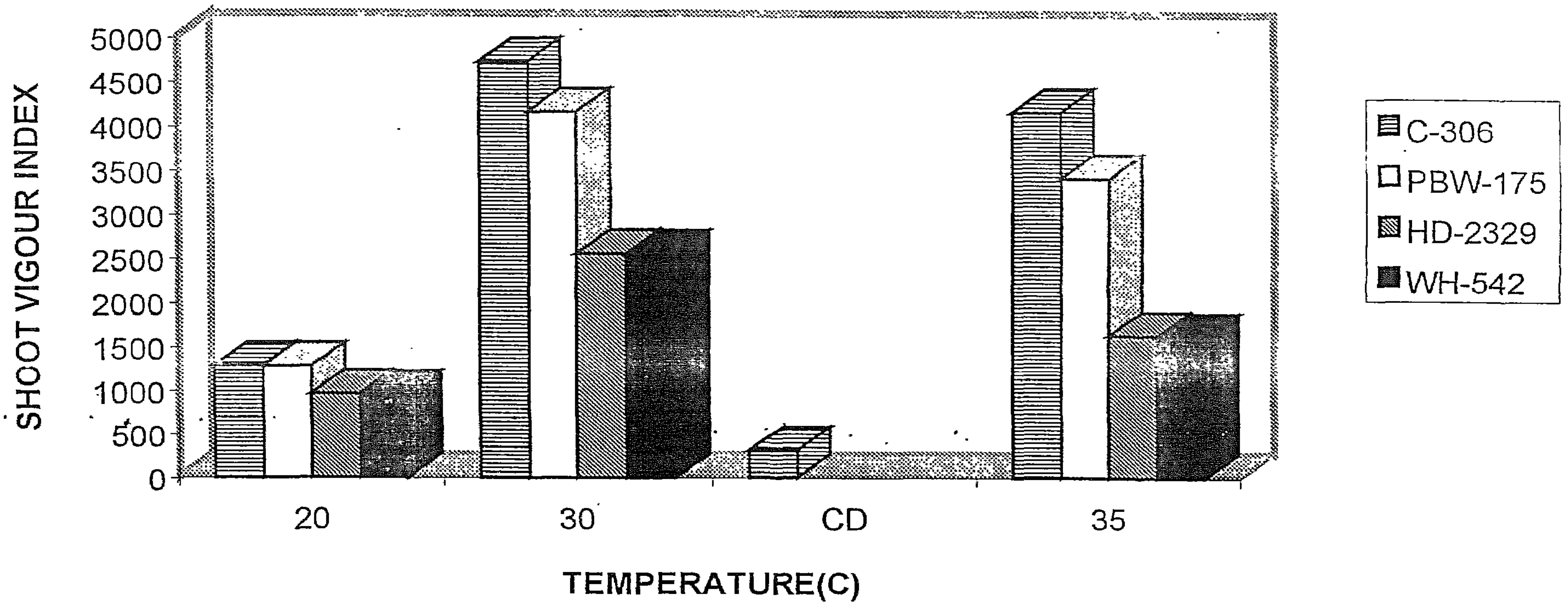


FIG-2. SHOOT VIGOUR INDEX AS INFLUENCED BY TEMPERATURE IN WHEAT GENOTYPES

TABLE -3.

EFFECT OF TEMPERATURE ON α-AMYLASE ACTIVITY (µg strach hydrolyzed/seed/sec) IN GERMINTAINE SEEDS OF VARIOUS WHEAT GENOTYPES

Duration (hrs)	24					48					72					96				
Temp/var	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
T1	5.0	5.0	5.0	5.0	5.0	12.0	12.0	12.0	12.0	12.0	40.0	40.0	30.0	30.0	35.0	43.0	40.0	30.0	30.0	35.8
T2	20.0	20.0	10.0	10.0	12.5	30.0	30.0	16.0	16.0	23.0	60.0	45.0	30.0	30.0	41.3	105	95.0	50.0	50.0	75.0
T3	10.0	5.0	5.0	5.0	6.3	20.0	20.0	15.0	15.0	17.5	60.0	50.0	20.0	20.0	37.5	85.0	75.0	25.0	25.0	52.5
T4	10.0	5.0	5.0	5.0	6.3	20.0	20.0	15.0	15.0	17.5	50.0	40.0	15.0	15.0	30.5	80.0	70.0	15.0	15.0	45.0
M	11.3	8.75	5.0	5.0	7.5	20.5	20.5	14.5	17.5	16.8	52.5	43.8	23.8	23.8	36.0	75.8	67.5	27.5	27.5	52.0

	CD at 5%	CD at 5%	CD at 5%	CD at 5%
T	1.02	2.27	3.24	4.34
V	1.02	2.27	3.24	4.34
TxV	2.03	4.55	6.47	8.69

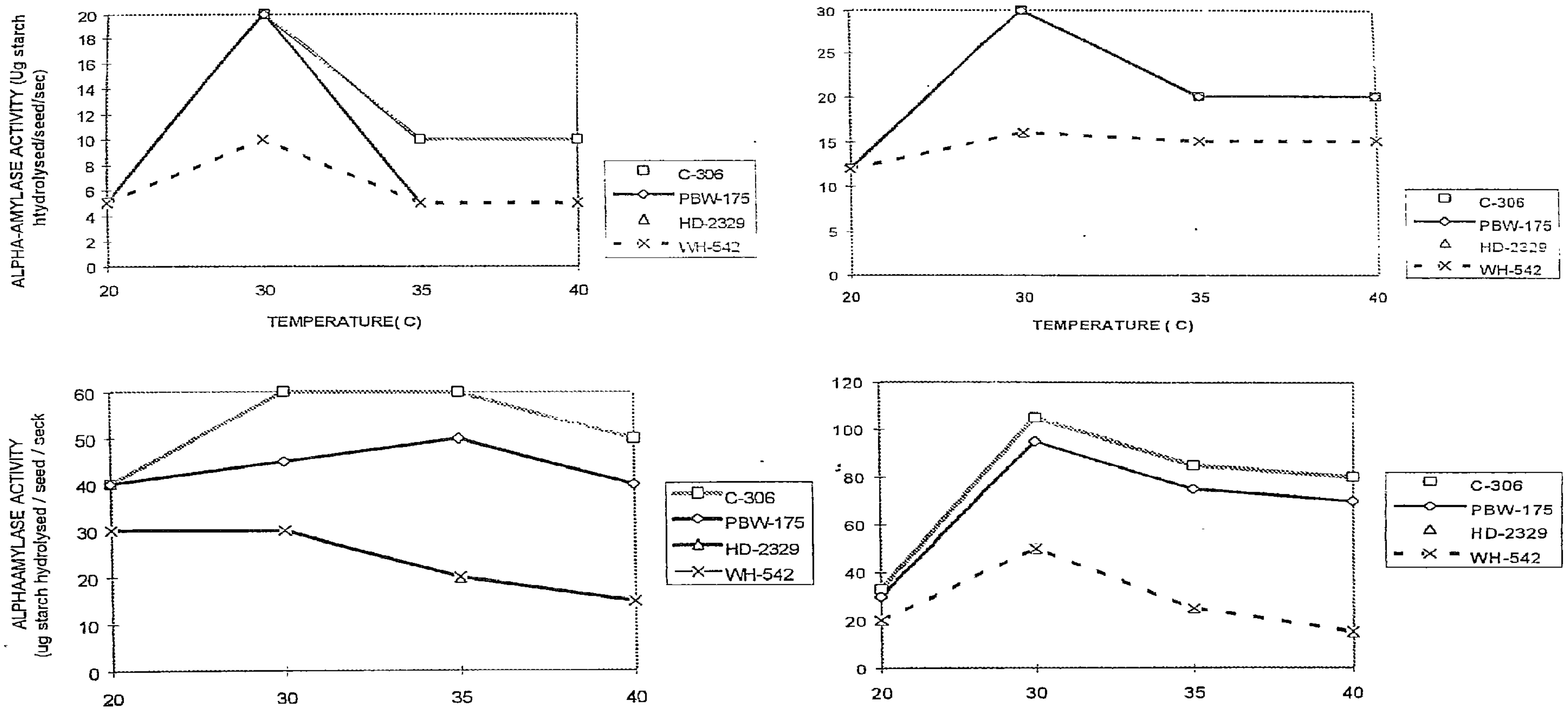


FIG -3: ALPHA - AMYLASE ACTIVITY AS INFLUENCED BY TEMPERATURE IN GERMINATING SEEDS OF VARIOUS WHEAT GENOTYPES significantly 20, 55 and 55 μg more when compared to V_2, V_3 and V_4. Increase in temperature from 30 to 35°C and 35 to 40°C gradually decreased the activity at 72 and 96 hours duration but more in V_3 and V_4 compared to V_1 and V_2. The differences in activity between V_1 and V_3, V_4 and V_2 and V_3, V_4 were found significatn at all temperatures and durations (Table-3).

CATALASE ACTIVITY

Table 4 shows catalase activity in 4 wheat genotypes. This was estimated in 20 day old seedling leaves and expressed in m ml H_2O_2 broken down/min/mg protein. Increasing temperature from 20 to 30 and 30 to 40°C significantly increased catalase activity in all four varieties (Fig-4). Significant varietal differences either between V_1 and V_3, V_4 or V_2 and V_4 was also seen in this Table. However, no significant differences between V_1 and V_2 and/or V_3, V_4 was observed.

PEROXIDASE ACTIVITY

The data regarding effect of various temperatures (20,30 and 40°C) on peroxidase activity in various wheat varieties is shown in Table-5. In all four varieties increasing temperature from 20 to 40°C increased peroxidase activity significantly. This increase in activity was in the order of V_1,V_2, V_3 and V_4 (Fig-5). When varietal response to different temperatures were considered. V_1,V_2 had highest activities. Significant differences among V_1 and V_3,V_4 and V_2 and V_3, V_4 were also observed at 30 and 35°C treatments

EXPERIMENT II

DAYS TO ANTHESIS

Data on days to anthesis (sowing to 50 per cent anthesis) is shown in Table-7. The duration from sowing to 50 per cent anthesis

TABLE - 4.

EFFECT OF TEMPERATURE ON LEAF CATALASE ACTIVITY (mgH2O2 broken down min-1 mg-1 protein) IN 20 DAYS OLD SEEDLINGS OF VARIOUS WHEAT GENOTYPES

Temp / Variety	V1	V2	V3	V4	M
20°C	1.85	1.80	1.45	1.40	1.63
30°C	2.37	2.30	1.23	1.28	1.80
40°C	3.05	3.05	1.65	1.60	2.34
M	2.42	2.38	1.44	1.43	1.92

	CD at 5 %
T	0.17
V	0.20
T x V	0.34

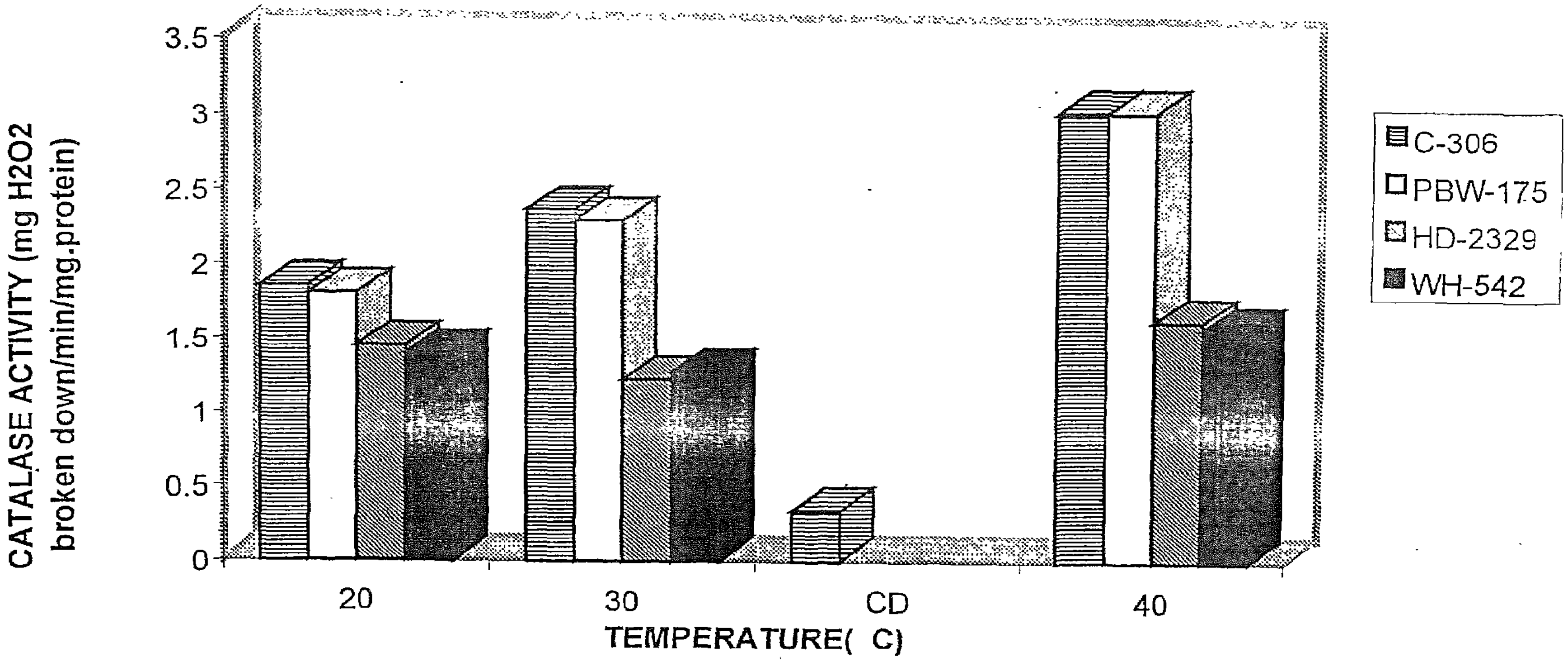


FIG-4:LEAF CATALASE ACTIVITY AS INFLUENCED BY TEMPERATURE IN WHEAT GENOTYPES

TABLE - 5.

EFFECT OF TEMPERATURE ON LEAF PEROXIDASE (Δ O.D. /min /mg. protein) IN 20 DAYS OLD SEEDLINGS OF VARIOUS WHEAT GENOTYPES

Temp / Variety	V1	V2	V3	V4	M
20°C	0.60	0.60	0.50	0.45	0.54
30°C	1.00	1.00	0.70	0.65	0.84
40°C	1.70	1.50	1.07	1.05	1.33
M	1.10	1.03	0.76	0.72	0.90
	CD at 5 %				
T	0.20				
V	0.23				
T x V	0.40				

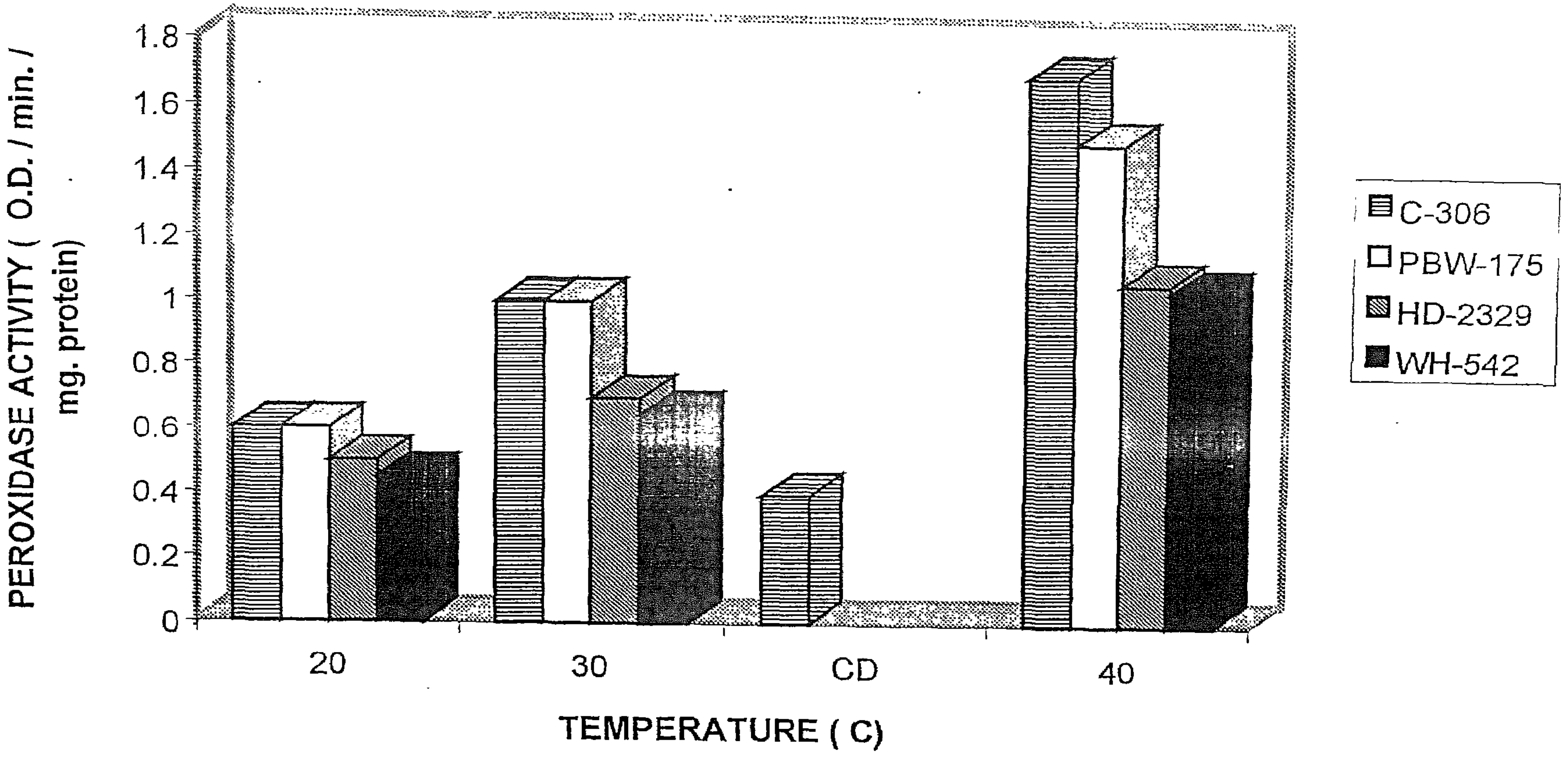


FIG-5: LEAF PEROXIDASE ACTIVITY AS INFLUENCED BY TEMPERATURE IN WHEAT GENOTYPES was influenced significantly under stress conditions. There was a difference of (means values) 5 days in early planting and 4.2 days in normal planting. Different sowing dates also resulted variation in this duration significantly. The difference between EP (early planting) and NP (normal planting) was 4 and 4.8 days in control and stress condition, respectively. Significant differences between varieties were also observed. The varieties HD-2329 and WH-542 showed early anthesis compared to C-306 and PBW 175 both in early and normal planting conditions under stress (Table-7).

DAYS FROM ANTHEISIS TO MATURITY.

Table-7 also shows data pertaining to days from anthesis to maturity. Stress imposition significantly decreased this duration by 6.5 and 5.25 days over control in early and normal plantings respectively. However, either planting conditions or varietal differences did not show significance for this trait.

DAYS TO MATURITY.

The days to maturity was much significantly influenced than the individual durations i,e sowing to anthesis and anthesis to maturity due to stress. 11.5 and 9.5 days were reduced upon stress imposition in early and normal planting respectively. Change in planting dates also showed significant differences. Early planting effected this duration by 2.8 days in control and 4.8 days in stress conditions. Among varieties, V_3 V_4 group matured earlier. compared to V_1, V_2. The differences between V_1 and V_2, V_3, V_4 and V_2 and V_3 and V_4 were significant (Table -7).

PERCENT ION-LEAKAGE

Percent Ion-leakage was significantly more under stress treatment compared to control in both the sowings. Stress treatment

TABLE - 6

MEAN MAXIMUM, MINIMUM TEMPERATURES AND RAINFALL PATTERN DURING CROP SEASON 1994-95

	WEEKS AFTER SOWING																
Plantings/ Week	1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th	13th	14th	15th	16th	17th
October Planting (Early Planting)																	
Avg Max Temp	31.3	32.6	29.7	29.2	27.6	26.2	26.9	26.9	22.2	22.2	24.3	19.3	17.2	17.1	19.9	21.7	22.8
Avg. Min. Temp	14.0	16.9	11.5	12.4	11.7	9.6	10.3	11.8	6.0	4.1	11.1	4.8	7.6	9.0	5.0	6.4	8.3
Avg Rain Fall	-	-	-	-	-	-	-	-	-	-	-	-	2.1	.45	-	-	-
November Planting (Normal Planting)																	
Avg Max. Temp	27.6	26.2	26.9	26.9	22.2	22.2	24.3	19.3	17.2	17.1	19.9	21.7	22.8	24.0	21.6	22.0	24.6
Avg. Min. Temp	11.7	9.6	10.3	11.8	6.05	4.1	11.1	4.8	7.6	8.0	5.0	6.4	8.3	12.9	10.4	10.4	9.4
Avg. Rain Fall	-	-	-	-	-	-	-	-	2.11	0.45	-	-	-	1.14	0.71	1.23	1.06

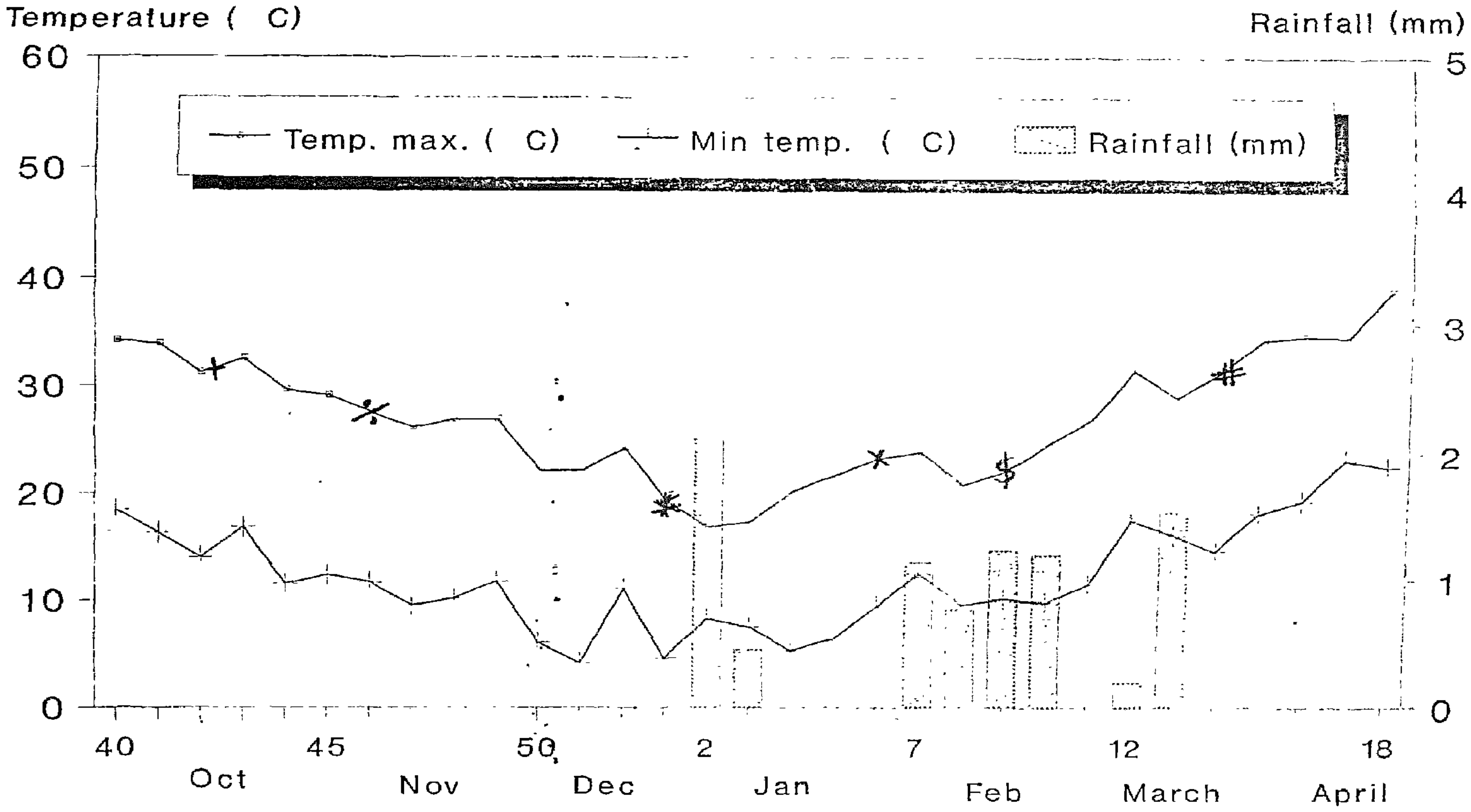


Fig-6: MEAN MAXIMUM, MINIMUM AND RAINFALL PATTERN DURING CROP SEASON 1994-95

+ SOWING - EP : % SOWING -NP : * ANTHESIS - EP : X ANTHESIS - NP : $ MATURITY - EP

MATURITY - NP

TABLE - 7

PHENOLOGICAL STAGES AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS IN WHEAT GENOTYPES

	SOWING TO 50% ANITHESIS					ANTHESIS TO MATURITY					SOWING TO MATURITY				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	90	88	84	84	86.5	55	55	56	56	55.5	145	143	140	140	142
NP	90	90	91	91	90.5	55	55	54	53	54.3	145	145	145	144	145
M	90	89	87.5	87.5	88.4	55	55	55	54.5	54.9	145	144	143	142	143
STRESS															
EP	88	85	77	76	81.5	49	49	48	50	49	137	134	125	126	131
NP	89	88	84	84	86.3	50	50	48	48	49	139	138	132	132	135
M	88.5	86.5	80.5	80.0	83.9	49.5	49.5	48	49	49	138	136	129	129	133
IRRIGATIONS MEAN		88.5	83.9				54.9	49.0				143	133		
PLANTINGS MEAN		84.0	88.4				52.3	51.6				136	140		
VARIETIES MEAN		89.3	87.8	84.0	83.8		52.3	52.3	51.8	51.8		142	140	136	136
			CD 5%					**CD 5%**					**CD 5%**		
I			3.20					1.43					2.86		
P			2.06					.NS					1.84		
V			2.91					.NS					2.61		
I x P			.NS					.NS					.NS		
I x V			.NS					.NS					3.68		
P x V			.NS					.NS					.NS		
I x P x V			.NS					.NS					.NS		

(mean values) resulted 30.1, 15.9 & 21.6 per cent, significantly higher ion-leakage in early planting and only 24.3, 13.7 & 16.9 per cent higher in normal planting at 45, 85 and 105 DAS respectively. Early planting conditions significantly increased per cent ion-leakage values in both control and stress tretments. When compared to normal planting, in early planting the per cent ion-leakage was 19.7, 12.0 and 12.6 per cent more under control condition and 25.3, 14.2 and 17.1 per cent more under stress conditions at 45, 85 and 105 DAS respectively (Table -8).

Among all genotypes studied, V_1 and V_2 genotypes showed lower values for per cent ion-leakage over V_3, V_4 genotypes. C-306 showed its tolerance to early planting and stress conditions by maintaining less membrane damage in all the treatment combinations studied. The varietal differences among V_1 and V_3, V_4 and V_2 and V_3, V_4 were found significant at all the stages . Per cent ion-leakage increased with increase in age. Higher values for per cent ion-leakage were observed at the last stage i,e 105 DAS. (Table -8)

PERCENT RELATIVE WATER CONTENT (PER CENT RWC)

Stress treatment reduced per cent RWC significantly in both the sowings and at all the stages studied. However, the per cent decrease was more in case of of early planting when compared to normal planting. In normal planting, the decrease was only 21.3, 16.8 and 22.1 per cent at 45, 85 and 105 DAS where as in early planting it was 31.9, 24.3 and 33.5 per cent. With respect to planting dates, early planting showed significantly lower values under both control and stress treatments (Appendix -V).

Difference in per cent RWC was also observed among V_1, V_2, V_3 and V_4 the varieties. Among these varieties, C-306 showed better

TABLE - 8

PERCENT IONLEAKAGE AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	42.8	44.9	45.9	46.0	44.9	44.4	46.9	47.2	47.8	46.6	54.5	57.0	59.9	60.2	57.9
NP	37.5	38.1	36.9	37.7	37.5	41.7	42.3	40.9	41.5	41.6	50.5	51.4	51.5	52.0	51.4
M	40.2	41.5	41.4	41.8	41.2	43.1	44.6	44.1	44.6	44.1	44.0	54.2	55.7	56.1	52.5
STRESS															
EP	54.5	56.9	60.9	61.3	58.4	50.4	52.3	56.4	57.0	54.0	66.4	68.7	73.8	72.5	70.4
NP	44.8	45.2	47.9	48.4	46.6	45.6	46.2	48.3	49.0	47.3	57.6	58.4	61.8	62.6	60.1
M	49.7	51.1	54.4	54.9	52.5	48.0	49.3	52.3	53.0	50.7	62.0	63.6	67.8	67.6	65.2
IRRIGATIONS MEAN		41.2	52.5				44.1	50.7				52.5	65.2		
PLANTINGS MEAN		51.7	42.1				50.3	44.5				64.2	55.8		
VARIETIES MEAN		44.9	46.3	47.8	48.3		45.5	46.9	48.2	48.8		53.0	59.0	61.8	61.8
			CD 5%					CD 5%					CD 5%		
I			1.01					0.99					1.86		
P			1.43					0.90					1.80		
V			1.36					1.40					2.03		
I x P			1.43					.NS					.NS		
I x V			1.28					.NS					.NS		
P x V			1.20					.NS					.NS		
I x P x V			.NS					.NS					.NS		

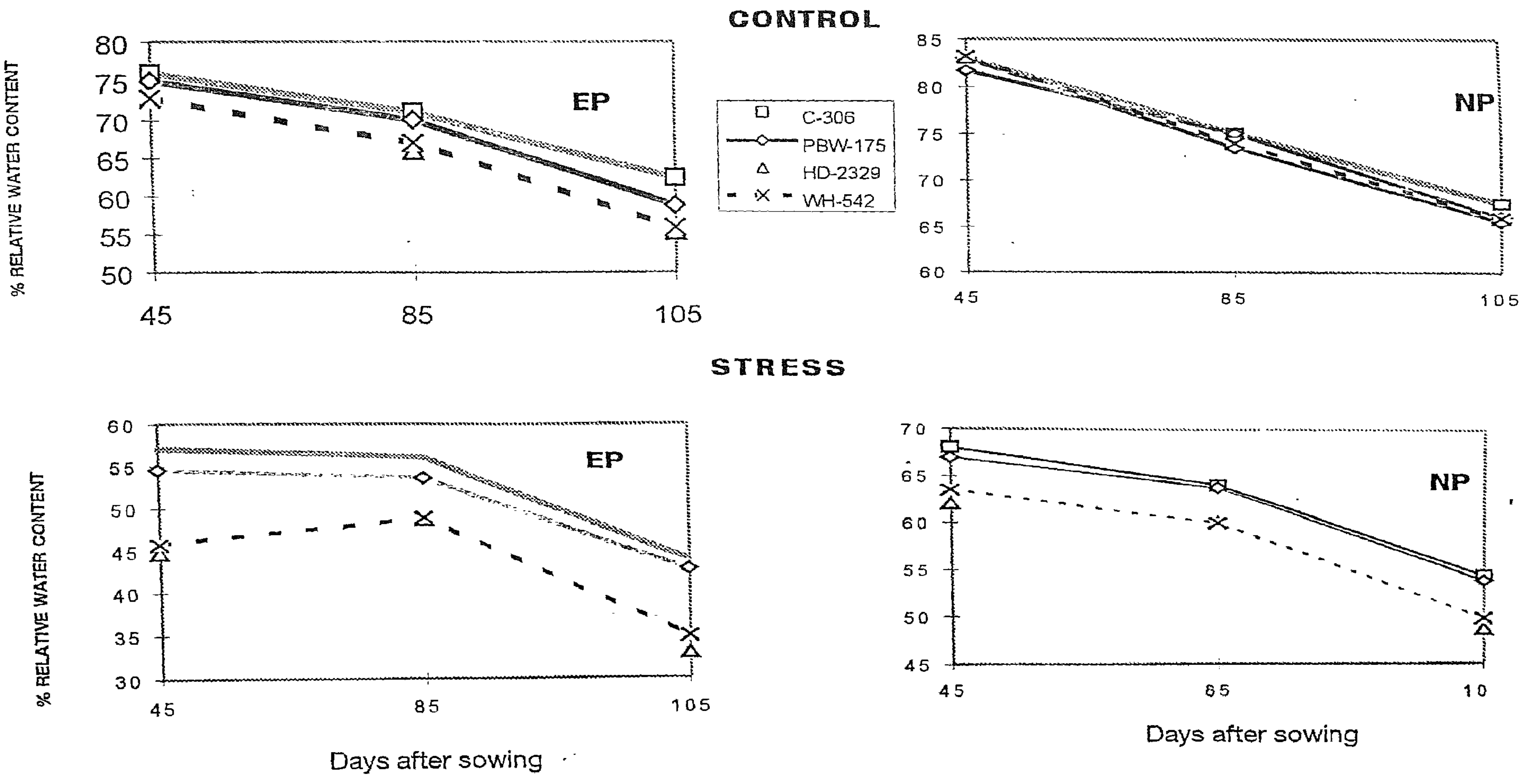


FIG - 7 : PERCENT RWC AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT VARIOUS STAGES OF PLANT GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES perfomance by maintaining higher per cent RWC values even under stress and early planting conditions at all the stages studied (Fig-7). Appendix-V also shows gradual decline in per cent RWC with increase in DAS. Higher per cent RWC values were observed at 45 DAS only. Significant differences (mean values) between V_1 and V_3,V_4 and V_2 and V_3,V_4 were observed at all the stages.

NITRATE REDUCTASE ACTIVITY (NRA)

Data regarding NRA was presented in Table-9. Nitrate reductase activity was found affected significantly more under moisture stress condition in all the treatment combinations studied. Early planting resulted significantly lower values for NRA under control as well as moisture stress conditions. The decrease in NRA was to the extent of 9.71,7.86 and 9.74 per cent in control and 19.2,18.4 and 24.8 per cent in stress conditions at 45, 85 and 105 DAS respectively. Table-9 also shows significant differences for NRA between V_1,V_2 and V_3,V_4 group in all other combinations studied. The decrease in NRA in V_2,V_3,V_4 over V_1 mean value was observed to be 1.28, 22.2 and 17.5 at 45 DAS and 1.99, 11.7 and 11.7 at 85 DAS and 2.98, 21.8 and 21.8 per cent at 105 DAS NRA was highest at 45 DAS and showed gradual decline in its activity at 85 DAS and 105 DAS.

PERCENTAGE NITROGEN (PER CENT N)

The data regarding percent nitrogen is presented in Table-10. Significantly lower values were observed for per cent nitrogen due to stress in all the treatments. The values (mean) range from 3.18 to 2.90 at 45 DAS, 1.61 to 1.41 at 85 DAS and 1.19 to 0.94 at 105 DAS stage, under normal planting conditions. Higher values for per cent nitrogen was observed in V_1 followed by V_2, V_3 and V_4 in all the

TABLE - 9

NRA (u moles NO2- g-1 fwt hr-1)AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105 DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	2.60	2.55	2.47	2.43	2.51	2.17	2.09	2.09	2.10	2.11	1.85	1.77	1.69	1.72	1.76
NP	2.77	2.78	2.79	2.80	2.78	2.29	2.25	2.30	2.30	2.29	1.97	1.95	1.94	1.94	1.95
M	2.69	2.67	2.63	2.62	2.65	2.23	2.17	2.19	2.20	2.20	1.91	1.86	1.82	1.83	1.85
STRESS															
EP	1.83	1.75	0.99	0.99	1.39	1.68	1.62	1.20	1.20	1.42	1.40	1.35	0.82	0.79	1.09
NP	2.17	2.15	1.05	1.50	1.72	1.88	1.90	1.60	1.60	1.74	1.69	1.67	1.22	1.20	1.45
M	2.00	1.95	1.02	1.25	1.55	1.78	1.76	1.40	1.40	1.58	1.55	1.51	1.02	0.99	1.27
IRRIGATIONS MEAN		2.65	1.55				2.20	1.58				1.85	1.27		
PLANTINGS MEAN		1.95	2.25				1.77	2.02				1.43	1.70		
VARIETIES MEAN		2.34	2.31	1.82	1.93		2.01	1.97	1.80	1.80		1.73	1.68	1.42	1.41

	CD 5%	CD 5%	CD 5%
I	0.38	0.26	0.15
P	0.35	0.22	0.13
V	0.54	0.30	0.30
I x P	0.54	0.30	0.30
I x V	0.42	0.21	0.25
P x V	0.45	0.25	0.29
I x P x V	.NS	.NS	.NS

TABLE - 10

PERCENT LEAF NITROGEN AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	3.1	3.0	2.7	2.7	2.9	1.7	1.65	1.46	1.40	1.55	1.10	1.10	1.07	1.07	1.09
NP	3.3	3.2	3.1	3.1	3.2	1.7	1.7	1.55	1.5	1.6	1.15	1.2	1.2	1.2	1.19
M	3.2	3.1	2.9	2.9	3.0	1.7	1.68	1.50	1.45	1.58	1.13	1.15	1.13	1.13	1.14
STRESS															
EP	2.9	2.7	2.0	2.0	2.4	1.45	1.4	1.09	1.05	1.25	0.96	0.92	0.75	0.70	0.83
NP	3.2	3.0	2.7	2.7	2.9	1.53	1.50	1.30	1.30	1.41	1.00	1.0	0.9	0.85	0.94
M	3.10	2.85	2.35	2.35	2.65	1.49	1.45	1.20	1.18	1.33	0.98	0.96	0.83	0.78	0.88
IRRIGATIONS MEAN		3.0	2.7				1.58	1.33				1.14	0.88		
PLANTINGS MEAN		2.65	3.05				1.40	1.51				0.96	1.07		
VARIETIES MEAN		3.13	2.98	2.63	2.63		1.59	1.56	1.35	1.31		1.05	1.05	0.98	0.95
			CD 5%					**CD 5%**					**CD 5%**		
I			0.12					0.10					0.07		
P			0.10					0.10					0.05		
V			0.28					0.21					0.10		
I x P			0.28					0.21					0.10		
I x V			0.17					0.13					0.08		
P x V			0.17					0.13					0.05		
I x P x V			.NS					.NS					.NS		

reatments studied, except under normal planting X control interaction. Among all the varieties, C-306 showed significantly more per cent nitrogen which was 5.03, 19.3 and 19.0 at 45 DAS and 1.92, 20.5 and 20.0 at 85 DAS and 0,7.14 and 7.0 per cent at 105 DAS more over V_2,V_3 and V_4 respectively. Table-10 also shows gradual decrease in per cent nitrogen from pre-anthesis (45 DAS) to grain filling (105DAS) stage in all treatments studied.

NITRATE CONTENT

Stress treatment significantly increased the NO_3 content in both EP and NP conditions. The per cent increase in NO_3 content due to stress in EP was 101, 56, 75 per cent and in NP it was 82, 31, 38 per cent at 45, 85 and 105 DAS respectively. Appendix-VI shows significant difference in NO_3 content due to sowing. Under EP conditions there was 11.2, 5.7 and 9.16 per cent more NO_3 content in control and 22.6, 25.5 and 38.6 per cent more in stress conditions at 45, 85, 105 DAS respectively when compared to NP.

Higher NO_3 content was observed in V_1, V_2 group compared to V_3,V_4 group of varieties (Fig-8). Among the stages studied, the stage at 105 DAS had relatively higher NO_3 content in comparison to 85,45 DAS in all the treatment combinations studied.

TOTAL CHLOROPHYLL CONTENT

Exposure to moisture stress reduced total chlorophyll content significantly in all the treatment combinations studied. The decrease in percent was found to be 38.6, 36.2 and 27.0 in early planting and 29.8, 23.2 and 20.6 in normal planting at 45, 85 and 105 DAS respectvely. This cleraly indicates that the magnitude of decrease was more in early planting compared to normal planting. Planting

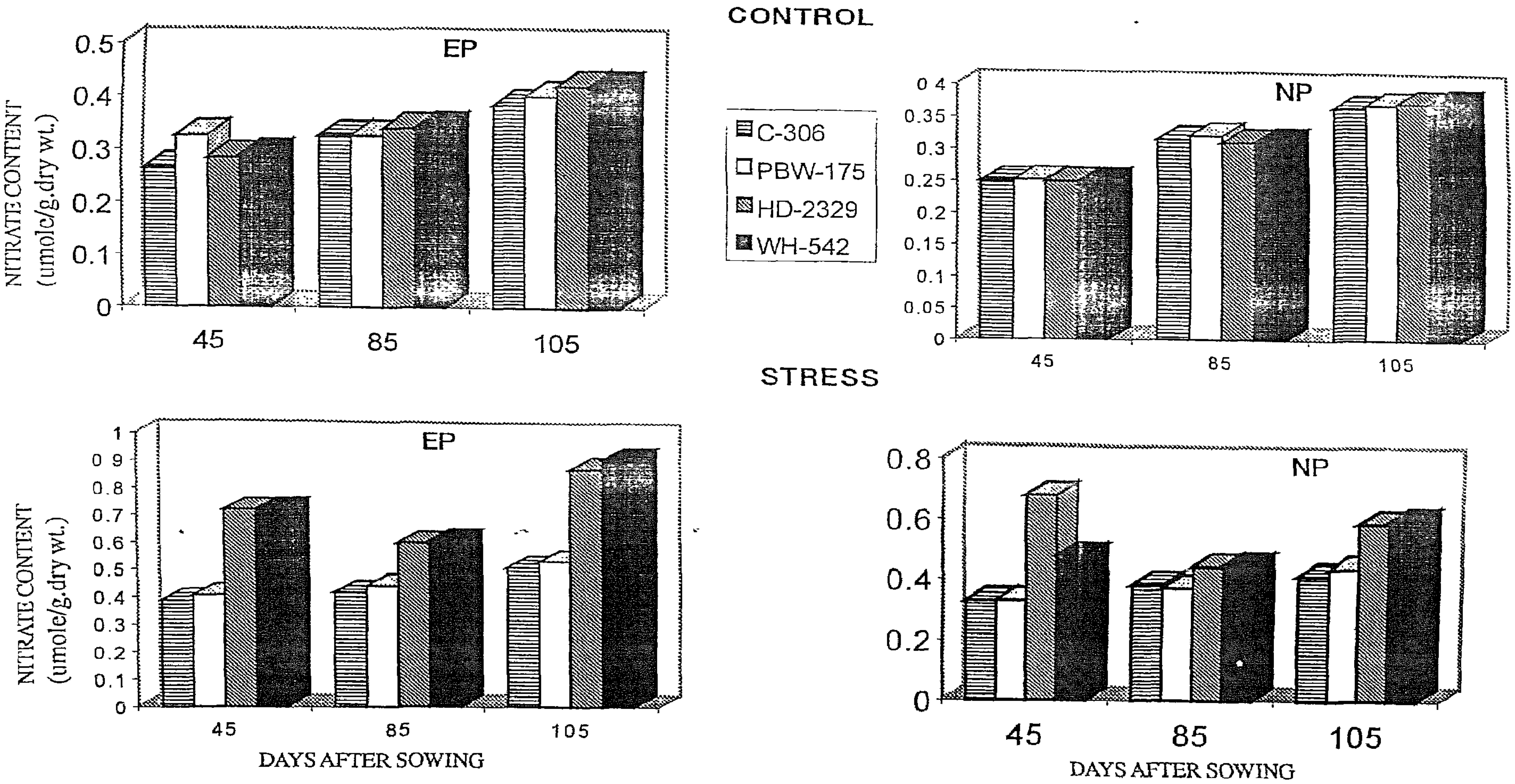
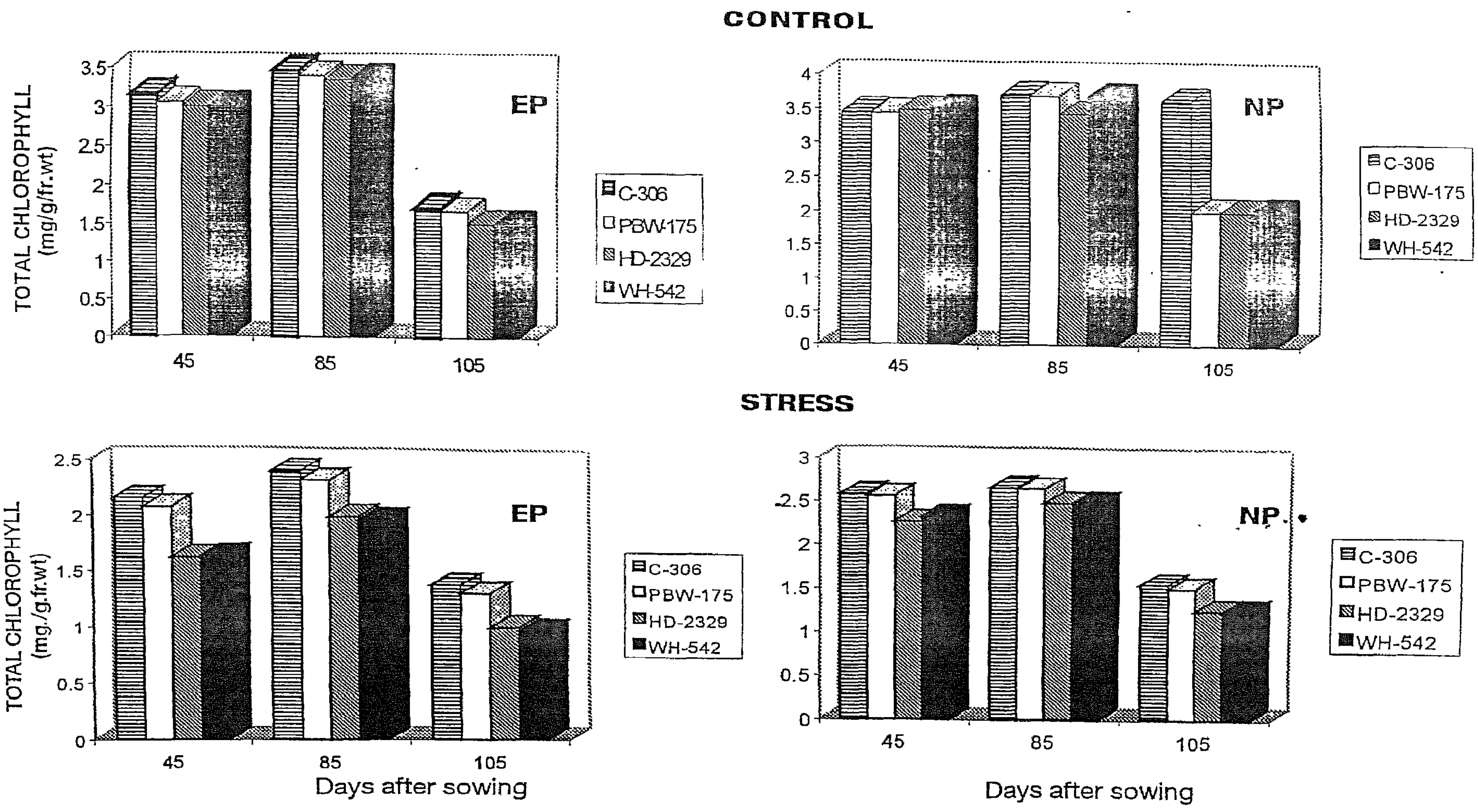


FIG-8:NITRATE CONTENT AS INFLUENCED BY MOISTURE AND TEMPERATURE AT VARIOUS STAGES OF GROWTH AND DEVELOPMENT IN WHEAT AND GENOTYPES



CONTROL

STRESS

FIG - 9 : TOTAL CHOLOROPHYLL CONTENT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT VARIOUS STAGES OF PLANT GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES early also reduced the total chlorophyll content significantly in all the treatment combinations studied over normal planting. The decrease due to EP at 45, 85 and 105 DAS was 11.8, 6.1 and 9.14 per cent in control and 23.0, 15.9 and 16.5 per cent in stress, respectively (Appendix-VII).

All the varieties showed comparatively higher chlorophyll content at 85 DAS. Among the varieties, significant differences were observed between V_1 and V_3, V_1 and V_4 and V_2 and V_3 and V_2 and V_4 at all the stages studied. Highest chlorophyll content at all stages was exhibited by V_1 followed by V_2 at all treatment combinations (Fig-9).

MOTHER SHOOT HEIGHT

Mother shoot height measured at different stages under different treatment combinations is presented in Table-11. Stress treatment significantly decreased mother shoot height at all the stages studied except at 45 DAS under both early and normal planting conditions. Planting conditions also resulted in significant differences at all the stages. Due to early planting mother shoot height was significantly lowered from 54.9 to 49.4, 78 to 73 and 78.9 to 73.7 under control and from 51 to 44, 71.9 to 65.8 and 72.8 to 67.0cm under stress at 45, 85 and 105 DAS respectively. Significant differences among V_1 and V_3,V_4 and V_2 and V_3,V_4 were observed at all the stages studied. With increase in DAS, increase in mother shoot height up to 105 DAS was observed.

TILLER NUMBER / m^2

There was significant decrease in mean tiller number due to stress in all treatment combinations (Table-12). This was from 462

TABLE - 11

MOTHER SHOOT HEIGHT (cm) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS ATDIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	51.8	49.5	48.8	47.5	49.4	75.0	73.0	72.0	72.0	73.0	76.2	73.2	74.0	74.3	74.7
NP	54.8	53.0	56.9	55.0	54.9	77.0	75.2	80.0	80.0	78.0	77.5	76.0	81.2	81.2	78.9
M	53.3	51.2	52.9	51.2	52.2	75.0	74.1	76.0	76.0	75.5	76.9	74.6	77.5	77.8	76.7
STRESS															
EP	49.0	47.4	40.0	40.0	44.1	72.0	68.3	61.5	61.5	65.8	72.8	69.3	63.0	63.0	67.0
NP	53.0	52.0	49.5	49.5	51.0	75.0	72.5	70.0	70.0	71.9	75.0	73.0	71.8	71.5	72.8
M	51.0	49.7	44.8	44.8	47.5	73.5	70.4	65.8	65.8	68.9	73.9	71.2	67.4	67.2	69.9
IRRIGATIONS MEAN		52.2	47.6				75.5	68.9				76.7	69.9		
PLANTINGS MEAN		46.8	53.0				69.4	75.0				70.7	75.9		
VARIETIES MEAN		52.2	50.5	48.8	48.0		74.7	72.3	70.9	70.9		75.4	72.9	72.4	72.5

	CD 5%	CD 5%	CD 5%
I	.NS	5.59	5.60
P	1.87	1.48	1.76
V	2.65	2.10	2.49
I x P	.NS	.NS	.NS
I x V	3.74	2.97	3.53
P x V	3.74	2.97	3.53
I x P x V	.NS	.NS	.NS

to 319, 309 to 248 and 297 to 272 in EP and 705 to 555, 422 to 383 and 408 to 368 in NP at 45, 85 and 105 DAS respectively. Table-12 also shows significant decrease in mean tiller number due to sowing treatment. EP invariably reduced the total tiller number/m^2 by 34.5, 26.8 and 27.2 under control and 42.5, 35.1 and 25.9 per cent under stress conditions at 45, 85 and 105 DAS respectively.

In all the treatment combinations, C-306 produced higher tiller number when compared to other varieties. Significant differences among varieties *viz.*, V_1 and V_3, V_4 and V_2 and V_3, V_4 were observed at all the stages. Higher tiller number in all the treatment was observed at 45 DAS, where as lower tiller number at 105 DAS (Table-12).

TOTAL LEAF AREA

Changes in total leaf area due to moisture stress and change in date of sowing is depicted in Fig.10. Stress decresed total leaf area significantly from 164 to 113, 264 to 315 and 182 to 228 under early planting conditions at 45,85 and 105 DAS respectively. However, when compared EP the effect of stress is less in NP. Change in date of sowing also brought same effect. Under controlled conditions, advancing planting from NP to EP decreased total leaf area significantly from 223 to 164, 388 to 315 and 275 to 228. This decrease was much more steeper under stress condition. Among varieties V_1 followed by V_2, V_3, V_4, had higher total leaf area both under control and Stress conditions of EP and NP (Fig-10).

TOTAL LEAF DRY WEIGHT

Figure 11 depicts changes brought in total leaf dry weight due to stress and planting date at all growth stages. Similar to total leaf area, total leaf dry weight was gradually increased from 45 to 85

TABLE - 12

TILLER NO./SQ.MT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105 DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	535	491	411	409	462	370	315	260	290	309	311	310	279	287	297
NP	765	725	665	665	705	453	425	390	420	422	442	411	376	404	408
M	650	608	538	537	584	411.5	370	325	355	365	376.5	360.5	327.5	346	353
STRESS															
EP	450	395	215	215	319	300	275	210	208	248	346	332	210	202	273
NP	715	655	425	415	553	419	400	352	360	381	407	386	335	343	368
M	583	525	320	315	436	360	338	281	284	315	377	359	273	273	320
IRRIGATIONS MEAN		583	438				365	315				353	320		
PLANTINGS MEAN		390	629				279	402				285	388		
VARIETIES MEAN		620	567	429	426		386	354	303	320		377	360	300	309

	CD 5%	CD 5%	CD 5%
I	7.29	31.8	35.7
P	11.1	8.27	9.30
V	15.7	11.7	.NS
I x P	22.3	11.7	18.6
I x V	.NS	16.5	18.6
P x V	.NS	16.5	18.6
I x P x V	31.5	.NS	26.3

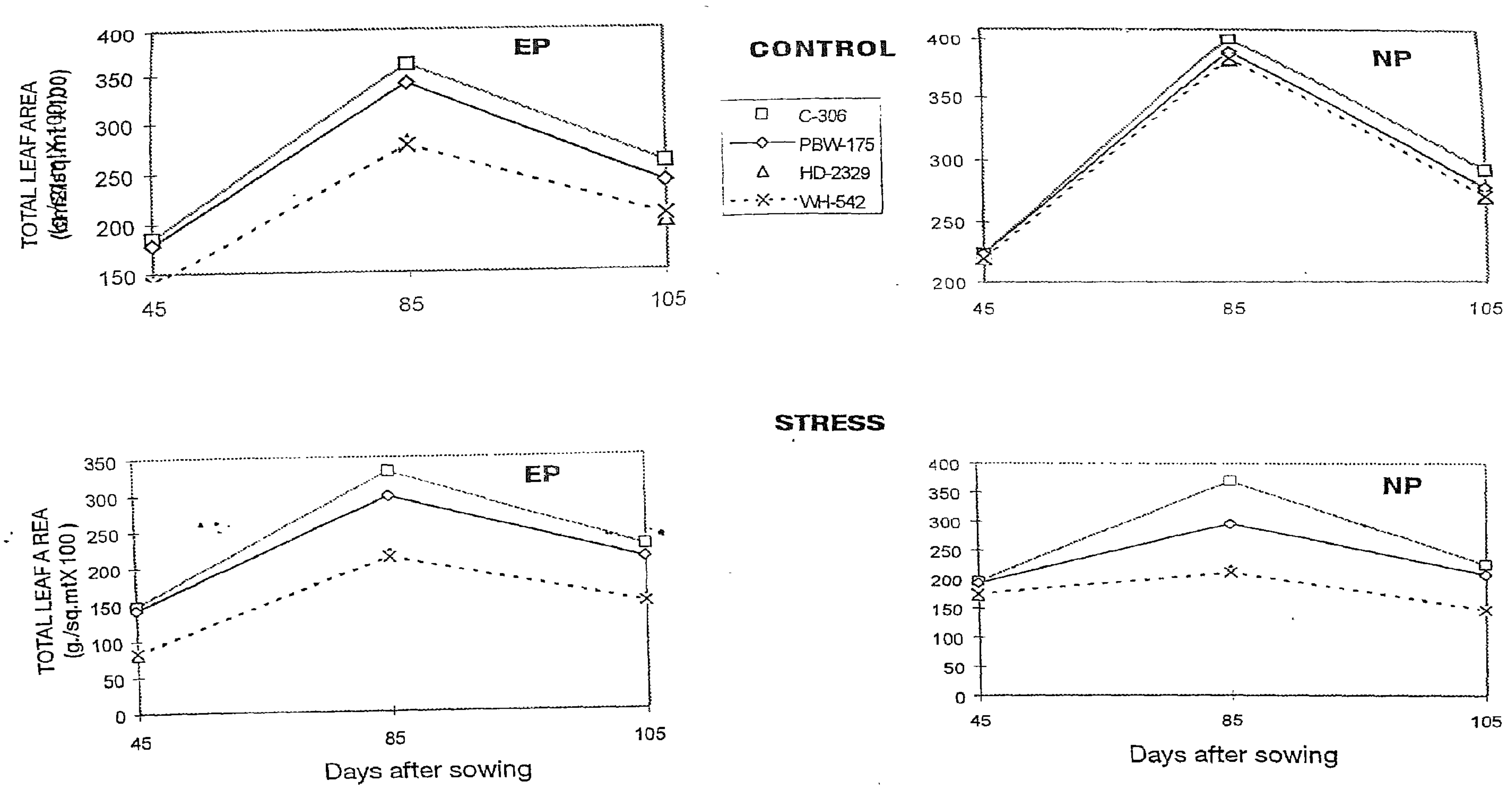


FIG - 10 : TOTAL LEAF AREA AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT VARIOUS STAGES OF PLANT GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

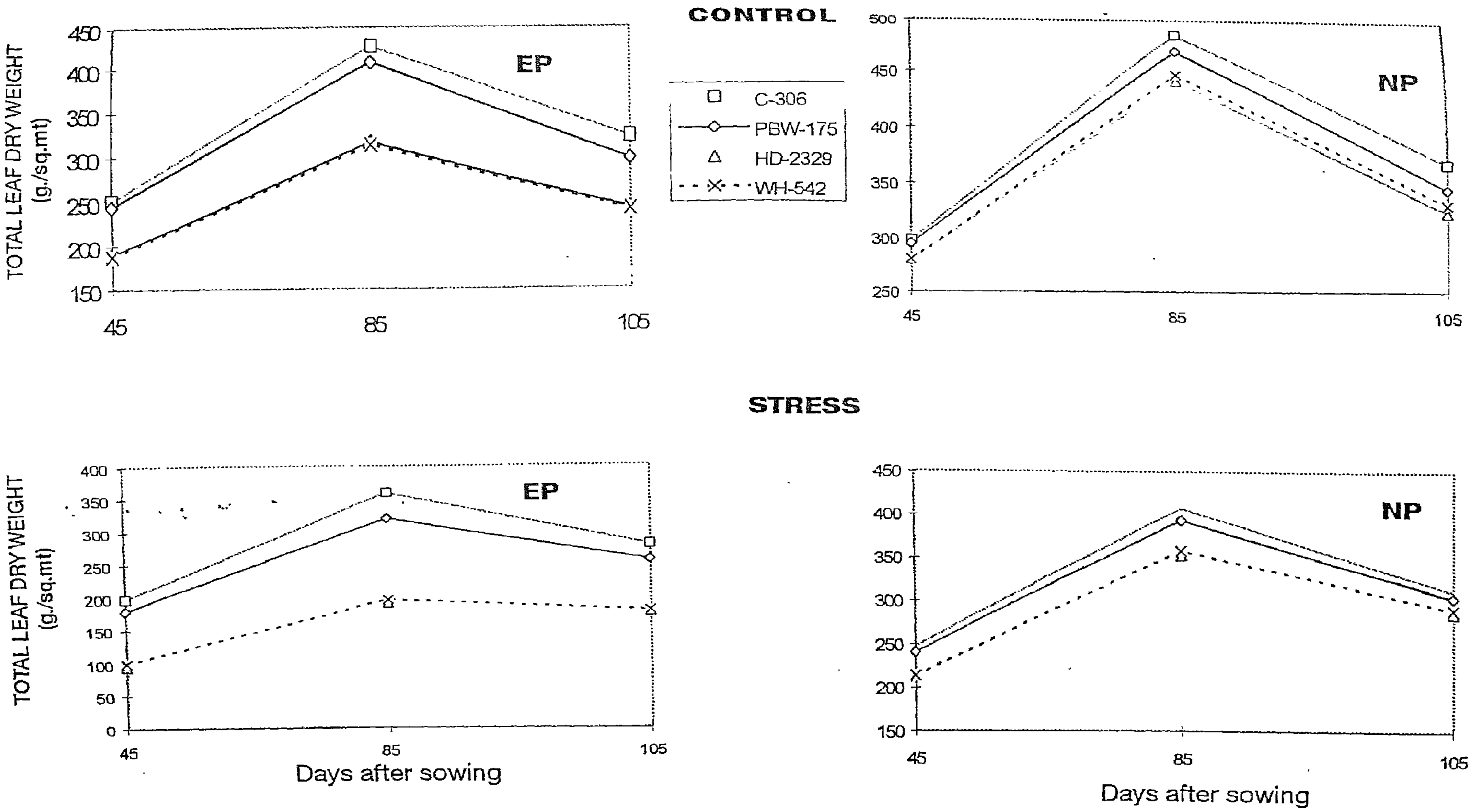


FIG - 11 : LEAF DRY WEIGHT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT VARIOUS STAGES OF PLANT GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

DAS and decreased there after. Both treatments (Water stress and Planting date) significantly decreased total leaf dry weight. However, this effect was much seen in V_3 and V_4 compared to V_1 and V_2 (Fig.11).

LEAF AREA INDEX (LAI)

Data regarding the effect of moisture and temperature stress on is presented in Table-13. There was 28.7, 12.5 and 15.5 per cent and 31.5, 2.6 and 29.1 per cent reductions due to water stress and early planting stress respectively. At all growth stages V_1 had significantly higher LAI over V_2,V_3 and V_4. However at 45 DAS no significant differences in V_1 and V_2 were observed.

SPECIFIC LEAF WEIGHT (SLW)

Specific leaf weight was influenced both by stress and planting date treatment at all growth stages. The SLW was heighest at 85 DAS and there after decreased. All the main effects i.e. irrigation, planting and varieties effects on SLW were significant. When individual varieties performance was estimated, V_1 followed by V_2 had higher SLW compared to V_3 and V_4 even under stress conditions (Table-14).

TOTAL PLANT BIOMASS

Table-15 shows the variation in total plant biomass at different stages at various treatments. Stress treatment significantly resulted lower values for total plant biomass in all the treatment combinations. Total plant biomass reduces by 32.3, 35 and 37.9 in EP and 24.5, 15.5 and 33.6 per cent reductions in NP due to stress at 45, 85 and 105 DAS respectively. Sowing treatments also showed significant variation in total plant biomass. The EP showed a decrease in total biomass by 13.7,12.8 and 25.1 in control and 22.6, 32.9 and 46.8 under stress environments at 45, 85, and 105 DAS respectively.

TABLE - 13

LEAF AREA INDEX AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105 DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	1.85	1.79	1.40	1.40	1.64	3.60	3.40	2.80	2.78	3.15	2.60	2.40	2.00	2.07	2.28
NP	2.24	2.24	2.22	2.22	2.23	4.00	3.88	3.80	3.82	3.88	2.89	2.75	2.67	2.68	2.75
M	2.05	2.02	1.81	1.81	1.94	3.80	3.64	3.30	3.30	3.52	2.75	2.58	2.34	2.38	2.52
STRESS															
EP	1.47	1.42	0.80	0.83	1.13	2.30	2.96	2.16	2.12	2.64	2.25	2.80	1.49	1.47	1.82
NP	1.96	1.93	1.72	1.74	1.84	3.70	3.56	3.38	3.40	3.51	2.56	2.48	2.30	2.31	2.41
M	1.72	1.68	1.26	1.29	1.49	3.50	3.62	2.77	2.76	3.08	2.41	2.28	1.90	1.89	2.12
IRRIGATIONS MEAN		1.94	1.49				3.51	3.07				2.51	2.12		
PLANTINGS MEAN		1.39	2.03				2.89	3.69				2.05	2.89		
VARIETIES MEAN		1.88	1.85	1.57	1.55		3.65	3.45	3.04	3.04		2.58	2.42	2.12	2.14

	CD 5%	CD 5%	CD 5%
I	0.18	0.18	0.14
P	1.12	1.12	0.09
V	0.16	0.16	0.13
I x P	.NS	.NS	.NS
I x V	.NS	.NS	.NS
P x V	.NS	0.23	0.18
I x P x V	.NS	.NS	.NS

TABLE - 14

SPCIFIC LEAF WEIGHT(mg. / cm^2) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105 DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	7.48	7.53	7.20	7.30	7.38	9.22	9.18	9.00	9.05	9.11	8.40	8.33	7.50	7.50	7.93
NP	7.60	7.60	7.60	7.55	7.59	9.45	9.48	9.40	9.42	9.44	8.61	8.45	8.06	8.16	8.32
M	7.54	7.57	7.4	7.43	7.49	9.34	9.33	9.20	9.24	9.28	8.51	8.39	7.78	7.83	8.18
STRESS															
EP	7.40	6.58	5.70	5.90	6.40	9.15	9.00	7.10	7.20	8.11	6.60	6.40	5.70	5.80	6.12
NP	6.60	6.40	6.30	6.20	6.38	8.20	8.36	8.10	8.15	8.23	7.60	7.40	7.25	7.20	7.36
M	7.00	6.49	6.0	6.05	6.39	8.68	8.68	7.6	7.68	8.17	7.1	6.9	6.48	6.5	6.74
IRRIGATIONS MEAN		7.49	6.39				9.28	8.17				8.13	6.74		
PLANTINGS MEAN		6.89	6.99				8.61	8.83				7.03	7.84		
VARIETIES MEAN		7.27	7.03	6.7	6.74		9.03	9.01	8.40	8.46		7.80	7.65	7.13	7.16
			CD 5%					**CD 5%**						**CD 5%**	
I			0.22					0.22						0.20	
P			0.14					0.14						0.13	
V			0.20					0.20						0.18	
I x P			.NS					.NS						0.18	
IxV			0.28					0.28						.NS	
PxV			0.28					0.28						.NS	
IxPxV			0.40					0.40						.NS	

TABLE -15

TOTAL PLANT BIOMASS(g/sq.mt)AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105 DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	326	314	283	287	303	726	662	598	575	640	1125	1063	970	903	1015
NP	374	361	335	335	351	850	816	790	780	734	1404	1333	1360	1325	1356
M	350	338	309	311	327	588	739	694	678	687	1265	1198	1165	1114	1186
STRESS															
EP	251	235	173	161	205	555	480	323	306	416	851	755	470	445	630
NP	310	291	232	226	265	710	662	555	551	620	1075	1061	915	895	987
M	281	263	203	194	235	633	571	439	429	518	963	508	693	670	808
IRRIGATIONS MEAN		327	235				687	518				1186	808		
PLANTINGS MEAN		254	308				528	677				823	1172		
VARIETIES MEAN		316	301	256	253		711	655	567	554		1114	1053	929	892

	CD 5%	CD 5%	CD 5%
I	9.2	8.9	8.4
P	8.0	8.0	7.7
V	7.7	7.5	7.0
I x P	7.7	7.5	7.0
I x V	7.0	9.3	9.0
P x V	7.0	9.3	9.0
I x P x V	12.2	13.1	12

Significat variation among all genotypes was also observed. Among varieties V_1 had accumlated more biomass at all three growth stages which was significantly 4.98, 23.4 and 24.9 at 45 DAS and 8.55, 25.4, and 28.3 at 85 DAS and 5.79, 19.9 and 24.9 per cent more over V_2, V_3 and V_4, respectively (Table-15).

YIELD COMPONENTS-MAINSHOOT

EARLENGTH

No significant difference due to stress was observed in earlength in both early and normal planting conditions. EP significantly reduced earlength over NP, only in stress treatment. No difference between EP and NP under control condition was observed (Table -16).

EAR NUMBER/m^2

Data regarding ear number/m^2 is given in Table-16. Ear number decreased significantly under both sowings. 16.4 and 2.08 per cent are the values representing decrease due to stress in EP and NP respectively. Table-16 also showed significant decrease in ear number due to sowing treatment. EP resulted about 11.5 and 24.5 per cent reduction in ear number over NP in control and stress treatment respectively. The differences among varieties in any combinations were significant. Variety C-306 had 1.09, 16.3 and 12.1 per cent more ear number over PBW- 175 HD 2329 and WH-542 for mean values.

SPIKELET NUMBER/m^2

Changes in spikelet number/m^2 due to various treatments is represented in Table-16. Significant reduction in spikelet number/m^2 was observed in both the sowings due to stress. This was 18.1 per cent in early planting and 9.03 per cent in normal planting.

TABLE - 16

MAIN SHOOTYIELD COMPONENTS AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS ATDIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	EARLENGTH (cm)					EAR NO../ m^2					SPIKELET NO. /m^2					GRAIN NO. /m2				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL																				
EP	9.6	9.3	9.5	9.5	9.48	187	182	150	159	170	4114	3458	2850	3021	3361	7068	7056	6285	6217	6656
NP	9.6	9.5	9.85	9.83	9.70	195	198	182	194	192.2	4875	4554	4004	4268	4425	9185	9306	8936	9137	9141
M	9.61	9.40	9.68	9.67	9.60	191	190	166	177	181	3145	4066	3427	3644	3561	8127	8181	7611	7677	7899
STRESS																				
EP	9.5	9.0	8.8	8.8	9.02	161	160	125	122	142	3703	3360	2000	1952	2754	6919	6552	3750	3648	5217
NP	9.75	9.4	9.4	9.4	9.49	199	193	179	183	188.4	4975	4246	3401	3477	4025	8537	8299	7321	7576	7933
M	9.62	9.20	9.10	9.10	9.26	180	177	152	153	165	4339	3803	2700	2714	3389	7728	7425	5536	5612	6575
IRRIGATIONS MEAN		9.6	9.3				175	171				3829	3453				7899	6575		
PLANTINGS MEAN		9.26	9.6				156	190				3057	4225				5934	8537		
VARIETIES MEAN		9.5	9.7	9.0	9.5		185	183	159	165		4417	3905	3064	3180		7927	7803	6573	6645

	CD 5%	CD 5%	CD 5%	CD5%
I	.NS	1.47	94.6	196
P	0.34	1.54	92.4	72
V	.NS	2.20	130.7	102
I x P	.NS	.NS	.NS	102
I x V	NS	3.10	185	144
P x V	.NS	3.10	185	144
I x P x V	.NS	4.38	262	204

Similar effect was also obtained due to planting conditions. Early planting resulted into 24.0 and 31.6 per cent reduction under control and stress respectively.

Varieties V_1 and V_2 showed marked differences significantly over other varieties V_3 and V_4. However the differences either between V_1 and V_2 or V_3 and V_4 were not significant. When comparative performance was taken in to account, C-306 had better performance by bearing more number of spikelets in both the stresses as well as planting treatments (Table-16).

GRAIN NUMBER /m^2

The data obtained on grain number/m^2 is presented in Table-16 indicates signficant reductions by 21.6 per cent in EP and 13.2 per cent in NP due to stress treatment. Decrease due to early planting conditions in grain number was also observed from the same Table-16. These values were 27.2 per cent and 34.2 per cent in control and stress respectively . The differences in grain number among varieties can also be observed here. For mean values, V_1 had 1.59, 20.6 and 19.3 per cent more grain number over V_2,V_3 and V_4 respectively.

YIELD COMPONENTS - TILLER

EAR NUMBER/m^2

Data of Table-17 shows significant reductions in tiller ear number due to stress in both early and normal planting conditions. A per cent of 14.2 and 17.0 were reduced in early and normal planting by giving stress.The effect of planting was also found to be significant. Early planting invariably reduced tiller ear number by 34.6 per cent in control and 32.5 per cent in stress compared to normal planting.

TABLE - 17

TILLER YIELD COMPONENTS AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS ATDIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	EARLENGTH (cm)					EAR NO../ m^2					SPIKELET NO. /m^2					GRAIN NO. /m2				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL																				
EP	9.40	9.30	9.30	9.30	9.3	127	120	110	109	116.5	2921	2280	1980	1962	2286	5017	4704	4125	3979	4456
NP	9.40	9.40	9.40	9.40	9.4	203	175	162	173	178.3	4669	3675	3402	3633	3845	7531	7473	7225	7370	7400
M	9.40	9.35	9.35	9.35	9.35	165	147.5	136	141	147.4	3795	2978	2691	2798	3065	6274	6089	5675	5675	5928
STRESS																				
EP	9.20	9.00	8.80	8.80	8.95	131	124	74	70	99.9	2751	2232	1110	1050	1786	4205	3856	1828	1708	2899
NP	9.40	9.30	9.20	9.20	9.28	170	159	130	133	148	3910	3180	2470	2394	2989	6205	5772	4719	4748	5361
M	9.30	9.15	9.00	9.00	9.11	150.5	141.8	102	101.5	124	3331	2706	1790	1722	2387	5205	4814	3274	3228	4130
IRRIGATIONS MEAN		9.35	9.11				147	124				3065	2387				5928	4130		
PLANTINGS MEAN		9.13	9.34				108	163				2035	3417				3678	6381		
VARIETIES MEAN		9.3	9.15	9.0	9.0		158	145	119	121		3563	2841	2241	2260		5740	5451	4474	4451
			CD 5%					**CD 5%**						**CD 5%**				**CD5%**		
I			0.1					4.26						340				160		
P			0.1					1.55						97.6				55		
V			0.3					2.20						138				78		
I x P			.NS					2.20						138				78		
I x V			.NS					3.11						195				110		
P x V			.NS					311						195				110		
I x P x V			.NS					4.39						.NS				155		

Significant differences among varieties was also observed here. Variety C-306 had significantly more tiller number among all the varieties both in control as well as in the treatments where stress was given.

SPIKELET NUMBER / m^2

Number of spikelets observed were less under stress over control in both the planting conditions. However, the impact of stress was much more evident under early planting condition. All the combinations studied above in relation to stress condition were found significant (Table-17). Effect of planting date was also found significant. Early planting resulted in 40.5 and 40.2 per cent reduction in spikelet number in control and stress respectively. Among the varities studied C-306 had maintained higher spikelet number over V_2,V_3 and V_4. This was found to be 27.4, 41.0 and 35.6 per cent increase in control where as 23.1, 86.1 and 93.4 per cent increase under stress.

GRAIN NUMBER/m^2

Tiller grain number as that of spikelet number was also much influenced due to stress. Values given in the Table-17 for stress treatment were 34.9 and 27.5 per cent less in early and normal plantings respectively over control. Grain number differed significantly in different planting dates also. Early planting highly reduced grain number both in control as well as in stress. However, this effect was more visible under stress conditions. All the values were found significant. Variation among genotypes in bearing tiller grain number was also evident here.Among various genotypes studied, C-306 maintained relatively more grain number over remaining varieties, in both control as well as stress condition (Table-18).

TABLE - 17

TILLER YIELD COMPONENTS AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS ATDIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	EARLENGTH (cm)					EAR NO../ m²					SPIKELET NO. /m²					GRAIN NO. /m2				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL																				
EP	9 40	9 30	9.30	9.30	9.3	127	120	110	109	116.5	2921	2280	1980	1962	2286	5017	4704	4125	3979	4456
NP	9.40	9.40	9.40	9.40	9.4	203	175	162	173	178.3	4669	3675	3402	3633	3845	7531	7473	7225	7370	7400
M	9.40	9.35	9.35	9.35	9.35	165	147.5	136	141	147.4	3795	2978	2691	2798	3065	6274	6089	5675	5675	5928
STRESS																				
EP	9.20	9.00	8.80	8.80	8.95	131	124	74	70	99.9	2751	2232	1110	1050	1786	4205	3856	1828	1708	2899
NP	9 40	9 30	9 20	9.20	9.28	170	159	130	133	148	3910	3180	2470	2394	2989	6205	5772	4719	4748	5361
M	9.30	9.15	9.00	9.00	9.11	150.5	141.8	102	101.5	124	3331	2706	1790	1722	2387	5205	4814	3274	3228	4130
IRRIGATIONS MEAN		9.35	9.11				147	124				3065	2387				5928	4130		
PLANTINGS MEAN		9.13	9.34				108	163				2035	3417				3678	6381		
VARIETIES MEAN		9.3	9.15	9.0	9.0		158	145	119	121		3563	2841	2241	2260		5740	5451	4474	4451
			CD 5%					**CD 5%**						**CD 5%**				**CD5%**		
I			0.1					4.26						340				160		
P			0.1					1.55						97.6				55		
V			0.3					2.20						138				78		
I x P			.NS					2.20						138				78		
I x V			.NS					3.11						195				110		
P x V			.NS					311						195				110		
I x P x V			.NS					4.39						.NS				155		

Significant differences among varieties was also observed here. Variety C-306 had significantly more tiller number among all the varieties both in control as well as in the treatments where stress was given.

SPIKELET NUMBER / m^2

Number of spikelets observed were less under stress over control in both the planting conditions. However, the impact of stress was much more evident under early planting condition. All the combinations studied above in relation to stress condition were found significant (Table-17). Effect of planting date was also found significant. Early planting resulted in 40.5 and 40.2 per cent reduction in spikelet number in control and stress respectively. Among the varities studied C-306 had maintained higher spikelet number over V_2,V_3 and V_4. This was found to be 27.4, 41.0 and 35.6 per cent increase in control where as 23.1, 86.1 and 93.4 per cent increase under stress.

GRAIN NUMBER/m^2

Tiller grain number as that of spikelet number was also much influenced due to stress. Values given in the Table-17 for stress treatment were 34.9 and 27.5 per cent less in early and normal plantings respectively over control. Grain number differed significantly in different planting dates also. Early planting highly reduced grain number both in control as well as in stress. However, this effect was more visible under stress conditions. All the values were found significant. Variation among genotypes in bearing tiller grain number was also evident here.Among various genotypes studied, C-306 maintained relatively more grain number over remaining varieties, in both control as well as stress condition (Table-18).

MAINSHOOT GRAIN YIELD.

Main shoot grain yields were high under controlled condition. Stress resulted significant reductions by showing the values 38.9 and 23.9 under early and normal planting, respectively (Table-18). Reduction in grain yields were also observed due to planting treatments. Early planting resulted in decreased grain yields in both control and stress. However, this effect was much more seen under stress i.e., 15.9 per cent over control.

Among varieties, V_1, V_2 group showed their stability by yielding more when compared to types V_3, V_4 group. However when overall performance (meanvalues) was compared C-306 had higher per cent grain yields significantly over other varieties in the order of 6.65, 21.9 and 27.7 per cent.

TILLER GRAIN YIELD/ m^2

Tiller grain yield also showed same pattern as that of mainshoot Under both early and normal planting stress resulted 51.2 and 38.1 per cent reductions respectively over control. The early planting significantly reduced tiller grain yields by 32.5 and 46.7 per cent in control and stress respectively. Significant variation for tiller grain yield was observed among the varieties (Table -18).

TOTAL GRAIN YIELD/m^2

Stress conditions reduced total grain yields significantly over control in both the sowings studied. The decrease was 43.6 per cent under early planting and 29.6 per cent under normal planting. Change in planting date also showed the similar trend. Early planting in comparsion to normal planting, showed reduced total grain yield by 24.1 per cent in control and 39.2 per cent in stress (Table - 18).

TABLE - 18

YIELD (g/sq.mt) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS ATDIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	Mainshoot Grain Yield (g/sq.mt)					Tiller Grain Yield (g/sq.mt)					Total Grain Yield (g/sq.mt)				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
Control															
EP	319.5	305.5	276.5	261.7	290.9	190.1	169.3	148.1	138.5	161.5	519.6	474.8	424.6	400.2	454.8
NP	360.1	354.6	368.2	357.3	360.1	240.2	231.0	247.1	238.1	239.1	600.3	585.6	615.3	595.4	599.2
M	339.8	330.2	322.5	309.5	325.5	215.2	200.2	197.5	188.3	200.3	560.0	530.2	520.0	497.8	527
STRESS															
EP	251.2	218.8	123.8	117.1	177.7	124.1	101.1	47.3	42.9	78.8	375.3	319.8	171.1	160.0	256.5
NP	314.2	288.8	252.6	239.4	273.8	185.5	161.0	127.4	117.8	147.9	499.7	449.8	380.0	357.2	421.7
M	282.8	253.7	188.2	178.2	225.7	154.8	131.0	87.3	80.2	113.3	437.5	384.7	275.5	258.7	339.1
IRRIGATIONS MEAN		326	226				200	113				527	339		
PLANTINGS MEAN		234	317				120	193				356	510		
VARIETIES MEAN		311	292	255	244		185	166	142	134		499	457	398	378
			CD 5%				CD 5%					CD 5%			
I			73.5				12.6					5.15			
P			12.8				5.86					4.02			
V			18.1				.NS					5.69			
I x P			18.1				8.29					5.69			
I x V			25.6				11.7					8.04			
P x V			25.6				11.7					8.04			
I x P x V			.NS				.NS					11.4			

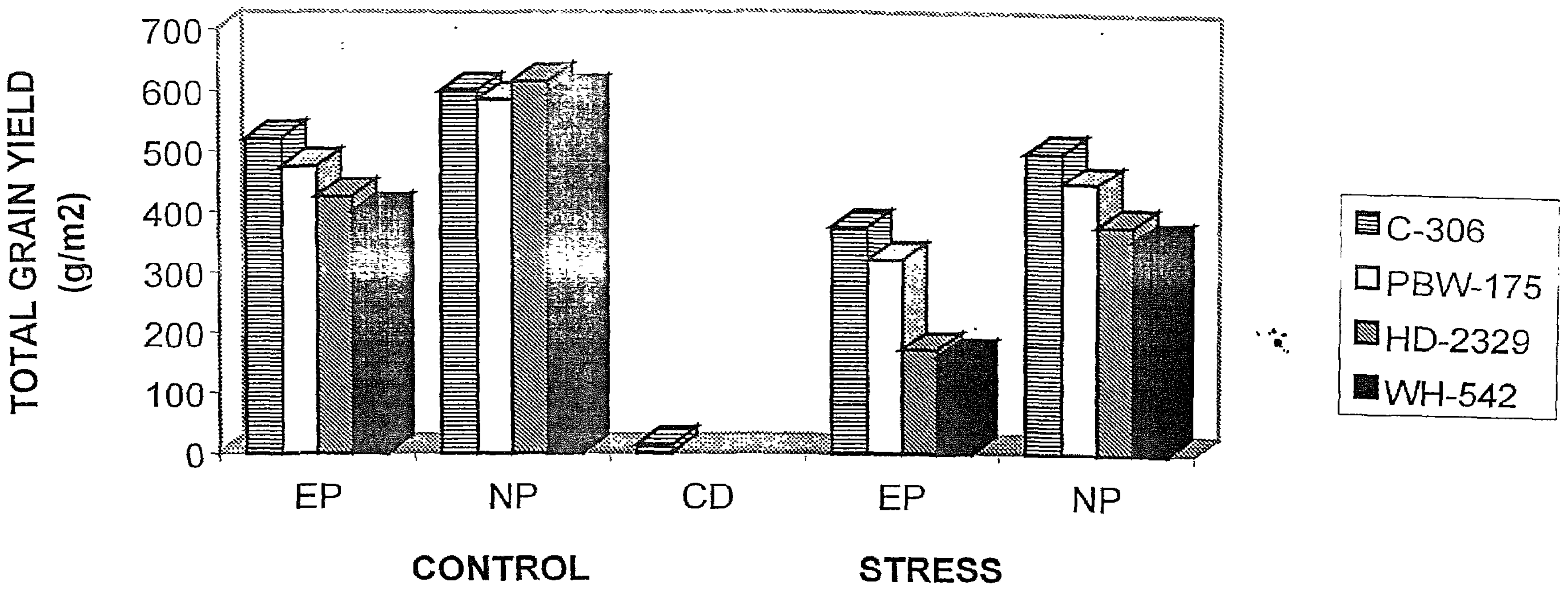


FIG - 12 : TOTAL GRAIN YIELD AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS IN WHEAT GENOTYPES

Among the varieties V_1 followd by V_2, V_3, V_4 had higher grain yield in both EP and NP under control as well as stress condition (Fig-12). Variety C-306 showed higher grain yield which was 5.62, 7.69 and 12.5 per cent significantly more in control over V_2 ,V_3 and V_4 respectively. A significant increase of 13.7, 58.8 and 69.1 per cent was also observed in C-306 over other varieties under stress conditions.

PER CENT HARVEST INDEX

Fig-13 depicts differences in harvest indices among varieties due to different treatments. Stress decreased HI significatnly over control both in EP and NP. Similiarly EP significatnly decreased per cent HI over NP in control as well as stress conditions.

THOUSAND GRAIN WEIGHT

The decrease in test weight due to stress was significant and found to be 6.27 and 4.3 per cent in early and normal planting respectively. Such a decrease was also observed by early sowings. Early planting decreased test weight by 1.34 and 3.37 in control and stress condition respectively. Significant differences between V_1 and V_2 and V_3 and V_4 were also observed. Among genotypes studied, C-306 had shown consistency in maintaining test weight under stress condition as well as early planting condition (Fig-14).

GRAIN DENSITY

Fig-15 shows data on grain density. Grain density was influenced upon stress exposure. Stress condition over control resulted 5.68 and 5.5 per cent reduction in early and normal planting respectively. Marked differences in grain density was also obtained by different sowing conditions. Against normal planting, early

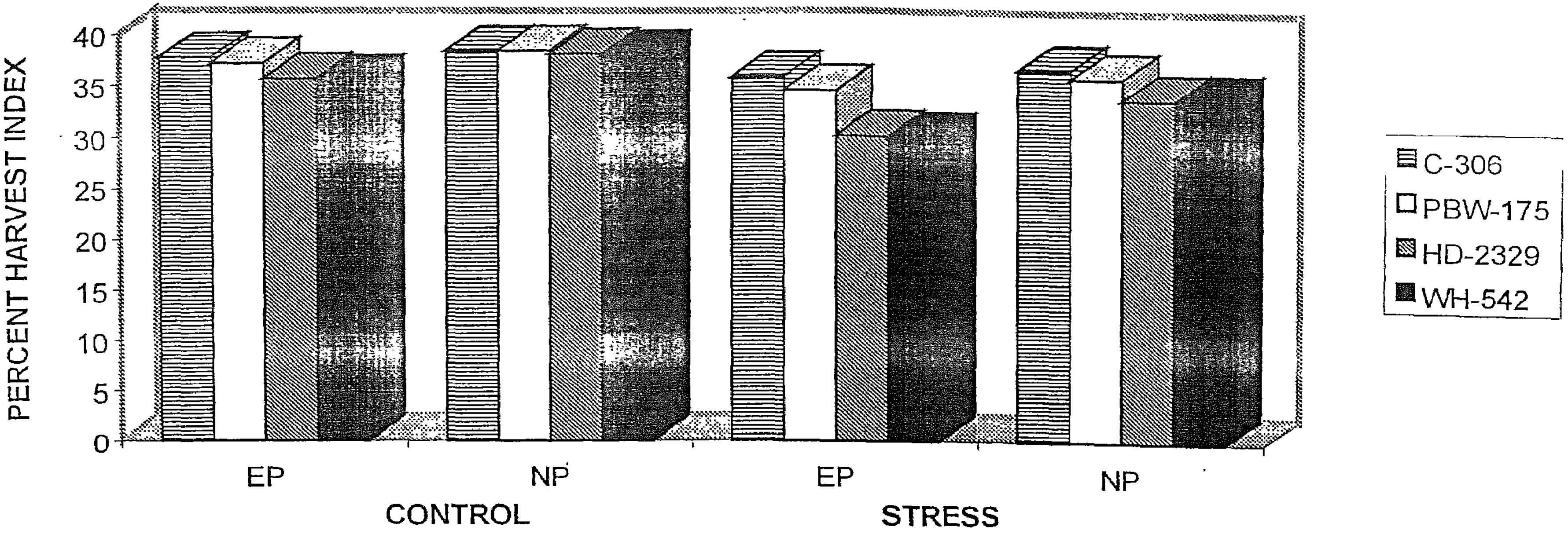


FIG-13 : PERCENT HARVEST INDEX AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS IN VARIOUS WHEAT GENOTYPES

EP = EARLY PLANTING
NP = NORMAL PLATING

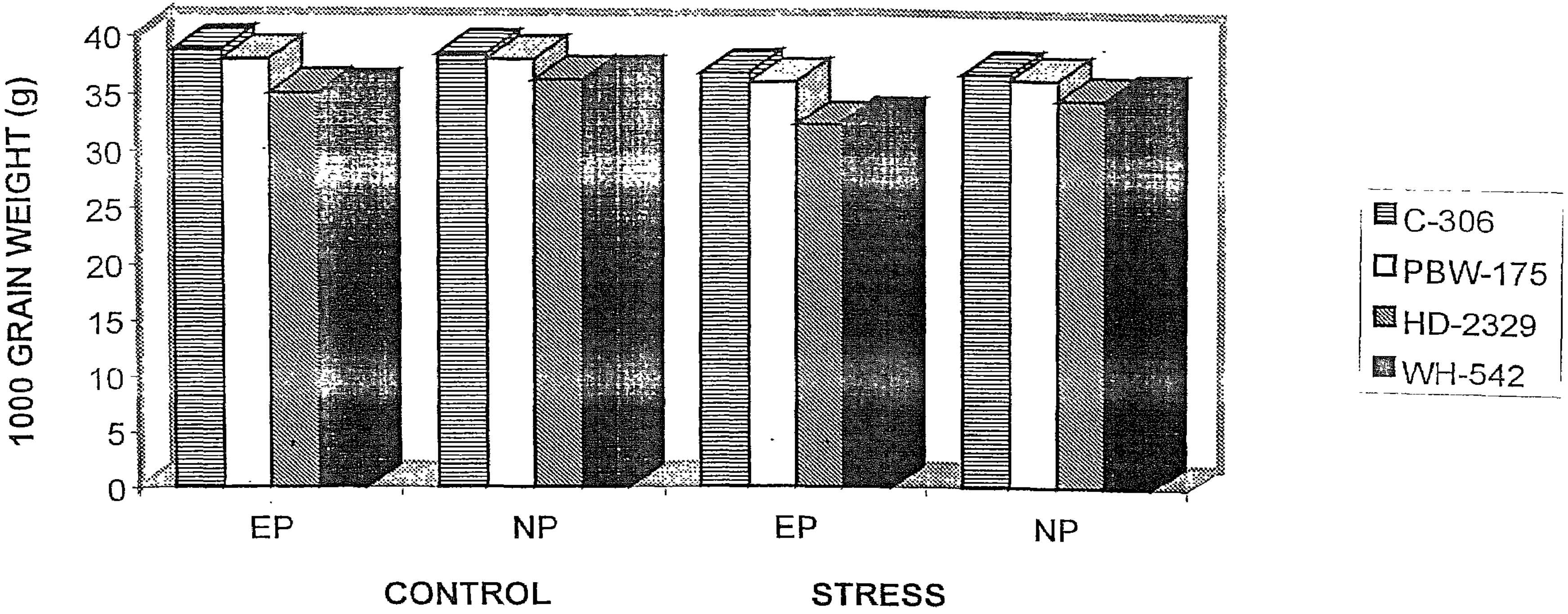


FIG-14 : 1000 GRAIN WEIGHT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS IN VARIOUS WHEAT GENOTYPES

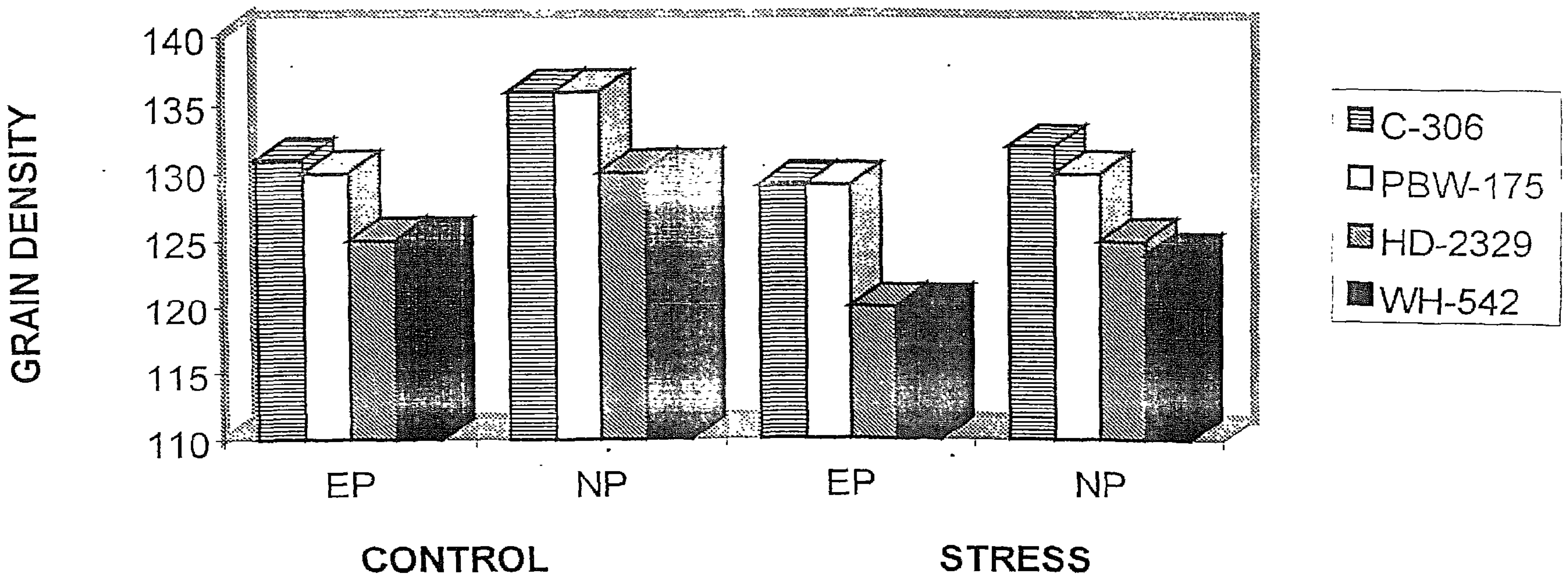


FIG-15 : GRAIN DENSITY AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS IN VARIOUS WHEAT GENOTYPES planting showed 2.58 and 2.75 per cent decrease over normal planting in control and stress respectively. Differences among genotypes in grain density were also seen from Fig-15. C-306 had shown higher grain density over rest of the varieties in all combinations studied.

EXPERMENT III

PER CENT ION-LEAKAGE (PER CENT IL)

The effect of moisture and temperature (early planting) stresses on per cent ion-leakage recorded at three different stages *viz.*, 15 days pre-anthesis (15 DPA), 15 days after anthesis (15 DAA) and 30 days after anthesis in (30 DAA) is presented in Table-19. Higher values for percent ion-leakage was observed at 30 DAA over the two other stages. Stress given at the three stages (15 DPA, 15 DAA and 30 DAA) significantly increased per cent ion-leakage values over control treatment. However, greater increase in both the sowings was observed at 15 DPA when compared to 15 DAA and 30 DAA. In early planting, these increases were in the order of 38.1, 31.1 and 30.8, where as in NP it was 30.8, 21.2 and 23.0 at 15 DPA, 15 DAA and 30 DAA respectively. The high per cent increase in ion-leakage at 15 DPA in both EP and NP compared to 15 DAA and 30 DAA indicates that this stages is more sensitive.

At all 3 stages, early planting showed significantly higher values when compared to normal planting. However, this affect was much more observed at 15 DPA stage. When varietal performance was considered, no significant difference either between V_1,V_2 or V_3,V_4 was observed. However, the differences among V_1 and V_3, V_4 and V_2 and V_3, V_4 were significant at all the stages. C-306, among all varieties, showed less per cent ion-leakage under both stress at all the stages studied (Table-19).

TABLE - 19

PERCENT IONLEAKAGE AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0 -15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	36.3	36.5	45.3	45.3	40.9	41.0	41.3	48.2	48.4	44.7	40.5	40.5	53.2	53.0	46.8
NP	33.0	33 0	38.4	38.6	35.8	39.0	39.0	46.0	46.0	42.5	41.0	38.9	47.9	48.0	40.0
M	34.7	34.8	41.9	42.0	38.30	40.0	40.2	47.1	47.2	43.6	40.8	39.7	50.5	50.5	45.4
STRESS															
EP	49.1	50.2	63.2	63.5	56 5	50.2	50 3	67.1	66.9	58.6	52.0	52.2	70.0	70.5	61.2
NP	43.1	43.2	50.3	50.5	46.8	47.1	47.0	55.9	55.9	51.5	49.0	49.0	59.0	59.5	54.1
M	46.1	46.7	56.8	57.0	51.6	48.7	48.7	61.5	61.4	55.1	50.5	50.6	64.5	65.0	57.7
IRRIGATION MEAN		38.3	51.6				43.6	55.1				45.4	57.6		
PLANTATING MEAN		48.7	41.3				51.7	47.0				54.0	49.0		
VARITIES MEAN		40.4	40.7	49.3	49.5		44.3	44.4	54.3	54.3		45.6	45.2	57.3	57.8
			CD 5%					**CD 5%**					**CD 5%**		
I			2.81					3.36					3.77		
P			2.81					3.36					3.77		
V			3.97					4.76					5.33		
I x P			.NS					.NS					.NS		
I x V			.NS					.NS					.NS		
p X V			.NS					.NS					.NS		
I x P x V													-		

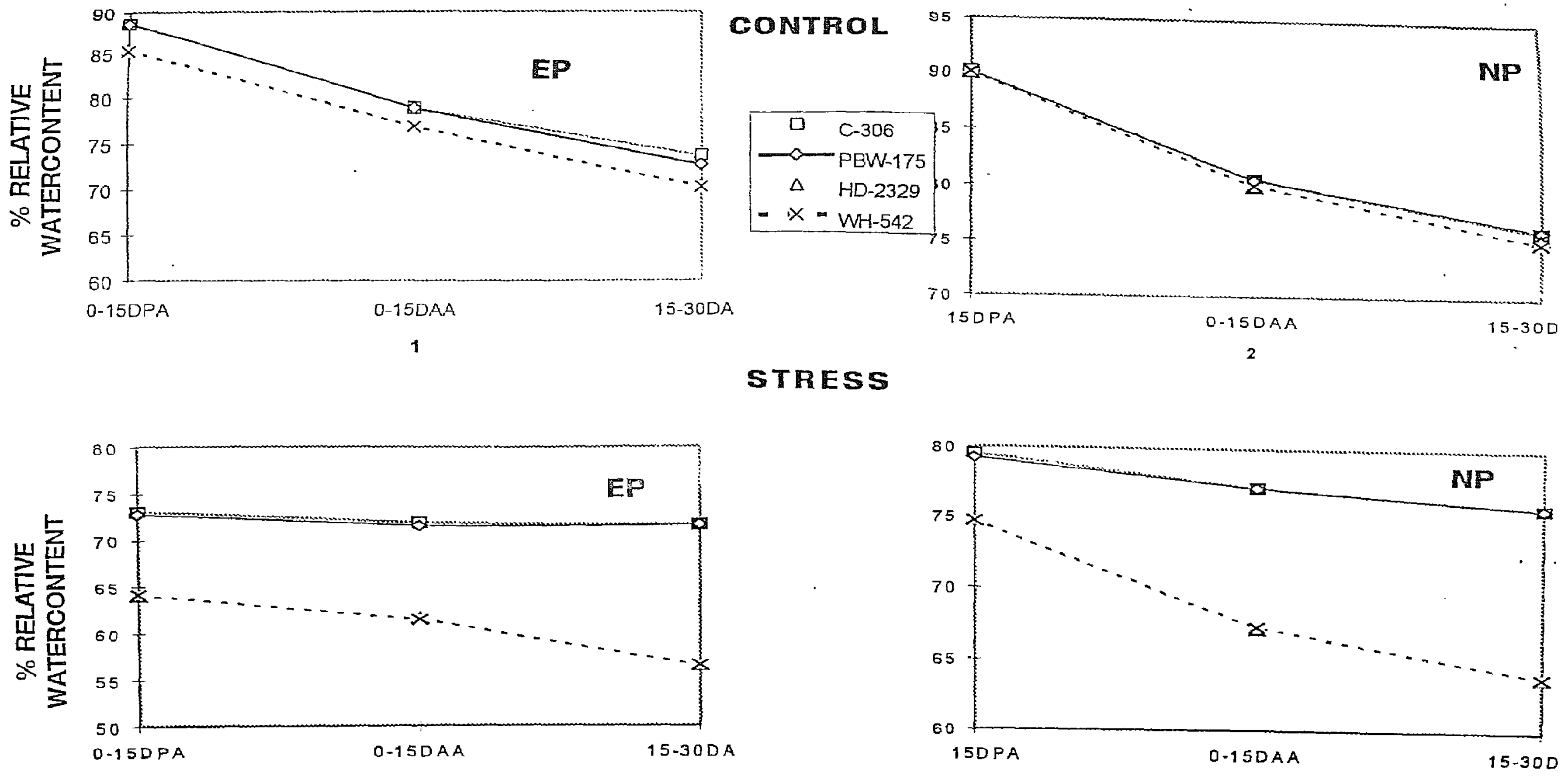
PER CENT RELATIVE WATER CONTENT (PER CENT RWC)

Data regarding the affect of intermittent stresses given for a brief period of 15 days at three important stages i.e., 15 DPA, 15 DAA and 30 DAA on percentage leaf relative water content is presented in Appendix-X. Stress given at all these 3 stages were found significant. There was 21.3, 14.7 and 10.9 per cent reductions in EP and 14.4, 9.98 and 8.03 per cent reduction in NP due to stress at 15DPA, 15 DAA and 30 DAA respectively. High percentage reductions at 15 DPA in both sowings over the other two stages indicates that this stage may be more sensitive to stress. At 15 DPA, high reductions in EP over NP is due to added affect of high temperature prevailing at this stage (Appendix-X).

The effect of plantings at all 3 stages were also resulted significant. Early planting significantly reduced per cent relative water content over normal planting in all the three stages showing greater reductions at 15 DPA when compared to other two stages. Significant differences among varieties was also observed. Variety C-306 followed by PBW-175 maintained high per cent RWC over rest of the varieties at all the stages studied (Fig-16).

NITRATE REDUCTASE ACTIVITY (NRA)

Among the three stages studied NR activity was more at 15 DPA (Table-20) and decreased gradually for the next two stages in order. Significant fall in NRA values was observed at all 3 stages due to stress. These values further reveals that the higher percentage reduction was at 15 DPA when compared to other stages. At 15 DPA the reduction in NRA due to stress was 44.8 in EP and 24.1 in NP. Where as at 15 DAA and 30 DAA these reductions were 26.7, 29.6 and in EP and 23.2 and 27.3 in NP, respectively.



DPA = DAYS PRIOR TO ANTHESIS
DAA = DAYS AFTER ANTHESIS

FIG - 16 :PERCENT RELATIVE WATER CONTENT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT VARIOUS STATEGES AROUND ANTHESIS IN WHEAT GENOTYPES

TABLE -20

NITRATE REDUCTASE ACTIVITY (µ moles NO_2^-gfwt^{-1}hr^{-1}) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	2.70	2.65	2.55	2.52	2.61	2.00	2.00	1.78	1.80	1.89	1.90	1.87	1.53	1.58	1.72
NP	2.85	2.83	2.88	2.88	2.86	2.29	2.29	2.10	2.13	2.20	2.20	2.20	1.95	2.00	2.09
M	2 78	2.74	2.69	2.70	2.74	2.14	2.14	1.94	1.96	2.05	2.05	2.03	1.74	1.79	1.90
STRESS															
EP	1.90	1.85	1.00	1.01	1.44	1.52	1 52	1.15	1.19	1.34	1.30	1.30	1.05	1.08	1.18
NP	2.23	2.27	1.58	1.60	2.17	1.85	1.86	1.51	1.53	1.69	1.73	1.73	1.30	1.32	1.52
M	2.07	2.06	1.29	1.31	1.81	1.69	1.69	1.33	1.36	1.52	1.51	1.51	1.18	1.02	1.35
IRRIGATION MEAN		2.73	1.68				2.05	1.52				1.90	1.35		
PLANTATING MEAN		2.02	2.39				1.62	1.95				1.45	1.80		
VARITIES MEAN		2.42	2.40	2.00	2.01		1.91	1.92	1.63	1.66		1.78	1.77	1.46	1.49
			CD 5%					CD 5%					CD 5%		
I			0.27					0.29					0.32		
P			0.27					0.29					0.32		
V			0.39					.NS					.NS		
I x P			.NS					.NS					.NS		
I x V			.NS					.NS					.NS		
P X V			.NS					.NS					.NS		
I x P x V			.NS					.NS					.NS		

Against normal planting, early planting showed significantly lower values for NRA both in control and stress at all the three stages studied. And the effect of EP is much more in stress compared to control at 15 DPA and this was up to 8.74 per cent in control and 33.6 per cent in stress. Table-20 also showed differences among varieties due to both moisture stress and high temperature (EP) stresses. C-306 had higher NR activity over all other varieties at all the stages studied. However, the varietal differences between V_1 and V_2 or V_2 and V_3 were not significant.

PER CENT NITROGEN CONTENT IN LEAF (PER CENT N)

At 15 DPA, per cent leaf nitrogen content was heighest and fell down sharply at 15 DAA and 30 DAA in both the sowings. At 15 DPA and 15 DAA there was 25.6 and 16.6 per cent reductions in EP and 13.6 and 15.5 in NP due to stress. Distinctly higher amount reductions in both the sowings at 15 DPA reveals the deep sensitivity of this stage to the stress over rest of the stages. At 30 DAA no effect of water stress was found (Table-21).

Data from the same table also illustrates the differences in per cent leaf nitrogen content due to planting.Compared to normal planting, early planting invariably resulted in lower values in both control and stress at all the stages except at 30 DAA. These reductions at 15 DPA were 11.5 and 23.8 in control and stress respectively. At 15 DPA, 15DAA and 30 DAA cultivars differed significanlty in leaf per cent nitrogen. All varieties possesed higher leaf% N at 15 DPA and reduced later on. C-306 maintained stable higher leaf % N at all stages studied over other varieties (Table-21).

TABLE - 21

PERCENT NITROGEN AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0 -15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	2.40	2.20	2.00	2 00	2.15	1.40	1.20	1.00	1.00	1.15	1.00	1.00	0.85	0.82	0.92
NP	2.50	2.40	2.40	2.40	2.43	1.50	1.50	1.60	1.60	1.55	1.17	1.10	1.00	1.00	1.07
M	2.45	2 30	2.20	2.20	2.29	1.45	1.35	1.30	1.30	1.35	1.08	1.05	0.93	0.91	0.99
-STRESS															
EP	2 10	1.70	1.30	1.30	1.60	1.29	1.10	0.80	0.80	1.00	1.00	1.00	0.75	0.70	0.86
NP	2.28	2.10	2.00	2 00	2.10	1.44	1.40	1.20	1.20	1.31	1.1	1.1	0.95	0.95	1.02
M	2.19	1.90	1.65	1.65	1.85	1.36	1.25	1.00	1.00	1.15	1.05	1.05	0.85	0.82	0.94
-IRRIGATION MEAN		2.29	1.85				1.35	1.15				0.99	0.94		
PLANTATING MEAN		1.88	2.26				1.07	1.43				0.89	1.05		
VARITIES MEAN		2.32	2.10	1.92	1.92		1.41	1.30	1.15	1.15		1.07	1.05	0.89	0.87
		CD 5%					CD 5%					CD 5%			
I		0.18					0.18					.NS			
P		0.18					0.18					0.10			
V		0.25					.NS					0.14			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

TOTAL CHLOROPHYLL CONTENT

Total chlorophyll content was gradually decreased from 15 DPA to 30 DAA (Table-22) showing maximum at 15 DPA and minimum value at 30 DAA. When compared to control, stress treatment showed lower values at all stages. The reductions in these values were 27.3, 13.6 and 10.6 in EP and 14.9, 11.1 and 7.3 in NP.

Table-22 also reveals the significant reductions due to early planting over normal planting at all 3 stages studied. Cultivar differences in total chlorphyll content was also evident at all the stages studied.Varieties C-306 and PBW-175 had higher chlorophyll content over rest of the varieties significantly at all stages. However in all varieties total chorophyll content is more at 15 DPA and decreased later on (Fig-17).

PHOTOSYNTHETIC RATE

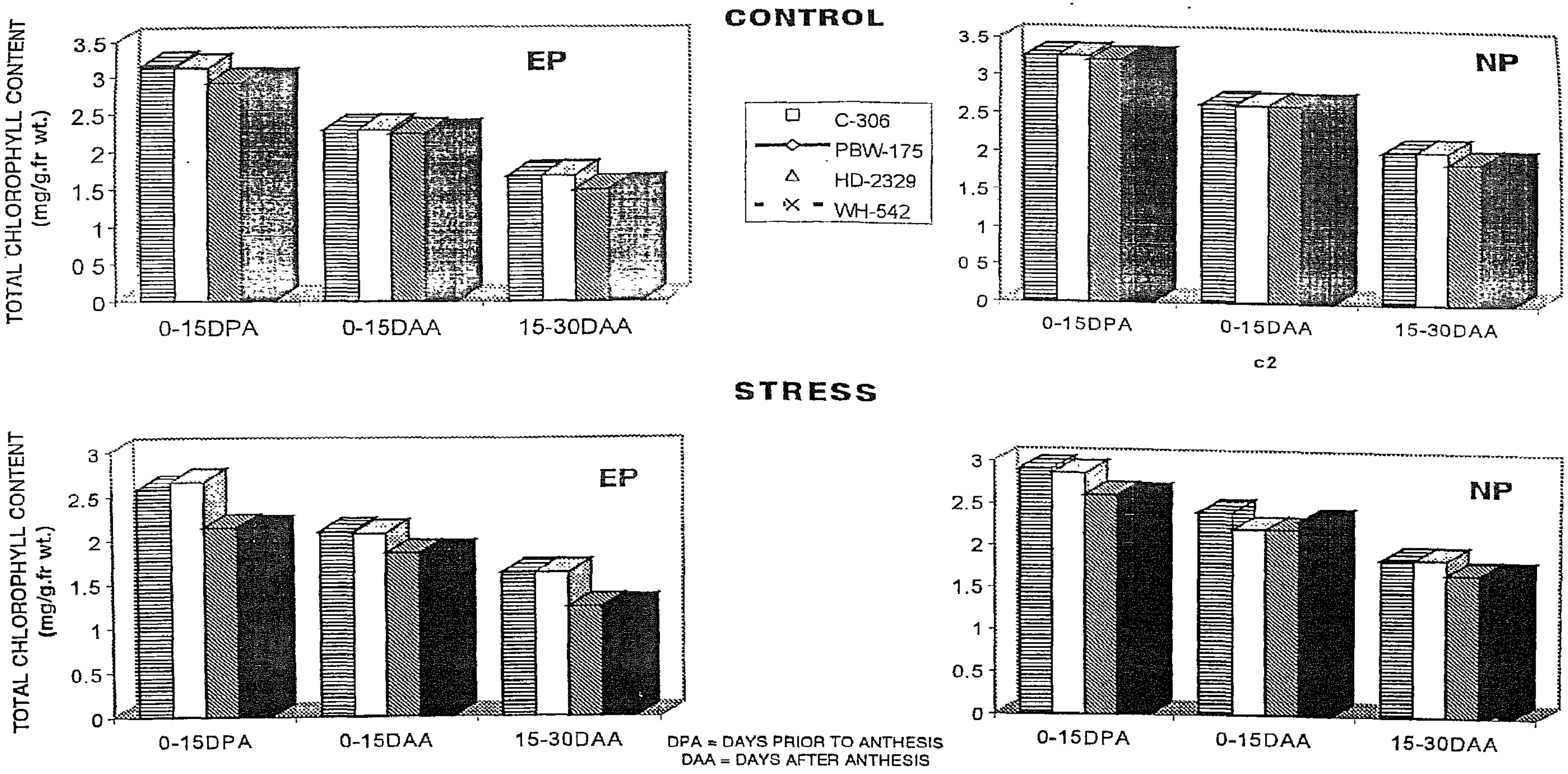
The rate of photosynthesis measured at 15DPA, 15 DAA and 30 DAA is given in Table-23. It is seen from the same table that at 15 DPA, the net photosynthesis was higher in both the sowings. When compared photosynthesis at 15 DPA, 15DAA and 30 DAA there was reductions in photosynthetic rate to the tune of 20.3, 10.6 and 8.76 in EP and 12.6, 5.09 and 3.97 in NP, due to stress over control. These values also emphasizes the relative tolerance of different stages to stres and it was clear that the stage at 15DPA is least tolerant. Significant effect of stress only at 15 DPA indicates the relative sensitivity of this stage compared to 15 DAA and 13 DAA.

Fig-18 further depicts differences due to planting.The values for early planting were significantly lower than normal planting at all stages studied. When the percent reductions at 15 DPA and 15 DAA

TABLE - 22

TOTAL CHLOROPHYLL CONTENT (mg $gfwt^{-1}$) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	3.15	3.12	2.92	2.92	3.03	2.30	2.30	2.25	2.23	2.27	1.69	1.70	1.51	1.52	1.60
NP	3.25	3.25	3.20	3.20	3.23	2.62	2.60	2.59	2.59	2.60	1.99	2.00	1.85	1.85	1.92
M	3.20	3.19	3.06	3.06	3.13	2.46	2.45	2.42	2.41	2.44	1.84	1.85	1.68	1.69	1.76
STRESS															
EP	2.58	2.66	2.14	2.12	2.37	2.09	2.07	1.85	1.84	1.96	1.63	1.63	1.24	1.23	1.43
NP	2.91	2.86	2.61	2.60	2.75	2.42	2.04	2.21	2.21	2.31	1.87	1.87	1.70	1.70	1.78
M	2.74	2.76	2.38	2.36	2.56	2.25	2.23	2.03	2.02	2.14	1.75	1.75	1.47	1.47	1.61
IRRIGATION MEAN		3.13	2.56				2.44	2.14				1.76	1.61		
PLANTATING MEAN		2.70	2.98				2.12	2.45				1.52	1.85		
VARITIES MEAN		2.97	2.97	2.72	2.71		2.36	2.34	2.23	2.22		1.80	1.80	1.57	1.58
		CD 5%					CD 5%					CD 5%			
I		0.26					.NS					.NS			
P		0.26					0.32					0.21			
V		.NS					.NS					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			



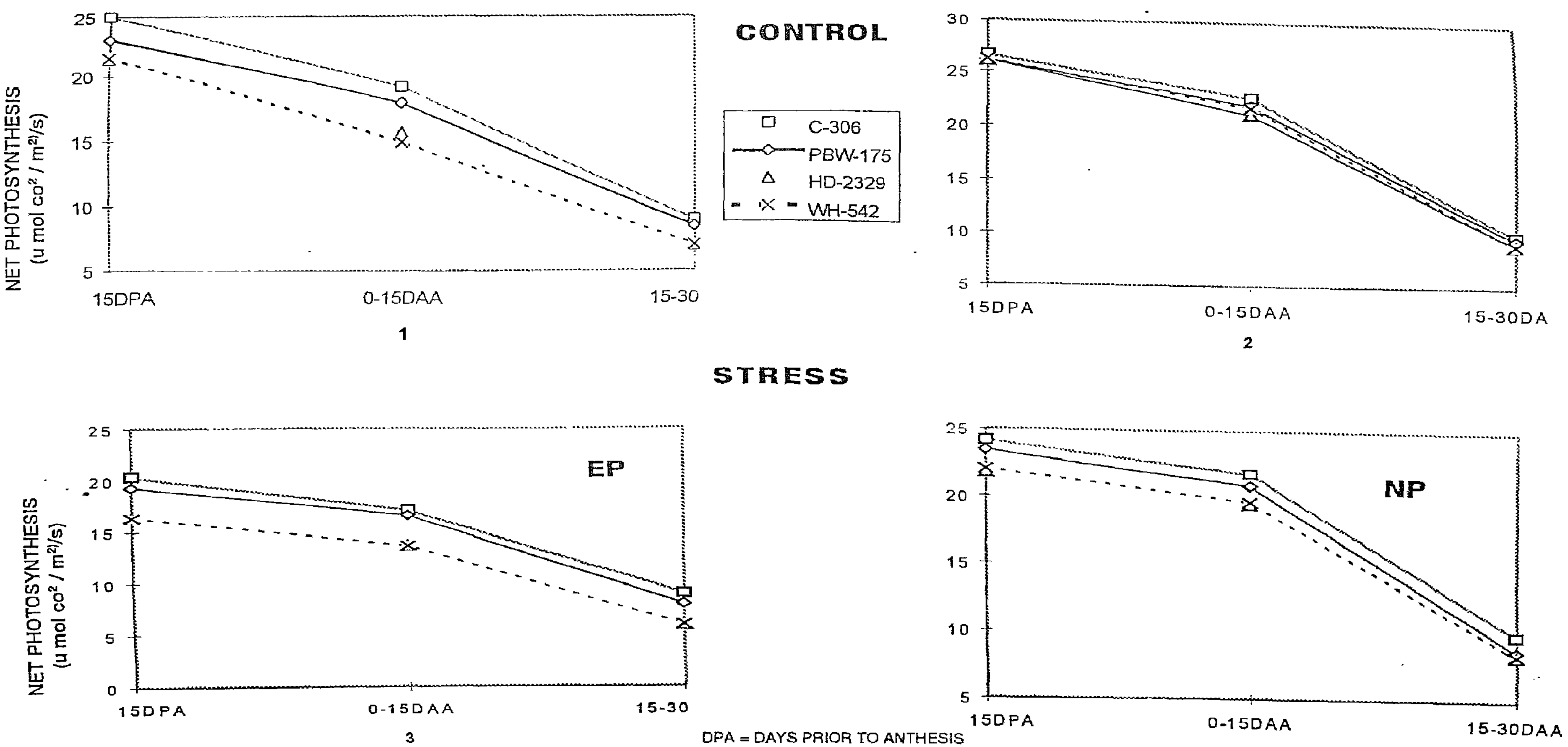
DPA = DAYS PRIOR TO ANTHESIS
DAA = DAYS AFTER ANTHESIS

FIG - 17 :TOTAL CHOLROPHYLL CONTENT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT VARIOUS STATEGES AROUND ANTHESIS IN WHEAT GENOTYPES

Table - 23.

NET PHOTOSYNTHESIS (μ mol $co_2/m^2/s$) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	25.0	23.0	21.4	21.5	22.7	19.2	18.0	15 7	15.0	17.0	9.0	8.5	7.0	7.0	7.88
NP	26.5	26.0	26.0	26.0	26.1	22.5	21.8	21.0	21.0	21.6	9.8	9.5	9.0	9.0	9.33
M	25.8	24.5	23.7	23.8	24.4	20.9	19.9	18.4	18.0	19.3	9.4	9.0	8.0	8.0	8.60
-STRESS															
EP	20.3	19.3	16.4	16.3	18.1	17.1	16.6	13.6	13.6	15.2	8.94	7.94	5.94	5.94	7.19
NP	24.1	23.4	21 7	22.0	22.8	21.8	20.9	19.5	19.7	20.5	9.84	8.74	8.40	8.40	8.84
M	22.2	21.4	19.1	19.2	20.4	19.5	18.8	16.6	16.7	17.9	9.39	8.34	7.17	7.17	8.02
-IRRIGATION MEAN		24.4	20.4				19.3	17.9				8.60	8.02		
PLANTATING MEAN		20.4	24.5				16.1	21.0				7.53	9.08		
VARITIES MEAN		24.0	22 9	21.4	21.5		20.2	19.3	17.5	17.3		9.4	8.7	7.6	7.6
		CD 5%					**CD 5%**					**CD 5%**			
I		2.18					-					-			
P		2.18					1.51					1.03			
V		3.08					2.13					1.45			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			



DPA = DAYS PRIOR TO ANTHESIS
DAA = DAYS AFTER ANTHESIS

FIG - 18 :NET PHOTOSYNTHESIS AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT VARIOUS STATEGES AROUND ANTHESIS IN WHEAT GENOTYPES were compared the reduction in photosynthetic rate was more steeper at 15 DPA. Photosynthetic rate was highest at 15 DPA irrespective of cultivar. Cultivar differences at all three stages were significant (Fig-18).

MOTHER SHOOT HEIGHT

Data regarding mothershot height is presented in Table-24. Only planting effects significantly decreased mothershoot at all 3 stages except at 30 DAA Stage.

TOTAL LEAF AREA/PLANT

Total leaf area/plant, shown in Table-25 was significantly reduced at all 3 stages in both the sowings, due to stress. At 15 DPA, the reductions due to stress in EP and NP were upto 39.7 and 32.7 per cent and incase of 15 DAA, 33.7 and 28.2 per cent were the reductions in EP and NP respectively. However, these per cent reductions at 30 DAA were comparitively less and were only 28.2 in EP 18.9 in NP.

Early planting at all the 3 stages distinctly reduced total leaf area/plant over normal planting, both in control and stress but much more in later. Significant differences among genotypes were also seen at all 3 stages. At 15 DPA, C-306 had more leaf area significantly over any other genotype. similar superiority of C-306 was also found in the other two stages (Table-25).

LEAF DRY WEIGHT

Among three stages, the stage at 15 DPA had more leaf dry weight and declined gradually in subsequent stages of 15 DAA and 30 DAA, under both early and normal plantings. 40.3, 29.2 and 26.5 per cent in early planting 28.6, 24.6 and 22.3 per cent in NP,

TABLE - 24

MOTHERSHOOT HEIGHT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0 -15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	63.4	61.2	60.4	60.0	61.3	78.3	76.2	75.0	75.0	76.1	79.4	76.3	77.1	77.4	77.6
NP	65.9	63.8	67.9	67.5	66.4	80.1	78.2	82.9	83.0	81.1	80.4	80.0	83.0	83.0	81.6
M	64.7	62.6	64.2	63.8	63.8	79.2	79.0	78.6	80.0	78.6	79.9	78.1	80.1	80.2	79.6
STRESS															
EP	58.9	57.0	56.2	55.8	57.0	74.4	72.4	71.1	70.7	72.2	75.8	75.3	73.5	73.8	74.4
NP	61.7	59.8	63.5	63.1	62.0	76.5	75.9	79.0	79.0	77.6	77.2	77.0	79.0	79.0	78.1
M	60.3	58.4	59.9	59.5	59.5	75.5	74.2	75.1	74.9	74.9	76.5	76.2	76.3	76.0	76.2
IRRIGATION MEAN		63.8	59.5				78.6	74.9				79.6	76.2		
PLANTATING MEAN		59.1	64.2				74.1	79.3				76.0	79.8		
VARITIES MEAN		62.5	60.5	62.0	61.6		77.3	75.7	77.0	76.9		78.2	77.2	78.2	78.1
		CD 5%					**CD 5%**					**CD 5%**			
I		.NS					.NS					.NS			
P		4.28					4.85					.NS			
V		.NS					.NS					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

Table - 25

LEAF AREA (cm^2 / plant) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	475	450	300	285	378	378	371	195	185	282	217	210	85	85	149
NP	515	500	375	355	436	405	400	235	225	316	225	220	105	105	164
M	495	475	338	320	407	392	386	215	205	299	221	215	96	95	157
STRESS															
EP	320	273	159	159	228	275	257	115	100	187	160	150	59.0	59.0	107
NP	378	317	250	230	294	319	276	160	153	227	188	180	78.0	83.3	133
M	349	295	205	195	261	297	266	138	127	207	174	165	68.5	71.2	120
IRRIGATION MEAN		407	261				299	207				157	120		
PLANTATING MEAN		303	365				234	272				128	148		
VARITIES MEAN		422	385	271	257		344	326	176	166		198	190	82.2	83.1
		CD 5%					**CD 5%**					**CD 5%**			
I		30.2					26.3					17.0			
P		30.2					26.3					17.0			
V		42.7					37.2					24.0			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

were the values of reduction due to stress at 15 DPA, 15 DAA and 30 DAA respectively. High temperatures at early growth phase in EP may be accounted for more reduction due to stress in EP when compared to normal planting (Table-26).

Data in the same table further shows the significant effects on total leaf dry weight due to change in sowing dates. Against normal planting, early planting showed unfavourable effect on leaf dry weight, in both control and stress resulting lesser values at all 3 stages studied. Noted variation among genotype at all 3 stages can also be observed from Table-26 .In all 3 stages, C-306 had higher leaf dry weights over rest of the genotypes. The values for leaf dry weights at all stages for V_1,V_2,V_3 and V_4 were in descending order at three stages.

TOTAL PLANT BIOMASS.

Total plant biomass measured at 15 DPA, 15DAA and 30 DAA is given in Table-27. It is also seen from the table the accumlation in total plant biomass is more between 15 DPA and 15 DAA. Irrespective of plant weight at a particular stage, stress affected plant weight at all the stages to the tune of 17.5, 12.3 and 12.9 in EP and 10.2, 8.37 and 9.78 in NP at 15 DPA, 15 DAA and 30 DAA respectively. The higher amount of reductions in EP when compared to NP may be attributed to added affect of high tmperatures prevailing at vegetative phase of crop growth.

Similar deteriorating affect on total plant biomass due to change in sowing dates was also evident from the same Table-27. Variations in degree of tolerance to stress and early planting conditions among cultivars, was also observed. Cultivar C-306 accumulated more biomass when compared to rest of the varieties under stress as well as early planting conditions.

Table - 26.

LEAF DRY WEIGHT (g/plant) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	8 05	7.84	5.39	5.18	6.62	5.77	5.69	3.29	3.20	4.49	3.04	2.93	1.54	1.54	2.26
NP	8.47	8.32	6.30	5.97	7.27	6.25	6.07	3.79	3.70	4.95	3.30	3.31	2.08	2.05	2.69
M	8.26	8.08	5.85	5.58	6.94	6.01	5.88	3.54	3.45	4.72	3.17	3.12	1.81	1.79	2.47
STRESS															
EP	5 13	4.58	3.05	3.05	3.95	4.27	4.03	2.13	2.03	3.18	2.00	1.95	1.33	1.36	1.66
NP	6.34	5.90	5.43	4.10	5.19	4.78	4.65	2.79	2.69	3.73	2.26	2.20	1.95	1.95	2.09
M	5.74	5.24	3.74	3.58	4.57	4.53	4.34	2.46	2.36	3.46	2.13	2.08	1.64	1.66	1.87
IRRIGATION MEAN		6.94	4.57				4.72	3.42				2.47	1.87		
PLANTATING MEAN		5.29	6.23				3.80	4.34				1.96	2.39		
VARITIES MEAN		7.00	6.65	4.80	4.58		5.27	5.11	3.00	2.90		2.65	2.60	1.72	1.72
		CD 5%					**CD 5%**					**CD 5%**			
I		0.65					0.50					0.33			
P		0.65					0.50					0.33			
V		092					0.71					0.47			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

TABLE - 27

TOTAL PLANT BIOMASS(g/Plant) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	14.0	13.5	13.7	13.7	13.7	21.0	20.0	20.0	20.0	20.3	25.4	23.9	23.4	23.4	24.0
NP	14.7	14.5	14.8	14.8	14.7	22.5	22.5	22.8	22.8	22.7	28.6	28.9	26.4	26.4	27.6
M	14.4	14.0	14.3	14.3	14.2	21.8	21.3	21.4	21.4	21.5	27.0	26.4	24.9	24.9	25.8
STRESS															
EP	12.7	12.6	10.0	10.0	11.3	18.9	18.4	16.9	16.9	17.8	23.5	22.0	19.0	19.0	20.9
NP	14.0	13.8	12.5	12.5	13.2	21.9	21.3	20.2	19.9	20.8	27.1	25.4	23.6	23.4	24.9
M	13.4	13.2	11.3	11.3	12.3	20.4	19.9	18.6	18.4	19.3	25.3	23.7	21.3	21.2	22.9
IRRIGATION MEAN		14.2	12.3				21.5	19.3				25.8	22.9		
PLANTATING MEAN		12.5	14.0				19.0	21.7				22.5	26.2		
VARITIES MEAN		13.9	13.6	12.8	12.8		21.1	20.6	20.0	19.9		26.2	25.1	23.1	23.1
		CD 5%					CD 5%					CD 5%			
I		1.18					1.90					2.56			
P		1.18					1.90					2.56			
V		.NS					.NS					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

EARLENGTH AND SPIKELET NUMBER /PLANT- MAINSHOOT

Neither stress treatment nor early planting conditions resulted significant differences in main shoot earlength at 15 DAA and 30 DAA. However, stress at 15 DPA significantly decreased ear length. No cultivar differences were also observed at all three stages (Appendix-XII). Similar effects were also observed in case of spikelet number (Table-28).

SPIKELET NUMBER / PLANT- TILLER

The impact of tiller spikelet number per plant was studied at all the three stages and data is presented in Table-29. Stress decrease tiller spikelet number at all three stages. These reductions were 28.7, 16.6 and 8.0 in EP and 24.1, 14.3 and 5.72 in NP at 15 DPA, 15 DAA and 30 DAA respectively. However, no effect of planting was found. Significant differences among varieties were observed at 15 DPA and 15 DAA only.

GRAIN NUMBER / PLANT-MOTHER SHOOT

The effect of stress on grain number per plant was found at all three stages both early and normal planting. Due to early planting grain number/plant significantly fell down in both control and stress, at all the stages. Against nomal planting there was 38.0 per cent, 17.2 per cent and 5.95 per cent reductions at 15 DPA, 15 DAA and 30 DAA under early planting. Among varieties, C-306 followed by PBW-175 maintained higher grain number under any situatons (Table-30).

GRAIN NUMBER/PLANT-TILLER

Data regarding tiller grain number/plant is presented in Table-31. Strees given at all 3 stages reduced grain number except

TABLE - 28.

MOTHER SHOOT SPIKELET NO: / PLANT AT HARVEST AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	22.5	22.5	22.5	22.8	22.6	22.5	22.5	22.5	16.1	21.0	22.5	22.8	22.5	22.5	22.6
NP	23.0	23.0	2.5	22.5	22.8	23.0	23.0	22.5	22.5	22.8	23.0	23.0	22.5	22.5	22.8
M	22.8	22.8	22.5	22.7	22.7	22.8	22.8	22.5	19.3	21.8	22.8	22.9	22.5	22.5	22.7
STRESS															
EP	17.5	17.0	15.0	15.0	16.1	20.3	20.0	17.5	17.5	18.8	22.5	22.5	20.0	22.0	21.6
NP	18.5	18.0	16.3	16.5	17.3	21.0	20.5	18.5	18.8	19.7	22.5	22.5	20.5	20.8	21.6
M	18.0	17.5	15.7	15.8	16.7	20.7	20.2	18.0	18.2	19.2	22.5	22.5	20.3	21.4	21.6
-IRRIGATION MEAN		22.7	16.7				21.8	19.2				22.7	21.2		
PLANTATING MEAN		19.4	20.0				19.9	21.2				22.2	22.2		
VARITIES MEAN		20.4	20.1	19.1	19.2		21.7	21.5	20.3	18.7		22.6	22.7	21.4	22.0

	CD 5%	CD 5%	CD 5%
I	2.03	.NS	.NS
P	.NS	.NS	.NS
V	.NS	.NS	.NS
I x P	.NS	.NS	.NS
I x V	.NS	.NS	.NS
P X V	.NS	.NS	.NS
I x P x V	.NS	.NS	.NS

TABLE - 29

TILLER SPIKELET NO. / PLANT AT HARVEST AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	39.8	38.8	37.0	36.8	38.9	40.8	40.0	38.5	39.0	39.6	41.0	40.5	38.8	39.0	39.8
NP	42.5	41.8	40.8	41.3	41.6	42.5	42.0	41.3	41.3	41.8	42.5	42.5	41.3	41.3	41.9
M	41.1	40.3	38.9	37.8	39.5	41.6	41.0	39.9	40.1	40.7	41.8	41.5	40.0	40.1	40.8
STRESS															
EP	31.3	32.3	22.5	22.0	27.0	36.3	35.5	30.5	29.5	33.0	38.5	38.3	34.5	35.0	36.6
NP	35.0	33.8	27.5	27.5	31.0	38.8	38.0	33.8	32.5	35.8	41.3	40.8	38.0	38.0	39.5
M	33.1	33.0	25.0	24.8	29.0	37.5	36.8	32.1	31.0	34.4	39.9	39.5	36.3	36.5	38.1
IRRIGATION MEAN		39.5	29.0			40.7	34.4				40.9	38.1			
PLANTATING MEAN		32.6	35.6			36.3	39.7				38.2	40.7			
VARITIES MEAN		37.2	36.7	32.0	31.3	39.6	38.9	36.0	35.5		40.8	40.5	38.2	38.3	
		CD 5%					CD 5%					CD 5%			
I		3.46					1.41					2.67			
P		.NS					.NS					.NS			
V		4.89					2.00					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

Table - 30.

MOTHER SHOOT GRAIN NO. /PLANT AT HARVEST AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	66.3	65.8	62.5	61.8	64.1	67.5	66.3	63.0	63.0	65.0	67.5	63.7	63.3	65.5	65.0
NP	68.0	67.5	67.5	67.5	66.6	68.8	67.5	65.8	66.3	67.1	68.8	68.8	65.5	65.5	67.2
M	67.2	66.7	64.0	63.7	65.4	68.1	66.9	64.4	64.7	66.0	68.1	66.2	64.4	65.5	66.1
STRESS															
EP	42.5	42.0	32.5	31.8	37.2	54.5	54.0	43.0	43.0	48.6	65.8	65.0	52.8	52.3	59.0
NP	45.3	45.0	38.8	39.3	42.1	59.0	60.0	53.0	52.5	56.1	68.8	68.0	60.5	60.8	64.5
M	43.9	43.5	35.7	35.6	39.7	56.8	57.0	48.0	47.8	52.4	67.3	66.5	56.7	56.6	61.8
IRRIGATION MEAN		65.4	39.7			66.0	52.4				66.1	61.8			
PLANTATING MEAN		50.7	54.4			56.8	61.6				62.0	65.9			
VARITIES MEAN		55.5	55.1	49.8	49.6	62.5	62.0	56.2	56.2		67.7	66.4	60.5	61.0	
		CD 5%					CD 5%					CD 5%			
I		3.47					4.60					3.80			
P		3.47					4.60					3.80			
V		4.90					5.00					5.38			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

at 30 DAA. Due to moisture stress, in EP there was 37.1, 22.2, 13.2 per cent reductions and in NP there was 31.8, 16.4, 9.0 per cent reduction at 15 DPA, 15 DAA and 30 DAA respectively. The more reductions at 15 DPA indicates that this stage is more sensitive to stress. Similarly early planting resulted lesser grain number both in control and stress at all the 3 stages due to high temperature exposure at EP compared to NP (Table-31).

GRAIN WEIGHT/PLANT-MAINSHOOT

Main shoot grain weight was decreased due to stress at all stages except at 30 DAA. Stress decreased grain weight in both EP and NP. When effect of stress given at 3 different stages were compared, 15 DPA was much effected indicating it is more sensitive (Table-32). Simlarly planting early where high temperature exists compared to normal planting also reduced grain weights. These reductions were more under stress, than control. No difference in varieties for this parametre was also found.

GRAIN WEIGHT/PLANT-TILLER SHOOT

Tiller shoot grain weight was also influenced significantly due to waterstress as well as early planting (high temperature) conditions. Compared to control, stress in early planting decreased tiller grain weight significantly by 42.4, 28.6, 36.8 per cent at 15 DPA, 15 DAA and 30DAA. Stress in NP also decreased tiller grain weight but with less effect as compared to effect seen under EP. Planting dates also showed significance. Early planting invariably reduced grain weight significantly over normal planting at all three stages. However no differences among varieties under these conditions were found (Table-33).

Table - 31.

TILLER GRAIN NO. / PLANT AT HARVEST AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	88.7	87.0	79.7	60.7	79.0	91.0	91.0	85.0	81.7	87.2	82.0	90.0	86.0	86.0	88.5
NP	114	110	107	108	110	113	110	108	109	110	114	112	109	109	111
M	101	98.5	93.4	84.3	94.4	102	101	96.5	95.3	98.6	103	101	97.5	97.5	99.8
STRESS															
EP	64.6	56.3	38.8	38.8	49.7	78.5	76.3	56.0	58.3	67.3	85.0	82.0	70.0	70.5	76.8
NP	85.5	81.3	67.5	67.5	75.0	101	99.3	82.3	83.8	92.0	108	105	95.8	96.3	101
M	75.0	68.8	53.2	53.2	63.0	89.8	87.8	69.2	71.1	79.4	96.5	93.5	82.9	83.4	89.1
IRRIGATION MEAN		94.4	63.0				98.6	79.4				99.8	89.1		
PLANTATING MEAN		64.3	92.6				67.3	91.6				82.7	106		
VARITIES MEAN		88.2	83.7	73.3	68.8		95.9	94.2	82.8	83.2		99.8	97.3	90.2	90.5
		CD 5%					**CD 5%**					**CD 5%**			
I		13.5					12.7					.NS			
P		13.5					12.7					11.8			
V		.NS					.NS					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

TABLE -32.

MOTHER SHOOT GRAIN WEIGHT (g / plant)AT HARVEST AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	2.70	2.63	2.60	2.60	2.63	2.75	2.75	2.60	2.60	2.67	2.70	2.70	2.68	2.65	2.68
NP	3.13	3.08	3.08	3.08	3.09	3.18	3.18	3.08	3.08	3.13	3.18	3.18	3.13	3.13	3.15
M	2..91	2.86	2.84	2.84	2.86	2.97	2.97	2.84	2.84	2.90	2.94	2.94	2.91	2.89	2.92
STRESS															
EP	2 08	1 95	1.70	1 70	1 86	2.35	2 33	1.80	1 83	2 08	2.56	2 47	2.25	2.25	2.38
NP	2 50	2.40	2.20	2.20	2.33	2.80	2.75	2.30	2.33	2.55	3.00	3.02	2.72	2.72	2.93
M	2.12	2 17	1.95	1.95	2.05	2.58	2.54	2.05	2.08	2.31	2.78	2.75	2.48	2.48	2.66
IRRIGATION MEAN		2.86	2.05				2.90	2.31				2.92	2.66		
PLANTATING MEAN		2.25	2.67				2.38	2.84				2.53	3.01		
VARITIES MEAN		2 52	2.52	2.40	2.40		2.77	2.75	2.45	2.46		2.86	2.84	2.70	2.69
		CD 5%					CD 5%					CD 5%			
I		0.34					0.36					.NS			
P		0.34					0.36					0.39			
V		.NS					.NS					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

TABLE - 33.

TILLER GRAIN WEIGHT(g /plant) AT HARVEST AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	5.32	5.2	4.78	3.64	4.74	5.46	5.46	5.1	4.9	5.2	5.5	5.4	5.16	5.16	5.31
NP	6.84	6.66	6.42	6.40	6.60	6.78	6.60	6.48	6.54	6.60	6.84	6.72	6.54	6.54	6.66
M	6.05	5.9	5.6	5.04	5.67	6.12	6.0	5.8	5.7	5.9	6.2	6.06	5.85	5.8	5.99
STRESS															
EP	3.55	3 10	2.13	2.10	2.73	4.32	4.2	3.08	3.21	3 71	4.68	4.51	3.96	3.90	4.22
NP	4.71	4.47	3.71	3.71	4.12	5.56	5.46	4.53	4.61	5.07	5.94	5.78	5.27	5.30	5.56
M	4.13	3.78	2.93	2.93	3.47	4.94	4.83	3.81	3.91	4.37	5.31	5.14	4.56	4.59	4.91
-IRRIGATION MEAN		5 67	3.47				5.90	4.37				5.99	4.91		
PLANTATING MEAN		3 73	5.36				4.46	5.84				4.77	6.11		
VARITIES MEAN		5.9	4 84	4 27	3.99		5.53	5.42	4.81	4.81		5.76	5.60	5.21	5 20
		CD 5%					CD 5%					CD 5%			
I		0.72					0.78					0.80			
P		0.72					0.78					0.80			
V		.NS					.NS					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

DISCUSSION

Productivity of wheat is reduced due to non availability of moisture and high temperatures at various stages of growth and development. Depending on the region where wheat is grown, these factors vary. In the present experiment, efforts are made to study the influence of moisture and early high temperature stresses (early planting) on various biochemical, physiological and morphological processes that are required for development of source and sink. The development of proportionate source which will enable the sink to meet its requirement is also a matter of investigation so as to obtain high grain yields.

Results obtained from Experiment 1 (Lab), Experiement 2 (field) and Experiment 3 (pots) are discussed here in the light of review of literature cited to illustrate the variation in genotypes response to moisture and temperature stress conditions.

EXPERIMENT 1

Since the information regarding high temperature response of genotypes (C 306, PBW-175, HD-2329 and WH-542) under present study is scanty, an experiment under controlled conditions was conducted where all these genotypes were exposed to different temperatures ranging from 20 to 40°C. Highest percentage of germination was observed at 20°C and increasing temperature beyond this decreased germination in all genotypes, but with little effect on C-306, PBW-175 compared to HD-2329 and WH-542. This reduction upon increasing temperature from 20 to 35°C was only 6.1 and 8.2 per cent in C-

306 and PBW-175. But this was upto 14.5 and 14.7 in HD-2329 and WH-542 (Table-1). Kamaha and Maguire (1992) also reported that the optimum temperature for wheat germination was 20°C and the rate of germination increased to highest level at 25°C and decreased with further increase in temperature. Similarly decrease in germination from 84 to 56 per cent with increase of mean average temperature from 26.5 to 30.2°C under field conditions was reported by Upadhyaya and Ruwali (1984). Such a variation in per cent germination among wheat genotypes was also reported by Laford and Baker, (1986); Alka, (1990); Nayeem and Mahajan (1991).

Seedling growth is a most sensitive process. The seedling growth in wheat after 72 hours was decreased from 95 mm to 25 mm if heat stress of 45°C for 2 hours was given Blumenthal *et al.* (1990). Increasing temperature also influenced shoot and root growth in the present investigations. Both shoot length and fresh weight were maximum at 30°C in all the genotypes and these were decreased with increase in temperature (35°C) but with less reductions in C-306 and PBW-175 compared to HD-2329 and WH-542. At 96 hours duration, there was10, 13, 31 and 31per cent reductions in shoot length and 38.5,39, 57and 57 per cent reductions in shoot fresh weight in C-306, PBW-175, HD-2329 and WH-542 respectively due to increasing in temperature from 30 to 35°C (Appendix-III and IV). Studies regarding root length and fresh weight also showed similar trend (Appendix I and II). Concomitant to our results, Nayeem and Mahajan (1991) also observed progressive decrease in shoot length and root length in various genotypes with increase in temperature from 25 to 35°C. However, thermo tolerant varieties showed higher values for these parameters when compared to susceptible varieties. The inhibition in plumule growth recorded at 72 hours post heat shock of 40°C for 2 hours was about 30 per cent in cultivar WH-147 (Sensitive), while it was less than 9 per cent in thermotolerant mutant WH-147 M. Like was reduction in radicle growth was about 36 per cent in WH-147 and 25 per cent in WH-147 M (Gupta *et al.*, 1987). Shoot vigour index is one more important character for screening genotypes in wheat (Nayeem and Mahajan, 1991). It has been calculated on the basis of the shoot length multiplied by per cent germination. Table-2 shows high shoot vigour index at 30°C and decrease with further increase in temperature in all genotypes but with less reductions in C-306 and PBW-175. Similar results have been reported by Nayeem and Mahajan (1991) in wheat. Variability in all the above discussed seedling characters among different wheat genotypes has also been reported (Chaudhary *et al.*, 1984).

Environmental factors are known to influence synthesis and activity of enzymes. α-amylase synthesis have been found to be temperature dependent by Groat and Briggs (1969), Ching (1975) and Alka (1990). Increase in temperature from 20°C to 30°C increased amylase activity at 96 hrs duration and decreased later on in all the genotypes (Table-3). However, significantly higher values of α-amylase were maintained by C-306 and PBW-175 over other two varieties at 30°C and 40°C. Probably, this could be one of the reason for early seedling vigour (shoot vigour index) of C-306 and PBW-175. Correlation between α- amylase activity and shoot vigour in rice was reported by Williams and Peterson (1973) and Karrer *et al.* (1993). Contrary to this Bhupinder Singh *et al.* (1996) observed no correlation between α-amylase activity of germinating seeds and seedling emergence in wheat varieties. Catalase and peroxidase are the two other important enzymes, which remove single oxygen species that causes membrane damage under high temperatures (Zhou *et al.*, 1995). High temperatures above normal (30°C, 40°C) raised catalase (Table-4) and peroxidase (Table-5) activities in all the genotypes but more incase of C-306 and PBW-175 there by enabling them to save membrane damage more from oxygen radicles. Increase in the activity of these enzymes due to high temperatures in cabbage leaves (Wu *et al.*, 1995) and variations in genotypes with more activity in thermotolerant cultivar CV. 90-80 compared to thermosensitive cultivar Wumai-74 in rice (Zhou *et al.*, 1995) was also reported.

Thus, this experiment (1) clearly indicates that C-306 and PBW-175 are relatively thermo-tolerant when compared to HD-2329 and WH 542 as they have maintained higher germination percent, shoot and root growth, vigour index with more alpha amylase, catalase and peroxidase activities even under supra-optimal temperature conditions.

EXPERIMENT 2 AND 3

Since the function of metabolic process and their rate in plants are related with water content (Barrs and Weatherly, 1962) it would be appropriate to begin with parameters like ion-leakage, and relative water content (RWC) which indicates relative water status of various genotypes under stress. Ion-leakage and RWC as indicators of tolerance, (Misra,1990) are the important parameters to be associated with stress studies. Results on percent ion-leakage in our present investigations have revealed that both moistutre and early high temperature stress (October planting) increased percent ion leakage by 18 and 14 per cent (mean values) under field conditions, where continuous stress applied (Table-8) and 22.5, 11.1 per cent in pot culture conditions, where 15 day breif stress was given (Table-19). Increase in per cent ion-leakage due to water and high temperature stress in durum wheat cultivar was also reported by Navari-Izzo *et al.* (1993). This increase was due to crystalization of cellular components which in sequence damages cellular structures (Ingram and Bartles, 1996). However, when the performance of genotypes was taken into account, results revealed that among all the genotypes C-306 followed by PBW-175 had less per cent ion-leakage than HD-2329 and WH 542 in both moisture and early high temperature stress in both field (Table 8) and pot culture (Table 19) conditions which might be due to stable cell membrane even under stress conditions. Stable cell membrane that remains functional during water stress appear central mechanism to adapatation to high temperatue and found related to heat and drought tolerance (Sullivan and Ross, 1979; Raison *et al.*, 1980). In accordance to our resuts, variation in genotypes response to stresses was also reported by many. Exposing leaf discs of two different cultivars WH-147 and WH-147 M to 50°C and 55°C for varying periods resulted more ion-leakage from WH-147 as compared to thermo tolerant WH-147 M leaf discs. At this temperature, the per cent leakage in WH-147 M is 24 per cent less when compared to WH-147 (Kaur *et al.*, 1989). Ion-leakage can also be used as a measurement index for screening genotypes against heat and drought stress (Krishnamani *et al.*, 1984; Saadalla *et al.*, 1900; Deshmukh *et al.*, 1996).

Significant reduction in per cent RWC (mean values) due to moisture and early high temperatue (early planting) to the tune of 25 and 15 in field (Appendix -V) and 13.6 and 6.1 in pot culture (Appendix -X) conditions is also observed in present experiments. Decrease in RWC due to moisutre stress in cotton (Janagoudar *et al.*, 1983) and due to high temperature stress in wheat (Shah, 1992) was already reported. However, the genotypes used in present experiment responded differently to both moisture and early high temperature stresses. Among the genotypes, C-306 followed by PBW-175 had higher percent RWC values compared to HD-2329 and WH 542. In accordance to our results, Sinha and Rajagopal (1975) have also observed variation in genotypes performance where sorghum genotypes CSH-1and CSH-604 showed different per cent reduction i.e 21.4 and 19.5 per cent respectively over control when subjected to water stress. Moreover from present findings, it is interesting to note that those genotypes (C-306 and PBW-175) that maintained high per cent RWC had also shown less per cent ion-leakage values indicating that higher relative water content in the genotypes was due to less membrane damaged during stress. Such a relationship between RWC and ion leakage was also observed in the findings of Misra (1990).

Besides water status, nitrogen metabolism is another important aspect included in the present investigations to understand relative adaptability of these contrasting genotypes under different stress environments. Nitrate reductase activity (NRA), percentage leaf nitrogen (%N) and leaf nitrate content (NO_3) were the parameters studied in relation to stress tolerance behaviour. Both moisture stress and early high temperature stress (early planting) affected all the above parameters. Under pot culture conditions there was 32 and 15 per cent reductions due to moisutre stress and 21 and 19 per cent reductions (mean value) due to early high temperature stress over control in NR activity (Table -20) and per cent N content (Table -21) respectively. Moisture stress declining NR activity (Nair and Abrol, 1982 ; Singh and Sawhney, 1989) and leaf nitrogen per cent (Misra, 1990) was reported earlier in support of current experimental findings. Similarly high temperatures above optimum influencing NR activity in corn (Singh and Sawheny, 1989) and leaf nitrogen per cent (Misra, 1990) was also well reported. Moreover, results of our investigations showed variations in all the genotypes. Genotypes like C-306 and PBW-175 had more NR activity, nitrogen per cent and less NO_3^- content at all the stages of growth and development and reverse is true with HD-2329 and WH-542. Studies with C-306, HD-2428 wheat genotypes revelaed that under stress conditions C-306 showed higher NR activity than HD-2428 (Sairam, 1994). Deshmukh *et al.* (1985) measured NR activity in four wheat cultivars and reported that the drought tolerant types (C-306 and NI-5439) had less reduction in NR activity as compared to susceptible types (Sonalika and HD-2329). In the light of above references quoted here which are in accordance to present results, It may be understood that C-306 and PBW-175 are relatively suitable to mositure and temperature stress conditions compared to rest of the varieties as they have more NR activity and per cent N even under stress conditions. High relative water content and less membrane damage discussed in previous paragraphs could be the reason for efficient nitrogen metabolism in C-306 and PBW-175. Further it is also interesting to note that genotypes (C-306, PBW-175) having high NR activity (Table 9 and 20) had less accumulation of leaf NO_3^- content (Appendix VI and XI) indicating that most of NO_3^- is converted into nitrate by prevailing high NR activity. This kind of reverse relation between NR and NO_3^- content in accordance to present results was also reported. (Grover *et al.*, 1978; Misra, 1990).

The development of leaf area is another important factor that could effect the crop response to water availability (Rawson and

Turner, 1982). Both moisture stress and early high temperature stress (early planting) in our investigations reduced total leaf area and LAI under field as well as under pot culture conditions. Decrease in leaf area in wheat under water stress may be due to fall in leaf expansion rate (Passioura and Gardner, 1990) and where as under heat stress it may be due to reduction in duration of vegetative growth (Shpiler and Blum, 1986). In the present experiment among the genotypes C-306 followed by PBW-175 maintained higher leaf area and LAI compared to HD-2329 and WH-542. The leaf area indices of these genotypes, at anthesis stage were in the order of 3.8, 3.6, 3.3 and 3.3 under control and 3.5, 3.6, 2.8,and 2.8 per cent under moisture stress in field conditions (Table-13). These varieties (C-306 and PBW-175) also performed better under early high temperature stress. Concomitant to our findings, variations in wheat genotypes having high leaf area in drought tolerant types compared to susceptible genotypes was also reported (Gummuluru *et al.*, 1989). The better performance of C-306 and PBW-175 in maintaining high LAI may possible be linked to high per cent relative water content (Appendix -V)) with less membrane damage (Table-8) there by keeping cells turgid necessary for leaf expansion.

Studies on photosynthetic efficiency of a crop under stress environment is essential, because ultimately it is the photosynthetic capacity of a genotype that determines biomass production. It is widely accepted that total canopy photosynthesis during growth is closely related to yield (Ashley and Boerma, 1989). Indeed total biomass, the result of (Total solar radiation received by the crop)x I (Fraction of Q intercepted by Canopy).x E(overall photosynthetic effciency) can be physiologically understood as the consequence of crop photosynthesis over time (Slafer *et al.*, 1993). Total chlorophyll content, specific leaf weight (SLW) and photosynthetic rate (PR) are the parameters to be discussed togehter here in connection to find out the response of genotypes under stress environments. The present experiment results in general showed reduction in total chlorophyll content (Appendix-VII and Table-22), SLW (Table-14) and potosynthetic rate (Table -23) of all genotypes due to both moisture and early high temperature stress at all the stages of growth and development. Khanna Chopra *et al.* (1980) also observed considerable reduction in total chlorophyll content under water stress as compared to non stressed plants. The decrease in chlorophyll content was due to decrease in leaf per cent nitrogen (Wolfe *et al.* 1988). Chlorophyll content and photosynthetic rate are also related. Investigations in soybean by Buttery and Buzell (1977) revealed that variability in photosynthetic rate nearly 44 per cent was due to variability in chlorophyll content. Rate of photosynthesis is also related to nitrogen status and nitrogen limitations decreased photosynthetic rate (John *et al.*, 1996). Similarly high temperatures also decreased chlorophyll content and photosynthetic rate. Al-khatib and Paulsen (1990) measured net photosynthesis, thylakoid membrane stability, chlorophyll variability under moderate (22/17°C day/night) and high (32/27°C day/night) temperature from two week seedlings and/or from anthesis to maturity. They found that heat stress decreased mean photosynthetic rate by 32 and 11 per cent respectvely. This may be due to loss of chlorophyll conent (Morgan *et al.*, 1993 and Amani *et al.*, 1996). A large amount of variation among genotypes in chlorphyll content and photosynthetic rates was observed. Gummuluru *et al.*, (1989) have observed that in wheat drought tolerant types had higher chlorophyll 'a' and 'b' contents than drought susceptible types where as Ritch *et al.* (1990) in same crop found more photosynthetic capacity in TAM W-101 (Tolerant) compared to Sturdy (Senstive). Similarly under high temperture treatments Kaur *et al.*, (1989) had observed only 32 per cent reduction in photosynthetic thermotolerant cultivar WH-147 M whereas 82 per cent reduction in thermosensitive cultivar WH-147. The results obtained in present investigations also revelaed such a signficant variations among genotypes. Under field conditions at anthesis stage (85 DAS) there was 29,30,34 and 37 per cent and 7.8, 9.6, 9.6 and 13.8 per cent reduction (mean Values) in total chlorophyll contents in C-306, PBW-175, HD-2329, and WH-542 due to moisture and early high temperature stress respectively (Appendix-VII). Similar reduction were also observed in other two stages (45,105 DAS) studied. When the effect of these stresses on photosynthetic rate (Table-23) under pot culture conditions is considered there was 14,12.6, 19.4 and 19.3 per cent reductions mean values due to moisture stress and 10.4, 14.4, 20.8 and 21 per cent reductions due to high temperatures at 15 DPA stages. Similar reductions were also observed in other two stages (45, 105 DAS) studied. The present investigations, further supports the view that C-306, PBW-175 are relatively superior as they maintained higher values over other two varieties under both the stress conditions. Thus from the ongoing discussion it is understood that the tolerance of C-306 and PBW-175 with high photosynthetic rate might be a reflection of high water retention capacity, well developed nitrogen metabolism, optimum leaf area development with high specific leaf weight (SLW) and chlorophyll content under stress conditions. Similar conclusion for general crop potential productivity irrespective of water regime was given by Blum, (1996).

The importance of tillering as selection index under water stress conditions is still unresolved. Asana (1968) and Dofing and Karlsson (1993) advocated for profuse tillering capacity in wheat for water limited environment. However, water stress causes tiller mortality Turner (1966) and Simane *et al.* (1993) have reported that water deficit in wheat increased the rate of tiller death. In the present experiment also tiller number/sq. m. was significantly decreased at all the stages due to both water stress and early high temperature stress. Under field conditions, at anthesis stage (85 DAS) water stress compared to control decreased tiller number (Mean values) by 13.4 per cent and early high temperature of October planting reduced it by 30.6 per cent (Table-12). In support of present results Singh *et al.* (1978) and Randhawa *et al.* (1981) reported decrease in tiller number in early planting compared to normal planting due to high mean temperature. High temperature decreasing tiller number in early planting compared to normal planting due to high mean temperature (Table-6). High temperature decreasing tiller number under field conditions was reported recently by Waiens (1994). The genotypic responses to tillering have been studied by many workers (Austin *et al.*, 1980). Results of present experiment also shows variation among genotypes for tiller number/m^2. Under both water stress and early high temperature stress (EP), C-306 followed by PBW-175 maintained higher values compared to HD-2329 and WH-542. These values (mean) under field stress conditions are 583, 525, 320 and 315 for C-306, PWB-175, HD-2329 and WH-542 respectively (Table-12). Similar kind of variations among various wheat genotypes under moisture stress (Aggarwal and Sinha, 1983) and under early planting (Singh *et al.*, 1978 ; Singh *et al.*,1985) were also reported.

Plants try to complete its life cycle early under moisture stress conditions in order to make better use of existing moisture. Wheat cultivars subjected to unirrigated treatments showed 50 per cent anthesis 3 days earlier compared to irrigated treatment (Aggarwal and Sinha, 1984). This was true in current experiment also, where water stress decreased days to anthesis and maturity by 4.5 and 10 days in field conditions (Table-7). Besides moisture content, temperature is also known to influence the days to emergence and anthesis (Rawson and Bagga, 1979 ; Tongoona and Mostby, 1983). The most apparent and striking effect of high temperature on wheat growth is the acceleration of plant development and over whole reduction in plant size (Behl *et al.*, 1993). Similar kind of effet is also seen in the present experiment (Table-7) where early high temperature in October planting (Tabl-6) reduced days to anthesis and hence days to maturity by 4.4 and 4 days in field conditions. And this acceleration of phasic development due to high temperature (Waines,1994) can be directly or indirectly related to wheat yield reduction at high temperature (Shpiler and Blum, 1986). Cultivars are reported to differ in their phenophases independently of their response to factors due to the action of intrinsic genetic factors commonly termed as basic development rate (Mase *et al.*, 1989). Table-7 further shows the variations in genotypes response to the mositure and early high temperature stress. It is clear from the same table that among the varieites C-306 followed by PBW-175 took more days to anthesis and maturity compared to HD-2329 and WH-542 indicating their tolerance to both kind of stresses. Such type of variations in genotypes was also reported under water stress and high temperature (Saini *et al.*, 1986; Bagga *et al.*, 1987; Tandon *et al.* 1996; Slafer and Rawson, 1995).

Accumulation of biomass in contrasting wheat genotypes under stress environments is the another important key aspect studied in the present experiment to find out and high light the role of biomass yield under these environments. Austin (1994) suggested that for all crops, breeding to increase yield will either have to increase harvest index or total biomass production and further expressed that the later should be given priority . According to Sharma (1993), biomass in wheat has high economic value yet selection for it is not generally made. There is almost a consensus among cereal breeders that future yield increases will be possible primarily through manipulation of morpho-physiological traits including biomass yield. Table-15 shows reduction in total biomass yield due to water and early high temperature (EP) stress at all growth stage and development. At anthesis under field conditions there was 25 and 22 per cent reduction in biomass due to water stress and early high temperatutes respectively. Almost similar effects due to moistue stress were reported in wheat by Monayeni *et al.* (1984); Paligham shah *et al.* (1996) and due to high temperatuers in wheat by Singh *et al.* (1985); Chaturvedi *et al.* (1985) and in corn by Stephan and Wallace (1996). Plants experiencing a 3°C increase in day and night temperatues relative to local long mean temperatures, dry matter yield were reduced by 18 per cent compared to control in wheat (Moot *et al.*, 1996). Biomass accumulation is resultant of several factors. Factors that lead to biomass reduction under stress conditions were reported by many. Water stress may affect growth and yield through disturbance in several morpho-physiological process and nutrient uptake (Turner and Begg, 1981). Reduction in biomass was due to reduction in CGR, LAI (Bhatt,1995) or decrease in photosynthetic rate which in turn was due to decrease in leaf nitrogen per cent

(Gregory *et al.*,1981)or less percent ion leakage (Ashraf *et al.*, 1994) or per cent relative water content and SLW or days to anthesis and maturity (Tompkins *et al.*, 1991 and Viswanathan and Chopra, 1996). These reasons given by various researchers are also true in the present experiment where decrease in all these parameters decreased biomass weight in all genotypes, in both stresses. However, when individual genotypes performance was studied, C-306 followed by PBW-175 had maintained higher biomass accumulation over HD-2329 and WH-542. This was clearly due to thier ability to maintain higher values for all the parameter discussed so far. In accordance to our results, Gummulur *et al.* (1989) have also observed drought tolerent varieties having higher shoot dry weight than drought susceptible types. Contradictory to this, no difference or on par in dry weight upon subjecting to stress in contrasting wheat varieties *viz.*, C-306 and Kalyansona was reported by Agarwal and Sinha (1983).

A large sink is an inherent characterstics of the high yielding genotype. The maintenance of large sink poses demand on the source. The capacity of the source to fill the sink is an essential component of yield potential (Blum, 1996). In the present discussion, the capacity of source is so far studied and sink developement under stress environments has to be discussed further in connection. Many investigations have been shown that grain yield in wheat depends on several yield componets including grain number,grain weight, pre and post anthesis dry matter and harvest index (Bingham,1969, Asana, 1975 ; Aggarwal and sinha, 1987; Saini *et al.*, 1988; Bansal and Sinha, 1991; Slafer *et al.*, 1996). All these components were known to influenced by water stress in wheat (Hassan *et al.*, 1987; Pal, 1992) and by high temperature also (Chaturvedi *et al.*, 1985, Abrol *et al.*, 1991 and Hunt, 1996). In support of their views the current investigation has also observed that both moisture stress and early high temperature stress reduced ear number (Tables 16,17) and grain weight (Table-18). Results of pot culture also showed similar effect (Tables 32,33). There was 22.5 and 9 per cent decrease (mean values) in grain number in field and pot culture conditions due to water stress and there was 35 and 15.7 per cent reduction in field and pot culture conditions due to early high temperatures. Decrease in ears/plant, spikelet/plant, grain number/plant and grain weight/plant due to moisture stress was also reported (Hassan *et al.* 1987 and Pal, 1992). Similarly reductions in these components due to early high temperatures in October sowing were also reported (Randhawa *et al.*, 1985). Under early planting the reduction in spike number per plant and kernel number per spike may be due to less duration of GS_1 (emergence to double ridge) and GS_2 (double ridge to anthesis) and reduction in grain weight may be due to less duration of anthesis to physiological maturity as reported by Warrigton *et al.* (1977) and Behl *et al.* (1993). The same reasoning is well fit for the present investigations also, since both water stress and early planting (high temperature) reduced days to anthesis and antheis to maturity (Table-7). When genotypes performance was taken in to account, C-306, followed by PBW-175 maintained superiority in all these components as compared to HD-2329 and WH-542 in both the stresses. This superiority of the first two varieties may be due to their better acclimatization to both stress conditions.

The outstanding performance of C-306 and PBW-175 further reflected in harvest index and thousand grain weight.Both the genotypes had higher harvest indices even under stress conditions which was mainly due to their ability to partition more assimilates towards sink (Fig-13). The percentage depletion in stem shown in Appendix-VIII further clearly indicated that there was more translocation of assimilates in C-306 and PBW-175 towards sink. Thus the effective partitioning coefficient resulted in to more thousand grain weight (Fig-14) in these genotypes and yield stability particularly under stress environments. However, when general effect of watert stress and early high temeprature stress were considered, both harvest index and thousand grain weight were significantly reduced due to these stresses in all genotypes (Fig-13 and 14).

Results of pot culture experiment further concluded that among the stages studied (15 DPA,0-15DAA,15-30 DAA), 15 days pre anthesis stage was more sensitive to water stress as there were more reductions for ion leakage, NR activity, photosynthetic rate and yield losses when compared to stress given at the rest of stages (Appendix-XIII). There was 33,26 and 22 per cent reductions in normal plating in grain yield due to 15 days water stress given at 0-15 DPA, 0-15 DAA, 15-30 DAA respectively. The more decrease in grain yield at 0-15 DPA was mainly due to more decrease in spikelets /spike and grain number per plant at this stage (Appendix-XII). The search for the most important stages in building yield potential is not recent. Hudson(1934) stated that the period between terminal spikelet initiations and anthesis was of paramount importance for yield determination. More recently, others have also confirmed this association experimentally (Fischer, 1984,85; Kirby,1988; Siddique *et al.*, 1989; Slafer *et al.*, 1990, 1994). Experiments conducted by Fischer (1985) further precisely stated that even when numerical component of final grain number/m^2 are produced during the whole seedling emergence anthesis period, only short period coinciding with active stem and spike growth (20 days before anthesis) appear to be critical. This approach was later followed in independent studies (Thorne and Wood 1987; Savin and Slafer, 1991) with similar results reinforcing the conclusions.

The present investigatios thus clearly indicate that C-306 and PBW-175 are relatively drought / thermotolerant compared to HD-2329 and WH-542 as there was relatively less reduction in grain yield (a resultant of several factors) due to moisture and early high temperature stress. Both these genotypes had shown superiority in different phenophases. Therefore it is understood that there are several processes which when linked together resulted in their better performance under stress enviornment. These are:

1. Early seedling vigour index due to more α-amylase,catalase and peroxidase activities with profuse root growth.
2. Less damage to membrane resulting high relative leaf water content, which enabled C-306 and PBW-175 to have better leaf nitrogen content, nitrate reductase activity and less accumulation of nitrate content in leaves.
3. Higher photosynthetic efficiency associated with higher chlorophyll content.
4. Higher leaf area index and specific leaf weight which resulted in to better accumulation of assimilates in the stem as well as developing sink.
5. Longer vegetative growth to accumulate more reserves in the stem and thus strengthening the source.
6. Higher value for ear number/m^2, spikelet number/ear and grain number/ear and 1000 grain weight.

7. Better harvest index due to efficient partitioning of assimilates resulting high grain yields.

It can be concluded from the above mentioned points that both the tolerant genotypes (C-306, PBW-175) possessed a better co-ordination between the physiological and biochemical processes which lead them to produce higher biomass production under the stress conditions. Austin (1994) recommended to use these parameters in breeding programme because they are generally highly heritable and also easy to exploit for breeding for increased yield. The greater need to look into the genetic routes of increasing total dry matter production and better water use efficiency particularly under stress enviornments is also assertained by the research. Further-in support of conclusions drawn from present experment, Sharma (1993) also emphasized the selection for higher biomass as important trait to obtain high productivity in wheat both under normal and stress conditions. Recently Slafer *et al.* (1996) pointed out that biomass must be increased incase to obtain increase in wheat yield potential in future. Longer vegetative period, the another desirable character which both the tolerant types (C-306 and PBW-175) accquired, should be given higher priority for increasing grain productivityas suggested. The present investigation also suggests for consideration of grain number under stress environments as both the tolerant types (C-306 and PBW-175) possesed significantly higher grain number/ ear than individual grian weight (Slafer *et al.*, 1994; Viswanathan and Chopra, 1996). In recent findings from CIMMYT where semi dwarf cultivars released in Mexico over the past 35 years were compared, it was found that increasing in yield since 1962 were associated with increase in grain number per unit area.

Though increasing productivity in wheat by increasing biomass seems to be attractive but there going to be losses due to lodging in these genotypes. Therefore the further investigation should be diverted for evaluating genotypes with high biomass but with stronger stem and efficient diversion of assmilates for formation of stronger sink particulary under stress conditions. For better partitioning and increased yield under high temperature conditons, use of growth regulators like Benzyl Adenine (BA) can be considered as suggested by Gupta (1996).

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APPENDIX- I

EFFECT OF TEMPERATURE ON ROOT LENGTH (mm/seedling) IN VARIOUS WHEAT GENOTYPES

Duration (hrs)	24					48					72					96				
Temp/var	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
20°C	-	-	-	-	-	12.0	12.0	10.0	10.0	11.0	28.0	28.0	20.0	20.0	24.0	55.0	52.0	35.0	35.0	44.3
30°C	-	-	-	-	-	20.0	20.0	15.0	15.0	17.5	60.0	55.0	40.0	40.0	48.8	72.0	65.0	50.0	50.0	59.3
35°C	-	-	-	-	-	20.0	20.0	15.0	15.0	17.5	45.0	40.0	22.0	22.0	33.3	50.0	45.0	25.0	25.0	36.3
40°C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	-	-	-	-	-	17.3	17.3	13.3	13.3	15.3	44.3	41.0	27.3	27.3	35.0	59.0	54.0	36.7	36.7	46.6

	CD at 5%	**CD at 5%**	**CD at 5%**	**CD at 5%**
T	.NS	1.48	4.95	1.93
V	.NS	1.71	5.71	2.23
TxV	.NS	.NS	.NS	.NS

___ Not dectable ___

APPENDIX-II

EFFECT OF TEMPERATURE ON ROOT FRESH WEIGHT (mg/seedling) IN VARIOUS WHEAT GENOTYPES

Duration (hrs)	24					48					72					96				
Temp/var	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
20^{0}C	-	-	-	-	-	10.0	10.0	7.0	7.0	8.5	15.0	15.0	12.0	12.0	13.5	25.0	22.0	15.0	15.0	19.3
30^{0}C	-	-	-	-	-	18.0	17.0	15.0	15.0	16.3	41.0	38.0	30.0	30.0	34.8	55.0	47.0	38.0	38.0	44.5
35^{0}C	-	-	-	-	-	18.0	17.0	15.0	15.0	16.3	30.0	27.0	15.0	15.0	21.8	41.0	36.0	20.0	20.0	29.3
40^{0}C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	-	-	-	-	-	15.3	14.7	12.3	12.3	13.7	28.7	26.7	19.0	19.0	23.3	40.3	35.0	24.3	24.3	31.0

	CD at 5%	CD at 5%	CD at 5%	CD at 5%
T	.NS	1.66	2.28	4.90
V	.NS	1.92	2.64	5.65
TxV	.NS	.NS	.NS	.NS

____ Not detectable

APPENDIX- III.

EFFECT OF TEMPERATURE ON SHOOT LENGTH (mm/seedling) IN VARIOUS WHEAT GENOTYPES

Duration (hrs)	24					48					72					96				
Temp/var	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
20° C	-	-	-	-	-	10	10	90	90	9.5	10	10	9.0	9.0	9.5	13.0	13.0	10.0	10.0	11.5
30° C	-	-	-	-	-	80	80	70	70	7.5	35.0	35.3	24.0	24.0	29.6	50.0	44.0	29.0	29.0	38.0
35° C	-	-	-	-	-	80	80	40	40	6.0	30.0	26.0	15.0	15.0	21.5	45.0	38.0	20.0	20.0	30.8
40° C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	-	-	-	-	-	8.7	8.7	6.7	6.7	7.7	24.3	23.1	14.7	14.7	20.2	36.0	31.7	19.7	19.7	26.8

	CD at 5%	CD at 5%	CD at 5%	CD at 5%
T	.NS	1.52	2.22	3.03
V	.NS	1.75	2.56	3.50
TxV	.NS	.NS	4.43	6.06

_____ Not detectable

APPENDIX-IV

EFFECT OF TEMPERATURE ON SHOOT FRESH WEIGHT (mg/seedling) IN VARIOUS WHEAT GENOTYPES

Duration (hrs)	24					48					72					96				
Temp/var	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
20° C	-	-	-	-	-	10	10	8	8	9	12	12	8	8	10	18	15	10	10	13.3
30° C	-	-	-	-	-	10	10	8	8	9	35	32	24	25	29	52	46	35	35	42
35° C	-	-	-	-	-	10	8	6	6	8	25	20	10	10	16	32	28	15	15	22.5
40° C	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
M	-	-	-	-	-	10	9.3	7.3	7.3	8.5	24	21	14	14	18	34	30	20	20	26

	CD at 5%	**CD at 5%**	**CD at 5%**	**CD at 5%**
T	.NS	1.19	1.97	2.73
V	.NS	1.68	2.28	3.15
TxV	.NS	.NS	3.94	.NS

___ Not detectable

APPENDIX - V

PERCENT RWC AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS ATDIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105 DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	76.0	74.9	73 0	72.8	74.2	71.0	69.9	66.0	66.9	68.4	62.5	58.9	55.5	56.0	58.2
NP	83.0	81.7	83.0	83.2	82.7	75.0	75.0	73.5	74.0	74.4	67.5	66.6	65.5	65.9	66.4
M	79.5	78.3	78.0	78.0	78.5	73.0	72.0	69.8	70.5	71.3	66.0	63.8	61.5	66.0	63.3
STRESS															
EP	51.0	54.5	44 7	45.7	50.5	56.0	53.6	48.6	48.8	51.8	44.0	42.8	33.0	35.0	38.7
NP	68.0	66.9	62 0	63.4	65.1	64.0	63.7	60.0	59.9	61.9	54.3	53.8	48.7	49.8	51.7
M	62.5	60.7	53.4	54.5	57.8	60.0	58.7	54.3	54.3	56.8	49.2	48.3	40.1	42.4	54.2
IRRIGATIONS MEAN		78.5	57.8			71.3	56.8				62.3	45.2			
PLANTINGS MEAN		62.3	73.9			60.0	68.1				48.5	59.1			
VARIETIES MEAN		71.0	69.5	65.7	66.3	66.5	65.3	62.0	62.4		57.1	55.5	50.7	51.7	
		CD 5%				**CD 5%**					**CD 5%**				
I		0.86				0.89					0.71				
P		0.84				0.85					0.71				
V		1.18				1.20					1.76				
I x P		1.18				1.20					1.01				
I x V		1.67				1.69					.NS				
P x V		1.67				1.69					.NS				
I x P x V		.NS				.NS					.NS				

APPENDIX - VI

LEAF NITRATE CONTENT (µ mole g^{-1} dry wieght) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105DAS				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	0.265	0.273	0.284	0.288	0.278	0.325	0.325	0.339	0.341	0.332	0.383	0.400	0.420	0.418	0.405
NP	0.250	0.251	0.249	0.249	0.250	0.315	0.320	0.310	0.312	0.314	0.366	0.370	0.373	0.375	0.371
M	0.258	0.262	0.267	0.269	0.264	0.230	0.232	0.235	0.237	0.323	0.375	0.389	0.397	0.397	0.388
STRESS															
EP	0.387	0.405	0.718	0.720	0.558	0.418	0.440	0.600	0.609	0.517	0.510	0.533	0.874	0.910	0.708
NP	0.329	0.330	0.680	0.479	0.455	0.383	0.373	0.444	0.448	0.412	0.415	0.438	0.590	0.600	0.511
M	0.358	0.368	0.699	0.600	0.507	0.401	0.407	0.522	0.529	0.465	0.463	0.486	0.732	0.755	0.610
IRRIGATIONS MEAN		0.264	0.507				0.323	0.465				0.388	0.610		
PLANTINGS MEAN		0.418	0.353				0.425	0.363				0.557	0.441		
VARIETIES MEAN		0.31	0.31	0.48	0.43		0.36	0.36	0.42	0.43		0.42	0.44	0.56	0.58
			CD 5%					**CD 5%**					**CD 5%**		
I			0.12					0.10					0.07		
P			0.10					0.10					0.05		
V			0.28					0.21					0.10		
I x P			0.28					0.21					0.10		
I x V			0.15					0.13					0.12		
P x V			0.13					0.13					0.12		
I x P x V			.NS					.NS					.NS		

APPENDIX - VII

TOTAL CHLOROPHYLL CONTENT (mg/gfwt) AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES OF GROWTH AND DEVELOPMENT IN WHEAT GENOTYPES

	45DAS					85 DAS					105 DAS				
GM	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	3.15	3.05	3.0	3.0	3.05	3.47	3.40	3.35	3.37	3.40	1.71	1.67	1.50	1.50	1.59
NP	3.45	3.43	3.47	3.50	3.46	3.70	3.68	3.42	3.68	3.62	2.00	2.00	2.00	2.01	2.00
M	3.30	3.24	3.23	3.25	3.26	3.59	3.54	3.38	3.52	3.38	1.86	1.84	1.25	1.75	1.80
STRESS															
EP	2.15	2.07	1.62	1.63	1.87	2.40	2.32	1.99	1.96	2.17	1.38	1.30	1.00	0.97	1.16
NP	2.58	2.56	2.27	2.33	2.43	2.67	2.65	2.49	2.50	2.58	1.55	1.50	1.25	1.25	1.39
M	2.37	2.32	1.94	1.98	2.15	2.54	2.48	2.24	2.23	2.37	1.47	1.40	1.13	1.11	1.27
IRRIGATIONS MEAN		3.26	2.15				3.38	2.57				1.67	1.27		
PLANTINGS MEAN		2.46	2.95				2.79	2.97				1.34	1.57		
VARIETIES MEAN		2.83	2.78	2.59	2.62		3.06	3.01	2.81	2.88		1.66	1.62	1.44	1.43
			CD 5%					CD 5%					CD 5%		
I			0.16					0.27					0.14		
P			0.10					0.24					0.10		
V			0.26					0.19					0.23		
I x P			0.26					0.19					0.23		
I x V			0.18					0.10					0.13		
P x V			0.15					0.10					0.10		
I x P x V			.NS				.NS					.NS			

APPENDIX VIII

PERCENT DEPLETION IN MOTHERSHOOT STEM WEIGHT FROM ANTHESIS TO MATURITY AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS IN WHEAT GENOTYPES

	C-306	PBW-175	HD -2329	WH-542
Control				
EP	33.0	31.0	23.0	30.0
NP	35.0	35.0	30.0	30.0
Stress				
EP	32.0	30.0	20.0	20.0
NP	35.0	35.0	28.0	28.7

APPENDIX- IX

DROUGHT SUSCEPTIBILITY INDEX OF VARIOUS WHEAT GENOTYPES

	C-306	PBW-175	HD-2329	WH-542
EP	0.64	0.75	1.37	1.37
NP	0.56	0.78	1.29	1.35

>1 = Susceptible
<1 = Tolerant

APPENDIX -X

PERCENT RWC AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	88.5	88.5	85.5	85.3	87.0	79.0	79.0	77.1	77.0	78.0	74.0	73.1	70.6	70.5	72.1
NP	90.0	90.0	89.8	89.9	90.0	80.5	80.5	79.9	80.0	80.2	76.6	76.1	75.5	75.6	76.0
M	89.3	89.3	87.6	89.1	88.1	79.8	79.8	78.5	78.5	79.1	75.3	74.6	73.1	73.1	74.0
STRESS															
EP	73.0	72.7	64.0	64.1	68.5	71.8	71.5	61.5	61.4	66.5	71.5	71.5	56.5	56.5	64.0
NP	79.5	79.2	74.7	74.7	77.0	77.2	77.2	67.1	67.3	72.3	75.9	75.9	63.9	63.9	69.9
M	76.3	76.0	69.4	69.4	72.7	74.5	74.4	64.3	64.4	69.4	73.7	73.7	60.2	60.2	67.0
IRRIGATION MEAN		88.8	72.7				79.1	69.4				74.0	67.0		
PLANTATING MEAN		78.1	83.5				72.3	76.2				68.0	72.9		
VARITIES MEAN		82.8	82.6	78.6	79.3		77.1	77.1	71.4	71.4		74.5	74.2	66.6	66.6
		CD 5%					CD 5%					CD 5%			
I		1.77					2.73					3.17			
P		1.77					2.73					3.17			
V		2.5					3.86					4.49			
I x P		2.5					.NS					.NS			
I x V		3.53					5.46					6.35			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

APPENDIX - XI.

NITRATE CONTENT AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

	0-15 DPA					0-15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	0.27	0.28	0.28	0.28	0.28	0.30	0.30	0.38	0.35	0.33	0.40	0.41	0.43	0.43	0.42
NP	0.24	0.22	0.26	0.26	0.25	0.30	0.30	0.30	0.30	0.30	0.37	0.35	0.37	0.38	0.37
M	0.26	0.25	0.27	0.27	0.26	0.30	0.30	0.34	0.32	0.32	0.38	0.38	0.40	0.40	0.39
-STRESS															
EP	0.40	0.40	0.75	0.77	0.58	0.45	0.50	0.63	0.62	0.55	0.49	0.50	0.90	0.90	0.70
NP	0.38	0.30	0.65	0.65	0.50	0.38	0.37	0.45	0.48	0.42	0.39	0.42	0.60	0.60	0.50
M	0.39	0.35	0.70	0.71	0.54	0.41	0.43	0.54	0.55	0.48	0.44	0.46	0.75	0.75	0.60
-IRRIGATION MEAN		0.26	0.54				0.32	0.48				0.38	0.60		
PLANTATING MEAN		0.43	0.37				0.44	0.36				0.56	0.43		
VARITIES MEAN		0.32	0.30	0.49	0.49		0.36	0.37	0.44	0.44		0.41	0.42	0.57	0.58
		CD 5%					**CD 5%**					**CD 5%**			
I		0.03					0.07					0.04			
P		0.03					0.07					0.04			
V		0.04					0.07					0.06			
I x P		.NS					.NS					0.06			
I x V		0.06					.NS					0.08			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

APPENDIX - XII

MOTHER SHOOT EAR LENGTH (cm) AT HARVEST AS INFLUENCED BY MOISTURE AND TEMPERATURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

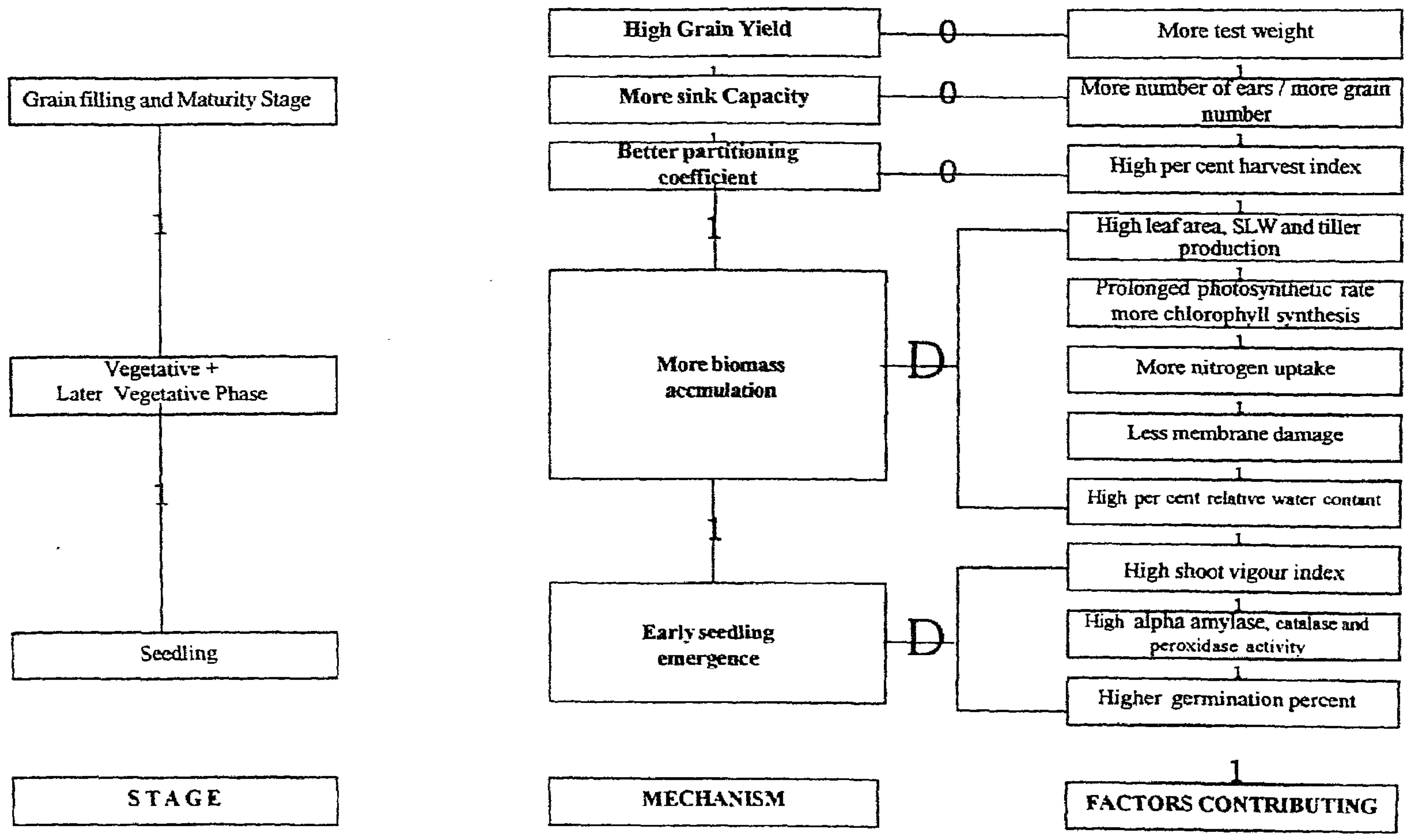
	0-15 DPA					0 -15 DAA					15-30 DAA				
	V1	V2	V3	V4	M	V1	V2	V3	V4	M	V1	V2	V3	V4	M
CONTROL															
EP	11.6	11.6	11.2	11.2	11.4	11.8	11.8	11.5	11.5	11.7	11.8	11.8	11.5	11.5	11.7
NP	11.8	11.8	11.5	11.5	11.7	11.8	11.8	11.5	11.5	11.7	11.8	11.8	11.5	11.5	11.7
M	11.7	11.7	11.4	11.4	11.5	11.8	11.8	11.5	11.5	11.7	11.8	11.8	11.5	11.5	11.7
STRESS															
EP	8.2	8.2	7.5	7.5	7.85	11.0	11.0	10.5	10.5	10.8	11.5	11.5	11.0	11.0	11.3
NP	8.5	8.5	8.0	8.0	8.25	11.0	11.0	10.8	10.8	10.9	11.8	11.8	11.5	11.5	11.7
M	8.35	8.35	7.75	7.75	8.05	11.0	11.0	10.7	10.7	10.8	11.7	11.7	11.3	11.3	11.5
IRRIGATION MEAN		11.5	8.05				11.7	10.8				11.7	11.5		
PLANTATING MEAN		9.62	9.95				11.2	11.3				11.5	11.7		
VARITIES MEAN		10.0	10.0	9.6	9.6		11.4	11.4	11.1	11.1		11.7	11.7	11.4	11.4
		CD 5%					**CD 5%**					**CD 5%**			
I		0.73					.NS					.NS			
P		.NS					.NS					.NS			
V		.NS					.NS					.NS			
I x P		.NS					.NS					.NS			
I x V		.NS					.NS					.NS			
P X V		.NS					.NS					.NS			
I x P x V		.NS					.NS					.NS			

APPENDIX - XIII

COMPARISON OF PERCENT REDUCTIONS OVER CONTROL DUE TO MOISTURE STRESS AT DIFFERENT STAGES AROUND ANTHESIS IN WHEAT GENOTYPES

Parametres/ Plantings	EP	NP	EP	NP	EP	NP
% Relative water Content	21.3	14.4	14.7	9.9	10.9	8.03
% Ion Leakage	38.1	30.8	31.0	21.2	30.8	23.0
Nitrate Reductase Activity	44.8	24.1	26.7	29.6	23.2	27.3
Total Chlorophyll Content	27.3	14.9	13.6	11.1	10.6	7.3
Photosynthetic Rate	20.3	12.6	10.6	5.1	8.7	3.97
Total Plant Biomass	17.5	10.2	12.3	8.4	12.9	9.78
Total Grain Number	39.3	33.7	24.2	16.4	11.5	7.12
Total Grain Weight	37.7	33.4	26.4	21.6	17.4	13.4

APPENDIX - XIV



FLOW DIAGRAM SHOWING THE MECHANISM OF DROUGHT AND THERMOTOLERANCE IN TOLERANT WHEAT GENOTYPES