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PHYSIOLOGICAL BASIS OF TEMPERATURE TOLERANCE IN WHEAT GENOTYPES

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PHYSIOLOGICAL BASIS OF TEMPERATURE TOLERANCE IN WHEAT GENOTYPES

Thesis Submitted to the
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in partial fulfilment of the requirements for the
Degree of

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in
CROP PHYSIOLOGY

By

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CERTIFICATE

This is to certify that the thesis entitled **"PHYSIOLOGICAL BASIS OF TEMPERATURE TOLERANCE IN WHEAT GENOTYPES"** submitted by **Mr. RAMAGOUDA P. PATIL**, for the degree of **MASTER OF SCIENCE** (AGRICULTURE) in **CROP PHYSIOLOGY** of the University of Agricultural Sciences, Dharwad, is a record of research work done by him during the period of his study in this University under my guidance and supervision and the thesis has not previously formed the basis of the award of any degree, deploma, associateship, fellowship or other similar titles.

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August, 1991

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4. (P. W. BASARKAR)

Affectionately Dedicated
To My Beloved
Father Late Shri Paragouda
and
Mother Smt. Gouramma

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DHARWAD

R. P. PATIL

CHAPTER - I

INTRODUCTION

I INTRODUCTION

Wheat is one of the most important cereal crops of the world, both with regard to antiquity and its use as a source of human food. Wheat has been described as the "King of Cereals" for centuries and continues to retain the pride of place even today because of the acreage it occupies, the high production it commands and the pre-eminent position it holds in the International food trade.

Wheat is the main staple food of nearly a billion people or about 35 per cent of the world's population. It is grown across a wide range of environments around the world. Large quantities of wheat are being produced by the countries favoured with cool and moist weather during growing period followed by dry and warm weather during grain filling to ripening. The total area under wheat in the world is 240.0 m.ha. with an annual production of 515.10 m.tons (Anon, 1990). Wheat attains premier position in human nutrition mainly because of its unique protein, gluten, which is responsible for bread making properties of wheat flour. It is also rich in carbohydrates, vitamins, minerals, etc.

In India, wheat is the second most important food crop being next to rice, and it contributes nearly 25 per cent to the total food grain production of the country. The total estimated area under wheat in India during 1989-90 was 24 m.ha. with a production of 54 m.tons (Anon, 1991). Average productivity of

India is 22.40 $q.ha^{-1}$. It is one of the important rabi cereals grown in Karnataka on an area of 2.62 lakh hectares, with a production of 1.34 lakh tons (Anon, 1989). The average productivity in Karnataka is 5.43 $q.ha^{-1}$, which is much below the national average of 22.40 $q.ha^{-1}$ (Anon, 1989).

Poor yields in Karnataka, as compared to national average could be attributed to both environmental and genetic factors. Cereal yields are determined by variety, management practices and environment. Among various climatic factors, low water availability and high temperature are major production constraints. These constraints may occur throughout the growing season as in the low land tropics or as terminal stresses affecting the crop during the grain filling period in Mediterranean environments and highlands. Most crop plants of temperate origin do not tolerate prolonged exposure to maximum temperatures above 35°C. Under field conditions, temperatures of 35-38°C are common in many wheat producing areas of the world. However, agronomists and physiologists have found that for planting of wheat, the average temperature should be around 20-22°C, for tillering around 16-20°C and for proper development of wheat plant, the best temperature range is 20-23°C (Tandon, 1984). At mean daily temperatures higher than 20°C in the early tillering phase, the tillering is poor and heading is accelerated. At temperatures higher than 25°C in the grain development phase, the plant dries up prematurely. These temperature limits represent the limits of crop growth duration in these areas (Hanchinal, 1987).

It is very difficult to adequately define the heat stress in plants because the response depends on thermal adaptation, duration of exposure, and stage of growth. Furthermore, the effects of high temperature stress are intimately linked with those of water stress, with respect to energy balance of plant organs. One of the important means of dissipating excess net radiation is through latent heat via, transpiration, so that the plant transpiring surfaces may be several degrees below the ambient temperature.

The mechanisms for adaptation to high temperature can be at both the morphological and at molecular level, for example, heat avoidance in *Encelia* involves leaf pubescence, which results in the greater reflectance and thereby causing reduction in leaf temperature. The adaptation to high temperatures has been well characterized in wild plant species, and such knowledge would certainly help to interpret crop response to high temperatures.

Interest in crop response to environmental stresses has increased greatly in recent years because severe losses may result from heat, cold, drought and high concentrations of toxic mineral elements (Blum, 1985). Unfavourable temperature and lack of water, limit the expression of full genetic yield potential of the plant and it appears that heat and drought affect plants and crop yields differently. An understanding of the mechanisms of stress would help in developing improved crop management and breeding techniques. Therefore these mechanisms would help in increasing crop production in unfavourable environments also. With this background, the present study was aimed with the following objectives

1 To find out the morpho-physiological changes due to high temperatures and their significance with respect to productivity.

2 To study the effect of temperature on biophysical parameters viz., stomatal conductance, transpiration rate and leaf temperature in three cultivated wheat species viz., *Triticum dicoccum* L., *T. durum* and *T. aestivum*.

3 To relate the changes in biophysical and biochemical parameters to productivity in different temperature regimes.

4 To find out the relationship between glaucousness and tolerance to higher temperature in different wheat genotypes.

5 To find out the physiological basis of high temperature tolerance in wheat genotypes.

CHAPTER - II

REVIEW OF LITERATURE

II REVIEW OF LITERATURE

In its widest context, the stress environment is one of the major factors responsible for the current global map of distribution patterns of various crops. The temperature environment is probably the most effective force affecting the crop distribution. The thermal regime is critical by way of affecting plant phenology, developmental phases, growth rates, yield components and the final yield. Growth and development processes follow distinct temperature response curves, displaying a peak or a plateau at what is defined as an optimum temperature. In the present review, an attempt has been made to present relevant literature on the physiology of heat stress and heat resistance with special reference to the influence of high temperature on (1) Growth parameters and yield (2) Biophysical parameters such as transpiration rate, diffusive resistance and leaf temperature and (3) Various physiological and biochemical aspects viz., chlorophyll content, sugar content, free proline accumulation and wax deposition.

2.1 GROWTH PARAMETERS

Temperature is one of the important environmental factors which affects the plant growth and development. In case of wheat, cool temperatures favour the growth and development.

The effect of heat in reducing the number of tillers produced or the killing of secondary tillers is a principle reason for poor stands under high temperature regimes (Kohli, 1984).

When soil temperature reached 40 to 45°C, seedling emergence and plant population were seriously affected and thereby reducing the crop yield (Midmore, 1976). Heinrich (1981) demonstrated that the yield stability was more related to genotype x temperature interaction than genotype x moisture interaction, and the tolerance to high temperature at panicle development stage is an important contributing factor for yield stability. Brief exposures to extreme soil temperature inhibited the crown root growth and tiller initiation (Fischer, 1985b).

Biryukov (1987) observed various growth functions viz., RGR, CGR, NAR and LAR in relation to temperature and found that these growth functions had high values at low temperature and decreased with an increase in the temperature. The increase in day temperature from 21 to 27°C or night temperature from 13 to 21°C adversely affected the initiation of new tillers and resulted in the shorter and slender culms, smaller leaves with a decreased leaf area and dry matter production (Campbell and Read, 1968). Similarly, Friend (1966) reported that the number of tillers and leaf area ratio (LAR) increased in the temperature from 10 to 25°C and decreased thereafter at 30°C. He reported that the optimum temperature for vegetative growth of wheat and for getting maximum RGR and NAR is 20°C.

An increase in the temperature from 10 to 25°C led to an increase in dry weights of the whole plant. At 30°C and above, the rate of initiation of primordia and leaf emergence were lower than that at 25°C (Friend *et al.*, 1962b). Temperature is also known to influence the leaf morphology and expansion in wheat i.e., the broadest leaves were formed at 15°C, the longest at 25°C, where as the intermediates at 20°C (Friend *et al.*, 1962a). In another experiment, they indicated the effect of temperature on the number and area of leaves which inturn alter the leaf area ratio (LAR), leading to changes in leaf thickness and the rate of photosynthesis per unit leaf area.

Downes (1969) observed the dry matter production at two different temperature regimes, and reported that the dry matter production decreased from 3.63 to 2.56 g plant^{-1} with an increase in the temperature from 25 to 30°C and the leaf area from 225 to 337 cm^2 plant^{-1}. The net assimilation rate also decreased at 30°C as compared to 25°C. Wardlaw (1970) reported that under natural day light at a temperature of 21/16°C, increase in dry weight of the stem exceeded that of the ear for the first ten days following anthesis. Further increase in the temperature to 26/22°C resulted in the shortening of stem growth period.

The substrate required for growth may be partitioned in three ways; a part into the final product, a part into respiration to supply the energy needed to form the end product and a part into respiration required for the maintenance (Thorney, 1971). It is possible that an increased maintenance respiration, with an increase in temperature might limit the amount of substrate available for the growth.

Friend et al. (1963) noticed that an increase in temperature from 10 to 30°C and light intensity from 200 to 2500 foot candles resulted in an increased rate of elongation of the developing inflorescence and earlier anthesis. Warlington et al. (1977) studied the temperature effects on growth of wheat Cv. Gamenya under codntrolled evnironments with day/night temperatures of 25/20, 20/15 and 15/10°C at the vegetative, ear development and grain growth stages. They found that the ear development phase is most sensitive as far as temperature effects are concerned. Plants grown at lower temperatures had long culms, large flag leaves and more potentially fertile florets/spikelet. Finally they concluded that the number of florets which produced harvestable grains and the weight of these grains at maturity were more affected by high temperatures during the grain growth stage.

The dry matter accumulation and tillering occured at a higher rate in late varieties which were exposed to high temperatures, but the total dry matter production was more in early varieties, when exposed to low temperatures (Moshkov, 1984). The duration, dry matter accumulation and cell division were reduced in both drought and high temperature treatments and the combined effect of drought and high temperature was much more severe than that of separate treatments (Nicolas et al., 1984).

Musikenko et al. (1986) determined the response of rate of dry matter increments (RI) in relation to high temperature and reported that irrespective of the growth supression, the RI reached a minimum in the day following heat stress. Similarly Rawson (1986) opined that rapid phenological development, poor biomass production and sterility are major factors leading to the poor yields in wheat grown under high temperature regimes throughout the crop growth period.

2.2 YIELD AND YIELD COMPONENTS

Temperature pacing the plant senescence and shortening the duration of grain filling is a common manifestation in commercial winter wheat and the temperature in excess of 15°C apparently explains the dependence of 1000 Kernel weight on grain filling duration (Wiegand and Cuellar, 1981). In the sub-tropics, wheat yields are very sensitive to sowing time. At 28° N, the simulations showed a narrow band of optimal sowing time (between 15 October and 15 November) and for every day's delay in sowing, grain yield was reduced sharply by 50 kg ha^{-1} (Aggarwal, 1988).

The temperature can often be related directly to Kernel weight (Bagga and Rawson, 1977) and the exposure of whole plant or ears alone to short periods of high temperatures above 25°C resulted in reduced final grain weight (Ford et al., 1976). They also reported that the exposure of ears alone to high temperature are unlikely to reduce the accumulation of dry matter in other parts.

For each degree celsius increase in temperature during grain filling period, 1.04 mg decrease in kernel weight was observed in Russian spring wheat (Ulanova, 1975). Similar study was done by Indian researchers (Asana, 1968 and Wattal, 1965), who observed that high temperature during grain filling have a detrimental effect on kernel weight and subsequently on grain yield through shortening of grain filling period.

Asana and Williams (1965) revealed that high temperature (30/25°C) after anthesis reduced yield largely through its effect on weight per grain and the grain development rather than grain number. It was shown that optimum temperature for maximum kernel dry weight is 15/10°C (day/night) in wheat (Chowdhury and Wardlaw, 1978).

While studying the effect of temperature on grain yield pattern in response to different day/night temperature regimes of 18/13, 21/16 and 24/19°C in Goba and Petic-62 wheat varieties, the highest yield was obtained at 21/16°C (Devidson *et al.*, 1978). The grain set was maximum when temperature was low and at high light intensity from the time of anthesis to maturity. It ranged from 28 grains per ear at 27/22°C under 17.5% sunlight to 49 grains per ear at 15/10°C under full sunlight (Wardlaw, 1970).

Wardlaw *et al.* (1989) observed on overall reduction in the duration of kernel filling period from 60 to 36 days when temperature was increased from 15/10 to 21/16°C, and was compensated by an increase in the rate of growth from 0.73 to 1.49 mg kernel^{-1} day^{-1}, but there was a little change in weight per kernel at maturity. Further increase in temperature from 21/16 to 30/25°C decreased the duration of growth from 36 to 22 days but was no longer compensated by an increase in the rate of dry matter accumulation and therefore the grain weight was much reduced at maturity.

When wheat crop was exposed to hot wind for a short period at boot stage or brief exposure to higher temperature at anthesis, the grain number per spike was reduced drastically which was mainly due to reduction in grain set at temperatures higher than 30°C (Smike and Shawcraft, 1980). Saini and Aspinal (1982) exposed wheat plants to 30°C for 3 days and noticed that the kernel weight was reduced by 68 per cent than those grown continuously at 20°C.

The yield in wheat was decreased by 400 kg/ha with an increase in 1°C in maximum temperature beyond 25°C and the adverse effects of temperature were reduced with increasing frequency of irrigation (Morey and Sodaphal, 1981). Brief warming of ears reduced total grain weight and also caused small reduction in grain number (Bhullar and Jenner 1983). Grain yield in soybean was strongly correlated with maximum leaf area index (LAI) but not with NAR or RGR, and it was concluded that the grain yield generally depends on leaf area duration (LAD) after anlthesis (Annandale et al., 1984).

Warrington et al. (1977) indicated that wheat grown at 25°C during double ridge to anthesis had only 30 grains in the main ear, whereas plants grown during this period 15°C had approximately 70 grains in the main spike, and the spike dry weight at anthesis was also reduced by higher temperatures.

The effect of temperature after floral initiation is on the number of kernels per unit area and the number of kernels per unit area decreased by about 4% for each degree celsius increase in the mean temperature over the range of 14 to 22°C after 30 days preceeding anthesis (Fischer, 1985a).

McDonald et al. (1983) revealed that in non-limiting water supply, grain yield in late planting was low, which was attributed to the hastened crop development and high temperatures during grain filling. Similar observations were made by Mercellos and Single (1971), who stated that poor yield can also be caused by higher post-anthesis temperatures resulting in reduced duration of the grain filling period and reduced kernel weight. Heat stress meiosis in wheat reduced the yield through abnormal ovary development resulting in reduced growth of pollen tube and seed set (Saini et al., 1983). In another report, Svihra and Hudcova (1986) reported that the high temperature reduced the development of grain weight thereby resulting in decreased 1000-grain weight.

The negative effect of heat during the early growth stages of wheat was identified in its effect towards reduced duration of the spike initiation period and a subsequent reduction in the number of kernels per spike (Warrington et al., 1977 and Shpiler and Blum, 1986).

Wardlaw et al. (1989) demastrated the sensitivity of grain number to high temperature during booting and sensitivity of weight per grain to high temperatures after anthesis and they found a general reduction in yield per ear of 3 to 4 per cent for each 1°C rise in temperature above a mean of 15°C. Further, the response to temperature varied with the stage of development; some cultivars may respond well at booting and some at grain development stage. The wheat spikes when exposed to temperatures of 23 to 35°C from anthesis to maturity, restricted the growth by limiting sucrose conversion to starch (Manes, 1988).

Increase in the mean temperature above 15°C during grain filling has commonly been observed to reduce final kernel weight (Peters et al., 1971 and Spiertz, 1974). Reduction in grain size with higher temperatures operates by hastened senescence and increased respiration, resulting in the reduced availability of photosynthates for grain filling (Sofield et al., 1974; Spiertz, 1974 and Fischer and Laing, 1976). Fischer and Maurer (1976) showed that 1°C rise in temperature above the ambient between the end of tillering to the beginning of grain filling stage reduced by yield by 4 per cent. The reduction in the grain number per spike in hot environments was mediated by the reduced number of grains per spikelet and spikelets per spike (Shpiler and Blum, 1986).

Peters et al. (1971) revealed that high night temperatures markedly reduced (almost 50%) the grain yield in wheat as compared to cool night temperatures. Grain number is one of the most important determinants of yield in wheat. High temperatures beyond 20°C, between ear initiation and anthesis cause considerable reduction in the number of grains per spike (Fischer and Maurer, 1976). No other period of growth appears to be more sensitive to high temperature than the appearance of double ridge on the shoot apex and the emergence of flag leaf in wheat. The per cent grain set was reduced from 54.7 to 17.2 when the plants were shifted from 20 to 30°C (Saini and Aspinall, 1982).

Recent investigations (Jenner, 1991a) have revealed that continuous exposure to high temperature resulted in decrease concentrations of the products of sucrose synthase, the major pathway for the metabolism of sucrose in the endosperm, thereby reducing the grain dry weight. Jenner (1991b) reported that the final single grain weight of the more tolerant cultivar (Kalyansona) was not significantly affected by exposure to high temperature (35/25°C, day/night) but it was reduced in the cultivar (Sun 9E) by approximately 15.5 per cent as compared to low temperature (21/16°C, day/night).

2.3 BIOPHYSICAL PARAMETERS

Among different biophysical parameters, the leaf transpiration and diffusive resistance are directly related to number of stomata present per unit leaf area. The optimum temperature for net CO_2 uptake was reported to be about 24°C for wheat and barley and above this temperature, net CO_2 uptake decreased, because of increased stomatal and mesophyll resistances (Leach, 1979).

Miller (1983) reported that the number of stomata per unit leaf area is influenced by environmental conditions and plants had a lower stomatal frequency under optimal moisture conditions than under stress conditions (Van deRoovaart and Fuller, 1935). Significant reduction in net CO_2 fixation rate accompanied decreases in stomatal aparture, which coincided with periods of high temperature, low humidity, maximum solar radiation and water stress (Morris et al., 1983).

The effect of air temperature on transpiration of wheat at different relative humidity levels have been studied by Smirnov et al. (1987), and reported that the maximum transpiration was observed at 30 per cent relative humidity and decreased with an increase in relative humidity. Transpiration rate increased with increase in air temperature from 30 to 46°C, irrespective of relative humidity. However, Downes (1970) reported that the transpiration rate in wheat increased with increased temperature, but the photosynthesis was independent of temperature. It was also observed that the CO_2 concenteration difference between the air and intracellular spaces increased with temperature.

Konda (1990) reported the genotypic differences in leaf diffusion resistance, transpiration rate and leaf temperature. Among various genotypes tested, Local Khapli and Bijaga yellow were found to have higher diffusion resistance, low transpiration rate and leaf temperatures.

2.4 BIOCHEMICAL PARAMETERS

2.4.1 Chlorophyll content

A rise of 0.5°C temperature beyond 34°C did change the pattern of normal chlorophyll accumulation and subsequent growth leading to failure of chlorophyll accumulation and early death (Fischer. 1962). The total chlorophyll content and chlorophyll a/b ratio were decreased as the temperature increased from 25/15 to 35/25°C (Kassim and Paulsen, 1984).

2.4.2 Proline content

In recent years, attempts have been made to screen genotypes for drought tolerance based on their capacity to accumulate free proline under moisture stress conditions. Genotypic differences in the accumulation of proline under stress in wheat have been noticed by Rao and Nainawatee (1980) and Pandey (1982) While, Singh *et al.* (1972) noticed the direct relation between yield stability index of genotypes of barly and their ability for proline accumulation under water stress. Genotypic differences in the accumulation of proline has also been recorded in sorghum

(Sinha and Rajugopal, 1975). Sorghum genotypes which accumulated higher amount of proline also had higher recovery rating than other genotypes (Blum and Ebercon. 1976).

Nath and Ghoshal (1978) pointed out the significant accumulation of proline content. under water stressed leaves of ten wheat cultivars belonging to *Triticum aestivum*. *T. durum* and *T. dicoccum*. Similar study was done on wheat varieties. S-308, C-304 and C-306, and observed greater increase in proline accumulation with an increase in the stress in these varieties.

It was observed that the course of free proline accumulation in leaves, stems. roots and ears, was related to leaf water potential of these organs and indicated that there was a perfect correlation between the proline accumulation and a decrease in the water potential of these organs (Karamanos *et al*., 1983). They further revealed that the increased amounts of the free proline can be associated with more effective dehydration and drought avoidance mechanisms. However, the influence of temperature regimes on the accumulation of free proline has not been reported and most of the work has been centered under limited moisture supply conditions.

2.4.3 Wax deposition

Johnson *et al*. (1983) reported that the presence of glaucous in wheat lines is beneficial under rainfed condition and other environmental stresses. They observed an increase in dry matter production, grain yield and harvest index in glaucous lines than in non-glaucous lines. The differences in yield between bloom and bloomless sorghum varieties were observed under semiarid conditions and were attributed mainly to difference in gas exchange ratio (Ross, 1972).

Jordan _et_ _al_. (1983) reported that the moisture stress significantly enhanced the development of epicuticular wax and the ability to accumulate greater amount of wax in response to moisture stress varied widely among different lines. Richards (1984) observed no difference in leaf areas between glaucous and non-glaucous plants under irrigated conditions whereas, in drought treated plants, glaucousness resulted in higher leaf area than in non-glaucous plants.

Gas exchange studies of the _durum_ lines under both irrigated and drought treatments indicated that the ears of non-glaucous plants had higher rates of photosynthesis, transpiration and stomatal conductance and the photosynthesis rate increased with an increase in light levels (Rechards, 1986). While, Nizamuddin and Marshal (1988) evaluated the epicuticular wax content in _durum_ and _aestivum_ wheats and its relationship with drought tolerance and spectral reflectance, and reported that the epicuticular wax is associated with drought tolerance. The surface reflectance was reduced when the waxy layer from the leaf was removed with chloroform.

Non-glaucous sorghum genotypes exhibited higher rates of transpiration than glaucous lines (Chatterton et al., 1975). Similarly O'Toole et al. (1979) observed that the removal of epicuticular wax from the rice leaves significantly reduced the cuticular resistance to water loss.

Bengtson et al. (1978) reported that wax was related to drought tolerance of oat varieties. O'Toole and Cruz (1983) observed that rice cultivars adapted to dry land conditions had a greater amount of epicuticular wax than those adapted to wet environments.

2.4.4 Sugars accumulation

Sugar is one of the most important metabolites accumulated during environmental stresses, which is ben ficial to the plant growth and development. Osmotic adjustment in response to water stress enables many plants to withstand the moderate water stress or grow in areas of limited water availability (Hsiao et al., 1976). In cotton, sugars seem to accumulate in stress hardened plants (Cutler and Rains, 1978 and Cutler et al., 1977). Maximum accumulation of sucrose was observed during noon-time in cotton due to lower water potentials (Ackerson, 1981). Decrease in starch content of the chloroplast of the spinach leaves and a corresponding increase in sugar concentration could lead to an increase in the heat resistance (Santarius and Mullar, 1979).

Jenner (1991a) compared the wheat ears exposed for 7 days to high temperature (35°C day/25°C night) with those maintained at lower temperatures (21°C day/16°C) and found that raising the temperature resulted in the increase of sucrose content. When two cultivars of wheat known to differ in their post-anthesis tolerance of high temperature were compared, the response interms of carbohydrate metabolism was similar in both the cultivars. However. Bhuller and Jenner (1985) reported that the accumulation of starch is more sensitive than the deposition of proteins and the exposure to elevated temperature results in decreased conversion of sucrose to starch in Vitro. Further, the activities of the enzymes, sucrose synthase (MacLeod and Duffus, 1988) and starch synthase (Rijven, 1986) have been reported to be reduced in cereal endosperm by high temperature.

CHAPTER - III

MATERIAL AND METHODS

III MATERIAL AND METHODS

A field experiment was conducted during *rabi* (November 1990 to March 1991), to study the physiological basis of heat tolerance in wheat genotypes. The details of the materials used and techniques adopted during the course of investigation are described here under.

3.1 EXPERIMENTAL SITE

The experiment was carried out at the Wheat Improvement Project, Main Research Station, University of Agril. Sciences, Dharwad.

3.2 CLIMATE

The Main Research Station, Dharwad is situated in the transitional tract of Karnataka at 15°12' N latitude, 75°07' E longitude and at an altitude of 774 m above the mean sea level. The average annual rainfall during 1990-91 was 730.5 mm and was fairly distributed from April to November. The maximum and minimum temperatures during *rabi*, 1990-91 were 38.9 and 9.4°C respectively. The relative humidity during the crop growth period ranged from 74.0 to 90.4 per cent. The meteorological data for the year 1990-91 and the mean of previous 40 years was collected from the meteorological observatory, College of Agriculture, Dharwad and is depicted in Fig. 1.

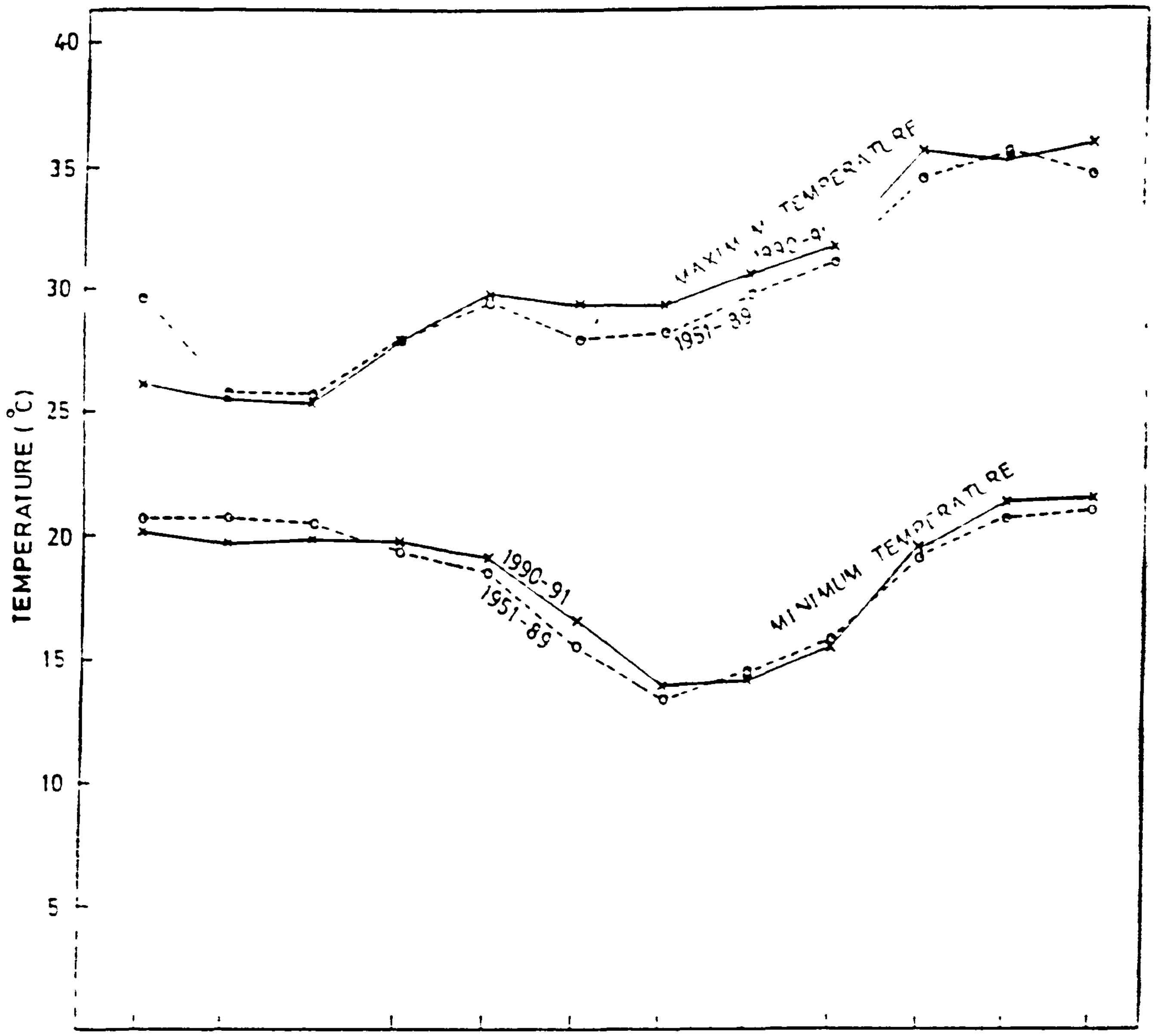

FIG. 1a. MONTHLY MINIMUM AND MAXIMUM TEMPERATURE AT M.R.S DHARWAD, DURING 1990-91 AND THE AVERAGE OF 40 YEARS (1951-90)

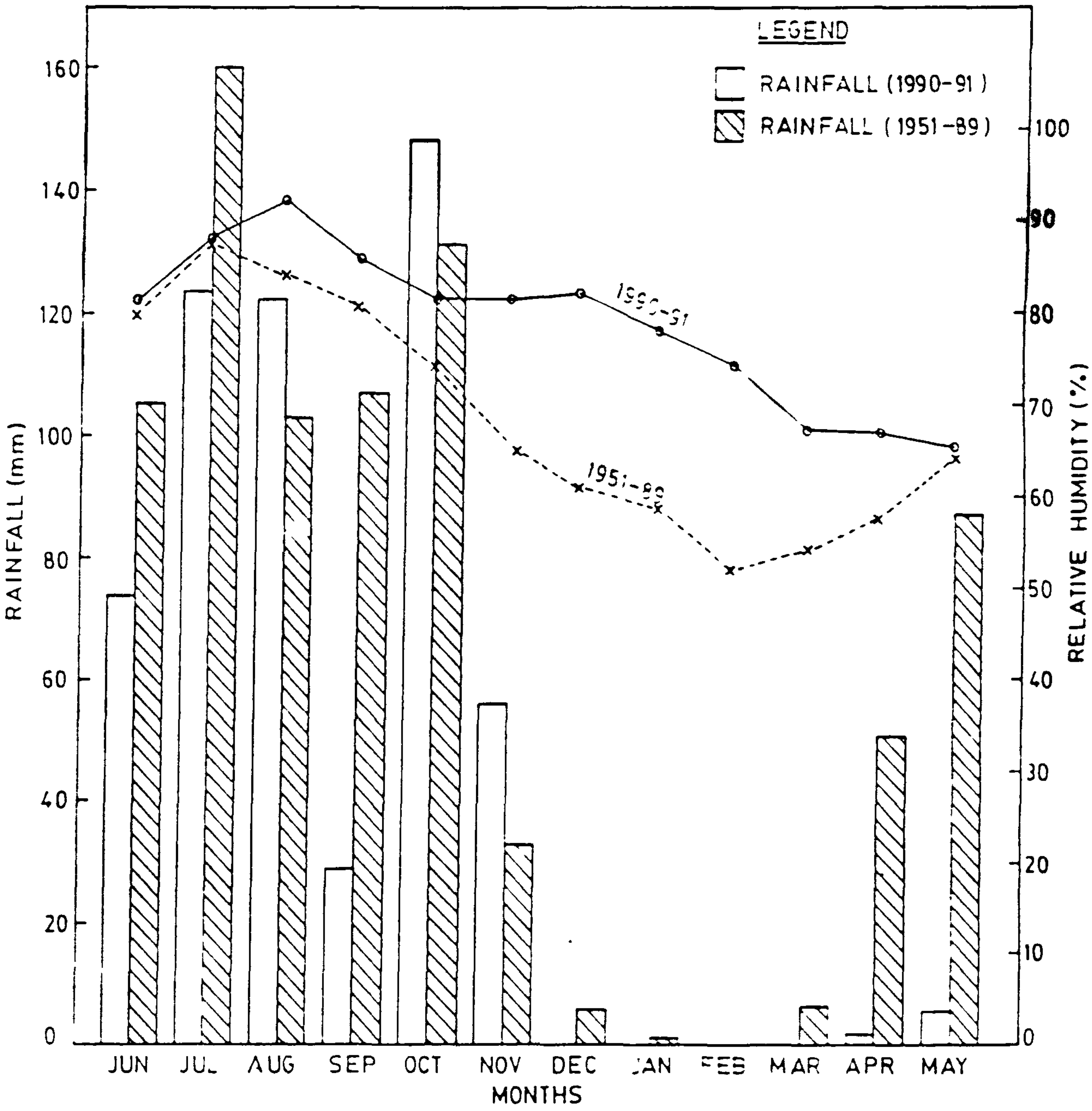

FIG.1b. MONTHLY RAINFALL AND RELATIVE HUMIDITY AT M.R.S. DHARWAD, DURING 1990-91 AND THE AVERAGE OF 40 YEARS (1951-90)

3.3 SOIL AND ITS CHARACTERISTICS

The experimental site consisted of medium black clay loam soil. Composite soil samples from the experimental site were analysed for various physical and chemical properties. The data of soil analysis and the methods employed are given in Table 1.

3.4 EXPERIMENTAL DETAILS

The experiment consisted of 12 genotypes representing three cultivated wheat species viz.. *T. dicoccum*. *T. durum* and *T. aestivum*, the details of which are indicated in Table 2.

3.4.1 Temperature regimes

1. Normal date of sowing - 9 November 1990 (Low temperature regime)
2. Late sowing - 5 December 1990 (High temperature regime)

The daily maximum and minimum temperatures recorded under both the temperature regimes of crop growth are given in Appendix-I and II.

3.4.2 Plot size

Gross plot = 3.0 m length x 1.38 m width

Net plot = 2.5 m length x 0.92 m width.

3.5 CULTURAL PRACTICES

3.5.1 Land preperation

The land was harrowed twice after the harvest of the

Table 1. Physical and chemical properties of the soil of experimental site

Particulars	Values obtained	Method employed
1. <u>Physical properties</u>		
Sand %	15.03	Puri's method (Shankaram, 1966)
Silt %	27.19	-do-
Clay %	52.06	-do-
Bulk density (gm cc^{-1})	1.30	Core Sampler method (Piper, 1966)
2. <u>Chemical properties</u>		
Available N (kg ha^{-1})	177.5	Modified Kjeldahl's method (Jackson, 1967)
Available P_2O_5 (kg ha^{-1})	77.5	Olson's method (Muhr *et al.*, 1965)
Available K_2O (kg ha^{-1})	260.0	Flame photometer (Muhr *et al.*, 1965)
PH (Soil to water ratio 1:2.5)	7.6 to 8.0	PH meter (Piper, 1966)

Table 2. Salient features of wheat genotypes selected for the **present investigation**

	Genotypes	Pedigree	Production conditions	Main characteristics
	1	2	3	4
	Triticum dicoccum			
1.	Local Khapli	Selection from local wheat of Ghataprabha and Krishna Valley	Marginal to high fertility, early, timely and late sown irrigated and rainfed conditions	A tall dicoccum wheat having high degree of field resistant to black and brown rusts. Tolerant to drought and heat stress. Grains are red, valved and medium bold. Protein content over 14%, good for making "uppama".
	Triticum durum			
2.	Bijaga yellow	**Local red x Gaza**	Medium to low fertility, suitable for timely sown rainfed conditions	A tall durum wheat having attractive, yellow, hard, bold and lustrous grains; more suitable and popular for cultivation under rainfed conditions. Protein content over 13%. Tolerant to drought and high temperature conditions.
3.	Raj-1555	Cocorite x Raj-911	Suitable for timely sown, irrigated and good fertility conditions	A double dwarf durum variety of medium-late maturity and high yield potential. Fairly resistant to rust; grains are amber, hard and bold. Protein content over 12%. Good for semolina recovery and vermicelli preperations.
4.	**HD-4502**	$(P_i'S' \times By^2 - TC) \times (Z - B \times W)$	Suitable for high fertility, timely sown and irrigated conditions	A doulbe dwarf durum wheat having good degree of resistant to rusts; medium and late in maturity. Grains are amber, hard and bold with tendency for mottling. Tolerant to high temperature at early stage of growth.

Table 2. continued

1	2	3	4
5. DWR-174	CPAN-6018 x Raj-1555^2	Suitable for high fertility, timely sown and irrigated conditions	A double dwarf *durum* wheat having good degree of resistant to black and brown rust, medium to late in maturity. Grains are amber, hard, bold and lustrous. Protein content over 14%. Tolerant to high temperature during the crop growth.
6. Bulk-776	*T. timopheevi*/NI-146^2/DWL-5023	Suitable for timely sown, good fertility and irrigated conditions	A double dwarf *durum* having medium degree of resistant to rust, medium in maturity, grains are amber, hard, bold and lustrous. Protein content over 13%.
7. Sham-1	*T. timopheevi*/NI-146^2/DWL-5023	Suitable for timely sown, good fertility and irrigated conditions	A semi dwarf *durum* wheat having medium degree of resistance to rusts, medium in maturity, grains are amber, hard, bold and lustrous.
8. EIGSN-17	Snip/Fg/Ato	Suitable for timely sown and dryland conditions	A tall *durum* having good degree of resistance to rust. Medium in maturity, grains are amber, hard, bold and lustrous.
9. Furat-4	CD 34346-2 x TR-2 AP-1 AP - O AP	Suited for high fertility, timely sown and irrigated conditions	A double dwarf *durum* wheat having good degree of resistant to rust, medium to late maturity having good degree of tolerance to heat stress during post anthesis stage. Grains are amber, hard, bold and lustrous. Protein content over 13%.

Table 2. continued

1	2	3	4
10. D-417-29	*T. timopheevi*/HD-4502^2/ Raj-1555	Suited for high fertility, timely sown and irrigated conditions	A double dwarf *durum* wheat having good degree of resistant to rust, medium in maturity. Grains are amber, hard, bold and lustrous. Protein content over 13%. Tolerant to heat stress during post anthesis.
Triticum aestivum			
11. HI-977	Gallo-**Aust-61-157**	Suited for late sown, good fertility and irrigated conditions	A double dwarf *aestivum*, early maturity, slow rusting. Grains are amber, hard and medium bold, very good for chapati making. Protein content over 14%. Tolerant to post anthesis heat stress.
12. HD-2501		Suited for late sown, good fertility and irrigated conditions	A double dwarf *aestivum*, early maturity, highly resistant to rusts. Grains are amber, semiarid and medium bold. Protein content over 14%. Tolerant to post anthesis heat stress.

previous crop and then smoothened with a wooden plank to a fine tilth so as to facilitate easy sowing. Plots were prepared as per the plan given in Fig. 2.

3.5.2 Seeds and sowing

Seeds were obtained from wheat breeder, All India Co-ordinated Wheat Improvement Project, Main Research Station (MRS), Dharwad and treated with organomercuric compound, Vitawax at the rate of 2.0 g kg^{-1} of seeds as a preventive measure against foot rot, seed rot and damping off. The sowing time was staggered to achieve different temperatures as described in 3.4.1. A recommended seed rate of 45 g $plot^{-1}$ was used. The furrows were opened at 23 cm apart and seeds were dibbled in the furrows at 5 cm distance. Soon after the sowing plots were irrigated and then regular irrigations were given at an interval of 12 days.

3.5.3 Fertilizer application

Recommended fertilizer dose of 120:60:40 kg N : P_2O_5 : K_2O/ha was applied. 50 per cent of Nitrogen along with full dose of P_2O_5 and K_2O were applied at the time of sowing and the rest 50 per cent of Nitrogen was applied 5 cm away and 5 cm below the soil at 30 days after sowing (DAS).

3.5.4 After care

Two hand weedings were done at 15 and 45 DAS and one intercultivation was done at 30 DAS. There was no incidence of any pests and diseases and hence no plant protection chemicals were sprayed.

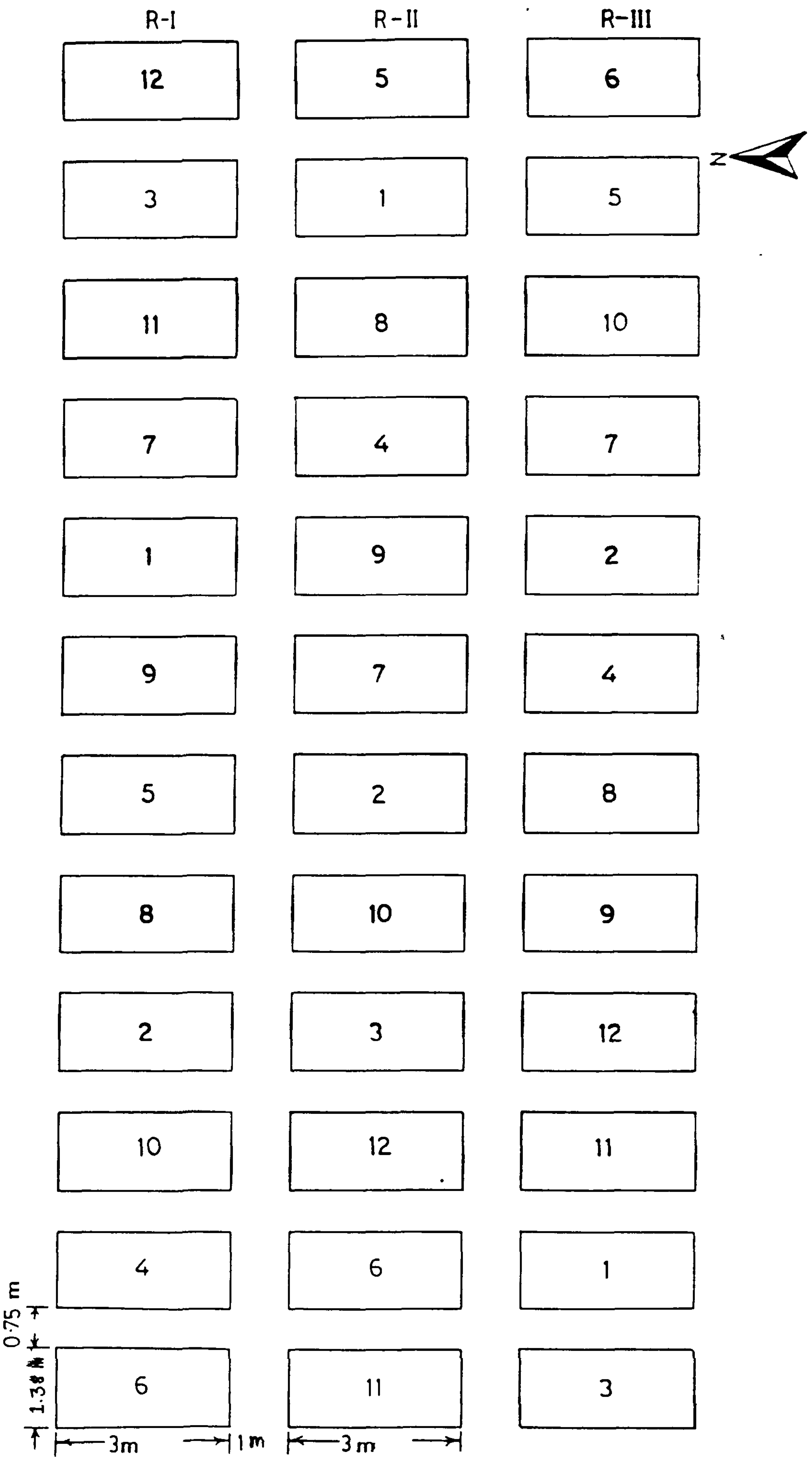

FIG. 2. PLAN OF LAYOUT OF THE EXPERIMENT

3.5.5 Harvesting

The crop was cut to the ground level at physiological maturity. For the purpose of yield and yield attributes. plants from five hills tagged earlier were seperated from rest of the plants and were oven dried at 80°C to a constant weight to determine the total dry matter.

3.6 COLLECTION OF EXPERIMENTAL DATA

Five plants from each plot were tagged randomly on 35th day after sowing for recording various morphological observations, yield and yield attributes.

3.6.1 MORPHOLOGICAL CHARACTERS

3.6.1.1 Number of tillers per hill

Five hills in each treatment tagged earlier were used for counting the number of tillers at 35. 60, 85 DAS and at maturity. Numbers of tillers per hill was computed by taking the average of five hills.

3.6.1.2 Plant height

Plant height was measured from the base of the plant to the top fully opened leaf of the main shoot at 35, 60, 85 DAS and at harvest. Measurements were taken from the main shoots of five hills in each treatment tagged earlier and average height of the single plant was calculated and expressed in cm.

3.6.1.3 Number of green leaves

Number of green leaves present on the main shoot and tillers were counted from the tagged plants of five hills in each replication at 35. 60 and 85 DAS. At harvest, all the leaves were dry and hence was not taken into account. The average of five hills was taken and expressed on per hill basis.

3.6.1.4 Leaf area

Leaf area was computed by using Index leaf method of Stickler *et al.* (1961) as given below.

Leaf area = L x W x F x number of green leaves

where,

L = maximum length (cm)
W = maximum width (cm)
F = factor (0.707 for wheat)

Maximum length (cm) and width (cm) of the third leaf from the top were measured.

3.6.1.5 Total dry matter production

For this purpose. plants from five hills at random were uprooted and seperated into leaf. stem and spike and were oven dried at 80°C to a constant weight at 35, 60, 85 DAS and at harvest. The data was expressed on per hill basis in g.

3.6.1.6 Days to anthesis

The day on which 50 per cent of the spikes emerged was noted as anthesis day and the total number of days required to emerge as the days to anthesis.

3.6.2 PHYSIOLOGICAL STUDIES

3.6.2.1 Growth analysis

Various growth parameters were calculated from the data obtained on dry weights of different plant parts and leaf area as described below.

3.6.2.1.1 Leaf area index (LAI)

The LAI per hill was calculated by using the formula,

$$\text{LAI} = \frac{\text{Leaf area/hill}}{\text{Land area/hill}}$$

3.6.2.1.2 Leaf area duration (LAD)

Leaf area duration is the integral of leaf area index over the growth period (Watson, 1952). LAD for various growth periods was worked out as per the formula of Power *et al.* (1967).

$$\text{LAD} = \frac{L_i + (L_{i+1})}{2} (t_2 - t_1)$$

where,

LAD = Leaf area duration (days)

L_i = LAI at i^{th} stage

L_{i+1} = LAI at $(i+1)^{th}$ stage

t_1 and t_2 = time interval between i and $(i+1)^{th}$ stage (days)

3.6.2.1.3 Absolute growth rate (AGR)

It expresses the dry weight increase per unit time and was calculated by using the following formula.

$$AGR = \frac{W_2 - W_1}{t_2 - t_1} \quad g\ day^{-1}$$

Where.

W_2 and W_1 are the dry weight of the plant per hill at time t_1 and t_2.

3.6.2.4 Relative growth rate (RGR)

It is the rate of increase in the dry weight per unit dry weight already present and was calculated as follows.

$$RGR = \frac{\log_e W_2 - \log_e W_1}{(t_2 - t_1)} \quad g\ g^{-1}\ day^{-1}$$

where.

W_1 = Dry weight of the plant at time t_1

W_2 = Dry weight of the plant at time t_2

3.6.2.1.5 Crop growth rate (CGR)

Crop growth rate is the rate of dry matter production per unit ground area per unit time (Watson. 1952). It was calculated by using the formula,

$$\text{CGR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{1}{A} \quad \text{g dm}^{-2} \text{ day}^{-1}$$

where,

W_1 = Dry weight of the plant (g) at time t_1

W_2 = Dry weight of the plant (g) at time t_2

A = Land area (dm^2)

3.6.2.1.6 Net assimilation rate (NAR)

Net assimilation rate is the rate of dry weight increase per unit leaf area per unit time (Watson, 1952). It was calculated by following the formula of Radford (1967).

$$\text{NAR} = \frac{(W_2 - W_1)}{(t_2 - t_1)} \times \frac{(\log_e L_2 - \log_e L_1)}{(L_2 - L_1)} \quad \text{g dm}^{-2} \text{ day}^{-1}$$

where.

L_1 and W_1 = Leaf area (dm^2) and dry weight of the plant (g) at time t_1.

L_2 and W_2 = Leaf area (dm^2) and dry weight of the plant (g) at time t_2.

3.6.2.1.7 Specific leaf weight (SLW)

The specific leaf weight indicates the leaf thickness and was determined by the method of Radford (1967).

$$\text{SLW} = \frac{\text{Leaf dry weight (g)}}{\text{Leaf area (dm}^2\text{)}} \quad \text{g dm}^{-2}$$

3.6.2.1.8 Specific leaf area (SLA)

The inverse of specific leaf weight is the specific leaf area and was calculated by using the following formula,

$$\text{SLA} = \frac{\text{Leaf area (dm}^2\text{)}}{\text{Leaf dry weight (g)}} \ \text{dm}^2\ \text{g}^{-1}$$

3.6.2.1.9 Harvest index (HI)

It was calculated by using the formula given by Donald (1962) and expressed in per cent.

$$\text{HI} = \frac{\text{Economic yield}}{\text{Biological yield}} \times 100$$

3.6.3 Biophysical studies

Measurements of various biophysical parameters viz., stomatal resistance for CO_2 and water vapour exchange, transpiration rate and leaf temperature were made on the abaxial surface of the top fully expanded leaf at 60 and 80 DAS using steady state porometer (LICOR model LI 1600). These measurements were made between 10.00 AM to 12.00 noon on all sampling dates. Stomatal resistance was expressed as s cm^{-1}, whereas, the transpiration rate and leaf temperatures were expressed in terms of $\mu g\ cm^{-2}\ s^{-1}$ and °C, respectively.

The transpiration rate ($\mu g\ cm^{-2}\ s^{-1}$) was measured directly from the same leaf used for measuring stomatal conductance by the porometer. The leaf temperature (°C) was recorded using the built in thermocouple of the steady state porometer pressed against the abaxial surface of the leaf. The leaves used for measuring stomatal conductance and transpiration rate were simultaneously used for recording the leaf temperature.

3.6.4 BIOCHEMICAL STUDIES

3.6.4.1 Estimation of chlorophyll content

Total chlorophyll Chl.a and Chl.b contents were determined following the method of Arnon (1949) at 35, 60 and 85 DAS.

Fresh leaves from top of the canopy were brought in an ice box from the field and were cut into small pieces. Approximately 250 mg of leaves were weighed from each sample and were homogenised with acetone. The extract was filtered through Whatman No.1 filter paper and washed twice with 80 per cent acetone. The final volume of the extract was made to 25 ml. The absorbance of the extract was measured at 645, 652 and 663 nm in Ultraspec double beam Spectrophotometer (model CL-54). The total chlorophyll, chlorophyll 'a' and chlorophyll 'b' contents were calculated using the following formulae.

$$\text{Total chlorophyll} = \frac{(20.2 \times A_{645}) + (8.02 \times A_{663})}{a \times 1000 \times W} \times V \text{ mg g}^{-1} \text{ fr.wt.}$$

$$\text{Chl.a} = 12.7\,(A_{663}) - 2.69\,(A_{645}) \times \frac{25}{1000 \times 0.25}$$

$$\text{Chl. b} = 22.9\ (A_{645}) - 4.68\ (A_{663})\ \times \frac{25}{1000 \times 0.25}$$

where.

A_{645} = Absorbance of the extract at 645 nm

A_{663} = Absorbance of the extract at 663 nm

a = Path length of light in the cuvette (1 cm)

V = Volume of the extract (25 ml)

W = Fresh weight of the sample (0.25 g).

3.6.4.2 Estimation of total soluble sugars

The amount of total soluble sugars present in the extract was estimated by anthrone method (Dobois et al.. 1951).

Reagents:

1. Ethanol (80%)
2. Anthrone reagent : 0.29 g of anthrone was dissolved in 100 ml of concentrated sulphuric acid.

Procedure:

1. Extraction of plant sample

Fresh leaf samples were collected randomly from each plot, washed and one gram of the sample was homogenised with 80 per cent ethanol. Homogenised leaf extract was allowed to boil for 2-3 minutes on hot water bath and filtered through Whatman No.1 filter paper. The residue was once again boiled in alcohol for 2-3 minutes and filtered through Whatman No.1 filter paper. The extraction process was repeated three to four times.

Extracted alcohol was used for the estimation of total soluble sugars by using anthrone reagent.

2. Estimation of sugars

One ml of alcohol extract was taken in the test tube and four ml of anthrone reagent was allowed to run down the side of the test tube by keeping the test tubes in an ice bath. The samples were boiled on hot water bath for 10 minutes, and allowed to cool at room temperature. The absorbance of the blue green solution was measured at 625 nm and the amount of sugars present in the sample was calculated by using the standard curve prepared from glucose (Fig. 3).

3.6.4.3 Determination of free proline content

Proline content was estimated by the method of Bates *et al.* (1973).

Reagents:

1. Aqueous sulfosalicylic acid (3%)
2. Glacial acetic acid
3. Toluene
4. Acid ninhydrin : 1.25 g of ninhydrin was dissolved in a warm mixture of 30 ml of glacial acetic acid and 20 ml of 6 M phosphoric acid.

Procedure:

Fresh leaf samples (0.5 g) were collected, ground well

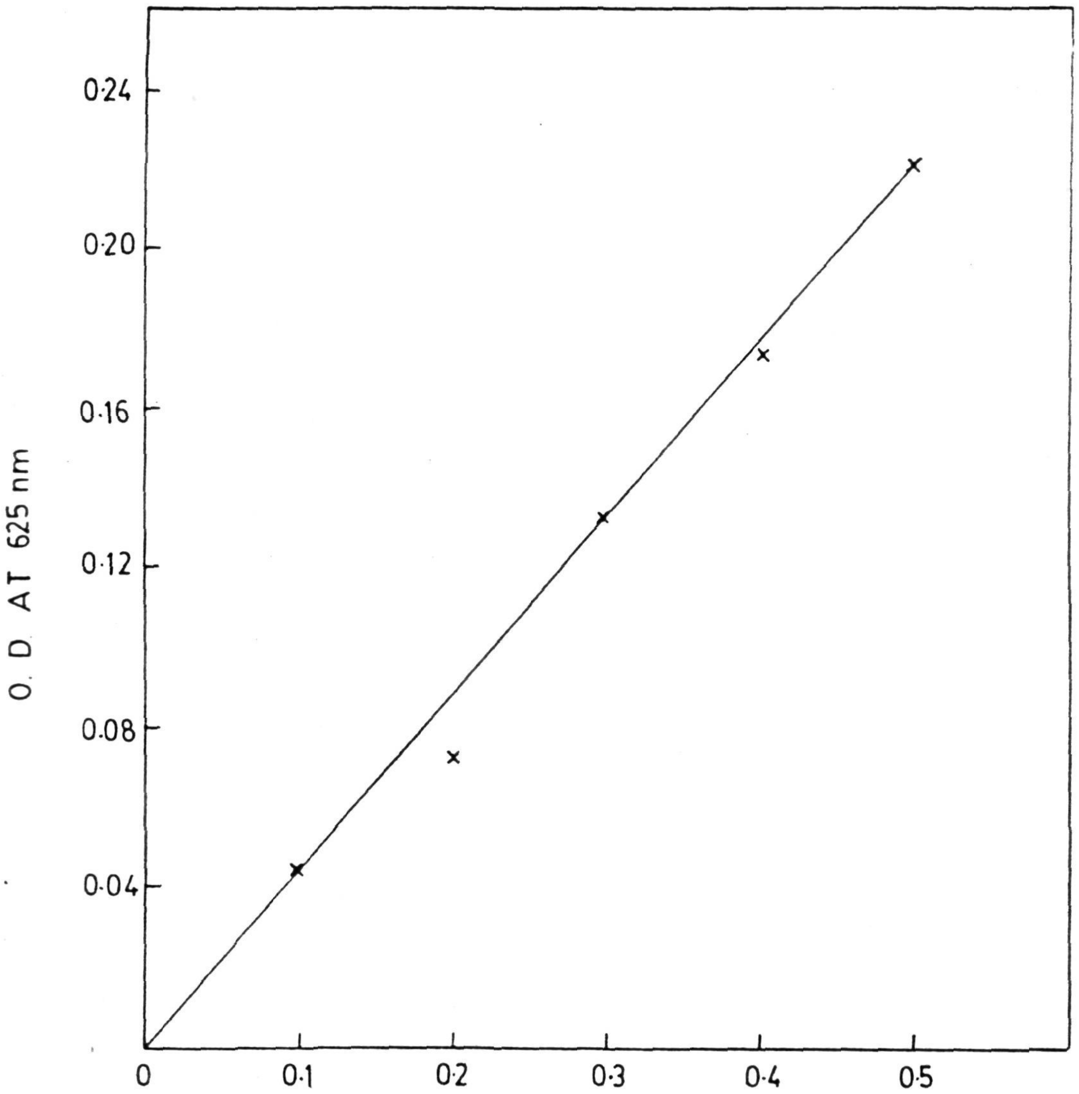

FIG.3. STANDARD CURVE FOR SUGAR

in a mortar using pestle and extracted in 10 ml of three per cent sulphosalicylic acid. The extract was filtered through Whatman No.1 filter paper and the filtrate was used for proline estimation.

An aliquot of two ml from each sample was taken in separate test tubes and to each test tube, two ml of acid ninhydrin reagent and two ml of glacial acetic acid were added and boiled on hot water bath for an hour. Then. the test tubes were transferred to ice water bath for cooling and the contents of each test tube were transferred to a separating funnel. To this. four ml of toluene was added shaken thoroughly and allowed to form two separate layers.

The upper toluene layer containing the colour complex due to proline ninhydrin interaction was taken into a separate test tube and the colour was read in ultraspec double beam spectrophotometer (model CL-54) at 520 nm. The proline concentration was determined from a standard curve prepared using proline (Fig. 4) and expressed on dry weight basis.

3.6.4.4 Wax estimation

The wax content was determined by the colorimetric method of Ebercon *et al.* (1977). This method is based on the colour change produced by the reaction of wax with acidic potassium bichromate ($K_2Cr_2O_7$).

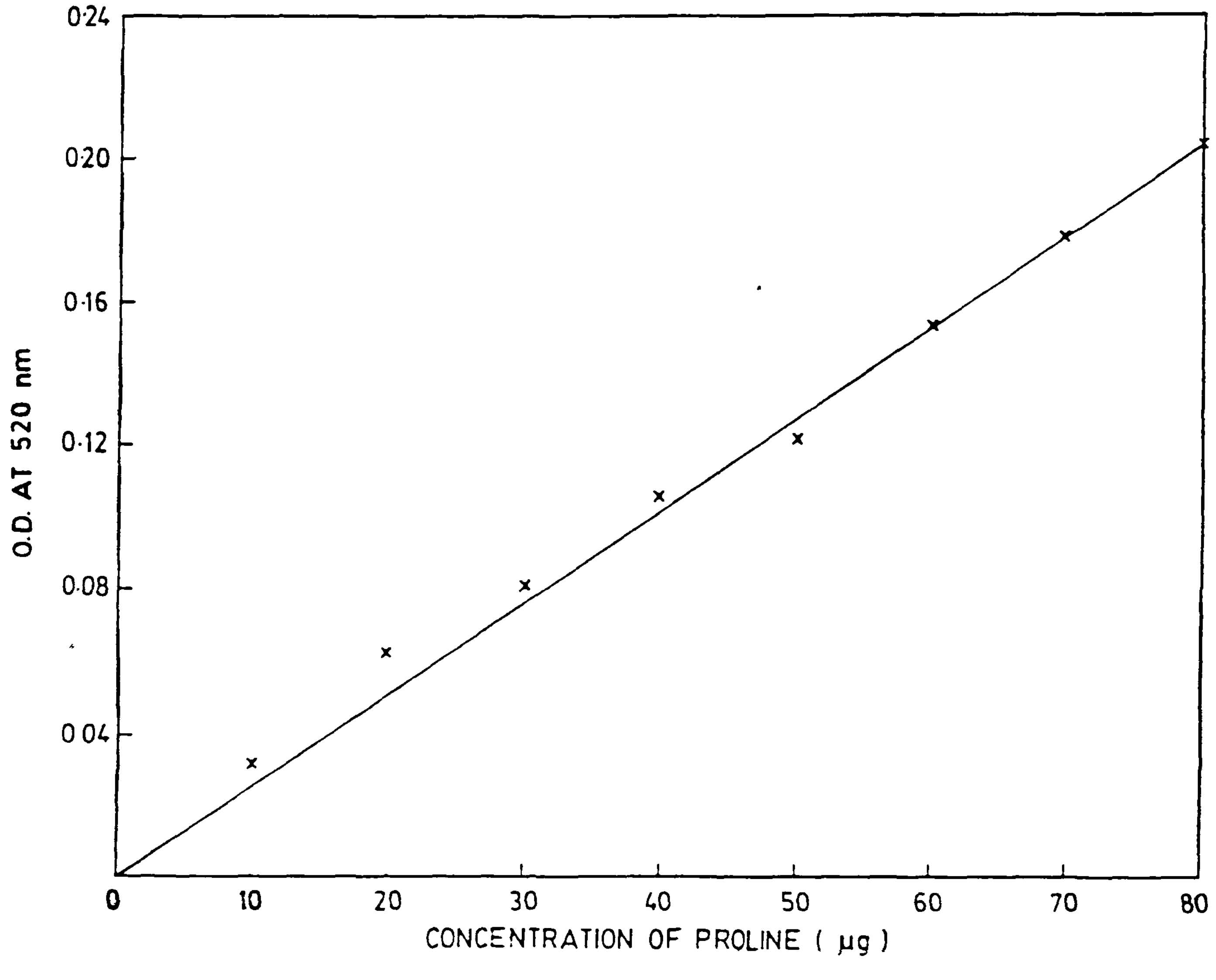

FIG.4. STANDARD CURVE FOR PROLINE

Reagents

1. Chloroform
2. Acidic potassium bichromate reagent:- This was prepared by mixing 40 ml of deionised water with 20 g powdered potassium bichromate. The resulting slurry was mixed vigorously with one litre concentrated sulphuric acid and heated (below boiling point) until a clear solution was obtained.

Procedure

The individual sample consisting of 10 wheat leaf discs of known area (both surfaces) was immersed in 15 ml of chloroform for 15 seconds. The extract was filtered and evaporated to dryness on a boiling water bath, until the smell of chloroform could not be detected. **Five** ml of acidic $K_2Cr_2O_7$ was added to the samples and placed in boiling water for 30 minutes. After cooling, 12 ml of deionised water was added. 15-20 minutes were allowed for the colour development, and the optical density of the sample was read at 590 nm.

Wax was quantified by using the standard curve prepared by using carbowax 3000 (Polyethylene glycol 3000), and expressed as mg per dm^2 area (both surfaces - since wax is present on both the surfaces).

3.7 STATISTICAL ANALYSIS

Fischer's method of analysis of variance was applied

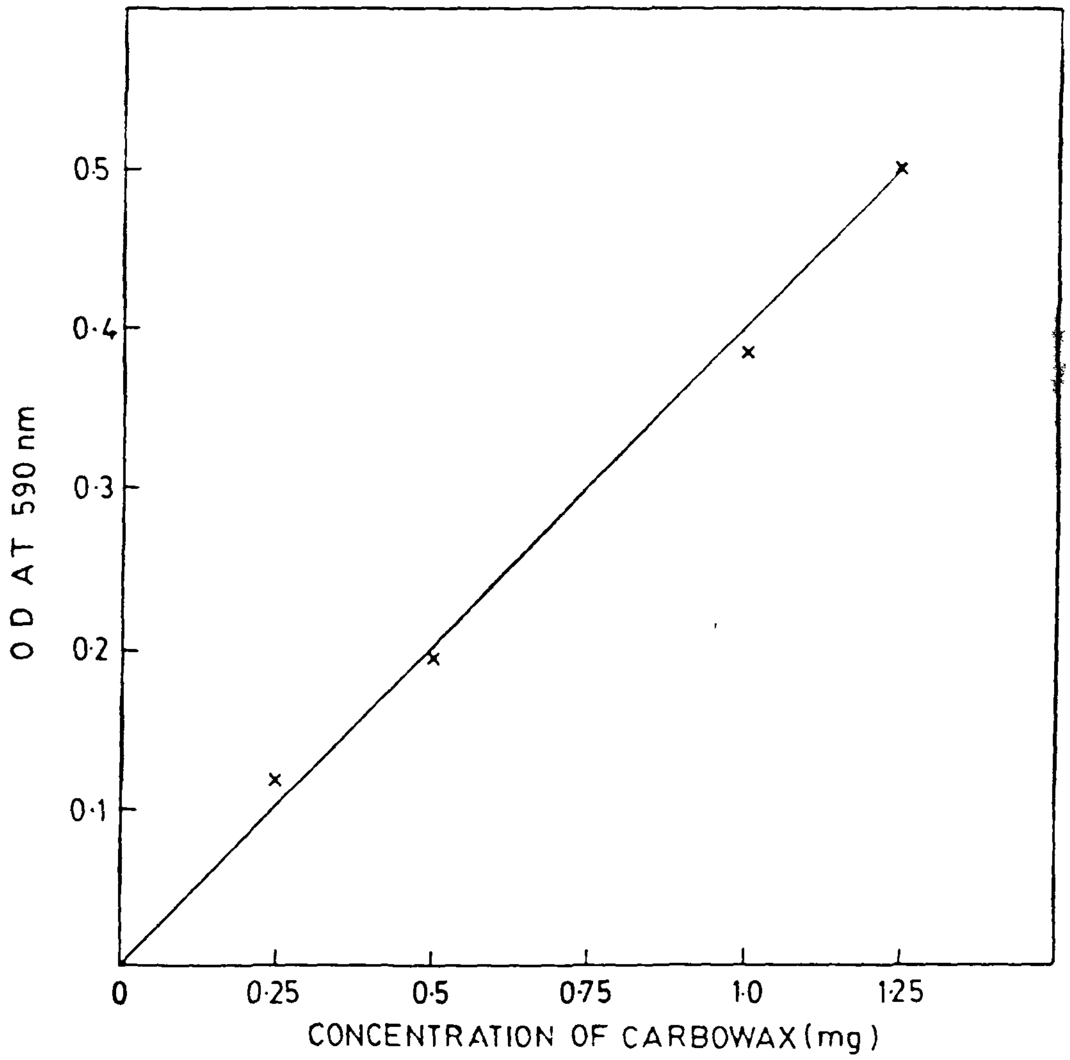

FIG. 5. STANDARD CURVE FOR WAX

for the analysis of the data and interpretation of results as suggested by Panse and Sukhatme (1967) and Sundarraj *et al*. (1972). The level of significance used in 'F' and 't' test was $P = 0.05$. Critical difference (CD) values were calculated at 5 per cent probability level, wherever 'F' test was significant.

CHAPTER - IV

EXPERIMENTAL RESULTS

IV EXPERIMENTAL RESULTS

A field experiment was conducted during rabi. 1990-91 to evaluate the physiological basis of temperature tolerance in twelve wheat genotypes. The crop was exposed to different growth temperature regimes during its life cycle by varying the sowing dates. In the absence of growth cabinets, the normal practice of undertaking the temperature tolerance studies is through variation in the sowing time. The crop was raised under two temperature regimes and the genotypes were evaluated at different stages for various morphological characters, growth parameters, biophysical, physiological and biochemical characteristics. In order to give emphasis on the temperature aspects, the table captions are designated as "influence of temperature regimes", instead of "date of sowing". The mean values of each parameter at each crop growth stage and the mean values of temperature regimes are described in this chapter.

4.1 ENVIRONMENTAL CONDITION DURING THE CROP GROWTH PERIOD

The data pertaining to different weather parameters viz., rainfall, relative humidity and temperature during the crop growth period (1990-91) and the average of 40 years (1951-90) are depicted in Fig.1 and Appendix I and II.

4.1.1 Temperature

It was observed that the maximum temperature varied from 26.1 to 35.6°C and 27.2 to 38.9°C during normal sown and late sown crop respectively, whereas, the minimum temperature ranged from 9.4 to 19.8°C in normal sown crop and 9.4 to 20.9°C during the late sown crop. The difference in the mean minimum temperature over the entire crop growth period of both normal and late sown crop was 1°C. The mean of minimum and maximum temperatures ranged from 12.9°C in normal sown to 13.5°C in late sown crop. It was further evident from the data that the normal sown crop experienced higher maximum and minimum temperatures upto 35 DAS. Although, there was no appreciable changes in the mean maximum temperature between the normal sown and late sown crop, they differed by 2°C, with the normal sown crop recording higher mean temperature upto 35 DAS. From 35 DAS to harvest, the late sown crop recorded higher temperature with a difference of 2.4°C in the maximum and 1.7°C in the minimum temperature as compared to normal sown crop (Table 3).

The crop attained early physiologic maturity (107 days) in the late sown crop as compared to normal sown crop (115 days). The data indicated a clear difference in growth temperatures between normal sown crop and late sown crop and hence, it is further used in the text throughout as 'low temperature' and 'high temperature' regimes instead of 'normal sown' and 'late sown crop', respectively.

4.1.2 Relative humidity

The relative humidity during the crop growth period ranged from 68 per cent (March) to 82 per cent (December),

Table 3. Mean maximum and minimum temperatures prevailing during different growth stages under two sowing dates of wheat

Growth stages	Temperature (°C)			
	Normal sown crop (9 Nov 1990)		Late sown crop (5 Dec 1990)	
	Mean Maximum	Mean Minimum	Mean Maximum	Mean Minimum
Sowing to 35 days	29.6	16.1	29.5	13.8
35 to 60 days	29.3	13.5	31.3	15.0
60 to 85 days	31.2	15.2	33.6	15.4
85 days to Harvest	33.6	15.4	36.1	18.7
Mean	30.9	15.0	32.6	15.7

whereas, the average relative humidity for the last 40 years was 65 per cent (November) and 52 per cent (February).

4.1.3 Rainfall

During the crop growth period, rainfall occured only during the month of November, which was 56.8 mm and in other months i.e. from November to March, no rainfall was recorded. Whereas, the average rainfall for the last 40 years during the same period (November to March) ranged from 0.7 mm in January to 32.2 mm in November (Fig. 1b).

4.1.4 Growing Degree Days (GDD)

The data on the influence of temperature regimes in GDD upto 50 per cent anthesis in different wheat genotypes indicated that there was no difference between normal and late sown crop (Table 4). Genotypic differences in the GDD values were evident in both the temperature regimes. Of all the genotypes tested, Local Khapli had the higher GDD followed by EIGSN-17 under both normal and late sown crop. The minimum GDD was observed with respect to genotype HD-2501 under both temperature regimes. The difference between the maximum and minimum GDD values were 394 and 369 respectively, for low temperature and high temperature regimes.

4.2 MORPHOLOGICAL CHARACTERS

4.2.1 Days to 50 per cent anthesis

Table 4. Influence of temperature regimes on growing degree days (GDD) upto 50 per cent anthesis in different wheat genotypes

Genotypes	Growing degree days	
	Low temperature	High temperature
Local Khapli	1125	1134
Bijaga yellow	919	918
Raj-1555	1068	1076
HD-4502	1073	1114
DWR-174	1014	1002
Bulk-776	874	841
Sham-1	983	951
EIGSN-17	1106	1114
Furat-4	950	917
D-417-29	964	968
HI-977	774	785
HD-2501	731	766
Mean	965	966

The data indicated that the days to 50 per cent anthesis were lower under low temperature regime as compared to high temperature regime (Table 5). The maximum number of days required for 50 per cent anthesis was more in Local Khapli under both temperature regimes followed by HD-4502 and the minimum was in HD-2501. Days to 50 per cent anthesis was same in Bulk-776 under both temperature regimes.

4.2.2 Plant height

Plant height differed significantly among genotypes, temperature regimes and their interaction at all the stages studied (Table 6). In general, the plant height was slightly more in the low temperature regime as compared to high temperature regime at all the stages, except at 35 DAS, where, the plant height in high temperature regime registered a marginal increase over low temperature regime. The maximum plant height was recorded in Bijaga yellow followed by Local Khapli in both the temperature regimes.

At 35 DAS, Bijaga yellow had the maximum plant height (36.60 cm) followed by Local Khapli (35.60 cm) in high temperature regime. The similar trend was observed in low temperature regime. No significant differences were observed between HD-4502 and DWR-174 and D-417-29 and HI-977 at high growth temperature. At 85 DAS and at harvest, the differences in the plant height were significant due to genotypes, temperature regimes and their

Table 5. Influence of temperature regimes on 50 per cent anthesis in wheat genotypes

Genotypes	Days to 50 per cent anthesis	
	Low temperature regime	High temperature regime
Local Khapli	64	65
Bijaga yellow	50	53
Raj-1555	60	62
HD-4502	63	64
DWR-174	57	58
Bulk-776	49	49
Sham-1	54	55
EIGSN-17	62	64
Furat-4	52	53
D-417-29	55	56
HI-977	44	46
HD-2501	42	45

Table 6. Influence of temperature regimes on plant **height (cm) at different growth** stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS			Harvest		
	Temperature regimes											
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	34.8	35.6	35.2	79.0	76.5	77.5	88.6	88.0	88.0	89.4	88.5	88.9
Bijaga yellow	36.3	36.6	36.4	83.2	79.9	81.6	90.3	88.4	89.3	90.6	89.9	90.3
Raj-1555	31.1	31.9	31.4	70.3	73.5	71.9	79.5	78.0	78.7	80.0	78.6	79.3
HD-4502	32.7	32.8	32.7	69.3	68.6	68.9	77.8	76.1	76.9	78.1	76.7	77.4
DWR-174	32.4	32.8	32.6	69.2	66.6	67.9	75.2	74.4	74.8	75.6	75.0	75.3
Bulk-776	31.1	31.8	31.5	74.3	72.2	73.5	72.8	71.5	72.1	83.3	82.0	82.6
Sham-I	31.4	31.3	31.4	71.8	70.3	71.1	77.6	76.5	77.0	78.0	76.8	77.4
EIGSN-17	30.2	30.2	30.2	69.4	68.5	69.0	75.9	74.7	75.3	76.0	75.0	75.5
Furat-4	30.9	31.2	31.0	73.2	72.5	72.8	77.5	76.0	76.8	78.3	77.5	77.9
D-417-29	31.8	32.6	32.2	74.8	73.5	74.2	79.7	79.0	79.4	80.1	79.5	79.2
HI-977	32.4	32.4	32.4	76.8	74.8	75.8	82.3	80.3	81.3	81.3	80.6	81.0
HD-2501	33.5	33.7	33.6	72.5	70.8	71.7	78.1	75.6	76.9	78.6	77.2	77.9
Mean	32.4	32.7		73.7	72.3		80.4	79.0		80.8	79.8	

	S.Em±	C D at 5%	S.Em±	C D at 5%	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.08	0.21	0.61	NS	0.32	0.92	0.11	0.33
Genotypes	0.18	0.52	1.49	4.25	0.79	2.26	0.28	0.80
Interaction	0.26	0.74	2.11	6.01	1.22	3.19	0.40	1.13

* DAS = Days after sowing

interaction. The range of plant height varied from 72.86 cm (Bulk-776) to 90.31 cm (Bijaga yellow) at low growth temperature and 71.51 cm (Bulk-776) to 88.35 cm (Bijaga yellow) at nigh growth temperature. The difference in the plant height due to temperature regimes was significant in all the genotypes indicating a significant reduction in plant height due to increase in growth temperature.

4.2.3 Number of green leaves

Number of green leaves differed significantly among genotypes, temperature regimes and their interaction at all the stages (Table 7). In general, the number of green leaves was more at low growth temperature as compared to high temperature in all the stages except at 35 DAS, where the late sown crop had more number of green leaves. The maximum number of green leaves recorded at high growth temperature was in D-417-29 (14.8) followed by Furat-4 (13.4), EIGSN-17 (11.8) and Raj-1555 (11.75). The genotypes DWR-174 and Sham-1, HD-4502 and Bijaga yellow and HD-2501 and Bulk-776 did not differ significantly among each other under this temperature regime. A similar trend was observed at low temperature also.

At 60 DAS, the maximum number of green leaves were observed in HD-4502 (19.9) followed by Raj-1555 (18.9) at low temperature and this trend corraborated with that of high temperature. At 85 DAS, there was no significant difference due to

Table 7. Influence of temperature regimes on **number of green leaves at different** growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	5.3	7.2	6.2	9.1	9.1	9.4	8.2	6.2	7.7
Bijaga yellow	7.7	9.9	8.8	10.4	9.2	9.8	2.4	2.0	2.2
Raj-1555	9.3	11.8	10.5	18.9	14.3	16.6	8.0	3.4	5.7
HD-4502	8.4	9.7	9.0	19.9	12.9	16.4	10.7	3.1	6.9
DWR-174	10.1	11.0	10.6	16.8	9.6	13.2	3.6	1.6	2.6
Bulk-776	8.3	9.2	8.8	15.2	12.0	13.6	4.8	4.1	4.5
Sham-1	10.4	11.2	10.8	13.6	6.1	9.8	5.1	3.9	4.5
EIGSN-17	11.7	11.8	11.7	10.6	10.2	10.4	9.6	3.4	6.6
Furat-4	12.9	13.4	13.2	11.0	9.8	10.4	4.7	2.7	3.7
D-417-29	14.7	14.8	14.8	12.7	11.0	11.8	8.3	2.0	5.2
HI-977	10.8	11.1	10.9	11.0	5.4	8.2	5.3	2.8	4.1
HD-2501	6.8	9.8	8.4	10.4	7.6	9.0	4.3	3.0	3.7
Mean	9.7	10.9		13.3	9.8		6.2	3.2	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.11	0.31		0.15	0.41		0.16	NS	
Genotypes	0.27	0.77		0.35	1.02		0.26	0.75	
Interaction	0.38	1.09		0.50	1.44		0.37	1.05	

*DAS = **Days** after **sowing**

temperature regimes, but significant differences were observed due to genotypes and their interaction. The differences in the number of green leaves due to temperature regimes, irrespective of genotypes indicated a significant reduction due to increase in the growth temperature.

4.2.4 Number of tillers

The data on the number of tillers per hill recorded at different stages as influenced by temperature regimes in different genotypes are presented in Table 8. Number of tillers per hill were generally more at low growth temperature as compared to high growth temperature at 60, 85 DAS and at harvest. Whereas, at 35 DAS, the number of tillers were more in high temperature regime. The maximum number of tillers at 35 DAS was in HD-4502 (5.31) followed by Sham-1 (4.96) at high temperature regime. A similar trend was noticed at low temperature regime.

At 60 DAS, all the genotypes registered the maximum number of tillers under low growth temperature. The maximum number of tillers were observed in Raj-1555 (6.63) followed by DWR-174 (6.43). No significant differences were observed between Bulk-176 and Sham-1 and Local Khapli and Bijaga yellow at low temperature regime. At 85 DAS and at harvest also, the difference in the number of tillers was evident with respect to genotypes, temperature regimes and their interaction. The number of tillers varied from 2.90 (Bijaga yellow) to 6.86 (Raj-1555) at low temperature regime, and at high temperature regime, the number of

Table 8. Influence of temperature regimes on **number of tillers at different** growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS			Harvest		
	Temperature regimes											
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	2.11	2.40	2.25	3.63	3.50	3.57	4.90	3.97	4.43	3.73	3.46	3.43
Bijaga yellow	3.26	3.58	3.42	3.56	3.20	3.38	2.90	2.53	2.71	2.50	2.20	2.35
Raj-1555	3.63	3.80	3.72	6.63	4.30	5.46	6.86	4.96	5.91	5.31	3.70	4.50
HD-4502	4.98	5.31	5.15	6.13	4.10	5.11	4.07	6.90	3.98	4.00	3.77	3.89
DWR-174	3.56	3.75	3.65	6.43	4.90	5.66	6.45	5.30	5.87	5.15	4.00	4.57
Bulk-776	3.63	3.88	3.72	4.00	3.63	3.82	3.40	2.45	2.93	2.75	1.73	2.24
Sham-1	4.31	4.96	4.64	4.21	3.11	3.65	3.50	3.33	3.42	3.05	2.11	2.58
EIGSN-17	3.91	4.58	4.25	4.30	2.73	3.51	3.70	2.60	3.15	3.20	2.30	2.75
Furat-4	4.31	4.75	4.53	3.56	2.95	3.26	3.50	2.30	2.90	2.91	1.73	2.32
D-417-29	3.90	4.53	4.21	5.73	4.40	5.06	3.90	3.20	3.45	3.68	2.70	3.19
HI-977	4.20	4.30	4.25	5.30	3.92	4.61	4.50	2.90	3.70	3.40	2.60	3.00
HD-2501	3.51	3.70	3.60	4.80	2.63	3.72	4.40	2.53	3.32	3.36	1.63	2.49
Mean	3.95	4.29		4.85	3.61		4.34	3.33		3.58	2.66	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.04	0.12		0.05	0.13		0.06	0.16		0.05	0.15	
Genotypes	0.10	0.29		0.11	0.33		0.14	0.40		0.13	0.37	
Interaction	0.14	0.41		0.16	0.46		0.20	0.57		0.19	0.53	

*DAS = Days after sowing

tillers varied from 1.63 (HD-2501) to 4.00 (DWR-174).

4.2.5 Leaf dry weight

The accumulation of dry matter in the leaf was low upto 35 DAS and increased almost 10 fold between 35 and 60 DAS (Table 9). Temperature regimes had significant differences in leaf dry weight only at 60 and 85 DAS. However, the differences due to genotypes and their interaction were significant at all the stages.

It was observed that, the leaf dry weight was more in high temperature regime at 35 DAS and later on, the leaf dry weight decreased significantly under high temperature regime. There was a difference in the attainment of peak leaf dry weight among genotypes. The maximum dry weight was noticed at 60 DAS in Raj-1555, HD-4502, DWR-174 and HD-2501, whereas, in rest of the genotypes, the maximum dry weight was noticed at 80 DAS.

At 35 DAS, the genotype Furat-4 had the maximum dry weight under both temperature regimes. At 60 DAS, Raj-1555 had significantly higher leaf dry weight (4.43 g/hill) over other genotypes under low temperature regime. The minimum dry weight was recorded in Sham-1 (1.40 g/hill). Whereas, under high temperature regime, DWR-174 (3.52 g/hill) and EIGSN-17 (0.90 g/hill) accumulated the maximum and minimum leaf dry weights, respectively. It was observed that the leaf dry weight increased marginally in all the genotypes except Raj-1555, HD-4502, DWR-174 and HD-2501 at 85 DAS. There was no significant difference between

Table 9. Influence of temperature regimes on leaf dry weight (g hill^{-1}) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS			Harvest		
	Temperature regimes											
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	0.27	0.32	0.29	2.21	1.68	1.97	3.00	3.08	3.04	3.05	2.78	2.92
Bijaga yellow	0.29	0.35	0.32	1.97	1.48	1.73	2.67	2.03	2.35	3.03	2.49	2.76
Raj-1555	0.23	0.35	0.29	4.43	2.28	3.36	2.86	1.96	2.41	2.03	2.00	2.02
HD-4502	0.26	0.29	0.28	4.03	2.35	3.19	3.15	2.45	2.80	2.88	3.59	3.24
DWR-174	0.33	0.38	0.35	3.84	3.52	3.68	2.46	2.64	2.55	2.30	2.52	2.41
Bulk-776	0.26	0.26	0.26	1.81	1.18	1.50	2.98	2.05	2.52	2.15	1.84	1.99
Sham-1	0.24	0.26	0.25	1.40	0.97	1.19	2.17	1.04	1.61	2.15	2.15	2.15
EIGSN-17	0.33	0.39	0.36	1.86	0.90	1.38	1.98	1.21	1.59	2.16	1.34	1.75
Furat-4	0.45	0.47	0.46	1.89	1.16	1.53	1.85	0.84	1.35	2.50	1.21	1.94
D-417-29	0.33	0.40	0.37	2.50	1.42	1.96	3.09	2.10	2.60	3.26	2.39	2.83
HI-977	0.26	0.30	0.28	2.31	1.70	2.01	3.04	2.18	2.61	2.78	2.47	2.63
HD-2501	0.29	0.34	0.32	3.18	1.48	2.33	3.13	1.56	2.35	1.34	0.96	1.02
Mean	0.30	0.34		2.61	1.67		2.69	1.93		2.46	2.15	

	35 DAS S.Em±	35 DAS C D at 5%	60 DAS S.Em±	60 DAS C D at 5%	85 DAS S.Em±	85 DAS C D at 5%	Harvest S.Em±	Harvest C D at 5%
Temperature regimes	0.005	NS	0.014	0.041	0.012	0.033	0.028	NS
Genotypes	0.012	0.035	0.035	0.101	0.029	0.082	0.069	0.197
Interaction	0.017	0.050	0.050	0.142	0.041	0.116	0.098	0.278

*DAS = Days after sowing

HD-4502, D-417-29 and HD-2501, under low temperature regime during which, these genotypes had maintained slightly higher leaf dry weight over other genotypes. Local Khapli had significantly higher leaf dry weight (3.08 g/hill) under high temperature regime. The minimum leaf dry weight was noticed in Furat-4 (0.84 g/hill). At harvest, the maximum leaf dry weight was recorded in D-417-29 (3.26 g/hill) and in HD-4502 (3.59 g/hill) respectively, under low and high temperature regimes. Although, the mean leaf dry weight was slightly more in high temperature regime as compared to low temperature regime, it was non-significant.

4.2.6 Stem dry weight

The data on the influence of temperature regimes on stem dry weight recorded at different stages is presented in Table 10. It indicated that the stem dry weight increased continuously from 35 DAS till harvest under high temperature regime. Whereas, under low temperature regime, it increased from 35 to 60 DAS and decreased slightly at 85 DAS as compared to 60 DAS and at harvest. The temperature regimes significantly reduced the stem dry weight at all the stages except at 35 DAS. The differences due to genotypes, temperature regimes and their interaction were significant at all the stages.

At 35 DAS, the genotype, DWR-174 recorded significantly higher stem dry weight over other genotypes under both temperature regimes. At 60 DAS, HD-4502 (2.29 g $hill^{-1}$) and Raj-1555 (2.15 g $hill^{-1}$) had slightly higher stem dry weight over other

Table 10. Influence of temperature regimes on stem dry weight (g $hill^{-1}$) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS			Harvest		
	Temperature regimes											
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	0.28	0.29	0.28	2.06	1.91	1.98	0.92	0.15	0.53	0.76	2.08	1.42
Bljaga yellow	0.47	0.55	0.51	1.27	1.35	1.29	1.04	1.01	1.02	0.88	1.98	1.43
Raj-1555	0.27	0.32	0.29	2.15	1.07	1.61	1.43	1.72	1.58	1.80	1.98	1.89
HD-4502	0.31	0.37	0.34	2.29	1.50	1.89	2.84	3.72	3.28	3.39	4.17	3.78
DWR-174	0.49	0.69	0.59	1.70	1.78	1.74	1.46	2.49	1.98	2.38	3.27	2.82
Bulk-776	0.35	0.48	0.26	2.08	2.14	2.11	1.81	2.19	2.00	2.39	2.95	2.67
Sham-1	0.24	0.34	0.29	1.45	1.61	1.53	1.96	2.00	1.98	2.79	2.43	2.61
EIGSN-17	0.29	0.39	0.34	1.80	1.73	1.76	1.71	2.28	1.99	2.75	3.42	3.08
Furat-4	0.33	0.37	0.35	2.01	2.13	2.07	2.55	1.49	2.02	2.50	1.41	1.95
D-417-29	0.47	0.56	0.51	1.44	1.43	1.43	1.40	0.44	0.92	2.78	3.27	3.02
HI-977	0.33	0.38	0.36	1.43	1.51	1.47	1.99	2.23	2.11	2.49	2.20	2.34
HD-2501	0.45	0.60	0.52	2.12	1.39	1.75	2.00	0.97	1.48	3.30	2.46	2.88
Mean	0.36	0.45		1.82	1.62		1.76	1.72		2.35	2.63	

	S.Em±	C D at 5%	S.Em±	C D at 5%	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.007	NS	0.010	0.028	0.010	0.030	0.012	0.035
Genotypes	0.016	0.046	0.024	0.068	0.025	0.072	0.030	0.086
Interaction	0.023	0.065	0.034	0.097	0.036	0.102	0.043	0.122

*DAS = Days after sowing

genotypes under low temperature regime. Whereas, in high temperature regime, Bulk-776 and Furat-4 were at par with each other and were superior over other genotypes under both low and high temperature regimes.

The genotype HD-4502 had the maximum stem dry weight under both temperature regimes and it had significantly higher values under high temperature regime as compared to low temperature regime at 85 DAS. The lowest stem dry weight was recorded in Local Khapli followed by Bijaga yellow under low temperature regime and Local Khapli followed by D-417-29 under high temperature regime. The similar trend was noticed with respect to Local Khapli and Bijaga yellow under low temperature regime at harvest. However, the maximum stem dry weight was recorded in HD-4502 under high temperature regime at this stage. All the genotypes recorded maximum stem dry weight under high temperature regime, except Sham-1, Furat-4, HI-977 and HD-2501 at harvest.

4.2.7 Spike weight

Similar to that of leaf dry weight and stem dry weight, no significant differences due to temperature regimes were observed in spike weight at 60 DAS. However, the differences due to temperature regimes, genotypes and their interaction were significant at 85 DAS and at harvest (Table 11).

Among the genotypes, HD-2501 had the maximum spike weight of 0.94 g hill^{-1} and 0.81 g hill^{-1} under low and high

Table 11. Influence of temperature regimes on spike weight (g $hill^{-1}$) at different growth stages in wheat genotypes

Genotypes	60 DAS*			85 DAS			Harvest		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	0.39	0.26	0.32	3.35	2.93	3.14	5.33	4.91	5.12
Bijaga yellow	0.77	0.50	0.63	4.25	3.50	3.87	6.73	5.67	6.20
Raj-1555	0.70	0.58	0.64	7.50	6.00	6.75	11.70	9.93	10.82
HD-4502	0.35	0.40	0.38	7.50	5.75	6.62	9.91	8.20	9.06
DWR-174	0.70	0.63	0.56	8.15	6.25	7.20	11.70	10.50	11.10
Bulk-776	0.84	0.70	0.77	5.75	4.00	4.87	7.00	5.35	6.17
Sham-1	0.66	0.57	0.61	5.25	3.50	6.37	7.22	5.00	6.11
EIGSN-17	0.35	0.16	0.25	5.50	4.00	4.75	7.51	5.50	6.50
Furat-4	0.65	0.59	0.62	4.75	3.15	3.95	7.00	5.50	6.25
D-417-29	0.52	0.21	0.37	7.00	6.25	6.62	9.25	8.10	8.67
HI-977	0.71	0.46	0.58	5.25	4.35	4.80	8.41	7.50	7.95
HD-2501	0.94	0.81	0.88	5.00	3.91	4.45	8.37	7.00	7.67
Mean	0.63	0.49		5.77	4.45		8.34	6.93	
	S.Em±	C.D at 5%		S.Em±	C.D at 5%		S.Em±	C.D at 5%	
Temperature regimes	0.008	NS		0.014	0.040		0.014	0.040	
Genotypes	0.020	0.006		0.035	0.099		0.035	0.099	
Interaction	0.029	0.082		0.049	0.140		0.049	0.140	

*DAS = **Days after sowing**

temperature regimes, respectively at 60 DAS. The lowest spike weight was recorded in EIGSN-17 and HD-4502 under low temperature and EIGSN-17 under high temperature regime at this stage. In general, the spike weight increased from 60 DAS till harvest in all the genotypes under both temperature regimes. At 85 DAS, DWR-174 had significantly higher spike weight under low temperature (8.15 g hill^{-1}) and high temperature (6.25 g hill^{-1}) regimes, however, it had the same spike weight as that of D-417-29 under high temperature regime. The minimum spike weight was observed in Local Khapli under low temperature (3.35 g hill^{-1}) and high temperature (2.93 g hill^{-1}) regimes at this stage. At harvest, Raj-1555 and DWR-174 had similar spike weight of 11.70 g hill^{-1} and were superior over rest of the genotypes under low temperature regime. The genotype DWR-174 maintained its position even under high temperature regime. The genotypes Bijaga yellow, Bulk-776, Sham-1, EIGSN-17, Furat-4 and Local Khapli recorded relatively low spike weight under both temperature regimes.

4.2.8 Total dry matter

The total dry matter per hill was obtained by adding individual leaf, stem and spike dry weights at different growth stages in both the temperature regimes for all the genotypes and presented in Table 12.

The data indicated significant differences in the total dry matter production due to temperature regimes, genotypes and their interaction at all the growth stages. There was a sharp

Table 12. Influence of temperature regimes on total dry matter production (g $hill^{-1}$) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS			Harvest		
	Temperature regimes											
	Low	High	Mean	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	0.55	0.61	0.58	4.67	3.85	4.26	7.27	6.16	7.04	9.14	9.77	9.45
Bijaga yellow	0.76	0.90	0.83	4.01	3.34	3.67	7.96	6.54	7.25	10.64	10.14	10.39
Raj-1555	0.50	0.67	0.58	7.28	3.94	5.61	11.80	9.70	10.75	15.53	13.91	14.72
HD-4502	0.57	0.66	0.61	6.68	4.26	5.47	13.49	11.94	12.44	16.18	15.96	16.07
DWR-174	0.82	1.08	0.95	6.26	5.93	6.10	12.07	11.39	11.73	16.38	16.29	16.33
Bulk-776	0.65	0.75	0.68	4.74	4.03	4.38	10.55	8.25	9.40	11.54	10.14	10.84
Sham-1	0.47	0.60	0.53	3.51	3.16	3.42	9.39	6.54	7.96	12.16	9.58	10.87
EIGSN-17	0.60	0.78	0.70	4.02	2.80	3.41	9.20	7.48	7.31	12.41	10.26	11.33
Furat-4	0.79	0.84	0.82	4.56	3.89	4.22	9.14	5.49	7.16	12.00	8.12	10.06
D-417-29	0.80	1.01	0.91	4.47	3.07	3.77	11.49	8.79	10.14	15.59	13.76	14.68
HI-977	0.60	0.68	0.64	4.46	3.67	4.06	10.29	8.76	9.52	13.68	12.17	12.92
HD-2501	0.74	0.94	0.84	6.25	3.69	4.97	10.14	6.44	8.29	12.99	10.42	11.70
Mean	0.65	0.79		5.08	3.80		10.23	8.12		13.18	11.71	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.01	0.04		0.09	0.11		0.03	0.08		0.08	0.10	
Genotypes	0.02	0.07		0.22	0.61		0.07	0.19		0.21	0.58	
Interaction	0.03	0.10		0.30	0.86		0.09	0.26		0.29	0.83	

*DAS = Days **after** sowing

increase in the total dry matter (TDM) between 35 and 60 DAS in both the temperature regimes. In general, there was a significant reduction in TDM due to high temperature at 60, 85 DAS and at harvest. Whereas, at 35 DAS, the increase in TDM was observed at high temperature as compared to low temperature. Among the genotypes, DWR-174, D-417-29, HD-2501, Furat-4 and Bijaga yellow recorded significantly higher TDM over other genotypes under low temperature regime. A similar trend was noticed even at high temperature regime also. At 60 DAS, the maximum dry matter was recorded in Raj-1555 and DWR-174 respectively, under low and high temperature regimes. However, no significant differences were observed between HD-4502, DWR-174, HD-2501 and between Local Khapli, Bulk-776, Furat-4, D-417-29 and HI-977 under low temperature regime. A similar trend was noticed even under high temperature regime at this stage.

At 85 DAS, HD-4502 recorded significantly higher TDM over other genotypes under both temperature regimes. The lowest TDM was recorded in Local Khapli and HD-2501 under low and high temperature regimes respectively. Whereas, at harvest, DWR-174 recorded maximum TDM followed by HD-4502 under both the temperature regimes and these had significantly high TDM over rest of the genotypes. The mean maximum TDM was recorded in DWR-174 at harvest. Again the low dry matter was recorded in Local Khapli under low temperature regime and Furat-4 under high temperature regime.

4.2.9 Leaf area

The leaf area increased nearly four-fold between 35 to 60 DAS and decreased slightly thereafter at 85 DAS (Table 13). It was observed that the leaf area decreased significantly under high temperature regime in all the stages except at 35 DAS, where, it increased significantly under high temperature regime. At 35 DAS, all the genotypes recorded a significant increase in leaf area under high temperature regime. The genotype Furat-4 had significantly higher leaf area over other genotypes in both the temperature regimes.

At 60 DAS, Raj-1555 had the maximum leaf area of 475.0 cm^{2} hill^{-1} and 373.4 cm^{2} hill^{-1} under low and high temperature regimes, respectively. The minimum leaf area was recorded in EIGSN-17 (301.7 cm^{2} hill^{-1}) under low temperature regime and Sham-1 (156.1 cm^{2} hill^{-1}) under high temperature regime. However, HD-4502 and D-417-29 did not differ significantly each other under low temperature regime. Similarly, EIGSN-17 and Furat-4 were at par with each other under high temperature regime. At 85 DAS, D-417-29 had significantly higher leaf area (385.3 cm^{2} hill^{-1}) over other genotypes under low temperature regime. Whereas, under high temperature regime, Local Khapli maintained significantly higher leaf area (308.6 cm^{2} hill^{-1}) over other genotypes and was at par with DWR-174 (304.5 cm^{2} hill^{-1}). The genotypes Bijaga yellow and Raj-1555, DWR-174 and HI-977, HD-2501 and HI-977 did not differ significantly with each other under low temperature regime. Whereas, under high temperature

Table 13. Influence of temperature regimes on **leaf area** (cm^2 $hill^{-1}$) at different stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	76.2	84.2	81.2	344.5	320.4	332.4	321.0	308.6	314.8
Bijaga yellow	68.2	110.6	89.4	323.6	285.7	304.6	315.0	275.3	295.1
Raj-1555	56.7	104.9	80.8	475.0	373.4	424.2	316.0	236.7	276.3
HD-4502	87.3	111.7	99.5	425.0	345.9	385.4	344.5	271.1	307.8
DWR-174	72.9	106.0	89.4	433.0	361.6	397.3	368.2	304.5	336.3
Bulk-776	52.5	63.1	57.8	375.4	246.6	311.0	305.0	215.6	260.3
Sham-1	59.4	80.7	70.0	313.6	156.1	234.8	261.0	152.7	206.8
EIGSN-17	67.0	90.6	78.8	301.7	174.6	238.1	275.0	169.3	222.1
Furat-4	103.1	137.0	120.1	307.6	175.2	241.4	295.0	149.8	222.4
D-417-29	74.2	104.9	89.6	400.0	301.2	350.6	385.3	275.5	330.4
HI-977	74.9	91.7	83.3	389.6	313.6	351.6	363.0	300.2	331.6
HD-2501	84.2	93.9	89.0	374.6	237.3	305.9	359.0	230.0	294.5
Mean	73.1	92.3		371.9	274.3		325.7	240.8	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	1.19	3.39		1.24	3.52		0.77	2.20	
Genotypes	2.92	8.30		3.03	8.63		1.91	5.39	
Interaction	4.12	11.73		4.29	12.21		2.68	7.63	

*DAS = Days after sowing

regime, the genotypes Bijaga yellow and HD-4502, Bijaga yellow and D-417-29, DWR-174 and HI-977 did not have significant differences among themselves.

4.3 GROWTH PARAMETERS

4.3.1 Crop Growth Rate

The data on the crop growth rate (CGR) was recorded at different growth stages in all the genotypes and are presented in Table 14. At 35-60 DAS, maximum CGR was observed in Raj-1555 (0.216 g dm^{-2} day^{-1}) followed by HD-4502 (0.213 g dm^{-2} day^{-1}) and the minimum was observed in Sham-1 (0.106 g dm^{-2} day^{-1}) at low temperature regime. At high temperature regime, DWR-174 showed maximum CGR (0.168 g dm^{-2} day^{-1}) and minimum was in Bijaga yellow (0.085 g dm^{-2} day^{-1}). No significant differences were observed between Furat-4 and D-417-29 and between Raj-1555 and HD-4502 at low temperature regime and at high temperature regime, non-significant difference was observed between Raj-1555 and HD-4502.

At 60-85 DAS, the maximum CGR was observed in Furat-4 and D-417-29 (0.243 g dm^{-2} day^{-1}) and minimum in Local Khapli (0.09 g dm^{-2} day^{-1}) at low temperature regime. At higher temperature regime, the maximum CGR was observed in HD-4502 (0.267 g dm^{-2} day^{-1}) and minimum was in Furat-4 (0.056 g dm^{-2} day^{-1}). Significant differences were observed among genotypes, temperature regimes and their interactions. However, no

Table 14. Influence of temperature regimes on crop growth rate (CGR, g dm^{-2} day^{-1}) at different growth stages in wheat genotypes

Genotypes	35 - 60 DAS*			60 - 85 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	0.142	0.112	0.127	0.090	0.104	0.097
Bijaga yellow	0.113	0.085	0.099	0.139	0.111	0.125
Raj-1555	0.216	0.113	0.164	0.177	0.200	0.188
HD-4502	0.213	0.125	0.169	0.236	0.267	0.268
DWR-174	0.189	0.168	0.178	0.202	0.189	0.195
Bulk-776	0.143	0.114	0.128	0.201	0.146	0.173
Sham-1	0.106	0.088	0.097	0.204	0.117	0.160
EIGSN-17	0.118	0.069	0.094	0.159	0.120	0.139
Furat-4	0.131	0.106	0.118	0.243	0.056	0.149
D-417-29	0.127	0.071	0.099	0.243	0.184	0.213
HI-977	0.134	0.103	0.174	0.202	0.176	0.189
HD-2501	0.191	0.095	0.143	0.135	0.095	0.115
Mean	0.151	0.104		0.185	0.147	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.005	0.007	0.012	0.033
Genotypes	0.012	0.033	0.029	0.082
Interaction	0.016	0.047	0.041	0.116

*DAS = Days after sowing

significant difference was observed between Bulk-776 and Sham-1 at low temperature regime.

4.3.2 Absolute Growth Rate

The data as influenced by temperature regimes on absolute growth rate (AGR) at different stages in wheat genotypes are presented in Table 15. It indicated that AGR decreased from 35-60 DAS to 60-85 DAS, irrespective of temperature regimes. At 35-60 DAS, AGR decreased at high temperature regime over low temperature regime in all the genotypes. The maximum AGR was recorded in Raj-1555 (0.248 g day^{-1}) which was closely followed by HD-4502 (0.246 g day^{-1}) at low temperature regime. But, in high temperature regime, DWR-174 recorded maximum AGR (0.194 g day^{-1}), and the lowest was in EIGSN-17 (0.08 g day^{-1}). Significant differences were observed due to temperature regime, genotypes and their interaction. However, no significant differences were observed between Raj-1555, HD-4502, Furat-4 and D-417-29 at low temperature regime.

At 60-85 DAS, the maximum AGR was observed in D-417-29 (0.280 g day^{-1}) and Raj-1555 (0.230 g day^{-1}) at low and high temperature regimes, respectively. The lowest AGR was recorded in Local Khapli (0.104 g day^{-1}) at low temperature regime and at high temperature regime, the genotype HD-2501 recorded the lowest AGR (0.110 g day^{-1}). Significant differences were observed between DWR-174, Bulk-776, Sham-1 and HI-977 at low temperature regime. Whereas, at high temperature regime, no significant

Table 15. Influence of temperature regimes on absolute growth rate (AGR, g day^{-1}) at different growth stages in wheat genotypes

Genotypes	35 - 60 DAS*			60 - 85 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	0.164	0.129	0.146	0.104	0.120	0.112
Bijaga yellow	0.130	0.098	0.114	0.160	0.128	0.144
Raj-1555	0.248	0.130	0.189	0.204	0.230	0.217
HD-4502	0.246	0.144	0.195	0.272	0.307	0.309
DWR-174	0.218	0.194	0.206	0.232	0.218	0.225
Bulk-776	0.165	0.131	0.148	0.232	0.168	0.200
Sham-1	0.122	0.102	0.112	0.233	0.135	0.192
EIGSN-17	0.136	0.080	0.108	0.207	0.133	0.172
Furat-4	0.151	0.122	0.136	0.183	0.064	0.123
D-417-29	0.147	0.082	0.114	0.280	0.212	0.206
HI-977	0.142	0.119	0.130	0.233	0.203	0.218
HD-2501	0.220	0.110	0.165	0.156	0.110	0.133
Mean	0.174	0.120		0.208	0.172	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.002	0.006	0.003	0.008
Genotypes	0.005	0.015	0.007	0.019
Interaction	0.007	0.021	0.010	0.027

*DAS = Days after sowing

differences were observed between Sham-1 and EIGSN-17.

4.3.3 Relative Growth Rate (RGR)

The computation of the data for relative growth rate (RGR) indicated that all the genotypes maintained higher RGR in low temperature at 35-60 DAS, as compared to high temperature regime. However, at 60-85 DAS, the RGR was more in the high temperature regime as compared to low temperature regime (Table 16). It was evident from the data that the differences due to genotypes, temperature regimes and their interaction was significant at both the stages. At 35-60 DAS, Raj-1555 recorded the maximum RGR (0.103 g g^{-1} day^{-1}) which was closely followed by HD-4502 (0.098 g g^{-1} day^{-1}) under low temperature, whereas, under high temperature, HD-4502 and Local Khapli had the maximum RGR (0.074 g g^{-1} day^{-1}) and were closely followed by Raj-1555 (0.070 g g^{-1} day^{-1}) and were significantly superior over other genotypes. No significant differences were observed between DWR-174, Bulk-776, Sham-1 and HI-977 under both the temperature regimes at this stage. At 60-85 DAS, Sham-1 maintained the highest RGR (0.039 g g^{-1} day^{-1}) and the lowest was recorded in Local Khapli under low temperature regime. In general, the RGR increased under high temperature as compared to low temperature in all the genotypes except, Bulk-776, Sham-1 and Furat-4, where it declined. No significant differences were observed between Raj-1555 and HI-977, DWR-174, Bulk-776 and Sham-1, Local Khapli and HD-4502 under high temperature regime at this stage.

Table 16. Influence of temperature regimes on relative growth rate (RGR, g g^{-1} day^{-1}) at different growth stages in wheat genotypes

Genotypes	35 - 60 DAS*			60 - 85 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	0.085	0.074	0.079	0.017	0.023	0.020
Bijaga yellow	0.066	0.052	0.059	0.027	0.048	0.037
Raj-1555	0.103	0.070	0.086	0.023	0.036	0.029
HD-4502	0.098	0.074	0.086	0.028	0.041	0.063
DWR-174	0.081	0.068	0.084	0.026	0.026	0.026
Bulk-776	0.082	0.067	0.050	0.032	0.029	0.030
Sham-1	0.080	0.066	0.073	0.039	0.029	0.034
EIGSN-17	0.074	0.051	0.062	0.033	0.039	0.036
Furat-4	0.070	0.061	0.062	0.028	0.014	0.021
D-417-29	0.068	0.044	0.056	0.038	0.040	0.039
HI-977	0.080	0.067	0.074	0.033	0.035	0.034
HD-2501	0.085	0.055	0.068	0.019	0.022	0.020
Mean	0.081	0.062		0.028	0.032	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.001	0.003	0.001	0.003
Genotypes	0.002	0.006	0.001	0.003
Interaction	0.003	0.008	0.001	0.004

*DAS = Days after sowing

4.3.4 Net Assimilation Rate (NAR)

The net assimilation rate (NAR) values decreased from 35-60 DAS under both temperature regimes (Table 17). Significant differences due to temperature regimes were observed only at 35-60 DAS. Whereas, the differences due to genotypes and the interaction between temperature regimes and genotypes were significant at both the stages. At 35-60 DAS, Raj-1555 recorded significantly higher NAR (0.126 g dm^{-2} day^{-1}) over other genotypes. The differences between DWR-174, HD-4502 and HD-2501, and between Bijaga yellow, Sham-1, EIGSN-17, Furat-4 and HI-977 were not significant at low temperature regime. The NAR decreased due to high temperature in all the genotypes, with Bulk-776 maintaining a high NAR (0.098 g dm^{-2} day^{-1}) followed by DWR-174 (0.093 g dm^{-2} day^{-1}) and Sham-1 (0.090 g dm^{-2} day^{-1}). No significant differences were observed Bijaga yellow, Raj-1555, HD-4502, D-417-29, HI-977 and HD-2501 under high temperature regime. Although, the NAR was marginally increased under high temperature regime over low temperature, the increase was non-significant. However, in Bijaga yellow and Furat-4 there was a slight decrease in NAR under high temperature regime. The genotype EIGSN-17 had the maximum NAR (0.109 g dm^{-2} day^{-1}) followed by HD-4502 (0.100 g dm^{-2} day^{-1}) at 60-85 DAS.

4.3.4 Leaf Area Index (LAI)

The data on the influence of temperature regimes on leaf area index (LAI) indicated that LAI increased from 35 DAS to 60 DAS and decreased thereafter at 85 DAS in both the temperature

Table 17. Influence of temperature regimes on net assimilation rate (NAR, g dm^{-2} day^{-1}) at different growth stages in wheat genotypes

Genotypes	35 - 60 DAS*			60 - 85 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	0.093	0.073	0.083	0.031	0.038	0.037
Bijaga yellow	0.079	0.053	0.066	0.050	0.046	0.048
Raj-1555	0.126	0.062	0.094	0.052	0.077	0.064
HD-4502	0.115	0.070	0.092	0.071	0.100	0.085
DWR-174	0.108	0.093	0.100	0.058	0.066	0.062
Bulk-776	0.101	0.098	0.099	0.069	0.074	0.072
Sham-1	0.080	0.090	0.085	0.082	0.088	0.085
EIGSN-17	0.087	0.063	0.075	0.072	0.109	0.090
Furat-4	0.081	0.078	0.079	0.061	0.040	0.050
D-417-29	0.077	0.044	0.060	0.072	0.074	0.073
HI-977	0.081	0.066	0.073	0.062	0.066	0.064
HD-2501	0.114	0.071	0.092	0.042	0.047	0.044
Mean	0.095	0.071		0.060	0.068	
	S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.003	0.010		0.004	NS	
Genotypes	0.008	0.024		0.010	0.029	
Interaction	0.012	0.034		0.014	0.041	

*DAS = Days after sowing

regimes (Table 18). Differences due to temperature regimes, genotypes and their interaction were significant at all the stages studied.

At 35 DAS, the LAI was more under high temperature regime as compared to low temperature regime in all the genotypes and was significant. Among the genotypes, Furat-4 recorded significantly higher LAI over other genotypes under both the temperature regimes. The lowest LAI was recorded in Bulk-776 under low (0.46) and high (0.54) temperature regimes. At 60 DAS, the LAI was more in low temperature regime as compared to high temperature regime in all the genotypes. The genotype Raj-1555 had the maximum LAI under both high and low temperature regimes (4.13 and 3.25, respectively). However, no significant differences were observed between HD-4502 and DWR-174 and between Sham-1, EIGSN-17 and Furat-4 under low temperature regime. Whereas, under high temperature regime, Local Khapli, D-417-29 and HI-977 did not differ significantly among themselves. At 85 DAS, the maximum LAI was recorded in D-417-29 and Local Khapli under low and high temperature regimes, respectively. The lowest LAI was recorded in Sham-1 (2.27) and Furat-4 (1.30) respectively, under low and high temperature regimes. However, Sham-1 and Furat-4; HD-4502, Bijaga yellow and D-417-29; DWR-174 and HI-977; Raj-1555 and HD-2501 did not differ significantly among themselves.

4.3.6 Leaf Area Duration (LAD)

The data on the influence of growth temperature on

Table 18. Influence of temperature regimes on leaf area index (LAI) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	0.66	0.73	0.69	2.99	2.78	2.88	2.79	2.68	2.73
Bijaga yellow	0.59	0.96	0.77	2.80	2.48	2.64	2.73	2.39	2.56
Raj-1555	0.49	0.91	0.70	4.13	3.25	3.69	2.74	2.05	2.40
HD-4502	0.76	0.97	0.86	3.69	3.01	3.35	2.99	2.35	2.67
DWR-174	0.63	0.92	0.77	3.66	3.14	3.45	3.20	2.64	2.92
Bulk-776	0.46	0.54	0.50	3.26	2.14	2.70	2.65	1.87	2.26
Sham-1	0.52	0.70	0.61	2.72	1.35	2.03	2.27	1.32	1.79
EIGSN-17	0.58	0.79	0.68	2.62	1.52	2.07	2.39	1.47	1.93
Furat-4	0.90	1.19	1.05	2.67	1.52	2.09	2.56	1.30	1.93
D-417-29	0.64	0.91	0.78	3.47	2.61	3.04	3.35	2.40	2.88
HI-977	0.65	0.80	0.72	3.38	2.72	3.05	3.15	2.61	2.88
HD-2501	0.73	0.82	0.78	3.25	2.06	2.66	3.12	2.00	2.56
Mean	0.63	0.85		3.22	2.38		2.82	2.09	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.01	0.03		0.02	0.06		0.02	0.06	
Genotypes	0.03	0.08		0.06	0.16		0.05	0.14	
Interaction	0.04	0.11		0.08	0.22		0.07	0.20	

*DAS = Days after sowing

leaf area duration (LAD) recorded at different growth stages indicated that LAD increased from 35-60 to 60-85 DAS in all the genotypes (Table 19). The highest LAD was observed in Raj-1555 (57.8 days) and the lowest in HD-2501 (49.8 days) between 35-60 DAS in low temperature regime. At high temperature also, Raj-1555 (52 days) retained its position which was closely followed by DWR-174 (50.8 days) and the lowest was in Sham-1 (25.6 days). The significant differences were observed among temperature regimes, genotypes and their interactions at both the stages.

At 60-85 DAS, the maximum LAD was recorded in DWR-174 (87.0 days) which was significantly higher over other genotypes at low temperature. At high temperature also, the maximum LAD was observed in DWR-174 (72.2 days) followed by Local Khapli (68.2 days). It was observed that the LAD was almost reduced to half in the genotypes Sham-1, EIGSN-17 and Furat-4 at high temperature regime. The mean maximum LAD was recorded in DWR-174 (79.6 days) followed by Raj-1555 (76.1 days) and the mean minimum in sham-1 (47.9 days) at 60-85 DAS. However, no significant differences were observed between Sham-1 and EIGSN-17 at low temperature and between Raj-1555 and HD-4502 at high growth temperature.

4.3.7 Specific Leaf Area (SLA)

The data on the influence of temperature regimes on specific leaf area (SLA) at different growth stages in wheat genotypes is presented in Table 20. It was observed that the mean

Table 19. Influence of temperature regimes on leaf area duration (LAD, days) at different growth stages in wheat genotypes

Genotypes	35 - 60 DAS*			60 - 85 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	45.6	43.9	44.6	72.2	68.2	70.2
Bijaga yellow	42.4	40.0	41.2	69.1	60.9	65.0
Raj-1555	57.8	52.0	54.9	85.9	66.2	76.1
HD-4502	55.6	49.8	52.7	83.5	67.0	75.2
DWR-174	54.9	50.8	52.8	87.0	72.2	79.6
Bulk-776	46.5	33.5	40.0	73.9	50.1	62.0
Sham-1	40.5	25.6	33.1	62.4	33.4	47.9
EIGSN-17	40.0	28.9	34.4	62.6	37.4	50.0
Furat-4	44.6	33.9	39.2	65.4	35.2	50.3
D-417-29	51.3	44.0	47.7	85.2	62.6	73.9
HI-977	50.3	44.0	47.2	81.6	66.6	74.1
HD-2501	49.8	36.0	42.9	79.6	50.8	65.2
Mean	48.3	40.2		75.7	55.9	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.14	0.38	0.90	2.53
Genotypes	0.33	0.94	0.63	1.78
Interaction	0.47	1.34	0.26	0.73

*DAS = Days after sowing

SLA significantly increased under high temperature regime only at 35 and 60 DAS. Genotypes, temperature regimes and their interaction indicated significant differences at all the stages. At 35 DAS, Bulk-776 and HD-4502 recorded the maximum SLA under low (4.16 dm^2 g^{-1}) and high temperature (3.84 dm^2 g^{-1}) regimes, respectively. Although, the SLA increased under high temperature regime over its corresponding value in low temperature regime. It decreased in the genotypes Local Khapli, Bulk-776 and HD-2501. The minimum SLA was recorded in the genotype EIGSN-17 under both temperature regime.

At 60 DAS also, the SLA was more under high temperature regime as compared to low temperature regime, except in genotypes Sham-1 and Furat-4. The maximum SLA was recorded in Sham-1 (2.27 dm^2 g^{-1}) and was significantly superior over rest of the genotypes under low temperature regime. However, no significant differences were observed between Local Khapli, Bijagar yellow, EIGSN-17, Furat-4, D-417-29 and HI-977 under low temperature regime. Under high temperature regime, D-417-29 (2.14 dm^2 g^{-1}) and Bulk-776 (2.08 dm^2 g^{-1}) recorded significantly higher SLA over other genotypes.

At 85 DAS, the differences between the two temperature regimes were not significant in all the genotypes except Sham-1, Furat-4, HI-977 and HD-2501. Among the genotypes, Furat-4, recorded significantly higher SLA under both the temperature regimes.

Table 20. Influence of temperature regimes on specific **leaf area** (dm^2 g^{-1}) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	2.85	2.63	2.74	1.56	1.92	1.74	1.07	1.00	1.03
Bijaga yellow	2.38	3.22	2.80	1.63	1.96	1.79	1.19	1.36	1.27
Raj-1555	2.38	2.94	2.66	1.01	1.63	1.36	1.11	1.20	1.15
HD-4502	3.33	3.84	3.58	1.06	1.47	1.26	1.09	1.11	1.10
DWR-174	2.22	2.77	2.49	1.13	1.03	1.08	1.49	1.16	1.32
Bulk-776	4.16	2.38	3.27	2.08	2.08	2.08	1.03	1.05	1.04
Sham-1	2.50	3.03	2.76	2.27	1.61	1.94	1.20	1.47	1.34
EIGSN-17	2.08	2.32	2.20	1.61	1.96	1.78	1.38	1.40	1.39
Furat-4	2.25	2.94	2.59	1.63	1.51	1.57	1.61	1.78	1.69
D-417-29	2.25	2.63	2.44	1.61	2.12	1.86	1.25	1.31	1.28
HI-977	2.85	3.03	2.94	1.69	1.85	1.77	1.16	1.38	1.27
HD-2501	2.85	2.77	2.81	1.17	1.61	1.39	1.14	1.49	1.32
Mean	2.68	2.88		1.54	1.73		1.23	1.31	

	S.Em±	C D at 5%	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.05	0.15	0.03	0.09	0.04	0.10
Genotypes	0.13	0.36	0.08	0.22	0.09	0.24
Interaction	0.18	0.51	0.11	0.31	0.12	0.34

*DAS = **Days** after **sowing**

4.3.8 Specific Leaf Weight (SLW)

The data on the influence of temperature regimes on specific leaf weight (SLW) indicated that the SLW increased from 35 DAS to 85 DAS under both the temperature regimes (Table 21). In general, mean SLW of various genotypes decreased with an increase in growth temperature with exceptions at 60 and 85 DAS. At 35 DAS, the SLW decreased under high temperature regime in *all the* genotypes except in Local Khapli, Bulk-776 and HD-2501 in which there was a slight increase over its corresponding value under low temperature regime but was non-significant. The differences due to temperature regimes, genotypes and their interaction were significant at all the stages studied. Among the genotypes. EIGSN-17 recorded significantly higher SLW under both the temperature regimes. There were no significant differences between Bijaga yellow, Raj-1555, DWR-174, Sham-1, EIGSN-17, Furat-4 and D-417-29 under low temperature regime. Whereas, under high temperature regime, Local Khpali, Bulk-776, EIGSN-17 and D-417-29 did not differ significantly among themselves.

At 60 DAS, HD-4502 (0.94 g dm^{-2}) and Raj-1555 (0.93 g dm^{-2}) recorded significantly higher SLW over other genotypes under low temperature regime. At high temperature regime, DWR-174 had the maximum SLW (0.97 g dm^{-2}) and was significantly higher over rest of the genotypes. Considering all the samplings and growth temperatures, the maximum SLW was registered in Local Khapli (1.00 g dm^{-2}) under high temperature regime at 85 DAS. Although SLW decreased under high temperature

Table 21. Influence of temperature regimes on specific **leaf** weight (g dm^{-2}) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	0.35	0.38	0.37	0.64	0.52	0.58	0.93	1.00	0.97
Bijaga yellow	0.42	0.31	0.36	0.61	0.51	0.56	0.84	0.73	0.78
Raj-1555	0.42	0.34	0.38	0.93	0.61	0.77	0.90	0.83	0.86
HD-4502	0.30	0.26	0.28	0.94	0.68	0.81	0.91	0.90	0.91
DWR-174	0.45	0.36	0.41	0.88	0.97	0.92	0.67	0.86	0.76
Bulk-776	0.24	0.42	0.33	0.48	0.48	0.48	0.97	0.95	0.96
Sham-1	0.40	0.33	0.36	0.44	0.62	0.53	0.83	0.68	0.75
EIGSN-17	0.48	0.43	0.46	0.62	0.51	0.57	0.72	0.71	0.72
Furat-4	0.44	0.34	0.39	0.61	0.66	0.63	0.62	0.56	0.59
D-417-29	0.44	0.38	0.41	0.62	0.47	0.54	0.80	0.76	0.78
HI-977	0.35	0.33	0.34	0.59	0.54	0.56	0.86	0.72	0.79
HD-2501	0.35	0.36	0.36	0.85	0.62	0.74	0.87	0.67	0.77
Mean	0.39	0.35		0.68	0.60		0.83	0.78	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.01	0.03		0.01	0.01		0.02	0.05	
Genotypes	0.02	0.06		0.01	0.03		0.04	0.13	
Interaction	0.03	0.09		0.02	0.05		0.06	0.18	

*DAS - Days after sowing

regime as compared to low temperature regime at 85 DAS, the genotypes Local Khapli and DWR-174 recorded increase in SLW under high temerature regime, but the differences were non-significant.

4.4 YIELD AND YIELD COMPONENTS

The data on the influence of temperature regimes on grain yield, and yield components such as Harvest index (HI), 1000-grain weight and spike length are presented in Table 22a and 22b.

4.4.1 Harvest Index (HI)

In general, the Harvest index (HI) decreased at high growth temperature as compared to low growth temperature in all the genotypes. The differences due to genotypes, temperature regimes and their interaction were significant. Among the genotypes, Raj-1555 had significantly higher HI (64.6%) over other genotypes under low temperature regime. The lowest HI was recorded in Bijaga yellow (47.0%). Under high temperature regime also, Raj-1555 recorded significantly higher HI (56.9%) over other genotypes. The lowest HI was noticed in Bulk-776 (40.4%). However, no significant differences were observed in Bijaga yellow, Local Khapli, Furat-4, D-417-29, HI-977 and HD-2501.

4.4.2 1000-grain Weight

The data on 1000-grain weight also differed significantly due to temperature regimes, genotypes and their interaction. The maximum 1000-grain weight was recorded in

Table 22a. Influence of temperature regimes on harvest index (%), **1000-grain** weight (g) and spike length (cm) in wheat genotypes

Genotypes	Harvest index (%)			1000-grain weight (g)			Spike length (cm)		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	46.50	46.10	46.30	42.10	40.20	41.15	8.35	8.05	8.20
Bijaga yellow	47.00	46.50	46.75	40.30	37.40	38.85	6.99	6.73	6.86
Raj-1555	64.60	56.90	60.60	39.40	32.80	36.10	5.76	4.35	5.05
HD-4502	59.90	49.30	54.60	38.60	33.70	36.15	6.31	5.96	6.13
DWR-174	60.30	51.50	55.90	41.00	37.20	39.10	6.01	5.35	5.68
Bulk-776	47.60	40.40	44.00	36.90	30.20	33.20	5.79	4.69	5.24
Sham-1	49.60	41.50	45.55	36.20	28.50	32.35	7.22	5.81	6.51
EIGSN-17	50.30	42.90	46.60	39.60	32.80	36.20	8.21	7.10	7.65
Furat-4	49.40	46.10	47.75	37.40	29.10	33.25	5.87	4.67	5.27
D-417-29	53.90	45.90	49.90	35.73	31.82	33.77	5.76	4.83	5.29
HI-977	51.40	46.80	49.10	36.60	32.30	34.45	6.94	6.66	6.80
HD-2501	51.90	47.00	49.45	33.30	26.40	29.85	7.33	6.53	6.93
Mean	52.70	46.74		38.09	32.70		6.70	5.89	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.63	1.80		0.40	1.13		0.05	0.14	
Genotypes	1.55	4.40		0.97	2.80		0.12	0.34	
Interaction	2.19	6.23		1.38	3.92		0.17	0.48	

Local Khapli in both the temperature regimes followed by D-417-29. The 1000-grain weight was drastically reduced due to high growth temperature in all the genotypes, except Local Khapli, Bijaga yellow and DWR-174. The lowest weight was recorded in D-417-29 and HD-2501 under low and high temperature regimes, respectively.

4.4.3 Spike Length

The spike length differed significantly due to temperature regimes, genotypes and their interactions. There was a significant reduction in spike length due to high growth temperature in all the genotypes. Among the genotypes, the maximum spike length was noticed in Local Khapli under both the temperature regimes. At low temperature regime, the spike length in EIGSN-17 was at par with Local Khapli. The minimum spike length was recorded in Raj-1555 under both the temperature regimes. However, HI-977 and HD-2501 did not differ significantly in their spike length at high temperature regime.

4.4.4 Grain Yield

The data on the grain yield indicated that it was significantly influenced by temperature regimes, genotypes and their interaction. In general, there was 21 per cent reduction in grain yield due to high growth temperature. Among the genotypes, Raj-1555 (9.75 g $hill^{-1}$) recorded significantly higher grain yield over other genotypes under low temperature regime. This was followed by DWR-174 (9.6 g $hill^{-1}$) and HD-4502 (9.5 g $hill^{-1}$). The yield levels were same in Sham-1 and Furat-4 (5.75 g $hill^{-1}$) and

Table 22b. Influence of temperature regimes on grain yield (g $hill^{-1}$) in wheat genotypes

Genotypes	Grain yield (g $hill^{-1}$)		Mean
	Low temperature regime	High temperature regime	
Local Khapli	4.26	4.10 (3.76)*	4.12
Bijaga yellow	5.00	4.49 (10.20)	4.74
Raj-1555	9.75	7.75 (20.52)	8.75
HD-4502	9.50	7.88 (17.15)	8.69
DWR-174	9.60	8.40 (12.50)	9.00
Bulk-776	5.50	4.10 (25.44)	4.80
Sham-1	5.75	3.75 (34.79)	4.75
EIGSN-17	6.25	4.40 (29.60)	5.30
Furat-4	5.75	3.75 (34.79)	4.75
D-417-29	7.50	5.85 (22.00)	6.68
HI-977	6.75	5.70 (15.56)	6.22
HD-2501	6.75	4.90 (27.41)	5.82
Mean	6.86	5.42	

	S.Em±	C D at 5%
Temperature regimes	0.006	0.027
Genotypes	0.020	0.066
Interaction	0.030	0.093

*Figures in the parenthesis indicate per cent decrease over low temperature regime.

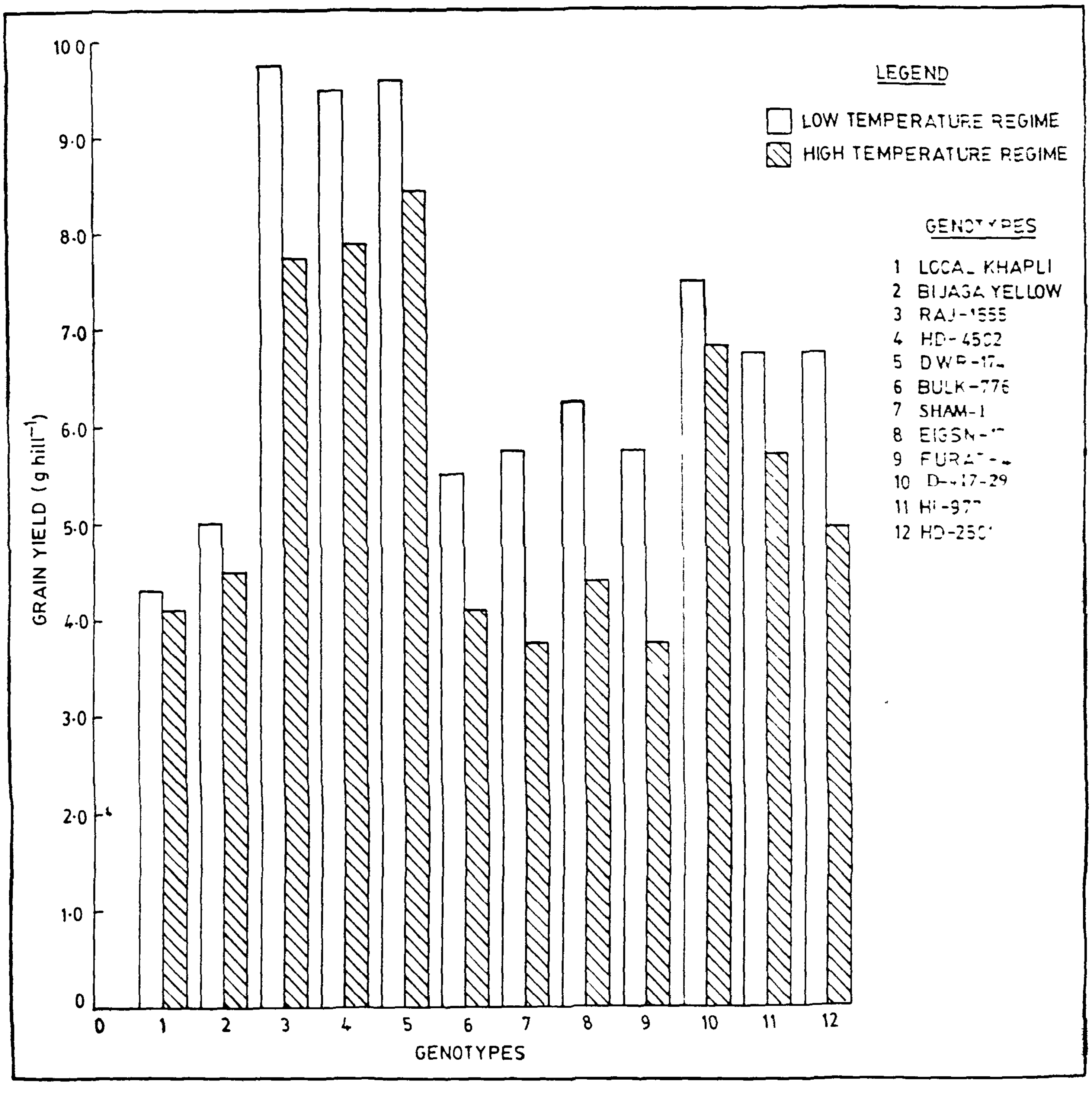

FIG. 6. INFLUENCE OF TEMPERATURE REGIMES ON GRAIN YIELD IN WHEAT GENOTYPES

in HI-977 and HD-2501 (6.75 g hill^{-1}). The lowest yield was recorded in Local Khapli (4.26 g hill^{-1}) under low temperature regime. The maximum yield under high temperature regime was recorded in DWR-174 (8.40 g hill^{-1}) followed by HD-4502 (7.88 g hill^{-1}) and Raj-1555 (7.75 g hill^{-1}). The lowest yield under high temperature regime was recorded in Sham-1 and Furat-4 (3.75 g hill^{-1}). If we compare the per cent reduction in grain yield due to high growth temperature, the genotype Local Khapli had the lowest per cent reduction (3.75%) followed by Bijaga yellow (10.2%) and DWR-174 (12.5%). The maximum per cent reduction in grain yield was recorded in Sham-1 and Furat-4 (34.79%).

4.5 BIOPHYSICAL CHARACTERS

4.5.1 Leaf Diffusion Resistance (LDR)

The data pertaining to the influence of temperature regimes on leaf diffusion resistance (LDR) was measured at 60 and 85 DAS and presented in Table 23. The LDR increased by nearly three-fold from 65 to 80 DAS, under both temperature regimes. It also indicated significant differences between temperature regimes. genotypes and their interaction at both the stages. At 60 DAS. Bulk-776 and Furat-4 had the maximum and minimum LDR under both temperature regimes. The genotypes DWR-174, Sham-1, HI-977 and HD-2501 recorded moderately high leaf resistance values and there were no significant differences amongst them under high temperature regime at 60 DAS. The genotypes, Bijaga yellow, Raj-1555, HD-4502 and EIGSN-17 also did not differ significantly with each other.

Table 23. Influence of temperature regimes on leaf diffusion resistance (LDR, s cm^{-1}) at different growth stages in wheat genotypes

Genotypes	60 DAS*			80 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	0.30	0.57	0.43	0.62	3.52	2.07
Bijaga yellow	0.39	0.83	0.61	1.21	4.40	2.81
Raj-1555	0.36	0.89	0.63	0.87	1.92	1.40
HD-4502	0.24	0.83	0.54	0.58	1.84	1.21
DWR-174	0.32	1.10	0.70	0.78	1.86	1.32
Bulk-776	0.50	1.48	0.99	1.30	2.52	1.91
Sham-1	0.28	1.06	0.67	1.13	1.87	1.50
EIGSN-17	0.36	0.79	0.57	1.24	2.49	1.87
Furat-4	0.20	0.69	0.42	0.69	1.47	1.08
D-417-29	0.31	0.53	0.42	0.73	2.01	1.37
HI-977	0.38	1.24	0.81	0.91	2.94	1.93
HD-2501	0.48	1.21	0.85	0.86	2.03	1.45
Mean	0.34	0.94		0.91	2.43	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.02	0.06	0.03	0.10
Genotypes	0.06	0.15	0.08	0.24
Interaction	0.07	0.21	0.12	0.34

*DAS = Days after sowing

The lowest resistance was recorded in D-417-29 (0.53 s cm^{-1}) under high temperature regime. At 80 DAS, the maximum resistance was recorded in Bulk-776 at low temperature (1.30 s cm^{-1}) and Bijaga yellow (4.40 s cm^{-1}) at high temperature regime. The genotypes HD-4502 (0.58 s cm^{-1}) and Furat-4 (1.47 s cm^{-1}) had minimum resistance under low and high temperature regimes, respectively. Although, Bulk-776 had the maximum resistance under low temperature regime, it did not differ significantly with Bijaga yellow, Sham-1 and EIGSN-17. Similarly, no significant differences were observed between Bulk-776 and EIGSN-17, between Raj-1555, HD-4502, DWR-174 and Sham-1, and between D-417-29, HD-2501 and Raj-1555 under high temperature regime. Bijaga yellow recorded significantly higher LDR over all other genotypes.

4.5.2 Transpiration Rate (TR)

The transpiration rate (TR) as influenced by the growth temperature was recorded at 60 and 80 DAS and is presented in Table 24. The data indicated that the TR decreased from 60 DAS to 80 DAS under both low and high temperature regimes and it was also boserved that the TR decreased with an increase in the growth temperature. Temperature regimes, genotypes and their interaction differed significantly in TR at both the stages studied.

At 60 DAS, the maximum TR was recorded in Furat-4 and D-417-29 under low (49.57 μg cm^{-2} s^{-1}) and high (31.95 μg cm^{-2} s^{-1}) growth temperature, respectively. These values were significantly higher in Furat-4 over other genotypes. Whereas, the

Table 24. Influence of temperature regimes on transpiration rate ($\mu g\ cm^{-2}\ s^{-1}$) at different growth stages in wheat genotypes

Genotypes	60 DAS*			80 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	38.16	19.00	28.58	12.54	6.24	9.42
Bijaga yellow	31.43	22.57	27.00	13.91	7.25	10.58
Raj-1555	33.77	19.01	26.39	20.18	11.30	15.74
HD-4502	46.53	16.32	31.42	17.38	8.09	12.73
DWR-174	39.01	16.40	27.75	18.58	8.90	13.74
Bulk-776	27.26	14.13	20.69	14.10	9.28	11.69
Sham-1	40.93	24.03	32.48	22.02	11.73	16.87
EIGSN-17	37.15	23.67	30.41	26.08	7.96	17.02
Furat-4	49.57	24.65	38.01	15.77	14.03	14.90
D-417-29	40.41	31.95	36.17	22.83	8.43	15.63
HI-977	31.78	16.13	23.95	19.10	8.13	13.62
HD-2501	28.10	16.74	22.42	17.85	11.11	14.48
Mean	37.00	20.38		18.36	9.37	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.46	1.31	0.14	0.40
Genotypes	1.13	3.21	0.34	0.97
Interaction	1.59	4.54	0.48	1.38

*DAS = Days after sowing

least TR was recorded in Bulk-776 under both the temperature regimes. Bijaga yellow and HI-977, Bulk-776 and HD-2501 did not differ significantly among themselves at low growth temperature. Whereas, the genotypes Sham-1, EIGSN-17 and Furat-4 maintained moderate transpiration rates. The genotypes HD-4502, DWR-174, HI-977 and HD-2501 maintained low transpiration rates and were non-significant with each other.

At 85 DAS, the genotype EIGSN-17 had the maximum TR (26.08 $\mu g\ cm^{-2}\ s^{-1}$) under low temperature and Furat-4 (14.03 $\mu g\ cm^{-2}\ s^{-1}$) under high temperature regime. They maintained significantly superior TR over rest of the genotypes. The least TR was recorded in Local Khapli and Bijaga yellow under both the temperature regimes. However, Bijaga yellow and Bulk-776 under low temperature regime, and D-417-29 and HI-977 under high temperature regime did not differ significantly with each other.

4.5.3 Leaf Temperature (LT)

The influence of growth temperature on leaf temperature indicated a marginal increase in leaf temperature (LT) at high growth temperature over low growth temperature, but was non-significant both at 60 and 85 DAS (Table 25).

The genotype DWR-174 had the maximum LT both under low (28.6°C) and high (31.3°C) temperature regimes. The differrences in the LT were significant only among the genotypes at both the dates of sampling. The lowest LT was recorded in

Table 25. Influence of temperature regimes on leaf temperature (°C) at different growth stages in wheat genotypes

Genotypes	60 DAS*			80 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	28.2	29.4	28.8	28.5	29.0	28.7
Bijaga yellow	28.4	29.7	29.0	28.7	30.2	29.6
Raj-1555	27.4	29.1	28.2	27.1	29.1	28.1
HD-4502	27.5	29.2	28.4	26.6	29.4	28.0
DWR-174	28.6	31.3	29.9	27.4	30.7	29.1
Bulk-776	28.2	28.4	28.3	26.4	30.7	28.6
Sham-1	28.3	29.4	28.8	27.3	31.3	29.3
EIGSN-17	27.8	29.3	28.6	27.5	30.8	20.2
Furat-4	28.0	28.6	28.3	27.1	30.5	28.8
D-417-29	27.3	29.4	28.3	28.1	30.7	29.4
HI-977	28.6	29.1	28.8	28.9	31.3	30.1
HD-2501	27.9	29.4	28.6	28.3	31.8	30.0
Mean	28.0	29.4		27.7	30.5	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.64	NS	0.16	NS
Genotypes	0.45	1.29	0.40	1.15
Interaction	0.18	NS	0.57	NS

*DAS = Days after sowing

D-417-29 (27.3°C) which was at par with Raj-1555 (27.4°C) under low temperature regime and Bulk-776 (28.4°C) under high temperature regime. At 85 DAS, among the genotypes, HI-977 (28.9°C) and HD-2501 (31.8°C) had the maximum LT under low and high temperature regimes, respectively. Under high temperature regime, Local Knapli recorded the minimum LT of 29.0°C.

4.6 PHYSIOLOGICAL AND BIOCHEMICAL CHARACTERS

4.6.1 Chlorophyll a Content

The data on the influence of temperature regimes on chlorophyll a content indicated that the chl.a content increased from 35 to 60 DAS and decreased thereafter at 85 DAS under both the temperature regimes (Table 26). The differences due to growth temperatures, genotypes and their interaction were significant at all the stages.

At 35 DAS, there was an increase in the chl.a content from low to lhigh growth temperature in all the genotypes. Among the genotypes, DWR-174 (1.69 mg g fresh wt.$^{-1}$) and HI-977 (1.66 mg g fresh wt.$^{-1}$) recorded significantly higher chl.a content under low temperature regime. Whereas, under high temperature regime, it was with Bulk-776 (2.10 mg g fresh wt.$^{-1}$). The genotypes Bijaga yellow, HD-4502, Bulk-776 and D-417-29 did not differ significantly with each other under low temperature regime.

At 60 DAS, the genotypes HD-2501 (2.20 mg g fr. wt.$^{-1}$)

Table 26. Influence of temperature regimes on Chlorophyll 'a' content (mg g fr.wt.$^{-1}$) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	1.31	1.92	1.62	2.01	1.68	1.85	1.61	1.38	1.50
Bijaga yellow	1.38	1.40	1.39	1.71	1.00	1.35	1.60	1.21	1.40
Raj-1555	1.57	1.73	1.65	1.90	1.72	1.81	1.65	1.35	1.50
HD-4502	1.40	2.05	1.73	1.95	1.65	1.80	1.55	1.50	1.53
DWR-174	1.69	1.71	1.70	1.97	1.88	1.93	1.75	1.45	1.50
Bulk-776	1.42	2.10	1.76	1.81	1.41	1.61	1.80	1.30	1.55
Sham-1	1.55	1.71	1.63	1.39	1.19	1.30	1.20	0.91	1.05
EIGSN-17	1.61	1.89	1.75	1.99	1.51	1.75	1.35	1.01	1.18
Furat-4	1.51	1.59	1.55	1.52	1.22	1.37	1.29	1.02	1.15
D-417-29	1.41	1.45	1.43	1.45	1.41	1.43	1.28	1.20	1.24
HI-977	1.66	1.94	1.80	1.78	1.72	1.75	1.60	1.48	1.54
HD-2501	1.49	1.53	1.51	2.20	1.64	1.92	1.66	1.30	1.42
Mean	1.50	1.75		1.80	1.50		1.53	1.26	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.007	0.021		0.008	0.023		0.008	0.023	
Genotypes	0.018	0.051		0.020	0.056		0.020	0.057	
Interaction	0.025	0.072		0.028	0.079		0.028	0.081	

*DAS = Days after sowing

and DWR-174 (1.88 mg g fresh wt.$^{-1}$) recorded significantly higher chl.a content over rest of the genotypes under low and high temperature regimes, respectively. The lowest chl.a content was recorded in Sham-1 (1.39 mg g fresh wt.$^{-1}$) under low temperature regime and Bijaga yellow (1.00 mg g fresh wt.$^{-1}$) under high temperature regime. However, the genotypes Local Khapli, HD-4502, DWR-174 and EIGSN-17 did not differ significantly each other under low temperature regime. Similarly, Bulk-776, D-417-29, HD-4502, Local Khapli and HD-2501 did not differ significantly with each other under high temperature regime.

At 85 DAS, a similar trend of decrease in chl.a content due to increase in growth temperature was recorded in all the genotypes. Among the genotypes, Bulk-776 and HD-4502 had the maximum chl.a content under low and high temperature regimes, respectively. Whereas, Sham-1 had the lowest value under low (1.20 mg g fresh wt.$^{-1}$) and high (0.91 mg g fresh wt.$^{-1}$) temperature regimes. The genotypes HD-4502, DWR-174 and HI-977 did not differ significantly with each other under high temperature regime.

4.6.2 Chlorophyll b Content

Similar to that of chl.a, chlorophyll b content also increased from 35 to 60 DAS and decreased slightly at 85 DAS under both the temperature regimes (Table 27). The differences due to temperature regimes, genotypes and their interactions were significant at all the three stages.

Table 27. Influence of temperature regimes on Chlorophyll 'b' content (mg g fr. wt.$^{-1}$) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	0.670	0.970	0.820	0.750	0.818	0.783	0.750	0.905	0.827
Bijaga yellow	0.393	0.520	0.465	0.817	0.761	0.789	0.600	0.863	0.731
Raj-1555	0.560	0.783	0.671	1.047	0.782	0.914	0.762	0.720	0.741
HD-4502	0.313	0.481	0.397	0.847	0.705	0.776	0.705	0.581	0.643
DWR-174	0.593	0.885	0.739	1.020	0.862	0.942	0.764	0.723	0.743
Bulk-776	0.632	0.940	0.786	0.850	0.632	0.741	0.581	0.551	0.566
Sham-1	0.455	0.880	0.667	0.641	0.604	0.622	0.713	0.470	0.592
EIGSN-17	0.537	0.733	0.635	0.832	0.615	0.720	0.813	0.567	0.690
Furat-4	0.400	0.617	0.508	0.764	0.723	0.740	0.772	0.617	0.694
D-417-29	0.571	0.647	0.609	0.882	0.767	0.824	0.745	0.604	0.674
HI-977	0.634	0.691	0.662	0.913	0.900	0.906	0.800	0.762	0.781
HD-2501	0.492	0.610	0.551	1.220	0.820	1.020	0.907	0.829	0.868
Mean	0.521	0.730	0.881	0.881	0.750		0.742	0.682	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.005	0.015		0.004	0.013		0.006	0.018	
Genotypes	0.013	0.038		0.011	0.031		0.016	0.045	
Interaction	0.019	0.054		0.015	0.044		0.022	0.063	

*DAS = **Days after sowing**

At 35 DAS, the high temperature regime recorded significantly higher chl.b content over low temperature regime in all the genotypes. Among the genotypes, Local Knapli had significantly higher chl.b content under low (0.670 mg g fr.wt.$^{-1}$) and high (0.970 mg g fresh wt.$^{-1}$) temperature regimes. Among the genotypes, Bulk-776 and HI-977 under low temperature regime and Furat-4 and D-417-29 under high temperature regime did not have significant differences among themselves. Similarly, Local Khapli, Bulk-776 and HI-977 did not differ significantly with each other under high temperature regime.

At 60 DAS, the maximum chl.b content was recorded in HD-2501 (1.220 mg g fresh wt.$^{-1}$) and HI-977 (0.900 mg g fr. wt.$^{-1}$) respectively, under low and high temperature regimes. In all other genotypes, the chl.b content decreased significantly due to high growth temperature except in Local Khapli, where, there was a significant increase under high growth temperature as compared to low growth temperature. The lowest chl.b content was recorded in Sham-1 under both the temperature regimes. The genotypes HD-4502, Bulk-776 and EIGSN-17 did not differ significantly with each other at low temperature regime.

At 85 DAS also, chl.b content significantly decreased under high temperature regime in all the genotypes except in Local Khapli and Bijaga yellow. Whereas, a significant increase was recorded in these genotypes under high temperature regime. Among the genotypes, the maximum chl.b content was recorded in

HD-2501 and Local Khapli under low and high temperature regimes, respectively. The minimum chl.b content was however, noticed in Sham-1 under high temperature regime.

4.6.3 Chlorophyll a/b Ratio

It was observed that the low temperature regime maintained a higher chlorophyll a/b ratio as compared to high temperature regime at all the stages (Table 28). Differences due to temperature regimes were significant only at 35 and 80 DAS, whereas, the genotypic differences were significant at all the stages.

At 35 DAS, HD-4502 maintained a significantly higher ratio both under low (4.47) and high (4.26) temperature regimes. The lowest ratio was in Local Khapli at low temperature regime and DWR-174 and Sham-1 under high temperature regime. However, the genotypes Bijaga yellow, EIGSN-17, Furat-4 and HD-2501 did not differ significantly with each other under high temperature regime.

At 60 DAS, the maximum chlorophyll a/b ratio was observed in Local Khapli (2.68) and EIGSN-17 (2.44) under low and high temperature regimes, respectively. The genotype Bijaga yellow had the lower chl. a/b ratio (1.32) under high temperature regime. At 85 DAS, Bulk-776 (3.10) and HD-4502 (2.56) recorded significantly higher chl. a/b ratio under low and high temperature regimes, respectively. However, the genotypes Sham-1, EIGSN-17, Furat-4, D-417-29 and HD-2501 did not have significant differences

Table 28. Influence of temperature regimes on chlorophyll a/b ratio at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	1.95	1.97	1.96	2.68	2.06	2.37	2.15	1.52	1.84
Bijaga yellow	3.52	2.69	3.10	2.08	1.32	1.70	2.66	1.39	2.02
Raj-1555	2.80	2.20	2.50	1.81	2.19	2.00	2.16	1.88	2.02
HD-4502	4.47	4.26	4.36	2.30	2.34	2.32	2.20	2.56	2.39
DWR-174	2.85	1.93	2.39	1.93	2.18	2.05	2.28	2.01	2.14
Bulk-776	2.24	2.23	2.23	2.12	2.23	2.17	3.10	2.36	2.73
Sham-1	3.40	1.93	2.66	2.18	1.98	2.08	1.67	1.93	1.80
EIGSN-17	2.99	2.58	2.78	2.39	2.44	2.41	1.66	1.78	1.72
Furat-4	3.77	2.57	3.17	1.99	1.68	1.83	1.66	1.64	1.65
D-417-29	2.46	2.24	2.35	1.64	1.83	1.74	1.72	1.99	1.85
HI-977	2.61	2.81	2.71	1.95	1.91	1.93	2.00	1.95	1.97
HD-2501	3.02	2.51	2.76	1.80	2.00	1.90	1.70	1.57	1.64
Mean	3.01	2.49		2.07	2.01		2.08	1.88	
	S.Em+	C D at 5%		S.Em+	C D at 5%		S.Em+	C D at 5%	
Temperature regimes	0.04	0.11		0.05	NS		0.01	0.04	
Genotypes	0.09	0.26		0.12	0.45		0.03	0.09	
Interaction	0.13	0.36		0.04	NS		0.04	0.12	

*DAS = Days after sowing

with each other under low temperature regime. Similarly, the genotypes Local Khapli and Raj-1555 were at par with each other under this regime. Whereas, at high temperature regime, the genotypes D-417-29, HI-977 and Sham-1 were at par each other.

4.6.4 Total Chlorophyll Content

The data on the influence of temperature regimes on total chlorophyll content presented in Table 29, indicated that it increased from 35 to 60 DAS and decreased thereafter at 85 DAS. Temperature regimes, genotypes and their interaction differed significantly at all the stages. In general, the total chlorophyll content decreased due to high temperature in all the genotypes at 60 and 85 DAS.

At 35 DAS, the maximum total chlorophyll codntent was recorded in DWR-174 (2.28 mg g fresh wt.$^{-1}$) and Local Khapli (2.89 mg g fresh wt.$^{-1}$) under low and high temperature regimes, respectively. Among the genotypes, Raj-1555, EIGSN-17 and HI-977 had the higher total chlorophyll content and did not differ significantly with each other under low temperature regime. The lowest chlorophyll content was recorded in HD-4502 (1.71 mg g fesh wt.$^{-1}$) under low and Bijaga yellow (1.92 mg g fresh wt.$^{-1}$) under high temperature regime.

At 60 DAS, the maximum chlorophyll content was recorded in HD-2501 under low temperature regime which was significantly superior over rest of the genotypes, whereas,

Table 29. Influence of temperature regimes on total chlorophyll (mg g fr.wt.$^{-1}$) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	1.96	2.89	2.42	2.76	2.50	2.63	2.37	2.28	2.32
Bijaga yellow	1.77	1.92	1.84	2.53	1.76	2.14	2.20	2.06	2.13
Raj-1555	2.13	2.51	2.32	2.95	2.50	2.72	2.41	2.07	2.24
HD-4502	1.71	2.53	2.12	2.60	2.35	2.47	2.25	2.08	2.16
DWR-174	2.28	2.59	2.43	2.95	2.74	2.84	2.51	2.17	2.34
Bulk-776	2.05	3.04	2.54	2.66	2.04	2.35	2.38	1.85	2.11
Sham-1	1.95	2.59	2.27	2.03	1.75	1.85	1.90	1.38	1.64
EIGSN-17	2.15	2.62	2.38	2.82	2.11	2.41	2.16	1.58	1.87
Furat-4	1.91	2.21	2.06	2.26	1.94	2.10	2.05	1.64	1.84
D-417-29	1.97	2.10	2.03	2.33	2.17	2.25	2.02	1.80	1.91
HI-977	2.25	2.64	2.44	2.69	2.62	2.65	2.40	2.24	2.32
HD-2501	1.98	2.16	2.07	3.42	2.46	2.94	2.45	2.12	2.28
Mean	2.00	2.48		2.66	2.25		2.25	1.93	
	S.Em±	CD at 5%		S.Em±	CD at 5%		S.Em±	CD at 5%	
Temperature regimes	0.02	0.05		0.01	0.04		0.01	0.02	
Genotypes	0.04	0.12		0.03	0.09		0.02	0.05	
Interaction	0.06	0.17		0.05	0.13		0.03	0.07	

*DAS = Days after sowing

at higher growth temperature, the maximum was in DWR-176 (2.74 mg g fresh wt.$^{-1}$), which was significantly superior over rest of the genotypes. However, Local Khapli, Raj-1555 and HD-2501 did not differ significantly with each other under higher temperature regime. At 85 DAS, DWR-174 had significantly higher total chlorophyll content over other genotypes under low temperature regime. The genotypes Local Khapli (2.28 mg g fresh wt.$^{-1}$) and HI-977 (2.24 mg g fresh wt.$^{-1}$) had significantly higher total chlorophyll content under high temperature regime. It was also observed that genotypes Bijaga yellow, Raj-1555 and HD-4502 were at par each other under this growth temperature.

4.6.5 Proline Content

The data on proline content indicated an increase from 35 to 85 DAS under both low and high temperature regimes (Table 30). The maximum proline content was recorded at 85 DAS in all the genotypes. The differences due to temperature regimes, genotypes and their interaction were significant at all the stages, except due to temperature regime at 35 DAS, where, the proline content decreased in all the genotypes under high growth temperature as compared to low growth temperature. Among the genotypes, Local Khapli recorded the maximum proline content at all the growth stages.

At 35 DAS, the minimum proline content was recorded in Sham-1 under both low (101.2 μg g dry wt.$^{-1}$) and high (94.7 μg g dry wt.$^{-1}$) temperature regimes. The genotypes,

Table 30. Influence of temperature regimes on proline content (μg g dry wt.$^{-1}$) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
	Temperature regimes								
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	231.7	210.8	220.8	279.3	306.4	292.8	288.0	326.7	307.3
Bijaga yellow	169.3	144.1	156.7	226.6	259.9	243.2	245.1	271.6	258.3
Raj-1555	162.7	133.3	148.0	255.2	264.6	259.9	270.2	275.0	272.6
HD-4502	173.3	132.6	152.9	234.0	245.7	239.8	241.6	259.3	250.4
DWR-174	166.7	151.3	159.0	248.6	251.6	250.1	256.0	286.7	271.3
Bulk-776	139.3	134.4	136.8	287.1	300.0	293.5	295.2	302.0	298.6
Sham-1	101.2	94.7	98.0	201.2	210.3	205.7	230.3	232.0	231.1
EIGSN-17	117.0	105.6	111.3	274.6	280.2	277.4	295.4	297.7	296.5
Furat-4	135.6	121.0	128.3	252.7	264.8	258.7	256.3	288.6	272.4
D-417-29	153.7	123.2	138.4	252.3	281.6	266.9	268.1	290.3	279.2
HI-977	164.3	139.2	151.8	257.0	271.7	264.3	255.1	281.1	268.1
HD-2501	136.0	119.4	127.7	240.1	270.6	255.3	248.0	276.6	262.3
Mean	154.2	134.1		250.7	267.2		260.6	284.1	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	1.7	NS		1.6	4.6		1.3	3.9	
Genotypes	4.1	11.7		3.9	11.0		3.2	9.0	
Interaction	5.8	16.6		5.5	15.6		4.5	12.7	

*DAS = **Days after sowing**

Bijaga yellow, Raj-1555, HD-4502, DWR-174 and HI-977 did not differ significantly with each other under low growth temperature, whereas, under high growth temperature, Furat-4, D-417-29 and HD-2501 were at par with each other.

At 60 DAS, Bulk-776 (287.1 g g dry wt.$^{-1}$) and Local Khapli (306.4 μg g dry wt.$^{-1}$) recorded significantly higher proline content under low and high temperatures, repsectively. The genotypes Raj-1555, Furat-4 and D-417-29 were at par with each other under low temperature regime. Whereas, under high temperature regime, the genotypes EIGSN-17, D-417-29, HI-977 and HD-2501 did not differ significantly with each other.

At 85 DAS, the proline content increased under high temperature regime in all the genotypes. The maximum proline content was observed in EIGSN-17 (295.4 μg g dry wt.$^{-1}$) and Local Khapli (326.7 μg g dry wt.$^{-1}$) under low and high temperature regimes, respectively. Though, EIGSN-17 had the maximum proline content, it did not differ significantly with Local Khapli and Bulk-776. Under high temperature regime, the genotypes, Bijaga yellow, Raj-1555, HI-977 land HD-2501 did not have significant differences among themselves.

4.6.6 Wax Deposition

The data on the wax deposition indicated that it increased from 35 DAS to 60 DAS, irrespective of growth temperature. Significant differences due to temperature regimes and

Table 31. Influence of temperature regimes on wax deposition (mg dm^{-2}) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS		
	Temperature regimes					
	Low	High	Mean	Low	High	Mean
Local Khapli	0.81	0.75	0.78	0.98	1.56	1.27
Bijaga yellow	0.95	0.71	0.83	1.18	1.47	1.33
Raj-1555	1.22	1.10	1.16	1.28	2.13	2.00
HD-4502	0.98	0.82	0.90	1.46	1.60	1.53
DWR-174	0.62	0.45	0.53	0.87	0.91	0.89
Bulk-776	0.61	0.41	0.51	0.95	0.98	0.97
Sham-1	1.35	1.15	1.25	1.91	2.04	1.98
EIGSN-17	1.28	1.18	1.23	1.85	2.01	1.93
Furat-4	1.70	1.32	1.50	2.12	2.13	2.13
D-417-29	1.50	1.10	1.30	1.96	2.22	2.09
HI-977	1.89	1.75	1.82	2.71	3.04	2.88
HD-2501	2.09	1.78	1.93	2.65	2.81	2.73
Mean	1.25	1.04		1.66	1.91	

	S.Em±	C D at 5%	S.Em±	C D at 5%
Temperature regimes	0.01	0.02	0.02	0.06
Genotypes	0.02	0.05	0.04	0.12
Interaction	0.02	0.07	0.06	0.17

*DAS = Days after sowing

their interactions were obtained at both the stages (Table 31). At 35 DAS, the maximum wax deposition was recorded under low temperature regime (1.25 mg dm^{-2}) as compared to high temperature regime (1.04 mg dm^{-2}). The reverse was the trend at 60 DAS. Among the genotypes, the maximum wax content was registered in HD-2501 under both the temperature regimes and was significantly superior over rest of the genotypes at 35 DAS. The lowest wax deposition was noticed in Bulk-776 in both the temperature regimes. No significant differences were observed between Local Khapli and Bijaga yellow; DWR-174 and Bulk-776; HI-977 and HD-2501 and between Sham-1 and EIGSN-17 under high temperature regime.

At 60 DAS, the maximum wax deposition was observed in HI-977, whereas, the lowest was observed in D-417-29 under both the temperature regimes. Among the genotypes, Local Khapli and DWR-174, did not differ significantly with each other. Similarly, at high temperature regime, the differences between DWR-174 and Bulk-776; Sham-1 and EIGSN-17; Local Khapli and Bijaga yellow and Raj-1555 and Furat-4 were non-significant.

4.6.7 Total Sugars

The data on the influence of temperature regimes on total sugar content indicated a steady increase from 35 DAS to 85 DAS, irrespective of temperature regimes (Table 32). It also indicated significant differences due to temperature regime at 60 and 85 DAS and the differences due to genotypes and their interaction were significant at all the stages.

Table 32. Influence of temperature regimes on total sugar **content** (**mg g dry wt.**$^{-1}$) at different growth stages in wheat genotypes

Genotypes	35 DAS*			60 DAS			85 DAS		
				Temperature regimes					
	Low	High	Mean	Low	High	Mean	Low	High	Mean
Local Khapli	2.05	1.80	1.92	2.64	3.46	3.05	2.72	3.92	3.32
Bijaga yellow	3.86	3.15	3.50	4.08	4.31	4.19	4.19	4.40	4.29
Raj-1555	2.73	1.72	2.22	3.33	3.81	3.57	3.20	3.90	3.55
HD-4502	2.95	2.65	2.80	3.18	3.76	3.47	3.12	3.88	3.55
DWR-174	3.43	2.98	3.20	3.73	3.96	3.84	3.79	4.05	3.92
Bulk-776	2.53	2.34	2.43	2.63	2.75	2.69	2.81	3.00	2.90
Sham-1	3.10	2.90	3.00	3.28	3.45	3.36	3.50	3.91	3.70
EIGSN-17	2.25	2.22	2.24	2.30	2.34	2.32	2.70	2.80	2.75
Furat-4	3.00	2.56	2.78	3.16	3.88	3.52	3.41	4.10	3.75
D-417-29	3.60	3.02	3.31	3.83	4.06	3.94	3.90	3.95	3.82
HI-977	3.10	2.95	3.02	3.30	4.28	3.79	3.50	4.20	3.85
HD-2501	3.15	2.99	3.07	3.28	3.98	3.63	3.49	4.05	3.77
Mean	2.98	2.61		3.23	3.67		3.36	3.84	
	S.Em±	C D at 5%		S.Em±	C D at 5%		S.Em±	C D at 5%	
Temperature regimes	0.07	NS		0.05	0.15		0.02	0.06	
Genotypes	0.17	0.48		0.13	0.37		0.05	0.14	
Interaction	0.24	0.69		0.18	0.52		0.07	0.20	

*DAS = Days **after** sowing

At 35 DAS, the maximum sugar content was recorded in Bijaga yellow under both the temperature regimes. Among the genotypes, though Bijaga yellow had maximum value, it did not differ significantly with DWR-174 and D-417-29 under low temperature regime. At high temperature regime, Bijaga yellow did not differ significantly with D-417-29, DWR-174, HI-977 and HD-2501.

At 60 DAS also, Bijaga yellow had the maximum sugar content under low (4.08 mg g dry wt.$^{-1}$) and high (4.31 mg g dry wt.$^{-1}$) temperature regime. The lowest sugar content at this stage was recorded in EIGSN-17 under both the temperature regimes. In general, the high temperature regime had significantly higher sugar content in all the genotypes except Bijaga yellow, DWR-174, Bulk-776, Sham-1, EIGSN-17 and D-417-29. At 85 DAS, among the genotypes, Bijaga yellow recorded significantly higher sugar content under both the temperature regimes. Though, Local Khapli had the least sugar content (2.72 mg g dry wt.$^{-1}$) under low temperature regime, it increased substantially (3.92 mg g dry wt.$^{-1}$) due to higher growth temperature.

CHAPTER - V

DISCUSSION

V DISCUSSION

It is well known that various plant species considerably differ in their thermal resistance behaviour and the characteristic variations in the upper limits of heat resistance (Weis *et al.*, 1986). For most plants, high temperature effects are reversible as long as the temperatures do not cause extensive damage to organell membranes (Berry and Bjorkman, 1980). The extent and time required for recovery depends on the length and severity of high temperature treatments. The capacity of plants to acclimate various physiological processes to differing temperature regimes is the most notable phenomenon for their survival under harsh environments. Investigations connected with the action of high temperature on plants deal with many questions concerning the physiological, biophysical, anatomical and morphological modifications.

Wheat is a winter cereal and adopts well to the cooler climates. As the crop growth advances the temperature may approach mid-summer levels, exceeding the limits of tolerance for it's normal functioning and maintaining the desired productivity levels. It also shortens the duration of the reproductive growth particularly, the grain filling period, which is more essential for maintaining higher yields. The genetic variation in heat tolerance for various attributes such as germination, growth, photosynthesis, translocation, flowering, fruit or seed set and stability of cellular membrances have ben reported in many crop plants (Wehner and Watschke, 1981; Mackill and Coffman, 1983 and Smillie and Hetherington, 1983).

In India, wheat is grown under a wide range of environmental conditions and there is a differential response of wheat genotypes belonging to different species in their yielding ability under these situations indicating that these effects are not only controlled by the surrounding environment but also by the genetic make up of the plant. Therefore, there is an urgent need for more supporting evidences of yield associations in wheat from different genetic backgrounds with yields measured in greater range of environments before such criterion could be considered for use in breeding programmes. Hence, the present investigation was undertaken with the wheat genotypes belonging to different genetic background and were evaluated for their relative performance with respect to various morphological, physiological, biochemical and biophysical parameters in two differing temperature regimes. The results thus obtained are discussed in this chapter.

The environmental conditions during the crop growth period indicated clear cut differences with respect to temperature between the two dates of sowing. It was observed that, the normal sown crop had an exposure to high temperatures during the early crop growth i.e., upto 35 DAS as compared to late sown crop. On the contrary, the late sown crop was exposed to higher temperatures (both maximum and minimum) during the later phases of crop growth, thus justifying the use of low and high temperature regimes in the text. Due to prevalence of high temperatures in the late sown crop, the crop was harvested in 107 days as compared to 115 days in the normal sown crop. Wardlaw et al. (1980) reported that the duration of kernel filling period was reduced from 60 to 36 days when temperature was increased from 15/10°C to 21/16°C, and a further increase in the temperature from 21/16°C to 30/25°C, decreased the duration of growth from 36 to 22 days accompanied by the reduction in grain weight. In the present investigation it was observed that the grain yield was more in the normal sown crop as compared to late sown crop resulting in 21 per cent reduction in the grain yield due to high growth temperature. In most of the field crops, the longer the duration better will be the productivity and is true in wheat, irrespective of the genetic background.

The data did not indicate any appriciable variation in the growing degree days (GDD) upto 50 per cent anthesis in all the wheat genotypes (Table 4) indicating that certain amount of heat units are required for the attainment of a particular phenological stage, irrespective of their growth temperature. But, there was variation in the number of days for 50 per cent anthesis between the two temperature regimes in all the genotypes. The number of days taken for 50 per cent anthesis was slightly more in high temperature regime as compared to low temperature regime. This was mainly because of the prevalence of high temperature particularly during the early crop growth stage (upto 35 DAS) under normal sown crop. The occurrence of a particular phenological stage is temperature dependent and is amply explained from the present investigation that the required heat units are met early in the normal sown crop as compared to late sown crop for the attainment of 50 per cent flowering.

5.1 MORPHOLOGICAL CHARACTERS

The various morphological characters such as plant height, spike length, leaf area, dry matter production and its distribution in different plant parts as influenced by temperature regimes indicated that they performed relatively better under high temperature regime (late sown crop) as compared to low temperature regime (normal sown crop) at 35 DAS. Although, we are designating the environmental conditions as low and high temperature regimes, it doesnot strictly apply to the earlier growth stages since, the average temperature is more in the normal sown crop. The reasons for better performance of all the morphological characters under this regime at 35 DAS was mainly because of the prevalence of low temperature, particularly, the mean minimum temperature (13.8°C). The corresponding mean minimum temperature was 16.1°C in the normal sown crop. Thus, it is evident that the minimum temperature plays an important role than the maximum temperature. Among the various genotypes tested, Bijaga yellow had the maximum plant height at all the growth stages. The differences in the plant height were found to be significant due to genotypes, temperature regimes and their interaction at all the growth stages except at 60 DAS, with respect to temperature regime. This clearly indicates that it is influenced both by genetic and environmental factors, of which, the genetic factors are predominant. Similar to plant height, reduction in other morphological parameters viz., number of leaves and number of tillers, were observed under high temperature regime indicating the adverse effect of growth temperatures on plant growth and development. The results are in confirmity with Friend et al. (1962b) who stated that the leaf emergence was lower at 30°C as compared to 25°C.

In the present investigation, D-417-29 showed maximum number of green leaves (14.8) at high temperature regime at 35 DAS. Although, at later stages, Raj-1555 land HD-4502 maintained higher number of green leaves under both temperature regimes, the reduction in the number of green leaves due to high temperature was significantly lower in Bijaga yellow and Local Khapli. The maximum reduction was observed in genotypes Sham-1 and HI-977 indicating the sensitive nature of these genotypes to the increase in growth temperature. There was a reduction in the number of green leaves at 85 DAS as compared to 60 DAS in all the genotypes. This was mainly attributed to the drying of lower leaves both due to senescence and exposure to higher temperatures as the growth advanced. The senescence is also accelerated due to increase in the growth temperature which accounted for the reduction in the number of green leaves.

The data on number of tillers revealed that Raj-1555, HD-4502 and DWR-174 were significantly superior over other genotypes under both the temperature regimes upto 85 DAS. At harvest, it was observed that the reduction in the number of tillers due to high temperature was least in Local Khapli and Bijaga yellow indicating the tolerance nature of these two genotypes due to increase in the temperature. Kohli (1984) and Fischer (1985b) also reported that, the initiation of new tillers and their subsequent development was reduced at high growth temperature in wheat. The leaf dry weight indicated significant differences due to temperature regimes only at 60 and 85 DAS. This clearly shows the sensitivity of leaves to high temperatures at these two stages. Though, Raj-1555, HD-4502 and DWR-174 accumulated maximum dry weight in leaf under low temperature regime, it reduced drastically due to increase in the growth temperature. The dry matter accumulation was low in Local Khapli and Bijaga yellow under low temperature, but its subsequent reduction due to high temperature was also low. The genotypes, EIGSN-17 and HD-2501 resulted in 50 per cent reduction in their leaf dry weight. Such reduction in the leaf dry weight was mainly because of the reduction in the number of green leaves in these genotypes. The results are in agreement with those of Kassim and Paulsen (1984).

On the codntrary to leaf dry weight, the stem dry weight increased due to high growth temperature at harvest indicating the accumulation of dry matter in the stem rather than its translocation to economic parts. Among the genotypes, the maximum dry weight accumulation in the stem was observed in the genotypes Snam-1, EIGSN-17, Furat-4 and HD-2501. Whereas, the genotypes Local Khapli, Bijaga yellow and Raj-1555 indicated the minimum accumulation in the stem at harvest under both the temperature regimes (Table 33).

The dry matter accumulation in the spike indicated that the genotypes Raj-1555, DWR-174, HD-4502 and D-417-29 had the maximum values under both the temperature regimes (Table 11). In general, the dry matter accumulation in the spike reduced under high temperature regime as compared to low temperature regime. These are in confirmity with the results of Warington (1977) who stated that the ear development phase is most sensitive to high temperature and the number of florets which produced harvestable grains and the weight of these grains were more affected by an increase in the temperature from 15/10°C to 25/20°C. The differential response of genotypes in its spike weight due to changes in the growth temperatures was evident. The per cent distribution of dry matter in the spike increased from 60 DAS till harvest and the maximum accumulation was observed in the genotypes, Raj-1555 followed by DWR-174, HD-2501 and Bijaga yellow. The extent of reduction due to high temperature also varied among the genotypes. The maximum per cent reduction was observed in the genotypes, Bulk-776, Sham-1, EIGSN-17 and Furat-4. However, the genotypes Local Khapli, Bijaga yellow and Raj-1555 though, reduced the spike weight at high temperature, the per cent reduction was minimum.

Table 33. Influence of temperature regimes on per cent distribution of dry matter in different plant parts at different growth stages in wheat genotypes

Genotypes		35 DAS*		60 DAS		85 DAS		Harvest	
		Temperature regimes							
		Low	High	Low	High	Low	High	Low	High
1		2	3	4	5	6	7	8	9
Local Khapli	L	49.4	52.4	47.3	43.6	41.3	50.0	33.4	28.4
	S	50.6	47.4	44.3	49.7	12.6	2.4	8.3	21.3
	P	-	-	8.4	6.7	46.1	47.6	58.3	50.3
Bijaga yellow	L	36.6	38.8	49.2	44.6	33.5	31.0	28.5	24.6
	S	63.4	61.2	31.7	40.5	13.1	15.5	8.2	19.5
	P	-	-	19.1	14.9	53.4	53.5	63.3	55.9
Raj-1555	L	47.0	52.2	60.9	58.1	24.2	20.3	13.1	14.4
	S	53.0	47.8	29.5	27.3	12.2	17.8	10.9	14.2
	P	-	-	19.6	14.6	63.6	61.9	76.0	71.4
HD-4502	L	45.9	43.9	60.3	55.2	23.4	20.5	17.8	22.5
	S	54.1	56.1	34.4	35.4	21.0	31.2	21.0	26.1
	P	-	-	5.3	9.4	55.6	48.3	61.2	51.4
DWR-174	L	39.7	35.3	61.5	59.4	20.4	23.2	14.1	15.5
	S	60.3	64.7	27.3	30.0	12.1	21.9	14.5	20.1
	P	-	-	11.2	10.6	67.5	54.9	71.4	64.4

Contd...

Table 33. continued

1		2	3	4	5	6	7	8	9
Bulk-776	L	42.3	35.7	38.3	29.3	28.3	24.8	18.6	18.1
	S	57.7	64.3	44.0	53.3	17.2	26.6	20.7	29.1
	P	-	-	17.7	17.4	54.5	48.6	60.7	52.8
Sham-1	L	50.0	44.2	40.1	30.9	23.2	15.9	17.7	22.4
	S	50.0	55.8	41.2	51.0	20.9	30.6	22.9	25.3
	P	-	-	18.7	18.1	55.9	53.5	59.4	52.3
EIGSN-17	L	52.4	50.2	46.3	32.3	21.5	16.3	17.4	13.1
	S	47.6	49.8	45.0	62.1	18.7	30.2	22.2	33.3
	P	-	-	8.7	5.6	59.8	53.5	60.4	53.6
Furat-4	L	57.6	55.9	41.6	30.0	20.2	15.3	20.8	14.9
	S	42.4	44.1	44.1	54.8	27.9	27.3	20.4	17.4
	P	-	-	14.3	15.2	51.9	57.4	58.4	67.7
D-417-29	L	41.3	41.7	56.0	46.3	26.9	23.9	20.9	17.3
	S	58.7	58.3	32.3	46.9	12.2	5.0	17.8	23.8
	P	-	-	11.7	6.8	60.9	71.1	61.3	58.9
HI-977	L	43.8	44.4	52.0	46.5	29.6	24.9	20.3	20.3
	S	56.2	55.6	32.1	41.1	19.4	25.5	18.2	18.1
	P	-	-	15.9	12.4	51.0	49.6	61.5	61.6
HD-2501	L	39.4	36.1	50.9	40.3	30.9	24.3	10.3	9.2
	S	60.6	63.9	34.0	37.8	19.8	15.0	25.4	23.6
	P	-	-	15.1	21.9	49.3	60.7	64.3	67.2

L = Leaf S = Stem P = Panicle *DAS = Days after sowing

The dry matter distribution in different plant parts further indicated that there was reduction in the per cent distribution in both leaf and reproductive parts due to high growth temperature. However, there was a substantial increase in its distribution in the stem under this temperature in all the genotypes, except, in Local Khapli, where, the per cent distribution in stem decreased with a subsequent increase in the leaf and spike. The influence of temperature regimes on total dry matter production at different growth stages indicated that. the maximum mean reduction was observed at 60 DAS (25.2%) and gradually decreased to 21.1 per cent and 11.2 per cent, respectively at 85 DAS and at harvest. This clearly shows that, the formation of double ridges to the terminal spikelets initiation which approximately coincides at 60 DAS is more sensitive to high temperature stress as far as the total dry matter is concerned. Among the genotypes, Local Khapli, Bijaga yellow and DWR-174 indicated a marginal decrease in total dry matter production under high temperature regime in comparison to other genotypes. It is evident from the data that the heat stress particularly, from anthesis to maturity affected mainly the assimilate availability and its subsequent translocation to the grain and the genotypic differences were evident.

The growth temperatures had marked effects on the assimilatory surface area resulting in the significant reduction in leaf area due to high growth temperature. Similar to that of total dry matter production and its distribution in plant parts, the genotypic differences were evident with respect to leaf area. The maximum leaf area was recorded at 60 DAS in all the genotypes and the maximum reduction in the leaf area was observed in genotype, Sham-1 followed by Furat-4, EIGSN-17, HD-2501 and Bulk-776. However, the minimum reduction in leaf area was observed in Local Khapli, Bijaga yellow, DWR-174 and HD-4502 due to high growth temperature indicating the tolerance nature of these genotypes. A similar trend was noticed even at 85 DAS. However, at 35 DAS, the maximum leaf area was observed under high temperature regime in all the genotypes. This was mainly because of the cool temperature prevailing upto 35 DAS under this temperature regime due to delay in sowing time. The decrease in leaf area under high temperature regime may be due to the adverse effect on cell alongation and meristematic activity at the growing apex. It has been documented that the rate of leaf emergence and leaf expansion hastened from 10 to 25°C and with an increase in the temperature to 30°C. there is a reduction in both leaf emergence and expansion, resulting in the reduced leaf area (Friend _et al._, 1962a). Once, the assimilatory surface area is reduced, the production of photosynthates and their consequent supply to various organs would be decreased. Thus, overall total dry matter production is dependent on leaf surface. The LAD indicate the maintenance of assimilatory surface area over a period of time. It is well known that the maintenance of the assimilatory surface area is a pre-requisite for the prolonged photosynthetic activity and the ultimate productivity in crop plants. In the present investigation, it was observed that the LAD increased from

35-60 DAS to 60-85 DAS in all the genotypes. The genotypic differences under both the temperature regimes were significant and had differential response to changes in the growth temperatures. Though, the genotypes Raj-1555 and DWR-174 had the maximum LAD under high temperature regime, the extent of reduction in LAD was less in Local Khapli and Bijaga yellow indicating the minimum effect of high growth temperature on the assimilatory surface area. However, the extent of reduction in Sham-1, EIGSN-17 and Furat-4 was to the tune of 50 per cent under high temperature regime. A similar decrease in LAD due to increase in the growth temperature from 25/15 to 35/25°C has been observed in wheat by Kassim and Paulsen (1984). Such decrease in the LAD due to high growth temperature regime could be attributed to the acceleration of senescence, deterioration of photosynthetic activity and degradation of proteinaceous constituents (Nooden, 1980).

The computation of various growth parameters such as CGR, RGR, NAR, AGR, SLA and SLW indicated differential response at different growth stages in these parameters. It was observed that both CGR and AGR decreased with the advancement in the crop growth. They also decreased under high temperature regime in all the genotypes except, in Raj-1555, Local Khapli and HD-4502 at later stages of crop growth. This may be mainly attributed to the better maintenance of the total dry matter even under high growth temperature in these genotypes. The pattern of RGR and NAR indicated a significant increase due to high temperature between 60-85 DAS in all the genotypes except, Bulk-776, Sham-1 and

Furat-4. It indicates the sensitive nature of these genotypes due to increase in the growth temperature through their effect on leaf area and total dry matter production. Though, the total dry matter production decreased due to high growth temperature in rest of the genotypes between 60-85 DAS, their capacity to accumulate the dry matter or to produce leaf area per unit of these already present slightly enhanced due to increase in the growth temperatures. Similar response of winter wheat to increasing growth temperature has been reported by Friend et al. (1963), who repoorted that an increase in the temperature upto 25°C could lead to higher rate of initiation of leaf primordia. Among the genotypes which recorded an increased RGR and NAR under high temperature regime as compared to low temperature regime, the maximum increase was noticed in Local Khapli, Bijaga yellow and HD-4502.

It was observed that, the SLW decreased and SLA increased under high temperature regime as compared to low temperature regime. This response was not uniform among the genotypes. The increase in the SLA under high temperature regime indicates that the leaves are becomming thinner. However, the genotypes Sham-1, Furat-4 and DWR-174 differed in the response by showing decreased SLA under high temperature regimes. SLW decreased substantially in Sham-1, Furat-4 and HD-2501 indicating a decrease in the leaf thickness. On the contrary, the genotypes Local Khapli and DWR-174 recorded a significant increase in SLW under high temperature regime. SLA has been reported to play both active and negative role through its link with photosynthetic volume (Charles Edward, 1982). Thus lower SLA equates with more layers of mesophyll and greater light absorption per unit leaf area (Dornhoff and Shibles, 1976). A reduction in SLA however, also equates with an increased utilization of carbon substrate in the production of leaf mass and the incorporation of more nitrogen per unit leaf area (Gifferd, 1987). Rawson et al. (1987) reported dthat SLA declined at approximately 4 cm^2 g^{-1} for each mole quanta m^{-2} day^{-1} increase in radiation and it differed among genotypes without changining the ranking due to changes in radiation. As the usefullness of SLA is debated by crop physiologist, McClendan (1962) argued that species which achieved the highest net CO_2 exchange rate per unit leaf area from the minimum leaf material are the most efficient. This implies that high SLA is in a positive association with high carbon exchange rate and could be useful in screening for efficiency. However, Khan and Tsunoda (1970) have demanstrated negative correlations of SLA with the carbon exchange rate amongst several genotypes of wheat. In the present investigation, though the genotypes Local Khapli and HD-4502 had maintained low SLA under high temperature regime, might have compensated their carbon exchange rate through increased layer of mesophyll cells for maintaining the yield stability under high temperature regime, which is evident from its corresponding SLW values.

5.2 YIELD AND YIELD COMPONENTS

The net result of heat stress during the crop growth is the reduction in the grain yield. It was observed from the data that the reduction in grain yield was minimum in Local Khapli (3.76%) followed by Bijaga yellow (10.20%) and DWR-174 (12.5%) under high temperature regime, though the yielding ability under favourable temperature (low temperature regime) was low in Local Khapli and Bijaga yellow. the maximum reduction in grain yield due to high temperature regime was observed in Sham-I and Furat-4 (34.79%) followed by EIGSN-17 (29.6%) and HD-2501 (27.4%). The studies of Wardlaw et al. (1980) and Wiegand and Cuellar (1981) showed that over the range of 12 to 26°C increase in mean temperature during grain filling, the grain weight was reduced from 4 to 8 per cent per degree increase in temperature. These results are in confirmity with out findings. The lower grain yield due to increase in growth temperature was attributed to decrease in 1000-grain weight and to spike length to some extent. Lower grain weight is believed to result from the combined effects of the duration and rate of grain filling process. Decreased duration of grain filling would decrease the final grain weight unless offset by an increase in the rate of grain filling. It is supplimented by the dates of physiologic maturity in 107 days under high temperature regime as compared to 115 days under low temperature regime. Sofield et al. (1977) showed that an increase in the temperature from 15/10 to 21/16°C (day/night) would dreduce the duration of kernel filling from 60 to 36 days. The duration in grain growth decreased further from 36 to 22 days with an increase in temperature from 21/16 to 30/25°C. It is quite possible that in some cases, the decrease in the duration of grain filling would be compnesated by an increase in the grain growth rate. Friend et al. (1963) reported that an increase in temperature from 10 to 30°C caused earlier floral initiation. This effect could result from either an increased rate of production of flower inducing substances or from an increased sensitivity of meristematic cells to a given level of flower inducing substance. The reduction in the total grain weight due to elevated growth temperatures was mainly attributed to a reduction in individual grain weight and a small reduction in grain number (Bhullar and Jenner, 1983). The data on harvest index (HI), indicated a significant reduction due to high growth temperature in all the genotypes except Local Khapli and Bijaga yellow. Among the genotypes, the maximum reduction was observed in HD-4502, Furat-4 and Sham-1. However, the maximum HI under high temperature regime was recorded in DWR-174 and Raj-1555. The reasons for the decrease in HI would be mainly because of the poor translocation of photosynthates from source to sink or may be because of the poor production of dry matter itself. Acevedo et al. (1990) reported that heat stress during anthesis to maturity affects mainly assimilate availability, translocation of photosynthates to grain and the synthesis and deposition of starch in the developing grain. The genotypic differences in harvest indices depict the relative efficiency of these genotypes in terms of the development of the phloem channels and the better source-sink relationship.

5.3 BIO-PHYSICAL CHARACTERS

It is difficult to determine the effect of specific plant characteristic on the grain yield and the total dry matter production because, these effects are usually small and depend on both the environment and the genetic constitution of a particular genotype. Although, plant performance is attributed to genetic factors, differences of great magnitude in stomatal aperture among cudltivars under changing environmental situations could be expected to over ride the genetic factor (Shimshi and Ephrat, 1975). Thus, the physiological mechanism by which stomata are controlled, which in turn, influence greatly the transpiration rate (TR) and leaf temperature play an important role in the survival of a plant. An attempt was made to investigate the behaviour of different wheat genotypes in low and high temeprature regimes with respect to various biophysical characters.

The data indicated that the genotypes, Local Khapli and Bijaga yellow, while maintaining the low diffusive resistance (DR) under low temperature regime, increased the diffusive resistance to a greater extent under high temperature regime. The increase in leaf diffusive resistance (LDR) was accompanied by a concomitant decrease in the transpiration rate (TR) thereby, maintaining a favourable water balance in the plant system. It was observed that the LDR increased almost three-fold from 60 to 80 DAS indicating that it is influenced by the age factor also. The extent to which stomatal conductance may be limiting photosynthesis, obviously, is very dependent upon the photosynthetic characters of leaf cells and the conditions under which the measurements are made along with the ambient environmental conditions of the crop. It is evident from the data that the LDR increased substantially under high temperature regime both at 60 and 80 DAS. The genotypes, Bulk-776, Sham-1, EIGSN-17, Furat-4 and HI-977 which had indicated a substantial increase in LDR at 60 DAS, did not maintain their status at 80 DAS. The genotypes Local Khapli and Bijaga yellow recorded 468 per cent and 264 per cent increase in the LDR respectively, at 80 DAS. Similarly, the TR decreased due to high growth temperature both at 60 and 80 DAS. The maximum reduction in TR was noticed in HD-4502, DWR-174 and Local Khapli at 60 DAS, while, at 80 DAS, it was with EIGSN-17, D-417-29 and HI-977. Among the genotypes, the maximum TR was recorded in Sham-1, EIGSN-17, D-417-29 while, the low TR was observed in Local Khapli, Bijaga yellow and Bulk-776. For maintaining favourable water balance in plants, the plant should have the low TR while, maintaining optimum stomatal conductance for normal functioning of gas exchange. However, under adverse environmental conditions, such as stresses due to water and high temperatures, the LDR should be more while maintaining the low TR. Leach (1979) reported that the stomatal and mesophyll resistance to CO_2 transfer was optimum at a temperature of 24°C for net CO_2 uptake, with an increase in the temperature, the net CO_2 uptake decreased mainly because of both stomatal and mesophyll resistances. Our results are in confirmity with his findings. In the present investigation, the variation in the growth temperature between two temperature regimes was 2°C, which resulted in an increase in the LDR and decrease in TR. The temperature regimes did not have any significant influence on leaf temperature (LT) measured at 60 and 80 DAS. However, genotypes exhibited significant differences in maintaining the leaf temperature. It was observed that the genotypes Sham-1, EIGSN-17, HI-977 and HD-2501 had maintained maximum leaf temperature at 80 DAS under high temperature regime. It has already been stated earlier that every degree celsius rise in the temperature would lead to 3-4 per cent reduction in the grain yield (Wardlaw, 1989). The reduction in the grain yield in the present investigation may be related to an increase in the leaf temperature. Another reason for increase in the leaf temperature could be because of decrease in the TR thereby reducing transpirational cooling of leaf surfaces particularly, under high temperature regime. .

5.4 BIOCHEMICAL PARAMETERS

In the fore going discussion, the effect of temperature regimes on plant growth and development and its relationship with biophysical parameters has been discussed. It is possible that there must be some mechanism to impart tolerance nature to the plants. Blum (1988) reported that cell membrance thermostability is a fair index of genetic variation in heat tolerance that bears a reasonable relationship to plant performance under heat stress. The possible biochemcial explaination for these responses appear not to have been investigated hitherto and hence, the nature of thermotolerance has been discussed with respect to these aspects. The present study revealed that, both chlorophyll a, chlorophyll b and total chlorophyll contents decreased with an increase in the growth temperature. on the whole, it was observed that the per cent reduction in chl.a content was more as compared to chl.b indicating that chl.b is less sensitive to increase in the growth temperature. The increase in the chlorophyll content under high temperature regime at 35 DAS, was mainly because of the cooler temperature under this regime due to delay in sowing time as comapred to low temperature regime. Among the genotypes, Sham-1, EIGSN-17 and Bulk-776 recorded the maximum decrease in the chlorophyll content indicating the sensitive nature of the photosynthetic apparatus in these genotypes to high temperature. The least reduction in chlorophyll content was observed in Local Khapli, Bijaga yellow, HD-4502, HI-977 and DWR-174. Yordanov <u>et al</u>. (1979) reported that a high temperature treatment of barley seedlings to 42 to 45°C for 4 to 8 hours inhibited chlorophyll biosynthesis, which could be a consequence of the decrased photochlorophyllide quantity or its transformation. A similar decrease in the chlorophyll content due to high temperature during grain development in wheat was observed by Kassim and Paulsen (1984). Thus, it can be concluded that the temperature is one of the most important factors in controlling the formation and functional activity of the photosynthetic apparatus.

The protein macromolecule has the capacity to undergo a transition from one structural state to another and such conformational changes of proteins are involved with heat stress (Alexandrov, 1977). The greater is the conformational flexibility of proteins in terms of lability of their bonds, the greater is their injury by heat and their susceptibility to their enzymatic denaturation. The evoluation of heat adaptation was considered to involve conformational flexibility, perhaps partly through the substitution of the amino acids. Other solutes, such as organic acids as well as hormones like Kinetin were shown to excercise protection against the heat stress (Zeng and Khan, 1984). The role of proline, an imino acid has been found to increase many fold due to water stress has been shown in many crops and has been assigned a specific role of supplying carbon and nitrogen. The studies relating to the role of proline and its accumulation due to high temperature stress are very meager. In the present investigation, the proline content increased significantly due to high temperature stress in all the genotypes and per cent increase was more at later stages of crop growth which coincided with the high growth temperature. The genotypes, Bijaga yellow, Local Khapli, DWR-174 and HD-2501 consistantly recorded the maximum proline accumulation under high temperature regime in comparison to other genotypes. Although, the specific nature of its significance in inducing tolerance to high temperature stress could not be elucidated, it is certain that it has got positive relationship with the yield stability in these genotypes under high temperature regime.

Glaucousness, which is the visible manifestation of epicuticular wax has been found to increase the grain yield and dry matter of drought tolerant wheat and the time of development of epicuticular wax is an important factor (Richards, 1984). The temperatures of photosynthetic tissue were 0.7°C cooler in glaucous than non-glaucous lines of wheat (Richards et al., 1986). The development of epicuticular wax is an adaptive mechanism to maintain the water balance through reduction in transpirational losses. Our data indicate that the wax content increased from 35 to 60 DAS. Which again coincided with an increase in the growth temperature indicating the synthesis of wax under adverse climatic conditions. The comparison of wax deposition between the two temperature regimes revealed that the wax content was more under high temperature regime as compared to low temperature regime at 60 DAS. Among the genotypes, Local Khapli, Raj-1555 and Bijagar yellow recorded the maximum per cent increase in wax content as compared to other genotypes. However, the genotypes, DWR-174, Bulk-776, Sham-1 and EIGSN-17 did not show much wax deposition under high temperature regime. The increase in the leaf diffusion resistance and decrease in the transpiration rate in Local Khapli, Bijaga yellow, DWR-174, Raj-1555 could be attributed to increased deposition of wax in these genotypes.

It has been shown that the rate of accumulation of starch at 25°C is greater at 15°C and resulted in an accelerated rate or grain growth (Jenner, 1968 and 1991a). Our data also indicated that the total sugars increased with an increase in the growth temperatures and with an advancement in the crop growth. The increase in the sugar content due to high growth temperature might play a role in the osmoregulation to maintain normal metabolic activity of the cell. Among the genotypes, the maximum sugar content was recorded in Bijaga yellow, HI-977, DWR-174.

The reduction in the sugar content of other genotypes at high growth temperature could be due to high respiratory losses or due to the restriction for the flow of sucrose which is regarded as the substrate for the starch synthesis as well as for respiration. It has been shown that the various water soluble compounds such as sugar, proteins etc., are able to protect the sensitive cell structure agianst heat inactivation (Kraus and Santarius, 1975).

There are several possibilities to explain the nature of increased heat tolerance in crop plants. Although, it is well known that heat resistance of plants increases during exposure to supraoptimal, but sublethal temperatures, very little information is available on the molecular mechanism of adaptation of cells to high temperature conditions. The present investigation has brought forth some new information regarding the influence of growth temperatures on various physiological parameters in different wheat genotypes grown under field conditions. It is hoped that information generated in the present study would be useful in characterising the genotypes for their relative tolerance to high temperatures based on various physiological parameters studied and would be sueful in the selection of genotypes in further breeding programme.

CHAPTER - VI

SUMMARY

VI SUMMARY

The present study was aimed in understanding the influence of high temperature stress on various morphological, physiological, biochemical and biophysical parameters in twelve genotypes of wheat belonging to different genetic background and their relationship with productivity. For this purpose, the crop was raised under irrigated conditions in the field in two different temperature regimes during rabi, 1990-91. The high temperature stress is usually accompanied by water stress at later stages, particularly in the rabi season, which complicates the interaction between the temperature and water stress. Hence, the crop was raised under irrigated conditions to overcome this problem. To attain the variation in growth temperatures, the crop was sown on 9 November 1990 and 5 December 1990. The salient features of the findings are summerised below.

1. Due to variation in sowing period, the late sown crop was exposed to higher temperature by nearly 2°C at later stages of crop growth i.e., from 35 days onwards. On the contrary, the crop which was sown on 9 November 1990 (normal sown) had an exposure to higher temperature (nearly 1°C) upto 35 days. There was not much difference in the rainfall received and the relative humidity between the two temperature regimes.

2. Most of the morphological, physiological, biochemical and biophysical parameters indcated better performance in high temperature regime as compared to low temperature regime at

35 DAS. This was mainly because of exposure of the crop to higher ambient temperature under low temperature regime. The treatments, 'low temperature regime' and 'high temperature regime' are designated considering the temperatures prevailing throughout the entire crop growth period rather than a particular stage.

3. Various morphological parameters studied indicated that, the genotypes Local Khapli, Bijaga yellow, DWR-174, HD-4502 and Raj-1555 performed better under high temperature regime as compared to low temperature regime. The maximum reduction with respect to these parameters was observed in Sham-1, Furat-4 and EIGSN-17.

4. The exposure of the crop to high temperature regime resulted in the significant decrease in the assimilatory surface area. The minimum reduction was observed in Local Khapli and Bijaga yellow and the maximum in Sham-1 at 60 DAS. However, the genotypes, Raj-1555, DWR-174 and HD-4502 had the maximum leaf area production both under low and high temperature regimes. A similar trend was noticed with respect to leaf area duration and leaf area index.

5. The results of various growth parameters indicated that the CGR, RGR, AGR and SLW decreased with an increase in the growth temperature, whereas, a significant increase in NAR and SLA was observed under high growth temperature regime.

6. Leaf diffusive resistance (LDR) increased with a decrease in transpiration rate (TR) under high temperature regime. There were no significant increase in the leaf temperature due to high growth temperature. Among the genotypes, Local Khapli, Bijaga yellow, DWR-174 and HD-4502 recorded the maximum increase in LDR over their corresponding values under low temperature regime. However, the genotypes, EIGSN-17, Sham-1 and Furat-4 had low LDR and the reduction in the TR was less under high temperature regime.

7. Though, both chl.a and chl.b contents decreased due to high growth temperatures, the per cent decrease chl.a was more as compared to per cent decrease in chl.b. The genotypes, Sham-1, EIGSN-17 and Bulk-776 had the maximum per cent reduction of total chlorophyll, indicating the sensitive nature of these genotypes to increase in the growth temperatures.

8. The proline content was found to decrease from 35 to 85 DAS in all the genotypes under both temperature regimes. The differences due to growth temperature were significant only at later stages i.e., 60 and 85 DAS with high temperature regime recording higher proline content. The per cent increase in the proline content due to high temperature indicated that the genotypes Local Khapli, DWR-174, Bijaga yellow and HD-2501 had the maximum increase due to high temperature.

9. The growth temperatures significantly increased the wax

deposition in all the genotypes, but, the extent of increase varied among the genotypes. There was nearly 60 per cent increase in wax deposition in Raj-1555 and Local Khapli followed by Bijaga yellow. The genotypes Bulk-776, DWR-174, HD-2501 and Sham-1 showed a marginal increase in their wax content due to high growth temperature.

10. There was an increase in the total sugar content due to high temperature. Among the genotypes, Bijaga yellow had the maximum total sugar content under both temperature regimes. The lowest sugar content was noticed in EIGSN-17 under high temperature regime at 85 DAS.

11. Among the genotypes, the maximum reduction in the yield was recorded in Sham-1 and Furat-4. Though, the grain yield per hill was low in Local Khapli and Bijaga yellow, the reduction due to high temperature was very low in these genotypes thus indicating the high temperature tolerance. The genotype DWR-174, while maintaining the high yield both under low and high temperature regime, its reduction due to high temperature was also less. The reduction in grain yield in high temperature was mainly attributed to the significant reduction in the 1000-grain weight and spike length.

CHAPTER - VII

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VII REFERENCES

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* Original not seen

CHAPTER - VIII

APPENDICES

Appendix I

Maximum and minimum temperatures prevailing during growth period of normal sown crop

Temperature (°C)				Temperature (° C)			
Date	Maximum	Minimum	Mean	Date	Maximum	Minimum	Mean
1	2	3	4	1	2	3	4
9-11-90	30.0	17.0	23.5	5-12-90	30.7	15.2	23.0
10-11-90	30.0	17.2	23.8	6-12-90	31.0	15.0	23.0
11-11-90	30.5	17.5	24.0	7-12-90	31.5	15.2	23.4
12-11-90	30.5	18.0	24.2	8-12-90	30.1	14.6	22.4
13-11-90	28.3	12.1	20.3	9-12-90	29.2	14.6	21.9
14-11-90	29.7	14.8	22.2	10-12-90	28.9	15.4	22.2
15-11-90	29.2	13.8	21.5	11-12-90	29.5	14.9	22.2
16-11-90	31.1	20.4	25.8	12-12-90	29.6	13.2	21.4
17-11-90	26.7	19.8	23.3	13-12-90	30.1	13.4	21.8
18-11-90	26.8	19.2	23.0	14-12-90	27.2	14.3	20.8
19-11-90	27.0	18.3	22.7	15-12-90	28.1	15.9	22.0
20-11-90	31.1	18.5	24.8	16-12-90	28.3	14.9	21.6
21-11-90	30.5	16.5	23.5	17-12-90	28.9	15.4	22.2
22-11-90	30.0	15.4	22.7	18-12-90	28.5	14.8	21.6
23-11-90	29.5	15.0	22.2	19-12-90	29.0	14.6	21.8
24-11-90	29.7	15.0	22.4	20-12-90	29.0	14.6	21.8
25-11-90	29.9	15.2	22.6	21-12-90	29.2	14.3	21.8
26-11-90	29.5	14.8	22.2	22-12-90	29.0	14.0	21.5
27-11-90	28.9	18.7	23.8	23-12-90	28.6	14.2	21.4
28-11-90	26.1	19.3	22.7	24-12-90	28.9	13.4	21.2
29-11-90	27.0	19.0	23.0	25-12-90	29.0	13.2	21.1
30-11-90	30.0	15.4	22.7	26-12-90	29.2	13.3	21.3
1-12-90	29.4	15.0	22.2	27-12-90	28.6	13.0	20.8
2-12-90	30.6	15.2	22.9	28-12-90	29.0	13.2	21.1
3-12-90	31.0	15.5	23.2	29-12-90	29.2	11.1	20.2
4-12-90	31.2	15.0	23.4	30-12-90	29.4	11.2	20.3

Contd....

Appendix I. continued

1	2	3	4	1	2	3	4
31-12-90	30.1	13.2	21.6	1-2-91	31.2	14.6	22.9
1-01-91	29.6	12.1	20.8	2-2-91	32.3	12.8	22.6
2-01-91	30.6	9.4	20.0	3-2-91	33.8	13.8	23.8
3-01-91	30.5	9.6	20.1	4-2-91	35.6	13.9	24.7
4-01-91	29.4	9.8	19.6	5-2-91	34.3	14.0	24.2
5-01-91	29.1	14.0	21.6	6-2-91	33.9	14.3	24.1
6-01-91	32.2	15.9	24.1	7-2-91	32.5	14.2	23.4
7-01-91	31.1	17.1	24.1	8-2-91	32.1	13.5	22.8
8-01-91	30.5	16.8	23.6	9-2-91	33.5	14.8	24.2
9-01-91	32.2	16.5	24.4	10-2-91	33.9	15.4	24.6
10-01-91	31.4	15.4	23.4	11-2-91	33.9	15.9	24.9
11-01-91	31.1	14.0	22.5	12-2-91	32.0	15.5	33.5
12-01-91	31.5	14.0	22.8	13-2-91	33.0	15.7	24.4
13-01-91	31.7	13.7	22.7	14-2-91	35.0	16.8	25.9
14-01-91	31.1	15.1	23.1	15-2-91	34.4	16.5	25.4
15-01-91	30.5	16.0	23.2	16-2-91	33.2	16.4	24.8
16-01-91	31.2	15.8	23.5	17-2-91	31.9	15.4	23.6
17-01-91	33.3	15.4	24.3	18-2-91	32.0	15.0	23.5
18-01-91	30.6	15.9	23.5	19-2-91	35.0	14.8	24.8
19-01-91	30.8	16.0	23.4	20-2-91	34.4	17.4	25.9
20-01-91	31.0	16.1	23.6	21-2-91	33.9	17.1	25.5
21-01-91	32.2	16.3	24.2	22-2-91	33.3	14.6	23.9
22-01-91	33.1	15.4	24.2	23-2-91	34.4	15.4	24.9
23-01-91	32.8	16.2	24.5	24-2-91	33.8	15.0	24.4
24-01-91	32.2	17.9	25.2	25-2-91	34.4	15.4	24.9
25-01-91	31.7	14.8	23.2	26-2-91	33.5	17.2	25.4
26-01-91	30.8	15.0	22.9	27-2-91	32.8	17.0	24.9
27-01-91	28.7	14.3	21.5	28-2-91	33.9	17.6	25.8
28-01-91	29.8	14.2	22.0	1-3-91	32.9	16.5	24.7
29-01-91	30.0	13.3	21.6	2-3-91	33.9	16.8	25.3
30-01-91	29.8	13.2	21.5	3-3-91	34.2	17.6	25.9
31-01-91	31.0	14.0	22.5				

Appendix II

Maximum and minimum temperatures prevailing during growth period of late sown crop

	Temperature (°C)				Temperature (°C)		
Date	Maximum	Minimum	Mean	Date	Maximum	Minimum	Mean
1	2	3	4	1	2	3	4
5-12-90	30.7	15.2	22.9	31-12-90	30.1	13.2	21.6
6-12-90	31.0	15.0	23.0	1-1-91	29.6	12.1	20.8
7-12-90	31.5	15.2	23.4	2-1-91	30.6	9.4	20.0
8-12-90	30.1	14.6	22.4	3-1-91	30.5	9.6	20.1
9-12-90	29.2	14.6	21.8	4-1-91	29.4	9.8	19.6
10-12-90	28.9	15.4	22.2	5-1-91	29.1	14.0	21.6
11-12-90	29.5	14.9	22.2	6-1-91	32.2	15.9	24.1
12-12-90	29.6	13.2	21.4	7-1-91	31.1	17.1	23.5
13-12-90	30.1	13.4	21.8	8-1-91	30.5	16.8	23.6
14-12-90	27.2	14.3	20.8	9-1-91	32.2	16.5	24.4
15-12-90	28.1	15.9	22.0	10-1-91	31.4	15.4	23.4
16-12-90	28.3	14.9	21.6	11-1-91	31.1	14.0	22.6
17-12-90	28.9	15.4	22.5	12-1-91	31.5	14.0	22.8
18-12-90	28.5	14.8	21.6	13-1-91	31.7	13.7	22.7
19-12-90	29.0	14.6	21.8	14-1-91	31.1	15.1	23.1
20-12-90	29.0	14.6	21.8	15-1-91	30.5	16.0	23.2
21-12-90	29.2	14.3	21.8	16-1-91	31.2	15.8	23.5
22-12-90	29.0	14.0	21.5	17-1-91	33.3	15.4	24.4
23-12-90	28.6	14.2	21.4	18-1-91	30.6	15.9	23.2
24-12-90	28.9	13.4	21.2	19-1-91	30.8	16.0	23.4
25-12-90	29.0	13.2	21.1	20-1-91	31.0	16.1	23.6
26-12-90	29.2	13.3	21.2	21-1-91	32.2	16.3	24.2
27-12-90	28.6	13.0	20.8	22-1-91	33.1	15.4	24.2
28-12-90	29.0	13.2	21.1	23-1-91	32.8	16.2	24.5
29-12-90	29.2	11.1	20.2	24-1-91	32.2	17.9	25.1
30-12-90	29.4	11.2	20.3	25-1-91	31.7	14.8	23.2

Contd....

Appendix II. continued

1	2	3	4	1	2	3	4
26-1-91	30.8	15.0	22.9	23-2-91	34.4	15.4	24.9
27-1-91	28.7	14.3	21.5	24-2-91	33.8	15.0	24.4
28-1-91	29.8	14.3	22.1	25-2-91	34.4	15.4	24.9
29-1-91	30.0	13.3	21.6	26-2-91	33.5	17.2	25.4
30-1-91	29.8	13.3	21.6	27-2-91	32.8	17.0	24.9
31-1-91	31.0	14.0	22.5	28-2-91	33.9	17.6	25.8
1-2-91	31.2	14.6	22.9	1-3-91	32.9	16.5	24.7
2-2-91	32.3	12.8	22.6	2-3-91	33.9	16.8	25.4
3-2-91	33.8	13.8	23.8	3-3-91	34.2	17.6	25.9
4-2-91	35.6	13.9	24.8	4-3-91	35.6	18.7	27.4
5-2-91	34.3	14.0	24.2	5-3-91	36.1	18.7	27.2
6-2-91	33.9	14.3	24.1	6-3-91	35.6	17.9	26.6
7-2-91	32.5	14.2	23.4	7-3-91	35.3	17.6	26.3
8-2-91	32.0	13.5	22.8	8-3-91	35.0	16.5	26.2
9-2-91	33.5	14.8	24.2	9-3-91	36.0	17.0	26.7
10-2-91	33.9	15.4	24.6	10-3-91	36.4	17.9	28.4
11-2-91	33.9	15.9	21.9	11-3-91	38.9	20.4	28.0
12-2-91	32.0	15.5	23.8	12-3-91	35.6	20.9	28.6
13-2-91	33.0	15.7	24.4	13-3-91	36.4	20.9	28.9
14-2-91	35.0	16.8	25.9	14-3-91	36.9	19.0	27.7
15-2-91	34.4	16.5	25.4	15-3-91	36.4	18.7	27.6
16-2-91	33.2	16.4	24.8	16-3-91	36.4	19.3	28.0
17-2-91	31.9	15.4	23.6	17-3-91	36.7	19.8	28.2
18-2-91	32.0	15.0	23.5	18-3-91	37.2	20.4	28.8
19-2-91	35.0	14.8	24.9	19-3-91	37.3	20.2	28.8
20-2-91	34.4	17.4	25.9	20-3-91	37.7	19.3	28.5
21-2-91	33.9	17.1	25.5	21-3-91	38.3	20.4	29.4
22-2-91	33.3	14.6	23.9				