2010

Growth and Yield of Some HYVs of Wheat (Triticum aestivum L.) As Affected by Sowing Dates and Soil Moisture

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GROWTH AND YIELD OF SOME HYVs OF WHEAT (*Triticum aestivum* L.) AS AFFECTED BY SOWING DATES AND SOIL MOISTURE

Ph. D. THESIS

Submitted to the University of Rajshahi in the Fulfilment of the Requirements for the Degree of Doctor of Philosophy in Botany

BY

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January 2010

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DEDICATION

DEDICATED TO
MY PARENTS

DECLARATION

I hereby declare that all the works reported in this thesis entitled **"GROWTH AND YIELD OF SOME HYVs OF WHEAT (*Triticum aestivum* L.) AS AFFECTED BY SOWING DATES AND SOIL MOISTURE"** for the degree of Doctor of Philosophy of the University of Rajshahi is the result of my own investigation. This work has not been submitted before to this University or any other Institution to obtain a degree or any other academic certificate, honour or title.

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CERTIFICATE

This is to certify that the thesis entitled, **"GROWTH AND YIELD OF SOME HYVs OF WHEAT (*Triticum aestivum* L.) AS AFFECTED BY SOWING DATES AND SOIL MOISTURE"** submitted for the degree of Doctor of Philosophy in the Department of Botany, University of Rajshahi, Rajshahi is a bonafide research work by **Md. Golam Mohiuddin** under our supervisions and none of the part of this thesis has been submitted for any other degree.

The advice and guidance received during the course of investigation have been fully acknowledged.

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ACKNOWLEDGEMENTS

I express my deepest sense of gratitude to my supervisor, Dr. Nishit Kumar Paul, Professor and co-supervisor Dr. M. Anisuzzaman, Professor, Department of Botany, University of Rajshahi, Bangladesh for their proper guidance, constant advice and encouragement and for spending too much time throughout the course of study and preparation of this thesis.

I wish to extend my thanks to the former Chairman, Professor Dr. M. S. Alam and the present Chairman Professor Dr. M. A. Khaleuqe, Department of Botany of this University for providing facilities to carry out this research work.

I am also highly indebted and expressing my gratification and sincere appreciation to my respected teachers Professor Dr. A.K.M. Rafiul Islam, Professor Dr. Shamsun Nahar, Professor M. Monzur Hossain, Professor Md. Kashed Ali Sarker, Professor Md.Firoz Alam, Professor Dr. M. Shahidul Alam, Professor Dr. Nasima Joarder, Professor Dr. Golam Kabir, Professor Dr. S. A. Haider, Associate Professor Dr. G. P. Ghosh, Professor Dr. Md. Zahangir Alam, Dr. Mrs. Lipika Ghosh and Dr. Mrs. Ferdousi Begum, Associate Professors, Department of Botany, Rajshahi University, Rajshahi for their valuable suggestions during the entire period of study in my experimental fields and preparation of the thesis.

I would like to thank to all the students of the Plant Breeding and Biotechnology Laboratory, Department of Botany, Rajshahi University, specially, Mrs. Tanija Tasnim (Mouly) and Mrs. Syeda Sifat-E-Nuri (Ruhi), M. Sc. students, Department of Botany, Rajshahi University for their technical support and kind co-operation during the time of my research work.

I also express my thanks to Md. Ilias Hossain and Md. Abdul Kaleque, Senior Scientific Officer of Regional Wheat Research Centre, Shyampur, Rajshahi, Bangladesh for providing seeds of the experimental work. Thanks also due to the staffs of Meteorological Office at Shyampur, Rajshahi for providing meteorological data.

I am extremely indebted to Mr.Md. Joynul Abedeen, Md. Abu Masud, Md. Murshidul Hassan and Mr. Motiar Rahman Ph.D. fellows, IBSc., Rajshahi University and Md. Mizanur Rahman of Bishnupur, Chuadanga for their valuable suggestions of conducting research, analyzing data and preparating the manuscript.

Finally, I wish to convey deepest and most sincere gratitude to my family members, specially my elder brother Md. Youshub Ali for their support, sacrifice, endless love, encouragement and blessing to complete higher education.

The author

ABSTRACT

The experiment was conducted at the research field of the Department of Botany, Rajshahi University, Rajshahi, Bangladesh. Growth and yield of wheat (*Triticum aestivum* L.) in relation to sowing dates and soil moisture regime were studied. Four wheat varieties, namely Shatabdi (V_1), Gaurav (V_2), Shourav(V_3) and Kanchan (V_4) were tested for the above mentioned parameters. Three sowing dates were November 15, November 30 and December 15 and two soil moisture levels were rainfed and irrigation at every 15 days interval in two growing seasons.

Significant sowing time and soil moisture effect was found on different growth attributes in both the experimental years. Generally early sowing and irrigation increased total dry matter (TDM), leaf area (LA) and leaf area index (LAI) at most of the growth stages. Variety Shatabdi (V_1) had the highest TDM and lowest in Gaurav (V_2) in both the years. The highest leaf area index was in Shatabdi (V_1), whereas the lowest in Gaurav (V_2). Plant height, leaf number and tiller number at different growth stages were also higher in the early sowing and with irrigation. The highest values of these characters were exhibited by Shatabdi (V_1) as well.

Crop growth rate (CGR), leaf area ratio (LAR) and relative leaf growth rate (RLGR) were increased due to early sowings (S_1 and S_2). In addition, most of the growth attributes increased due to irrigation. Relative growth rate (RGR), relative leaf growth rate (RLGR) and specific leaf area (SLA) showed decreasing tendency towards the later stages of growth. All the characters showed their highest values except net assimilation rate in Shatabdi (V_1).

In the present study, yield and yield components were significantly affected by sowing dates and soil moisture regimes. Sowing times significantly influenced the grain yield of wheat. The maximum grain yield was obtained in S_1 planting and it was followed by S_2 and S_3. Irrigated plants had higher growth, development and yield than the rainfed plants for all the varieties. Yield and yield components were significantly affected by sowing times and soil moisture regimes in both the years. Plant height, fertile tiller number per plant, spike length, number of grains per spike, weight of 1000-grain and total dry matter were reduced by delay in sowing time and low soil moisture stress.

Simple correlation coefficients between yield and yield components indicated that grain yield was positively correlated with most of the yield components under the three

sowing times and the irrigation level. It was also observed that plant height, fertile tiller number per plant, spike length, number of spikelets per spike, grain number per spike and total dry matter per plant was found to be the most closely associated yield components.

Path coefficient analysis revealed that fertile tiller number showed the highest positive direct contribution to grain yield followed by number of spikelets per spike, plant height and number of grains per spike in 2005-06 season and plant height, number of grain per spike and spike length in 2006-07 season. Fertile tiller number had positive indirect effects on grain yield via total dry matter. Fertile tiller number appeared to be the important character for getting higher grain yield in wheat.

Phenotypic regression analysis was done to select most adaptive genotypes to varying environments. The phenotypic stability of each variety was expressed by two parameters: the slope of regression line and sum of squares of deviation from regression. A stable variety was defined as `one with unit regression (bi=1) and low deviation from linearity ($\overline{S}^2_{di}$=0). Phenotypic regression analysis also showed that Shatabdi (V_1) had unit regression slope with low stability value for plant height, grain number per spike, 1000-grain weight and grain yield indicating its stability to varying sowing time and soil moisture treatments.

Among the four varieties, Shatabdi (V_1) had significantly higher grain yield under all the sowing times and soil moisture conditions. Shatabdi (V_1) also showed high ear bearing tillers, 1000-grain weight, total dry matter, crop growth rate. and relative growth rate and leaf weight ratio.

It was suggested that for better yield of wheat, variety Shatabdi (V_1) should be sown within the third week of November with irrigation in the wheat growing area, especially in the northern region of Bangladesh.

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Chapter 1

INTRODUCTION

1.1. General Account

Wheat is the leading grain crop of the temperate regions of the world, just as rice is the leading grain crop in the tropics. It is the second major cereal crop in Bangladesh after rice and is widely adapted crop as it is grown from temperate irrigated to dry and high rainfall environments. The yield of wheat is very low in Bangladesh in comparison to other wheat growing countries of the world. In Bangladesh the average yield is only 1,930 kg/hectare; which is even lower than the world average (FAO, 1987).

Bangladesh is one of the densely populated countries in the world. It has to feed her 140 million people from the production of only 8.87 million hectares of arable land. The continuous increase in human population has put tremendous pressure for increasing food production. Every year Bangladesh fails to feed her population with her own food production. Food deficit has become a chronic problem for the country. Therefore, feeding of ever increasing hungry population is one of the most important critical challenges the nation facing today. To meet up the shortage, effort should be made to increase total production of food crop including wheat. Its production in 2006 was around 1 million metric tons but requirement was 3.0-3.51 million metric tons and consumption is increasing at 3% per year (Sufian, 2005).

About 50 countries of the world, wheat is regarded as the staple food. In Europe and Russia, over 33% calories come from wheat, while in most other regions less than 20% is derived from wheat. At present, people in general are giving more importance to wheat for its nutritional values. About 1050.2 thousand tons of wheat grain was produced in the year of 2004-05 in Bangladesh (BBS, 2006).

Wheat remains a very reliable, environmentally compensating crop in Bangladesh by which growers can obtain a cereal crop during the lean months between the rice crops. With the recent stable prices of wheat, the growers have an additional incentive to raise wheat for cash. Wheat prices in Bangladesh presently remain at world price levels but are the highest in south Asia. To remain close to or at the world level, wheat prices with an open policy of wheat imports at those prices is a way to maintain sustainable cereal production for the nation (CIMMYT, 1997-98).

1.2 Origin and History

The cultivated wheat (*Triticum aestivum*) was originated from tetraploid emmer wheat *Triticum dicoccum* (2n=6x=28) and *Aegilops squarrosa.* Tetraploid wheat originated as an all polyploidy from a cross between Einkorn wheat *Triticum monococcum* (2n=6x=14) and *Aegilops speltoides* (diploid) (Poehlman and Brothakur, 1969; Purseglove, 1972).

Wheat was already an important crop when history was first recorded and so accurate information on the exact time and place of its origin is not available (Clarke, 1963). The distribution of the wild wheat and grasses believed to be the progenitors of the cultivated wheat, supports the belief that wheat originated in the south-western Asia. Some species were cultivated in Greece, Persia, Turkey and Egypt in pre historic time while the cultivation of other species may be of more recent origin (Poehlman and Borthakur, 1969).

Helback (1966) found archaeological remains of *Triticum aestivum* in Mesopotamia dated 5800-5600 BC. It appears with the first trace of agricultural activities in Switzerland, England, Germany and Denmark from 3000 BC.

1.3 Botanical Aspects

The common wheat (*Triticum aestivum* L.) is a hexaploid (2n=6x=42) and belongs to the family Poaceae (Graminae) and is a world wide popular grain crop. The plant is erect, usually unbranched, herb and annual in nature. The plant is a winter annual grass with flat blades and a terminal spikes. The culm of the mature wheat plant is a hollow, jointed cylinder that comprised 3 to 6 nodes and internodes. The peduncle bears the spike; culms are white to yellow or in some varieties, mostly purple in color. The wheat inflorescence is a terminal spike, which is usually 3 to 4 inches in length, but it may vary from 3 to 5 inches. Spike may be flattened parallel or right angle to the place of face of the spikelets. They may be bursiform, oblong, claret or elliptical in shape. Spikelets consist of 1 to 5 flowers or florets attached alternately to opposite sides of a central axis or rachilla. Flowers are bisexual, stigma feathery, anthers are three in number and the mature grains consist of an embryo and a starchy endosperm.

1.4 Environment and Agriculture of Bangladesh

Environment is an important factor for agriculture. It is heterogeneous in space and time. It includes physical, biological and social factors and their interaction. Now a - days, many high yielding varieties are developed, which are successfully grown in the environment of Bangladesh. Bangladesh with humid subtropical climate is suitable for growth and cultivation of a wide variety of tropical and subtropical crop species.

The economic activities especially agricultural practices of human beings and their impacts on the environment have resulted in reduced resilience and regeneration of environmental resources. The consumption of natural resources of the earth by the expanding human population had failed to maintain the harmony and equilibrium of our ecosystems. Thus, for the last several decades, as a result of population expansion, uncontrolled exploitation of resource through advanced technology, widespread, industrialization, over consumption of natural resources has become disproportionate to their availability and growth. Among the natural resources, the forest, land and water resources have been depleted seriously due to man interventions in nature. Through this most diverse and devastating scientific and technological capabilities, man has destroyed the structure and function of most the ecosystems of the nature and converted some ecosystems. One of these, the agricultural ecosystem, with its modern high yielding varieties (HYV) and high demands for inputs, has resulted intense utilization of resources from natural ecosystem thus raising the concept of sustainability.

Bangladesh includes a wide range of agricultural environments, al together 30 agro-ecological zones (Brammer, 1994) naturally providing a range of opportunities and limitations to agricultural development (Mahtab and Karim, 1992). Environmental diversity is evident not only at national and regional levels but also at the local and village levels. The small scale complexity of soils and of hydrology is a characteristic of the floodplains of Bangladesh pointing to a diversified cropping system. Thus, crop like wheat and barley requiring far less water can be cultivated in areas where irrigation water is less easily obtainable. It is these water deficit areas where agricultural production rates are very low and there is every scope of higher income generation adopting less water requiring cropping patterns where Boro-rice can be replaced by barley and wheat.

Wheat in Bangladesh has made impressive gains in recent years in term of area under cultivation. In Bangladesh, wheat is grown only in the winter season, which is very mild and short. Time of sowing is one of the important factors controlling yield. Time of sowing determines time of flowering and it has great influence on dry matter accumulation, seed set and seed yield (Scott *et al.*, 1973; Ali *et al.*, 1985; Uddin *et al.*, 1986; Saran and Giri, 1987). But the sowing season is often delayed in the northern Bangladesh due to the late withdrawal of the monsoon. Thus wheat sowing is often delayed and yield rate is aversely affected. Moreover, delayed sowing increases the chance of the wheat crop to face drought more intensely than the early sown crop.

Trials over the years have been shown that the maximum yield can be obtained from sowing made between the middle of November to early December. The farmers generally sow wheat after the Aman harvest. This in turn often delays wheat sowing in late December and early January. This delay in wheat sowing results in reduction in crop yield as well as quality.

The growing period for wheat is about 90 to 105 days in this country. Late sowing of wheat exposes the crop to high temperature (>28^0C) resulting in poor stand, tillering, grain filling and increased attack by insects and diseases. Towards the end of season, warmer temperature during the three or four weeks after flowering may ripen the grain prematurely. Thus due to late sowing (beyond December 5), reduced yields are obtained primarily because of rising temperature in late February coinciding with heading which adversely influences grain filling.

Water is an important constraint to wheat yield (Austin, 1983; Begg and Turner, 1976). Stabilizing crop production through the selection of drought tolerant lines and better water management, especially irrigation is a major objective in many of the wheat growing areas of the world (Reitz, 1987). This crop is largely grown in stored soil moisture. Irrigation is needed for its successful production, especially for the modern varieties. So the irrigated area for more production of wheat is needed to be increased day by day.

The statistical reports indicate that the irrigated area for wheat cultivation was 2,72367 hectares in Bangladesh in 1992-93 (BBS, 1994). The remaining part of land is cultivated depending upon natural rainfall, throughout the whole crop period. The modern varieties of wheat do not give satisfactory yield in this non-irrigated land. As a matter of fact total production is decreased severely (Haque, 1993).

High yields of wheat can be obtained in Bangladesh with proper irrigation, adequate fertilizer and timely sowing of seed (Joarder *et al.,* 1979, 1981; Islam *et al.,*1987), Ahmed and Meisner (1996) observed that high wheat yield can only be obtained with irrigation under adequate fertility levels. Water stress develops inevitably as a consequence of water loss from the leaf while the stomata are open to allow the uptake of CO_2 from the atmosphere for photosynthesis. The water drawn from the soil by roots replaces the water lost from the leaf mesophyll cells during transpiration (Savin and Nicolass, 1996; Paul and Nahar, 2000; Begum, 2003).

The yield response of wheat to irrigation water depends mainly on proper irrigation scheduling. Irrigation scheduling based on growth stage does not always meet the water requirement of the crop properly. It may result in over-irrigation sometimes and under-irrigation in others and in both cases crop yield is affected. Different varieties have different ability to respond to drought condition in terms of growth and yield.

Numerous physiological phenomena related to crop growth and development is influenced by water stress (Pandit *et al.*, 2001). It is not yet understood, however, how these interact to cause a particular reduction in yield on wheat varieties and some show better yield under limited water supply than another. The effects of water stress mainly depend on soil moisture but the duration and timing of the stress and the related atmospheric conditions are also associated with the effects of water stress. The sensitivity of crop to water stress at different stages of their life cycle depends on the kinds of crop, its genetic potential to adapt the growth stage at which it occurs and the intensity of water shortage. Shortage at any growth stage in the life cycle of crop is likely to have consequences for yield. Water stress at almost any growth stage between spike initiation and maturity may cause a significant decrease in grain yield in various cereals (Day and Intalap, 1970; Hossain and Farid, 1988).

The effect of water stress on yield of wheat depends mainly on the proportion of water used in the total dry matter production through photosynthesis and is considered as useful material for evaluation (Fischer and Hagan, 1965). It has been shown for a number of cereals that dry matter stored in the seeds or grains is mainly the result of photosynthesis that occurs after flowering (Thorne, 1966). The drastic effects of water stress are found at the time of flowering of plant. In general, water stress, except at the most critical time will have less effect on the yield of grains than the total growth of he plants (Arnon, 1975). Wheat with moisture shortage during heading and filling were inefficient in moisture use (Lehane and Staple, 1962). Yield reduction was calculated with a view to finding out the varietal differences in susceptibility for moisture stress.

At present, the major wheat growing areas are located in the north-western, north-central and western parts of the country above 23^0 N latitude. Rajshahi division is one of the most important wheat growing areas in Bangladesh.

1.5 Cropping Pattern in Bangladesh

Crop yield depends on a number of factors such as climate (rainfall, temperature, solar radiation, and flooding), topography of soil, soil structure, fertility and other socio-economic conditions. The crops in this country are grown throughout the year in three distinct growing seasons: the First Kharif season (K1) lasting from the end of March to May, hot with moderate humidity, the Second Kharif season (K2) hot and humid with monsoon rain from May to September and the Rabi season(R) lasting from October to early March which is a cool and dry winter period.

In this context, the widespread cultivation of wheat is important not only in food production but also in environmental conservation and sustainable development. The people of Bangladesh now a-days have become accustomed to wheat as a substitute of rice. The advantage of wheat is that it requires less water than rice and it can be cultivated under both irrigated and rainfed conditions. Moreover, it requires fewer inputs thus the cost of production is low and provides assurance of next crop (Aus paddy / jute) after the harvest. Wheat has a bright prospect when grown in the Rabi season (October-March) in place of water and fertilizer requiring HYV Boro rice (Islam, 1975). Wheat can be grown under rainfed condition provided suitable varieties adaptable to low water conditions can be obtained. This change to `one wheat-one paddy instead of two paddy crops or one paddy-fallow cropping system will economy the water requirement as well as increase the diversity in crop production.

The present analysis clearly suggests more attention is needed on a diversified cropping system during the dry Rabi season than the Boro rice. The study emphasizes the need for giving a greater impetus to the growth of wheat, barley, pulses, oil seed and spices to reduce irrigation dependence. Obviously, Boro rice should be grown where easily managed irrigation is available.

1.6 Uses and Nutritional Composition

Wheat is a grass that is cultivated world wide. Globally, in the most important human food grain and ranks the second in total production as a cereal crop (FAOSTAT, 2006).

Wheat alone contributes a larger proportion of protein and calories to human being than all other foods or cereals. Walton (1969) stated that wheat is the most important source of concentrated carbohydrate for man and it contains considerable. As food, wheat is the major ingredient in most breads rolls, chapattis, crackers, coolies biscuits, cakes, doughnuts, muffing, pancakes, waffles, noodles, ice-cream cones, macaroni, spaghetti, puddings, pizza, burger, rolled flakes and many hot baby foods.

The whole grain contains approximately: water 13%, protein 11%, fat 2%, carbohydrate 70%, fibre 2%, ash 1.5% (Purseglove, 1972).

Wheat grain is rich in food value containing 12% protein, 1.72% fat, 69.60% carbohydrate and 27.20% minerals (BARI, 1997).

One hundred gram of hard red winter wheat contain about 12.6 g protein, 1.50 m total fat, 71 g carbohydrate (by difference), 12.20 g dietary fibre and 3.20 g iron or 17% of the amount required daily (USDA, 2006).

One hundred gram of hard red spring wheat contain about 15.40 g protein, 1.90 g total fat, 68 g carbohydrate (by difference), 12.20 g dietary fibre and 3.60 g iron or 20% of the amount required daily (USDA, 2006).

Wheat is nutritionally superior to most other cereals in many ways except in carbohydrate value. Wheat compares very will in nutritive value with rice. It is high in fat, iron and fibre content. It is high energetic food having digestible carbohydrate, protein, cholesterol free oil and good quality of trace mineral (Martin and Leonard, 1967) **(Table 1).**

Table 1. Comparative analysis of food components between wheat and rice.

Food components (in 250 g)	Wheat (Flour of wheat)	Rice (Flour of boiling rice)
Food calories (kcal)	900	865
General Components (g)		
Carbohydrate or Starch	174	198
Protein	30	16
Fats	4.30	1.00
Fibres	4.80	.50
Minerals Components (g)		
Minerals	68	1.80
Calcium	120	23
Phosphorus	1065	385
Iron	8	8
Vitamins (μg)		
Vitamin A	73	0.0
Thiamin	1.23	.50
Riboflavin	0.73	0.50
Niacin	11	10

1.7 Aims and Objectives

Bangladesh has become a chronic food deficit country mainly due to the rise in population and the frequent occurrence of natural hazards. As crop production risk is comparatively less in the winter months, more emphasis has been given on intensive crop production program during this period. However, the yield per unit area has not increased significantly during the last decade. Attempt should be made to have simultaneous increase in yield per unit area too. New varieties must be developed that can withstand adverse climatic conditions, particularly sowing time and the soil moisture stress in order to produce increased yield per unit area.

Very little work has been done in our country to develop package of improved management practices required to achieve higher yield of this but potential cereal crop. The present study was undertaken for investigate the performance of yield and yield components of wheat under sowing time and soil moisture conditions.

Therefore, the objectives of this investigation were:

1. Study of variability of different growth attributes, grain yield and yield components of wheat.
2. Study of path coefficient and character association to estimate direct and indirect effects of component traits on grain yield under different environmental conditions.
3. Study of genotype environment interaction to select variety with good general adaptation in wide range of environments.

Chapter 2
REVIEW OF LITERATURE

Production of wheat is affected by many factors in Bangladesh. Among these factors, sowing date and soil moisture conditions play notable role regarding phenotypic/quantitative characters of wheat. Due to short winter period in Bangladesh sowing date of wheat is very critical. Sowing of wheat is generally delayed due to preceding Aman rice or jute. Delay in sowing results in an unusual change in physiological processes brought about by several environmental factors. As a result it affects vegetative and reproductive growth and finally reduction of yield and yield components occurs. The yield response of wheat to irrigation water depends mainly on proper irrigation scheduling. In Bangladesh, it is not possible at this time to implement a modern and scientific method of irrigation scheduling because of lack of facilities, non-availability of required information and lack of technical know-how on the part of the farmers.

Sowing time and soil moisture play important role in respect of growth and development as well as yield of wheat. Yield is a complex character and it is the final product of actions and interactions of various physiological and morphological characters and it is highly influenced by the genetic as well as environmental flactuations.The yield of wheat is very low in Bangladesh as compared to other wheat growing countries of the world. Lack of proper sowing time and irrigation level are the main reasons for low yield of wheat in Bangladesh. Some related literature reveals that proper sowing time and proper level of irrigation influence growth yield and yield components of wheat.

Some related literatures are reviewed here under the following heads.

2.1 Sowing Date

Sharma and Singh (1972) studied the yielding abilities of dwarf wheat in different dates of sowing for three years. They sowed the wheat varieties on five dates (from the end of October to the beginning of January). They observed that November 1 and 15 for the first year, November 29 for the second year and November 9 for the third year, gave significantly higher grain yield than the other sowings. They reported that the optimum time of sowing was the beginning of November for long duration varieties like Kalyansona, the second half of November for short duration varieties like Sonalika and the middle of November for medium late varieties like Hira. They also found that Sonalika gave higher yield in the first year, Kalyansona in the second year and Hira in the third year. They stated that the interaction between sowing dates and varieties was significant both in the first and the second year.

Ahmed *et al.* (1975) studied the effect of time of sowing on the yield of Mexican wheat in the Northern part of Bangladesh. Five wheat varieties, namely, Penjano 62, Sonora 64, Mexipak 65, Inia 66 and Norteno 67 were sown on seven different dates at an interval of 10 days starting from October 20. The effect of different sowing dates on heading, maturity, height and yield was observed. Time taken from germination to 50% heading was reduced by the early sowing. It was also observed that late sowing reduced the duration from heading to 50% maturity but the early sowing lengthened the above period and took more 23 to 40 days. There was no appreciable difference in the plant height of the varieties in the highest yield on November 9 and among the varieties Mexipak 65 showed the best performance on that sowing.

Darwinkel *et al.* (1977) carried out the pattern of grain production as influenced by sowing date in winter wheat. They stated that delayed sowing decreased grain yield by causing a smaller number of grains per ear and a lower grain weight. The grain yield per ear depended on the age of the tiller. Early sowing emerged earlier and produced more and heavier ears in both the autumn and winter. Whereas, late sown wheat produced many late formed tillers only in the spring that were mostly non-fertile. The number of grains per ear and the grain weight were related to the rate of development of the ear bearing shoot that confirmed by the early sown plants.

In a field trial, **Ondruch (1977)** observed that delay in sowing decreased yield components of barley, especially number of fertile tillers per m^2 in cv.

Ametyst and number of grains per ear in cv. KM 1192 and decreased grain malting quality. They also found that increase in seeding rate increased yield at the later dates, but did not compensate for the decrease in yield due to late sowing.

Berrada (1979) worked on barley cultivation in the arid zone. He stated that early sowing gave much higher straw yield of 3.73 t/ha compared with 1.94 t/ha when drilled into a cover crop in early November than the average sowing date.

In an experiment, **Petr *et al.* (1979)** followed the tiller production, formation of ears and spikelets, the proportion of the grain yield on each tiller and 1000-grain weight. They observed that the maximum number of tillers was formed in mid-May and from end-May to mid-June there was a period of tiller reduction; the amount of reduction varied with the number of plants per m^2, cultivars, climate conditions and the number of tillers formed per m^2. At shooting, the number of stems per m^2 was 1400-2400; at harvest the main stem and tillers formed 35 and 65%, respectively of the total. The proportion of the main stem was 35-45% in modern and 50-60% in cv. Nurimbersky. They also observed that the grain yield was correlated (r=0.98) with the length of the period from the beginning of the third stage of growing point development to the maximum number of flower primordial occurred (23% with favourable rainfall to 41% in a dry year).They found that 1000- grain weight was the most stable component; it was same in the main stem and first 3 tillers and decreased in the further tillers. At>18000 grains/m^2, 1000 grain weight decreased and at>20000-22000 grains/m^2 there was no further yield increase.

In a field trial **Makki and Habib (1979)** cultivated barley plants (cv. Beacher) on 1 November, 20 November, 10 December, 30 December and 20 January. They studied yield growth characteristics. They found that grain yields were 2.90, 3.87, 3.67, 2.62, and 1.35 t/ha for the 5 sowing dates, respectively. Plant height was greatest (81.5 cm) when sown on 10 December. Tiller number per m^2 decreased with delay in sowing but the effect was not significant. 1000-grain weight was also not significantly affected by sowing date.

Rao *et al.* (1980) conducted a field experiment to find out the optimum date of sowing in wheat (*Triticum aestivum* L.) and the relationship between the date of sowing and the yield production. The dates of sowing were from November 5 to January 19 at fifteen days interval. They found that sowing on November 20 was the optimum time of sowing for the highest grain yield. They also found that sowing on December 20 did not occur much reduction in yield and further late sowing (January 4 and January 19) caused more reduction in yield due to high temperature at the grain filling stage.

Abdel-Raouf *et al.* (1983a) carried out an experiment to find out the associations between growth attributes of barley and grain yield under different seeding dates. They observed that plant height, dry weight, leaf area and leaf area index of 7-week old plants decreased with delay in sowing date. Highest CGR and RGR of 7 to 14-week old plants were obtained by sowing on 5 December. After 15-17-week the highest values were obtained by sowing on 15 November. Grain yield was positively correlated with plant height at all the growth stages. DM accumulation, leaf area and leaf area index at the latest growth stage were negatively correlated with RGR and NAR.

Sufian *et al.* (1983) carried out a field experiment to determine the effect of sowing time on ten wheat genotypes. They sowed ten genotypes of wheat for early (October), medium (November) and late (December) sowing with a view of finding the suitable genotypes. They reported that October and December sowings reduced the average growing period for all the genotypes in comparison to November sowing. The genotypes Jupateco 73, BAW 6 and Bulbul sown in October; Bulbul, Nacozari 76, Kal Bb, BAW 6, Indian, RLx4220 7C/yy 's', Chiroca 's', Pavon 's' sown in November and Bulbul, Nacozari 76, Chiroca 's', BAW 6 gave significantly higher yield in November sowing.

Kolbe (1984) studied the course of development of cereals (1968-1984) in relation to sowing time. He considered growth stages in cereals and defined average values of the starting dates at Hofchen and Laacherhof experiment stations in 1968-1983 of each stage in winter barley, winter rye, winter triticale, winter wheat, spring wheat, oats and barley, their mean deviations and durations and values in relation to day length, air and soil temperature, solar radiation and rainfall. Greatest deviations in starting dates were in tillering in winter barley, rye and triticale and in the 1 to 3-leaf stage in winter wheat and spring cereals and the least were in heading and flowering in all species. The length of the resting period between vegetative and reproductive stages differed widely among winter species and between winter and spring species. Cereals differed in their requirements for heat, water and solar radiation and in their response to early, normal and late sowing. With sowing at the local customary date generally giving the highest grain yields and early sowing favouring weed growth. Interspecific competition was important in yield formation with the ratio maximum number of shoots: number of ears highest and lowest at 3.1:1 and 1.5:1 in winter rye and spring barley.

Chaturvedi *et al.* (1985) studied the effects of sowing dates on the spike characters of mother shoot and various tillers of wheat (*Triticum aestivum* L.). They sowed the seeds of C 306, Kalyansona and Sonalika on seven days at an interval of 15 days starting from October 1. They also studied the phenology and yield components of the main shoot. The duration of phenological phases and the ear differentiation were affected more in Kalyansona than C 306 by a change in photoperiod and temperature. In the early sown plants, the difference between main shoot and tillers were negligible for the number of spikelets, grains per spike and grain weight per spike except in Sonalika, where grain weight per spike was more in the main shoots. They found that all the attributes of ear of each variety were affected with delayed sowing. The grain weight per spike, number of grains per spike and grain yield decreased significantly with the increase of temperature. They reported that Sonalika should be always higher seed rate irrespective of the date of sowing, whereas Kalyansona and C 306 had the higher seed rate only in the late sowings.

Ghadekar *et al.* (1985) studied the growth and heat unit accumulation in sorghum hybrids in wet season on the vertisols of Nagpur. They sowed sorghum hybrids of CSH 9, CSH 5 and CSH 1 on five different dates, viz. June 28, July 5, July 12, July 19 and July 26. They observed that the total dry matter, plant height, grain yield, number of grains per ear, fodder yield and husk yield were produced when sown on June 28, followed by July 5 and these characters were decreased with further delay sowing. Among the hybrids, CSH 9 was the best as the weather was helpful on those days. It was observed that the highest heat unit was accumulated by the crop sown on June 28 followed by July 5 for all the phenological stages and further delay in sowing.

Green and Ivins (1985) conducted an experiment to observe the effect of sowing times on yield of winter wheat. They sowed three winter wheat cultivars on optimum and late seeding condition under two growing seasons. They found that advancing the date of sowing for winter wheat cultivars increased the duration of the growing period and it increased the opportunity for the absorptions of photons. As sowing being delayed, TDM accumulation decreased which ultimately influenced the yield of wheat. They approached mid-September as an optimum sowing. They reported that yield potential declined at a rate of 0.35% for every day when sowing was delayed after September 22.

Green *et al.* (1985a) studied the influence of sowing date on the yield of winter barley *(Hordeum distichon* L. cv. Igri*)*. They sowed the seeds from early September to mid-November. They found that delayed sowing resulted in a linear decrease in maximum grain yield. They also found that advancing the date of sowing increased the duration of pre-anthesis development, increased the level of tillering and hence ear density at the final harvest. They reported that yield was linearly related to the resultant higher number of grains.

Green *et al.* (1985b) observed the influence of planting date on development of winter wheat crops grown during the season of 1981-82. They sowed 'Normal' cultivars at the rate of 450 seeds per m^2 at four sowing dates. They found that earlier sowing induced a faster production of tillers, a consequently higher maximum number of tillers because of higher mean temperature over the period of early vegetative growth. Delayed sowing reduced the tillering efficiency, did not compensate by increasing higher seed rate and resulted lower number of ears. Earlier sown crops had faster tendency to accumulate dry matter in grain than the late sown crops, which was not significantly affected by sowing time. As sowing was delayed, yield was reduced because of a decrease in number of grains caused by fewer tillers being produced. However, while mean individual grain yield was increased as sowing was delayed for barley, no similar effect could be detected for wheat.

Jepsen (1985) investigated the effects of sowing date and rate on yield of winter wheat and barley. He found that yields from sowings on 2 September and 23 September were not significantly different, but sowing on 15 October reduced yields by 9% (0.53 t/ha) in wheat and 15% (0.9 t/ha) in barley, with sowing rates from 240 to 540 viable seeds/m^2. He stated that there was a significant interaction between sowing date and rate in winter wheat. He mentioned that lower seed rate could be used for early than late sowing. He also observed that the number of ears per plant increased with decrease in sowing rate and was somewhat depending on sowing date. In winter barley, sowing rate of <360 viable seeds per m^2 decreased yield by 2.5% (0.1-0.3 t/ha) regardless of sowing date. Sowing rates of 360-540 viable seeds per m^2 did not affect yield. Early sowing increase tillering in barley and the average number of ears per plant increased from 2.4 to 4.1 as sowing rate decreased from 540 to 360 viable seeds per m^2. After sowing on 23 September and 15 October, the average number of ears per plant was 1.7 and 2.9, respectively.

Kirby *et al.* (1985) studied the effect of sowing date and variety on main shoot leaf emergence and number of leaves of barley and wheat. They found that the final number of leaves per plant decreased with advance in sowing date, except for the winter varieties with the last date, when the number rose. Differences in final number of leaves were observed among the varieties and there was a strong variety × sowing date interaction, which is attributed to differences in vernalization response. Leaf emergence rate rose with the delay in sowing date in both crops and differences in the rate were observed among the varieties, although there was no marked variety × sowing date interaction. In both crops, winter varieties tended to have higher rate. Rate of leaf emergence was correlated with rate of change of day length at different sowing dates.

Saini and Dadhwal (1986) worked on grain growth duration and kernel size in wheat as influenced by sowing dates. They found that when Kalyansona and Sonalika varieties of bread wheat *(Triticum aestivum* L.) and HD 4502 variety of macaroni wheat *(T. durum)* were grown in temperature between 13°C and 27°C, the grain growth duration from anthesis to maturity declined by 2 to 6 days for every 1°C rise in temperature. The photoperiod effects on the grain growth duration from anthesis to maturity were found to be negligible. For every year, 1°C rise in temperature, kernel weight declined by 2 to 5 mg in Sonalika, by 1.58 mg in Kalyansona and by 1.9 mg in HD 4502 which corresponded to decline of about 3.8% (HD 4502) to 4.5% (Kalyansona and Sonalika) of their maximum predicted kernel weight at 16°C.

Saini *et al.* (1986) studied the influence of sowing dates on pre-anthesis phenology in wheat. They observed the dates of the first spikelet initiation, terminal spikelet initiation and anthesis on HD 4502, a semi-dwarf medium duration variety of *Triticum durum* and three varieties of *T. aestivum* L., viz. Hindi 62, a tall late flowering variety; Kalyansona, a semi-dwarf medium duration variety and Sonalika, a semi-dwarf early flowering variety. They found that when sown early or late, the initiation of the first and terminal spikelet was hastened and anthesis occurred earlier. HD 4502 was less responsive to sowing earlier. When Hindi 62 was delaying in sowing, the duration from sowing to the first and terminal spikelet initiation decreased but the period between the first and terminal spikelet initiation did not change much. An eight day delay in sowing reduced the duration from sowing to the first spikelet initiation by one day.

Sarkar *et al.* (1986) conducted an experiment to investigate the effect of dates of planting on the growth and yield of some modern cultivars of wheat. They sowed four modern wheat varieties, e.g., Kanchan, Ananda, Akbar and Barkat on six different dates starting from November 15 at an interval of 10 days. They found no significant difference between cultivars in respect to yield. But they reported that Barkat produced significantly the highest straw yield in comparison to the other cultivars. They also reported that November 25 and December 5 sown plants produced significantly higher grain yield in respect to other dates of planting. They observed that the grain yield was severely reduced when planting was delayed beyond December 25 and January 4.

Zhao *et al.* (1986) worked in the influence of sowing dates on growth and development of barley. They observed that cv. Zhepi 1 sown on 28 October or 7, 17 or 27 November on a silt loam in 1982-1983 and 1983-84 had 10-12 leaves on the main stem irrespective of the sowing dates. With delay in sowing, tiller and ear number per plants decreased from 64 to 41 and from 49 to 18, respectively and the period from differentiation of outer and inner glumes to heading decreased from 88 to 30 days. The duration from heading to maximum grain weight was 35 days. The increase of the grain weight and filling rate were highest at 21-28 days after heading for most of the sowing dates. The full growth period was shortened with delay in sowing.

/**Rajput *et al.* (1987)** studied the influence of planting dates on phenology and heat unit relationship in wheat under late sown condition. They observed that the requirement of accumulated heat units (AHU) decreased with delayed planting. They computed helio-thermal unit (HTU) as the product of growing degree days with the bright sunshine hours. They also introduced phenothermal index as the AHU per growth day. They also observed that HTU was also decreased with delayed planting. The phenothermal index was nearly constant irrespective of planting dates and sites. A regression for predicting the maturity date for the wheat crop using heat units accumulated up to flowering initiation was developed.

An experiment was conducted by **Hossain and Farid (1988)** to study the influence of sowing date and seed rate on two wheat varieties (Akbar and Barkat). They were sown on four dates starting from November 5 at an interval of 15 days under irrigated condition. The higher grain yield was obtained on November 20 followed by December 5 due to higher number of spikes per m^2, number of grains per spike and 100-grain weight for favourable atmospheric temperature prevailing from sowing to grain filling period. The early sowing (November 5) caused reduction (8.8%) in grain yield due to high temperature prevailing from sowing to seedling emergence and tiller initiation resulting in lower number of tillers per unit area. The late sowing (December 20) produced low yield due to shorter growing period at the vegetative phase and steep rise in atmospheric temperature at the grain filling period. It was observed that the early sowing produced the taller plants than the late sowing. It was also observed that Akbar gave significantly higher grain yield than that of Barkat, irrespective date of sowing.

Dahiya and Narwal (1989) conducted an experiment to study the phenological behaviour and thermal requirements of maize varieties sown on various dates. They worked with four varieties, viz. Partapi, Ageti 76, Gange 5 and DHM 103 at four different sowing dates starting from December 19 at an interval of 10 days. Growing degree days were calculated using a growth-threshold temperature of maize (7°C). They found that the seedlings emerged at 11, 12, 13 and 14 days after sowing in maize sown on December 19, December 29 and January 8, January 18, respectively. They also found that the days to tassel emergence and silking decreased progressively with delay in sowing. The crops sown on December 19 and December 29 required less growing degree days for all the phenological phases than those sown on January 8 and January 18. The growing degree days requirement for tassel emergence, silking and maturity was identical in the crop sown on December 19 and December 29; whereas, the requirement for tassel emergence, silking and maturity was more in the crop sown on January 8 and January 18.

Kang *et al.* (1989) sowed barley cv. Chalbori on 20, 25 or 30 September or 5 October and was cut for green forage on 10 November and 10 December. Average winter green forage yield was highest (27.7 t/ha) with 20 September sowing. Total dry matter, crude protein and crude fat increased with increased delay in sowing date while crude fat and nitrogen fertilizer efficiency decreased. The percentage of cold injured leaves and tiller decreased with increased delay in sowing date. Heading and maturity dates were not affected by sowing date. Winter defoliation did not affect grain yield but reduced lodging.

Patel (1990) observed that delaying sowing after March reduced grain yields in all the experiments and these effects were gradually associated with reductions in number of ears and grains per ear. The changes in mean grain size were smaller and sometimes compensated for reductions in the other yield components. Sowing from October to January did not affect yield of winter cultivars and these cultivars sown in March gave similar yields to spring cultivars. Apical dissections were carried out in all the experiments and the durations of vegetative and reproductive phases and rates of initiation of spikelet primordial were studied. The duration of vegetative phase was reduced by delayed sowing, an effect which was determined by mean photoperiod. The rate of initiation of spikelet primordial increased with delay in sowing and was linearly related to time in all the cases.

Torofder and Altab (1991) observed the effect of sowing dates on the yield of four varieties of barley for two years. They sowed the varieties, namely Contineka, AP 19, AP 20 and Jamalpur local on October 30 to December 30 at an interval of 15 days at Jamalpur. The higher grain yields were obtained from November 5 to November 30 than those of the other sowing dates due to higher number of spikes per m^2, grains per spike and 1000-grain weight in both the years. Sowing after December 15 the grain yield decreased due to shorter growing period and higher temperature at the grain filling stages that caused early maturity. Compared to the other varieties, Jamalpur local produced the highest yield. There was no interaction effect between dates of sowing and varieties on the yield for both of the years.

Dofing (1992) studied the comparative growth, phenology and yield components of three early maturing barley and wheat during 1989-91 growing season at Palmer, Alaska. He found that barley cultivars produced an average of 1.1 more leaves than wheat and had a smaller (4.5 growing degree-days/leaf) phyllochron interval. They also stated that the early maturity of barley relative to wheat was due mainly to its ability to fill and ripen grain under cool conditions.

Jain *et al.* (1992) studied the effect of sowing time on wheat varieties. They worked with six varieties of bread wheat *(Triticum aestivum* L.) and one of macaroni wheat *(T. durum)* under five dates of sowing starting from December 20 at the interval of 10 days. They found that late sowing significantly reduced the grain yield in all the varieties, i.e., by 4.17%, 22.30%, 30.71% and 56.62% with delay in sowing by 10, 20, 30 and 40 days compared with crop sown on December 20.

Islam *et al.* (1993) studied the effect of sowing dates on the yield of wheat varieties at Regional Agricultural Research Station (RARS), Ishurdi, under irrigated condition. They sowed the existing (Sonalika) and newly released wheat variety (Ananda, Kanchan, Barkat, Akbar and Aghrani) on six dates starting from November 1 to January 15 at fifteen days interval. They reported that the best time of sowing was November 15 for producing the higher grain yield due to higher number of spikes per m^2, number of grains per spike and 1000-grain weight for favourable atmospheric condition during the growth period. Grain yield was decreased after December 15 sowing. The lower grain yield in the late sowing (January 15) was due to shorter growing period in vegetative phase and steep rise in temperature in the grain filling stages. Among the varieties, Kanchan produced the highest grain yield irrespective of sowing dates. The varieties followed the following order for the yield: **Kanchan > Akbar > Barkat > Aghrani > Ananda > Sonalika.** It was also observed that the yield due to different dates of sowing over the varieties followed the order: **November 15 > December 1 > November 1 > December 15 > January 1 > January 15.**

In a field experiment **Nilson (1993)** observed that seedling emergence and survival were 10 to 15% higher with the high sowing rate but grain yield was only increased when the crop was sown late. Seedling survival was decreased by 15% from sowing late (30 September) compared with 15 September sowing.

Quayyum *et al.* (1994) carried out an experiment to determine the optimum sowing dates of four maize cultivars at Joydebpur. In this study, there were five sowing dates starting from October 15 to February 15 at an interval of one month and four maize cultivars, namely, Pirsabak 8146, La-Maquina 7827, Khoibhutta and Shuvra. They observed yield and yield components for two years. The highest grain yield (4.3 ton/hectare) was obtained from November 15 sowing by producing the higher number of grains per cob in the both of the years. The lowest yield obtained from

January 15 sowing was probably due to low temperature during early vegetative phase and high temperature during grain filling period. They also observed that late sown crop took longer time to germinate that reduced the effective growth period of the crop. Among the cultivars, Pirsabak 8146 gave the highest grain yield of 5.13 ton/hectare followed by La-Maquina 7827, Khoibhutta and Shuvra.

Sekhon and Singh (1994) studied to assess the effect of kinetin and ethrel (2-Chloroethyl phosphoric acid) on grain development under different sowing dates. Wheat (cv. WI-1562) crop was sown on three different dates referred as early (October 16), normal (November 21) and late (December 30) under field conditions and the aqueous solution of kinetin (10 mg/litre) and ethrel (100 mg/litre) at the rate of 301itre/hectare were sprayed at 50% ear emergence stage and repeated after one week. They reported that kinetin and ethrel showed the highest rate of dry matter accumulation in the peak grain growth period (41 to 50 DAS) in the early sowing, but decreased in the late sowing. They also reported that starch and protein accumulation in the grains, responded differently to growth regulators and sowing dates. They found the highest activities of growth regulators in grains for early and normal sowing.

Bishnoi *et al.* (1995) conducted an experiment to develop the relationship of phenological development with thermal unit under different sowing dates and moisture levels in wheat. The crop was sown on 5 different days, viz. October 29, November 13, November 29, December 13 and December 29 and three moisture levels (lo, I_1 and I_2). The observed phenological stages *were* germination, crown root initiation, last tiller, flag leaf, last node, ear emergence, anthesis, grain filling, milking, hard dough and maturity. They found that the number of leaves emerged maximum in early sowing (October 29, followed by November 13). Its number was higher in main stem and decreased with later tillers. The emergence of leaves showed a linear response with cumulative heat units. They also found that the total number of leaves on the main stem and tillers were strongly related with the accumulated heat units and emergence of leaves. The requirement of heat units decreased with delay in sowing

Kernich *et al.* (1995) observed that the rate of leaf appearance of barley varied substantially with time of sowing. This variation had been related to both the length and the rate of change of photoperiod at the time of plant emergence.

Kirby (1995) observed that rate of leaf emergence of wheat and barley changed with sowing date and temperature and appeared to be set early in the plant life cycle. Four models that advanced different hypothesis to explain this variation were examined. None was completely satisfactory, partly because of a nonlinear response to thermal or photothermal time. Soil strength, N nutrition and depth of sowing affected rate of leaf emergence, as may sub-zero temperature or ontogeny. An alternative hypothesis proposes that leaf emergence rate depends on day length and acclimatization to temperature. Potential rate of leaf emergence may be determined by factors acting on leaf primordia, which are initiated early in the life cycle.

Shatilov *et al.* (1995) observed the effect of sowing date on rate of emergence, plant population, coefficient of productive tillering, plant height aboveground, plant dry weight, spike weight, number of grains per spike, seed germination and 1000-grain weight. Sowing before the end of April gave grain yields of 6.78-7.02 t/ha. After this yield decreased progressively 3.18 t/ha for the latest sowing.

Shaykewich (1995) reviewed the response of phenological developmental of cereal crops, primarily maize, wheat and barley, to environmental conditions. He concluded that the development rate of most species is a sigmoidal rather than a linear function of temperature. Consequently, phenological models assuming a liner relationship (e.g.; degree-days) are inappropriate. Another consequence of the way plant respond to temperature is that the most precise phenological models will require use of temperature data over relatively short period (e.g.; 3 hour) rather than just a daily mean temperature. He suggests the ways of standard climatological data used in phenological modeling. He also reviewed phenological response to photoperiod.

Khan *et al.* (1996) conducted an experiment at Bangladesh Agricultural University, Mymensingh, to observe the effect of boron and sowing dates on different wheat varieties. They sowed the three varieties, viz. Sonalika, Kanchan and Aghrani and applied boron at the rate of 10 and 3 kg boron per hectare on four days beginning from November 20 at an interval of 10 days. It was observed that the highest grain yield was obtained when seed was sown on November 30 and follows this order: **November 30 > November 29 >December 10** > **December** 30. Kanchan produced higher grain yield followed by Aghrani and Sonalika. It was observed that boron had positive significant effect on the number of grains per spike and grain yield. Boron treatment and sowing time influenced the wheat yield independently so that the yield loss due to late sowing was not compensated by added boron and similarly, the yield gap due to boron deficiency was not removed by timely sowing.

Lupu and Lupu (1996) observed that the number of days from sowing to emergence was 11-147 and varied according to the sowing date and weather conditions. With the increase in lateness in sowing by early spring, 18-23, 14-16 and 33-35% plants as a total germinable seeds sown had been lost.

Noworolnik and Leszczynska (1997) examined the cultivar response to sowing date (5-10, 15-20 and 25-30 April) for 9 spring barley cultivars during 1993-95. They observed that cv. Start and NAD 1592 had the greatest reduction in grain yield when sowing was delayed, even by 10 days. Most tolerant to delay sowing were RAII 792 and NAD 1391. They stated that lower yield due to delayed sowing was mainly due to a reduction in productive tillers and to a lesser extent reduced grain yield per ear (fewer grains per ear).

Samanta *et al.* (1997) studied the different growth stages and yield of prosomillet cultivars as influenced by sowing dates. They sowed four prosomillet cultivars viz. Kumardhan, BPM-24, BPM-40 and Tushar on five dates starting from November 15 at an interval of 15 days at BAU Farm, Mymensingh, Bangladesh. They observed that late sowing caused late germination and reduced the period (days) of panicle initiation, flowering and maturity due to low temperature at the seedling stage and high temperature at the grain filling stage. They also observed that sowing at November 15 took the highest number of days for attaining various growth stages and thereafter decreased with delayed sowing. Among the cultivars, Kumardhan took the highest number of days for attaining various stages of growth. They reported that LAI was the maximum at 50% flowering in all the cultivars and decreased sharply at 15 days after flowering (DAF) and LAD had similar trend as the LAI. The rate of dry matter accumulation gradually increased up to 15 DAF and then declined due to leaf senescence in all the cultivars and sowings. Grain yield was significantly higher on November 15 sowing, followed by November 30 than the other sowings due to shorter growth period and higher ambient temperature during the grain filling stage. The cultivar Kumardhan produced the highest number of leaves, LAI, LAD, TDM and grain yield on November 15 sowing followed by November 30 sowing.

Sandhu *et al.* (1999) studied the yield performance and heat unit requirement of wheat *(Triticum aestivum L.)*, varieties affected by sowing dates under rainfed conditions. They sowed the wheat varieties (PBW 175, PBW 299, PBW 320 and PBW 359) on four dates from October 25 to November 24 at an interval of 10 days. The crops sown on October 25 produced better grain yield, which decreased with delay in sowing. PBW 175 wheat variety gave the highest yield followed by PBW 299. They observed the occurrence of different growth stages as well as the heat units to relate to different sowing dates. They reported that crop growth duration and heat unit decreased with delay in sowing. The number of days taken for seedling emergence and jointing increased with a concomitant decrease in the duration of reproductive phase, particularly flowering to maturity. Heat units did not differ so much during seedling emergence but increased during emergence to jointing and decreased during jointing to flowering when crops were sown on November 4. The heat units decreased during flowering to maturity with delay in sowing due to shortening of the ripening period.

Muntasir and Ali (2000) observed the effect of sulphur and dates of sowing on yield and yield contributing characters of two wheat varieties. The experiment was laid out in a split plot design assigning the sowing dates (November 22 and 29) in the main plot varieties and sulphur levels (0, 20, 30 and 40 kg sulphur/hectare) in the sub plot having three replications. The results obtained from the study revealed that sowing dates exerted a significant effect on agronomic attributes except plant height, number of spikes per m^2, length of spike, grain and straw yields remained unaffected. Grain yield was found decreased progressively as the sowing was delayed, varieties differed significantly in respect of number of spike per m^2, length of spike, 1000-grain weight and straw yield were significantly influenced by sulphur levels. Significantly the lowest grain yield was obtained from 0 (zero) kg/hectare but with the increase of higher concentration of sulphur, the result was different. Significant positive relationship was also noticed in most of the cases when the relationship patterns were established between yield and yield contributing characters of wheat.

Singh and Jain (2000) worked on the effect of sowing time, irrigation and nitrogen on grain yield and quality of durum wheat *(Triticum durum).* They reported that mid-November sowing crop gave significantly higher grain yield than the early and late sowing crops and extent of increase were 12.3% and 33.6%, because of number effective tillers. The prevalence of higher yellow-berry content under irrigated environment could be ascribed to reduction in nitrogen status of grain. Each increase in nitrogen fertilization up to 1 to 0 (zero) kg/hectare significantly improved grain yield. The extent of mean increase in grain yield was of the order of 12.0% and 3.8% with each increase in nitrogen level from 40 to 80 and 80 to 120 kg/ hectare.

Verma *et al.* (2000) studied the nutrient utilization of late sown wheat *(Triticum aestivum L. emend.* Fiori and Paul) in a split plot design on acid soil of Bihar plateau. Main plot included four seeding times, viz. moderately late (December 1), late (December 16), very late (January 1) and extremely late (January 16) and sub plot consisted of four nutrient levels.

Paul and Sarker (2003) carried out an experiment in the experimental field of Rajshahi University Campus, Bangladesh to study the effect of sowing time on grain yield of two wheat (*Triticum aestivum* L.) cultivars. Two cultivars of wheat (Karan and BL 1183) were sown on four sowing dates, viz, 1 November (S_1), 19 November (S_2), 1 December (S_3) and 15 December (S_4). Sowing up to 19 November had no adverse effect but sowing of 1 and 15 December affected the grain yield. Simple correlation analysis indicated that grain yield was positively correlated with number of tillers per plant, number of fertile tillers per plant, number of spikelets per spike and total dry matter.

Haque *et al.* (2004) conducted a field experiment to find out the effect of temperature on grain filling and grain weight of eight cultivars of wheat. Eight cultivars of wheat (*Triticum aestivum* L.) were sown on four sowing dates, viz. 1 November, 15 November, 30 November and 15 December in the research field of IBSc, University of Rajshahi during 1995-96 and 1997-98. The slopes of regression equation indicated that 0.64 and 1.01 days shortened by per °C increasing mean daily air temperature during the grain filling period for the 1 and 2 year, respectively. Grain weight per panicle was decreased by 24.0 and 64.0 mg for the 1 and 2 year respectively per °C increase in temperature during anthesis to maturity. A positive association between grain weight and grain filling duration indicated that grain weight per panicle was increased by 50.0 and 58.0 mg for every 1 day increase in grain filling duration. Cultivars differed significantly in duration of grain filling and grain weight.

Alam *et al.* (2005) carried out an experiment in the research field of the Department of Botany, University of Rajshahi in 2002-2003 with four barely cultivars in a split plot design with four sowing times, five N treatments in each sowing and cultivars with three replications to study the effects of sowing dates (November to December) and some related characters of barely cultivars. Their results indicated that sowing in the 1 and 2 week of November resulted higher grain yield and total dry matter compared to other times. Delay in sowing i.e., after 17 November decreased dry matter accumulation.

Ahmed *et al.* (2006) conducted a field experiment at Farming System Research and Development (FSRD) site, Chabbishnagar, Godagari, Rajshahi under rainfed condition during rabi seasons of 2001-02 and 2002-03 to find out the suitable variety (BARI Barley-1, BARI Barely-2 and local) and sowing time of barely (30 November, 15 December, 30 December) in split plot design with three replications with basal fertilizer doses 85-25-45 kg/ha of N, P and K in the from of urea, TSP and MP, respectively in 4m×5m plot size where the sowing time was placed in the main plot and variety in sub-plot. They observed that grain and straw yields increased significantly with early sowing (30 Nov.) in all the varieties in both the years. The results showed that early sowing (30 Nov.) combined with BARI Barely-1 gave the highest grain yield (2.55t/ha) and straw yield (4.28t/ha), whereas the lowest grain yield (1.23t/ha) and straw yield (3.21t/ha) were obtained from local variety with delayed sowing.

Salam *et al.* (2006) conducted an experiment in randomized complete block design with three replications at Farming System Research and Development site (FSRD), Chabbvishnaor, Godanari, Rajshahi on high Barind Tract (Agro-Ecological Zone-26) during two consecutive rabi seasons of 2000-2001 and 2001-2002 to determine the optimum sowing time for maximizing yield of barley cv. BARI Barley 2. Four sowing dates viz. 15 November, 30 November, 15 December and 30 December were used as treatment variables. The November 30 sowing produced the highest yield (2.27 t ha^{-1}) of barley. It was closely followed by December 15 sowing (2.15 t $ha^{-1)}$ and the lowest grain yield (1.62 t ha^{-1}) was obtained from late sowing (December 30).

Alam *et al.* (2006) carried out an experiment at the experimental field of the department of Botany, University of Rajshahi, Bangladesh to study the effect of sowing dates on growth attributes of two barley (*Hordeum vulgare* L.) cultivars. Two cultivars of barley (BB1 and Karan 351) were sown in four sowing dates viz. 5 November (S_1), 17 November (S_2) 29 November (S_3) and 11 December (S_4). Results indicated that growth attributes like, RGR, NAR and RLGR of both the cultivars decreased when plants were sown after 17 November, but LAR increased at the later sowing.

Shahzad *et al.* (2007) carried out an experiment in the experimental field at the Agronomic Research Area, University of Agriculture, Faisalabad to study the growth, yield and quality of wheat varieties "MH-97" to the effect on sowing dates and seed treatment. Different sowing times included November 15, November 30 and December 15. The seed treatments comprised un-soaked, water soaked and 1% $NaHCO_3$ soaked seed. The water soaked and 1% $NaHCO_3$ seed treatments produced higher yield of 4.618 t/ha and maximum average grain yield of 5.09 t/ha was produced by sowing of wheat on November 15. Water soaked seeds sowing at November 15 was superior in all respect.

Alam *et al.* (2007) conducted an experiment in the research field of the Department of Botany, University of Rajshahi, Bangladesh to study the influence of sowing times on yield and its components of four barley cultivars (*Hordeum vulgare* L.). Four cultivars of barley (BBI, Karan 19, Karan 163 and Karan 351) were sown in four sowing dates [5 November (S_1), 17 November (S_2) 29 November (S_3) and 11 December (S_4)]. Most of the yield and its components were significantly highest in 17 November sowing. All the cultivars most of the characters showed their highest values in BB1 and the lowest in Karan 19.

Islam *et al.* (2008) conducted an experiment at the research field of the Bangladesh Rice Research Institute (BRRI), Gazipur during the boro season of 2005 to determine the appropriate seeding date of direct wet-seeded rice (DWSR) using drum seeder compared to traditional transplanted rice (TPR). The five planting dates were (i) 1 December (D_1), (ii) 15 December (D_2), (iii) 31 December (D_3), (iv) 15 January (D_4) and (v) 31 January (D_5). 31 December seeded DWSR produced the highest grain yield (6.18 t/ha), which was about 24% higher than TPR. Growth duration was reduced, on an average, by 8 days in DWSR compared to that of TPR. The highest number of panicles per m^2 (606) was found at 1 December planted direct wet-seeded rice, which was 128% higher than TPR. DWSR, which was planted in January significantly, reduced the number of panicles per m^2 but 1 December planted rice significantly reduced the grains per panicle and no significant difference in 1000-grain weight was observed between the planting methods irrespective of planting dates. Leaf area index (LAI) was higher in DWSR than TPR during the month of December. The month of December appeared to be suitable for direct wet-seeding using drum seeder for boro season.

2.2 Irrigation level

Fischer and Hagan (1965) observed that the effect of water stress on yield depends largely on the proportion of water used in the total dry matter production through photosynthesis and is considered as useful material for evaluation.

Campbell (1968) reported that increasing or decreasing the soil moisture stress at various stages of growth had relatively little effect on the number of floret per head, or on the mean grain weight. The main components influencing grain yield were the number of heads per plant and the percent of seed set.

Misra *et al.* (1969) reported that applying no irrigation at the crown root initiation stage and flowering stage adversely affected tillering, grain yield and 100-grain weight of wheat. They also observed that the grain yield increased with four irrigations applied at the crown root initiation, late tillering, and flowering and dough stages.

Patel *et al.* (1971) reported that omitting irrigation at the crown root initiation and at late tillering stages significantly reduced the plant height, number of tillers per plant, length of ear head and thereby the number of grains per panicle.

Anonymous (1975) reported that the irrigation had a significant effect on plant height, total and effective number of tillers per plant, panicle length, total and fertile grains per panicle, straw and grain yields, except 1000-grain weight. Four levels of irrigation, such as no irrigation, one irrigation (only at 22 days after sowing) and three irrigations (at 22, 45 and 65 days after sowing) were used. The highest yield of grain and straw were obtained with three irrigations. The height of the plants, total and effective tillers per plant, panicle length, total and fertile grains per panicle, straw and grain yields were gradually increased with the increased number of irrigation.

Pal *et al.* (1979) found at the Bundlekhand region of India that three irrigations given at CRI, tillering and milk stages produced higher grain yield than two irrigations at CRI and milk stages for durum wheats. They also added that one irrigation at CRI stage significantly increased yield over the control.

Lyall (1980) observed that barley yields in East Midlands in 1971-78 were negatively correlated with mean air temperature, soil temperature and total rainfall during the establishment stage, positively correlated with total rainfall in the vegetative stage and negatively correlated with mean air and soil temperature, sunshine hour, evaporation and humidity after anthesis. Average yields in Scotland in 1971-77 were not significantly correlated with climate, except for a positive correlation with sunshine hour during the vegetative stage.

Malik (1980) in India observed during three years of trials that the average grain yield of wheat increased from 2.68 to 4.42 ton per ha, in Kalyansona with the increasing number of irrigations from 1 to 4 applied at the crown root initiation, tillering, flowering and dough ripeness stages.

Koshta and Raghu (1981) carried out an experiment with three irrigation treatments (two splits: two-thirds nitrogen as basal + one-third at CRI, and one-third nitrogen as basal + two-thirds nitrogen equally spread over irrigations). Six irrigations with 120 kg N per ha in two splits-two-thirds as basal and one-third at CRI stage gave significantly higher yield than any of other treatments.

Rahman *et al.* (1981) reported that the yield of wheat was highest and irrigation efficiency maximum when two irrigations, totaling 9.5 cm, given at the tillering and the booting stages. The lowest grain yield was obtained in the treatments where irrigation was given at the grain filling stage.

Rao and Bhardwaj (1981) indicated that grain yield of wheat increased with increasing number of irrigation that resulted in increasing consumptive us of water and decreasing the water use efficiency of wheat crop.

Chetal *et al.* (1982) studied the chemical composition of wheat and barley leaves under water stress. Thy grew wheat cultivars S-308 and C-306 and barley cultivars BG-25 and C-138 during the winter season under water stress imposed by withholding irrigation at the tillering, ear emergence and grain filling stages. DNA, RNA, protein, lipid and chlorophyll contents of the leaves of both wheat and barley cultivars were decreased by water stress applied at all the growth stages. Effects were most marked at the grain filling stage. Thy also noticed that the effects of were stress on leaf chemical composition of both wheat and barley cultivars resulted in reduced grain weight pr ear and 1000-grain weight.

Idris and Karim (1982) reported that when three irrigations given at the crown root initiation, tillering and booting stages produced the highest grain yield of wheat. Thy also found that irrigation applied at the crown root initiation, tillering, booting and grain filling stages decreased yield slightly. They further stated that grain yield increased over control by 86% just by applying water only one at the tillering stage.

Munyindra *et al.* (1985) reported that the combined effect of irrigation and application of nitrogen in splits on wheat by maintaining soil moisture above 70% of field capacity and giving 0, 60, 120 and 180 kg N ha^{-1}. Nitrogen was applied during the renewal of growth n spring and the one-node stage or by foliar application at the one-node stage or during heading stage. The grain yield increased from 3.87 to 4.09 t ha^{-1} in irrigated condition with the nitrogen rate of 120 kg ha^{-1}.

Nicolas *et al.* (1985) reported on the effect of post-anthesis drought on developing wheat grains. They subjected wheat cultivar Warigal to 20 days of water deficit during the period of endosperm cell division. Drought accentuated the differences in final grain weight between spikelets and between grains within spikelets. The distal grains of top spikelets were most affected by drought. The maximum number of endosperm cells was, respectively, 30% and 40% lower in basal grains and distal grains of the droughted plant. In the basal grains of the middle spikelets, the number of large starch granules was more affected than cell division, because, severe water deficit occurred earlier during the former process than the latter. Final dry weight appeared to correlate well with the maximum number of endosperm cells, but depended also on the number of starch granules per cell. Consequently, the amount of dry matter per cell was not constant in both the treatments. The concentration of sucrose per endosperm cell was lower only in the droughted distal grains of top spikelets. The supply of sucrose to the endosperm cells did not regulate the initiation of small starch granules.

Mandal *et al.* (1986) studied water use of wheat, chickpea and mustard grown as sole crops or intercrops. They reported that the efficiency of water use was highest in sole wheat in terms of grain production.

Quayyum and Kamal (1986) observed that application of irrigation at all the critical growth stages significantly increased yield of wheat over control. They also found that crown root initiation stage showed the highest response to irrigation in increasing grain yield when only one irrigated was given. They added that for two irrigations, crown root initiation and maximum tillering stages and for three irrigations, CRI, maximum tillering and grain filling stages were effective for increasing grain yield. Yield ranged from 2.07 without irrigation to 4.09 t per ha, with four irrigations.

Bhuiya *et al.* (1987) studied grain yield of the spring bread and durum wheat grown in sand with Knop nutrient and at 80% or 40% field moisture capacity under controlled environment conditions. Shoot height was affected by nutrient and moisture regime. Number of grains per plant depended closely on cultivars and nutrient level, but 1000-grain weight depended on cultivar and moisture regime. Grain numbers and grain yield of main and lateral tillers and the whole plant depended more on cultivars than on nutrient or moisture regime.

BARI (1993) reported that maximum grain and straw yields were recorded with three irrigations applied at CRI, maximum tillering and grain filling stages of crop. Irrigations given at CRO+maximum tillering, CRI+booting and CRI+grain filling were at par in respect of number of spikes m^{-2} and grains $spike^{-1}$, but had highest spikes and grains over CRI+maximum tillering stages.

Sairam (1993) reported that water stress decreased relative water content and other metabolic activities of wheat cultivars C 306 and HD 2329. He suggested that the effect of homobrassinolide on plant metabolism under water stress appeared to be mediated through increased membrane stability, water balance and enzyme-protein synthesis.

Jana and Misra (1995) carried out an experiment on wheat cultivar Sonalika giving irrigation at the crown root initiation, tillering, flowering and dough stages. They found that irrigation increased plant height, number of effective tillers per ear, grain and straw yields.

Kumar *et al.* (1995) studied the response of wheat to irrigation and nitrogen in sodic soils reported that increasing levels of N from 0 to 180 kg ha^{-1} increased CGR. Cell developed with increasing levels of N tended to be increased and also had higher meristematic activities, formation and functioning of protoplasm, which consequently increased the plant growth.

Saha and Paul (1995) studied the effect of soil moisture on the growth parameters such as RGR, NAR, LAR, RLGR and LWR of five wheat cultivars. LAR, RLGR, and LWR were increased but NAR was decreased and RGR was unaffected by soil moisture. All the growth parameters decreased with plant age except NAR and RLGR which increased at the later stage of growth. They further reported the increase of grain yield due to soil moisture was not related to growth parameters.

Muhammad-Jamal *et al.* (1996) reported that low water stress affected wheat yield components. They grew three cultivars of wheat and subjected them to water stress (-10 bars leaf water potential) at the tillering, jointing, booting and anthesis stages. Water stress significantly decreased panicle length and grain weight per panicle compared with the unstressed controls. Water stress at anthesis was most critical for grain formation. They also reported that water stress applied at tillering did not significantly affect grain number per spike. Mean grain yields were also decreased due to the application of water stress at any growth stage.

Rahman and Paul (1996) stated that the irrigated wheat plants had higher panicle weight than the rainfed plants at all the stages of growth but significant effect was observed at 14 days after anthesis (DAA) in Akbar and 7 and 28 DAA in Barkat. Akbar had significantly higher panicle growth rate than the Barkat in the both irrigated and rainfed conditions. Grain weight increased very sharply with increasing time in the both cultivars. The irrigated wheat plants had higher grain weight than the rainfed plants.

Razi-us-shams (1996) observed that the effect of irrigation treatments in yields and yield contributing characters were statistically significant. When irrigation frequency was increased grain and straw yields, number of tillers, panicle length and number of grains panicle^{-1} were gradually increased over control.

Sarker *et al.* (1996) studied the effect of soil moisture on shoot and root growth of four wheat varieties (Opata, BL 1183, C 306 and Kanchan) in two seasons. There were two soil moisture treatments: plants were watered daily and at 5-6 days intervals. Dry weight of leaf, stem, panicle length, total dry weight, total leaf area and all the growth attributes except RGR and RLGR were higher in the well-watered plants than the water stressed plants. RGR and RLGR were slightly higher in the water stressed plants.

Savin and Nicolas (1996) studied the effect of drought on grain growth of barley. They examined the effects of high temperature and drought, alone or combined, on grain growth of two malting barley cultivars. Treatments were started at 15 days after anthesis and consisted of the factorial combination of three temperatures and three water regimes. The high temperature and drought treatments were maintained for 5 or 10 days. Drought reduced individual grain weight much more than high temperature for both cultivars. The reduction in individual grain weight was greatest when both stresses were combined. Among the two cultivars, Franklin appeared to be more sensitive to heat stress than the other cultivar. Schooner the reduction in mature grain weight under high temperature was due to a reduction in duration of grain growth for Schooner and to a reduction in both rat and duration of grain growth for Franklin. The reduction in duration of grain growth was the most important cause of reduced grain weight at maturity under drought alone (12-25%) or combined with high temperature (25-33%). They concluded that drought, particularly when combined with high temperature, is more likely than heat stress to cause large reductions in grain weight of barley under field conditions

Sarker and Paul (1997) studied the effect of soil moisture on growth, yield and quality of four varieties of wheat viz. Opata, BL1183, C 306, and

Kanchan in field experiment. There were two treatments: plants were irrigated at 5 times throughout the whole growing period and no irrigated (rainfed) was made. Total dry matter production, plant height, tiller number, and leaf number were higher in the irrigated plants than the rainfed plants. Phenological characters also showed their higher values in the irrigated plants except duration of anthesis, where slightly higher value was observed in the rainfed plants. However, protein content was greater in the rainfed plants. Again, all the characters related to yield except number spikelets per spike and number of florets per spike let was significantly increased by soil moisture. Among the four varieties, BL 1183 appeared to be more droughts susceptible and C306 appeared to be more droughts tolerant.

Nahar and Paul (1998) conducted an experiment to study the effect of two soil moisture regimes on dry matter production, leaf area and some growth attributes of two wheat cultivars viz. Sonalika and Kanchan. The two soil moisture regimes were irrigated and rainfed control. Significant effect of irrigation was observed for TDM and LAI at most of the growth stages studied. TDM was greater in the irrigated than in the rainfed plants. LAI was also greater in the irrigated plants except in a few cases of Kanchan. Among the growth attributes, CGR and SLA were significantly increased and NAR and LAR were decreased by irrigation. CGR at the post-flowering stage was significantly associated with grain yield.

Rahman and Paul (1998) studied the effect of soil moisture regimes on water relation characters, chlorophyll and proline contents and grain yield of two wheat cultivars- Akbar and Barkat in the field condition. The highest RLWC of both the cultivars was observed at 8 a.m. and it decreased gradually at the later part of the day. RLWC was higher in the irrigated than the rainfed plants. The irrigated plants had significantly higher extrusion length, panicle length, 1000-grain weight, harvest index and grain yield than the rainfed plants. They recommended Akbar for cultivation in the irrigated area and Barkat in the rainfed area.

Sarker and Paul (1998) studied the different growth attributes of four wheat varieties viz; Opta, BL 1183, C 306 and Kanchan under irrigated and rainfed conditions. Results obtained revealed the CGR, LAR and LWR were higher in the irrigated plants compared to rainfed plants. No definite pattern was found for RGR, NAR, RLGR and SLA in the irrigated and rainfed plant, but all of them except SLA declined with increasing age and plant dry weight. The decreasing tendency was found in SLA at the middle stages of growth. Higher values of CGR were found in the irrigated C306; RGR LAR and LWR in the irrigated Kanchan; RLGR and SLA in the rainfed Kanchan and NAR in the rainfed BL 1183.

Siddique *et al.* (1999) conducted an experiment under semi-controlled conditions at the Institute of Postgraduate Studies in Agriculture (IPSA), Bangladesh during November 1994 through March 1995. They evaluated drought stress effect on phenological characters of four wheat cultivars, such as Kanchan, Sonalika, kalyansona and C 306 grown in posts to four levels of water stress. They found that the reduction of plant height was severe in those plants which were subjected to drought stress both at vegetative and reproductive stage. Drought either at vegetative or at anthesis decreased tiller number significantly. Drought stress significantly reduced leaf area at one or both stages. Sonalika was the earliest cultivar which took 108 days to mature. The latest maturing cultivars was C 306 which took122 days. They also reported that drought stress treatments effect on days to maturity were insignificant.

Chandrasekar *et al.* (2000) conducted an experiment to investigate the physiological and biochemical responses of two hexaploid and two tetraploid wheat genotypes to water stress under pot culture condition. Water stress caused a decline in relative water content in all the genotypes. Both the tetraploids and hexaploids showed a lower reduction in relative water content under waster stress. They also reported that water stress declined chlorophyll and carotenoid of hexaploid (*Ttiticum aestivum*) and tetraploid (*Triticum dicoccum* and *Triticum durum*) wheat leaves.

Paul and Nahar (2000) studied the effect of irrigation on some physiological and leaf anatomical characters and water use of two cultivers of wheat. Stomatal and total transpiration rates of the irrigated plants were significantly greater than the rainfed plants. Chlorophyll content was unaffected and proline content was significantly in creased in the rainfed plants. Number of kernels/ear and grain yield were significantly greater in the irrigated plants than the rainfed plants. The consumptive use of water was significantly increased by irrigation, but water use efficiency was unaffected.

Pandit *et al.* (2001) stated that three times irrigation at the crown root initiation, booting and early grain filling stages resulted in higher grain and biological yield of wheat due to higher number of ears per m, grains per ear and plant height as against no irrigation. But higher 1000-grain weight and harvest index were observed from no irrigation. Grain protein content (%) and grain protein yield were increased by irrigation. The relationship of grain yield with protein content (%) and grain protein yield were significantly positive due to irrigation.

Rahman *et al.* (2001) conducted a field experiment to find out the effect of soil moisture on grain yield and yield components of eight cultivars (BAW 452, BAW 171, Paavon 76, Barkat, Opata, BL 1183, C 306 and Kanchan) of wheat. Theren were two treatments: five irrigations were given throughout the whole cropping period and no irrigation (rainfed). Plant height, tiller number per plant, number of spikelets per main spike, 100 grain weight, total dry matter per plant and grain yield were swignificantly increased in the irrigated plants than the rainfed plants. However, harvest index and protein content of grains were significantly higher in the rainfed plants. Plantsgrown under both irrigated and rainfed conditions, grain yield was positively correlated with total dry matter. Among the cultivars, BAW 452 gave highest grain yield in both the irrigated and rainfed conditions. On the other hand, BL 1183 gave lowest grain yield in the both soil conditions.

Paul *et al.* (2002) conducted a field study at Rajshahi, Bangladesh on eight cultivars of wheat (*Triticum aestivum* L). They showed that irrigated plants had higher RLWC and chlorophyll content but lower proline and sugar as compared to rainfed plants.

Haider and Paul (2003) studied physio-biochemical responses of four bread wheat cultivars under three different water regimes in field condition over two rabi seasons. Water stress decreased RLWC and chlorophyll a and b contents but increased chlorophyll a: b ratio. Increased proline and sugar content in the leaves of all the four cultivars were noticed when plants experienced water stress.

Paul *et al.* (2005) carried out an experiment in the experimental field of North Bengal University, Darjeeling, India to study the effect of three levels of soil moisture on leaf area, dry matter and growth attributes of *R. serpentina*. There were three irrigation treatments namely (i) rainfed (10=no irrigation), (ii) irrigation once in every month (11) and (iii) twice irrigation in every month (12). Both leaf area and dry matter were significantly affected by soil moisture. Relative growth rate (RGR), net assimilation rate (NAR), leaf area ratio (LAR) and relative leaf growth rate (RLGR) of the irrigated plants were significantly higher than the rainfed plants. There are no clear patterns of soil moisture on specific leaf area (SLA) and leaf weight ratio (LWR).

Al-Barrak (2006) carried out an experiment at the Agricultural and Veterinary Training and Research Station, King Faisal University during the winter seasons of 2002-2003 and 2003-2004 to study the effect of irrigation regimes on wheat productivity and water use efficiency (WUE) under subtropical arid conditions. Results showed that irrigation regimes significantly affected grain, straw and biological yields/ha. Grain, straw and biological yields were significantly increased as the volume of irrigation water increased. Irrigation regime of 9750 m^3ha^{-1} recorded the highest WUE for grain, straw and biological yields.

Mollah and Paul (2007) conducted a field experiment in the research field of Rajshahi University Campus (AEZ-11) to study the influence of soil moisture on grain growth of four varieties of barley (*Hordeum vulgare* L.). Higher values of spikelet number (SN), spike dry weight (SDW), grain number (GN), grain dry weight (GDW), spike relative growth rate (spike RGR) and grain relative growth rate (grain RGR) were found in the highest level of irrigation (40 mm).

Mollah and Paul (2008) carried out an experiment in the experimental field of Rajshahi University Campus, Bangladesh to study the growth attributes of four varieties of barley in relation to different soil moisture regimes. Three levels of irrigation (I_0 , I_1 and I_2) were adopted. Total dry matter (TDM), leaf area index (LAI) and crop growth rate (CGR) were increased with increasing number of irrigations. Net assimilation rate (NAR) fluctuated but in most of the cases, it was highest and lowest in the I_2 treatment at the first and the last harvest, respectively. With few exceptions, I_0 treatment had the highest and lowest leaf area ratio (LAR) at the first and the last harvest, respectively.

2.3 Correlation, Path Correlation and Stability

Razzaque *et al.* (1981) studied correlation and path analysis in 80 wheat cultivars for days to flower, grain filling period, days to mature, ears/plant, ear length, grains/ear, 100-grain weight and yield/plant. Genotypic correlation coefficients were higher than the corresponding phenotypic correlations in almost all the cases. Days to flower and grain filling period showed negative direct effects on yield, but total days to maturity had a moderately positive direct effect. Of the yield components, 100-grain weight was found to be the most important component of yield and grains/ear was next in importance.

Sarker (2002) carried out an experiment at BRRI, Regional Station, Rangpur during Boro and T. aman seasons in 1998-1999. The stability parameters-mean $\overline{X}$, phenotypic index (Pi), regression coefficient (bi) and deviation from regression (S^{-2}_{di}) were calculated for yield of different genotypes. Genotype x environment interaction as well as stability performance were determined for grain yield in eight boro and T. aman varieties of rice across eight different planting times. Highly significant estimates for genotypes, environment and G×E interaction were observed. Non-linear component (pooled deviation) was found highly significant for grain yield. All the varieties were stable for favourable environments except BRRI dhan 32, BR 24 and BRRI dhan 33. High mean and phenotypic index with significant regression coefficient (bi>1) and non-significant deviation from regression (S^{-2}_{di}=0) was observed in BRRI dhan 29 and BRRI dhan 28 which might be predicted as suitable for favourable environments. BRRI dhan 29 was observed to be top yielder due to its high mean (5.29) and phenotypic index (1.27) followed by BRRI dhan 28, BRRI dhan 27 and BRRI dhan 36. These varieties were favourable for 9 January planting.

Amiruzzaman *et al.* (2003) reported that the highest direct positive effect was contributed by number of tillers per plant followed by number of grains per spike on grain yield. Path analysis showed that number of tillers per plant and number of grains per spike directly contributed to grain yield but 1000-grain weight and spike length also accelerated the increase of yield.

Riaz-ud-Din *et al.* (2007) studied the effects of heat stress, genetic variability and character association in wheat. Twelve wheat genotypes were evaluated under normal and heat stress condition. Morphological characters were affected due to heat stress when planting was delayed by 60 days. Decline was recorded for grain yield (48.87%), number of spikes/m^2 (29.61%), days to anthesis (28.24%), days to maturity (28.89%), 1000-grain weight (24.80%), plant height (9.96%) and grains per spike (8.24%). Phenotypic and genotypic coefficients of variability indicated higher-moderate genetic variability for grain yield, 1000-grain weight, grains per spike, spikes/m^2 and plant height in both conditions, while moderate genetic variability for days to anthesis in heat stress. Days to anthesis exerted negative direct effect on grain yield and highest positive direct effect was for spikes m^{-2} followed by days to maturity. All the characters had shown non-significant association with grain yield in heat stress.

Anisuzzaman *et al.* (2007) observed that among all the variables in most of the cases, the magnitude of the variance components due to environment (irrigation treatment) was substantially larger than the other effects. Grain weight, extrusion length and spike length were affected mainly by its genetic potential lies within. Therefore, most of the variations in the performance of barley genotypes in these trails were due to environmental and not due to genotype by environment interactions. Differential fitness of genotypes to the environments is reported in different trials worldwide.

Debnath *et al.* (2008) carried out at the experimental field to study the variability and their interrelationship and direct and indirect effects to different characters on yield. They worked with 21 local genotypes of buckwheat. Correlation coefficient between seed yield (kg/rn^2) with number of inflorescence per plant and grain setting raceme per plant were significant and positive. Highly significant and positive correlation was observed between grain setting raceme per plant vs. inflorescence per plant. Path coefficient analysis revealed that grains per raceme had the highest positive direct effect on yield followed by inflorescence per plant and seed yield per plant. The direct effect of inflorescence per plant was almost equal to the correlation coefficient implies that there was a true relationship between inflorescence per plant and yield. Path coefficients indicated that maximum direct contribution towards seed yield (kg/rn^2) was obtained through grains per raceme which indicated that this trait should he considered as primary component of yield.

Singh *et al.* (2008) observed that estimate of genetic parameters for eight quantitative characters viz. tillers per plant, plant height, spikes per plant, seeds per spike, 100-grain weight, grain yield per plant, spike length and days to maturity in 18 genotypes of barley (*Hordeum vulgare* L.) revealed significant variability for all the traits. The estimates of genotypic and phenotypic coefficient of variation were high for grain yield per plant, the broad sense heritability estimates coupled with high genetic advance for plant height and grain yield per plant. Correlation studies indicated that grain yield per plant exhibited stable positive association with spikes per plant followed by 100-grain weight and tillers per plant. Path analysis revealed high positive and direct influence of 100-grain weight towards grain yield per plant followed by spike per plant and tillers per plant. Spikes per plant also contributed to grain yield mainly through indirect effect via tillers per plant.

Nanak Chand *et al.* (2008) assessed thirty diverse elite lines of barley along with six checks in three environments with two replications for three characters *i.e.* 1000-grain weight (g), harvest index (%) and grain yield per plant (g). The genotype × environments (G×E) interactions were significant for all the traits. A stable variety was defined as "one with unit regression (bi=1) and low deviation from linearity (S^{-2}_{di}=0)". Among twenty three average yielding genotypes, only sixteen genotypes showed suitability for wide adaptation. Better phenotypic stability were observed in four genotypes having high yield mean performance, bi=1 and S^{-2}_{di}=0. These were found promising for wide adaptation over sites across environments. Twelve genotypes had average mean performance with bi=1 and S^{-2}_{di}=0 showing stability over wider range of environments. Only two genotypes had average mean associated with bi<1 and S^{-2}_{di}=0 was found stability for poor environments.

Adhikary *et al.* (2009) conducted an experiment in the research field of Rajshahi University Campus, Bangladesh to study the grain growth pattern of eight cultivars of wheat and to find out association and linear regression of spike weight and grain weight with time. Linear regression and correlation coefficients reveled that the association between both spike weight and grain weight with time were highly positively significant among the cultivars but their regression coefficients were non-significant.

Chapter 3
MATERIALS AND METHODS

3.1 Materials

The materials of the study comprised four wheat (*Triticum aestivum* L.) varieties collected from the Regional Wheat Research Centre of Bangladesh Agricultural Research Institute (BARI), Shyampur, Rajshahi, Bangladesh.

The four modern varieties were as follows:

(1). Shatabdi (indicated herein as V_1)
(2). Gaurav (indicated herein as V_2)
(3). Shourav (indicated herein as V_3)
(4). Kanchan (indicated herein as V_4)

Short descriptions of the varieties are given below:

Shatabdi (V_1)

Shatabdi is a semi-dwarf variety developed and released by the Bangladesh Agricultural Research Institute in 2000. It is the most popular modern variety and increasing its area day by day. Leaf is light green and flag leaf is wide. Plant height ranges from 90-103 cm producing 4-7 tillers per plant. Grains are whitish in color. 1000-grain weight is 46-48 g. Shatabdi matures within 105-112 days. It is good both at optimum and late sown conditions. This variety is tolerant to rust and BpLB diseases.

Gaurav (V_2)

Gaurav is a high yielding variety evolved in Bangladesh in 1991. Originally the variety was developed in CIMMYT through selection from progenies of a cross between Turka and Chilero types. The leaves are deep and narrow. The flag leaf is straight and slightly rolled. The plant height ranges from 85-100 cm with 4-6 tillers per plant. Heading time ranges from 60-65 days. The spikes are long with 45-50 grains per spike. The grains are white and 1000-grain weight ranges from 40-48 g. Sowing to harvesting time ranges from 100-108 days. The grain yield per hectare ranges from 3.5-4.0 ton.

Shourav (V_3)

Shourav is also a high yielding variety evolved in Bangladesh in 1989. Shourav was selected in CIMMYT from progenies of a cross between Nekozari and Bheri types. The leaves are wide, inclined and deep green. The lower surface of the flag leaf is covered with waxy material. The stems are thick, stout and do not incline due to heavy rainfall. The plant height ranges from 90-101 cm with 5-6 tillers per plant. Heading time ranges from 60-70 days. The spikes are long and contain 42-48 grains per spike. The grains are white and 1000-grain weight ranges from 40-45 g. Sowing to harvesting time ranges from 102-110 days. The grain yield per hectare ranges from 3.5-4.5 ton.

Kanchan (V_4)

Kanchan is a semi-dwarf variety developed and released by the Bangladesh Agricultural Research Institute in 1985. It is the most widely cultivated variety in Bangladesh and occupies about 80% of the total wheat cultivated area. Grains are whitish in color. Leaf is green and plant height ranges from 85-100 cm, producing 5-7 tillers per plant. Kanchan matures within 110-112 days. It is good both at optimum and late sown conditions. This variety is becoming susceptible to Bipolarize leaf blight (BpLB) disease.

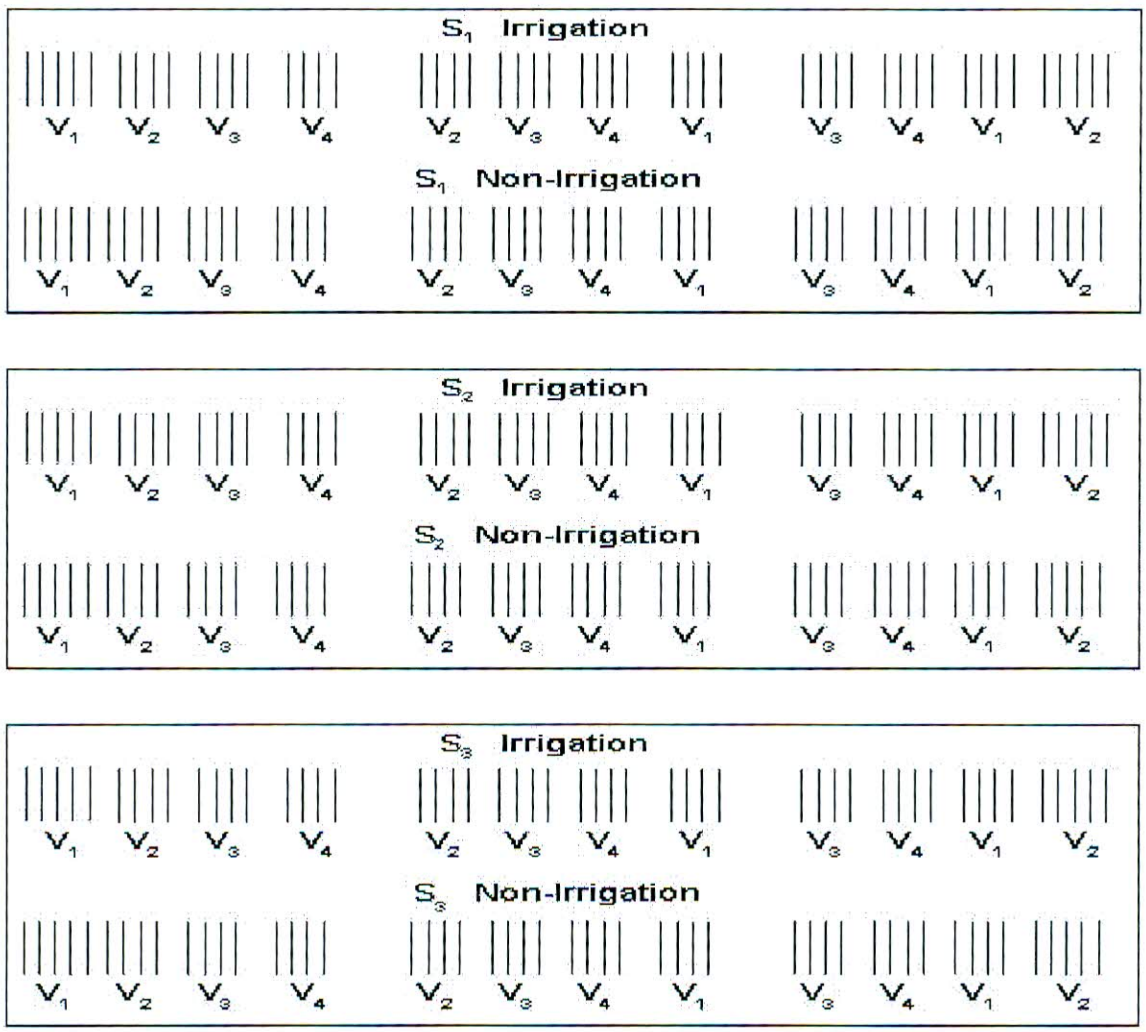
3.2 Methods

3.2.1 Experimental site and period

The experiment was conducted in the experimental field of Botany Department at Rajshahi University Campus during the period from November 2005 to April 2006 and November 2006 to April 2007. The soil of the experimental field was silty loam, with pH 7.5. The field was prepared after repeated ploughing and harrowing by removing weeds and stubbles of the previous crops.

3.2.2 Design

The experiment was arranged in **split-split plot** design with three replications. Each replicated field was divided into three main plots for sowing times. Irrigation and non-irrigation in the sub- plot and variety in the sub-sub plot. Row-to-row distance was 20 cm and plant to plant distance was 5 cm in all the plots, thus 100 plants were counted per square meter avoiding border row.



3.2.3 Size of the field and seed sowing

Each split plot size was **4 m × 1.8 m i.e. 7.2 m^2** where, plot to plot distance was 1 m to the north-south, 2 m to the east-west. Replication to replication distance was 2 m. Border rows were not considered because of the border effect.

The seeds of four wheat varieties were sown on three different times in the first season, the first sowing date (S_1) was on November 15, 2005; the second (S_2) was on November 30, 2005 and the third (S_3) was on December 15, 2005 and for the second season, the first sowing date (S_1) was on November 15, 2006; the second (S_2) was on November 30, 2006 and the third (S_3) was on December 15, 2006. Before sowing a basal dose of nitrogen (80 kg/hectare), phosphate (40 kg/hectare) and potassium (40 kg/hectare) was applied.

3.2.4 Levels of irrigation

Two levels of irrigation treatment were adopted viz., rainfed and irrigated.

1. Irrigated (I_1)

Wheat was grown with two irrigations, one irrigation at 25 days of sowing and the second irrigation at 50 days of sowing. The amount of water was added to moist the surface soil and care was taken so that no waterlogging condition developed.

2. Rainfed (I_0)

Non-irrigation wheat plants were grown under no irrigated and rainfed condition.

3.2.5 Collection of data (Growth attributes)

For growth analysis, seven harvests were done at equal intervals of ten days. Three plants were selected for each variety from each replication at each growth stage. The first harvest was taken at 20 days after sowing (DAS). At each harvest, plants were cut at the ground level and tops were separated into leaves, stem and spikes (when present). The plant parts were dried separately before weighing in an oven at about 85°C for 24 hours till they reached constant weight. The following characters were recorded.

1. Plant height (PH)

Three plants were selected randomly for each variety and height was measured in centimeter (cm) from the base of the plant to the tip of main tiller.

2. Total tiller numbers per plant (TTL)

The number of tillers per plant was counted at 10 days interval. When number of tillers at the final harvest was made the primary shoots from early tillers were included in tiller counts.

3. Number of leaves per plant

Total number of leaves per plant was counted for the selected plants.

4. Leaf area per plant

For leaf area determination after taking necessary steps, three segments were taken and weighed after oven drying and then leaf area was measured by using the following formula:

$$\text{Leaf Area} = \frac{\text{leaf disc area} \times \text{leaf dry weight}}{\text{disc dry weight}}$$

3.2.6 Growth analysis

The classical method of growth analysis was followed to determine the various growths attributes like crop growth rate, relative growth rate, relative leaf growth rate, net assimilation rate and leaf area ratio from the dry weight of different plant between two successive harvests. Leaf area index, specific leaf area and leaf weight ratio were also calculated separately for each harvest **(Radford, 1967).**

Crop Growth Rate (CGR)
$$= \frac{W_2 - W_1}{t_2 - t_1}$$

Relative Growth Rate (RGR)
$$= \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

Net Assimilation Rate (NAR)
$$= \frac{(W_2 - W_1)(\log_e LA_2 - \log_e LA_1)}{(LA_2 - LA_1)(t_2 - t_1)}$$

Leaf Area Ratio (LAR)
$$= \frac{(LA_2 - LA_1)(\log_e W_2 - \log_e W_1)}{(\log_e LA_2 - \log_e LA_1)(W_2 - W_1)}$$

Relative Leaf Growth Rate (RLGR) $$= \frac{\log_e LA_2 - \log_e LA_1}{t_2 - t_1}$$

Leaf Area Index (LAI) $$= \frac{\text{Leaf area}}{\text{Ground area}}$$

Specific Leaf Area (SLA) $$= \frac{\text{Leaf area}}{\text{Leaf dry weight}}$$

Leaf Weight Ratio (LWR) $$= \frac{\text{Leaf dry weight}}{\text{Total plant dry weight}}$$

Where, $\mathbf{W_2}$ and $\mathbf{W_1}$ are the total dry weight, $\mathbf{LA_2}$ **and** $\mathbf{LA_1}$ are the leaf area per plant, and $\mathbf{t_2}$ and $\mathbf{t_1}$ are the later and former harvest time, respectively.

3.2.7 Harvesting and data collection (Grain yield and its components)

The final harvest was done for V_1, V_2, V_3 and V_4 at 110 days after sowing. Three plants per variety per replication were harvested and measurements of yield and its components were made. The following characters were recorded.

Plants height (PH)

Three plants / variety / replication were harvested and plant height was measured in centimeter (cm).

Total tiller numbers per plant (TN/P)

The number of tillers per plant was counted.

Fertile tiller numbers per plant (FTN/P)

All ear bearing tillers per plant were recorded at the final harvest.

Extrusion length (EXL)

Extrusion length was measured in centimeters from the tip of the flag leaf sheath to the base of the spike of the main tiller.

Spike length (SPL)

Spike length was measured in centimeters from the base of the spike to the tip of the awns.

Number of spikelets per spike (SL/SP)

The longest spike of a plant was threshed and spikelets per spike were obtained from counting to get the number spikelets per spike.

Grain number per spike (GN/SP)

The longest spike of a plant was threshed and grains were counted to get the grain number per spike.

1000-grain weight (TGW)

After harvesting 1000 grains were counted and weight was recorded in gram.

Total dry matter (g m^{-2})

The plants after harvest were dried in oven at 85°C for 48 h overnight and weight of the grain was recorded.

Grain yield per plant (GY/P)

Total grain per plant was collected, weighed and recorded in gram.

Grain yield (kg/ha)

Total grain yield for each variety was collected from each sub-sub plot, weighed and recorded in kilogram and converted into kg/ha.

3.2.8 Statistical analysis of data

The techniques used for analysis of data are described under the following sub-heads:

i) Mean

Data on individual plant basis were added together than divided by the total number of observations and the mean was obtained as follows:

$$\text{Mean } (\overline{X}) = \frac{1}{n}\sum_{i=1}^{n} X_i$$

Where,

$\overline{X}$ = Arithmetic-mean

X_i =The individual reading was recorded on each plant

ΣX_i = Summation of variable

n= Number of observations

i= 1, 2, 3..................n

ii) Standard deviation (SD)

Standard deviation is the average deviation of the individual observation from the mean. It was calculated as the square root of the variance as follows:

$$SD=\sqrt{\partial^2}$$

Where,

SD =Standard deviation

∂^2 =Variance

iii) Standard error of mean (SE)

If several samples are considered instead of taking one, it will be found that the standard deviations of the different samples also vary. This variation was measured by the standard error of mean, which was calculated as follows:

$$SE=\frac{SD}{\sqrt{n}}$$

Where,

SD = Standard deviation

SE = Standard error of mean

n = Total number of individual.

iv) Analysis of variance

Variance analysis is a measure of dispersion of among the population. The analysis of variance is necessary. Variance analysis for each of the characters was carried out separately on mean value of 3 (three) plants.

The variance due to different sources such as genotype (V), replication (R), sowing (S), soil moisture (I), interaction V×I, S×I, S×V, S ×I ×V and error (E) of population were calculated as per the following skeleton of analysis.

v. Test of least significant differences (LSD)

The experimental design was a split-split plot design and the analysis of variance was done accordingly. Least significant difference (LSD) at 5% level was calculated according to following formula (Gomez and Gomez 1984). where the values for variance ratio (F) for each item viz. Variety (V), soil moisture (I) and sowing date (S) and Variety x soil moisture interaction (V x I), Variety x Sowing dates interaction (V x S), Variety x soil moisture x Sowing dates interaction (V x I x S) were significant.

The following formulae were used (according to Gomez and Gomez 1984).

$$\text{Sowing (a)} = \sqrt{\frac{2Ea}{rbc}}$$

$$\text{Soil moisture (b)} = \sqrt{\frac{2Eb}{rac}}$$

$$\text{Variety (c)} = \sqrt{\frac{2Ec}{rab}}$$

$$\text{LSD} = (ta)\,(\bar{s}d)$$

Here,

Ea = Sowing error mean square

Eb = Soil moisture error mean square

Ec = Variety error mean square

ta = Tabulated value (5% level)

$\bar{s}d$ = Calculated value

3.2.9 Correlation coefficient

The degree of relationship can be established by calculating a coefficient called the correlation coefficient, which gives a quantitative measure of the degree of closeness of the linear relationship between the two variables. Simple correlation coefficients were calculated between pairs of characters according to standard procedure (Steel and Torrie 1960) as follows:

$$r = \frac{\sum dx.dy}{\sqrt{\sum dx^2 \sum dy^2}}$$

Where, r is the correlation coefficient between x and y

$\Sigma dx.dy$ is the covariance between x and y

Σdx^2 is the variance of x

Σdy^2 is the variance of y

3.2.10 Path coefficient analysis

The path coefficient analysis was carried out using the formula of Wright (1923) as illustrated by Dewey and Lu (1959). The path-coefficient analysis was done at both the phenotypic and genotypic levels by solving the simultaneous equation using matrix method.

The form of equation is as follows:

$r_{xy} = P_{xy} + r_{x2} P_{2y} + r_{x3} P_{3y} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots r_{xn} P_{ny}$

r_{xy} = Correlation between one component character and yield.

P_{xy} = Path-coefficient between the same character and yield.

$r_{x2}, r_{x3}, \ldots\ldots r_{xn}$ = Represent correlation coefficient between that character and each of the other yield components in turn.

The above equation was written in a matrix form as:

A		B				C
r1y	=	r11	r12	r13	r1j	p1y
r2y		r21	r22	r23	r2j	p2y
r3y		r31	r32	r33	r3j	p3y
riy		ri1	ri2	ri3	rij	piy

A = B × C; Then $C = B^{-1} A$

Where

Pry = Direct effect of the character I on the dependent trait y (yield)

The indirect effect of a particular character through other characters was obtained by multiplication of direct path and particular correlation coefficient between those two characters respectively.

Indirect effect = $r_{ij} \times P_{ij}$

Where,

i =1,....................n,

J =1,....................n,

P_{iy}=P_{ly}.................P_{ny}

Where

R_{ij}= Correlation coefficient between two independent characters.

The residual effect is assumed to be independent to the remaining variables. It was calculated from the formula as proposed by Wright (1923).

Residual effect (χ) =1-R_2

R_2=P_{1y}+$P_{2y}r_{2y}$+.....................+$P_{ny}R_{ny}$.

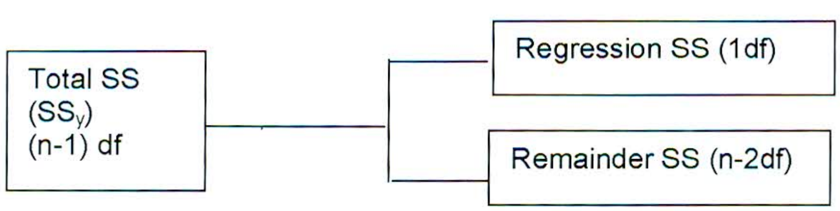
R_2 is the required multiple correlation coefficient and is the amount of variation in yield that can be accounted for by the component character.

3.2.11 Regression coefficient

To study the genotype-environment interaction, the data were analysed by the following techniques of analysis as developed and used by **Finlay and Wilkinson (1963)** in barley; **Eberhart and Russell (1966)** in maize; **Bucio Alanis and Hill (1966), Perkins and Jinks (1968)** in *Nicotiana rustica* L. and **Breese (1969)** in grasses. In this study the following analyses were computed:

Regression Analysis:

Regression analyses were done by the following **Eberhart and Russell's (1966)** models. The primary analysis of regression was done as follows:



Where, n = number of observation

Regression SS = $(SP_{xy})^2/SS_x$

Remainder SS = Total SS (SSy) – Regression SS

Where, $SSx = \Sigma x^2 - (\Sigma x)^2/n$

$SPxy = \Sigma xy - \Sigma x. \Sigma y/n$

$SSy = \Sigma y^2 - (\Sigma y)^2/n$

Regression coefficient (1 + bi) : The response of each genotype under different environments of the environmental means over all the genotypes are measured by regression coefficient. This was estimated as follows:

$$b_i = \frac{SPxy}{SSx}$$

Study of stability parametrs according to **Eberhart and Russell's** model:

In this approach, the regression coefficient and the deviation from regression are used as parameters of stability. As the regression of d_i on e_j is one, and regression of g_{ij} on e_j is βi, therefore, the b_i value of Eberhart and Russell's model is

$$b_i = 1 + \beta_i$$

$$\beta_i = \beta_I\text{-}1$$

Eberhart and Russell (1966) used the following model to study stability of the varieties under different environments:

$$Yij = m + \beta_i Ij + \sigma ij$$

Where, i varies from 1 to L, the number of lines and

J varies from 1 to I, the number of environment

yij = mean of ith lines over all the environments

m = Mean of all the lines over all the environments

βi = The regression coefficient of the ith lines on the environmental index which measures the response of this lines to varying environments.

Ij= The environmental index which is defined as the deviation of mean of all the varieties at a given environment from the over all mean.

$$= \frac{\sum_i Yij}{L} - \frac{\sum_i \sum_j Yij}{LI} \quad \text{With} = \sum_j I_J = 0$$

And σ_{ij} = The deviation from the regression of ith lines at the jth environment.

Two parameters of stability were calculated:

(a) The regression coefficient which is the regression of the performance of each variety under different environment on the environmental mean over all the genotypes. This is estimated as follows:

$$b_i = \sum_i Y_{ij} I_j / \sum_j I_j^2$$

Where $\sum_j Y_{ij} I_j$ is the sum of products and

$\sum_J I_j^2$ is the sum of squares.

(b) Mean square deviations, $\overline{S}^2$di (stability) from linear regression:

It is calculated from the following formula.

$$\overline{S}^2_{di} = \frac{\sum_j \sigma_{ij^2}}{(IY-2)} - \frac{S_e^2}{r}$$

Where,

$$\sum_j \sigma^2 ij = \left[\sum Y_{ij}^{\ 2} - \frac{Y_i^{\ 2}}{L}\right] - \frac{\left[\sum_j Y_{ij} I_j\right]}{\sum_j I_j^2}$$

$\sum_j \sigma^2 ij$ = The variance due to deviation from regression, i.e. remainder sum of square.

$\sum_j Y_{ij}^{\ 2} - \frac{Y_i^{\ 2}}{L}$ = The variance due to dependent variable (SS_Y)

$\frac{\left[\sum Y_{ij} I_j\right]^2}{\sum I_j^2}$ = The variance due to regression

S^2_e = the estimate of pooled error and

r =the number of replications.

The various computational steps involved in the estimation are as follow:

(1). Computation of environmental index (I_j): It is calculated as follows:

$$I_j = \frac{\sum_j Y_{ij}}{L} - \frac{\sum_i \sum_j Y_{ij}}{YI}$$

$$= \frac{\text{Total of the lines at the environment}}{\text{Number of lines}} - \frac{\text{Grand toal}}{\text{Total number of observations}}$$

(2). Computation of regression coefficient (bi) for each line:

$$bi = \frac{\sum_j Y_{ij} I_j}{\sum_j I_j^2}$$

Where,

$\sum_j Y_{ij} I_j$ for each line in the sum of products of environmental index (I_j) with the corresponding mean $(\overline{X})$ of that lines at each environment. These values may be obtained in the following manner:

$$[\overline{X}][Ij] = \left[\sum_j Y_{ij} I_j\right] = [S]$$

Where,

$(\overline{X})$ = Matrix of mean

I_j = Vector of environmental index

[S] = Vector of sum of products

i. e. $\sum_j Y_{ij} I_j$

(3). Computation of $\overline{S}^2_{di}$ in general, it is obtained by subtracting the variance due to regression from σ^2_y. It is calculated as follows:

$$\overline{S}^2_{di} = \left[\sum \sigma^2 ij/(IY - 2)\right] - \left(S^2 e/r\right)$$

(4). Standard error b_i was calculated as follows:

$$Sb = \sqrt{\frac{\text{RemainderSS}}{SS_x}}$$

3.2.12 Meteorological data

Monthly average maximum and minimum temperature (°C), relative humidity at 9 AM and 6 PM, sunshine hours and total rainfall (mm) during the crop period were collected from the Regional Meteorological Station, Shyampur, Rajshahi-6205. Bangladesh.

Air temperature (maximum and minimum), relative humidity (9 am. and 6 pm.), sunshine hours and total rainfall from sowing to the final harvest are shown in **Table 2** for the 2005-06 and 2006-07 growing seasons. It is observed that the early sowing times (S_1 and S_2) had higher air temperature than the late sowing (S_3) in both the growing seasons. Temperature was higher in November and March in both the seasons than in January. At the very beginning in March, temperature increased gradually and remained increasing up to the final harvest in both the growing reasons. Late sowing (S_3) had higher relative humidity than the early sowing (S_1) in both the growing seasons. Relative humidity had higher value in December, increased again sharply in January and finally declined at the later stages in March. Humidity at 6 pm. decreased gradually and remained decreasing up to the final harvest in both the growing seasons.

Lower bright sunshine hours were observed during December to January in both the growing seasons. Sunshine hours increased sharply and gradually in both the groaning seasons up to the final harvest.

During the growing period all the plots received 36 mm natural rainfall in 2005-2006 season. Of them, 8 mm was in January, 9 mm in February and 19 mm in March. But in 2006-07, all the plots received only 15 mm natural rainfall in March. So, the fluctuation in total rainfall was high in 2005-06 than in 2006-07.

Table 2. Temperature (maximum and minimum), humidity, sunshine hours and total rainfall during the crop season.

Season Time	Temperature (°C)		Humidity (%)		Sunshine hours	Total rainfall (mm)
2005-06	Max	Min	9AM	6PM		
Nov 2005	28.8	17.1	77.71	77	9.10	00
Dec 2005	26.3	12.0	81.48	74	8.08	00
Jan 2006	24.4	9.8	85.83	74	8.10	08
Feb 2006	26.5	12.5	73.46	68	8.34	09
Mar 2006	31.2	19.6	71.09	58	9.86	19

Season Time	Temperature (°C)		Humidity (%)		Sunshine hours	Total rainfall (mm)
2006-07	Max	Min	9AM	6PM		
Nov 2006	28.3	16.2	78.2	81.6	9.16	00
Dec 2006	25.7	13.00	79.5	80.8	8.40	00
Jan 2007	24.2	10.1	81	72.5	8.10	00
Feb 2007	27.0	13.6	68.1	62.8	8.50	00
Mar 2007	32.2	18.7	65.6	55.7	9.75	15

Source: Regional Meteorological Station, Shyampur, Rajshahi-6205. Bangladesh.

Chapter 4
RESULTS

4.1 Choice of Growth Analysis Technique:

Growth analysis has long been established as a standard technique for the study of plant growth and development. There are two different approaches of plant growth analysis-classical technique and functional technique. Out of these two approaches, classical technique was followed in the present experiment.

4.2 Total Dry Matter (TDM)

Experiment for 2005-06

Mean squares from the analysis of variance of total dry matter are shown in **Table 3a**. The result shows that the item sowing (S) was significant at 20, 30, 40, 50, 60, 70, 80 and 90 DAS indicating that the varieties were highly affected by different sowing times. Soil moisture (I) item was significant at all the harvesting dates. Varietal differences for total dry matter were significant at all the harvesting dates.

The interaction item S×I was significant at 30, 40, 50, 60, 70, 80 and 90 DAS. The interaction item S×V was significant at 50, 70, 80 and 90 DAS. The interaction item I×V was significant at all the harvesting dates. The interaction item S×I×V was significant at 50, 70, 80 and 90 DAS only.

Mean values of total dry matter as influenced by sowing dates (**Table 4a**) increased slowly at the early harvests and reached their highest value at 90 DAS. Generally S_1 plants had the highest total dry matter at several harvests than any other sowing date.

Mean values of total dry matter as influenced by soil moisture (**Table 4a**) increased steadily until at 80 DAS and then increased very rapidly and sharply for the last harvest at 90 DAS. The irrigated plants had higher total dry matter than the rainfed plants for all the varieties.

Mean values of total dry matter of all the four varieties (**Table 4a**) increased until at 90 DAS and reached their highest values at 90 DAS. Among the varieties, Shatabdi showed the highest total dry matter at most of the growth stages than any other variety of wheat.

The mean effect of sowing dates (S) on total dry matter (g m^{-2}) of four varieties of wheat at different growth stages are graphically shown in **Fig. 1a** (left portion). The result shows that at each DAS for total dry matter (g m^{-2}), S_1 (November 15 sowing) plants had higher value than S_2 (November 30 sowing) and S_3 (December 15 sowing) plants. Among the varieties, Shatabdi showed the highest value in S_1 (November 15 sowing) at different growth stages and followed by Shourav, Kanchan and Gaurav.

The mean effects of soil moisture (I) on total dry matter (g m^{-2}) at different growth stages of wheat are graphically shown in **Fig.1b** (left portion). At 90 DAS, in the irrigated condition, the highest total dry matter was shown by Shatabdi and the lowest total dry matter shown by Gaurav. All the varieties produced the highest total dry matter at the irrigated condition at all the sowing dates. The irrigated plants always had greater total dry matter than the rainfed plants.

The overall effects of varieties on total dry matter (g m^{-2}) at different stages of growth are graphically shown **Fig. 1c** (left portion). In all the varieties and sowing times starting from a lower value total dry matter increased with the increasing growth stages up to 90 DAS. Among the four varieties, the highest peak was found at 90 DAS. At 90 DAS, the highest peak was found in Shatabdi and the lowest peak was found in Gaurav. Shatabdi produced more total dry matter than the other varieties and was followed by Shourav, Kanchan and Gaurav.

Experiment for 2006-07

The result of analysis of variance (**Table 3b)** shows that the sowing time (S) item was significant at all the harvesting periods except at 20 DAS, which indicates that the varieties were highly affected by sowing times. Varietal differences for total dry matter were also significant at all the harvesting dates. The soil moisture (I) item was found to be significant at all the harvesting dates indicating that irrigation effect was significant for total dry matter production.

The interaction items between sowing and soil moisture (**S×I)** were significant at all the harvesting dates except at 20 and 40 DAS which indicates that the varieties responded differently in different sowing times and soil moisture regimes. The interaction item between sowing and varieties (S×V) were significant at 50, 60, 70, 80 and 90 DAS. The interaction items between soil moisture and varieties (I×V) were significant at all the harvesting dates except 30 DAS. The interaction items among sowing dates, soil moisture and varieties (S×I×V) were significant at 50, 60, 70, 80 and 90 DAS.

Mean values of total dry matter as influenced by sowing dates (**Table 4b**) gradually increased with the increase of days and reached their peak at 90 DAS. Generally S_1 had the highest total dry matter at several harvests than any other sowing of wheat.

Mean values of total dry matter as influenced by soil moisture (**Table 4b**) increased steadily until at 80 DAS and then increased very rapidly and sharply for the last harvest at 90 DAS. The highest total dry matter was observed in I_1 level than I_0 level of irrigation.

Mean values of total dry matter of all the four varieties (**Table 4b**) starting from a lower value total dry matter increased with the increasing growth stages up to 90 DAS and reached their peak at 90 DAS. Shatabdi produced the highest total dry matter at most of the growth stages than any other variety of wheat.

The mean effect of sowing dates (S) on total dry matter (g m^{-2}) of four varieties of wheat at different growth stages are graphically shown in **Fig. 1a** (right portion).The increase of total dry matter was slow at the early vegetative phases (20, 30 and 40 DAS) but increased rapidly with the advancement of growth period in all the varieties. It was also found that S_3 plants produced lowest total dry matter (g m^{-2}) at all the growing stages.

The mean effect of soil moisture on total dry matter (g m^{-2}) of four varieties of wheat at different stages of growth are graphically shown in **Fig. 1b** (right portion).The graphical presentation shows that in all the varieties, the highest peak was found at 90 DAS under the irrigated condition. The irrigated plants always had greater total dry matter than the rainfed plants.

The overall effects of varieties on total dry matter (g m^{-2}) at different growth stages of four varieties of wheat are graphically shown in **Fig. 1c** (right portion). Among the varieties at 90 DAS, Shatabdi was found to give the highest peak followed by Shourav and Kanchan and the lowest peak was found to be in Gaurav. Shatabdi produced the highest and Gaurav produced the lowest total dry matter at 90 DAS in different sowing times.

Table 3a. Mean squares (MS) from the analysis of variance of total dry matter (g m^{-2}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.003	0.462	17.514	45.125	1149.597	284.375	1141.681	1108.514
Sowing (S)	2	0.048*	3.242*	62.597**	7551.375**	60119.597**	187169.793**	249113.592**	298411.555**
Error (a)	4	0.003	0.181	3.222	45.125	449.181	419.792	1652.847	2268.701
Soil moisture (I)	1	0.624**	821.476**	15842**	273060.5**	1383061.68**	279858.681**	3226646.722**	3971501.38**
S X I	2	0.005	1.501*	54.125**	1376.375**	38361.264**	146692.014**	191142.764**	215777.555**
Error (b)	6	0.003	0.274	2.875	45.125	682.653	420.486	56.625	419.333
Variety (V)	3	0.072**	3.033**	165.870**	919.778**	23819.162**	57497.572**	96537.387**	120327.796**
S X V)	6	0.003	0.136	17.856	129.319**	817.468	2136.463**	2642.484**	3482.685**
I X V	3	0.014*	0.445**	39**	154.278**	7369.495**	13853.134**	16494.422**	25596.759**
S X I X V	6	0.003	0.209	14.792	129.319**	817.468	2194.791**	3298.683**	3914.870**
Error (c)	36	0.003	0.098	7.653	16.125	353.949	96.644	770.986	666.653

**=significant at 1% level, *=significant at 5% level, respectively.

Table 3b. Mean squares (MS) from the analysis of variance of total dry matter (g m^{-2}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.007	0.233	5.264	22.222	10.764	79.167	442.097	737.681
Sowing (S)	2	0.012*	7.336**	1207.763**	15369.388**	96147.097**	236948.666**	326740.513**	361143.013**
Error (a)	4	0.002	0.233	3.160	22.222	127.993	198.958	374.410	473.806
Soil moisture (I)	1	1.266**	651.003**	3230.347**	375989.013**	1577384.013**	3433073.388**	3588074.013**	4078368.01**
S X I	2	0.002	2.753**	53.181**	859.388**	36717.930**	137646.722**	187991.013**	194723.291**
Error (b)	6	0.004	0.233	3.861	22.222	82.250	27.778	396.972	358.986
Variety (V)	3	0.027**	3.855**	166.717**	2572.125**	21539.199**	87634.222**	131250.976**	147720.666**
S X V)	6	0.003	0.022	3.412	160.5**	2025.337**	5938.666**	7341.032**	8793.625**
I X V	3	0.031**	0.105	23.384**	745.125**	7696.717**	32694.129**	32189.754**	39004.03**
S X I X V	6	0.002	0.105	3.829	160.5**	2224.134**	6736.351**	9381.976**	10525.013**
Error (c)	36	0.003	0.057	4.861	22.222	31.602	31.829	234.528	239.338

**=significant at 1% level, *=significant at 5% level, respectively.

Table 4a. Mean values of total dry matter (g m^{-2}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	9.854	32.092	107.958	247.000	556.208	806.250	902.083	935.250
Sowing (S_2)	9.835	31.875	105.583	243.375	510.833	747.917	827.292	848.250
Sowing (S_3)	9.769	31.375	104.875	214.625	456.250	632.708	700.542	713.917
LSD 5%	0.044	0.341	1.438	5.383	16.984	16.419	32.580	38.170
Soil moisture (I)								
Irrigation (I_1)	9.913	35.158	120.972	296.583	646.361	926.111	1021.667	1067.333
Rainfed (I_0)	9.726	28.403	91.306	173.417	369.167	531.806	598.278	597.611
LSD 5%	0.032	0.302	0.978	3.874	15.069	11.827	4.340	11.811
Variety (V)								
Shatabdi (V_1)	9.864	32.361	109.333	242.500	560.278	810.833	912.778	946.500
Gaurav (V_2)	9.742	31.411	102.722	226.944	476.389	681.389	739.556	752.167
Shourav (V_3)	9.878	31.744	107.944	239.278	498.667	715.556	798.111	819.778
Kanchan (V_4)	9.794	31.606	104.556	231.278	495.722	708.056	789.444	811.444
LSD 5%	0.037	0.211	1.864	2.705	12.674	6.623	18.705	17.394

Table 4b. Mean values of total dry matter (g m^{-2}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	9.875	31.979	103.917	240.875	532.417	796.667	886.250	905.250
Sowing (S_2)	9.869	31.375	102.542	224.875	492.667	728.000	802.542	818.458
Sowing (S_3)	9.846	30.875	91.000	191.292	408.458	600.833	655.750	663.125
LSD 5%	0.036	0.387	1.425	3.778	9.066	11.303	15.506	17.443
Soil moisture (I)								
Irrigation (I_1)	9.999	34.417	120.333	291.278	625.861	926.861	1004.750	1033.611
Rainfed (I_0)	9.726	28.403	77.972	146.750	329.833	490.139	558.278	557.611
LSD 5%	0.036	0.278	1.133	2.719	5.231	3.040	11.492	10.928
Variety (V)								
Shatabdi (V_1)	9.875	32.083	103.444	234.722	527.500	803.056	895.278	916.778
Gaurav (V_2)	9.811	31.028	98.222	208.667	447.778	634.722	688.444	697.444
Shourav (V_3)	9.906	31.250	98.667	221.833	471.833	699.833	776.500	788.444
Kanchan (V_4)	9.861	31.278	96.278	210.833	464.278	696.389	765.833	779.778
LSD 5%	0.037	0.161	1.485	3.176	3.787	3.789	10.317	10.422

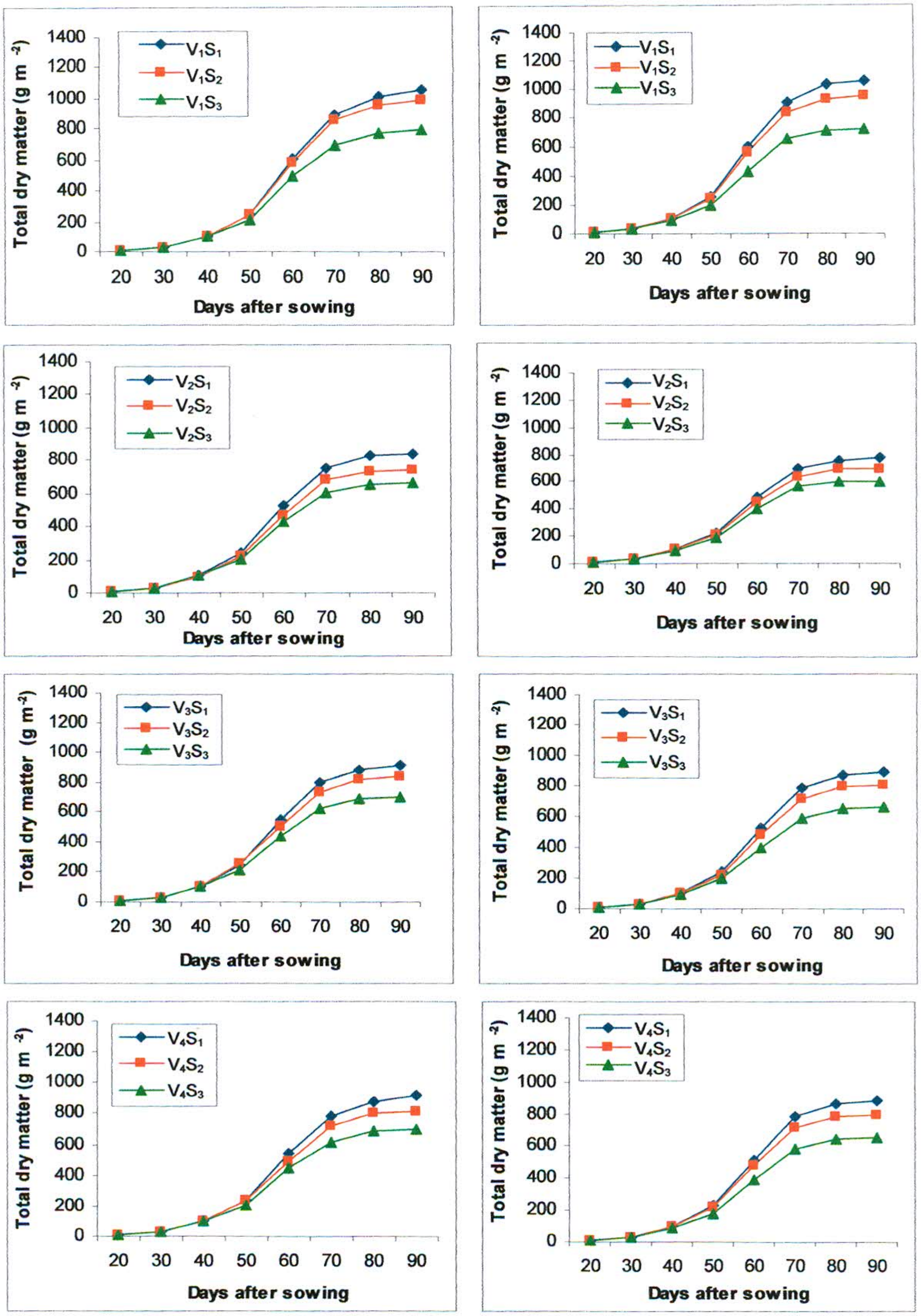


Figure 1a: Effects of sowing times on total dry matter (TDM) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

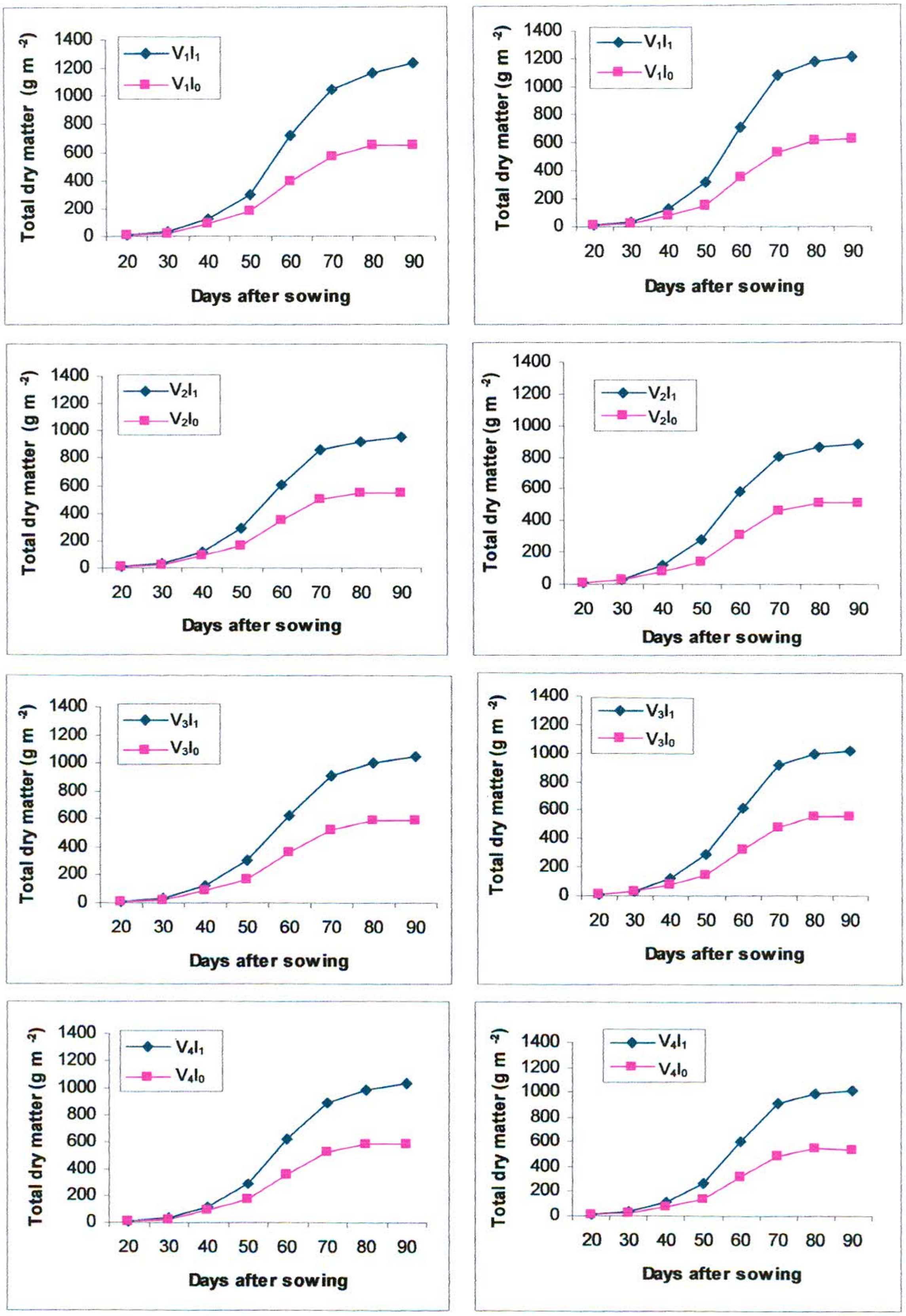


Figure 1b: Effects of soil moisture on total dry matter (TDM) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.3 Leaf Area Index (LAI)

Experiment for 2005-06

Mean squares from the analysis of variance of leaf area index are shown in **Table 5a.** The result shows that the replication was significant only at 40 DAS and the sowing time (S) differences for leaf area index were significant at 30, 40, 50,60,70,80 and 90 DAS. Soil moisture (I) item was significant at all the harvesting dates. Significant varietal differences were also observed at all the harvests except only at 20 DAS indicating that the varieties were highly affected by different sowing times and soil moisture regimes.

The interaction item $S \times V$ was significant at 30, 50, 60, 70, 80 and 90 DAS. The interaction items $S \times I$, $I \times V$ and $S \times I \times V$ were significant at all the harvesting dates except at 20 DAS.

Mean values of leaf area index as influenced by sowing date (**Table 6a**) indicated that generally lower leaf area index was observed at the early stages of growth and higher leaf area index at the middle stages and reached their highest value at 60 DAS and then declined to near zero. Among the sowing dates, S_1 plants showed the highest leaf area index than S_2 and S_3 plants at all the harvests.

Mean values of leaf area index as influenced by soil moisture also indicated that (**Table 6a**) starting from a lower value at the early stages of growth, reached their highest value at 60 DAS and then declined. The irrigated plants had higher leaf area index than the rainfed plants for all the varieties.

Mean values of leaf area index of all the four varieties (**Table 6a**) increased slowly at the initial stages of growth, reached their highest value at 60 DAS and then declined. Shatabdi had the highest leaf area index at several harvests than the other varieties.

The mean effect of sowing dates (S) on leaf area index at different growth stages are graphically shown in **Fig. 2a** (left portion). Sowing one (S_1) had the highest leaf area index at all the harvesting dates. Sowing three (S_3) produced the lowest leaf area index irrespective of varieties and soil moisture regime at all the growing stages. Increase of leaf area index was found to be steady but at the later stages of growth, sharp decline was found for all the varieties in all the sowing dates. It was also observed that almost all the varieties reached its highest peak at 60 DAS in different sowing times.

The mean effect of soil moisture (I) on leaf area index at different growth stages of wheat are graphically shown in **Fig. 2b** (left portion). The lowest leaf area index was found in the rainfed condition (I_0) for all the varieties at all the growing stages and generally higher leaf area index was found in the irrigated (I_1) condition in all the varieties.

The overall effects of varieties on leaf area index at different growth stages of wheat are graphically shown in **Fig. 2c** (left portion). A close study of the four varieties revealed that Shatabdi had the highest peak and Gaurav had the lowest peak at 60 DAS. It was also observed that almost all the varieties reached its highest peak approximately at 60 DAS. On average, Shatabdi (V_1) showed the highest and Gaurav (V_2) showed the lowest leaf area index among the varieties at all the growth phases.

Experiment for 2006-07

The results of analysis of variance in the experimental season 2006-07 are shown in **Table 5b.** The results show that the item sowing time (S), soil moisture (I) and variety for leaf area index were significant at all the harvesting dates, indicating that the varieties responded differently in different sowing times and soil moisture regimes.

All the interaction items were also significant at all the harvesting dates which indicated that the varieties responded differently in different sowing times and soil moisture regimes.

Mean values of leaf area index as influenced by sowing date (**Table 6b**) indicated that generally lower leaf area index was observed at the initial stages of growth and higher leaf area index at the middle stages and reached their highest value at 60 DAS and then declined. Among the sowing dates, S_1 plants showed the highest leaf area index than S_2 and S_3 plants at all the harvests.

Mean values of leaf area index as influenced by soil moisture (**Table 6b**) revealed that starting from lower values increased with increasing growth periods, reached their peak at 60 DAS and then declined. The highest leaf area index was observed in I_1 level than I_0 level of irrigation.

Mean values of leaf area index of all the four varieties (**Table 6b**) starting from lower values increased with increasing growth periods up to 60 DAS, reached their peak at 70 DAS and then gradually declined. Among the four varieties, it was observed that Shatabdi showed the highest peak and Gaurav showed the lowest peak at 60 DAS.

The mean effect of sowing dates (S) on leaf area index of four varieties of wheat at different growth stages are graphically shown in **Fig. 2a** (right portion). In all the sowing times and varieties leaf area index starting from lower values increased with increasing growth periods and then declined. All the four wheat varieties showed their highest peak at 60 DAS and then decreased at 70 DAS. All the varieties showed the highest leaf area index under sowing one (S_1) than sowing two (S_2) and sowing three (S_3).

Fig. 2b (right portion) shows that in all the varieties and soil moisture starting from a lower value, leaf area index reached a certain peak and then declined to near zero. In case of irrigation levels, the highest leaf area index was shown at 60 DAS. The irrigated plants had higher leaf area index values at all the stages of growth than those of the rainfed plants.

The overall effects of varieties on leaf area index of four varieties of wheat at different growth stages of wheat are graphically shown in **Fig. 2c** (right portion). In all the varieties, starting from lower value leaf area index increased with increasing growth periods and then declined. All the four wheat varieties showed their highest peak at 60 DAS and then decreased. Maximum leaf area index was found in Shatabdi followed by Kanchan, Shourav and Gaurav.

Table 5a. Mean squares (MS) from the analysis of variance of leaf area index at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.0003	0.00009	0.013*	0.0035	0.125	0.059	0.037	0.005
Sowing (S)	2	0.0013	0.0145**	0.678**	5.535**	6.78**	4.67**	1.62**	0.653**
Error (a)	4	0.0003	0.00004	0.0013	0.004	0.089	0.059	0.039	0.006
Soil moisture (I)	1	0.0145**	0.509**	11.174**	30.55**	48.91**	12.36**	9.35**	3.161**
S × I	2	0.0004	0.0011*	0.323**	2.67**	3.707**	8.02**	1.06**	0.441**
Error (b)	6	0.0003	0.0001	0.0012	0.007	0.097	0.064	0.038	0.007
Variety (V)	3	0.0003	0.013**	0.546**	2.79**	4.20**	2.39**	1.44**	0.646**
S × V	6	0.0004	0.00014**	0.0038	0.029**	0.049*	0.329**	0.058**	0.034**
I × V	3	0.0005	0.0003**	0.024**	0.622**	1.43**	0.635**	0.54**	0.292**
S × I × V	6	0.0004	0.0002**	0.0072*	0.017**	0.036*	0.159**	0.037**	0.020**
Error (c)	36	0.0003	0.00003	0.0017	0.0015	0.011	0.023	0.004	0.005

**=significant at 1% level, *=significant at 5% level, respectively.

Table 5b. Mean squares (MS) from the analysis of variance of leaf area index at different harvests of four wheat varieties as influenced sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.000026	0.000147	0.000035	0.000448	0.000446	0.000241	0.00113	0.000573
Sowing (S)	2	0.01661**	0.033807**	1.790564**	4.29305**	4.977803**	4.463815**	2.297446**	0.598468**
Error (a)	4	0.000017	0.000047	0.000467	0.000448	0.001161	0.000221	0.000702	0.011248
Soil moisture (I)	1	0.12719**	0.662391**	12.365734**	44.411229**	39.590489**	32.873069**	8.805027**	3.0478039**
(S×I)	2	0.00412**	0.000869**	0.608350**	2.642538**	2.647832**	1.5458849**	1.11779**	0.480764**
Error (b)	6	0.000026	0.000074	0.000323	0.000448	0.000883	0.000142	0.000821	0.008905
Variety (V)	3	0.00543**	0.018381**	0.500211**	2.5540536**	3.347286**	4.6279268**	1.390931**	0.549807**
S×V	6	0.00013**	0.000373**	0.006951**	0.036701**	0.041555**	0.0405715**	0.090457**	0.054363**
I×V	3	0.000424**	0.000956**	0.010578**	1.079103**	1.572009**	2.267064**	0.756932**	0.218104**
S×I×V	6	0.000151**	0.000501**	0.017130**	0.019427**	0.066883**	0.070051**	0.041758**	0.033173**
Error (c)	36	0.000022	0.000027	0.000145	0.000024	0.005093	0.001756	0.000827	0.006842

**=significant at 1% level, *=significant at 5% level, respectively;

Table 6a. Mean values of leaf area index at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	0.165	0.576	1.641	2.227	2.534	1.658	0.948	0.536
Sowing (S_2)	0.170	0.552	1.550	1.705	2.034	1.316	0.698	0.336
Sowing (S_3)	0.156	0.527	1.315	1.267	1.471	0.858	0.428	0.209
LSD 5%	0.014	0.005	0.029	0.051	0.239	0.195	0.158	0.062
Soil moisture (I)								
Irrigation (I_1)	0.178	0.636	1.896	2.384	2.838	1.873	1.052	0.570
Rainfed (I_0)	0.150	0.468	1.108	1.082	1.189	0.682	0.331	0.151
LSD 5%	0.010	0.006	0.020	0.048	0.180	0.146	0.112	0.048
Variety (V)								
Shatabdi (V_1)	0.163	0.584	1.702	2.258	2.652	1.887	1.082	0.626
Gaurav (V_2)	0.159	0.520	1.278	1.305	1.482	0.862	0.409	0.180
Shourav (V_3)	0.169	0.560	1.535	1.645	1.922	1.115	0.599	0.295
Kanchan (V_4)	0.164	0.543	1.492	1.724	1.997	1.244	0.674	0.341
LSD 5%	0.012	0.004	0.028	0.026	0.071	0.102	0.043	0.048

Table 6b. Mean values of leaf area index at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	0.172	0.551	1.537	1.992	2.198	1.846	0.951	0.536
Sowing (S_2)	0.172	0.528	1.334	1.730	1.788	1.432	0.617	0.336
Sowing (S_3)	0.158	0.478	0.996	1.165	1.288	0.984	0.332	0.225
LSD 5%	0.003	0.005	0.017	0.017	0.027	0.012	0.021	0.085
Soil moisture (I)								
Irrigation (I_1)	0.180	0.615	1.704	2.414	2.500	2.097	0.983	0.571
Rainfed (I_0)	0.154	0.423	0.875	0.843	1.017	0.745	0.284	0.160
LSD 5%	0.003	0.005	0.010	0.012	0.017	0.007	0.017	0.054
Variety (V)								
Shatabdi (V_1)	0.172	0.555	1.504	2.138	2.351	2.021	1.018	0.607
Gaurav (V_2)	0.160	0.478	1.097	1.233	1.318	0.785	0.360	0.191
Shourav (V_3)	0.171	0.528	1.277	1.534	1.654	1.385	0.541	0.310
Kanchan (V_4)	0.165	0.516	1.279	1.611	1.709	1.493	0.613	0.354
LSD 5%	0.003	0.004	0.008	0.003	0.048	0.028	0.019	0.056

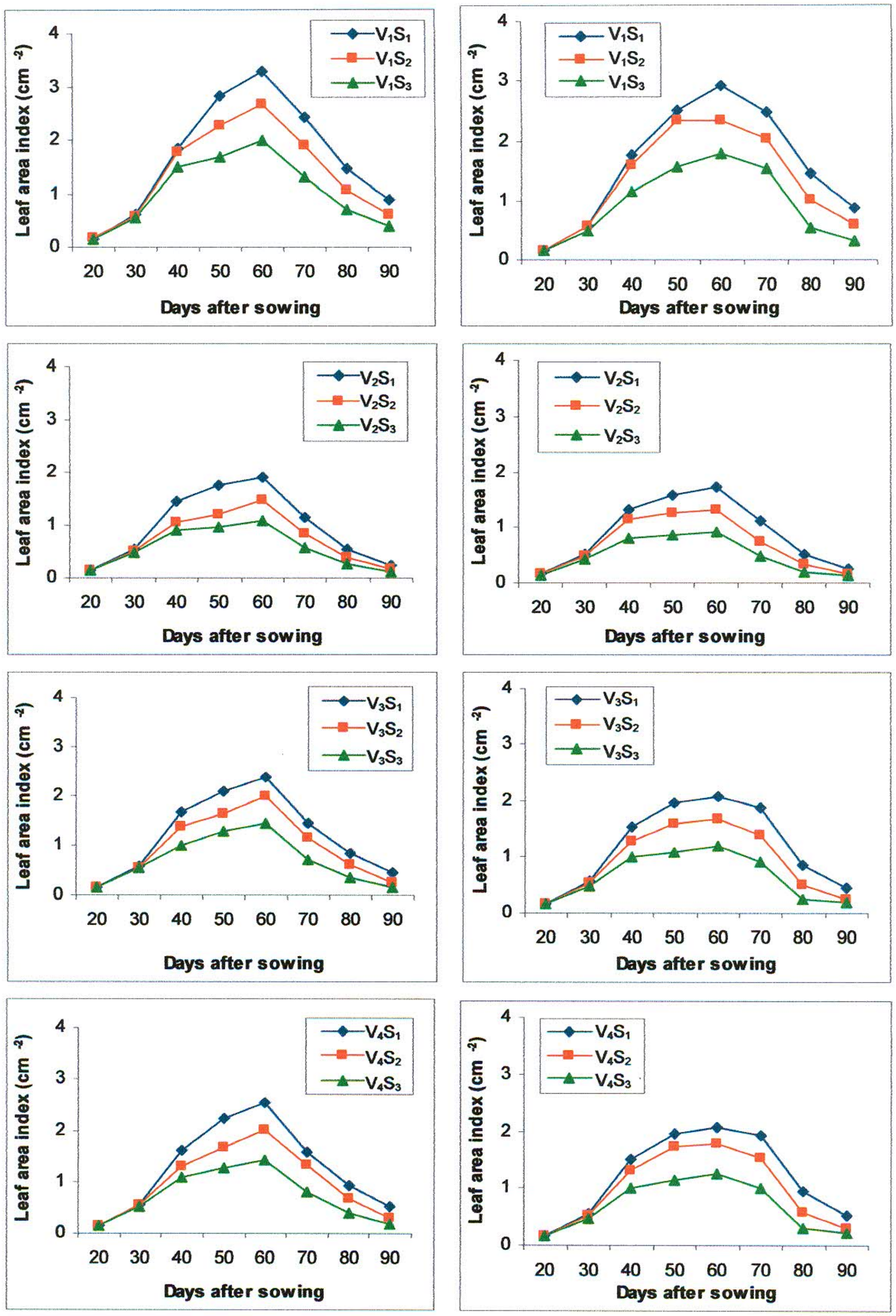


Figure 2a: Effects of sowing times on leaf area index (LAI) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

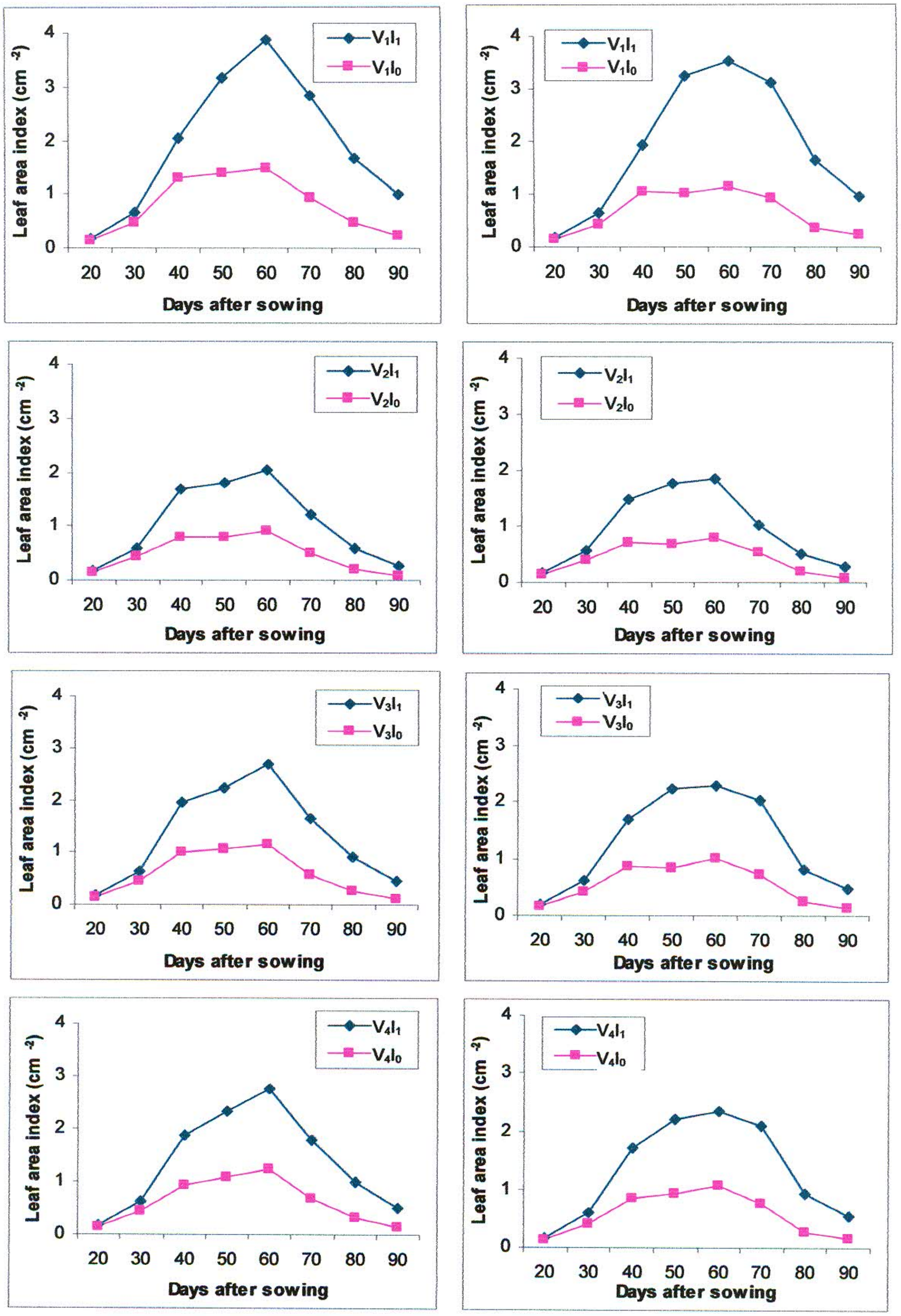


Figure 2b: Effects of soil moisture on leaf area index (LAI) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

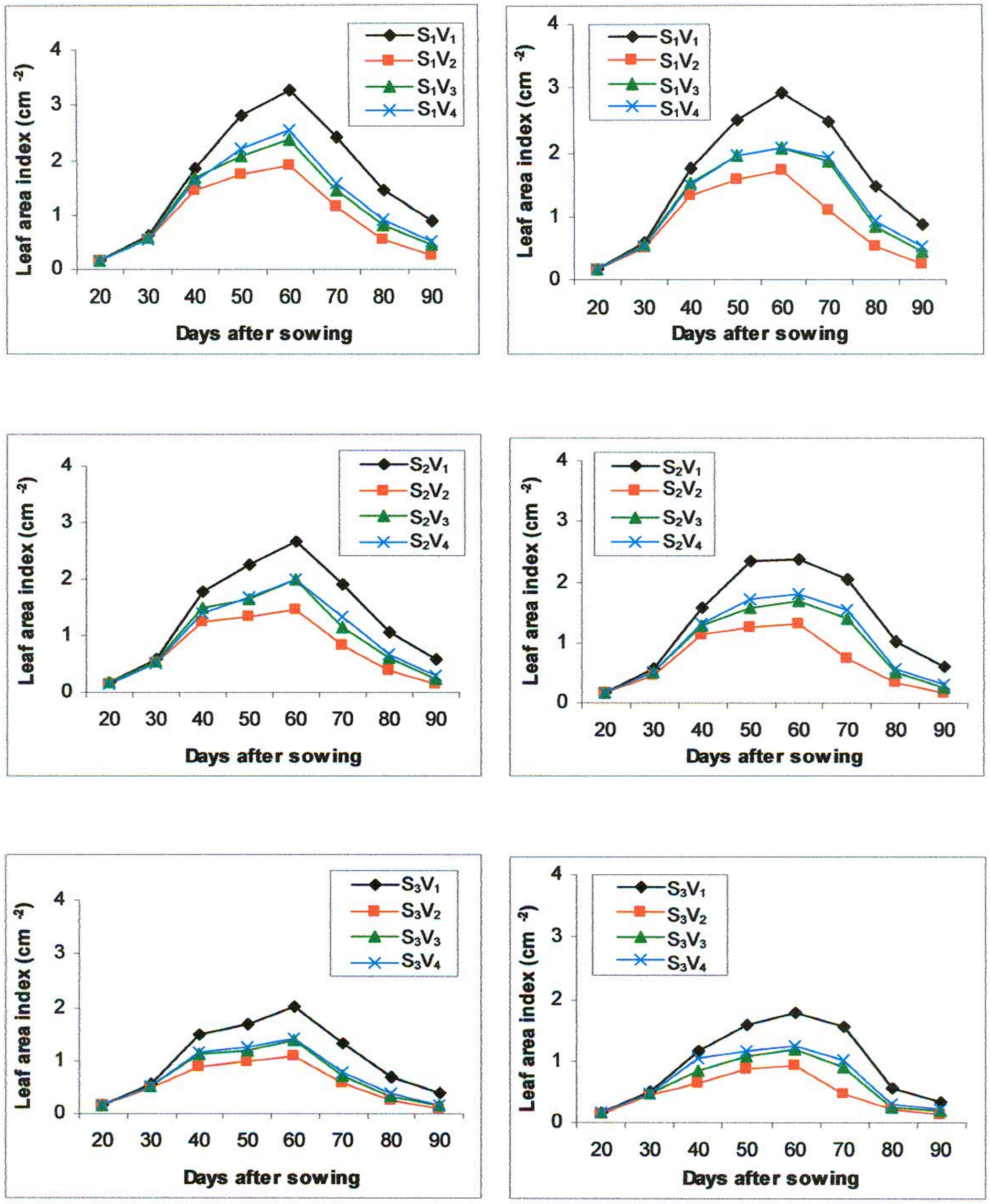


Figure 2c: Effects of varieties on leaf area index (LAI) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.4 Crop Growth Rate (CGR)

Experiment for 2005-06

Mean squares from the analysis of variance of crop growth rate are shown in **Table 7a**. The result shows that the sowing time (S) was significant at 20-30, 30-40, 40-50, 50-60 and 60-70 DAS indicating that the varieties were highly affected by different sowing times. Soil moisture (I) for crop growth rate was significant at all the harvesting dates. Significant varietal differences were also observed at all the harvests except only at 50-60 DAS.

The interaction item $S \times I$ was significant at most of the growth stages except at 80-90 DAS which indicates that the varieties responded differently in different sowing times. The interaction item $S \times V$ was significant at 30-40, 40-50 and 50-60 DAS. The interaction item $I \times V$ was significant at most of the growth stages except at 50-60 and 70-80 DAS. The interaction item $S \times I \times V$ was significant at 40-50 DAS only.

Mean values of crop growth rate as influenced by sowing dates (**Table 8a**) starting from a lower value increase with increasing growth periods, reached their highest peak at 50-60 DAS and then decreased. Generally S_1 plants increased crop growth rate at all the growth stages compared to other treatments, S_1 plants had the highest crop growth rate than the other sowings at all the growth stages.

Mean values of crop growth rate as influenced by soil moisture (**Table 8a**) starting from a lower value at the early stages of growth, reached their highest peak at 50-60 DAS and then decreased and reached towards negative direction at 80-90 DAS. The irrigated plants had higher crop growth rate than the rainfed plants of all the varieties.

Mean values of crop growth rate of all the four varieties (**Table 8a**) increased gradually and sharply, reached their peak at 50-60 DAS and then declined. Among the four varieties, Shatabdi showed the maximum crop growth rate and Gaurav showed the minimum crop growth rate at all the harvesting dates.

The mean effects of sowing times on crop growth rate at different stage of growth are graphically shown in **Fig. 3a** (left portion) shows that on all the varieties, the sowing one plants (November 15 sowing) reached their peaks at 50-60 DAS than the sowing two (November 30 sowing) and sowing three (December 15 sowing) at each DAS for crop growth rate.

The mean effects of soil moisture on crop growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 3b** (left portion) shows that in both the soil moisture crop growth rate starting from a lower value increased with increasing growth periods up to 50-60 DAS and then the value decreased rapidly and reached towards negative direction at 80-90 DAS. The irrigated plants had the higher value than the rainfed plants for all the varieties.

The overall effects of varieties on crop growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 3c** (left portion). A close study of the four varieties revealed that Shatabdi had the highest peak and Gaurav had the lowest peak. The highest crop growth rate was recorded for Shatabdi at 50-60 DAS.

Experiment for 2006-07

The analysis of variance in **Table 7b** shows that the item sowing time (S), soil moisture (I) and varieties for crop growth rate were significant at all the harvest dates, which indicates that the varieties responded differently in different sowing times and soil moisture regimes.

The interaction item S×I was significant at all the harvesting dates. The interaction item I×V was significant at most of the growth stages except at 70-80 DAS. The interaction items S×V and S× I ×V were significant in four harvests (at 40-50, 50-60, 60-70 and 80-90 DAS).

Mean values of crop growth rate as influenced by sowing dates (**Table 8b**) increased slowly and sharply during the growth stages, reached their highest value at 60-70 DAS and then declined. Generally, S_1 plants produced the highest crop growth rate than the S_2 and S_3 sowings of all the varieties.

Mean values of crop growth rate as influenced by soil moisture (**Table 8b**) increased rapidly throughout the all growth stages and reached their highest value at 50-60 DAS and then decreased and reached towards negative direction at 80-90 DAS. The highest crop growth rate was observed in I_1 level than I_0 level of irrigation.

Mean values of crop growth rate of all the four varieties (**Table 8b**) increased gradually and sharply, reached their highest value at 50-60 DAS and then declined. All the four varieties showed their highest crop growth rate value at 50-60 DAS. Shatabdi had the highest crop growth rate at 50-60 DAS than the other varieties.

The mean effects of sowing dates on crop growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 3a** (right portion). In all the sowing time for crop growth rate starting from a lower value increased with increasing growth periods and then declined. All the four wheat varieties showed their highest peak at 50-60 DAS and then decreased rapidly and reached towards zero direction at 80-90 DAS. The S_1 (November 15 sowing) plants indicates higher value than the S_2 (November 30 sowing) and S_3 (December 15 sowing) plants of all the varieties.

The mean effects of soil moisture on crop growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig.3b** (right portion) shows that in all the varieties showed the first peak at 50-60 DAS and then the value decreased rapidly and reached towards negative direction at 80-90 DAS. Most of the varieties showed more, less or similar crop growth rate at 70-80 DAS.

The overall effects of varieties on crop growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 3c** (right portion). Crop growth rate increased gradually with high fluctuations with increasing age of plants in all the four varieties. In all the varieties showed the first peak at 50-60 DAS and then the values decreased rapidly and reached towards zero direction at 80-90 DAS. The maximum crop growth rate value was found in Shatabdi and the minimum was found in Gaurav at 50-60 DAS.

Table 7a. Mean squares (MS) from the analysis of variance of crop growth rate (g m^{-2} day^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.004	0.221	0.896	15.684	23.088	13.008	1.198
Sowing (S)	2	0.025*	0.412*	65.835**	279.117**	370.312**	57.644	18.944*
Error (a)	4	0.002	0.035	0.586	4.880	7.189	16.511	2.411
Soil moisture (I)	1	7.768**	94.485**	1573.604**	4270.420**	2468.702**	152.251**	363.600**
S X I	2	0.014*	0.471**	10.001**	279.117**	374.800**	49.351*	5.144
Error (b)	6	0.003	0.031	0.528	8.481	10.488	6.060	2.318
Variety (V)	3	0.024**	1.289**	3.044**	169.089**	73.283**	57.756**	13.994**
S X V	6	0.001	0.189	0.952**	6.323	4.295	5.706	1.705
I X V	3	0.006**	0.324*	0.743*	79.735**	14.064**	6.830	11.136**
S X I X V	6	0.002	0.164	1.056**	6.323	4.784	9.332	1.190
Error (c)	36	0.001	0.078	0.192	3.944	3.201	6.791	2.282

**=significant at 1% level, *=significant at 5% level, respectively.

Table 7b. Mean squares (MS) from the analysis of variance of crop growth rate (g m^{-2} day^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.002	0.064	0.069	0.135	1.316	2.233	0.484
Sowing (S)	2	0.069**	10.481**	81.766**	346.343**	313.904**	72.526**	8.704**
Error (a)	4	0.002	0.036	0.107	0.466	1.150	3.673	0.288
Soil moisture (I)	1	5.931**	237.801**	1878.845**	4131.405**	3563.086**	17.111	156.940**
S X I	2	0.030**	0.317*	6.653**	289.385**	321.804**	42.203**	3.150*
Error (b)	6	0.002	0.045	0.428	1.800	0.480	3.310	0.367
Variety (V)	3	0.036**	1.261**	15.485**	98.895**	236.150**	46.032**	5.126**
S X V	6	0.000	0.035	1.688**	12.284**	10.780**	5.286	1.427**
I X V	3	0.002*	0.254**	6.498**	44.960**	102.288**	2.573	3.450**
S X I X V	6	0.001	0.040	1.539**	14.237**	13.213**	4.058	0.773**
Error (c)	36	0.001	0.051	0.271	0.538	0.346	2.858	0.027

**=significant at 1% level, *=significant at 5% level, respectively.

Table 8a. Mean values of crop growth rate (g m^{-2} day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	2.224	7.587	13.904	30.921	25.004	9.583	3.317
Sowing (S_2)	2.204	7.371	13.779	26.746	23.708	7.938	2.096
Sowing (S_3)	2.161	7.350	10.975	24.163	17.646	6.783	1.338
LSD 5%	0.036	0.150	0.613	1.770	2.149	3.256	1.244
Soil moisture (I)							
Irrigation (I_1)	2.525	8.581	17.561	34.978	27.975	9.556	4.567
Rainfed (I_0)	1.868	6.290	8.211	19.575	16.264	6.647	-0.067
LSD 5%	0.032	0.102	0.419	1.680	1.868	1.420	0.878
Variety (V)							
Shatabdi (V_1)	2.250	7.697	13.317	31.778	25.056	10.194	3.372
Gaurav (V_2)	2.167	7.131	12.422	24.944	20.500	5.817	1.261
Shourav (V_3)	2.187	7.620	13.133	25.939	21.689	8.256	2.167
Kanchan (V_4)	2.181	7.295	12.672	26.444	21.233	8.139	2.200
LSD 5%	0.021	0.188	0.295	1.338	1.205	1.756	1.131

Table 8b. Mean values of crop growth rate (g m^{-2} day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	2.210	7.194	13.696	29.154	26.425	8.958	1.900
Sowing (S_2)	2.151	7.117	12.233	26.779	23.533	7.454	1.592
Sowing (S_3)	2.103	6.013	10.029	21.717	19.238	5.492	0.738
LSD 5%	0.036	0.152	0.262	0.547	0.859	1.536	0.430
Soil moisture (I)							
Irrigation (I_1)	2.442	8.592	17.094	33.458	30.100	7.789	2.886
Rainfed (I_0)	1.868	4.957	6.878	18.308	16.031	6.814	-0.067
LSD 5%	0.026	0.122	0.377	0.774	0.400	1.049	0.349
Variety (V)							
Shatabdi (V_1)	2.221	7.136	13.128	29.278	27.556	9.222	2.150
Gaurav (V_2)	2.122	6.719	11.044	23.911	18.694	5.372	0.900
Shourav (V_3)	2.134	6.742	12.317	25.000	22.800	7.667	1.194
Kanchan (V_4)	2.142	6.500	11.456	25.344	23.211	6.944	1.394
LSD 5%	0.021	0.152	0.351	0.494	0.396	1.139	0.111

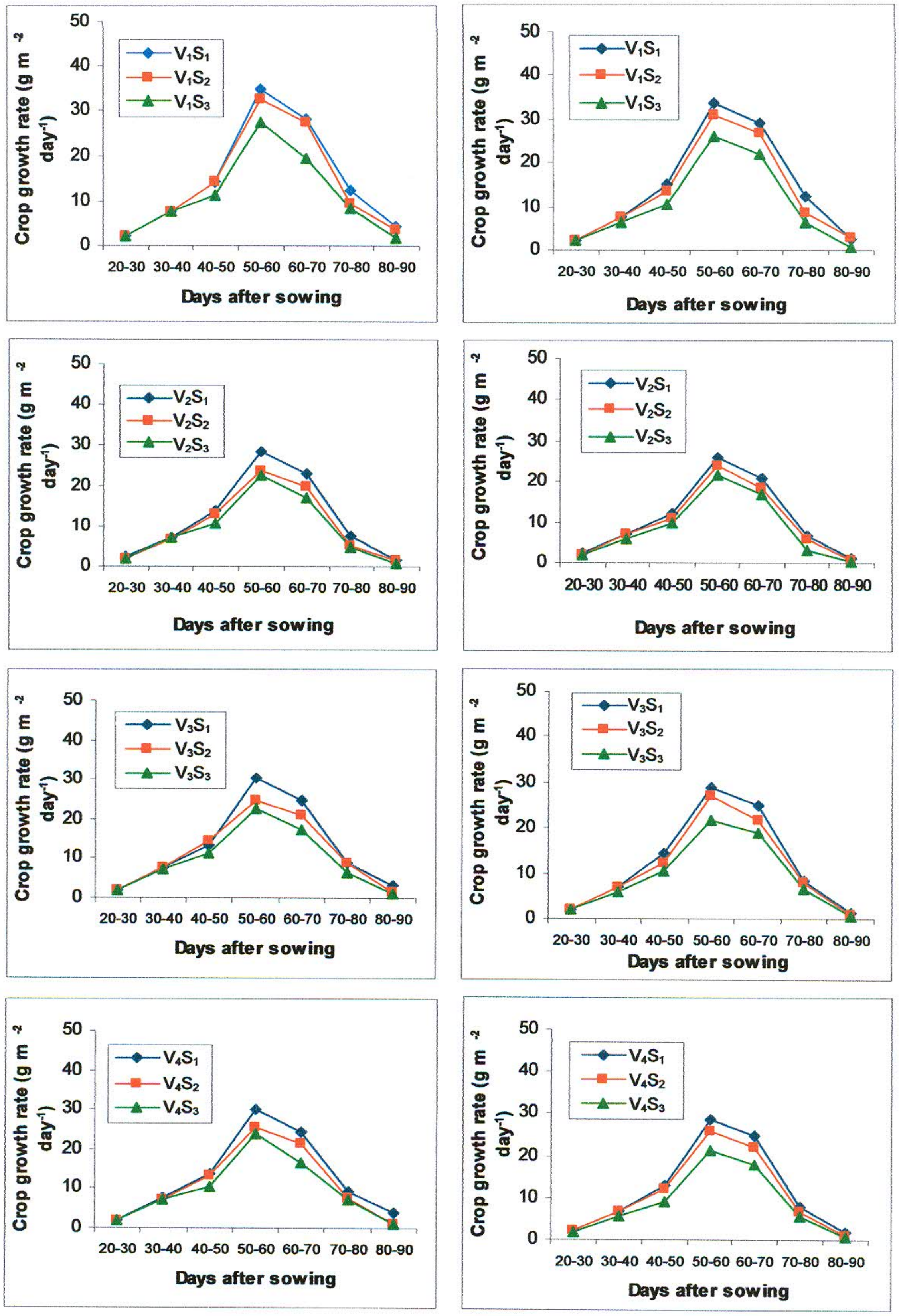


Figure 3a: Effects of sowing times on crop growth rate (CGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

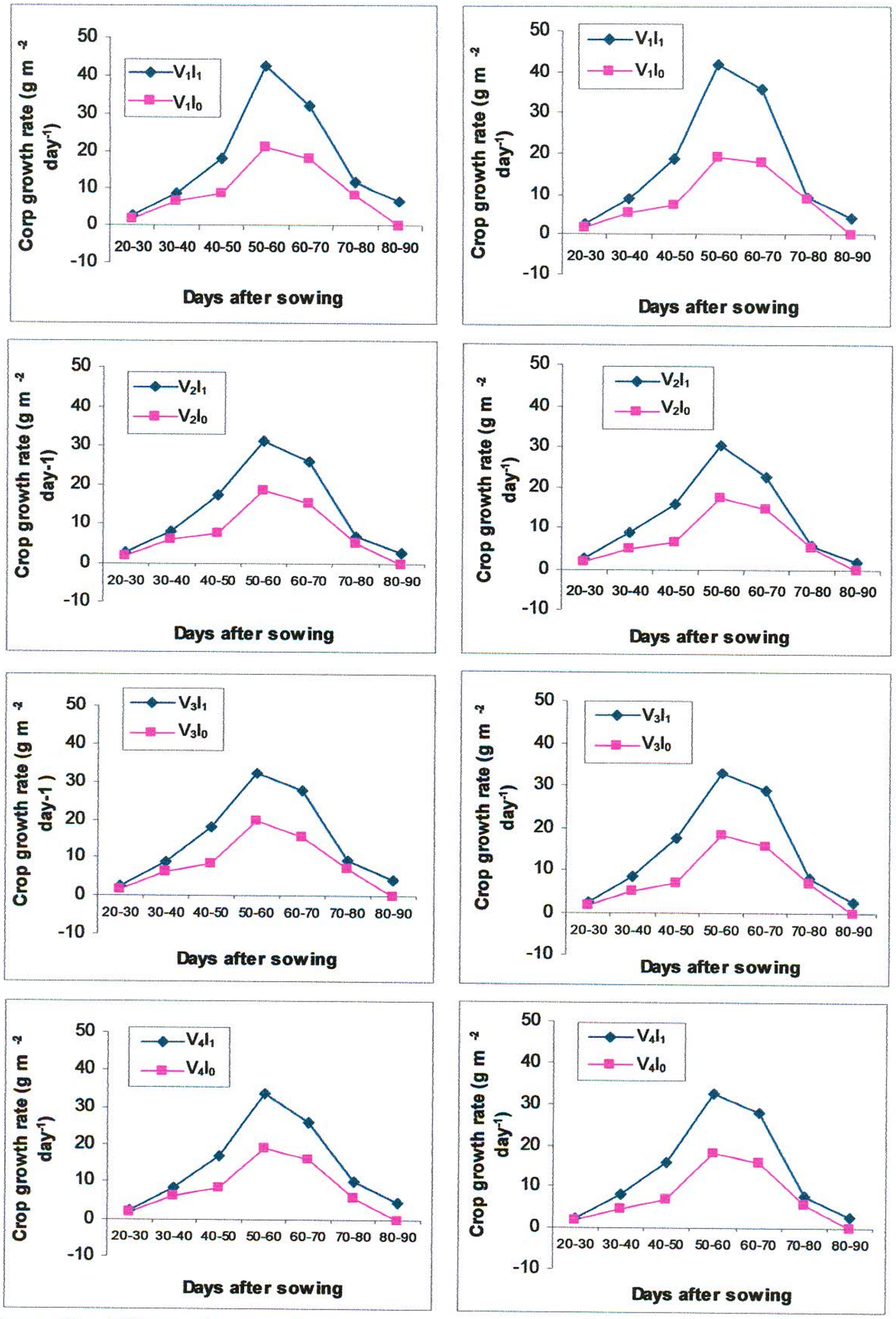


Figure 3b: Effects of soil moisture on crop growth rate (CGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

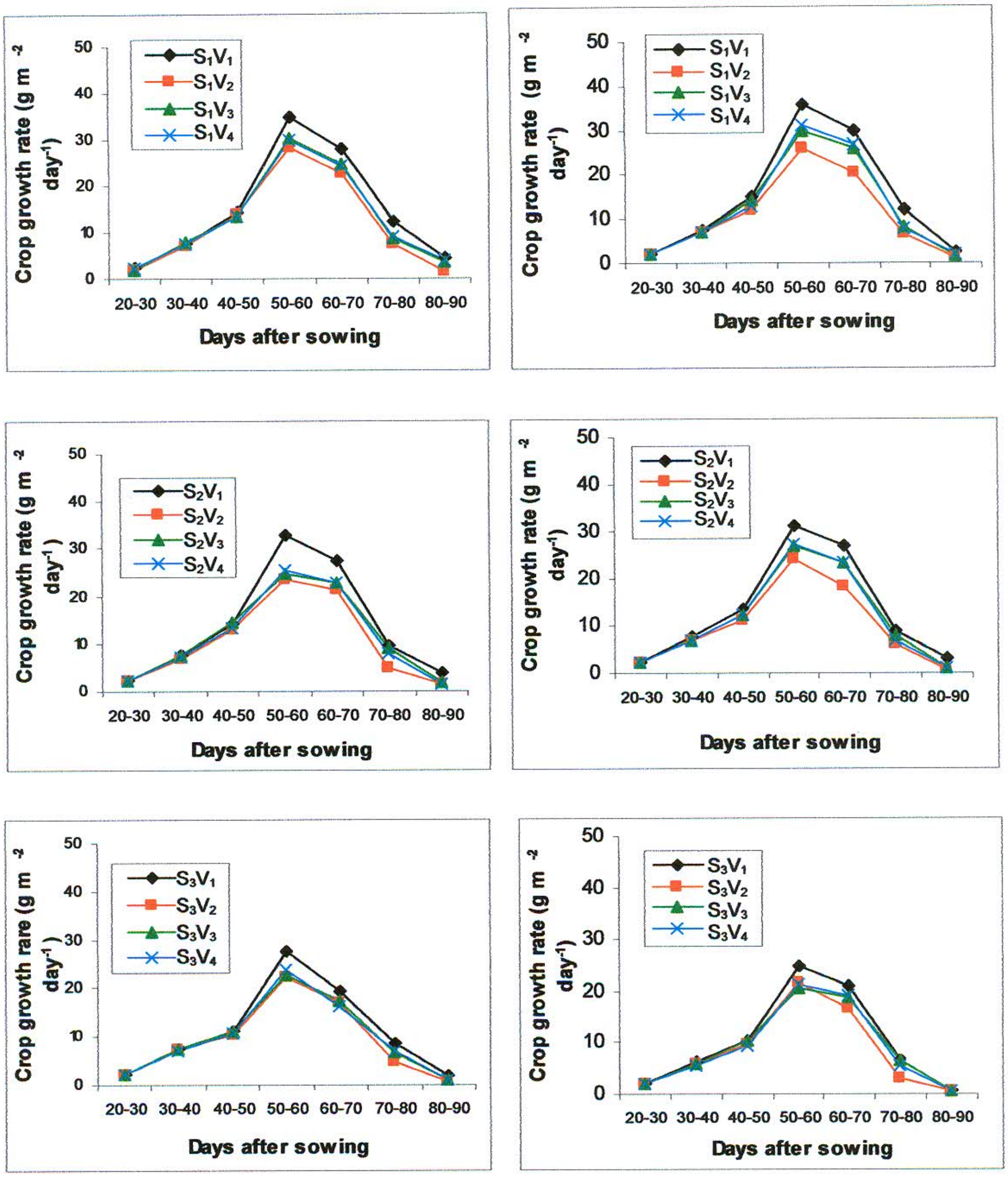


Figure 3c: Effects of varieties on crop growth rate (CGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.5 Relative Growth Rate (RGR)

Experiment for 2005-06

Mean squares from the analysis of variance of relative growth rate are shown in **Table 9a.** The result shows that the sowing time (S) was significant at 40-50 and 50-60 DAS. Soil moisture (I) item was significant at most of the harvesting dates except at 50-60 and 60-70 DAS. Varietal differences for relative growth rate were significant at most of the growth stages except at 40-50 and 60-70 DAS.

The interaction item $S \times I$ was significant only at 50-60 and 60-70 DAS. The interaction item $S \times V$ was non-significant at all the growth stages. The interaction item $I \times V$ was significant at 20-30, 40-50, 50-60 and 80-90 DAS. The interaction item $S \times I \times V$ was also non-significant at all the growth stages.

Sowing dates influenced mean values of relative growth rate (**Table 10a**) were found to be maximum at the second harvest (30-40 DAS) and then declined gradually with increasing the plant age. Generally S_1 plants increased relative growth rate at all the growth stages compared to other treatments, S_1 showed the highest relative growth rate than the other sowings.

Mean values of relative growth rate as influenced by soil moisture (**Table 10a**) declined throughout the whole growth period and then gradually declined with increasing the plant age and the rainfed plants reached towards negative direction at 80-90 DAS. The highest relative growth rate was observed at 20-30 DAS in the irrigated plants but the rainfed plants had the highest relative growth rate at 30-40 DAS. The irrigated plants had higher relative growth rate than the rainfed plants at all the harvests.

Mean values of relative growth rate of all the four varieties of wheat (**Table 10a**) were found to be maximum at 30-40 DAS and then declined with increasing the plant age the whole growth period. Among the varieties, Shatabdi had the highest relative growth rate and other varieties showed more, less or similar trends of relative growth rate at most of the growth stages.

The mean effects of sowing time (S) on relative growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 4a** (left portion). Relative growth rate showed the highest value at the first harvest (20-30 DAS) and then decreased rapidly and reached towards zero direction at 80-90 DAS. Among the varieties at 30-40 DAS for relative growth rate, S_2 (November 30 sowing) indicates higher value than the S_1 (November 15 sowing) and S_3 (December 15 sowing) plants. In all the sowing times had more or less or similar relative growth rate value at most of the growth stages of all the varieties.

The mean effect of soil moisture (I) on relative growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig.4b** (left portion). Between the irrigated and rainfed conditions of all the four varieties of wheat for relative growth rate also starting from the higher value at first harvest (20-30 DAS) and then declined gradually with increasing the plant age and then slowed down and reached towards negative direction at 80-90 DAS. The irrigated plants had higher relative growth rate than the rainfed plants at 20-30, 30-40, 40-50 and 50-60 DAS.

The overall effects of varieties of relative growth rate at different stages of growth are graphically shown in **Fig. 4c** (left portion). Graphical presentation shows that in all the varieties, the values of relative growth rate were found to be maximum at the first harvest and then decreased rapidly and reached towards zero direction at 80-90 DAS. At the second harvest (30-40 DAS) the maximum relative growth rate was recoded for Shourav and the minimum in Kanchan. On the other hand, at the forth (50-60 DAS) and fifth (60-70 DAS) harvests the maximum relative growth rate were recoded for Shatabdi and the minimum in Gaurav.

Experiment for 2006-07

From the results of analysis of variance in **Table 9b** it was observed that the item sowing time (S) was significant at 20-30, 30-40, 40-50 and 80-90 DAS. Significant varietals differences were also found at every harvest. The item soil moisture (I) was significant at all the harvesting dates except at 60-70 DAS.

The interaction item $S \times I$ was significant at all the harvesting dates except at 30-40 and 70-80 DAS. The interaction item $S \times V$ was significant at 50-60 and 80-90 DAS. The interaction item $I \times V$ was significant at most of the growth stages except 30-40 and 70-80 DAS and the interaction item $S \times V \times I$ was significant only at two harvests (50-60, and 80-90 DAS).

Sowing dates influenced mean values of relative growth rate (**Table 10b**) declined throughout the whole growth period and reached their peak at 20-30 DAS and then declined. Generally S_1 level increased relative growth rate at all the growth stages compared to other treatments, S_1 showed the highest relative growth rate than the other sowings.

Mean values of relative growth rate as influenced by soil moisture (**Table 10b**) declined throughout the whole growth period. The highest relative growth rate was observed at 20-30 DAS and then gradually declined with increasing time. The highest relative growth rate was observed in I_1 level than I_0 level of irrigation.

Mean values of relative growth rate of all the four varieties of wheat (**Table 10b**) starting from the higher values at first harvest and then declined throughout the whole growth period. The highest relative growth rate was observed at 20-30DAS. Among the varieties, Shatabdi had the highest relative growth rate at most of the growth stages than any other variety of wheat.

The mean effect of sowing times (S) on relative growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig.4a** (right portion). Among the varieties for crop growth rate showed the highest value at the first harvest and then slightly declined under different sowing times. At 30-40 DAS, S_2 (November 30 sowing) plants had higher value than the S_1 (November 15 sowing) and S_3 plants (December 15 sowing). All the varieties showed more, less or similar relative growth rate value in different showing times at most of the harvesting dates.

Fig. 4b (right portion) shows that the values of relative growth rate in both the irrigated and the rainfed conditions of all the varieties were also found to be maximum at 20-30 DAS. The irrigated plants showed the highest relative growth rate and rainfed plants showed the lowest at 20-30, 30-40, 40-50 and 50-60 DAS. All the varieties showed more, less or similar trends in irrigated and rainfed conditions at most of the growth stages.

The overall effects of varieties on relative growth rate at different stages of growth are graphically shown in **Fig. 4c** (right portion). Among the varieties, Shourav showed the maximum and Kanchan showed the minimum relative growth rate at the second harvest (30-40 DAS). On the other hand, Shatabdi showed the maximum and Gaurav showed the minimum relative growth rate at 50-60 DAS.

Table 9a. Mean squares (MS) from the analysis of variance of relative growth rate (g g $^{-1}$ day^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.0000038	0.0000324	0.0000276	0.000055	0.0000511	0.0000404	0.0000015
Sowing (S)	2	0.0000105	0.0000111	0.0009911**	0.0001680*	0.000113	0.0000385	0.0000124
Error (a)	4	0.0000016	0.0000065	0.0000116	0.0000180	0.0000183	0.0000361	0.0000025
Soil moisture (I)	1	0.0068101**	0.0008301**	0.0116001**	0.0000439	0.0000161	0.000057*	0.000339**
S × I	2	0.0000096	0.0000311	0.0000332	0.0005711**	0.000219*	0.0000171	0.0000002
Error (b)	6	0.0000025	0.0000068	0.0000083	0.0000303	0.0000216	0.0000061	0.0000026
Variety (V)	3	0.0000176**	0.0000530**	0.0000026	0.000270**	0.0000064	0.0000366*	0.0000069**
S × V	6	0.0000013	0.0000161	0.0000122	0.0000153	0.0000024	0.0000036	0.0000016
I × V	3	0.0000117**	0.0000117	0.0000232*	0.000184**	0.0000155	0.0000104	0.0000039*
S × I × V	6	0.0000018	0.0000152	0.0000128	0.000151	0.0000034	0.0000081	0.0000011
Error (c)	36	0.0000013	0.0000903	0.000079	0.0000114	0.0000073	0.0000115	0.0000013

**=significant at 1% level, *=significant at 5% level, respectively;

Table 9b: Mean squares (MS) from the analysis of variance of relative growth rate (g g $^{-1}$ day^{-1}) at different harvests of four wheat varieties as influenced sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.0000015	0.0000164	0.0000024	0.0000011	0.0000059	0.0000072	0.0000004
Sowing (S)	2	0.000056**	0.000842**	0.000752**	0.0000095	0.0000026	0.0000208	0.000016**
Error (a)	4	0.0000023	0.0000098	0.0000016	0.0000034	0.0000066	0.0000101	0.0000002
Soil moisture (I)	1	0.004854**	0.010585**	0.011641**	0.000597**	0.0000175	0.000454**	0.000079**
S × I	2	0.000029**	0.0000236	0.000262**	0.001205**	0.000156**	0.000011	0.000005**
Error (b)	6	0.000002	0.000012	0.0000182	0.0000198	0.0000055	0.0000091	0.0000003
Variety (V)	3	0.000035**	0.000062**	0.000119**	0.000055**	0.000118**	0.000039*	0.0000006**
S × V	6	0.00000014	0.0000036	0.0000174	0.000017*	0.0000014	0.0000086	0.00000013*
I × V	3	0.000006**	0.0000229	0.000038*	0.000061**	0.000051**	0.0000178	0.00000016*
S × I × V	6	0.0000012	0.0000044	0.0000205	0.000016*	0.0000023	0.00000197	0.0000003**
Error (c)	36	0.0000009	0.0000092	0.0000105	0.0000057	0.0000025	0.0000095	0.00000005

**=significant at 1% level, *=significant at 5% level, respectively;

Table 10a. Mean values of relative growth rate (g g $^{-1}$ day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	0.1175	0.1207	0.0803	0.0792	0.0368	0.0111	0.0028
Sowing (S_2)	0.1169	0.1194	0.0806	0.0740	0.0377	0.0106	0.0018
Sowing (S_3)	0.1162	0.1203	0.0693	0.0760	0.0336	0.0102	0.0015
LSD 5%	0.0010	0.0020	0.0027	0.0034	0.0034	0.0048	0.0013
Soil moisture (I)							
Irrigation (I_1)	0.1266	0.1235	0.0894	0.0772	0.0355	0.0097	0.0042
Rainfed (I_0)	0.1071	0.1167	0.0640	0.0756	0.0365	0.0116	-0.0001
LSD 5%	0.0009	0.0015	0.0017	0.0032	0.0027	0.0014	0.0009
Variety (V)							
Shatabdi (V_1)	0.1183	0.1214	0.0771	0.0821	0.0369	0.0122	0.0028
Gaurav (V_2)	0.1165	0.1182	0.0762	0.0742	0.0357	0.0084	0.0013
Shourav (V_3)	0.1161	0.1217	0.0768	0.0736	0.0357	0.0112	0.0020
Kanchan (V_4)	0.1166	0.1192	0.0769	0.0757	0.0357	0.0108	0.0021
LSD 5%	0.0008	0.0064	0.0060	0.0023	0.0018	0.0023	0.0008

Table 10b. Mean values of relative growth rate (g g $^{-1}$ day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	0.1170	0.1160	0.0806	0.0784	0.0394	0.0111	0.0018
Sowing (S_2)	0.1152	0.1166	0.0760	0.0782	0.0388	0.0105	0.0013
Sowing (S_3)	0.1139	0.1060	0.0695	0.0794	0.0394	0.0093	0.0008
LSD 5%	0.0012	0.0025	0.0010	0.0015	0.0021	0.0025	0.0004
Soil moisture (I)							
Irrigation (I_1)	0.1236	0.1250	0.0881	0.0758	0.0387	0.0078	0.0027
Rainfed (I_0)	0.1071	0.1007	0.0627	0.0815	0.0397	0.0128	-0.0002
LSD 5%	0.0008	0.0020	0.0025	0.0026	0.0014	0.0017	0.0003
Variety (V)							
Shatabdi (V_1)	0.1174	0.1151	0.0776	0.0807	0.0417	0.0119	0.0018
Gaurav (V_2)	0.1147	0.1128	0.0718	0.0778	0.0357	0.0085	0.0009
Shourav (V_3)	0.1144	0.1130	0.0769	0.0767	0.0391	0.0111	0.0011
Kanchan (V_4)	0.1149	0.1105	0.0752	0.0793	0.0403	0.0099	0.0013
LSD 5%	0.0006	0.0020	0.0022	0.0016	0.0011	0.0021	0.0005

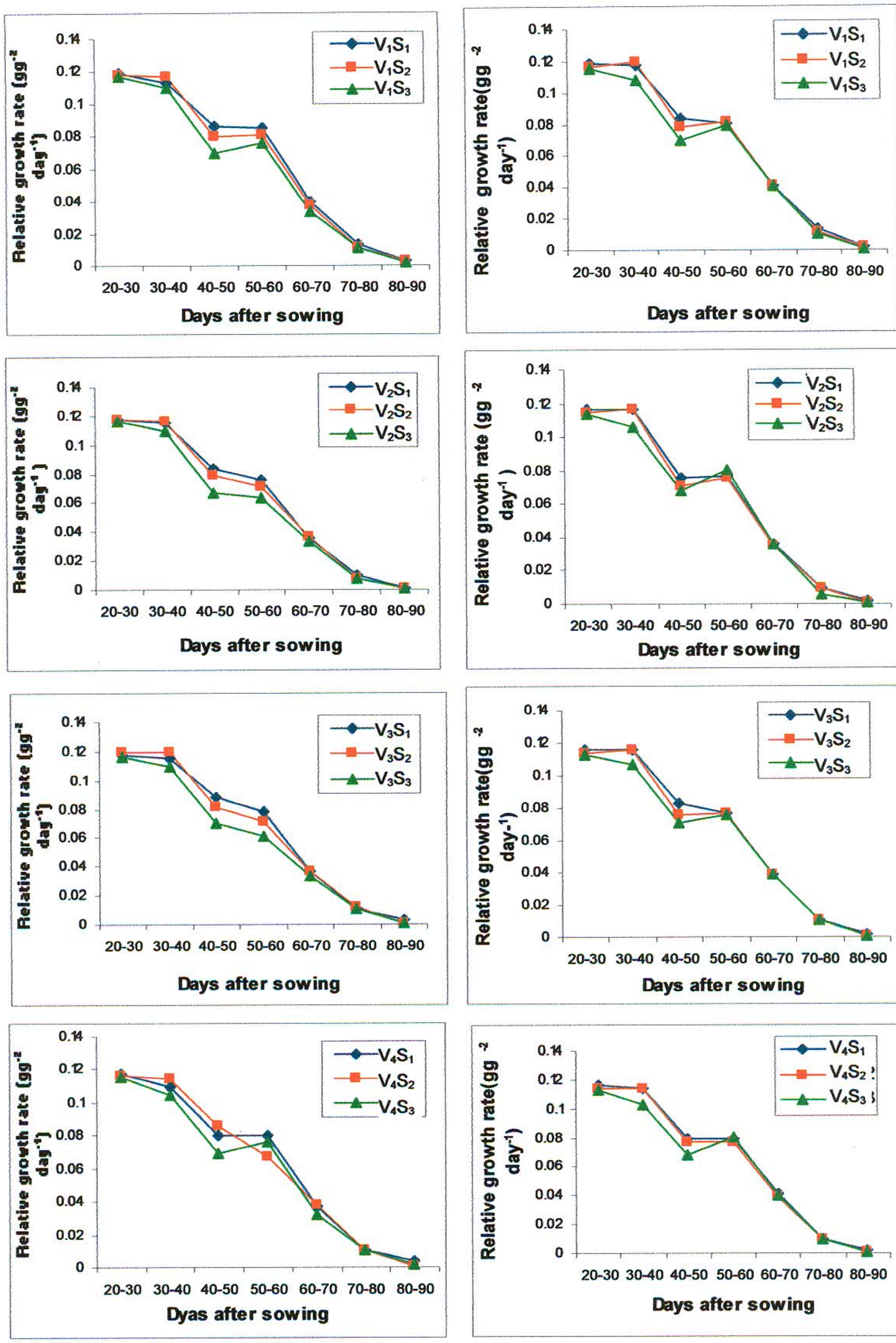


Figure 4a: Effects of sowing times on relative growth rate (RGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

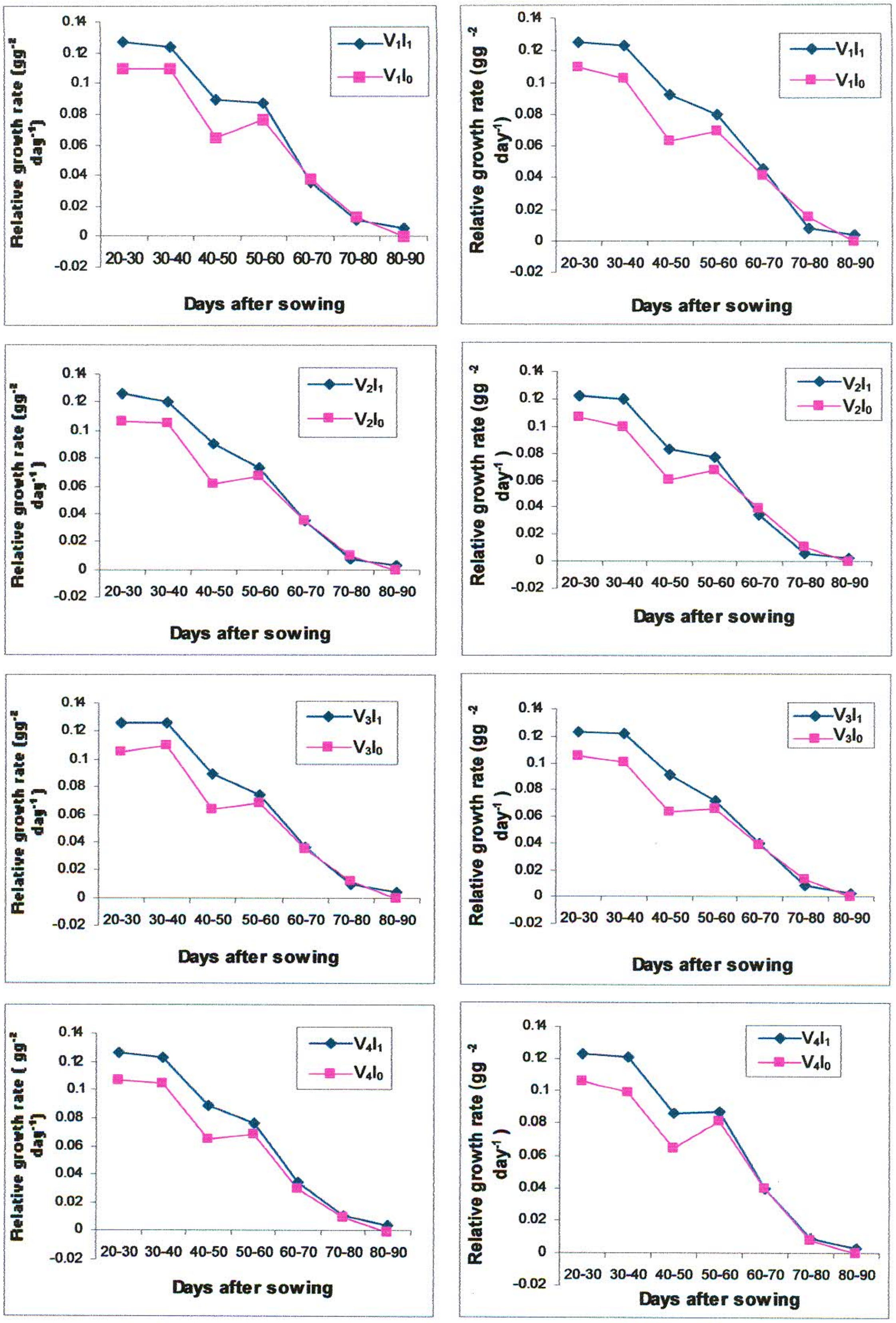


Figure 4b: Effects of soil moisture on relative growth rate (RGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

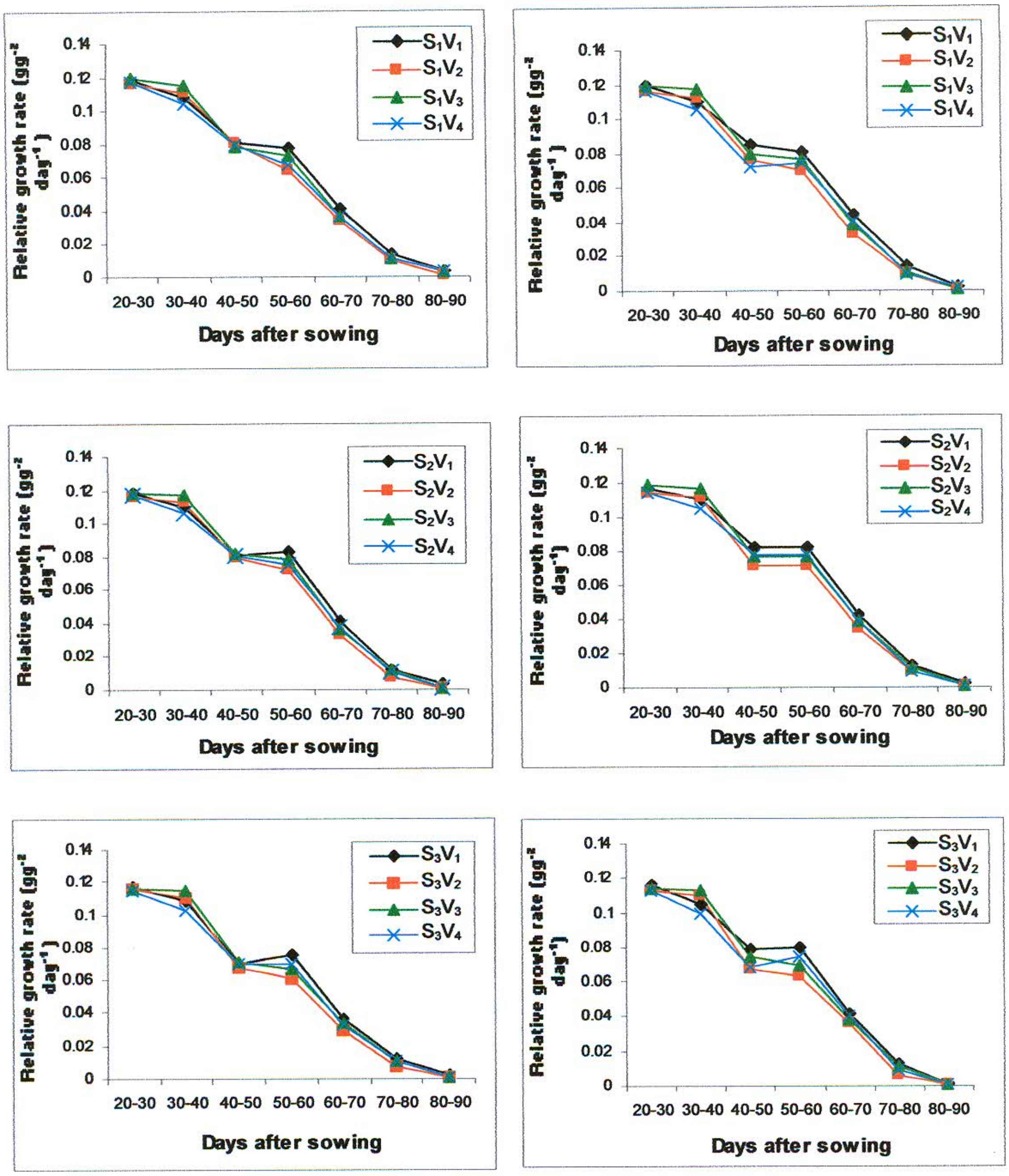


Figure 4c: Effects of varieties on relative growth rate (RGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.6 Net Assimilation Rate (NAR)

Experiment for 2005-06

Mean squares from the analysis of variance of net assimilation rate are shown in **Table 11a.** The result shows that the item sowing date (S) was significant at 30-40, 40-50, 50-60 and 60-70 DAS indicating that the varieties were highly affected by different sowing times. Significant variation between the irrigated and rainfed treatments was found in all the growth phases except at 20-30 DAS. Significant varietals differences for net assimilation rate were observed at 30-40, 40-50, 50-60 and 60-70 DAS.

The interaction item $S \times I$ was significant at 30-40, 40-50, 60-70 and 80-90 DAS. The interaction item $S \times V$ was significant at 30-40, 50-60 and 60-70 DAS which indicates that the varieties responded differently in different sowing times and soil moisture regimes. The interaction item $I \times V$ was significant at 30-40, 40-50, 50-60 and 80-90 DAS and the interaction $S \times I \times V$ was also significant at most of the growth stages except at 20-30 and 70-80 DAS.

Sowing dates influenced mean values of net assimilation rate (**Table 12a**) starting from the lower values and increased very sharply with advancements of time, reached their highest peak at 50-60 DAS. Generally S_3 plants increased net assimilation rate at all the growth stages compared to other treatments, S_3 plants showed the highest net assimilation rate than S_2 and S_1 plants at all the harvests.

Mean values of net assimilation rate as influenced by soil moisture (**Table 12a**) indicated that starting from the lower values and increased very sharply with advancements of time, reached their peaks at 50-60 DAS. The rainfed plants had higher net assimilation rate than the irrigated plants of all the varieties.

Mean values of net assimilation rate of four wheat varieties (**Table 12a**) also indicated that starting from the lower values and increased sharply with increasing the plant age, reached their peaks at 50-60 DAS and thereafter declined sharply at the later stages of growth. Among the varieties, Gaurav had the highest net assimilation rate value at 50-60 DAS than the other variety.

The mean effect of sowing dates (S) on net assimilation rate at different growth stages are graphically shown in **Fig. 5a** (left portion). In all the varieties net assimilation rate starting from lower values and reached the highest values at 50-60 DAS. All the varieties for net assimilation rate, S_3 (December 15 sowing) had higher value than the S_2 (November 30 sowing) and S_1 (November 15 sowing) plants at most of the harvesting dates.

The mean effect of soil moisture (I) on net assimilation rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 5b** (left portion). In all the varieties, the rainfed values exceeded the irrigated ones at a particular growth phases (at 50-60, 60-70 and 70-80 DAS). On the other hand, the irrigated values exceeded the rainfed values at the last stage. The rainfed plants showed the highest net assimilation rate value than the irrigated plants of all the varieties.

The overall effects of varieties on net assimilation rate at different stages of growth are graphically shown in **Fig. 5c** (left portion). In all the varieties a starting form lower values net assimilation rate increased with the increasing growth stage and reached their peaks at 50-60 DAS. Among the varieties, Gaurav showed the highest peak and Shatabdi showed the lowest peak at 50-60 DAS. In all the varieties, Gaurav had the higher value at several harvests than any other variety.

Experiment for 2006-07

The results of analysis of variance are shown in **Table 11b.** It shows that the soil moisture level (I) were significant at all the harvest days except at 30-40 DAS. Varietal differences were significant at most of the growth stages except at 70-80 and 80-90 DAS. The item sowing time (S) was significant at all the harvesting dates except only at 70-80 and 80-90 DAS which indicates that the varieties responded differently in different sowing times.

The interaction item S×I was significant at all the harvest except at 50-60 and 70-80 DAS. The interaction item S×V was significant at most of the growth phases except at 20-30, 30-40 and 70-80 DAS. The interaction item I×V was significant at 20-30, 40-50, 60-70 and 80-90 DAS. The interaction item S×I×V was significant at all the harvesting dates except at two harvesting dates (60-70 and 70-80 DAS).

Sowing dates influenced mean values of net assimilation rate (**Table 12b**) were found to be maximum at the forth harvest (50-60 DAS) and than decreased gradually with increasing the plant age. Among the sowing dates, S_3 plants showed the highest net assimilation rate than S_2 and S_1 plants at all the harvests.

Mean values of net assimilation rate as influenced by soil moisture (**Table 12b**) revealed that staring from the lower values and then declined within very short-time and reached towards negative direction at the last harvest. The rainfed plants had higher net assimilation rate value than the irrigated plants of all the varieties.

Mean values of net assimilation rate of all varieties (**Table 12b**) were found to be maximum at 50-60 DAS and then declined sharply, reached their highest values at 50-60 DAS and thereafter declined sharply at the later stages of growth. Among the varieties, Gaurav had highest peak and Shatabdi showed the lowest peak at 50-60 DAS.

The mean effect of sowing dates (S) on net assimilation rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 5a** (right portion). In all the sowing time for net assimilation rate showed the highest value at the fifth (50-60 DAS) harvest and then decreased rapidly and reached towards zero direction at 80-90 DAS. At each DAS for net assimilation rate, S_3 (December 15 sowing) indicates higher value than the S_2 (November 30 sowing) and S_1 (November 15 sowing) plants.

The mean effect of soil moisture (I) on net assimilation rate at different growth stages of wheat are graphically shown in **Fig. 5b** (right portion). In all the varieties, net assimilation rate starting from a lower values and then declined gradually with increasing plant age and reached the highest values at 50-60 DAS and then slowly decreased and than decreased rapidly and reached towards negative direction at 80-90 DAS. All the varieties, the rainfed values exceeded the irrigated ones at a particular growth phases. The rainfed plants had their highest net assimilation rate than the irrigated plants of all the varieties.

The overall effects of varieties on net assimilation rate are graphically shown in **Fig. 5c** (right portion). The values of net assimilation rate were found to be the maximum at the fifth harvest and then declined gradually with increasing plant age and reached towards zero direction at 80-90 DAS. The maximum net assimilation rate was found in Gaurav and the minimum in Shatabdi at 60-70 DAS. In all the varieties, Gaurav had the higher value at most of the harvests than any other variety.

Table 11a. Mean squares (MS) from the analysis of variance of net assimilation rate(g cm $^{-1}$ day^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.0000000041	0.0000000029	0.0000000074	0.0000000561	0.0000000604	0.000000288	0.000000012
Sowing (S)	2	0.0000000062	0.0000007**	0.000000072**	0.00000152**	0.000000913*	0.000000563	0.000000096
Error (a)	4	0.0000000046	0.0000000075	0.0000000012	0.0000000114	0.000000699	0.000000445	0.000000037
Soil moisture (I)	1	0.0000000077	0.0000021**	0.000000165**	0.00000239*	0.00000544**	0.00000765**	0.00000959**
S×I	2	0.0000000047	0.000000077**	0.000000123**	0.0000000422	0.000000317*	0.000000156	0.000000793**
Error (b)	6	0.0000000047	0.0000000046	0.0000000093	0.0000000223	0.0000000380	0.000000148	0.000000034
Variety (V)	3	0.0000000067	0.00000055**	0.000000256**	0.000001**	0.00000145**	0.000000422	0.000000039
S×V	6	0.0000000064	0.000000036**	0.0000000019	0.000000366**	0.0000000342*	0.000000048	0.000000043
I×V	3	0.0000000092	0.00000014**	0.0000000045*	0.0000000239*	0.0000000269	0.000000234	0.0000000962*
S×I×V	6	0.0000000050	0.000000024**	0.000000113**	0.000000585**	0.000000068**	0.000000205	0.0000000595*
Error (c)	36	0.0000000056	0.0000000054	0.0000000103	0.0000000069	0.0000000122	0.000000161	0.000000022

**=significant at 1% level, *=significant at 5% level, respectively

Table11b. Mean squares (MS) from the analysis of variance of net assimilation rate(g cm $^{-1}$ day^{-1}) at different harvests of four wheat varieties as influenced sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.0000000052	0.0000000027	0.0000000016	0.0000000012	0.0000000018	0.00000014	0.0000000189
Sowing (S)	2	0.000000026**	0.000000044**	0.000000045**	0.00000102**	0.00000198**	0.00000088	0.000000058
Error (a)	4	0.0000000027	0.0000000011	0.0000000042	0.0000000169	0.0000000109	0.000000015	0.0000000097
Soil moisture (I)	1	0.000000004**	0.0000000489	0.000000142**	0.00000598**	0.00000487**	0.00001452**	0.00000512**
S × I	2	0.000000015**	0.000000036**	0.000000529**	0.000000016	0.00000039**	0.00000052	0.00000082**
Error (b)	6	0.0000000097	0.0000000159	0.0000000244	0.000000019	0.000000009	0.000000137	0.0000000058
Variety (V)	3	0.000000011**	0.000000085**	.000000193**	0.000001184**	0.000001188**	0.00000024	0.0000000069
S × V	6	0.0000000027	0.0000000138	0.000000011**	0.000000088**	0.000000183**	0.00000016	0.000000027**
I × V	3	0.000000009**	0.0000000019	0.000000028**	0.000000019	0.000000085**	0.000000194	0.000000079**
S × I × V	6	0.000000009**	0.000000054**	0.000000047**	0.000000059**	0.0000000232	0.000000043	0.000000023**
Error (c)	36	0.0000000023	0.0000000133	0.0000000128	0.0000000085	0.0000000154	0.000000138	0.0000000036

**=Significant at 1% level, *=significant at 5% level, respectively;

Table12a. Mean values of net assimilation rate (g cm $^{-1}$ day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	0.0007	0.0008	0.0008	0.0014	0.0014	0.0009	0.0004
Sowing (S_2)	0.0007	0.0008	0.0008	0.0015	0.0016	0.0011	0.0002
Sowing (S_3)	0.0007	0.0009	0.0008	0.0019	0.0018	0.0013	0.0003
LSD 5%	0.00005	0.00007	0.00003	0.00009	0.00067	0.00053	0.00015
Soil moisture (I)							
Irrigation (I_1)	0.0007	0.0008	0.0009	0.0014	0.0013	0.0008	0.0007
Rainfed (I_0)	0.0007	0.0009	0.0008	0.0018	0.0019	0.0014	-0.0001
LSD 5%	0.00004	0.00004	0.00006	0.00009	0.00011	0.00022	0.00011
Variety (V)							
Shatabdi (V_1)	0.0007	0.0007	0.0007	0.0014	0.0013	0.0009	0.0003
Gaurav (V_2)	0.0007	0.0009	0.0010	0.0019	0.0020	0.0012	0.0003
Shourav (V_3)	0.0007	0.0008	0.0008	0.0016	0.0016	0.0013	0.0004
Kanchan (V_4)	0.0007	0.0008	0.0008	0.0015	0.0015	0.0010	0.0003
LSD 5%	0.00005	0.00005	0.00002	0.00006	0.00007	0.00027	0.00010

Table12b. Mean values of net assimilation rate (g cm $^{-1}$ day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	0.0007	0.0008	0.0008	0.0016	0.0014	0.0009	0.0002
Sowing (S_2)	0.0007	0.0008	0.0008	0.0017	0.0016	0.0010	0.0002
Sowing (S_3)	0.0007	0.0008	0.0009	0.0020	0.0020	0.0012	0.0002
LSD 5%	0.00001	0.00003	0.00002	0.00010	0.00008	0.00010	0.00008
Soil moisture (I)							
Irrigation (I_1)	0.0007	0.0008	0.0009	0.0015	0.0014	0.0006	0.0005
Rainfed (I_0)	0.0007	0.0008	0.0008	0.0020	0.0019	0.0015	-0.0001
LSD 5%	0.00002	0.00002	0.00003	0.00008	0.00005	0.00021	0.00004
Variety (V)							
Shatabdi (V_1)	0.0007	0.0008	0.0007	0.0015	0.0014	0.0010	0.0002
Gaurav (V_2)	0.0007	0.0009	0.0010	0.0021	0.0020	0.0011	0.0002
Shourav (V_3)	0.0007	0.0008	0.0009	0.0017	0.0016	0.0012	0.0002
Kanchan (V_4)	0.0007	0.0008	0.0008	0.0017	0.0016	0.0009	0.0002
LSD 5%	0.00001	0.00002	0.00002	0.00006	0.00008	0.00025	0.00004

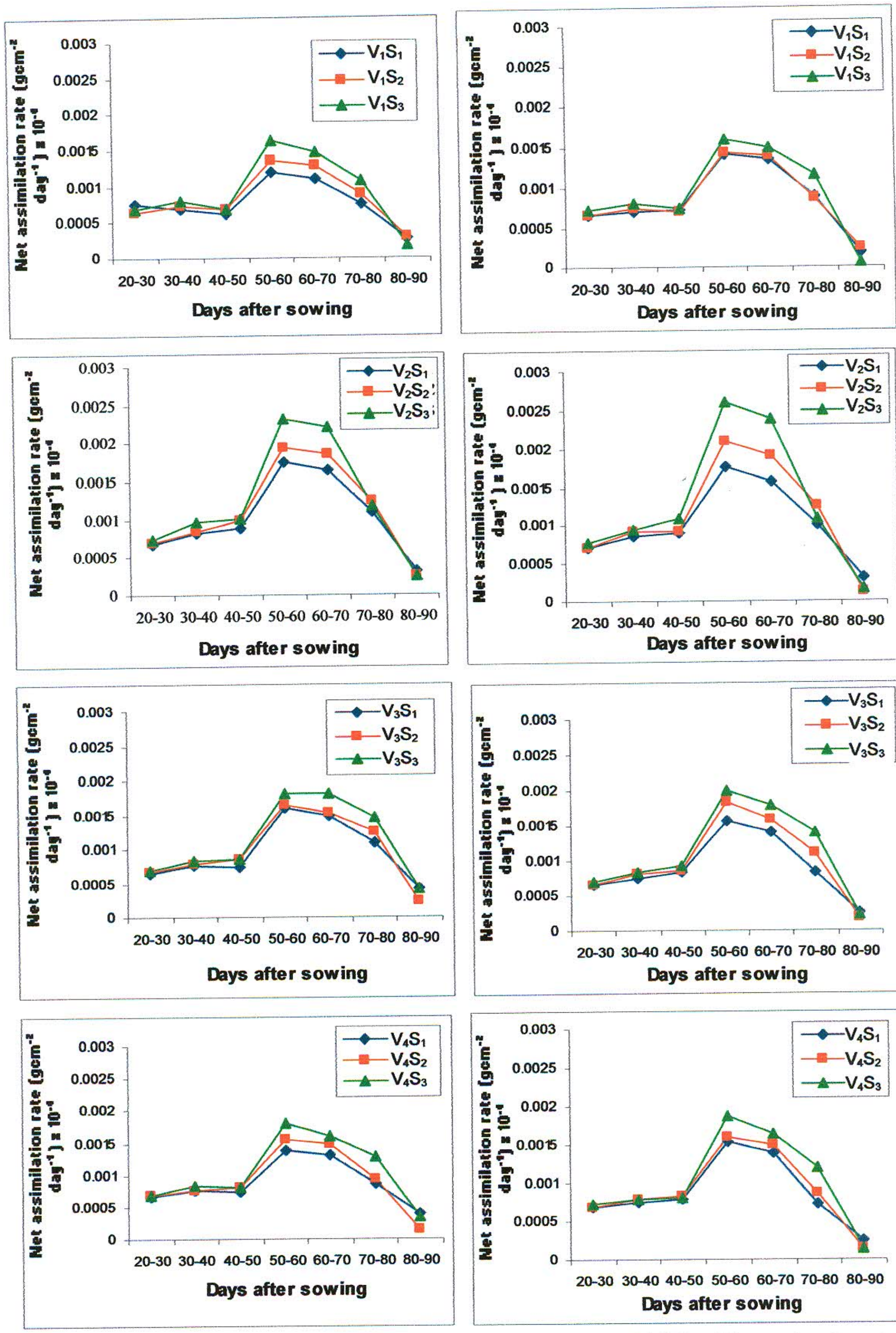


Figure 5a: Effects of sowing times on net assimilation rate (NAR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

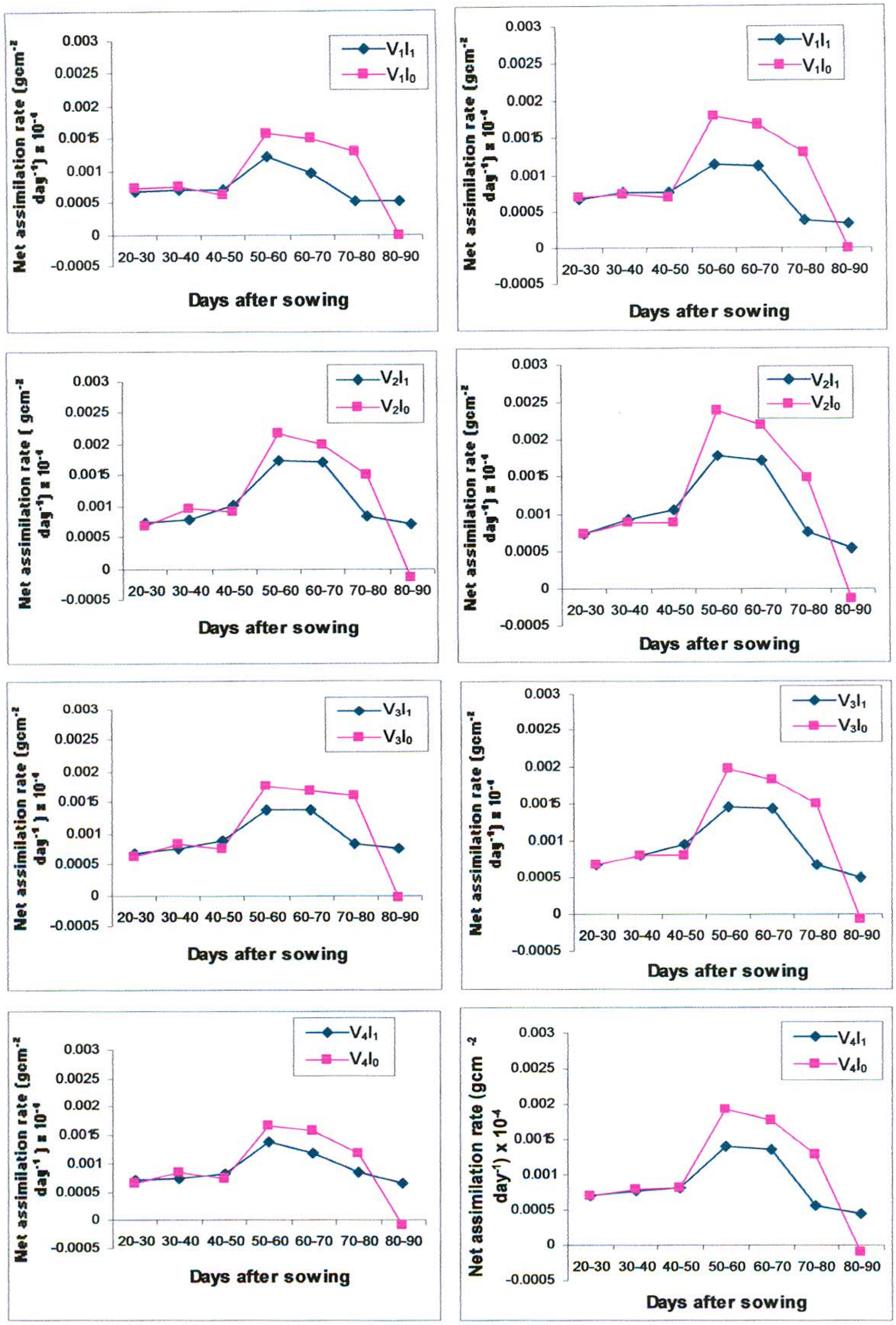


Figure 5b: Effects of soil moisture on net assimilation rate (NAR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

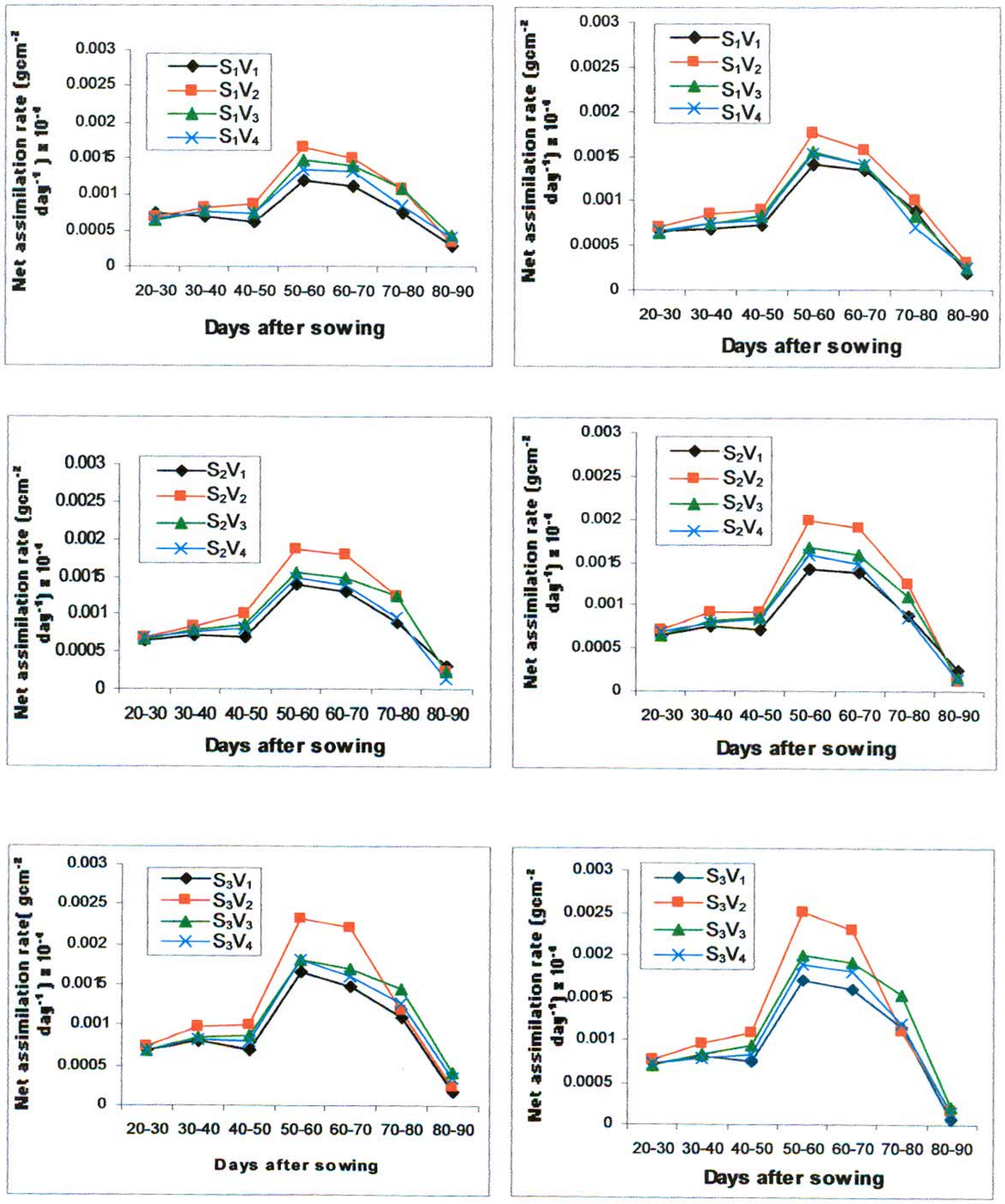


Figure 5c: Effects of varieties on net assimilation rate (NAR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.7 Leaf Area Ratio (LAR)

Experiment for 2005-06

Mean squares from the analysis of variance of leaf area ratio are shown in **Table 13a.** The result shows that the sowing date (S) item was significant at all the harvesting dates except at 20-30 DAS. The soil moisture (I) item was found to be highly significant at all the growth phases. Varietals differences for leaf area ratio were also significant at most of the growth stages except at 20-30 DAS.

All the interaction items were significant at P=0.01 level for the different growth stages except at 20-30 DAS, which indicates that the varieties responded differently in different sowing times and soil moisture regimes.

Sowing dates influenced mean values of leaf area ratio (**Table 14a**) were found to be maximum at the first harvest and then declined gradually with increasing the plant age. Generally S_1 plants decreased leaf area ratio in most of the growth stages. Among the sowing dates, S_1 plants showed the highest leaf area ratio value than the other sowings.

Mean values of leaf area ratio as influenced by soil moisture indicated that (**Table 14a**) starting from the higher values at the initial stages of growth and reached their highest values at 20-30 DAS and then declined the whole growth periods. The irrigated plants had higher leaf area ratio than the rainfed plants of all the varieties.

Mean values of leaf area ratio of four wheat varieties (**Table 14a**) revealed that starting from the higher values at the early stages of growth and then declined sharply throughout the whole growth period. The highest leaf area ratio values were observed at 20-30 DAS. Among the varieties, Shatabdi and Gaurav had the highest and lowest leaf area ratio value at all the growth phases, respectively.

The mean effect of sowing dates (S) on leaf area ratio of four varieties of wheat at different growth stages are graphically shown in **Fig. 6a** (left portion). Leaf area ratio values were found to be high at the first (20-30 DAS) harvest and then decreased rapidly and reached towards zero direction at 80-90 DAS. At most of the growth stages for leaf area ratio, S_1 (November 15 sowing) had higher value than the S_2 (November 30 sowing) and S_3 (December 15 sowing) plants of all the varieties.

The mean effect of soil moisture (I) on leaf area ratio of four varieties of wheat at different growth stages are graphically shown in **Fig. 6b** (left portion). Leaf area ratio started from the higher values and then decreased rapidly and sharply for the last harvest at 80-90 DAS. The maximum leaf area ratio was recorded in I_1 level than I_0 level of irrigation. The irrigated plants always had greater leaf area ratio value than the rainfed plants of all the varieties. No fluctuation of leaf area ratio was recorded in both cases.

The overall effects of varieties on leaf area ratio at different growth stage are graphically shown in **Fig. 6c** (left portion). The maximum values of leaf area ratio were found at the first harvest (20-30 DAS) of all the varieties. Among the varieties, the highest leaf area ratio was recorded in Shatabdi and the minimum in Gaurav.

Experiment for 2006-07

From the analysis of variance in **Table 13b** is noted that treatment of sowing date (S) difference was highly significant at most of the harvest days. In case of varietals differences highly significant values were found at all the growth phases. The soil moisture (I) item was significant at all of the harvesting dates.

The interaction item S×I was highly significant at all the growth phases. The interaction item S×V was also significant at all the harvesting dates. The interaction item I×V was significant at most of the growth stages except at 30-40 DAS. The interaction item S×I×V was significant at all the harvesting dates except at 80- 90 DAS.

Sowing dates influenced mean values of leaf area ratio (**Table 14b**) indicated that starting from the higher values at the early stages of growth and then declined gradually with time. The highest leaf area ratio values were observed at 20-30 DAS. Among the sowing dates, S_1 plants showed the highest leaf area ratio value than the other sowings.

Mean values of leaf area ratio as influenced by soil moisture (**Table 14b**) were found to be higher at the first harvest and then declined gradually with increasing the plant age. Among the four varieties, the highest peak was found at 20-30 DAS. The highest leaf area ratio was observed in I_1 level than I_0 level of irrigation.

Mean values of leaf area ratio of four wheat varieties (**Table 14b**) revealed that generally higher leaf area ratio was found at the early stages of growth and then declined sharply throughout the whole growth period. The highest leaf area ratio values were observed at 20-30 DAS. Among the varieties, at first harvest the maximum leaf area ratio was recorded in Shatabdi and the minimum in Gaurav.

The mean effect of sowing dates (S) on leaf area ratio of four varieties of wheat at different growth stages are graphically shown in **Fig. 6a** (right portion). Leaf area ratio values were also found to be high at the early stage (20-30 DAS) and then declined with increasing plant age. At each DAS for leaf area ratio, S_1 (November 15 sowing) and S_2 (November 30 sowing) had higher leaf area ratio than the S_3 (December 15 sowing) plants of all the varieties. All the varieties showed more, less or similar leaf area ratio values in both the first sowing and the second sowing at several harvests.

The graphically presentation **Fig. 6b** (right portion) shown that leaf area ratio of all the varieties was maximum at 20-30 DAS and then decreased rapidly and sharply and reached towards zero direction at 80-90 DAS. At each DAS, the irrigated plants always had higher leaf area ratio value than the rainfed plants of all the varieties.

The overall effects of varieties on leaf area ratio at different growth stage are graphically shown in **Fig. 6c** (right portion). The values of leaf area ratio were fond to be maximum at the first harvest (20-30 DAS) and then declined gradually with increasing growth period and reached towards zero direction at 80-90 DAS. Among the varieties, Shatabdi had the higher value at several harvests than any other variety of wheat. The maximum leaf area ratio was noted in Shatabdi and was followed by Shourav, Kanchan and Gaurav.

Table 13a. Mean squares (MS) from the analysis of variance of leaf area ratio ($cm^2 g^{-1}$) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	100.69	14.13	19	25.55	2.15	4.15	0.24
Sowing (S)	2	635.02	2498.57**	4197.44**	1718.86**	396.15**	124.19**	46.26**
Error (a)	4	102.34	5.77	4.01	9.24	1.11	4.2	0.24
Soil moisture (I)	1	7995.81**	14376.26**	9118.65**	3132.15**	1295.29**	525.91**	186.24**
S×I	2	67.67	424.57**	1436.39**	570.59**	68.91**	27.17*	17.03**
Error (b)	6	106.24	3.35	4.98	6.91	1.4	4.39	0.23
Variety (V)	3	310.98	2134.45**	3617.19**	1414.11**	449.26**	174.37**	65.99**
S×V	6	128.52	33.84**	11.74**	7.92**	4.58*	2.27**	1.31**
I×V	3	141.72	206.19**	65.34**	139.57**	50.06**	23.29**	12.12**
S×I×V	6	99.88	43.15**	62.24**	49.13**	13.39**	4.03**	2.08**
Error (c)	36	117.04	1.93	1.25	1.98	1.45	0.46	0.07

**=significant at 1% level, *=significant at 5% level, respectively;

Table 13b. Mean squares (MS) from the analysis of variance of leaf area ratio ($cm^2 g^{-1}$) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	2.681	9.317	2.598	0.056	0.193	0.329	0.122
Sowing (S)	2	1867.893**	4806.437**	2901.257**	679.258**	294.908**	183.559**	56.357**
Error (a)	4	2.624	5.113	5.005	3.937	0.979	0.168	0.764
Soil moisture (I)	1	12745.758**	14485.829**	11252.122**	3490.356**	1008.478**	515.628**	170.536**
S×I	2	273.803**	864.931**	2535.683**	535.098**	21.987**	11.417**	16.976**
Error (b)	6	1.915	4.291	1.106	0.465	0.366	0.030	0.438
Variety (V)	3	829.501**	2538.351**	2835.782**	1074.114**	473.629**	175.178**	52.259**
S×V	6	20.358**	37.988**	16.040**	8.148*	8.103**	1.459**	1.967**
I×V	3	47.403**	14.160	256.580**	207.458**	92.394**	50.541**	11.057**
S×I×V	6	23.569**	95.087**	71.660**	15.324**	13.889**	3.428**	0.702
Error (c)	36	2.669	5.098	2.015	2.543	1.977	0.148	0.320

**=significant at 1% level, *=significant at 5% level, respectively;

Table14a. Mean values of leaf area ratio ($cm^2 g^{-1}$) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	172.982	160.046	109.326	58.485	28.345	13.376	6.831
Sowing (S_2)	172.412	154.360	96.468	50.126	24.979	11.356	5.216
Sowing (S_3)	163.801	140.230	82.879	41.560	20.258	8.835	4.067
LSD 5%	8.107	1.925	1.605	2.436	0.844	1.642	0.393
Soil moisture (I)							
Irrigation (I_1)	180.270	165.676	107.478	56.653	28.769	13.891	6.979
Rainfed (I_0)	159.194	137.415	84.970	43.461	20.286	8.486	3.763
LSD 5%	5.945	1.056	1.287	1.516	0.682	1.208	0.277
Variety (V)							
Shatabdi (V_1)	171.724	163.948	114.007	61.063	30.908	15.328	7.956
Gaurav (V_2)	164.055	137.412	79.522	39.558	18.892	7.970	3.423
Shourav (V_3)	173.677	152.988	93.798	48.354	23.118	9.971	4.653
Kanchan (V_4)	169.471	151.833	97.570	51.254	25.192	11.487	5.452
LSD 5%	7.288	0.936	0.753	0.948	0.811	0.457	0.178

Table14b. Mean values of leaf area ratio ($cm^2 g^{-1}$) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	172.114	153.443	101.124	52.628	28.566	14.412	6.950
Sowing (S_2)	169.930	142.302	93.096	48.630	25.196	11.633	5.059
Sowing (S_3)	155.859	125.340	79.381	42.090	21.557	8.881	3.915
LSD 5%	1.298	1.812	1.793	1.590	0.793	0.328	0.700
Soil moisture (I)							
Irrigation (I_1)	179.273	154.546	103.701	54.745	28.849	14.318	6.847
Rainfed (I_0)	152.663	126.178	78.699	40.820	21.364	8.966	3.769
LSD 5%	0.798	1.195	0.607	0.393	0.349	0.100	0.382
Variety (V)							
Shatabdi (V_1)	172.523	153.203	106.609	57.461	30.841	15.395	7.596
Gaurav (V_2)	156.887	124.447	76.276	38.816	18.455	7.850	3.561
Shourav (V_3)	169.423	141.602	88.473	45.894	24.729	11.057	4.666
Kanchan (V_4)	165.038	142.195	93.442	48.961	26.400	12.266	5.409
LSD 5%	1.101	1.521	0.956	1.074	0.947	0.259	0.381

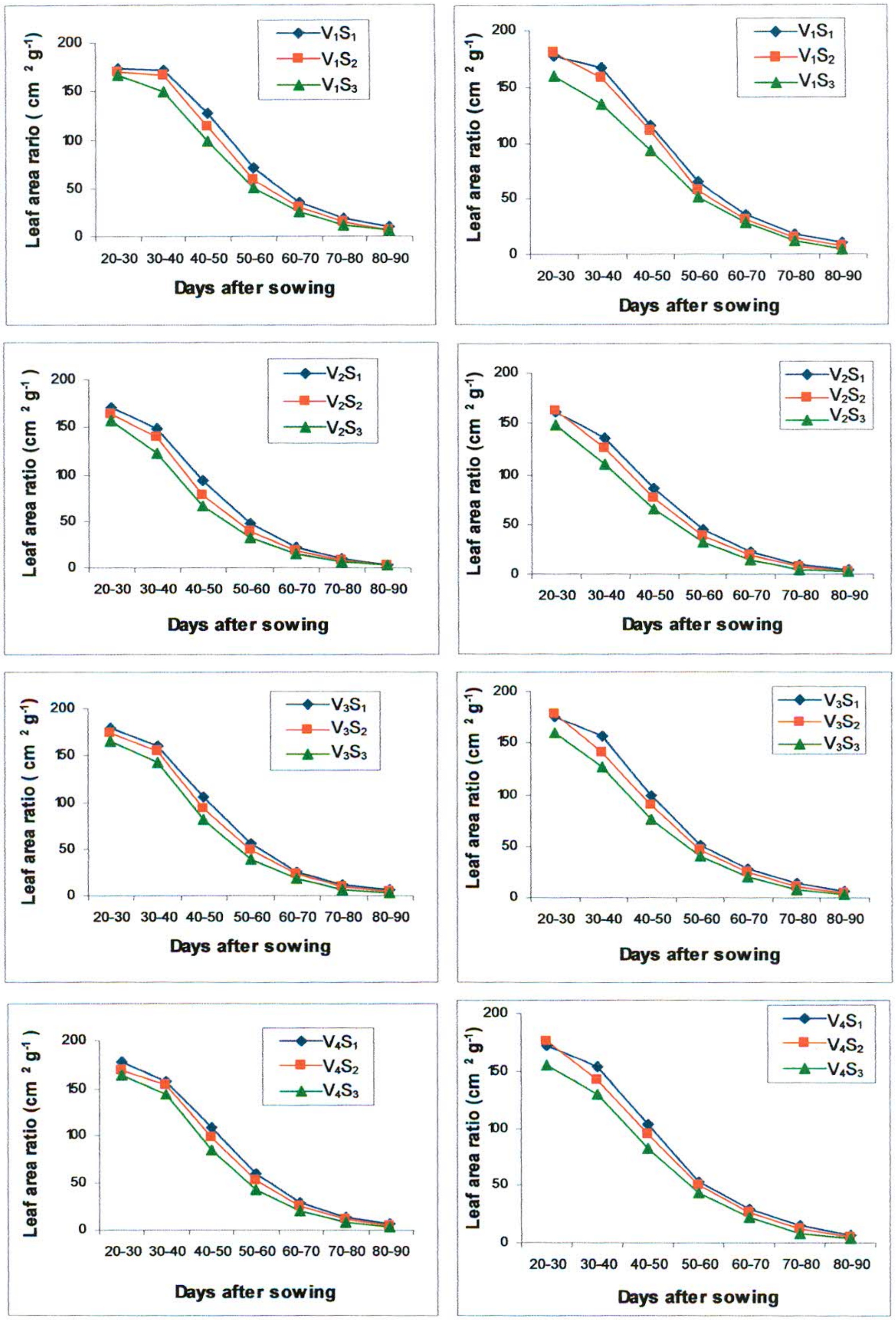


Figure 6a: Effects of sowing times on leaf area ratio (LAR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

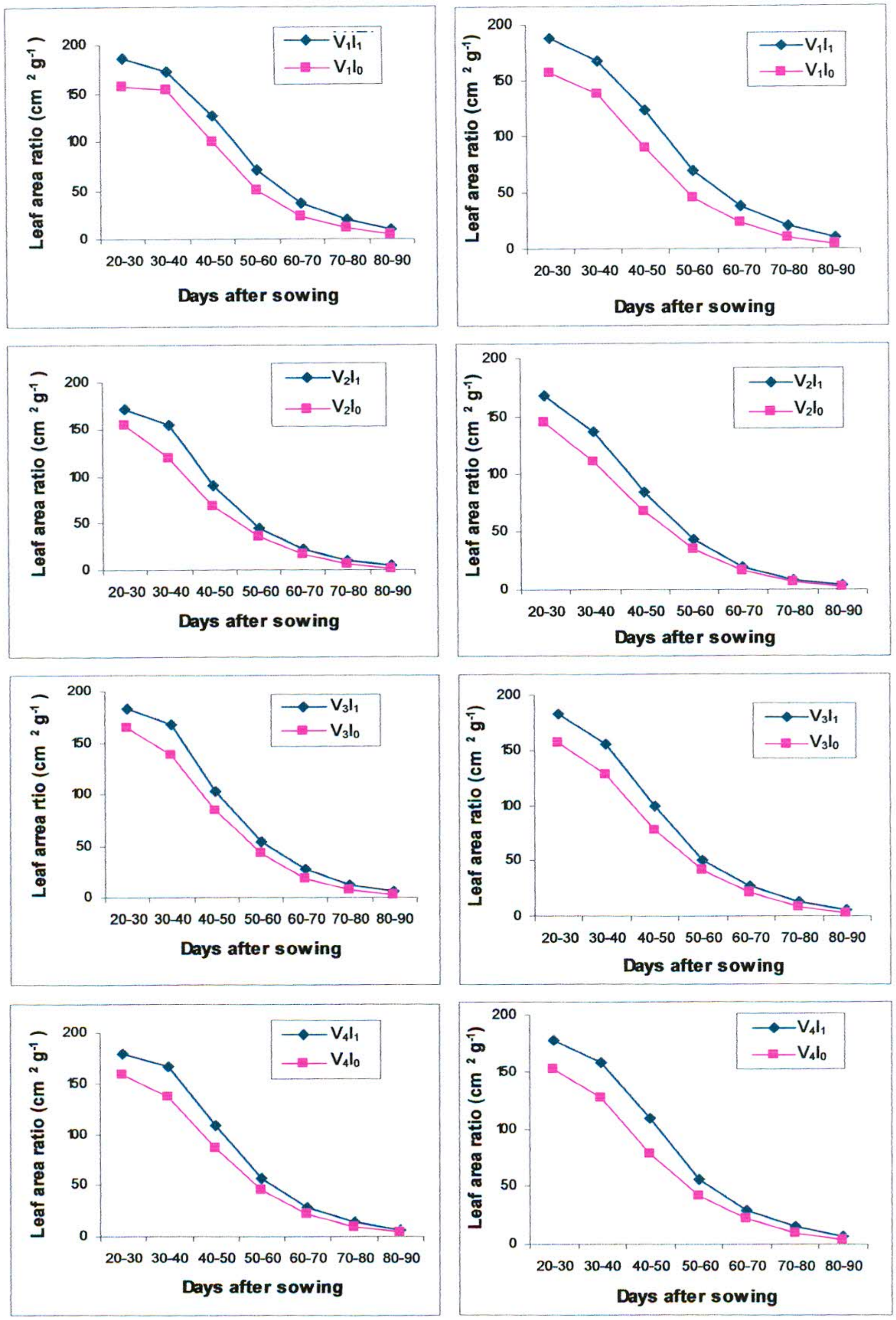


Figure 6b: Effects of soil moisture on leaf area ratio (LAR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

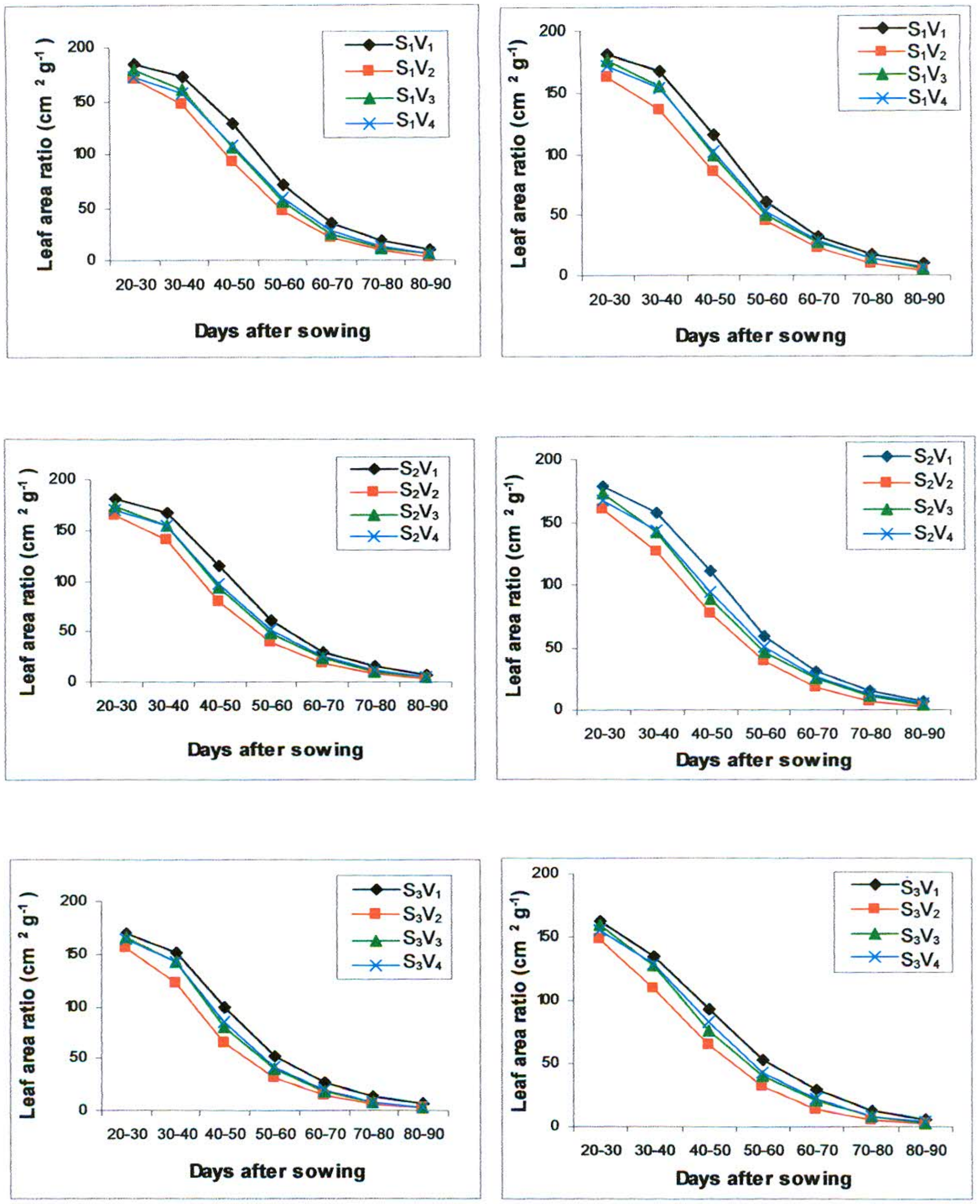


Figure 6c: Effects of varieties on leaf area ratio (LAR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.8 Relative Leaf Growth Rate (RLGR)

Experiment for 2005-06

Mean squares from the analysis of variance of relative leaf growth rate are shown in **Table 15a.** The result shows that significant the replication item was observed only at 30-40 DAS. Sowing time item (S) was significant at 30-40, 40-50 and 70-80 DAS. However, soil moisture (I) item differed significantly at 30-40, 40-50 and 70-80 DAS. Varietals differences for relative leaf growth rate were significant at most of the growth stages except at 20-30 and 50-60 DAS.

The interaction item S×I was significant at 30-40, 40-50 and 70-80 DAS which indicates that the varieties responded differently in different sowing times and soil moisture regimes. The interaction item S×V was significant only at 40-50 DAS. The interaction item I×V was significant at 30-40, 40-50 and 50-60 DAS. Significantly interaction item S×I×V was found at 40-50, 50-60 and 70-80 DAS.

Sowing dates influenced mean values of relative leaf growth rate (**Table 16a**) starting from the higher values with positive and then declined with heavy fluctuations and became negative at the later stages of growth. Among the sowing dates, S_1 plants showed the highest relative leaf growth rate than the other sowings.

Mean values of relative leaf growth rate as influenced by soil moisture (**Table 16a**) were found to be maximum at 20-30 DAS and then declined gradually and became negative after at 50-60 and 30-40 DAS in irrigated and rainfed conditions. The highest relative leaf growth rate was observed in I_1 level than I_0 level of irrigation.

Mean values of relative leaf growth rate of four wheat varieties (**Table 16a**) starting also from the higher values with positive and then declined gradually and became negative at the later stages of growth. The highest relative leaf growth rate values were found in Shatabdi and the lowest in Gaurav at 20-30 DAS.

The mean effect of sowing times (S) on relative leaf growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig.7a** (left portion). In all the sowing, relative leaf growth rate had the highest value at the first (20-30 DAS) harvest and then decreased rapidly and reached towards negative direction after 50-60 DAS. At 30-40 DAS for relative leaf growth rate, S_2 (November 30 sowing) indicates higher value than the S_1 (November 15 sowing) and S_3 (December 15 sowing) plants and 40-50 DAS for relative leaf growth rate, S_1 (November 15 sowing) had higher value than the S_2 (November 30 sowing) and S_3 (December 15 sowing) plants.

The mean effect of soil moisture (I) on relative leaf growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig.7b** (left portion). The maximum relative leaf growth rate was found at 20-30 DAS in both the irrigated and the rainfed conditions. All the varieties, relative leaf growth rate values become negative after at 50-60 DAS.

The overall effects of varieties on relative leaf growth rate at different stages of growth are graphically shown in **Fig. 7c** (left portion). In all the varieties had the highest peak at first harvest (20-30 DAS) and then rapidly declined and reached towards negative direction. Among the varieties, Shatabdi had the highest relative leaf growth rate value at all the harvesting dates except at 50-60 DAS.

Experiment for 2006-07

From the analysis of variance in **Table 15b,** it indicates that soil moisture (I) item differences were significant at all growth phases except at 80-90 DAS. Variety significantly differed at most of the growth stages except at 50-60 and 80-90 DAS. The sowing time (S) item was also significant at all the harvesting dates.

The interaction item S×I was significant at all the harvesting dates indicating that the varieties were highly affected by different sowing times and soil moisture regimes. The interaction item S×V was significant at all the harvesting stages except at 50-60 DAS. The interaction I×V was significant at all the harvesting dates. The interaction item S×I×V was significant at all the harvesting dates except at 80 -90 DAS.

Mean values of RLGR as influenced by sowing date (**Table 16b**) indicated that starting from the higher values at the first harvest (20-30 DAS) and than declined gradually with increasing age of plants and reached towards negative direction after at 50-60 DAS. Among the sowing dates, S_1 plants showed the highest relative leaf growth rate than the S_2 and S_3 plants of all the varieties.

Mean values of relative leaf growth rate as influenced by soil moisture (**Table 16b**) revealed that starting from the higher values with positive and then declined gradually and became negative after at 50-60. The irrigated plants had higher leaf area ratio than the rainfed plants of all the varieties.

Mean values of relative leaf growth rate of four wheat varieties (**Table 16b**) were found to be higher at the first harvest (20-30 DAS) and then declined gradually and became negative after at 50-60. Among the varieties, at first harvest (20-30 DAS) the maximum leaf area ratio was recorded in Shatabdi and the minimum in Gaurav.

The mean effect of sowing times (S) on relative leaf growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 7a** (right portion). In all the sowing times for relative leaf growth rate values became negative after at 50-60 DAS. Among the sowing dates, S_3 plants had the lowest value and the other sowings showed more, less or similar values of relative leaf growth rate at several harvests.

The mean effect of soil moisture (I) on relative leaf growth rate of four varieties of wheat at different growth stages are graphically shown in **Fig. 7b** (right portion). The maximum relative leaf growth rate was found at the first growth stage (20-30 DAS) in both the irrigated and the rainfed conditions. In most cases, relative leaf growth rate values become negative after at 50-60 DAS. The irrigated plants produced higher relative leaf growth rate than the rainfed ones in most of the growth stages.

The overall effects of varieties of relative leaf growth rate at different stages of growth are graphically shown in **Fig. 7c** (right portion). Graphical presentation shows that in all the varieties of relative leaf growth rate values were found to the maximum at the first harvest (20-30 DAS) and then decreased rapidly and reached towards negative direction. Among the varieties, Shatabdi showed higher relative leaf growth rate value at all the growth phase except at 50-60 DAS.

Table 15a. Mean squares (MS) from the analysis of variance of relative leaf growth rate ($cm^2 cm^{-2} day^{-1}$) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.00061	0.000094*	0.000027	0.000143	0.00063	0.000171	0.001631
Sowing (S)	2	0.00112	0.000827**	0.005573**	0.000097	0.000697	0.000413*	0.001701
Error (a)	4	0.00068	0.000012	0.000020	0.000093	0.000459	0.000059	0.001624
Soil moisture (I)	1	0.00168	0.009649**	0.008361**	0.000709	0.002765	0.002358**	0.002583
S X I	2	0.00098	0.000938**	0.002058**	0.000617	0.000041	0.001269**	0.000243
Error (b)	6	0.00068	0.000012	0.000026	0.000212	0.000592	0.000103	0.001716
Variety (V)	3	0.001247	0.001289**	0.001664**	0.0000013	0.001785**	0.001013**	0.001834**
S X V	6	0.000788	0.000012	0.000042**	0.000014	0.000037	0.000044	0.000156
I X V	3	0.001081	0.000353**	0.001202**	0.000168**	0.000079	0.000064	0.000242
S X I X V	6	0.000778	0.000028	0000117**	0.000058*	0.000138	0.000453**	0.000279
Error (c)	36	0.00073	0.000009	0.000008	0.000021	0.000104	0.000133	0.000334

**=significant at 1% level, *=significant at 5% level, respectively;

Table 15b. Mean squares (MS) from the analysis of variance of relative leaf growth rate ($cm^2 cm^{-2} day^{-1}$) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Replication (R)	2	0.0000052	0.0000058	0.0000019	0.0000015	0.00000004	0.0000202	0.0000642
Sowing (S)	2	0.0002038**	0.0038208**	0.0002313**	0.0000887*	0.0016956**	0.0061603**	0.0119665*
Error (a)	4	0.0000028	0.0000083	0.0000021	0.0000051	0.0000053	0.0000082	0.000797
Soil moisture (I)	1	0.0082071**	0.0140646**	0.0216432**	0.0038923**	0.0019903**	0.0041963**	0.000102
S X I	2	0.0000763**	0.0014957**	0.0007372**	0.0003674**	0.0007955**	0.0011722**	0.0049756*
Error (b)	6	0.0000036	0.0000039	0.000002	0.0000089	0.0000069	0.0000108	0.000624
Variety (V)	3	0.0001807**	0.0011559**	0.0009147**	0.000056	0.0039632**	0.0021571**	0.000881
S X V	6	0.0000041*	0.0000224**	0.0000758**	0.000029	0.0001318**	0.0009427**	0.0007508*
I X V	3	0.0000108**	0.0000802**	0.0009607**	0.000562**	0.0023297**	0.0005054**	0.0017907**
S X I X V	6	0.0000236**	0.0002509**	0.0000525**	0.0001483*	0.0000521**	0.0004572**	0.000498
Error (c)	36	0.00000114	0.0000014	0.00000055	0.0000430	0.0000064	0.0000339	0.000316

**=significant at 1% level, *=significant at 5% level, respectively;

Table16a. Mean values of relative leaf growth rate (cm ^{2} cm^{-2}day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	0.130	0.100	0.022	0.011	-0.047	-0.064	-0.067
Sowing (S_2)	0.116	0.100	0.017	0.014	-0.050	-0.069	-0.083
Sowing (S_3)	0.121	0.090	0.008	0.011	-0.057	-0.071	-0.078
LSD 5%	0.0209	0.0028	0.0036	0.0077	0.0172	0.0062	0.0323
Soil moisture (I)							
Irrigation (I_1)	0.127	0.108	0.018	0.017	-0.045	-0.063	-0.070
Rainfed (I_0)	0.118	0.085	-0.004	-0.010	-0.058	-0.074	-0.082
LSD 5%	0.0150	0.0020	0.0029	0.0084	0.0140	0.0059	0.0239
Variety (V)							
Shatabdi (V_1)	0.135	0.106	0.020	0.013	-0.038	-0.061	-0.062
Gaurav (V_2)	0.117	0.085	0.003	0.013	-0.058	-0.078	-0.086
Shourav (V_3)	0.119	0.098	0.002	0.014	-0.060	-0.068	-0.079
Kanchan (V_4)	0.119	0.098	0.009	0.014	-0.051	-0.067	-0.076
LSD 5%	0.0181	0.0020	0.0019	0.0031	0.0069	0.0078	0.0123

Table16b. Mean values of relative leaf growth rate (cm ^{2} cm^{-2}day^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20-30 DAS	30-40 DAS	40-50 DAS	50-60 DAS	60-70 DAS	70-80 DAS	80-90 DAS
Sowing (S_1)	0.115	0.096	0.016	0.012	-0.020	-0.077	-0.066
Sowing (S_2)	0.111	0.089	0.016	0.009	-0.028	-0.089	-0.072
Sowing (S_3)	0.109	0.071	0.010	0.011	-0.037	-0.109	-0.031
LSD 5%	0.0013	0.0023	0.0012	0.0018	0.0018	0.0023	0.0226
Soil moisture (I)							
Irrigation (I_1)	0.122	0.099	0.031	0.003	-0.023	-0.084	-0.055
Rainfed (I_0)	0.101	0.071	0.003	0.002	-0.034	-0.099	-0.058
LSD 5%	0.0011	0.0011	0.0008	0.0017	0.0015	0.0019	0.0144
Variety (V)							
Shatabdi (V_1)	0.115	0.096	0.024	0.010	-0.018	-0.081	-0.049
Gaurav (V_2)	0.108	0.076	0.007	0.008	-0.050	-0.083	-0.065
Shourav (V_3)	0.111	0.083	0.011	0.012	-0.024	-0.103	-0.059
Kanchan (V_4)	0.112	0.086	0.014	0.012	-0.021	-0.099	-0.053
LSD 5%	0.0007	0.0008	0.0005	0.0044	0.0017	0.0039	0.0120

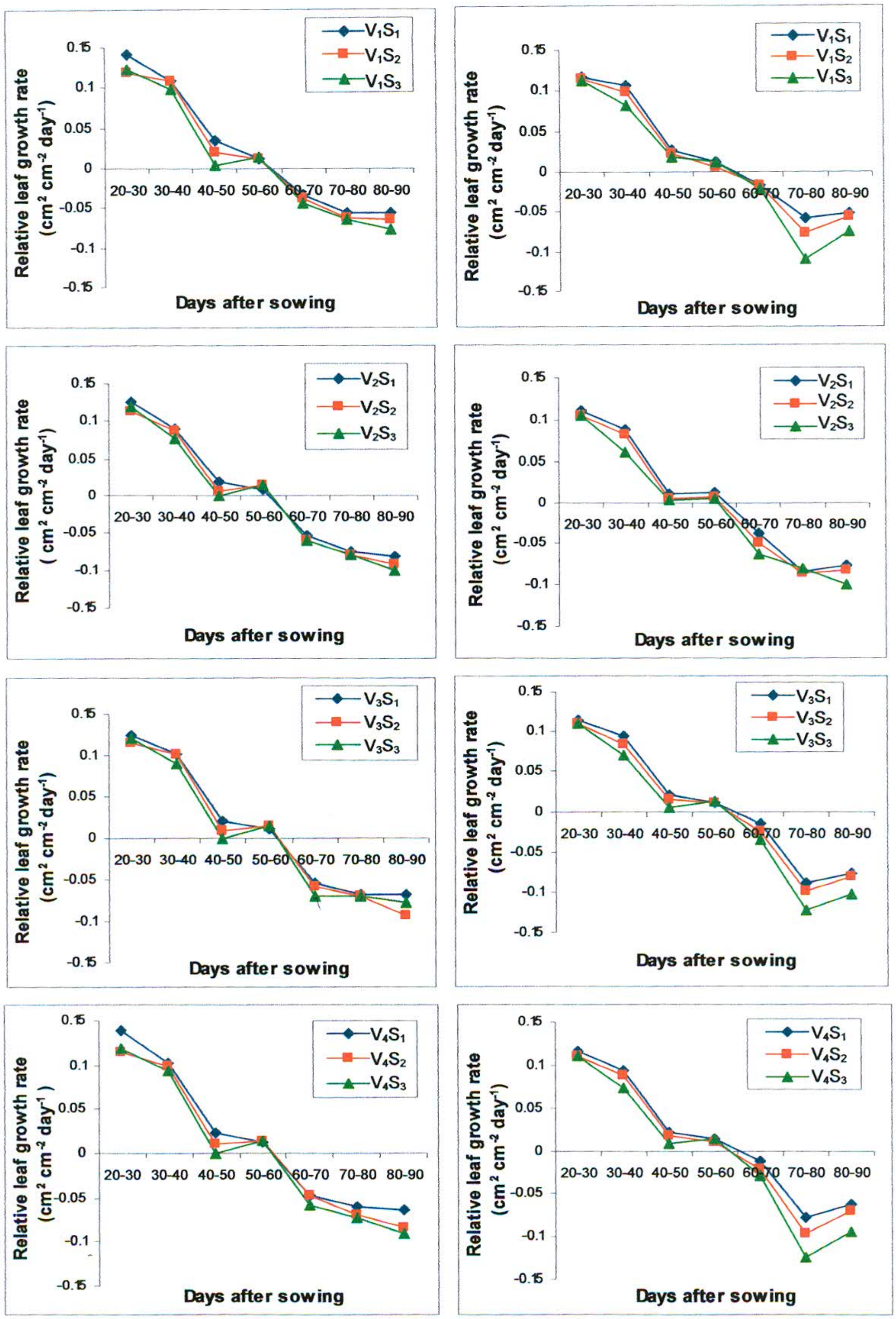


Figure 7a: Effects of sowing times on relative leaf growth rate (RLGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

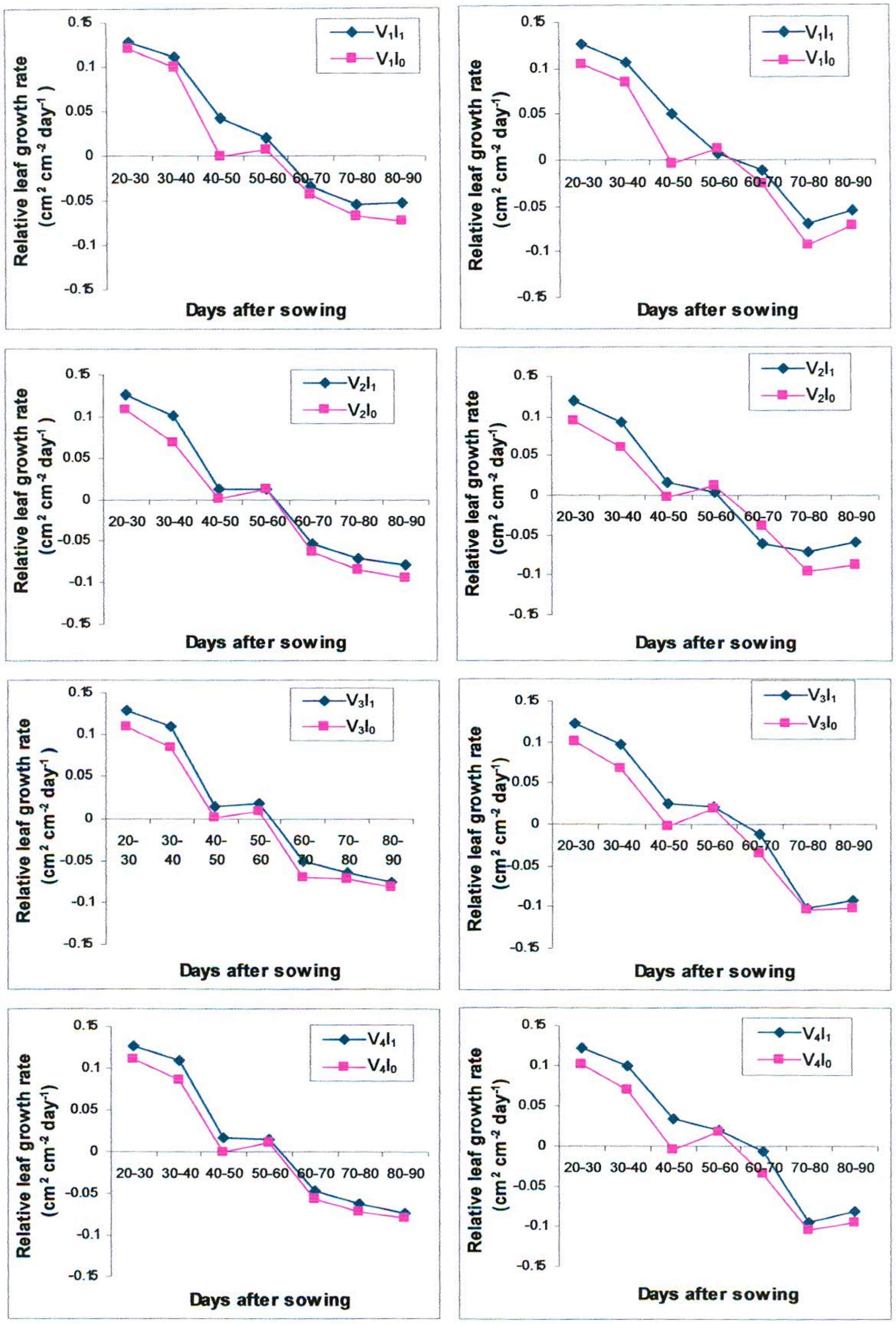


Figure 7b: Effects of soil moisture on relative leaf growth rate (RLGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

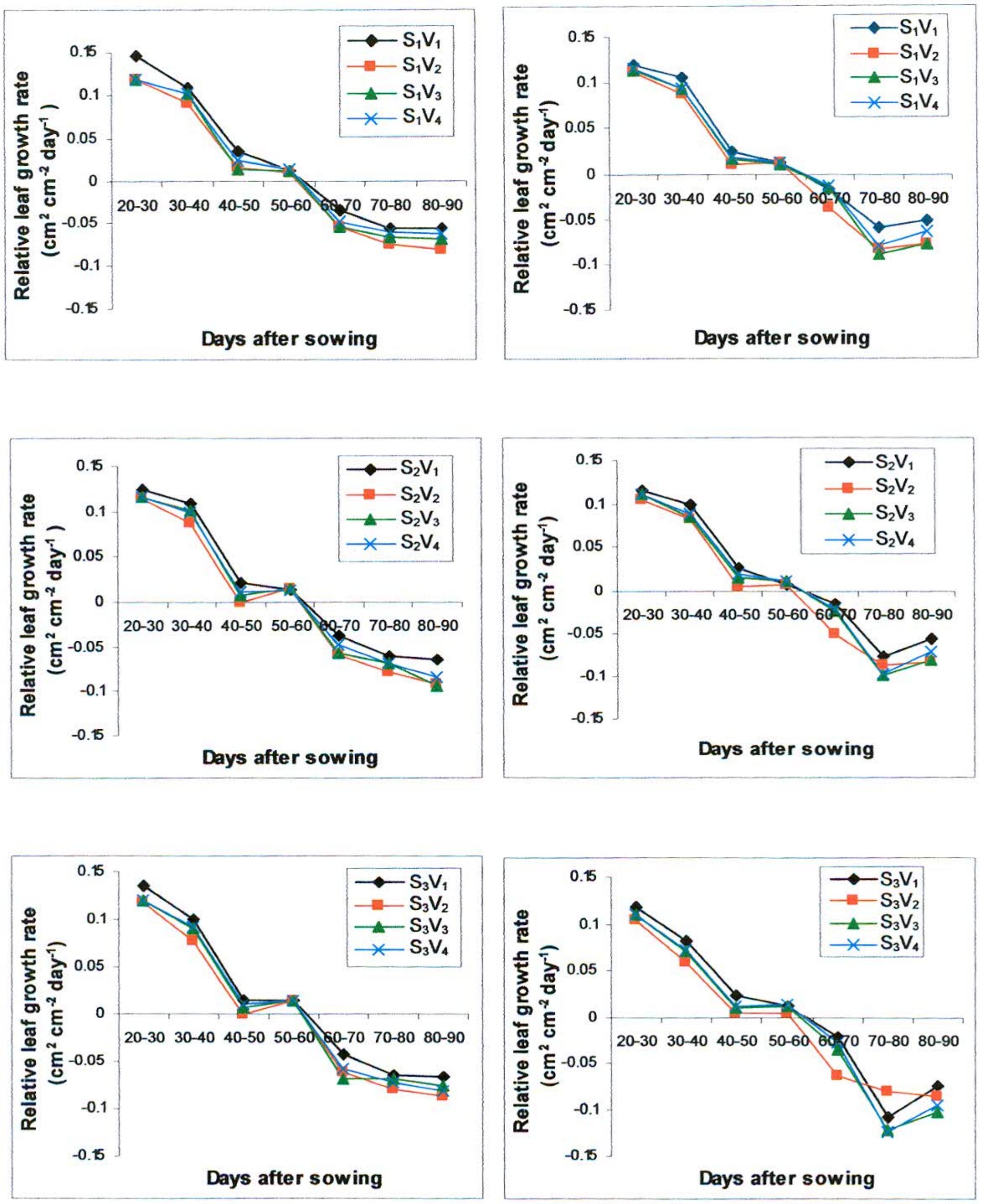


Figure 7c: Effects of varieties on relative leaf growth rate (RLGR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.9 Specific Leaf Area (SLA)

Experiment for 2005-06

Mean squares from the analysis of variance of specific leaf area are shown in **Table 17a**. The result shows that the item sowing time (S), soil moisture (I) and varietals differences for specific leaf area were significant at all the harvesting dates which indicating that the all the item were highly affected by different sowing times and soil moisture regimes.

The interaction item $S \times I$ was found to be significant at 30, 80 and 90 DAS. The interaction item $S \times V$ was significant at 20, 30, 40, 70 and 80 DAS. The interaction item $I \times V$ was significant at 20, 30, 50, 60 and 90 DAS. The interaction item $S \times I \times V$ was significant at most of the growth phases except at 20 and 50 DAS.

Sowing dates influenced mean values of specific leaf area (**Table 18a**) were found to be maximum at the first harvest and then declined gradually with time and reached their highest values at 20 DAS. Among the sowing dates, S_1 plants showed the highest specific leaf area than the other sowings.

Mean values of specific leaf area as influenced by soil moisture (**Table 18a**) had generally higher at the initial stages of growth and then declined and the lowest specific leaf area at the last stage. The irrigated plants had higher specific leaf area than the rainfed plants of all the varieties.

Mean values of specific leaf area of all varieties (**Table 18a**) had the higher specific leaf area at the early stages of growth and then declined sharply throughout the whole growth period. The highest specific leaf area values were observed at 20 DAS. Shatabdi and Gaurav had the highest and the lowest specific leaf area at all the growth stages, respectively.

The mean effect of sowing (S) on specific leaf area at different growth stages was graphically shown in **Fig. 8a** (left portion). The maximum specific leaf area values were found at the first growth stage (20 DAS) at different sowing times. Each DAS for specific leaf area, S_1 (November 15 sowing) plants had higher value than the S_2 (November 30 sowing) and S_3 (December 15 sowing) plants of all the varieties.

The mean effect of soil moisture (I) on specific leaf area at different growth stages of wheat are graphically shown in **Fig. 8b** (left portion). The maximum specific leaf area was recorded at first harvest. The irrigated plants had the higher specific leaf area than those of rainfed plants at all the growth stages.

The overall effects of varieties on specific leaf area at different growth stages are graphically shown in **Fig. 8c** (left portion). It was found from the graphical analysis that the maximum specific leaf area values were found at first harvest and then declined very slowly and at the later growth stages slightly decrease was noted. In all the varieties, at all the growth stages the maximum specific leaf area was recorded in Shatabdi and the minimum in Gaurav. No fluctuation of specific leaf area was found in all the cases.

Experiment For 2006-07

The analysis of variance in **Table 17b** shows that the item sowing time (S), soil moisture (I) and varieties differences for specific leaf area were significant at all the growing phases which indicating that the all the item were highly affected by different sowing times and soil moisture regimes.

The interaction item S×I was significant at 30, 40, 50 and 80 DAS. The interaction item S×V was significant at 40, 50, 60, 70 and 80 DAS. The interaction item I×V was significant at most of the harvesting dates except at 30 and 80 DAS. The interaction item S×I×V was significant at all the growth stages except only at 20 DAS.

Sowing dates influenced mean values of specific leaf area (**Table 18b**) had the higher specific leaf area at the early stages of growth and then declined gradually with increasing age of plants and reached their highest peaks at 20 DAS. Among the sowing dates, S_1 plants showed the highest specific leaf area than the other sowings.

Mean values of specific leaf area as influenced by soil moisture (**Table 18b)** were found to be maximum at the first harvest and then declined and reached the lowest specific leaf area at the last stage. The highest specific leaf area was observed in I_1 level than I_0 level of irrigation.

Mean values of specific leaf area of all varieties (**Table 18b**) starting from the higher values at the early stages of growth and then declined sharply throughout the whole growth period. The highest specific leaf area values were observed at 20 DAS. Among the varieties, at first harvest (20 DAS) the maximum specific leaf area was recorded in Shatabdi and the minimum in Gaurav at all the harvesting dates, respectively.

The mean effect of sowing times (S) on specific leaf area of four varieties of wheat at different growth stages are graphically shown in **Fig. 8a** (right portion). The mean values of specific leaf area of four wheat varieties started from the higher values at the early growth stages and then slightly decreased at the later growth stages in different sowing times. The highest specific leaf area values were found at the first harvest day (20 DAS) in all the varieties. S_1 plants showed the higher value than the other sowings at each DAS.

The mean effects of soil moisture on specific leaf area of four varieties of wheat at different growth stages are graphically shown in **Fig.8b** (right portion). The highest specific leaf area values were found at the first growth stage (20 DAS) in the irrigated and the rainfed conditions. The irrigated plants showed higher specific leaf area than those of the rainfed plants at all the growth stages.

The overall effects of varieties on specific leaf area at different growth stages were graphically shown in **Fig. 8c** (right portion). Graphical presentation shows that the varieties of specific leaf area values were found to be the maximum at the first harvest and then declined at the second harvest. After second harvest the specific leaf area values moved more or less horizontally in all the varieties and at the later growth stages slightly decrease was noted. Among the varieties, Shatabdi showed the maximum specific leaf area value and Gaurav showed the minimum specific leaf area value at all the harvesting dates.

Table 17a. Mean squares (MS) from the analysis of variance of specific leaf area (cm^2g^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	5.66	0.92	59.34	74.13	35.82	4.41	3.93	1.46
Sowing (S)	2	349.53**	828.26**	1733.04**	1851.02**	926.44**	921.92**	1320.36**	1266.18**
Error (a)	4	7.033	2.71	18.69	27.25	51.01	8.64	6.17	0.21
Soil moisture (I)	1	390.33**	6886.34**	5734.86**	5955.05**	2183.74**	1628.25**	1394.35**	696.03**
S × I	2	12.89	351.027**	65.93	74.31	175.21	9.32	88.74**	24.001**
Error (b)	6	5.81	2.11	32.24	42.87	45.94	7.23	2.05	0.96
Variety (V)	3	721.38**	981.63**	11.05.54**	712.46**	268.03**	1123.83**	867.24**	994.58**
S × V	6	16.35**	21.94**	16.23*	13.15	13.67	13.23**	36.41**	5.24
I × V	3	32.39**	19.88**	13.54	100.83**	35.16**	7.42	8.85	9.85**
S × I × V	6	5.35	74.13**	73.42**	17.55	65.06**	34.35**	51.08**	21.94**
Error (c)	36	2.44	0.106	6.198	7.99	6.85	3.706	3.904	2.26

**=significant at 1% level, *=significant at 5% level, respectively;

Table 17b. Mean squares (MS) from the analysis of variance of specific leaf area (cm^2g^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	6.55	23.12	4.61	2.22	0.58	1.08	16.04	7.93
Sowing (S)	2	284.59**	576.92**	2105.97**	2106.90**	1591.18**	1303.49**	1952.97**	2025.45**
Error(a)	4	4.25	6.91	14.76	2.22	14.56	1.08	4.24	7.93
Soil moisture (I)	1	732.15**	7605.39**	7159.76**	10980.74**	6017.74**	3791.07**	2959.27**	1736.82**
S × I	2	27.49	230.25*	102.11*	69.73**	44.80	20.54	160.59**	43.24
Error (b)	6	6.55	26.93	11.37	2.22	9.90	4.63	4.88	8.50
Variety (V)	3	900.33**	1087.47**	1067.63**	1036.66**	580.64**	1398.67**	862.37**	1035.4**
S × V	6	10.90	11.87	6.69*	14.63**	7.23**	18.11**	34.69**	5.54
I × V	3	20.36*	0.55	25.21**	104.69**	72.61**	8.07*	4.84	41.34**
S × I × V	6	8.07	54.34**	64.44**	33.25**	81.92**	67.20*	70.38**	66.38**
Error (c)	36	4.93	6.81	2.28	0.07	1.34	2.74	4.23	2.36

**=significant at 1% level, *=significant at 5% level, respectively;

Table 18a. Mean values of specific leaf area (cm^2g^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	250.000	237.379	239.222	225.701	209.199	200.868	194.552	192.014
Sowing (S_2)	249.000	228.695	233.706	218.486	203.807	196.798	185.382	181.457
Sowing (S_3)	242.000	226.183	222.570	208.225	197.092	188.687	180.321	178.134
LSD 5%	2.125	1.319	3.464	4.183	5.723	2.356	1.991	0.367
Soil moisture (I)								
Irrigation (I_1)	249.000	240.532	240.749	226.565	208.780	200.204	190.980	186.978
Rainfed (I_0)	245.000	220.972	222.916	208.376	197.952	190.698	182.524	180.759
LSD 5%	1.390	0.838	3.275	3.776	3.909	1.551	0.826	0.565
Variety (V)								
Shatabdi (V_1)	254.000	238.650	240.393	225.184	208.300	204.270	194.921	192.646
Gaurav (V_2)	239.000	221.722	222.428	210.069	199.575	185.692	177.748	174.892
Shourav (V_3)	251.000	234.404	235.573	218.802	203.903	198.560	189.093	186.003
Kanchan (V_4)	244.000	228.232	228.937	215.827	201.687	193.283	185.245	181.932
LSD 5%	1.052	0.219	1.677	1.904	1.763	1.297	1.331	1.013

Table18b. Mean values of specific leaf area (cm^2g^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	251.000	235.368	239.768	224.303	208.048	200.550	194.128	192.083
Sowing (S_2)	252.000	229.023	233.489	215.708	201.060	193.970	184.284	180.938
Sowing (S_3)	246.000	226.156	221.317	205.599	191.829	185.460	176.114	172.379
LSD 5%	1.652	2.107	3.079	1.194	3.058	0.833	1.650	2.257
Soil moisture (I)								
Irrigation (I_1)	253.000	240.336	241.506	227.548	209.454	200.456	191.257	186.107
Rainfed (I_0)	247.000	220.029	221.544	202.859	191.171	186.198	178.426	177.493
LSD 5%	1.359	2.993	1.945	0.859	1.815	1.241	1.274	1.682
Variety (V)								
Shatabdi (V_1)	257.000	237.824	239.696	224.170	206.695	203.270	192.820	190.151
Gaurav (V_2)	242.000	220.658	222.127	206.349	193.178	182.546	176.747	172.844
Shourav (V_3)	254.000	234.521	235.493	217.796	202.160	196.667	187.562	184.583
Kanchan (V_4)	246.000	227.726	228.784	212.498	199.217	190.823	182.239	179.621
LSD 5%	1.496	1.758	1.017	0.178	0.780	1.115	1.386	1.035

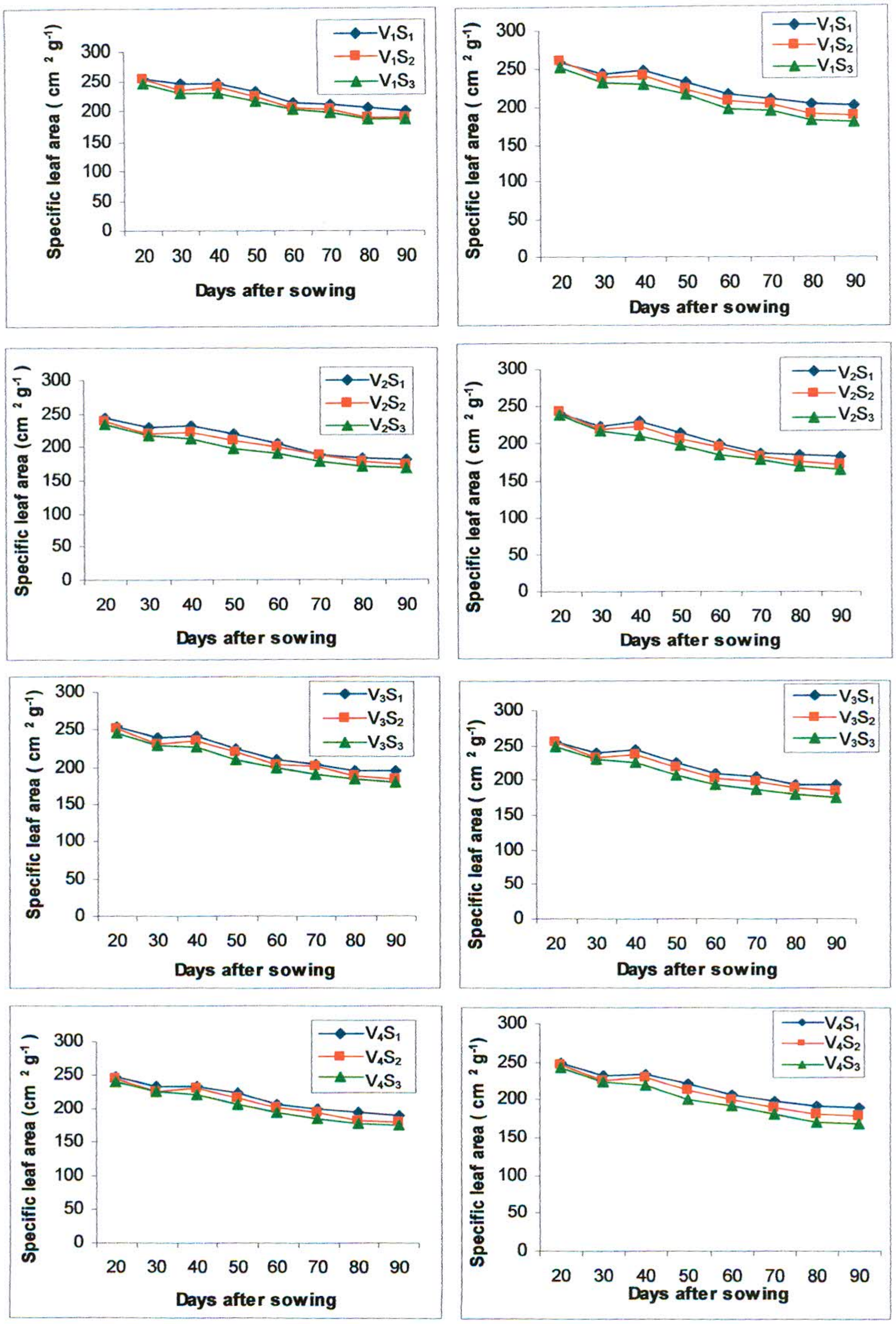


Figure 8a: Effects of sowing times on specific leaf area (SLA) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

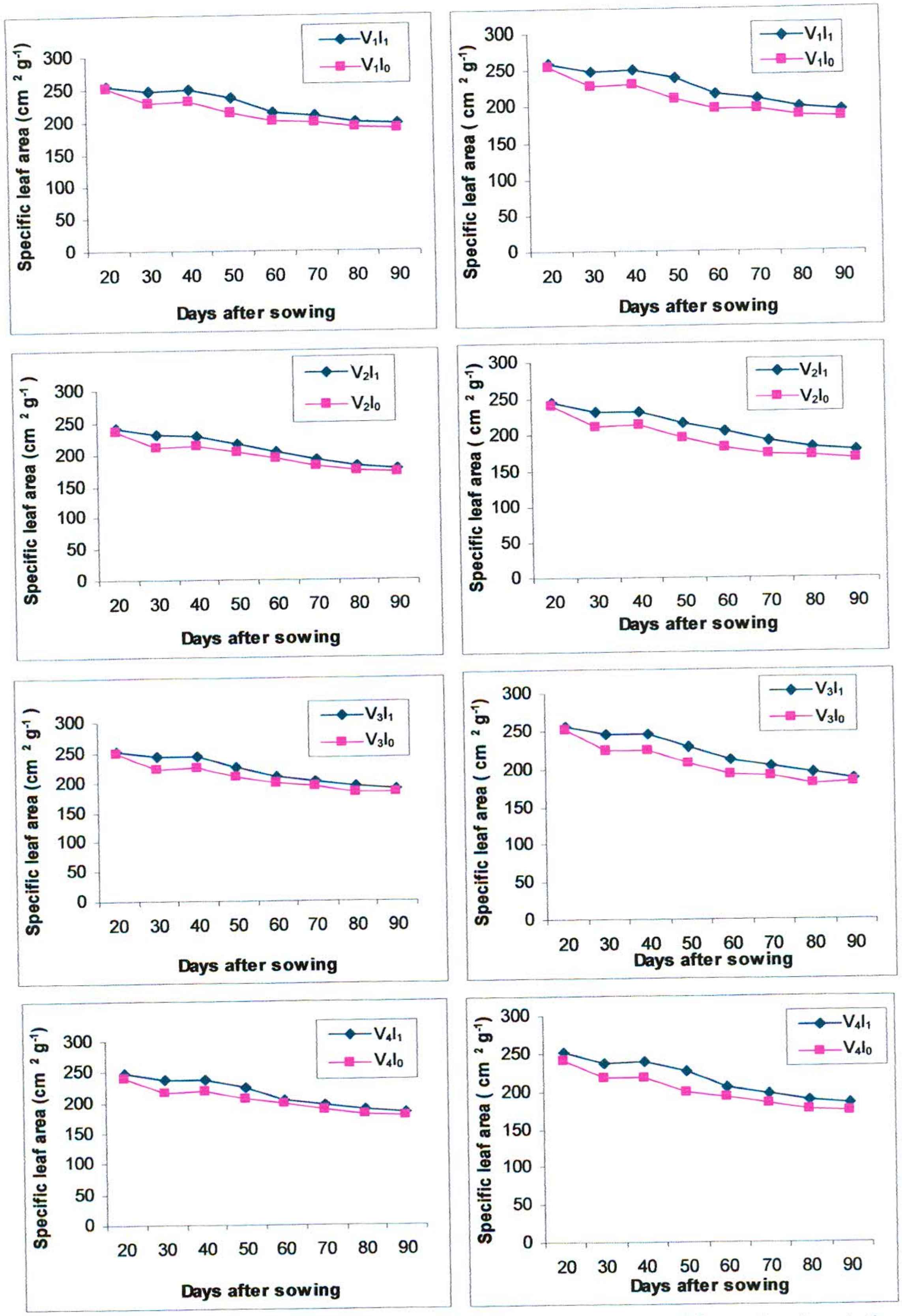


Figure 8b: Effects of soil moisture on specific leaf area (SLA) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

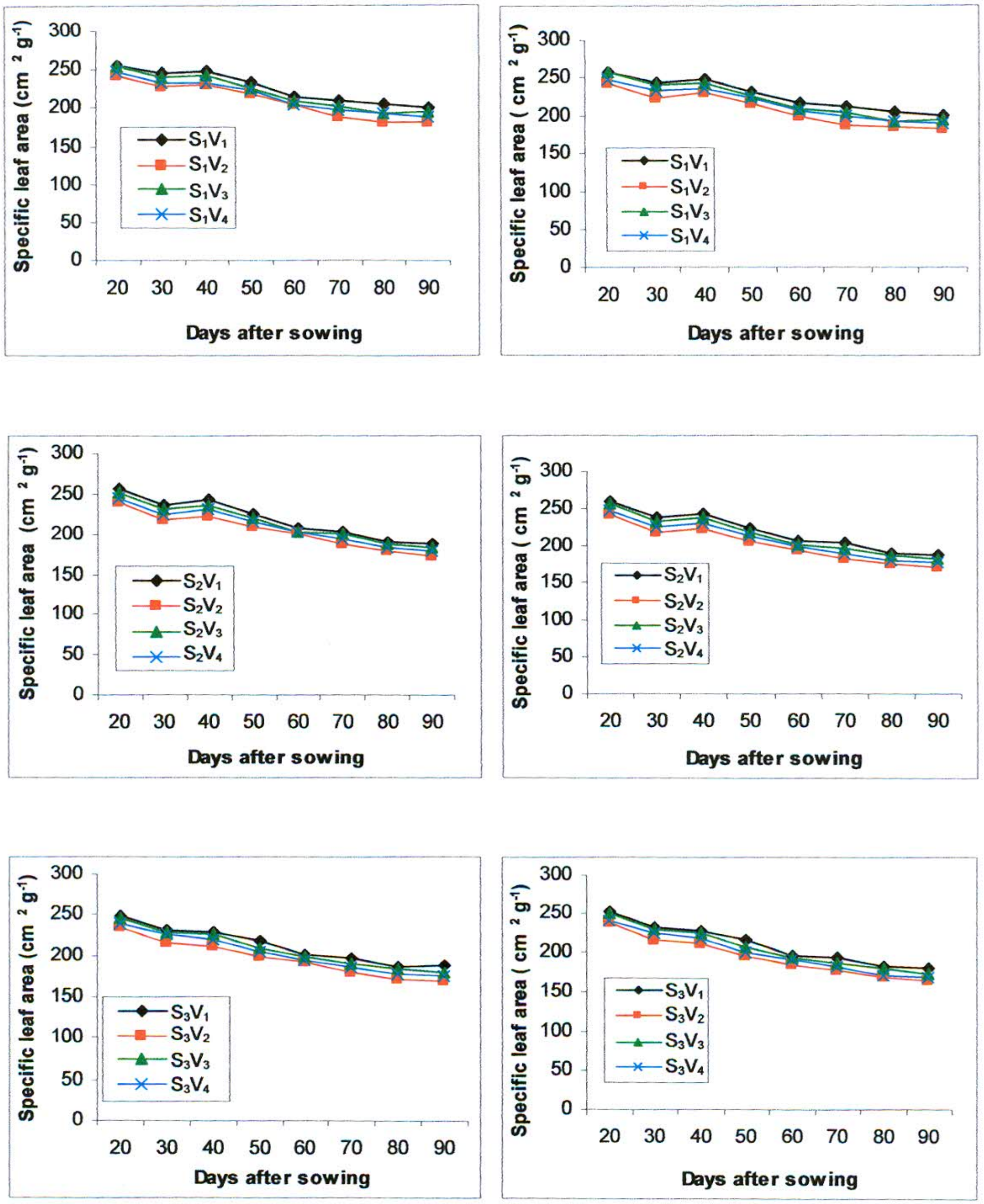


Figure 8c: Effects of varieties on specific leaf area (SLA) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.10 Leaf Weight Ratio (LWR)

Experiment for 2005-06

The analysis of variance (**Table 19a**) indicates that the item sowing date (S) was significant at all the harvesting dates except only at 20 DAS. The soil moisture (I) item was significant at all the growth phases. It was also found the varietals differences were significant at all the growth stages except only at 20 DAS.

The interaction item $S \times I$ was significant at 30, 40, 50 and 90 DAS. The interaction $S \times V$ was significant only at 40 and 50 DAS. The interaction item $I \times V$ was significant at most of the growth stages except at 20 and 30 DAS which indicating that the varieties responded differently in different sowing times and soil moisture regimes. The interaction item $S \times I \times V$ was significant at all the harvest days except only at 20 and 70 DAS.

Sowing dates influenced mean values of leaf weight ratio (**Table 20a**) were also higher leaf weight ratio at the second harvest and then declined gradually with advancement of time and reached their highest values at 30 DAS. Among the sowing dates, S_1 plants showed the highest leaf weight ratio than the other sowings.

Mean values of leaf weight ratio as influenced by soil moisture (**Table 20a**) showed the higher leaf weight ratio at the initial stages of growth and then declined gradually and lowest leaf weight ratio at the last stage. The irrigated plants always had higher leaf weight ratio than the rainfed plants at all the harvests.

Mean values of leaf weight ratio of all varieties (**Table 20a**) were found to be maximum at the second harvest (30 DAS) and then declined sharply with increasing plant age. The highest leaf weight ratio values were observed at 30 DAS. Among the varieties, at second harvest (30 DAS) the maximum leaf weight ratio was recorded in Shatabdi and the minimum in Gaurav at all the harvesting dates, respectively.

The mean effects of sowing dates (S) on leaf weigh ratio at different growth stages are graphically shown in **Fig 9a** (left portion). Leaf weigh ratio of all the varieties showed the highest value at the second harvest (30 DAS) and then decreased rapidly and reached towards zero direction at 90 DAS. At 20, 30 and 40 DAS for leaf weigh ratio, S_2 (November 30 sowing) indicates higher value than the S_1 (November 15 sowing) and S_3 (December 15 sowing) plants. In all the sowing dates had more, less or equal leaf weigh ratio values at several harvests.

The mean effects of soil moisture on leaf weight ratio of four varieties of wheat at different growth stages are graphically shown in **Fig. 9b** (left portion). Among the four wheat varieties had the highest peak at 30 DAS. The irrigated plants of all the varieties had the higher leaf weight ratio values than the rainfed ones at all the growth stages.

The growth pattern of leaf weight ratio is graphically presented in **Fig. 9c** (left portion). Leaf weight ratio of four wheat varieties started from the highest value at 30 DAS and then declined gradually with increasing plant age and reached at nearly zero at the last harvest. Among the varieties, Shatabdi produced the highest leaf weight ratio values and Gaurav produced the lowest at al the harvesting dates except at 20 and 30 DAS.

Experiment for 2006-07

From the results of analysis of variance in **Table 19b** it is indicated that the item sowing time (S) was significant at all of the harvesting dates, indicated that sowing times is strongly effect the leaf weight ratio. The soil moisture (I) item was significant at all the growth stages. It was also found the varietals differences were significant at all the harvesting dates.

The interaction item S×I was significant at all the growth stages. The interaction S×V was significant at most of the harvest days except only at 90 DAS. The interaction item I×V was significant at all the growth stages. It was also found the interaction item S×I×V was significant at all the difference harvesting dates except at 90 DAS.

Mean values leaf weight ratio as influenced by sowing date (**Table 20b**) indicated that the higher leaf weight ratio values at the second harvest (30 DAS) and then declined gradually with increasing plants age and reached at nearly zero at the last harvest (90 DAS). Among the sowing dates, S_1 plants showed the highest leaf weight ratio than the other sowings.

Mean values of leaf weight ratio as influenced by soil moisture (**Table 20b**) also indicated that the highest leaf weight ratio at the second harvest (30 DAS) and then declined gradually and the lowest leaf weight ratio at the last stage. The irrigated plants always had higher leaf weight ratio than the rainfed plants of all the varieties.

Mean values of leaf weight ratio of all the varieties (**Table 20b**) revealed that starting from the higher values at second harvesting dates and then declined sharply with increasing plant age. The highest leaf weight ratio values were recorded at 30 DAS. Among the varieties, Shatabdi and Gaurav had the highest and the lowest leaf weight ratio at all the growth stages, respectively.

The mean effect of sowing times (S) on leaf weight ratio of four varieties of wheat at different growth stages are graphically shown in **Fig. 9a** (right portion). Mean values of leaf weigh ratio of four varieties started from higher values at the early stages of growth and then declined sharply throughout the whole growth period and reached towards zero direction at 90 DAS. The highest leaf weigh ratio was observed at 30 DAS of all the varieties. In all the sowing dates, S_1 (November 15 sowing) plants showed the maximum leaf weigh ratio than the S_2 (November 30 sowing) and S_3 (December 15 sowing) plants at third harvest (40 DAS). All the sowing dates had more or less or equal leaf weigh ratio values at several harvests.

The mean effect of soil moisture (I) on leaf weight ratio of four varieties of wheat at different growth stages are graphically shown in **Fig. 9b** (right portion). The values of leaf weight ratio were found maximum at the second harvest (30 DAS) and declined sharply with increasing the plant age and reached towards zero direction at the last harvest. The irrigated plants always showed the higher leaf weight ratio values than the rainfed ones of all the varieties.

The overall effects of varieties of leaf weight ratio at different growth stages are graphically shown in **Fig. 9c** (right portion). Leaf weight ratio of four wheat varieties started from higher values at second harvest and declined gradually with increasing plant age and reached at nearly zero at 90 DAS. Among the varieties, Shatabdi and Gaurav had the highest and lowest leaf weight ratio at several growth stages, respectively.

Table 19a. Mean squares (MS) from the analysis of variance of leaf weight ratio (gg^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.0047	0.000014	0.000056	0.0000012	0.00058	0.00011	0.000109	0.000021
Sowing (S)	2	0.0088	0.0018**	0.02701**	0.055**	0.0118**	0.0037**	0.0013*	0.00059**
Error (a)	4	0.0046	0.000031	0.000029	0.0000016	0.00046	0.00013	0.000106	0.000020
Soil moisture (I)	1	0.153**	0.00085**	0.2050**	0.045**	0.031**	0.016**	0.0076**	0.0027**
S × I	2	0.0085	0.0004**	0.0251**	0.032**	0.0025	0.00045	0.00054	0.00025**
Error (b)	6	0.0049	0.000023	0.000039	0.0000081	0.0005	0.00012	0.000103	0.000022
Variety (V)	3	0.0051	0.00033**	0.3052**	0.051**	0.0128**	0.0056**	0.0021**	0.00097**
S × V	6	0.0044	0.000035	0.00077**	0.00021**	0.00015	0.000057	0.000022	0.000021
I × V	3	0.0072	0.000024	0.01212**	0.0036*	0.0011**	0.0006**	0.000345**	0.00019**
S × I × V	6	0.0054	0.00011**	0.00088**	0.0021*	0.00115**	0.00014	0.000086**	0.00004**
Error (c)	36	0.0051	0.000025	0.000056	0.0000045	0.000088	0.000062	0.0000095	0.000011

**=significant at 1% level, *=significant at 5% level, respectively;

Table 19b. Mean squares (MS) from the analysis of variance of leaf weight ratio (gg^{-1}) at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.000013	0.000129	0.000239	0.0000326	0.0000004	0.0000049	0.0000072	0.000002
Sowing (S)	2	0.0142**	0.02117**	0.06169**	0.01025**	0.00343**	0.00374**	0.00265**	0.000337*
Error (a)	4	0.000015	0.000129	0.000143	0.0000398	0.0000418	0.0000075	0.0000049	0.0000417
Soil moisture (I)	1	0.0940**	0.07782**	0.10321**	0.08712**	0.01085**	0.01335**	0.00645**	0.002223**
S × I	2	0.0099**	0.008745**	0.04894**	0.04546**	0.00215**	0.00021**	0.00036**	0.000384**
Error (b)	6	0.000014	0.000129	0.000175	0.000037	0.000025	0.0000027	0.0000008	0.0000281
Variety (V)	3	0.`00008**	0.00308**	0.03781**	0.03248**	0.00951**	0.00746**	0.00173**	0.000768**
S × V	6	0.00006**	0.00029**	0.00077**	4.60E+90	0.00037*	0.00029**	0.00004**	0.000035
I × V	3	0.00067**	0.00094**	0.00083**	0.00684**	0.00218**	0.00224**	0.00063**	0.000086**
S × I × V	6	0.00008**	0.00019**	0.00292**	0.001171**	0.00039*	0.00023**	0.00004**	0.000020
Error (c)	36	0.000009	0.000032	0.000195	0.0000374	0.000110	0.0000254	0.0000029	0.000019

**=significant at 1% level, *=significant at 5% level, respectively.

Table 20a. Mean values of leaf weight ratio (gg^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	0.670	0.754	0.617	0.371	0.202	0.093	0.047	0.025
Sowing (S_2)	0.695	0.752	0.610	0.315	0.187	0.083	0.041	0.019
Sowing (S_3)	0.657	0.738	0.556	0.276	0.158	0.068	0.032	0.015
LSD 5%	0.0544	0.0045	0.0043	0.0010	0.0172	0.0091	0.0083	0.0036
Soil moisture (I)								
Irrigation (I_1)	0.720	0.751	0.648	0.346	0.203	0.096	0.050	0.026
Rainfed (I_0)	0.628	0.744	0.541	0.296	0.161	0.066	0.030	0.014
LSD 5%	0.0404	0.0028	0.0036	0.0016	0.0129	0.0063	0.0059	0.0027
Variety (V)								
Shatabdi (V_1)	0.649	0.753	0.639	0.389	0.212	0.104	0.054	0.030
Gaurav (V_2)	0.681	0.742	0.541	0.260	0.148	0.063	0.029	0.012
Shourav (V_3)	0.681	0.749	0.588	0.304	0.179	0.072	0.035	0.017
Kanchan (V_4)	0.686	0.748	0.609	0.330	0.190	0.084	0.042	0.020
LSD 5%	0.0481	0.0034	0.0050	0.0014	0.0063	0.0053	0.0021	0.0022

Table 20b. Mean values of leaf weight ratio (gg^{-1}) at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	0.692	0.725	0.590	0.333	0.184	0.106	0.047	0.026
Sowing (S_2)	0.691	0.728	0.542	0.327	0.173	0.094	0.038	0.020
Sowing (S_3)	0.649	0.675	0.489	0.295	0.160	0.081	0.026	0.019
LSD 5%	0.0031	0.0091	0.0096	0.0050	0.0052	0.0022	0.0018	0.0052
Soil moisture (I)								
Irrigation (I_1)	0.714	0.742	0.578	0.353	0.184	0.107	0.047	0.027
Rainfed (I_0)	0.641	0.676	0.502	0.284	0.160	0.080	0.028	0.016
LSD 5%	0.0022	0.0066	0.0076	0.0035	0.0029	0.0009	0.0005	0.0031
Variety (V)								
Shatabdi (V_1)	0.679	0.718	0.589	0.371	0.199	0.113	0.050	0.030
Gaurav (V_2)	0.675	0.690	0.481	0.273	0.144	0.066	0.027	0.015
Shourav (V_3)	0.677	0.713	0.531	0.299	0.166	0.092	0.033	0.019
Kanchan (V_4)	0.680	0.716	0.560	0.331	0.178	0.103	0.038	0.022
LSD 5%	0.0020	0.0038	0.0094	0.0041	0.0071	0.0034	0.0011	0.0029

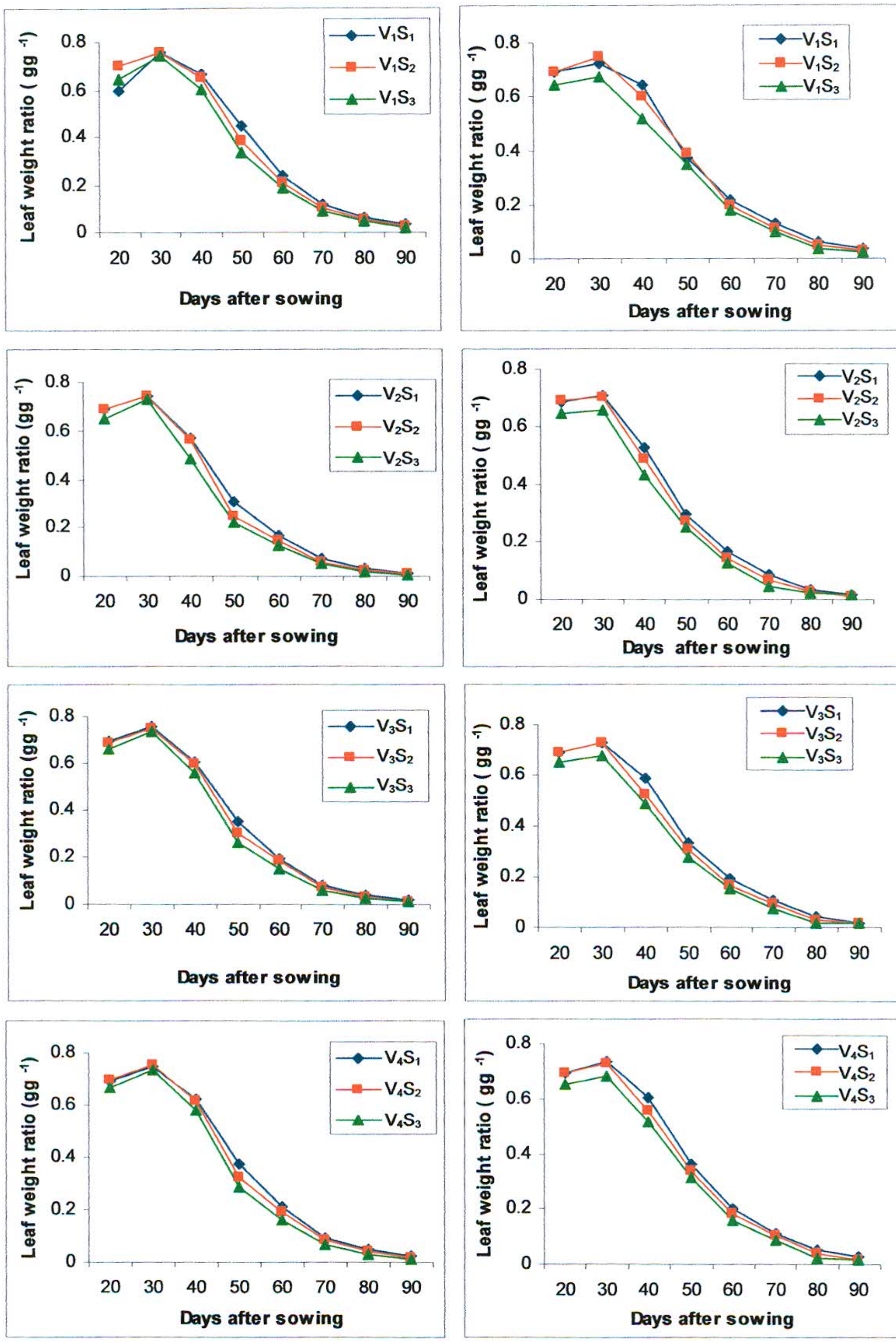


Figure 9a: Effects of sowing times on leaf weight ratio (LWR) wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

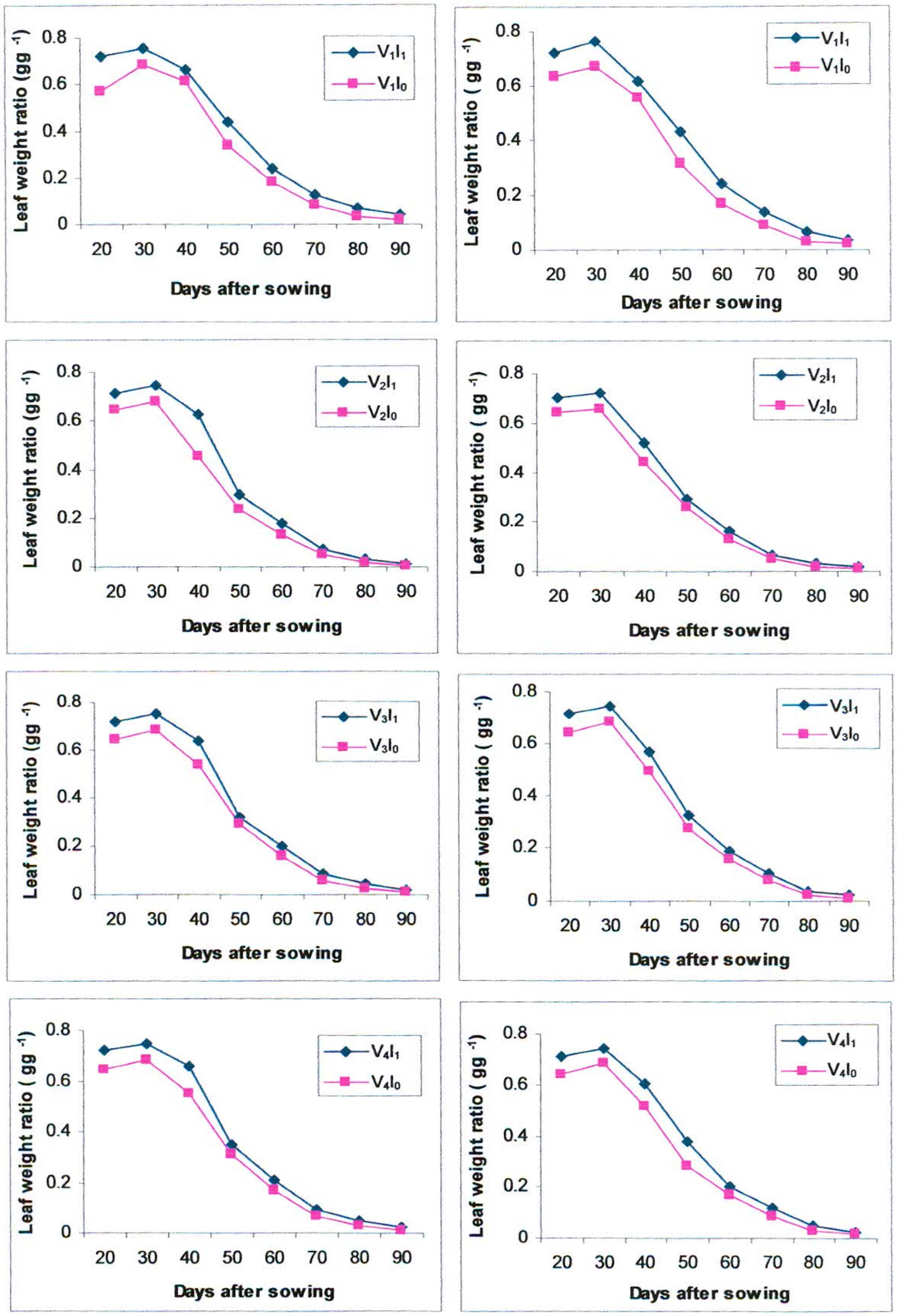


Figure 9b: Effects of soil moisture on leaf weight ratio (LWR) four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

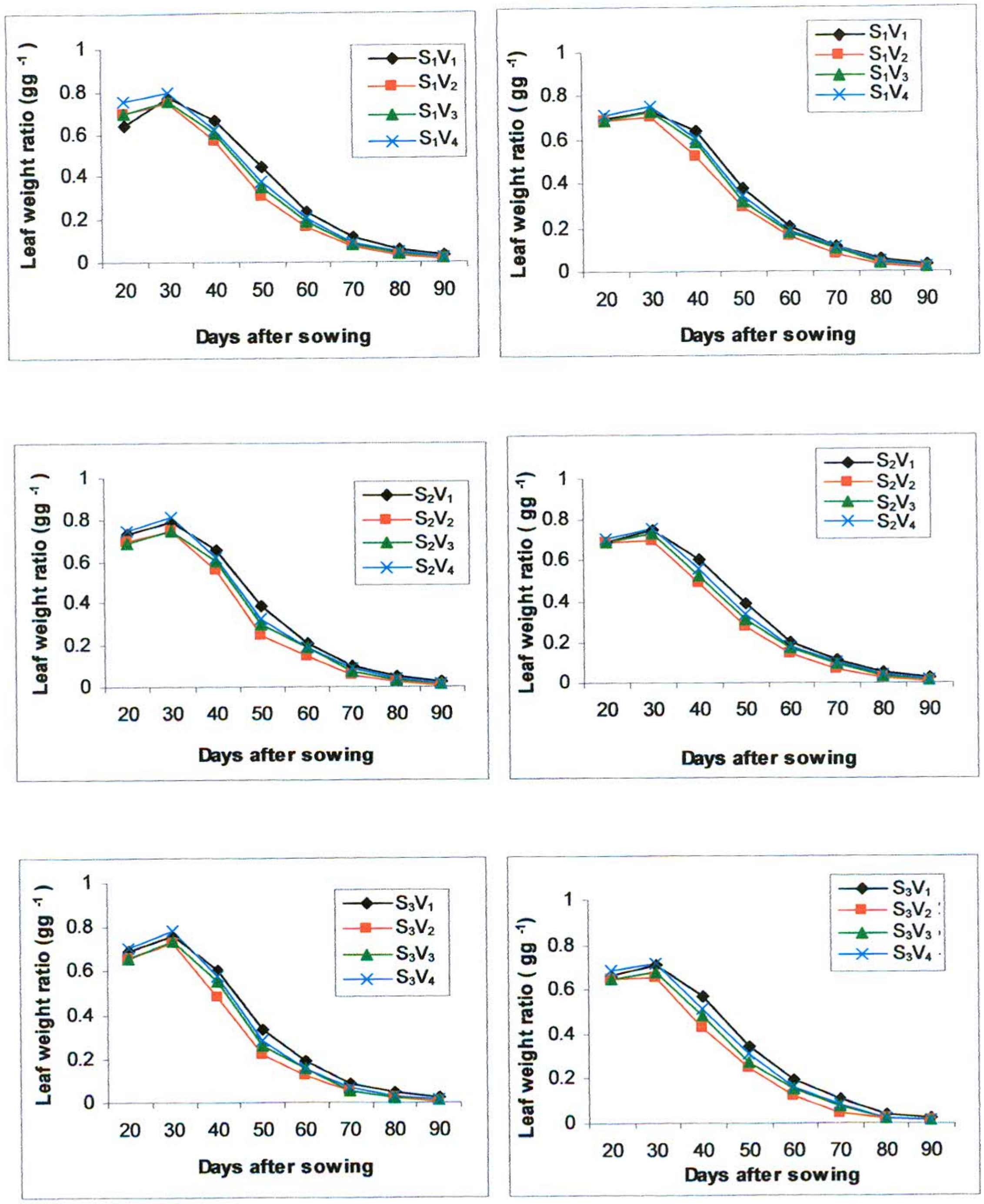


Figure 9c: Effects of varieties on leaf weight ratio (LWR) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.11 Plant Height (PH)

Experiment for 2005-06

The results of analysis of variance (**Table 21a**) show that the sowing date (S) item was significant for plant height at all the harvesting periods except 20 DAS, indicating that the varieties were highly affected by sowing times. Varietals differences for plant height were also significant at all the harvesting dates. The item soil moisture (I) was found to be significant at all the harvesting periods, indicating that the irrigation affected plant height.

The interaction item S×I was significant at all the harvesting dates, which indicates that the varieties responded differently in different sowing times and soil moisture conditions. The interaction item S×V was significant at 30, 60, and 80 DAS. The interaction item I×V was significant at most of the harvesting dates except at 30 and 40 DAS. The interaction item S×I×V was significant only at 30 and 50 DAS.

Plant height starting from a lower value increased with the increasing growth stages and reached their peaks at 80 DAS and then slightly decreased at the last harvest (**Table 22a**). Among the sowing dates, S_1 plants showed the highest plant height than the other sowings at most of the growth stages.

Mean values of plant height as influenced by soil moisture (**Table 22a**) increased very rapidly and sharply for the last harvest at 90 DAS. The irrigated plants had higher plant height than the rainfed plants for all the varieties. The higher plant height was recorded in I_1 level than I_0 level of irrigation.

Starting from a lower value at the early stages of growth plant height of all the four varieties reached their peaks at 90 DAS (**Table 22a**). Among the varieties, Shatabdi showed the highest plant height at most of the growth stages than any other variety of wheat.

The mean effect of sowing date (S) on plant height is graphically presented in **Fig. 10a** (left portion). Plant height increased from establishment of the seedlings and attained the first peak at 80 DAS and then slowed down. The second peak was at 90 DAS. The values of plant height were found to be the maximum at 80 and 90 DAS. At several harvests for plant height, S_1 (November 15 sowing) indicated higher value than S_2 (November 30 sowing) and S_3 (December 15 sowing) of all the varieties.

The mean effects of soil moisture (I) on plant height at different growth stages are graphically shown in **Fig.10b** (left portion). Among the four varieties, the first and the second peaks were attained at 80 and 90 DAS. The highest plant height was observed in I_1 level than I_0 level of irrigation at several harvests. The irrigated plants had the higher plant height than the rainfed plants in all the varieties.

The overall effects of varieties on plant height at different stages of growth are graphically shown in **Fig. 10c** (left portion). In all the varieties starting from a lower value, plant height increased with the increasing growth stages and reached their peaks at 80 DAS. Among the varieties, at 80 DAS Shatabdi had the highest plant height at several harvests than any other variety of wheat.

Experiment for 2006-07

The results of analysis of variance for plant height at different harvests are shown in **Table 21b.** The result shows that the item soil moisture (I) was significant at all the growth stages. Varietal differences for plant height were highly significant at all the harvesting dates. The sowing date (s) item was also significant at all the harvesting dates, which indicated that plant height was significantly affected by sowing date.

The interaction item $S \times I$ was significant at most of the growth phases except at 20 and 30 DAS which indicates that the varieties responded differently in different sowing times and soil moisture regimes. The interaction item $S \times V$ was significant at 40, 50, 60, 80 and 90 DAS. The interaction item $I \times V$ was significant at all the harvesting dates. The interaction item $S \times I \times V$ was significant at 40, 50, 60, 80 and 90 DAS.

Mean values of plant height as influenced by sowing date (**Table 22b**) started from lower values at the early harvests and then declined gradually with increasing plants age and reached their highest value at 90 DAS. Among the sowing dates, S_1 plants showed the highest plant height than the other sowings at all the harvesting dates.

Mean values of plant height as influenced by soil moisture (**Table 22b**) increased very rapidly and sharply for the last harvest at 90 DAS. The highest plant height was observed in I_1 level than I_0 level of irrigation.

Mean values of plant height of all the four varieties (**Table 22b**) starting from lower values at the initial stages of growth and then declined gradually with increasing plants age and reached their peaks at 90 DAS. Shatabdi showed the highest plant height at most of the growth stages than any other variety of wheat. Among the varieties, Shatabdi showed the highest peak and the lowest in Gaurav.

The mean effects of sowing dates (S) on plant height at different growth stages are graphically shown in **Fig. 10a** (right portion). In all the sowing dates of plant height starting from lower values increased gradually with increasing plant age. The values of plant height were found to be the maximum at 80 and 90 DAS. At each DAS for plant height, S_1 (November 15 sowing) plants had the higher value than S_2 (November 30 sowing) and S_3 (December 15 sowing) plants for all the varieties.

The mean effect of soil moisture (I) on plant height at different growth stages of wheat are graphically shown in **Fig. 10b** (right portion). The irrigated plants had higher plant height value at several harvests than the rainfed plants in all the varieties. The first peak was observed in the irrigated and the rainfed conditions at 80 DAS.

The overall effects of varieties on plant height at different stages of growth are graphically shown in **Fig. 10c** (right portion) In all the varieties starting from a lower value plant height increased with the increasing growth stages and reached their highest peak at 90 DAS. Among the four varieties, Shatabdi showed the highest peak followed by Shourav, Kanchan and Gaurav at 90 DAS.

Table 21a. Mean squares (MS) from the analysis of variance of plant height at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.29	0.88	0.89	2.54	5.18	4.50	1.06	3.041667
Sowing (S)	2	2.92	42.14**	186.26**	207.04**	116.01**	151.12**	136.76**	132.12**
Error (a)	4	0.66	0.76	1.97	2.08	1.18	1.44	1.12	0.92
Soil moisture (I)	1	13.72**	20.05**	1241.68**	6479.01**	6290.68**	9953.12**	9545.01**	9453.12**
S×I	2	4.08**	13.18**	54.26**	18.43**	73.93**	22.87*	19.26**	16.62**
Error (b)	6	0.15	0.43	2.44	1.21	1.59	4.04	0.51	0.63
Variety (V)	3	78.93**	190.95**	75.61**	83.71**	93.34**	97.49**	144.53**	132.45**
S×V	6	0.17	3.83*	1.13	2.13	12.18**	1.99	2.78**	1.95
I×V	3	2.03*	1.79	0.38	9.01**	12.45**	106.05**	85.53**	76.12**
S×I×V	6	0.99	6.47**	1.25	9.04**	2.21	2.63	0.94	2.12
Error (c)	36	0.54	1.24	1.42	1.77	1.61	2.45	0.82	0.96

**=significant at 1% level, *=significant at 5% level, respectively;

Table 21b. Mean squares (MS) from the analysis of variance of plant height at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.11	0.41	2.93	1.06*	2.09	5.85	0.68	0.26
Sowing (S)	2	4.81*	2.80**	110.39**	101.52**	113.93**	122.06**	143.84**	140.51**
Error (a)	4	0.35	0.10	0.81	0.12	0.81	4.22	1.04	0.91
Soil moisture (I)	1	12.61**	121.68**	1112.34**	5706.68**	8866.68**	9667.05**	8986.68**	9526.6**
S × I	2	2.09	2.10	76.22**	105.56**	98.76**	168.38**	106.35**	83.76**
Error (b)	6	0.43	1.66	1.51	1.76	0.82	3.09	0.75	0.44
Variety (V)	3	75.28**	97.18**	111.83**	63.35**	28.19**	97.86**	102.79**	109.93**
S×V	6	0.82	1.26	9.87**	5.33**	4.61*	5.14	3.18*	4.99**
I×V	3	2.32*	14.74**	11.94**	6.57**	16.19**	55.09**	40.45**	29.72**
S×I×V	6	0.93	1.21	5.15**	3.55**	3.78*	4.12	3.01**	3.02**
Error (c)	36	0.53	0.80	1.05	1.06	1.49	2.28	0.76	0.81

**=significant at 1% level, *=significant at 5% level, respectively;

Table 22a. Mean values of plant height at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	20.222	25.721	35.875	53.875	76.083	83.292	85.708	86.000
Sowing (S_2)	21.050	25.721	36.125	52.708	73.125	81.875	83.667	83.792
Sowing (S_3)	20.342	25.125	32.292	49.875	71.833	78.875	80.833	81.167
LSD 5%	0.651	0.699	1.125	1.156	0.871	0.962	0.848	0.769
Soil moisture (I)								
Irrigation (I_1)	20.956	26.822	38.694	61.056	84.778	94.611	96.306	96.306
Rainfed (I_0)	20.119	24.222	30.833	43.250	62.583	68.083	70.500	71.000
LSD 5%	0.223	0.378	0.901	0.634	0.727	1.159	0.412	0.458
Variety (V)								
Shatabdi (V_1)	19.672	23.922	34.500	52.722	74.167	84.000	86.222	86.667
Gaurav (V_2)	22.756	26.111	37.111	53.556	74.111	78.611	80.611	80.778
Shourav (V_3)	21.589	28.556	36.056	52.944	74.611	82.333	84.222	84.278
Kanchan (V_4)	18.135	23.500	31.389	49.389	71.833	80.444	82.556	82.889
LSD 5%	0.495	0.750	0.803	0.896	0.855	1.054	0.610	0.660

Table22b. Mean values of plant height at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	20.258	25.971	36.167	51.333	74.750	85.250	85.250	85.375
Sowing (S_2)	20.343	26.208	34.750	50.167	73.750	82.375	83.292	83.750
Sowing (S_3)	20.900	24.875	30.792	45.792	70.542	80.250	80.500	80.750
LSD 5%	0.474	0.253	0.721	0.278	0.721	1.646	0.817	0.764
Soil moisture (I)								
Irrigation (I_1)	20.937	26.731	38.056	58.611	82.361	94.500	94.528	94.750
Rainfed (I_0)	20.064	24.639	29.750	39.583	63.667	70.750	71.500	71.833
LSD 5%	0.378	0.743	0.709	0.765	0.522	1.014	0.499	0.383
Variety (V)								
Shatabdi (V_1)	19.633	24.350	32.944	49.667	73.500	84.833	86.000	86.167
Gaurav (V_2)	22.756	26.722	35.944	51.111	74.556	79.833	79.778	80.167
Shourav (V_3)	21.589	29.056	35.222	49.667	74.333	84.222	84.667	84.833
Kanchan (V_4)	18.024	22.611	31.500	45.944	69.667	81.611	81.611	82.000
LSD 5%	0.490	0.603	0.690	0.694	0.822	1.017	0.587	0.606

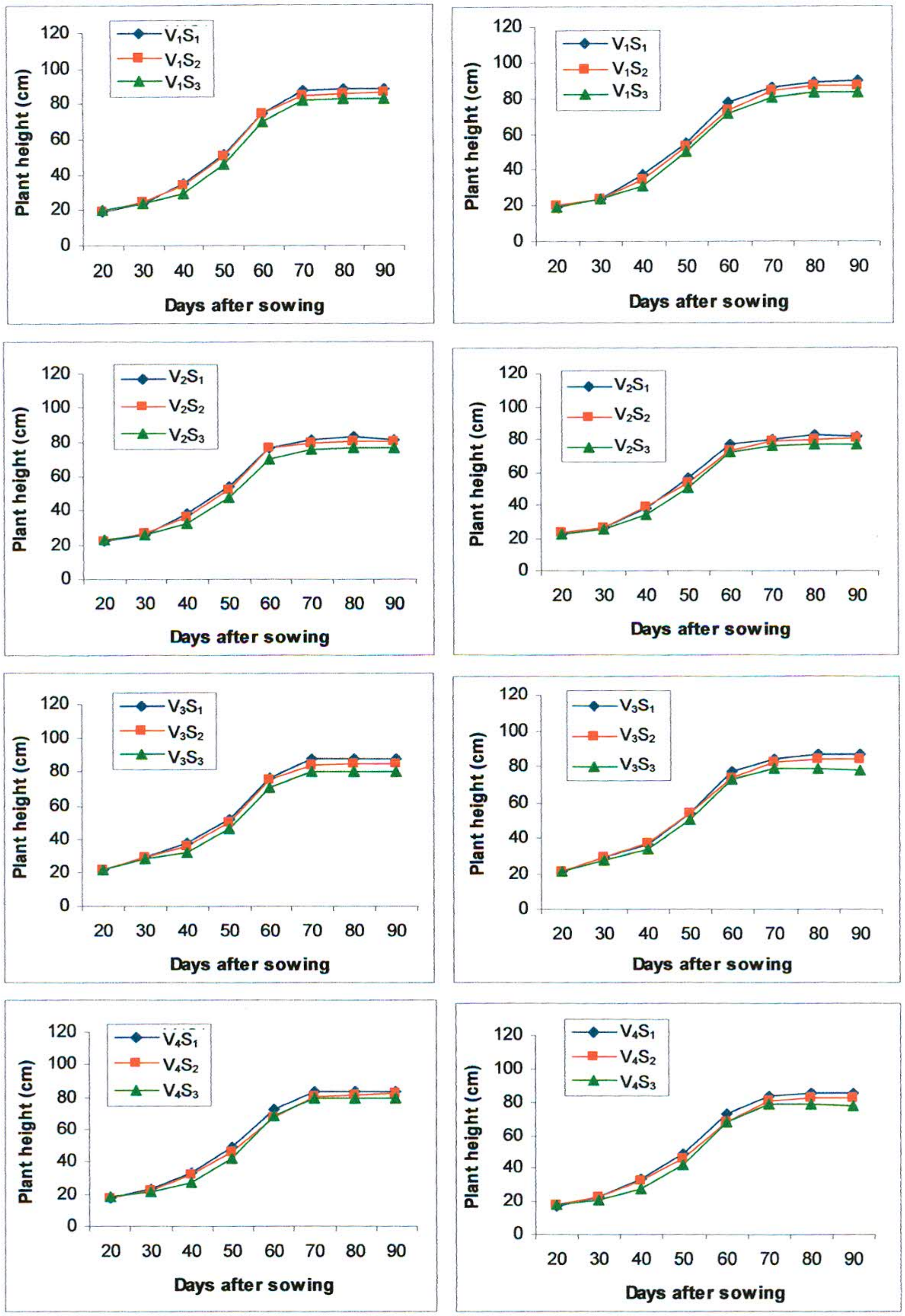


Figure 10a: Effects of sowing times on plant height (PH) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

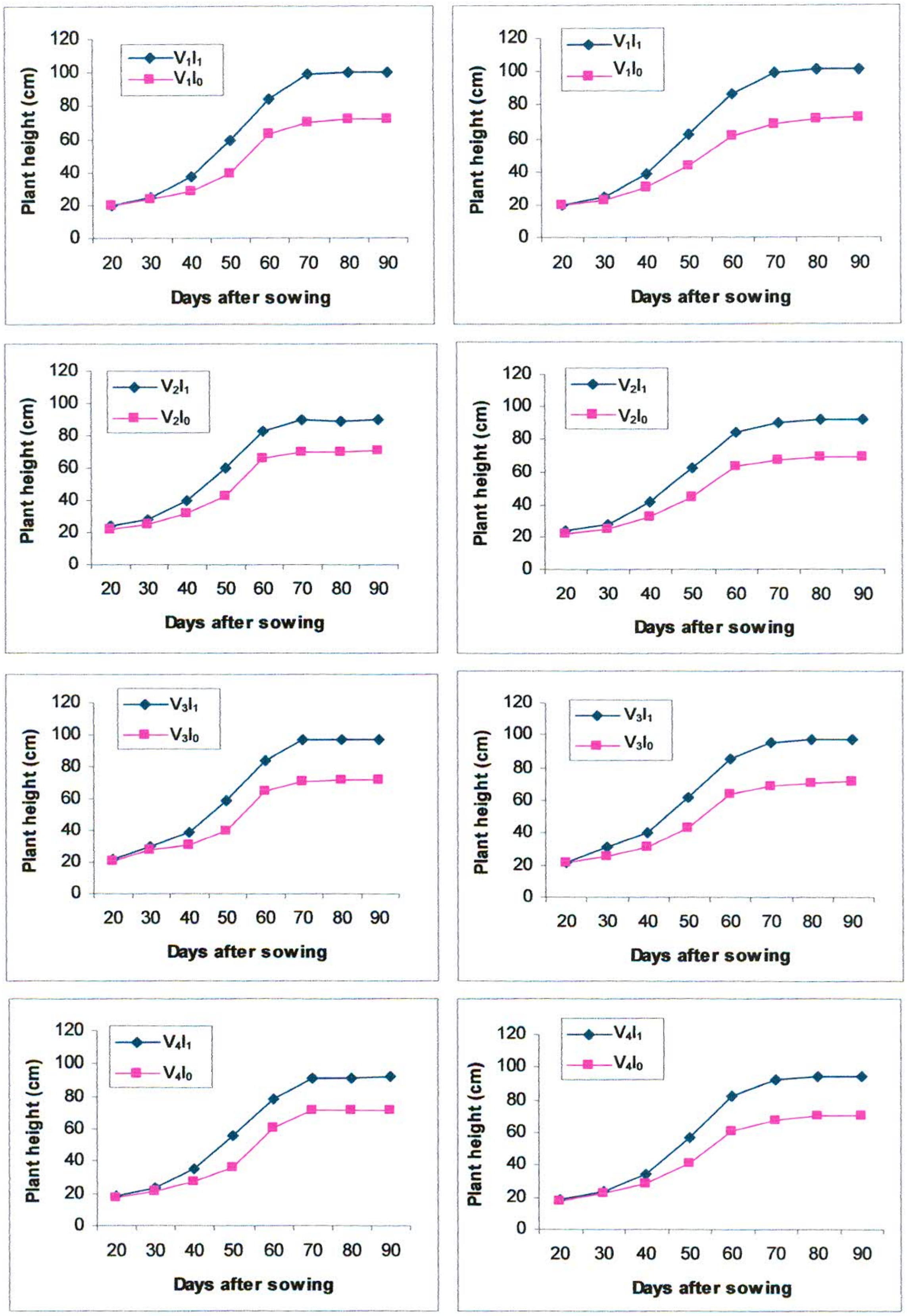


Figure 10b: Effects of soil moisture on plant height (PH) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

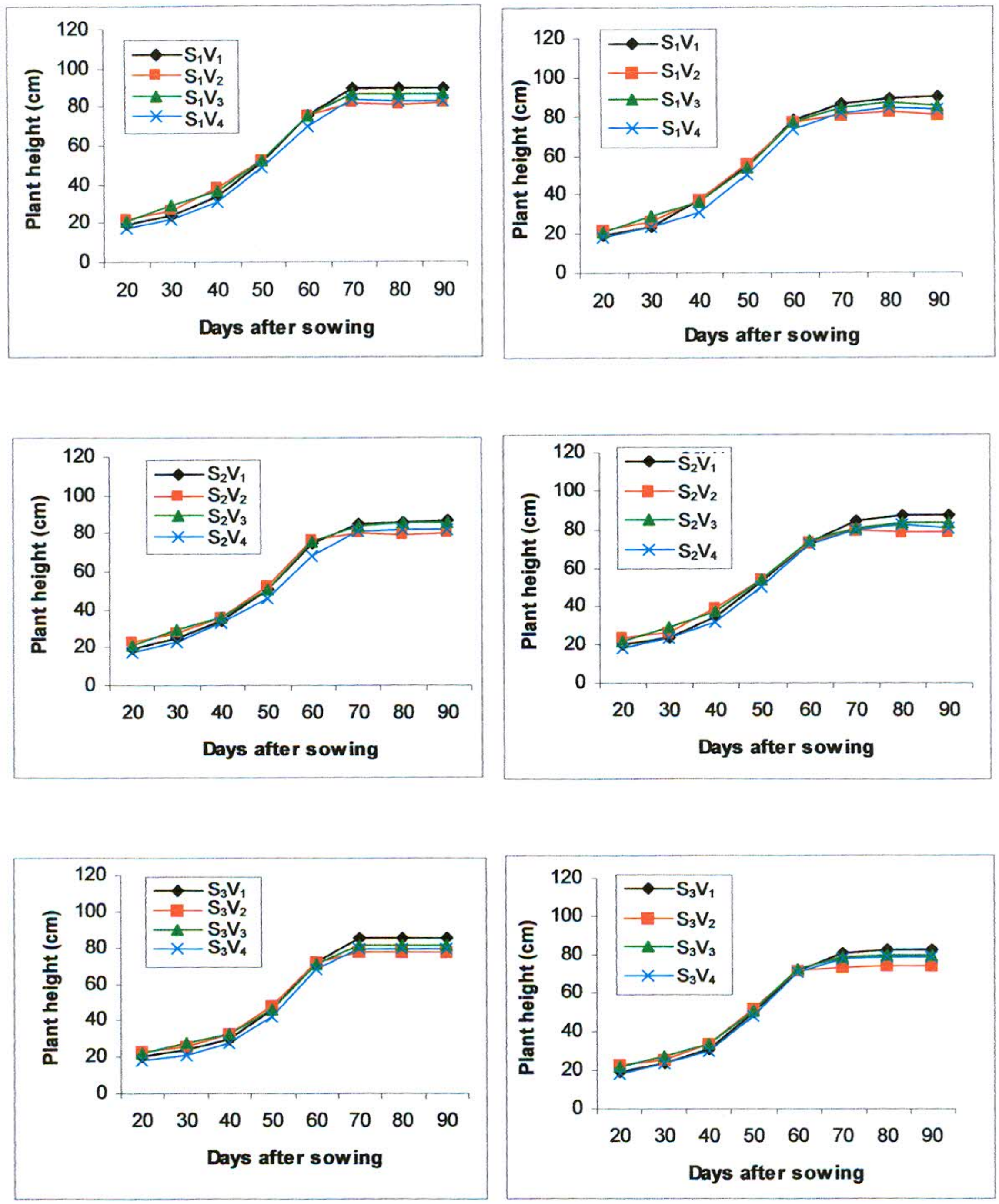


Figure 10c: Effects of varieties on plant height (PH) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.12 Tiller Number (TN)

Experiment for 2005-06

The results of analysis of variance are shown in **Table 23a.** The results indicate that the item sowing date was highly significant at all the harvesting dates. Soil moisture (I) item was significant at al the harvesting dates indicating that the varieties were highly affected by soil moisture regimes. Varietal differences for tiller number were also significant for all the harvesting dates.

The interaction S×I was significant at 30, 50, 60 and 80 DAS. The interaction item S×V was non-significant at all the growth phases. The interaction item I×V was also significant only at 20 DAS. The interaction item S×I×V was significant only at 30 DAS.

Mean values of tiller number as influenced by sowing date (**Table 24a**) indicated that starting from lower values increased with the increasing plant age and attained their peaks at 60 DAS. All the sowing dates showed more, less or equal tiller number value at most of the growth stage.

Mean values of tiller number as influenced by soil moisture (**Table 24a**) also indicated that starting increased very rapidly and sharply up to the harvest at 60 DAS. The irrigated plants had higher tiller number than the rainfed plants for all the varieties. The highest tiller number was observed in I_1 level than I_0 level of irrigation.

Mean values of tiller number of all the four wheat varieties (**Table 24a**) revealed that starting from lower values at the early stages of growth and reached their highest peaks at 60 DAS. Among the varieties, Kanchan showed the highest peak followed by Shatabdi, Shourav and Gaurav at several harvests.

The mean effect of sowing date (S) on tiller number per plant of four varieties of wheat at different growth stages are graphically shown in **Fig. 11a** (left portion). The number of tillers increased rapidly at the early stages and slightly decreased at the later stages and attained the first peak at 60 DAS. At several harvests for tiller number per plant, S_1 (November 15 sowing) and S_2 (November 30 sowing) indicated higher value than S_3 (December 15 sowing) plants in all the varieties.

The mean effect of soil moisture on tiller number per plant of four varieties of wheat at different growth stages are graphically shown in **Fig. 11b** (left portion). Graphical presentation shows that in soil moisture of tiller number per plant starting from lower values increased with increasing plant age and attained the first peak at 60 DAS and second peak at 70 DAS and then slowed down. The irrigated plants showed the higher values than the rainfed plants in all the varieties.

The overall effects of varieties on tiller number per plant different stages of growth are graphically shown in **Fig. 11c** (left portion). In all the varieties starting from a lower value of tiller number per plant increased with the increasing growth stages and reached their first peak at 60 DAS and then slightly decreased at the last harvest. Among the varieties, Kanchan showed the highest peak followed by Shatabdi, Shourav and Gaurav at 60 DAS.

Experiment for 2006-07

Mean squares from the analysis of variance of tiller number per plant are shown in **Table 23b.** The result shows that the item sowing date (S) was significant at three harvests (50, 80 and 90 DAS). Soil moisture (I) item was significant at all the harvesting dates. It was also found the varietals differences were significant at all the harvesting dates.

The interaction item $S \times I$ and $S \times V$ were non-significant at all the growth phases. The interaction item $I \times V$ was significant only at 30 and 50 DAS. The interaction item $S \times I \times V$ was significant at most only one harvest (50 DAS) days.

Mean values of tiller number as influenced by sowing date (**Table 24b**) was found to be lower values at the early growth stages and attained their peaks at 60 DAS. Among the sowing dates, S_3 plants showed the lowest tiller number than S_1 and S_2 plants at several harvest but S_1 and S_2 plants showed more, less or equal tiller number values at most of the growth stages.

Mean values of tiller number as influenced by soil moisture (**Table 24b**) increased very rapidly and sharply up to the harvest at 60 DAS. The irrigated plants always had the higher tiller number than the rainfed plants in all the varieties.

Mean values of tiller number of all the four varieties (**Table 24b**) starting from a lower value at the early stages of growth and reached their first peak at 70 DAS. Among the varieties, the maximum tiller number was recorded in Kanchan and the minimum in Gaurav at all the harvesting dates, respectively.

The mean effects of sowing dates (S) on tiller number per plant at different growth stages are graphically shown in **Fig. 11a** (right portion). The result shows that at most of the DAS for tiller number per plant, S_3 (December 15 sowing) plants had the lower value and S_1 (November 15 sowing) and S_2 (November 30 sowing) plants showed more, less or equal values in all the varieties.

The mean effect of soil moisture on tiller number per plant of four varieties of wheat at different growth stages are graphically shown in **Fig.11b** (right portion). At each DAS for tiller number per plant, the irrigated plants had higher value than the rainfed plants in all the varieties. At 60 DAS, the highest peak was observed in I_1 level than I_0 level of irrigation.

The overall effects of varieties of tiller number per plant at different growth stages are graphically shown in **Fig.11c** (right portion). Graphical presentation shows that in all the varieties for tiller number per plant starting from lower values increased with increasing plant age and reached first peak at 60 DAS and second peak at 70 DAS and then slightly decreased at 90 DAS. Among the varieties, Kanchan showed the highest tiller number per plant at several harvests than any other variety of wheat.

Table 23a. Mean squares (MS) from the analysis of variance of tiller number per plant at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.082	0.294	0.007	0.406	0.466	0.076	0.010	0.146
Sowing (S)	2	0.422*	0.719*	3.319**	3.639**	2.175*	1.839*	0.465*	0.931**
Error (a)	4	0.048	0.083	0.102	0.064	0.303	0.161	0.064	0.019
Soil moisture (I)	1	1.980**	4.332**	14.222**	26.766**	41.238**	16.684**	38.033**	36.082**
S × I	2	0.061	0.765**	0.154	1.083*	1.041**	0.084	1.893**	0.477
Error (b)	6	0.099	0.038	0.115	0.118	0.043	0.281	0.156	0.329
Variety (V)	3	2.186**	4.33**	2.634**	0.858**	1.222**	0.979**	0.878**	1.222*
S × V	6	0.046	0.142	0.078	0.046	0.035	0.075	0.042	0.027
I × V	3	0.543**	0.055	0.209	0.204	0.196	0.217	0.081	0.038
S × I × V	6	0.029	0.695**	0.159	0.135	0.091	0.179	0.227	0.085
Error (c)	36	0.0502	0.149	0.186	0.113	0.165	0.1799	0.193	0.347

**=significant at 1% level, *=significant at 5% level, respectively;

Table 23b. Mean squares (MS) from the analysis of variance of tiller number per plant at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.353	0.193	0.47	0.262	0.722	1.048	0.473	0.705
Sowing (S)	2	0.161	0.325	3.109	3.198*	1.763	1.17	1.066*	2.060*
Error (a)	4	0.117	0.099	0.734	0.227	0.555	0.236	0.103	0.236
Soil moisture (I)	1	4.336**	6.594**	21.67**	27.281**	50**	27.987**	26.088**	27.309**
S×I	2	0.078	0.039	0.036	0.039	0.292	0.333	0.141	0.176
Error (b)	6	0.171	0.057	0.421	0.236	0.277	0.206	0.523	0.551
Variety (V)	3	1.290**	5.37**	3.973**	3.535**	2.130**	2.833**	2.0509**	1.997**
S× V	6	0.096	0.323	0.086	0.073	0.121	0.116	0.351	0.292
I× V	3	0.075	.636*	0.321	0.929*	0.148	0.521	0.269	0.492
S×I× V	6	0.014	0.047	0.151	0.789*	0.218	0.257	0.102	0.441
Error (c)	36	0.097	0.165	0.413	0.251	0.388	0.287	0.319	0.361

**=significant at 1% level, *=significant at 5% level, respectively;

Table 24a. Mean values of tiller number per plant at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	1.486	2.541	4.330	4.986	5.302	5.229	4.944	4.830
Sowing (S_2)	1.343	2.623	4.125	4.874	5.215	5.183	4.813	4.858
Sowing (S_3)	1.221	2.291	3.608	4.263	4.763	4.728	4.666	4.504
LSD 5%	0.176	0.231	0.256	0.203	0.441	0.322	0.203	0.110
Soil moisture (I)								
Irrigation (I_1)	1.516	2.730	4.466	5.317	5.857	5.528	5.537	5.439
Rainfed (I_0)	1.184	2.240	3.577	4.098	4.330	4.566	4.078	4.023
LSD 5%	0.181	0.112	0.196	0.198	0.120	0.306	0.228	0.331
Variety (V)								
Shatabdi (V_1)	1.462	2.758	4.342	4.833	5.231	5.222	4.972	4.917
Gaurav (V_2)	1.056	1.813	3.567	4.403	4.761	4.742	4.537	4.394
Shourav (V_3)	1.089	2.444	3.842	4.700	5.014	4.987	4.712	4.657
Kanchan (V_4)	1.794	2.925	4.333	4.894	5.368	5.237	5.009	5.000
LSD 5%	0.151	0.260	0.291	0.226	0.274	0.285	0.296	0.397

Table 24b. Mean values of tiller number per plant at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	1.541	2.679	4.305	4.888	5.250	5.082	4.889	4.938
Sowing (S_2)	1.387	2.627	4.423	4.777	4.958	4.761	4.736	4.694
Sowing (S_3)	1.288	2.457	3.749	4.208	4.708	4.658	4.597	4.354
LSD 5%	0.274	0.252	0.687	0.382	0.597	0.389	0.257	0.389
Soil moisture (I)								
Irrigation (I_1)	1.626	2.890	4.708	5.240	5.806	5.457	5.398	5.278
Rainfed (I_0)	1.184	2.285	3.611	4.009	4.139	4.210	4.083	4.046
LSD 5%	0.239	0.138	0.374	0.280	0.304	0.262	0.417	0.428
Variety (V)								
Shatabdi (V_1)	1.462	2.795	4.518	4.832	5.167	4.943	4.944	4.833
Gaurav (V_2)	1.167	1.914	3.556	3.999	4.500	4.303	4.241	4.194
Shourav (V_3)	1.144	2.439	4.018	4.647	4.944	4.832	4.685	4.667
Kanchan (V_4)	1.848	3.202	4.546	5.018	5.278	5.257	5.092	4.953
LSD 5%	0.210	0.274	0.433	0.338	0.420	0.361	0.380	0.405

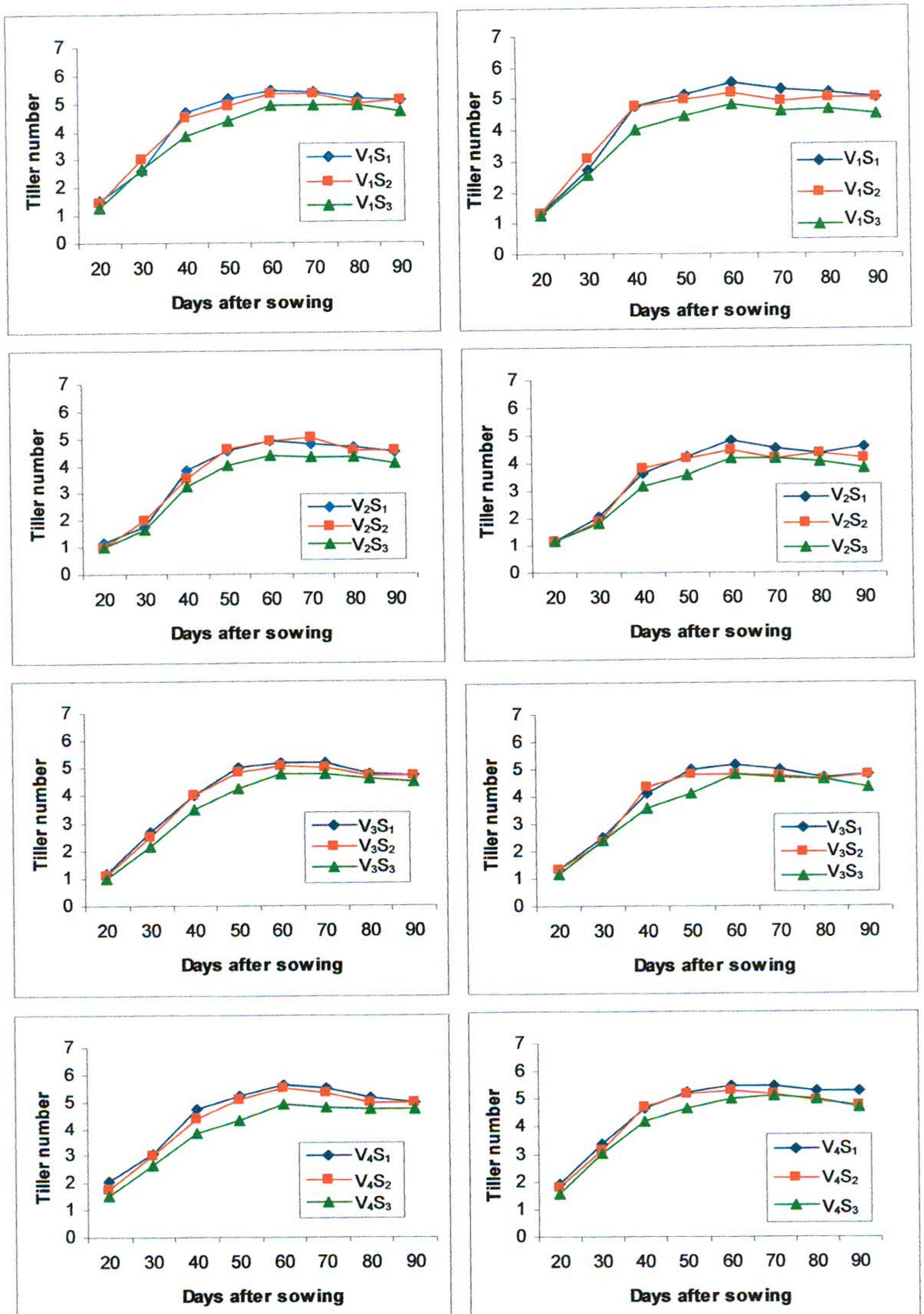


Figure 11a: Effects of sowing times on tiller number (TN) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

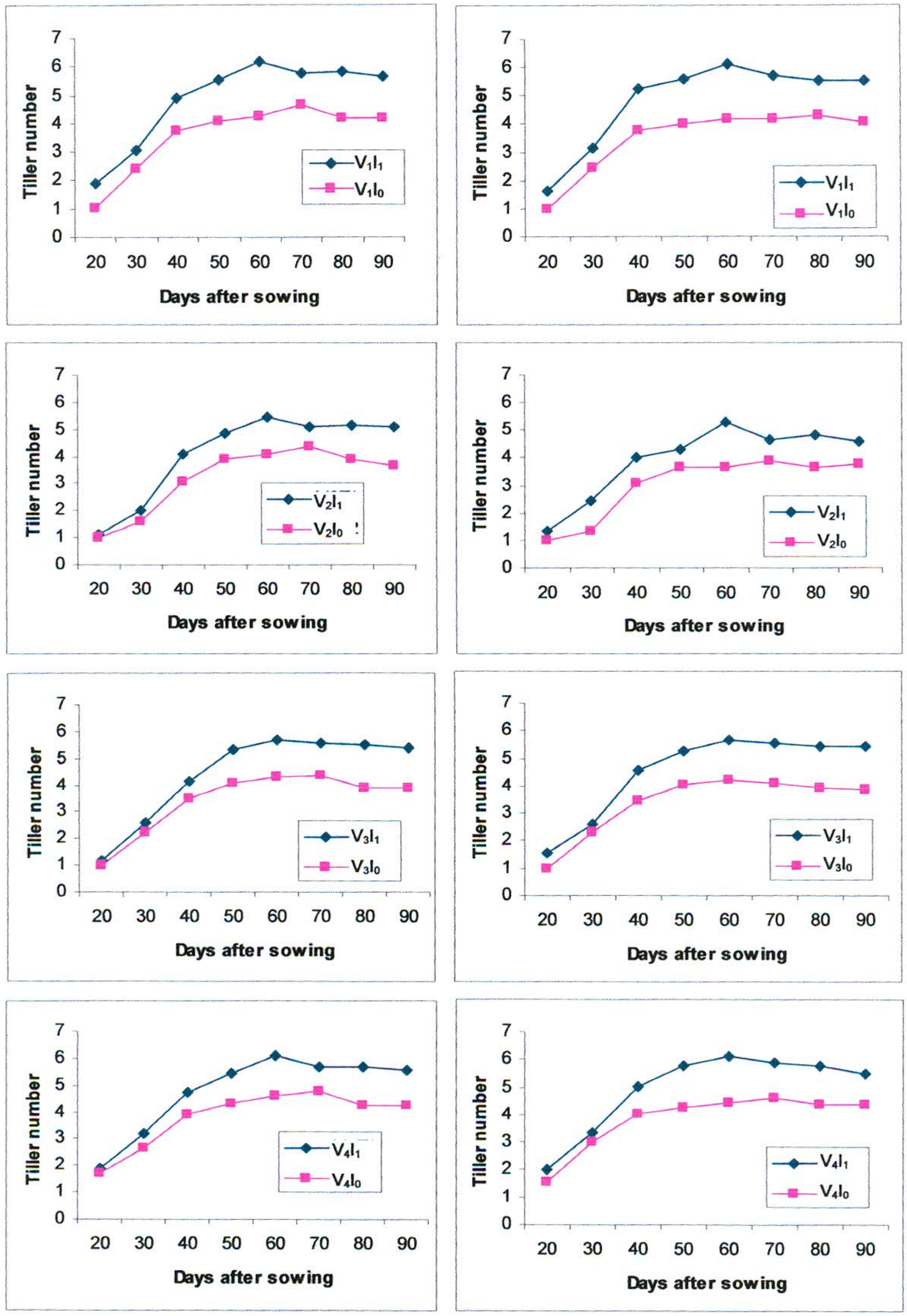


Figure 11b: Effects of soil moisture on tiller number (TN) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

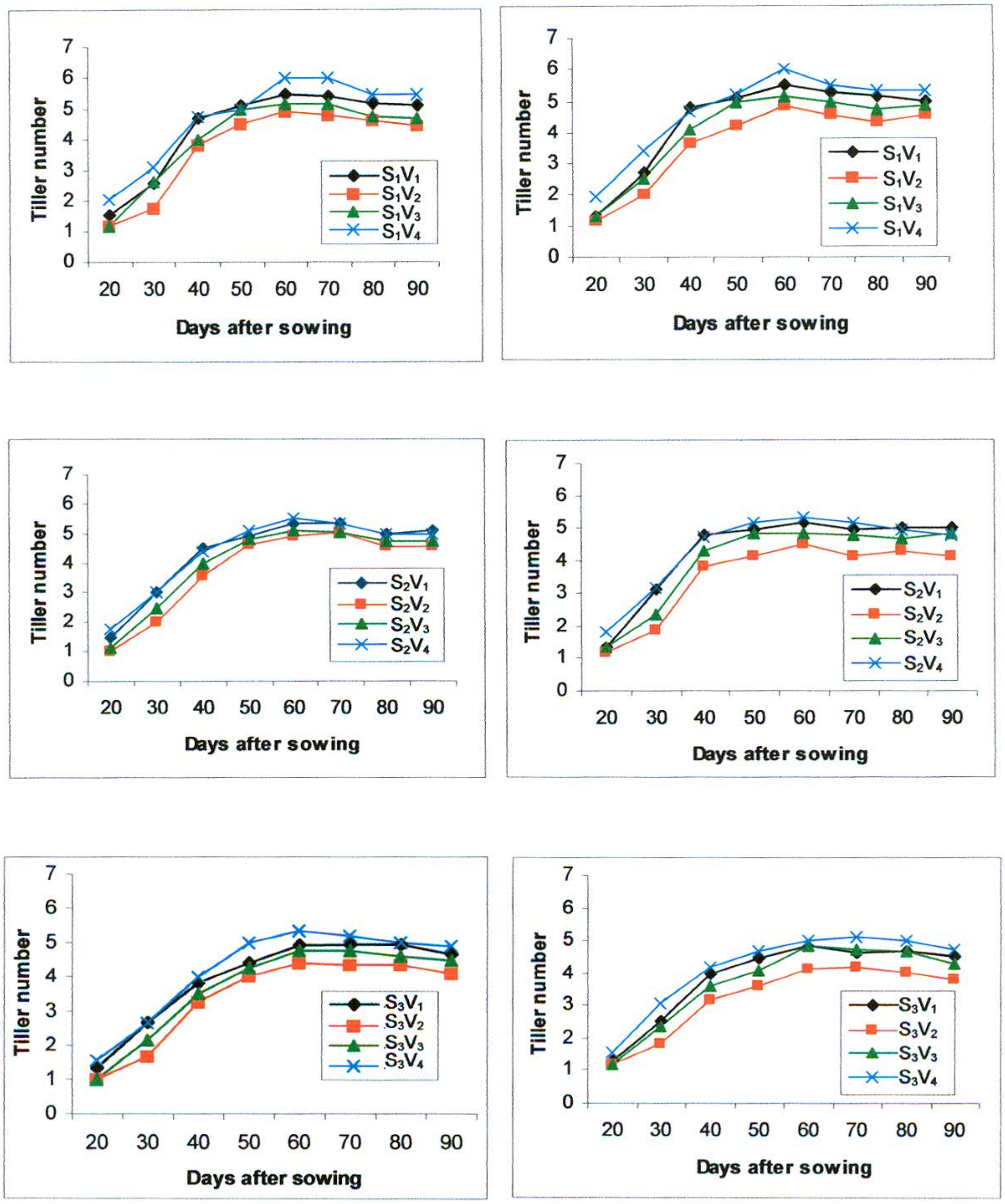


Figure 11c: Effects of varieties on tiller number (TN) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.13 Leaf Number (LN)

Experiment for 2005-06

The results of analysis of variance for leaf number per plant are shown in **table 25a.** The results indicated that the item sowing date (S) was found to be significant at most of the growth phases except 20 and 70 DAS. Varietal differences for leaf number per plant were also significant at all the harvesting dates. Soil moisture (I) item was also significant at all the growth stages.

The interaction item $S\times I$ was significant at most of the growth phases except 20 and 70 DAS indicated that the varieties responded differently in different sowing times and soil moisture conditions. The interaction item $S\times V$ was significant at 70 DAS. The interaction item $I\times V$ was significant at 20, 60 and 80 DAS. The interaction item $S\times I\times V$ was significant at 60 DAS.

Mean values of leaf number as influenced by sowing dates (**Table 26a**) indicated that starting from lower value at the initial stages of growth and showed higher leaf number at the middle stages and reached their first peak at 60 DAS. Generally S_3 had the lowest leaf number at several harvests than any other sowing of wheat.

Mean values of leaf number as influenced by soil moisture (**Table 26a**) increased steadily until at 60 DAS and then decreased very rapidly and sharply for the last harvest at 90 DAS. The irrigated plants had higher leaf number than the rainfed plants for all the varieties. The highest leaf number was observed in I_1 level than I_0 level of irrigation.

Mean values of leaf number of all the four varieties (**Table 26a**) increased until at 60 DAS and lower leaf number at the later stages but there was an increasing tendency at the middle stages and then declined, reached their highest values at 60 DAS and 70 DAS, respectively. Shatabdi showed the highest leaf number at most of the growth stages than any other variety of wheat.

The mean effect of sowing dates (S) on leaf number per plant of four varieties of wheat at different growth stages are graphically shown in **Fig. 12a** (left portion). All the varieties reached their peak at 60 DAS in different sowing times. The result shows that at several DAS for number of green leaves per plant, S_1 (November 15 sowing) and S_2 (November 30 sowing) had the higher value than S_3 (December 15 sowing) of all the varieties and S_1 (November 15 sowing) and S_2 (November 30 sowing) showed more, less or similar values at most of the growth stages.

The mean effect of soil moisture on leaf number per plant of four varieties of wheat at different growth stages are graphically shown in **Fig. 12b** (left portion). In case of number of green leaves per plant, the irrigated plants always showed the higher values than the rainfed ones at all the harvesting dates in all the varieties. It was also observed that almost all the varieties reached their highest peak at 60 DAS.

The overall effects of varieties of leaf number per plant at different stages are graphically shown **Fig. 12c** (left portion). In all the varieties starting from a lower value of leaf number per plant with the increasing growth stages and reached their peak at 60 DAS and then slowed down and showed the lowest value at 90 DAS. Shatabdi was found to be the highest peak and the lowest peak was found in Gaurav at 60 DAS.

Experiment for 2007

The analysis of variance in **Table 25b** show the item sowing date (S) was significant for leaf number at all the harvesting dates except at 20 DAS. Soil moisture (I) was significant at all the harvest days. Varietal differences were found to be significant at all the growth stages.

The interaction item S×I was significant at most of the growth phases except at 70, 80 and 90 DAS. The interaction item I×V was significant at all the harvest days. The interaction item S×V was significant only at 20 and 40 DAS. The interaction item S×I×V was significant at 20 and 40 DAS.

Mean values of leaf number as influenced by sowing date (**Table 26b**) started from lower values at the early stages of growth and showed higher leaf number at the middle stages and reached their first peak at 60 DAS. Generally S_1 and S_2 plants had the highest leaf number at several harvests than S_3 plants of all the varieties.

Mean values of leaf number as influenced by soil moisture (**Table 26b**) increased with the increasing growth stages and reached their first peak at 60 DAS and then decreased very rapidly and sharply for the last harvest at 90 DAS. The irrigated plants had the higher leaf number than the rainfed plants in all the varieties.

Mean values of leaf number of all the four varieties (**Table 26b**) increased until at 60 DAS and lower leaf number at the later stages but there was an increasing tendency at the middle stages and then declined, reached their highest values at 60 DAS and 70 DAS, respectively. Among the varieties, Shatabdi showed the highest leaf number followed by Kanchan, Shourav and Gaurav.

The graphical presentation (**Fig. 12a.** right portion) shows that in all the varieties starting from a lower value of leaf number per plant increased with the increasing growth stages and reached their peak at 60 DAS. At several DAS for number of green leaves per plant, S_1 (November 15 sowing) and S_2 (November 30 sowing) had the higher value than S_3 (December 15 sowing) of all the varieties. In case of the sowing dates item between S_1 (November 15 sowing) and S_2 (November 30 sowing) plants showed more, less or equal leaf number per plant values at most of the growth stages.

The graphical presentation (**Fig.12b** right portion) shows that the irrigated plants always produced the higher number of green leaves per plant than those of the rainfed plants in all the varieties. The maximum leaf area ratio was recorded in I_1 level than I_0 level of irrigation. All the varieties reached their peak at 60 DAS in both the irrigated and the rainfed conditions.

The overall effects of' varieties of leaf number per plant at different stages are graphically shown in **Fig. 12c** (right portion). In all the varieties starting from a lower value of leaf number per plant increased with the increasing growth stages and reached their peak at 60 DAS and then gradually decreased up to 90 DAS and showed the lowest value at this stage. Among the varieties, Shatabdi showed the highest green leaf number production followed by Kanchan, Shourav and Gaurav at most of the growth stages.

Table 25a. Mean squares (MS) from the analysis of variance of leaf number per plant at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.006	0.005	1.347	0.222	0.681	0.974	0.432	0.441
Sowing (S)	2	0.076	10.840*	22.183*	25.847**	35.097*	19.281	6.305**	7.015**
Error (a)	4	0.027	0.756	2.722	1.159	3.972	3.972	0.327	0.335
Soil moisture (I)	1	2.737**	117.222**	630.125**	522.72**	606.68**	975.49**	144.95**	525.14**
S×I	2	0.289	9.433**	28.042**	66.43**	54.511**	3.351	1.276*	45.124**
Error (b)	6	0.069	0.791	2.486	3.986	2.069	0.736	0.194	3.112
Variety (V)	3	2.207**	24.093**	50.274**	62.32**	73.511**	46.931**	14.041**	16.533**
S×V	6	0.075	0.463	1.939	0.384	4.912	3.092*	0.917	0.928
I×V	3	0.250*	0.744	3.384	3.574	14.202*	1.527	2.271*	1.113
S × I × V	6	0.168	1.911	5.356	3.115	15.593**	1.591	0.595	0.736
Error (c)	36	0.082	1.208	4.763	5.509	3.768	1.062	0.595	0.672

**=significant at 1% level, *=significant at 5% level, respectively;

Table25b. Mean squares (MS) from the analysis of variance of leaf number per plant at different harvests of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Replication (R)	2	0.0469	0.513	0.875	0.264	0.667	1.347	0.875	0.436
Sowing (S)	2	0.111	18.33**	135.875**	66.931*	83.625**	27.513*	7.057*	4.817*
Error (a)	4	0.043	0.138	2.125	0.493	1.104	1.889	0.979	0.522
Soil moisture (I)	1	2.872**	125.347**	435.125**	501.388**	780.125**	654.013**	435.420**	216.312**
S×I	2	0.234**	10.004**	45.875**	30.431**	25.125**	1.431	1.790	1.082
Error (b)	6	0.014	0.514	0.458	0.250	0.625	1.458	0.944	0.615
Variety (V)	3	1.875**	25.347**	51.828**	31.203**	31.125**	38.347**	37.187**	27.523**
S× V	6	0.211**	0.559	3.245**	1.968	0.958	0.736	0.743	0.521
I×V	3	0.265**	1.755**	4.939**	7.870**	14.236**	5.347**	15.261**	12.321**
S×I× V	6	0.128*	0.189	2.023*	0.467	2.236	0.986	0.605	0.716
Error (c)	36	0.040	0.259	0.843	1.121	1.236	0.898	1.574	1.118

**=significant at 1% level, *=significant at 5% level, respectively;

Table 26a. Mean values of leaf number per plant at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	3.996	8.250	14.542	16.875	17.792	14.500	8.008	2.374
Sowing (S_2)	4.039	8.833	14.250	16.708	17.542	13.583	7.664	2.417
Sowing (S_3)	3.928	7.493	12.750	15.000	15.500	12.708	7.000	2.167
LSD 5%	0.132	0.697	1.322	0.863	1.597	1.597	0.458	0.464
Soil moisture (I)								
Irrigation (I_1)	4.183	9.468	16.806	18.889	19.861	17.278	8.976	2.778
Rainfed (I_0)	3.793	6.917	10.889	13.500	14.028	9.916	6.139	1.861
LSD 5%	0.152	0.513	0.909	1.152	0.830	0.495	0.254	1.017
Variety (V)								
Shatabdi (V_1)	3.996	9.222	15.389	17.778	18.611	15.167	8.434	2.556
Gaurav (V_2)	3.590	6.629	11.667	13.667	14.333	11.499	6.349	1.943
Shourav (V_3)	3.924	8.028	13.444	15.944	16.278	13.222	7.481	2.222
Kanchan (V_4)	4.441	8.889	14.889	17.389	18.556	14.500	7.966	2.556
LSD 5%	0.193	0.740	1.470	1.581	1.308	0.694	0.520	0.552

Table 26b. Mean values of leaf number per plant at different growth stages as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	20 DAS	30 DAS	40 DAS	50 DAS	60 DAS	70 DAS	80 DAS	90 DAS
Sowing (S_1)	4.012	8.188	14.375	17.042	17.667	14.917	9.250	1.665
Sowing (S_2)	3.996	8.500	14.875	16.083	17.042	14.083	8.707	2.164
Sowing (S_3)	3.887	6.854	12.250	13.792	14.167	12.792	8.165	1.679
LSD 5%	0.166	0.298	1.168	0.563	0.842	1.101	0.793	0.579
Soil moisture (I)								
Irrigation (I_1)	4.165	9.167	17.000	18.278	19.583	16.944	11.167	2.452
Rainfed (I_0)	3.765	6.528	10.667	13.000	13.000	10.917	6.248	1.220
LSD 5%	0.068	0.414	0.390	0.288	0.456	0.696	0.560	0.452
Variety (V)								
Shatabdi (V_1)	3.923	9.167	14.944	16.722	17.578	15.333	10.221	2.257
Gaurav (V_2)	3.627	6.389	11.833	13.778	14.500	12.000	6.998	1.406
Shourav (V_3)	3.906	7.500	13.833	15.667	16.111	13.667	8.111	1.703
Kanchan (V_4)	4.404	8.333	14.722	16.389	17.278	14.722	9.500	1.979
LSD 5%	0.135	0.343	0.619	0.713	0.749	0.638	0.845	0.712

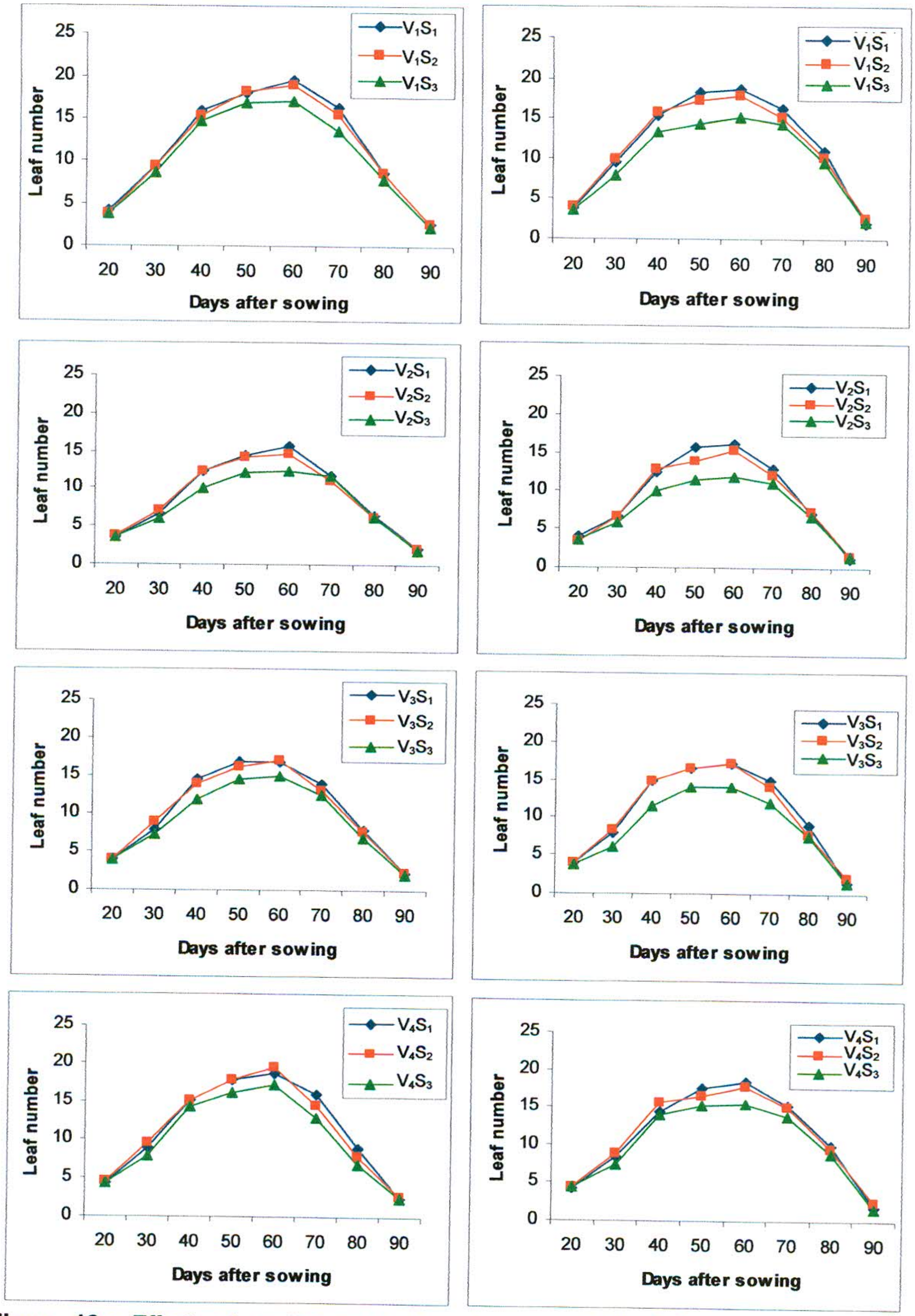


Figure 12a: Effects of sowing times on leaf number (LN) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

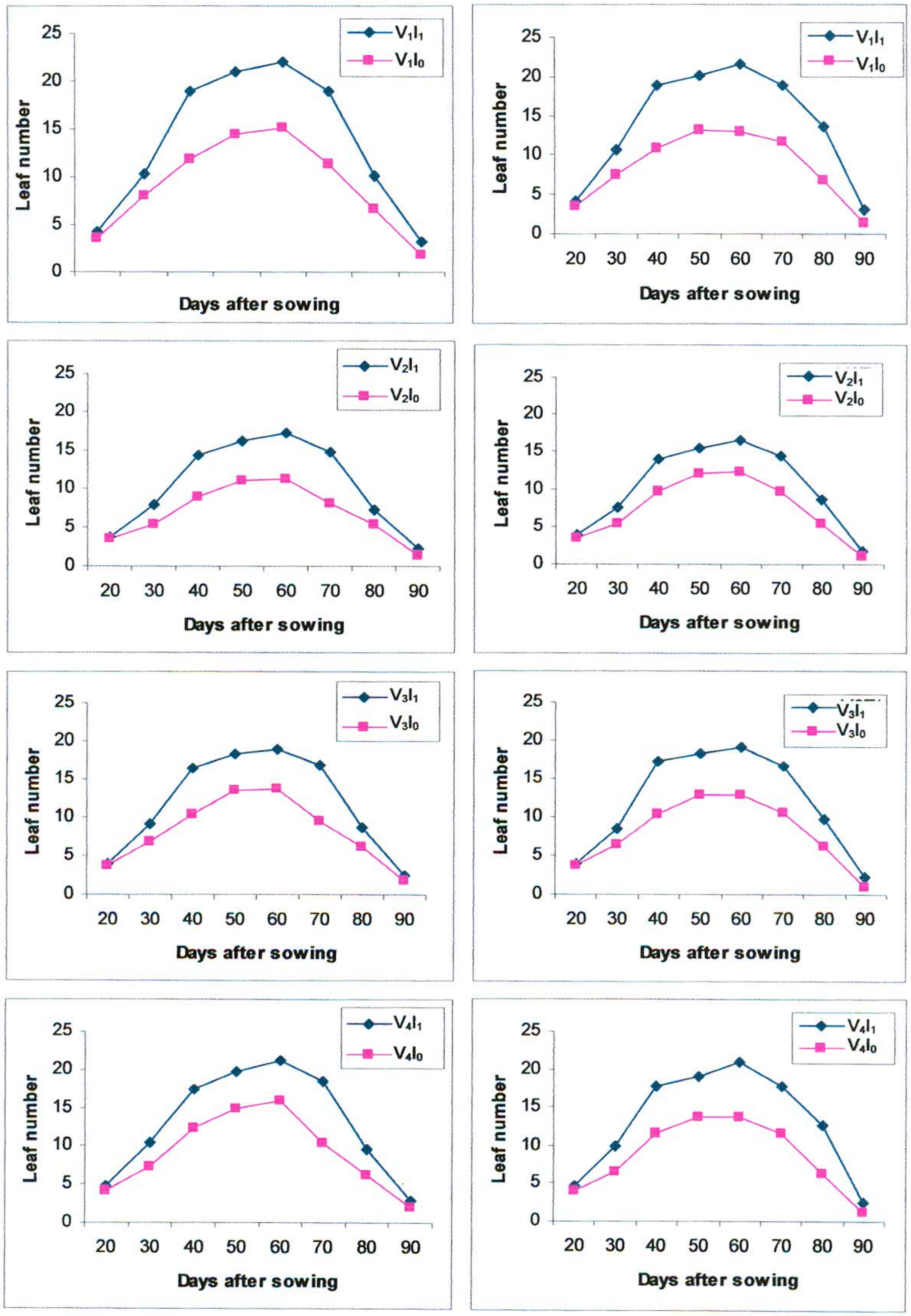


Figure 12b: Effects of soil moisture on leaf number (LN) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

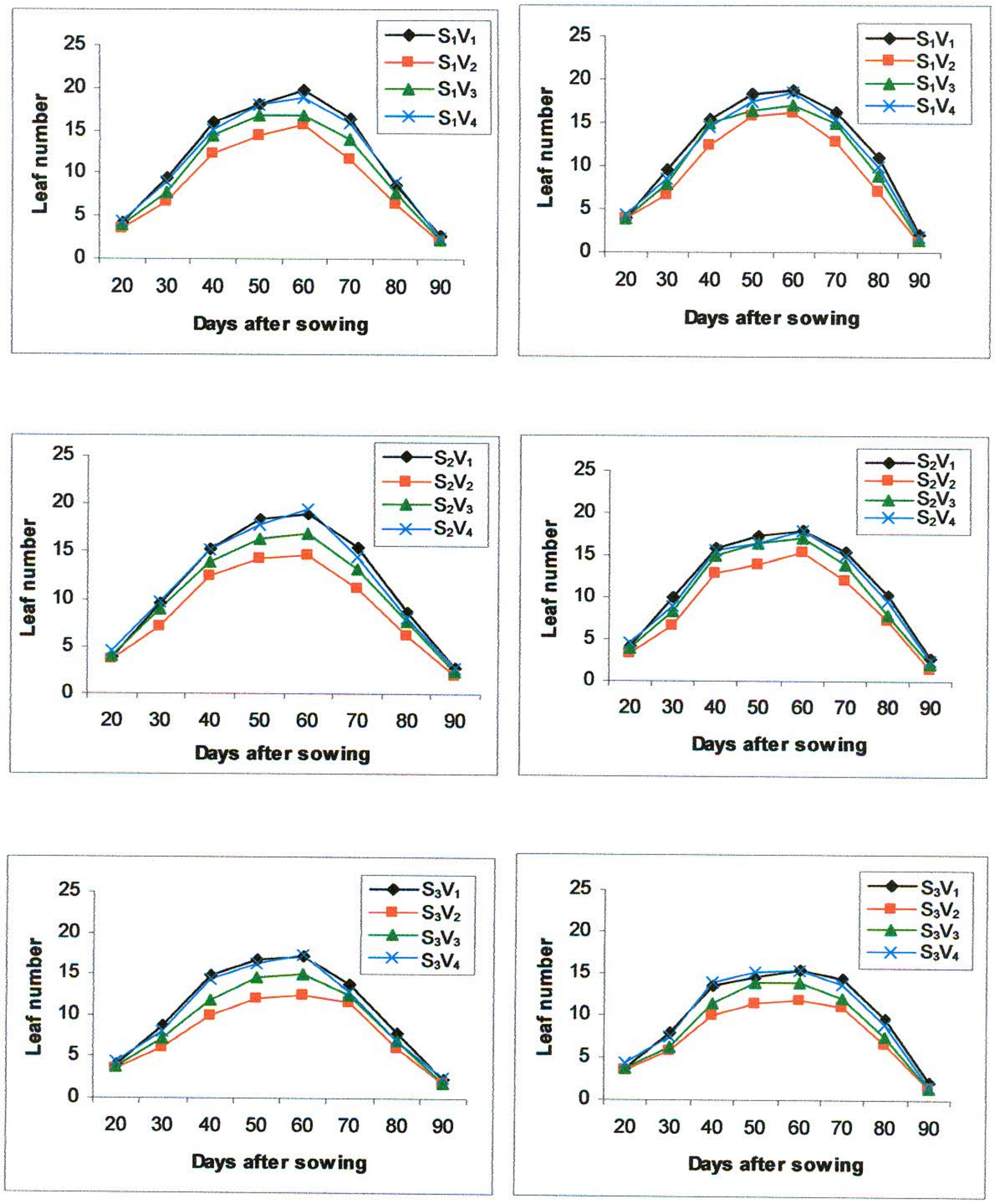


Figure12c: Effects of varieties on leaf number (LN) of four wheat varieties at different growth stages in 2005-06 experiment (left) and in 2006-07 experiment (right).

4.14 Yield and Yield Components

The grain yield in wheat is the final outcome of the contribution of different physio-morphological characters. As such ten different yield-contributing characters were studied. Data on plant height, tiller number per plant, fertile tiller number per plant, extrusion length, spike length, spikelets number per spike, grain number per spike, 1000-grain weight, total dry matter and grain yield of four wheat varieties under different sowing dates and soil moisture were collected at maturity. The results of different sowing dates and soil moisture on these yield-contributing characters are presented below.

Experiment for 2005-06

Plant height

Mean squares from the analysis of variance for plant height are shown in **Table 27a**. The results show that the sowing date, soil moisture and varietal items were significant. Significant S×I and I×V interactions were also found but S×V and S×I×V were not significant.

S_1 plants had the highest plant height in all the varieties **(Table 28a)**. The lowest plant height was in the S_3 plants in all the varieties. The irrigated plants had higher plant height than the rainfed plants in all the varieties. Among the varieties, the highest plant height was in Shatabdi followed by Shourov, Kanchan and Gaurav **(Table 28a).**

Number of tillers per plant

Mean squares from the analysis of variance as indicated in **Table 27a**, revealed that the sowing date, soil moisture and variety items were significant in the first season.

Number of tillers per plant was higher in the second sowing (S_2) than the other sowings (Table 28a). Higher number of tillers per plant was in the irrigated plants than in the rainfed plants **(Table 28a)**. Kanchan had the highest number of tillers per plant followed by Shourav, Shatabdi and Gaurav.

Number of fertile tillers per plant

From the results of analysis of variance in **Table 27a**, it was observed that the items sowing date, soil moisture, variety and I×V interaction were significant for number of fertile tillers per plant.

Generally, S_1 plants had the highest number of fertile tillers per plant than S_2 and S_3 plants in all the varieties **(Table 28a)**. The highest number of fertile tillers per plant was observed in I_1 level than I_0 level of irrigation **(Table 28a)**. In all the varieties, Shatabdi had higher number of fertile tillers number per plant followed by Shourav, Kanchan and Gaurav.

Extrusion length

From the results of analysis of variance in **Table 27a**, it was observed that the items sowing date, soil moisture, variety and S×V interaction were significant for extrusion length.

The higher extrusion length was observed in S_1 plants than the other sowings **(Table 28a).** The irrigated plants had higher extrusion length than the rainfed plants in all the varieties. Shourav produced the highest extrusion length and the lowest extrusion length **(Table 28a)** was recorded in Kanchan.

Spike length

The analysis of variance in **Table 27a**, shows that the items sowing date, soil moisture and S×I interaction were significant for spike length.

Generally S_1 plant had the highest spike length than S_2 plants and S_2 plants had the highest spike length than S_3 plants at several harvests **(Table 28a)**. In all the varieties, the irrigated plants had the higher spike length than the rainfed plants. The highest spike length was in Shourav followed by Shatabdi, Gaurav and Kanchan **(Table 28a)**.

Number of spikelets per spike

The results of analysis of variance for number of spikelets per spike are shown in **Table 27a**. The results indicated that the sowing date, soil moisture, variety and S×V interaction items were significant for number of spikelets per spike.

S_2 plants had higher number of spikelets per spike than S_1 and S_3 plants **(Table 28a)**. The highest number of spikelets per spike was observed in I_1 level than I_0 level of irrigation. Among the varieties, Shourav had the maximum number of spikelets per spike and Gaurav had the minimum **(Table 28a)**.

Number of grains per spike

The results of analysis of variance for number of grains per spike at different harvest are shown in **Table 27a**. The results indicated that the sowing date, soil moisture and variety items were significant for number of grain per spike.

In all the sowing dates, S_2 plants had the highest number of grains per spike than the other sowings **(Table 28a)**. The irrigated plants had higher number of grains per spike than the rainfed plants in all the varieties **(Table 28a)**. Among the varieties, Shourav showed the highest number of grains per spike followed by Kanchan, Shatabdi and Gaurav.

1000-grain weight

Mean squares from of analysis of variance for 1000-grain weight are shown in **Table 27a**. The results show that the sowing date, soil moisture and variety items were significant for 1000-grain weight.

Mean values of 1000-grain weight as influenced by sowing dates **(Table 28a)**. It was observed that the S_1 and S_2 plants had higher 1000-grain weight value than the S_3 plants in all the varieties **(Table 28a)**. The highest 1000-grain weight was observed in I_1 level than I_0 level of irrigation. Among the varieties, Shatabdi showed the maximum 1000 grain weight and Shourav showed the minimum 1000-grain weight.

Total dry matter

Mean squares from the analysis of variance for total dry matter are shown in **Table 27a**. The results indicated that the sowing date, soil moisture and variety items were significant. The interaction items S×I, S×V, I×V and S×I×V were also significant for total dry matter.

In all the sowing, S_1 plants had higher total dry matter than any other sowing of wheat **(Table 28a)**. The irrigated plants always had greater total dry matter than the rainfed plants **(Table 28a)**. Among the varieties, the maximum total dry matter was observed in Shatabdi and the minimum in Gaurav.

Grain yield

The results of analysis of variance for grain yield at different harvest are shown in **Table 27a**. The results shows that the sowing dates, soil moisture, variety and all the interaction items were significant for grain yield.

Generally S_1 plants had higher grain yield and S_3 plants had lower grain yield at several harvests **(Table 28a)**. The highest grain yield was observed in I_2 level than I_0 level of irrigation. Among the varieties, the highest grain yield was in Shatabdi followed by Shourav, Kanchan and Gaurav.

Experiment for 2006-07

Plant height

Mean squares from the analysis of variance for plant height are shown in **Table 27b**. The result shows that the sowing date, soil moisture and varietal items were significant at the maturity stage. Significant S×I and I×V interactions were also found but S×V and S×I×V were not significant for plant height.

S_1 plants had the highest plant height than any other sowings **(Table 28b)**. In all the varieties, the irrigated height of plants was higher than the rainfed plants **(Table 28b)**. Among the varieties, the highest plant height was in Shatabdi followed by Kanchan, Shourav and Gaurav.

Number of tillers per plant

Mean squares from the analysis of variance indicated in **Table 27b,** that the sowing date, soil moisture, variety and S×I interaction items were significant for number of tillers per plant.

Generally S_1 plant had the highest number of tillers per plant than S_2 plants and S_2 plants had the highest number of tillers per plant than S_3 plants at several harvests **(Table 28b)**. Higher number of tillers per plant was in the irrigated plants than in the rainfed plants in all the varieties. Shatabdi had the highest number of tillers per plant followed by Kanchan, Shourav and Gaurav.

Number of fertile tillers per plant

From the results of analysis of variance in **Table 27b,** it was observed that the items sowing date, soil moisture and variety were significant. The interaction items S×I, S×V and S×I×V were also significant for number of fertile tillers per plant.

Among the sowing dates, S_2 plants had the highest number of fertile tillers per plant than S_1 and S_3 plants in all the varieties **(Table 28b)**. The higher number of fertile tillers per plant was obtained in the irrigated condition **(Table 28b)**. In all the varieties, Shatabdi had higher number of fertile tillers number per plant followed by Kanchan, Shourav and Gaurav.

Extrusion length

From the results of analysis of variance in **Table 27b,** it was observed that the items sowing date, soil moisture, variety and S×I interaction were significant for extrusion length.

In all the sowings, S_2 plants had the highest extrusion length and the lowest in S_1 plants **(Table 28b)**. The highest extrusion length was observed in I_1 level than I_0 level of irrigation. Shourav had the highest extrusion length and Kanchan had the lowest extrusion length **(Table 28b)**.

Spike length

The analysis of variance in **Table 27b,** shows that the item sowing date, soil moisture and variety were significant. All the interaction items were also significant for spike length.

In all the sowings, S_2 plants had the highest spike length than the other sowings **(Table 28b)**. Spike length was higher in the irrigated plants than in the non-irrigated plants. The highest spike length was in Shourav followed by Shatabdi, Kanchan and Gaurav **(Table 28b)**.

Number of spikelets per spike

The results of analysis of variance for number of spikelets per spike are shown in **Table 27b.** The results indicated that the items sowing date, soil moisture and variety were significant. The interaction items S×I, S×V and S×I×V were also significant for number of spikelets per spike.

Generally, S_1 plants had higher number of spikelets per spike than S_2 and S_3 plants **(Table 28b)**. The irrigated plants showed the highest number of spikelets per spike than the rainfed plants. Among the varieties, Kanchan had the highest number of spikelets per spike followed by Shourav, Shatabdi and Gaurav **(Table 28b)**.

Number of grains per spike

The results of analysis of variance for number of grains per spike at different harvest are shown in **Table 27b.** The results indicated that the sowing date, soil moisture, variety and S×V items were significant in second year for number of grain per spike.

Generally S_1 plant had the highest number of grains per spike than S_2 plants and S_2 plants had the highest number of grain per spike than S_3 plants at several harvests **(Table 28b)**. In all the varieties, the irrigated plants always had higher number of grains per spike than the rainfed plants. Among the varieties, the maximum number of grains per spike was recorded in Shourav and the minimum in Gaurav.

1000-grain weight

Mean squares from of analysis of variance for 1000-grain weight are shown in **Table 27b.** The result shows that the sowing date, soil moisture and variety items were significant. The interaction items S×I, I×V and S×I×V were also significant for 1000-grain weight.

Among the sowing dates, S_1 and S_2 plants had higher 1000-grain weight value than the S_3 plants. The irrigated plants produced the highest 1000-grain weight in all the varieties. The highest 1000-grain weight was in Shatabdi and the lowest in Shourav **(Table 28b)**.

Total dry matter

Mean squares from the analysis of variance for total dry matter are shown in **Table 27b.** The results indicated that the sowing date, soil moisture and variety items were significant. All the interaction items were also significant for total dry matter.

Generally, S_1 plants had higher total dry matter than any other sowings of wheat (**Table 28b**). The highest total dry matter was observed in I_1 level than I_0 level of irrigation. The highest total dry matter was in Shatabdi followed by Shourav, Kanchan and Gaurav **(Table 28b)**.

Grain yield

The results of analysis of variance for grain yield at different harvest are shown in **Table 27b.** The result shows that the sowing date, soil moisture and variety item were significant. The interaction items S×I, S×V, I×V and S×I×V were also significant for grain yield.

In all the varieties, the higher grain yields were observed in S_1 plants than those of the other sowing dates. The irrigated plants had higher grain yield than the non-irrigated plants at several harvest **(Table 28b)**. In all the varieties, Shatabdi had higher grain yield and lower in Gaurav **(Table 28b)**.

Table 27a. Mean squares (MS) from the analysis of variance of grain yield and its components of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2005-06).

Source of Variation	df	Plant height (cm)	Tiller number/ plant	Fertile Tiller number/ plant	Extrusion length (cm)	Spike length (cm)	Spike lets No /Spike	Grain No. /Spike	1000-Grain weight (g)	Total dry matter/ Plant (g)	Grain yield (kg/ha)
Replication (R)	2	10.6805	0.5209	0.7341	0.8787	1.6568	0.5935	3.7638	0.4751	529.29	0.0157
Sowing (S)	2	99.2638**	4.9372**	2.2248**	14.4017*	25.9593**	16.2392**	26.0555*	3.5089*	337055.54**	0.6330**
Error (a)	4	2.6597	0.0876	0.1060	1.8835	0.9274	0.6931	3.0555	0.4154	766.08	0.0027
Soil moisture (I)	1	9512.501**	9.6800**	52.258**	25.2050**	225.4272**	465.0741**	12960.5**	44.7614**	4632460.68**	139.1112**
S X I	2	68.3750**	0.7016	0.9461	1.9516	8.3718*	4.5787	2.6666	3.0328	209854.59**	0.2872**
Error(b)	6	2.5833	0.1515	0.4837	0.9444	0.8386	1.5036	4.1527	0.7511	681.88	0.0074
Variety(V)	3	42.4814**	2.1204**	1.0499**	12.5825**	3.9011	14.4629**	16.4444*	30.8308**	67470.16**	0.1107**
S X V	6	8.8001	0.192	0.1325	2.1281*	5.7626	10.5020**	6.6111	1.5748	4307.57**	0.0363**
I X V	3	104.5370**	0.3677	0.8142**	1.7705	0.6483	0.6192	1.537	0.7082	80782.38**	0.1124**
S X I X V	6	7.3564	0.235	0.156	0.4855	1.8195	1.7597	4.8148	1.1179	14047.30**	0.0436**
Error (c)	36	8.2361	0.2972	0.1819	0.7447	2.676	0.9361	4.4444	0.7227	496.72	0.0029

**=significant at 1% level, *=significant at 5% level, respectively;

Table 27b. Mean squares (MS) from the analysis of variance of grain yield and its components of four wheat varieties as influenced by sowing time and soil moisture (Expt. 2006-07).

Source of Variation	df	Plant height (cm)	Tiller number/ plant	Fertile Tiller number/ plant	Extrusion length (cm)	Spike length (cm)	Spike lets No /Spike	Grain No. /Spike	1000-Grain weight (g)	Total dry matter/ Plant (g)	Grain yield (kg/ha)
Replication (R)	2	3.5970	0.2111	0.0004	0.2930	0.7351	0.4224	0.2916	0.1546	262.72	0.0058
Sowing (S)	2	353.597**	0.5117*	1.1225**	13.685**	15.2901**	11.5623**	6.5416*	27.2652**	350052.26**	0.6973**
Error(a)	4	1.4090	0.0464	0.0004	0.1060	0.3488	0.0698	0.8333	0.4328	393.24	0.0018
Soil moisture (I)	1	9637.347*	42.182**	40.395**	50.668**	263.7339*	359.9691**	11679.0138**	145.9987*	4419364.5**	143.3688**
S X I	2	17.931**	1.3041*	0.829**	7.229**	7.0543**	4.2430*	1.6805	0.6752**	202751.29**	0.4680**
Error (b)	6	0.8610	0.2201	0.0005	0.0960	0.1179	0.6900	0.8750	0.0349	70.15	0.0004
Variety(V)	3	144.458**	0.9605**	0.328**	21.457**	0.6907*	13.8673**	14.3842**	17.3081**	136196**	0.1777**
S X V	6	1.7630	0.0661	0.021**	0.5920	3.9675**	6.2537**	4.8009**	0.3947**	9438.09**	0.0121**
I X V	3	82.681**	0.1705	0.0008	0.3680	0.8527*	1.3604	1.5694	2.1820**	42229.98**	0.1175**
S X I X V	6	2.4300	0.0201	0.016**	0.3810	2.2398**	3.4763**	1.5694	0.4332**	11511.38**	0.0231**
Error (c)	36	1.2410	0.2067	0.0008	0.3240	0.2333	0.7906	1.2268	0.1121	428.07	0.0013

**=significant at 1% level, *=significant at 5% level, respectively;

Table 28a. Mean values of yield and yield components at final harvest as influenced by sowing date, soil moisture and variety (Expt. 2005-06).

Sowing (S)	PH	TN	FTN	EXL	SPL	SPS	GNS	TGW	TDM	GY(kg/h)
Sowing (S_1)	85.333	4.708	2.533	17.250	14.771	14.737	32.583	34.581	905.500	2.307
Sowing (S_2)	83.708	5.392	2.253	16.142	13.100	14.954	33.667	34.537	815.292	2.195
Sowing (S_3)	81.042	4.583	1.925	15.758	12.863	13.433	31.583	33.593	670.583	1.987
LSD 5%	1.307	0.237	0.261	1.100	0.772	0.667	1.401	0.516	22..180	0.042
Soil moisture (I)										
Irrigation (I_1)	95.528	5.278	3.089	16.975	15.347	16.916	46.028	35.127	1050.778	3.553
Rainfed (I_0)	71.194	4.511	1.385	15.792	11.808	11.833	19.194	33.347	543.472	0.773
LSD 5%	0.927	0.224	0.401	0.561	0.528	0.707	1.175	0.500	15.061	0.050
Variety (V)										
Shatabdi (V_1)	84.667	4.972	2.483	16.483	13.672	14.250	32.056	35.347	867.222	2.218
Gaurav (V_2)	81.722	4.383	1.906	15.800	13.322	13.172	31.611	34.739	719.500	2.050
Shourav (V_3)	84.444	5.044	2.300	17.528	14.189	15.222	33.722	32.378	812.667	2.214
Kanchan (V_4)	82.611	5.178	2.259	15.722	13.128	14.855	33.056	34.484	789.111	2.169
LSD 5%	1.933	0.367	0.287	0.581	1.101	0.652	1.420	0.573	15.014	0.036

Table28b. Mean values of yield and yield components at final harvest as influenced by sowing date, soil moisture and variety (Expt. 2006-07).

Sowing (S)	PH	TN	FTN	EXL	SPL	SPS	GNS	TGW	TDM	GY(kg/h)
Sowing (S_1)	81.638	5.288	1.960	13.875	13.268	15.261	33.500	38.947	896.042	2.269
Sowing (S_2)	79.792	5.008	2.380	15.615	13.905	15.039	32.667	38.735	799.292	2.201
Sowing (S_3)	78.514	4.832	1.876	14.065	11.640	12.797	31.958	36.560	656.000	1.958
LSD 5%	0.951	0.173	0.016	0.261	0.473	0.212	0.732	0.527	15.891	0.034
Soil moisture (I)										
Irrigation (I_1)	85.954	5.597	2.743	15.182	14.503	15.901	45.222	39.170	1031.528	3.547
Rainfed (I_0)	74.009	4.488	1.401	13.855	11.373	12.830	20.194	36.992	536.028	0.739
LSD 5%	0.535	0.271	0.013	0.179	0.198	0.479	0.540	0.108	4.831	0.012
Variety (V)										
Shatabdi (V_1)	83.294	5.207	2.167	13.568	13.227	14.169	33.111	39.436	900.333	2.231
Gaurav (V_2)	74.705	4.784	1.964	14.009	12.461	13.348	31.222	39.192	690.444	2.004
Shourav (V_3)	80.722	5.085	2.055	16.718	13.254	14.326	34.111	35.641	780.333	2.167
Kanchan (V_4)	81.203	5.094	2.102	13.779	12.809	15.619	32.389	38.056	764.000	2.169
LSD 5%	0.750	0.306	0.019	0.383	0.325	0.599	0.746	0.226	13.938	0.024

4.15 Correlation Coefficients between Grain Yield and Yield Components

The results of simple correlation coefficients between grain yield and its components of four wheat varieties in both the growing seasons are shown in **Tables 29 to 34**.

4.15.1 Correlation coefficients between grain yield and its components in the first sowing (S_1)

Plant height was positively and significantly correlated with most of the yield components over two growing seasons and with extrusion length and 1000-grain weight in the first season. Tiller number showed positively significant correlation with all the yield components in both the years except with extrusion length and 1000-grain weight. Fertile tiller number had positive significant correlation with most of the characters in both the experimental years and with extrusion length in the first year.

Extrusion length was positively significant correlated with spike length, number of spikelets per spike, number of grains per spike, total dry matter and grain yield in the first year. Spike length showed positive significant correlation with number of spikelets per spike, number of grains per spike, total dry matter and grain yield in both the years. Number of spikelets per spike had positive significant correlation with the number of grains per spike, total dry matter and grain yield in both the years and 1000-grain weight in the first year.

Number of grains per spike was significantly associated with total dry matter, 1000-grain weight and grain yield in both the years. Thousand grain weights had positive and significant correlation with total dry matter and grain yield and total dry matter was also significantly correlated with grain yield in both the years.

4.15.2 Correlation coefficients between grain yield and its components in the second sowing (S_2)

In the second sowing, plant height had positively significant correlation with most of the yield components in both the years and with tiller number in second year. Tiller number was positive significant correlation with spike length, number of grains per spike, total dry matter and grain yield in both the years and significantly correlated with fertile tiller and 1000-grain weight in the second season and with extrusion length and spikelets number per spike in the first year. Fertile tiller number had positively significant correlation with all the characters in both the experimental years and significant correlation with extrusion length and spikelets number per spike in the first year.

Extrusion length was significantly associated with spike length in both the years and significantly correlatied with number of spike lets per spike, number of grains per spike, total dry matter and grain yield in the first year. Spike length showed positively significant correlation with number of spikelets per spike, number of grains per spike, total dry matter and grain yield in both the seasons.

Number of spikelets per spike had positively and significantly correlated with number of grains per spike, total dry matter and grain yield in both the experimental years. Number of grains per spike was significantly associated with total dry matter, 1000-grain weight and grain yield in both the years. Thousand grain weights and total dry matter were also significantly correlated with all the yield components in both the years.

Table 29. Simple correlation coefficient between grain yield and yield components of four wheat varieties as influenced by first sowing (S_1) in the irrigated and rainfed conditions. (Upper diagonal shows values in 2006-07 and lower diagonal shows values in 2005-06 experiment)

	Plant height (cm)	Tiller no./plant	Fertile tiller no./plant	Extrusion length	Spike length	No. of spike lets /spike	No. of grains/ spike	1000-grain weight	Total dry matter	Grain yield
	1	2	3	4	5	6	7	8	9	10
1	-	0.447*	0.546**	0.298	0.868**	0.825**	0.752**	0.208	0.794**	0.743**
2	0.417*	-	0.575**	0.066	0.578**	0.469*	0.699**	0.079	0.699**	0.690**
3	0.817**	0.436*	-	0.298	0.732**	0.568**	0.856**	0.412*	0.798**	0.861**
4	0.612**	0.334	0.669**	-	0.301	0.324	0.351	0.019	0.236	0.324
5	0.564**	0.496*	0.426*	0.625**	-	0.863**	0.855**	0.317	0.843**	0.867**
6	0.859**	0.509*	0.859**	0.703**	0.662**	-	0.671**	0.167	0.676**	0.687**
7	0.934**	0.453*	0.833**	0.539**	0.596**	0.834**	-	0.455*	0.948**	0.979**
8	0.634**	0.101	0.569**	0.244	0.393	0.537**	0.619**	-	0.504*	0.956**
9	0.961**	0.541**	0.894**	0.563**	0.568**	0.864**	0.951**	0.641**	-	0.490*
10	0.951**	0.485*	0.861**	0.552**	0.615**	0.861**	0.986**	0.971**	0.641**	-

**=significant at 1% level, *=significant at 5% level, respectively;

Table 30. Simple correlation coefficient between grain yield and yield components of four wheat varieties as influenced by second sowing (S_2) in irrigated and rainfed conditions. (Upper diagonal shows values in 2006-07 and lower diagonal shows values in 2005-06 experiment)

	Plant height (cm)	Tiller no./plant	Fertile tiller no./plant	Extrusion length	Spike length	No. of spike lets /spike	No. of grains/ spike	1000-grain weight	Total dry matter	Grain yield
	1	2	3	4	5	6	7	8	9	
1	-	0.617**	0785**	0.607**	0.558**	0.541**	0.750**	0.321	0.870**	0.783**
2	0.389	-	0.797**	0.325	0.438*	0.231	0.715**	0.491*	0.811**	0.833**
3	0.869**	0.333	-	0.324	0.439*	0.392	0.913**	0.511*	0.911**	0.936**
4	0.578**	0.404*	0.497*	-	0.405*	0.248	0.349	-0.238	0.395	0.342
5	0.871**	0.424*	0.838**	0.579**	-	0.465*	0.467*	0.197	0.518**	0.487*
6	0.856**	0.525**	0.775**	0.612**	0.942**	-	0.464*	-0.001	0.456*	0.448*
7	0.952**	0.451*	0.853**	0.541**	0.904**	0.873**	-	0.443*	0.934**	0.991**
8	0.379	0.151	0.472*	-0.195	0.332	0.201	0.439*	-	0.525**	0.962**
9	0.942**	0.411*	0.909**	0.538**	0.868**	0.801**	0.916**	0.458*	-	0.476*
10	0.972**	0.426*	0.905**	0.576**	0.913**	0.874**	0.989**	0.956**	0.451*	-

**=significant at 1% level, *=significant at 5% level, respectively;

4.15.3 Correlation coefficients between grain yield and its components in the third sowing (S_3)

Plant height was positively significant correlated with fertile tiller number per plant, spike length, number of spikelets per spike, number of grain per spike, total dry matter and 1000-grain weight in both the experimental years. However, positive non-significant correlation was detected between plant heights with extrusion length in both the years and tiller number in the second year. Tiller number had positive significant correlation with all the yield components over two growing seasons except with extrusion length and 1000-grain weight.

Fertile tiller number was significantly relation with spike length, number of spikelets per spike, number of grains per spike, total dry matter, grain yield in both the years and with 1000-grain weight in the second season. Extrusion length was found to be positively significant correlated with spike length and number of grains per spike in the second season.

Spike length was found to be positively significant relation with number of spikelets per spike, grain number per spike, total dry matter, total dry matter and grain yield in the two years except 1000-grain weight in the first year. Spike lets number per spike had significantly correlated with grain number per spike, total dry matter and grain yield in both the years except 1000-grain weight in the second year. Grain number per spike had significantly correlated with total dry matter and grain yield in both the seasons except 1000-grain weight in first year.

1000-grain weight and total dry matter were also significantly correlated with all the yield components in both the experimental years.

4.15.4 Association between grain yield and its components of the irrigated plants

Plant height was positively and significantly correlated with fertile tiller number, extrusion length, spike length, number of spikelets per spike, total dry matter and grain yield in both the experimental years and number of grain per spike in the second season. Tiller number had positively significant correlation with number of spikelets per spike in both the years and thousand grain weights, total dry matter, grain yield in the second year.

Fertile tiller number was positively significant correlated with extrusion length and grain yield in both the years and with spike length and total dry matter in the first year. Extrusion length had positive significantly association with number of grain per spike and negative but significant relation with thousand grain weights in both the experimental years and positively significant associated with spike length, number of spikelets per spike, total dry matter and grain yield in the first season.

Spike length had positive significant correlation with number of spikelets per spike, number of grain per spike, total dry matter and grain yield in both the years. Number of spikelets per spike had positively and significantly correlated with number of grain per spike, total dry matter and grain yield in both the seasons. Number of grain per spike showed significantly relation with total dry matter and grain yield in both the years. Thousand grain weights and total dry matter were also significantly correlated with all the yield components in both the experimental years.

Table 31. Simple correlation coefficient between grain yield and yield components of four wheat varieties as influenced by third sowing (S_3) in irrigated and rainfed condition. (Upper diagonal shows values in 2006-07 and lower diagonal shows values in 2005-006 experiment)

	Plant height (cm)	Tiller no./plant	Fertile tiller no./plant	Extrusion length	Spike length	No. of spike lets /spike	No. of grains/ spike	1000-grain weight	Total dry matter	Grain yield
	1	2	3	4	5	6	7	8	9	
1	-	0.367	0.909**	0.231	0.904**	0.829**	0.904**	0.563**	0.917**	0.923**
2	0.741**	-	0.432*	0.156	0.410*	0.452*	0.541**	0.182	0.599**	0.531**
3	0.739**	0.684**	-	0.366	0.895**	0.841**	0.907**	0.422*	0.913**	0.919**
4	0.286	0.241	0.295	-	0.468*	0.379	0.436*	-0.351	0.332	0.384
5	0.639**	0.441*	0.568**	0.271	-	0.897**	0.943**	0.431*	0.931**	0.951**
6	0.857**	0.719**	0.654**	0.273	0.697**	-	0.925**	0.379	0.848**	0.918**
7	0.971**	0.747**	0.769**	0.347	0.672**	0.875**	-	0.438*	0.954**	0.991**
8	0.426*	0.309	0.184	-0.381	0.377	0.421*	0.396	-	0.471*	0.962**
9	0.948**	0.813**	0.742**	0.309	0.630**	0.851**	0.947**	0.407*	-	0.488*
10	0.971**	0.728**	0.742**	0.325	0.679**	0.865**	0.982**	0.946**	0.427*	-

**=significant at 1% level, *=significant at 5% level, respectively;

Table 32. Simple correlation coefficient between grain yield and yield components of four wheat varieties as influenced by irrigated condition. (Upper diagonal shows values in 2006-2007 and lower diagonal shows values in 2005- 2006 experiment)

	Plant height (cm)	Tiller no./plant	Fertile tiller no./plant	Extrusion length	Spike length	No. of spike lets /spike	No. of grains/ spike	1000-grain weight	Total dry matter	Grain yield
	1	2	3	4	5	6	7	9	8	10
1	-	0.099	0.382*	0.330*	0.545**	0.562**	0.501**	-0.106	0.502**	0.539**
2	0.045	-	0.209	-0.094	0.153	0.331*	0.224	0.340*	0.522**	0.468**
3	0.530**	0.177	-	0.330*	0.059	0.082	-0.051	0.181	0.184	0.367*
4	0.603**	-0.008	0.429**	-	0.321	0.064	0.364*	-0.338*	0.019	0.129
5	0.510**	0.024	0.497**	0.634**	-	0.570**	0.331*	-0.043	0.425**	0.455**
6	0.464**	0.392*	0.322	0.361*	0.514**	-	0.364*	-0.195	0.356*	0.397*
7	0.069	0.273	0.213	0.341*	0.407*	0.372*	-	0.117	0.445**	0.409*
8	0.065	0.048	0.115	-0.345*	0.051	-0.017	-0.152	-	0.526**	0.904**
9	0.759**	0.119	0.669**	0.540**	0.556**	0.408*	0.459**	0.385*	-	0.378*
10	0.687**	0.141	0.659**	0.652**	0.607**	0.523**	0.335*	0.885**	0.341*	-

**=significant at 1% level, *=significant at 5% level, respectively.

4.15.5 Association between grain yield and its components of the rainfed plants

Plant height was found to be non-significant correlation with tiller number, extrusion length, thousand grain weight and grain yield in both the experimental years. Plant height had positive significant correlation with spike length, number of spikelets per spike and total dry matter in second year and fertile tiller number and number of grain per spike in the first year. Tiller number was positively significant correlated with number of grain per spike, total dry matter and grain yield in the first season.

Fertile tiller number had positively significant association with total dry matter in the first year. Extrusion length was significantly correlated with spike length, number of spikelets per spike in both the seasons. Spike length showed positive significant relationship with number of spikelets per spike and grain yield in the both years and with total dry matter in the second year.

Number of spikelets per spike had positively and significantly correlated with number of grain per spike, total dry matter and grain yield in the second year. Number of grain per spike was found to be positively significant association with grain yield in both the years. Thousand grain weights had significantly correlated with grain yield in the first year. Total dry matter showed non-significant correlated with grain yield in both the experimental years.

4.15.6 Association between grain yield and its components in all the sowing dates and soil moisture levels

Plant height had positively significant correlation with all the yield components characters in both the experimental years. Tiller number showed positive association with extrusion length but the value was not significant and positively significant correlation with the rest characters in both the years and significantly correlated thousand grain weights in the second season.

Fertile tiller number showed positive significant relation with all the yield components in both the experimental years. Extrusion length was found to be positively and significantly correlated with most of the characters but it showed non-significant correlation with thousand grain weights in both the seasons.

Spike length was found to be positively and highly significant association with number of spikelets per spike, number of grain per spike, thousand grain weights, total dry matter and grain yield in both the years. Number of spikelets per spike showed positive significant correlation with number of grain per spike, thousand grain weights and grain yield over two growing seasons.

Number of grain per spike, thousand grain weights and total dry matter were also significantly correlated with all the yield components in both the experimental years.

Table 33. Simple correlation coefficient between grain yield and yield components of four wheat varieties as influenced by rainfed condition. (Upper diagonal shows values in 2006-2007 and lower diagonal shows values in 2005- 2006 experiment)

	Plant height (cm)	Tiller no./plant	Fertile tiller no./plant	Extrusion length	Spike length	No. of spike lets /spike	No. of grains/ spike	1000-grain weight	Total dry matter	Grain yield
	1	2	3	4	5	6	7	8	9	10
1	-	-0.209	0.191	-0.079	0.398*	0.383*	0.097	0.226	0.609**	0.213
2	-0.007	-	-0.121	-0.007	-0.166	-0.04	0.226	-0.366	-0.076	0.022
3	0.336*	0.081	-	0.122	0.161	0.063	0.154	0.129	0.135	0.034
4	-0.042	0.083	0.158	-	0.348*	0.335*	-0.121	-0.257	0.055	0.176
5	0.217	-0.129	0.041	0.349*	-	0.699**	0.094	0.319	0.501**	0.304
6	0.117	0.267	0.213	0.347*	0.475**	-	0.389*	0.294	0.435**	0.578**
7	0337*	0.399*	0.249	0.019	-0.272	0.087	-	-0.134	0.235	0.759**
8	0.103	-0.007	0.027	-0.134	0.061	-0.081	-0.026	-	0.246	0.323
9	0.179	0.509**	0.345*	0.162	0.027	0.254	0.239	-0.286	-	0.092
10	0.154	0.353*	0.104	0.296	0.207	0.215	0.418*	0.377*	0.281	-

**=significant at 1% level, *=significant at 5% level, respectively.

Table34. Simple correlation coefficient between grain yield and yield components of four wheat varieties as influenced by sowing time and soil moisture condition. (Upper diagonal shows values in 2006-2007 and lower diagonal shows values in 2005- 2006 experiment)

	Plant height (cm)	Tiller no./plant	Fertile tiller no./plant	Extrusion length	Spike length	No. of spike lets /spike	No. of grains/ spike	1000-grain weight	Total dry matter	Grain yield
	1	2	3	4	5	6	7	8	9	10
1	-	0.508**	0.695**	0.349**	0.735**	0.695**	0.794**	0.371**	0.812**	0.806**
2	0.463**	-	0.589**	0.163	0.457**	0.404**	0.684**	0.301*	0.720**	0.700**
3	0.869**	0.456**	-	0.390**	0.644**	0.551**	0.839**	0.450**	0.761**	0.861**
4	0.505**	0.225	0.509**	-	0.426**	0.319**	0.347**	-0.111	0.260**	0.324**
5	0.680**	0.273*	0.643**	0.535**	-	0.805**	0.719**	0.443**	0.711**	0.731**
6	0.844**	0.554**	0.766**	0.510**	0.762**	-	0.653**	0.358**	0.625**	0.644**
7	0.940**	0.523**	0.831**	0.426**	0.687**	0.842**	-	0.418**	0.862**	0.983**
8	0.500**	0.226	0.457**	0.030	0.384**	0.399**	0.483**	-	0.554**	0.907**
9	0.924**	0.493**	0.893**	0.545**	0.676**	0.803**	0.862**	0.548**	-	0.474**
10	0.965**	0.497**	0.866**	0.467**	0.719**	0.854**	0.981**	0.913**	0.516**	-

**=significant at 1% level, *=significant at 5% level, respectively.

4.16. Path Coefficient Analysis

The correlation coefficients between grain yield and other yield components were partitioned into direct and indirect effects through path coefficient analysis in order to find out more realistic figure of relationship. Direct and indirect effects of the component characters on grain yield are presented in **Tables 35 to 36 and Figures 13 to 14.**

The results of path coefficient analysis are described below.

4.16.1. Path coefficient analysis in 2005-2006

The results of path-coefficient analysis are presented in **Table 35**. This table shows that the highest positive direct effect was contributed by fertile tiller number on grain yield and it was followed by spikelets per spike and plant height. Tiller number and thousand grain weight showed lowest direct effect. Spikelets per spike had positive direct effect (4.720) on yield. However, this trait contributed to grain yield through large indirect effects of total dry matter (7.391), plant height (1.959) and spike length (1.465). On the other hand, plant height (-4.484) and total dry matter (-4.156) had negative indirect effect on grain yield through thousand grain weight and plant height. Total dry matter also contributed to grain yield through positive indirect effect of number of grains per spike, spike length and spikelets per spike. The indirect effect of total dry matter through plant height (-4.156), tiller number (-1.034), fertile tiller number (-2.970) and extrusion length (-1.165) were negative. Fertile tiller number showed the negative indirect effect through maximum characters. It had positive indirect effect through tiller number (0.005) and thousand grain weight (0.189). The character spike length showed the negative indirect effect through the fertile tiller number (-0.029), extrusion length (-0.521) and spikelets per spike (-1.441) and thousand grain weight (-0.240) on grain yield.

The considerable amount of residual effect (-4.357) indicated that some other characters which have not been included in this study have also effect on grain yield in this crop.

Table 35. Path coefficient analysis sowing in 2005-2006 showing direct and indirect effects of grain yield components on wheat.

Characters	Grain yield vs									rp with GY
	PH	TN	FTN	EXL	SPL	Spi/ Spike	No. of grain/spi	TGW	TDM	
PH	**3.414**	0.683	-0.529	-0.357	1.465	-2.083	-1.176	0.032	-4.156	0.965
TN	1.335	**0.893**	0.005	0.011	0.490	-1.037	-1.924	0.029	-1.034	0.497
FTN	-0.571	0.003	**4.812**	-0.056	-0.029	-0.096	-0.259	0.112	-2.970	0.866
EXL	-0.725	0.013	-0.100	**0.916**	-0.521	-0.123	0.450	0.374	-1.165	0.467
SPL	1.959	0.338	-0.039	-0.339	**2.306**	-1.711	0.865	-0.174	0.094	0.719
Spi/Spike	-2.357	-0.603	-0.098	-0.067	-1.441	**4.720**	-0.836	0.107	0.249	0.854
No. of grain/spi	-1.236	-0.978	-0.249	0.213	0.627	-0.728	**3.356**	0.172	7.391	0.982
TGW	0.071	0.028	0.189	0.337	-0.240	0.178	0.335	**0.901**	-1.288	0.516
TDM	-4.484	-0.565	-2.827	-0.593	0.062	0.230	2.976	-0.730	**2.390**	0.913

Residual effect = -4.357

Bold number denotes the direct effect

PH = Plant height
TN = Tiller number
FTN = Fetile tiller number
EXL = Extrusion length
SPL = Spike length
Spi/Spike = Spikelets per spike
No. of grain/sp = Number of grain per spike
TDM = Total dry matter
TGW = Thousand grain weight

DIAGRAM: PATH COEFFICIENT ANALYSIS

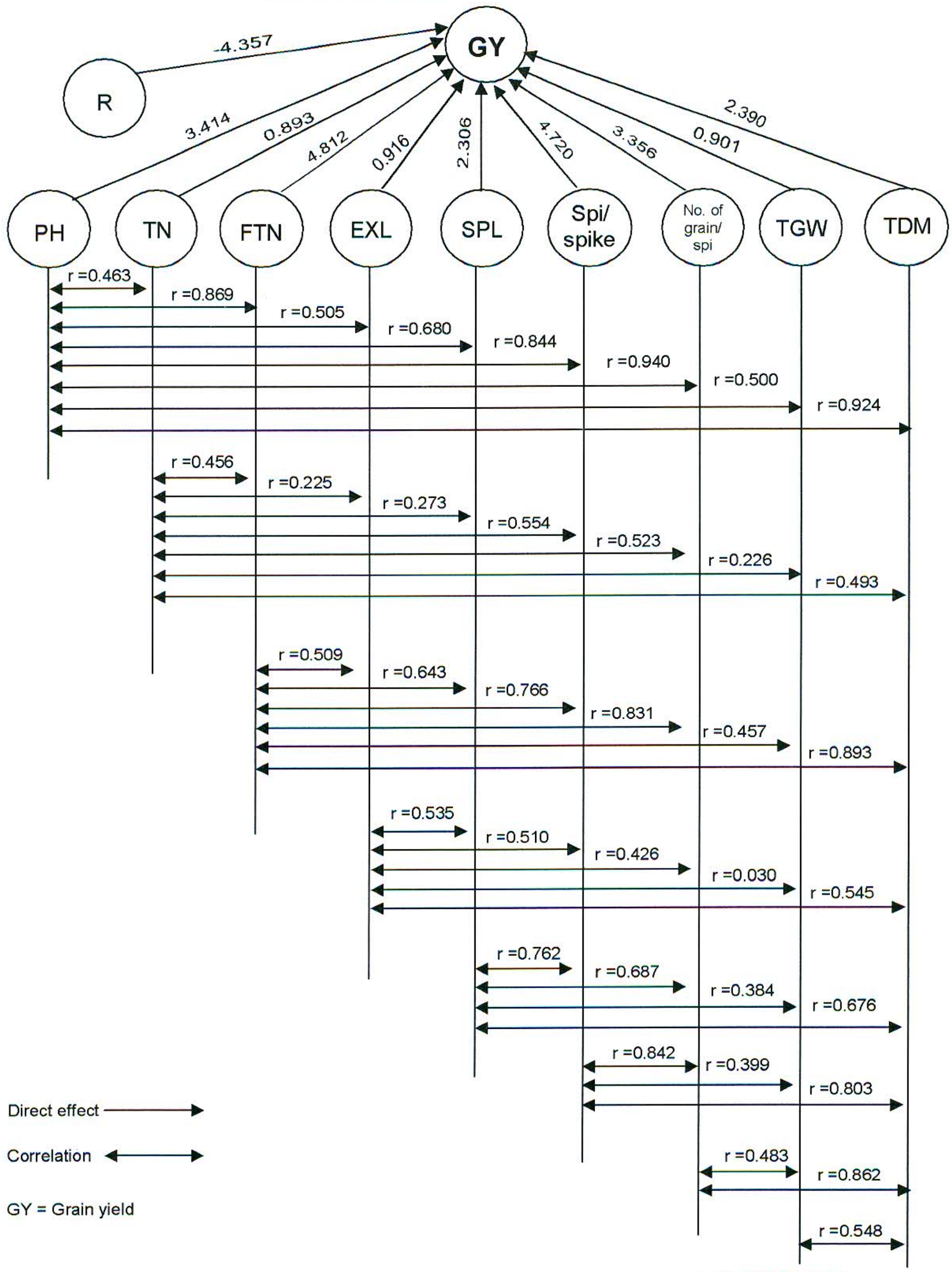


Figure 13. Path diagram of different grain yield contributing characters on yield (2005-2006)

4.16.2. Path coefficient analysis in 2006-2007

The results of path coefficient analysis in 2006-07 are presented in **Table 36.** This table shows that the highest positive direct effect was contributed by fertile tiller number (3.626) on grain yield and it was followed by plant height (3.391) and grain number per spike (3.321).

Extrusion length and thousand grain weight per plant showed the lowest direct effect. However, this trait contributed to grain yield through large indirect effects of pant height (0.649), tiller number (0.564) and grain number per spike (0.546). On the other hand, grain number per spike (-2.502) and total dry matter (-2.301) had negative indirect effect on grain yield through fertile tiller number and plant height.

Plant height showed negative indirect effect through the majority of the characters. It had positive indirect effect through tiller number (0.649) and thousand grain weight (0.463). The character fertile tiller number showed negative indirect effect through the tiller number (-0.226), extrusion length (-0.573), grain number per spike (-2.194) and thousand grain weight (-0.597) on grain yield. Spike length showed negative indirect effect through all the characters except tiller number and fertile tiller number. Grain number per spike showed negative indirect effect through the maximum characters. It had positive indirect effect through extrusion length (0.103) and thousand grain weight (0.546) on grain yield.

Total dry matter also found to contribute to grain yield through positive indirect effect of fertile tiller number (0.044) and spikelets per spike (0.282).

The indirect effect of total dry matter through plant height (-2.301), tiller number (-1.767), extrusion length (-0.015), spike length (-0.386), grain number per spike (-2.082) and thousand grain weight (-1.406) were negative.

The considerable amount of residual effect (-4.035) indicated that some other characters which have not been included in this study had also effect on grain yield in wheat crop.

It may be concluded from the results of the present study that total dry matter, fertile tiller number, spike length, number of grains per spike and plant height are the major components of grain yield in wheat and hence maximum stress should be given on these characters while selection is done for maximum grain yield.

Table 36: Path coefficient analysis sowing in 2006-2007 showing direct and indirect effects of grain yield components on wheat.

Characters	Grain yield vs									rp with GY
	PH	TN	FTN	EXL	SPL	Spi/ Spike	No. of grain/spi	TGW	TDM	
PH	**3.391**	0.564	-0.227	-0.007	-0.381	-0.471	-0.846	0.273	-2.301	0.806
TN	0.649	**1.711**	-0.226	0.063	0.064	-0.001	-0.717	0.215	-1.767	0.700
FTN	-0.213	-0.183	**3.626**	-0.216	0.018	0.150	-2.502	-0.328	0.044	0.861
EXL	-0.018	0.136	-0.573	**0.511**	-0.582	0.087	0.103	0.329	-0.015	0.324
SPL	-0.420	0.062	0.021	-0.258	**3.098**	-1.315	-0.460	-0.307	-0.386	0.731
Spi/Spike	-0.590	-0.002	0.201	0.044	-1.493	**1.999**	-0.479	0.004	0.282	0.644
No. of grain/spi	-0.696	-0.511	-2.194	0.034	-0.342	-0.314	**3.321**	0.264	-2.082	0.982
TGW	0.463	0.317	-0.597	0.225	-0.474	0.005	0.546	**0.925**	-1.406	0.474
TDM	-2.046	-1.364	0.042	-0.006	-0.311	0.200	-2.253	-0.735	**3.063**	0.907

Residual effect = -4.035

Bold number denotes the direct effect

PH = Plant height
TN = Tiller number
FTN = Fetile tiller number
EXL = Extrusion length
SPL = Spike length
Spi/Spike = Spikelets per spike
No. of grain/sp = Number of grain per spike
TDM = Total dry matter
TGW = Thousand grain weight

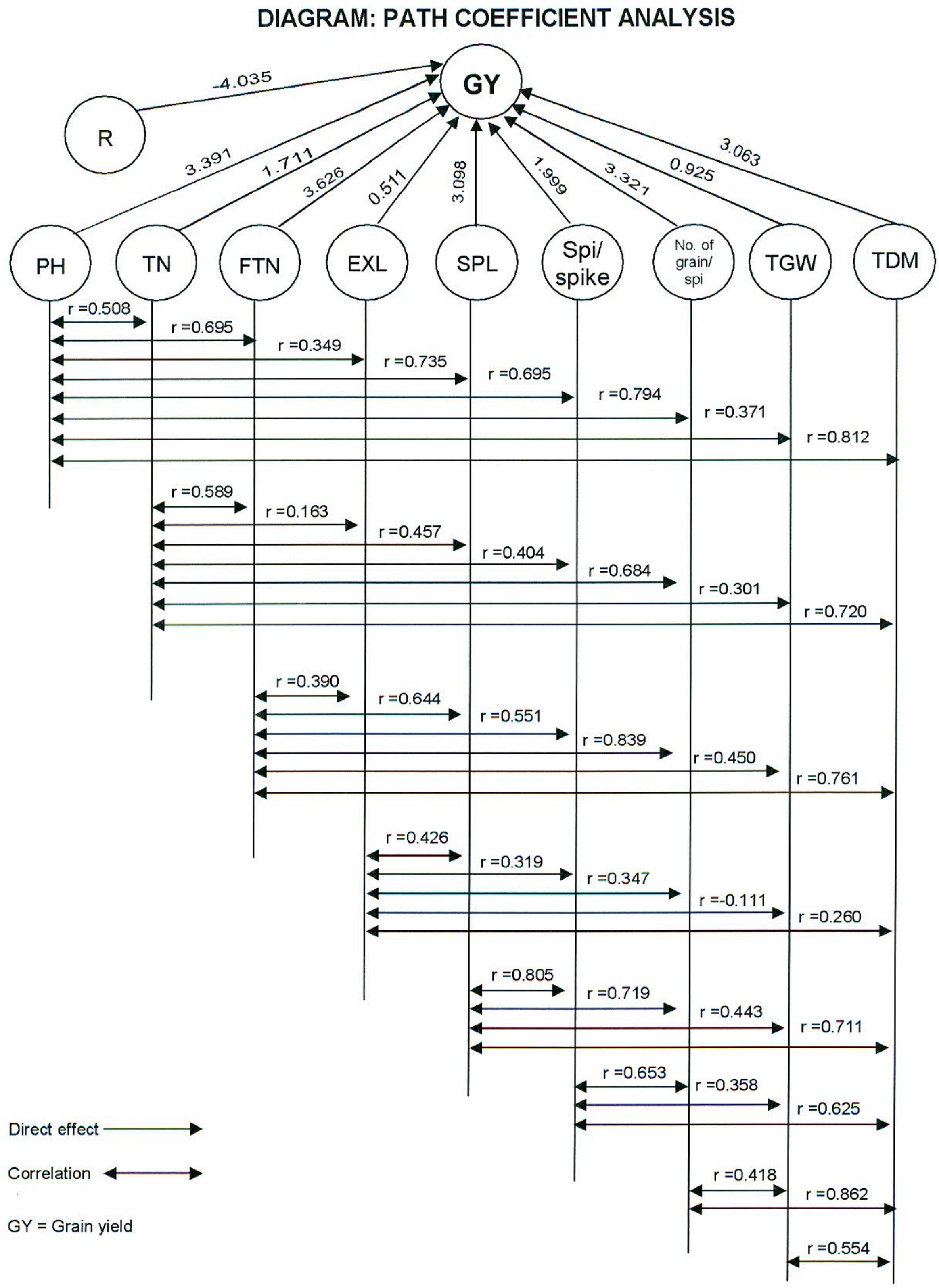


Figure 14. Path diagram of different grain yield contributing characters on yield (2006-2007)

4.17 Genotype-Environment Interaction and Stability Parameters

The phenotypic stability of each variety was expressed by two parameters: the slope of regression line and sum of squares of deviation from regression. A stable variety was defined as "one with unit regression (bi=1) and low deviation from linearity ($\bar{S}^2_{di}$)". Analysis of variance showed that the mean sum of squares due to genotype (G) and environment (E) difference tested against the G×E interaction were significant for all the traits studied, indicating the presence of wide variability among the genotypes and environments. The significant estimates of G×E interaction indicated that the characters were unstable and may considerably fluctuate with change in environments. The G×E (linear) interaction was significant against pooled deviation suggesting the possibility of the variation for all the characters (**Table 37**).

The distribution of four bi values was found to be heterogeneous in most of the characters and hence all these genotypes had different response to different environments. Grand mean ($\bar{X}$), regression coefficients (b_i), standard error of bi (Sbi) and stability ($\bar{S}^2_{di}$) values for different yield and its component characters are shown in **Table 38**.

In case of plant height two genotypes viz., Shatabdi and Shourav showed above average responses (bi>1) at the maturity stage. The grand mean ranged from 78.501 to 84.397 and the maximum grand mean was shown by Shatabdi and Gaurav showed the minimum grand mean. The regression coefficients ranged from 0.797 to 1.202. All the varieties showed highly significant regression coefficients (b_i) values. On the other hand, genotype Shatabdi had higher mean performance than the overall mean, regression value nearly one (bi=1.069) and stability ($\bar{S}^2_{di}$) value nearly zero ($\bar{S}^2_{di}$=0.213). This genotype had been regarded as stable and widely adapted.

For tiller number per plant two genotypes viz., Shatabdi and Gaurav showed above average responses (bi>1) at the maturity stage. The grand means ranged from 4.584-5.136 and regression coefficients ranged from 0.575 to 1.336. The highest grand mean was shown by Kanchan and the maximum regression value was shown by Shatabdi. On the other hand, the lowest grand mean was shown by Gaurav and Shourav showed the lowest regression value. The $\bar{S}^2_{di}$ values ranged from -0.037 to 0.012. Only one genotype viz., Kanchan with higher mean, bi<1 (bi=0.969) and stability value nearly zero ($\bar{S}^2_{di}$=-0.037) were unstable. All the regression coefficient (b_i) values were found to be highly significant in tiller number per plant at the maturity except Shourav.

In case of fertile tiller number per plant two genotypes viz., Shourav and Gaurav showed below average responses (bi<1). The grand mean ranged from 1.941 to 2.332 and regression parameter ranged from 0.876 to 1.110. Gaurav showed the lowest grand mean and below average response (bi<1). On the other hand, Shatabdi had the highest grand mean, above b_i value (bi=1.110) and stability value was nearly zero ($\bar{S}^2_{di}$=-0.006), indicating its instability to varying environment. All the varieties had more, less or similar $\bar{S}^2_{di}$ values. All the varieties showed highly significant regression coefficients (b_i) values.

In case of number of grains per spike, all the regression coefficient (bi) values were highly significant. The grand mean ranged from 31.917 to 33.417 and regression coefficients ranged from 0.972 to 1.047. The highest grand mean was shown by Shatabdi and the maximum regression value was shown by Shourav, On the other hand, the lowest grand mean was shown by Gaurav and Kanchan showed the lowest regression value. Two varieties showed below average response (bi<1). For number of grains per spike only one genotype viz., Shatabdi possessing higher mean than the overall mean, regression value (bi=1.000) and stability ($\bar{S}^2_{di}$) value nearly zero ($\bar{S}^2_{di}$ =0.034) showed wider stability over all sites across environments.

In case of thousand grain weight, three genotypes viz., Shatabdi, Gaurav and Shourav showed above average responses (bi>1). The grand mean ranged from 34.010 to 37.391, the regression coefficients ranged from 0.487 to 1.275 and stability ranged from -0.198 to 0.592. The lowest grand mean and the maximum stability value were recorded for Shourav. However, Shatabdi had higher mean performance, regression value nearly one (bi=1.110), and stability ($\bar{S}^2_{di}$) value nearly zero ($\bar{S}^2_{di}$=0.192), indicating its stability for favourable environments. All the varieties showed highly significant regression coefficient (b_i) values.

For grain yield three genotypes viz., Shatabdi, Kanchan and Shourav showed above average responses (bi>1). The grand means ranged from 2.027 to 2.214 and the regression values ranged from 0.923 to 1.029. The maximum grand mean was shown by Shatabdi but the same variety showed the b_i value nearly one (bi=1.020). On the other hand, Gaurav showed the lowest grand mean and b_i value. For this character, all the four varieties tested showed more, less or similar $\overline{S}^2_{di}$ values. Only one genotype viz. Shatabdi had higher mean, regression value nearly one (bi=1.020) and stability value nearly zero ($\overline{S}^2_{di}$=0.001), indicating its stability for favourable environments. In case of grain yield all the regression coefficient values were found to be highly significant.

Table 37. Pooled analysis of variance for grain yield and its components in wheat over six environments (Eberhart and Russell's 1966 model).

Source	df	Plant height		Tiller number		Fertile tiller number	
		SS	MS	SS	MS	SS	MS
Variety	3	109.478	36.493**	1.201	0.400**	0.471	0.157**
Environments	5	2022.365	404.473**	6.256	1.251**	15.654	3.131**
Var. × Env.	15	76.469	5.098**	1.198	0.080	0.264	0.018
Pooled error	36		0.967		0.049		0.008

Source	df	Grain number/spike		1000-grain weight		Grain yield (kg/ha)	
		SS	MS	SS	MS	SS	MS
Variety	3	11.689	3.896**	40.804	13.601**	0.125	0.042**
Environments	5	4072.867	814.573**	37.972	7.594**	46.697	9.339**
Var. × Env.	15	10.110	0.674	9.359	0.624**	0.165	0.011**
Pooled error	36		0.562		0.111		0.001

Table 38. Estimates of stability parameters [Grand mean ($\overline{X}$), regression coefficients (bi) and stability ($\overline{S}^2_{di}$)] for plant height, tiller number, fertile tiller number, number of grains per spike, thousand grain weight and grain yield.

Character	Stability parameter	Variety			
		V_1	V_2	V_3	V_4
Plant height (cm)	$\overline{X}$	84.397	78.501	82.583	81.907
	bi	1.069**	0.797**	1.202**	0.931**
	Sbi	0.056	0.084	0.057	0.038
	$\overline{S}^2_{di}$	0.213	2.612	0.704	-0.242
Tiller number	$\overline{X}$	5.090	4.584	5.065	5.136
	bi	1.336**	1.120**	0.575*	0.969**
	Sbi	0.056	0.084	0.057	0.038
	$\overline{S}^2_{di}$	0.004	0.005	0.012	-0.037
Fertile tiller number	$\overline{X}$	2.332	1.941	2.087	2.137
	bi	1.110**	0.876**	0.955**	1.060**
	Sbi	0.022	0.054	0.047	0.054
	$\overline{S}^2_{di}$	-0.006	0.004	0.001	0.003
Grain number/spike	$\overline{X}$	33.417	31.917	33.394	32.611
	bi	1.000**	0.980**	1.047**	0.972**
	Sbi	0.023	0.015	0.013	0.027
	$\overline{S}^2_{di}$	0.034	-0.318	-0.395	0.155
1000-grain weight	$\overline{X}$	37.391	36.965	34.010	36.270
	b_i	1.110**	1.275**	1.129**	0.487**
	Sbi	0.178	0.213	0.272	0.058
	$\overline{S}^2_{di}$	0.192	0.319	0.592	-0.198
Grain yield (kg/ha)	$\overline{X}$	2.214	2.027	2.190	2.153
	bi	1.020**	0.923**	1.027**	1.029**
	Sbi	0.023	0.029	0.012	0.005
	$\overline{S}^2_{di}$	0.001	0.010	0.002	0.003

Chapter 5
DISCUSSION

Crop yield is a production character depending upon a large number of environmental, morphological and physiological characters. Sowing time and soil moisture play an important role in respect of growth and development as well as yield of wheat. Yield is a complex character and it is the final product of actions and interactions of various physiological and morphological characters and it is highly influenced by the genetic as well as environmental fluctuations.The yield of wheat is very low in Bangladesh as compared to other wheat growing countries of the world. Lack of proper sowing time and irrigation level are the main reasons for low yield of wheat in Bangladesh.

If it is maintained properly, better growth and development of the crop occur which is ultimately reflected to the yield. Like any other crop, growth and yield of wheat is under control of many environmental factors, sowing times and soil moisture are one of these factors. In the present study, yield and yield components were significantly affected by sowing times and soil moisture levels.

Although the use of exponential polynomial equation in growth analysis is advocated (Hurd, 1977; Hunt, 1978; Sivakumar and Shaw, 1978), due to difficulty of selecting the degree of polynomial to be fitted, Nicholls and Calder (1973) suggested a statistically objective method. However, a serious problem arises when unequal degrees of polynomials describe the relationship between $\log_e$ dry weight and $\log_e$ leaf area with time in different sets of data under comparison. The main reason is that this results is strongly dissimilar patterns of divided growth parameters e.g. CGR, RGR, NAR etc., for which no physiological explanation can be offered.

The results revealed that total dry matter (TDM) were found to be significantly greater in S_1 plants than the other sowings in both the years. It was also found that delay in sowing resulted lower TDM in both the years. Similar results were reported in barley

(Berrada, 1979; Bonani and Macchia, 1980; Abdel-Raouf *et al.*, 1983a and Alam *et al.*, 2007). TDM increased slowly at the early stages of growth and then increased rapidly with the advancement of plant age. The rapid increase in TDM at the later stages of growth was due to the development of a considerable number of late tillers. Similar result was reported by Talukder (1987) in wheat and Sonmez (2000) in barley. The plants sown on 15 November (S1) produced higher TDM due to longer duration of vegetative phase and higher numbers of tillers with the tallest plant influenced by optimum temperature throughout its growth period. Delay in sowing reduced the tiller number, which results lower TDM. Photiades and Hadjichristodoulon (1984), Zhao *et al.* (1986) and Alam *et al.* (2005) also found similar results in barley.

The results of the present investigation show that total dry matter production in all the varieties in both the years were significantly greater in the irrigated plants. Similar results were reported in barley (Kirby, 1969; Mollah and Paul, 2008), in wheat (Singh *et. al.,* 1987; Sarker and Paul, 1997; Nahar and Paul, 1998; Rahman *et al.,* 2001 and Rahman, 2004), in mustard (Mandal *et. al.*, 1986; Haque *et. al.*, 1987; Begum and Paul, 1993; Mondal and Paul, 1994, 1995), in sorghum (Sivakumar *et. al.,* 1979; Wright, *et. al.,* 1983) and in groundnut (Srinivasan *et. al.,* 1987). Total dry matter increased slowly at the early vegetative stages but increased rapidly with the advancement of the growth period. On average of to experimental years and maximum values for total dry matter production was reported for Shatabdi followed by Shourav and Kanchan and the lowest values were reported for Gaurav.

Leaf area index (LAI) was found to be significantly greater in S_1 plants than the other sowings in both the years. Delay in sowing resulted lower LAI in both the years. Similar result was reported by Abdel-Raouf *et al.* (1983a) and Alam *et al.* (2005) in barley. Higher leaf area index (LAI) was observed for S_1 plants and lower for S_3 plant in both the experimental years. Similar results were also reported by Begum and Paul (2005) in cassava. LAI reached a certain peak and then declined with plant age. Among the four varieties in the present study Shatabdi produced the highest LAI in both the years.

Irrigated plants had higher LAI than that of the non-irrigated plants at all the growth stages in both the years. This result is in consonance with barley by Mollah and Paul (2008), Anisuzzaman (2003), Alam (2003) and Kirby (1995), in wheat by Nahar and Paul (1998), Siddique *et al.* (1999) and Rahman and Paul (1998), in mustard by Mondal and Paul (1992) and in rape by Kundu (1992). The highest LAI was produced by irrigated plants and starting from a lower value LAI reached at certain peak and then declined with plant age. The possible reason for the increase of LAI in the irrigation treated plants is greater expansion of the leaf blades. The depletion of LAI at the later stages was possibly due to the senescence of the older leaves and the result was in agreement with Boonchoo *et al.* (1998) in barley and Paul *et al.* (2002) in wheat. Among the varieties, Shatabdi produced the highest LAI in both the years.

CGR is regarded as the most meaningful growth function, since it represents the net results of photosynthesis, respiration and canopy area interaction. As noted by Williams *et al.* (1965), CGR is also representative of the most common agronomic measurement such as yield of dry matter per unit land area. In the present investigation, CGR was found higher for S_1 in both the years. Delay in sowing resulted lower CGR in all the varieties and years. This result is agreed with Alam *et al.* (2005), Alam (2003) and Abdel-Raouf *et al.* (1983a) in barley. Among the varieties, Shatabdi produced higher CGR in both the years.

Crop growth rate increased gradually with high fluctuations with increasing age of the plants in all the varieties and both the years. Significantly higher CGR was found in plants grown under irrigated condition than those grown under rainfed condition at almost all the stages of growth in the present investigation. Higher CGR was noted in the irrigated plant than in the non-irrigated plants. Similar trend of the effect of irrigation was also observed by Sarker *et al.* (1986), Sarker and Paul (1998), Nahar and Paul (1998) and Rahman (2004) in wheat, Mollah and Paul (2008) in barley, Mondal and Paul (1995) in mustard, Clarke and Simpson (1978) in rape, Srinivasan *et al.* (1987) in groundnut and Rabindranath and Shiv Raj (1983) in sorghum. Starting from lower value CGR reached a certain peak and then declined at the later stages of growth. Thus results is in agreement with Begum (2003) in wheat and Mollah and Paul (2008) in barley.

In both the years, RGR of all the varieties irrespective of irrigation and sowings declined with increasing plant age and plant dry weight. The reason for higher RGR values at the earlier stages of growth is possibly due to have the juvenility of the plants and less effect on accumulation of dry matter and decreased in RGR could be attributed to self-shading of lower leaves. Similar results were reported for RGR in sugar beet, potato and barley (Thome, 1960), in barley (Alam *et al.,* 2006), in cassava (Begum and Paul, 2005) and in wheat (Sarker and Paul, 1998). In the present investigation, higher RGR was found in S_1 in both the years than the other sowings.

Higher RGR was observed in the irrigated plants than in the non-irrigated plants in both the experimental years. The highest RGR was noted at 30-40 DAS in first the year and 20-30 DAS in the second year. For irrigation, similar results were reported by Saha and Paul (1995), Sarker and Paul (1998), and Rahman (2004) in wheat. In addition, Chanda *et al.* (1987) concluded that the declining tendency in RGR with plant age was possibly due to decline in LAR. Gaurav and Shourav had the lowest RGR in the first and second year, respectively. This result is in agreement with Paul *et al.* (2005) in *R. serpentina*, Mollah (2007), Yang *et al.* (1990) in barley and Begum and Paul (1993) in mustard. In the present investigation, it was observed that in all the four varieties RGR values for the rainfed plants were significantly higher than those of the irrigated plants at most of the harvest days in both the years. In both the years and four varieties irrigated RGR value exceeded rainfed value at the early and mid growth stages. Maximum RGR was recorded for Shatabdi and minimum for Shourav.

Net assimilation rate (NAR) increased slowly with the increasing growth period and reached its peak at 50-60 DAS and thereafter declined sharply at the later stage of growth. Similar information was made by Yang *et al.* (1990) and Alam *et al.* (2006). In many cases it reached negative values at the later stages of growth. Similar result was reported by Yang *et al.* (1990) in barley. Haloi and Baldev (1986) also reported that NAR was higher in chickpea at the vegetative stage and declined sharply as the plant experienced increasing age. Pandey *et al.* (1978) explained that the decrease in NAR at the later stages could be due to the mutual leaf shading and increase in the number of older leaves, which lost photosynthetic ability. In the present investigation, the highest NAR value was shown by Gaurav and lowest by Shatabdi in both the years. On the other hand, the highest NAR value was obtained in S_3 plants and lowest in S_1 plants in both the years.

In case of NAR in the present study no variation between the irrigated and rainfed treatments was encountered at the early growth stages but at the later growth stage this variation was found to be significant. Decrease in NAR due to irrigation was also noticed by El-Nadi (1969), Saha and Paul (1995), Sarker and Paul (1998), Nahar and Paul (1998), Haque (1993) and Rahman (2004) in wheat; Nerkar *et al.* (1981) in beans; Alam and Haider (2006) and Mollah (2007) in barley. In all the varieties, rainfed values exceeded irrigated ones at least at three growth stages in both the years. A similar occurrence was evident in *Brassica napus* by Allen and Morgan (1972, 1975); in *Brassica juncea* by Majid and Simpson (1998) and in soybean by Buttery (1969). The increase of NAR at the later stages may be due to decreased leaf area and increased ear photosynthesis. Higher NAR due to higher soil moisture was found by El Nadi (1969) in wheat, Nerkar *et al.* (1981) in beans and Rabindranath and Shiv Raj (1983) in sorghum. Watson (1958) had attributed the decline in NAR to increased mutual shedding of leaves, resulting in reduced photosynthesis. In both the years, NAR reached its peak at 50-60 DAS and thereafter, declined. A similar occurrence was noticed in barley by Yang *et al.* (1990), in soybean by Koller *et al.* (1970), in mustard by Mondal and Paul (1992) and in *Brassica campestris* by Kundu (1992).

LAR values of all the varieties and sowings in both the years declined with increasing plant age. It might be due to abscission of mature and older leaves at the later growing stages. Similar results were found in sugar beet, potato and barley (Thorne, 1960) and in wheat (Haque, 1993 and Rahman, 1993).

In the present investigation, the irrigated plants of both the years were found to give higher LAR at each growth phases in most cases. Similar results were reported by Paul *et al.* (2005) in *Rauvolfia serpentina*, Saha and Paul (1995) in wheat and Kundu and Paul (1998) in rape. Wallace and Munger (1965) reported that in dry beans LAR was highest during the early vegetative stage and later decreased rapidly with advancement of plant age.

In the present investigation, RLGR values were found to decrease with increasing plant age. Similar results were reported by Rahman (1993), Sarker and Paul (1998) and Sarker *et al.* (1999) in wheat and Alam *et al* (2006) in barley. The cause of decline of RLGR at the later stages was due to abcission of older leaves. It was also observed that high temperature at the later stages of growth accelerated the abscission of older leaves. RLGR was found lower in S_3 in both the years that confirmed the higher temperature at the later stages of growth. In the present study, RLGR was higher for S_1 in both the years. It might be due to available soil water. Mondal and Paul (1992) and Khan and Paul (1993) observed higher RLGR in the well-watered condition in mustard.

Comparatively higher RLGR was in the irrigated plants than in the non-irrigated plants. I_1 (irrigation) level had the highest RLGR in both the years in all the varieties which are similar to the findings of Mondal and Paul (1995) in mustard, Kundu and Paul (1998) in rape and Saha and Paul (1995), Sarker *et al.* (1996), Sarker and Paul (1998) in wheat and Mollah (2007) in barley. RLGR decreased with increasing plant age which is in agreement with Buttery (1969) in soybean, Paul (1980) in rape and turnip, Chanda *et al.* (1987) in pearl millet, Rahman (1993), Rahman (2004) in wheat and Paul *et al.* (2005) in *R. serpentina.*

All the varieties had generally higher SLA at the early stages of growth and gradually declined with the plant age. The S_1 plants had higher SLA in most of the cases in both the years than the other sowings. The decline of SLA with increasing plant age was noticed by Alam *et al.* (2005) in barley and Sarker and Paul (1993) in rape. The increasing tendency of SLA at the later stages of growth was common in the present experiment and it might be due to the translocation of assimilates from the leaves to sink organs (Mondal and Paul, 1992).

Specific leaf area (SLA) values in the treatments declined throughout the growth stage with fluctuations. The irrigated plants showed higher SLA than those of the rainfed plants at all the growth stages. Decrease of SLA with plant age was also reported in jute (Saha, 1983), in rape (Paul, 1980 and Islam and Paul, 1986), in wheat (Sarker and Paul, 1998; Nahar and Paul, 1998 and Rahman, 2004), in mustard (Mondol and Paul, 1995), in *R. serpantina* (Paul *et al.,* 2005). Chanda *et al.* (1987) observed that SLA values decreased with increasing plant dry weight in pearl millet.

In both the years, LWR showed increasing tendency within very short time and thereafter gradually declined with plant age. The declining pattern was downward drift throughout the growth period. The decrease of LWR was caused by increased plant dry weight and decreased LAI at the later stages. Saha and Paul (1995) studied LWR in wheat and reported that the sharp decrease in LWR at the later stages might be sharp increase of TDM. This result was also supported by Thorne (1960), Haider and Paul (2003) in barley, Sarker and Paul (1998), Nahar and Paul (1998) in wheat and Begum and Paul (2005) in cassava. In the present study, the S_1 plants had higher LWR than the other sowings in both the years. The high temperature prevailing in the S_3 growing period at the later stages of growth produced lower dry matter. Elias and Causton (1975) found that high temperature depressed the mean overall LWR mainly during the later part of the growth period.

The irrigated plants had the highest LWR than the rainfed plants in both the years. Saha and Paul (1995), Sarker and Paul (1998) and Rahman (2004) noticed higher LWR in the irrigated condition in wheat and Paul *et al.* (2005) in *R. serpentina.* The decrease of LWR was caused by increased TDM and decreased LAI at later stages.

Saha and Paul (1995) studied LWR in wheat and reported that the sharp decrease in LWR at later stages might be sharp increase of TDM. This result was also supported by Thorne (1960) in barley and Nahar and Paul (1998) in wheat. Starting from maximum value LWR declined sharply with increasing age and all the four varieties and both the years in the present study showed higher LWR when grown under irrigated condition than those of the rainfed plants in most cases. Strong drift of LWR with increasing plant dry weight was reported by Chanda *et al.* (1987) in pearl millet. The decrease of LWR was caused by increased plant dry weight and decreased LAI at the later stages.

Plant height is an important morphological character directly linked with the productive potential of plant in terms of grain yield. In the present study, S_1 plants (November 15 sowing) had higher height than S_2 plants (November 30 sowing) and S_2 plants (November 30 sowing) had higher height than S_3 plants (December 15 sowing) for all the varieties. Thus the results indicated that, there was significant variation in the rate of growth in plant height of varieties as influenced by sowing. Haque (2000) found similar result in the November 30 sowing, which showed better performance for plant height. Among the varieties, Shatabdi had the highest plant height in both the years. This finding was supported by Sarkar and Paul (1998) and Jat *et al.* (1990). Khan and Paul (1993) stated that the plant height was higher at the irrigated condition than the rainfed condition. Among the varieties, Shatabdi produced the tallest plant followed by Shourav, Kanchan and Gaurav in both the years.

In the present investigation, higher tiller number was obtained from the first and second sown plant and minimum in the third sown plants in both the experiment years. This observation is supported by Alam (2003), Paul and Sarker (2003) and Alam and Haider (2006).

The effect of irrigation on tiller number of each of four varieties of wheat showed that tiller number increased with increasing plant age and then gradually declined. The maximum increase was recorded at 60 DAS by Kanchan and minimum by Gaurav.

These results are supported by Jana and Misra (1995), Anisuzzaman (2003), Alam and Haider (2006), Mollah (2007) and BARI (2003-2004).

In the present investigation, delay in sowing reduced number of tillers plant^{-1}. These results are in agreement with Petr *et al.* (1979) and Makki and Habib (1979). Photiades and Hadjichristodoulon (1984), Zhao *et al.* (1986) and Alam *et al.* (2005) also found similar results in barley. Among the varieties, Kanchan had the highest tiller number plant^{-1} followed by Shatabdi, Shourav and Gaurav.

After germination, leaf number increases very slowly at first for a long period and then it follows a period of rapid expansion with variation in total leaf area of a plant due to the change in number of leaf and size of leaf per plant. The number of leaf present at a particular time is equal to the total number of leaves produced minus number of leaves that have been lost by abscission. The numbers of leaf is dependent on number of nodes, which is governed by the time during which leaves are produced and also by survival of the leaf. Initially, leaf size is determined by the number and size of cells of which leaf is built (Paul *et al.,* 2002 and Haider and Paul, 2003).

In both the years, the plants grown under irrigation condition produced higher leaf number than those grown under non-irrigation condition. Leaf number increased with increasing plant age. Similar result was found by Mollah (2007). These results were also supported by Dudas (1994), Alam (2003), Alam *et al.* (2005) and BARI (2003-2004).

In the present investigation, higher leaf number was obtained from the first and second sown plants and minimum in the third sown plants in both the experiment years. Shatabdi produced the highest leaf number and Gaurav produced the lowest. This result is supported by Alam (2003) and Alam and Haider (2006).

In the present study, higher grain yield was obtained from 15 November (S_1) sown crops in both the years. It might be the cumulative effect of optimum temperature at the vegetative and reproductive stages that provided highest number of fertile tillers per plant, highest number of spikelets per spike and highest 1000-grain weight. On the other hand, the lowest yield was obtained from S_3 crops was attributed due to lower value of the above-mentioned characters due to lower temperature at the early vegetative stage and sharp rise in temperature at the reproductive stage, which eventually shortened the growth period. Similar finding was observed by Alam *et al.* (2005, 2007), Paul and Sarker (2003), Green *et al.* (1985a), Chaturvedi *et al.* (1985), Ahmed *et al.* (1975) and Bajpai *et al.* (1981) in barley.

Ahmed *et al.* (2006) reported that BARI Barley-1 gave the highest grain yield, whereas the lowest grain yield was obtained from local variety with delayed sowing. Similar finding was also reported by Alam (2003) in barley, Dahiya and Narwal (1989) in maize and Darwinkel *et al.* (1977) in wheat.

Crop yield is a complex character depending upon a large number of morphological and physiological characters. In the present study, yield and yield components like plant height, extrusion length, spike length, number of grains per spike, 1000-grain weight and grain yield (kg/ha) were significant higher for S_1 (November 15 sowing). Shahzad *et al.* (2007) reported that November 15 and November 30 sown crop gave significant higher grain yield than the December 15. Among the varieties, Shourav showed the highest values of the above characters except 1000-grain weight and the lowest values of these characters were observed in Gaurav except 1000-grain weight. Haque (2000) found similar results for yield and yield components of wheat. Similar result was reported by Rahman *et al.* (2001), Sarker *et al.* (1999), Sarker and Paul (1998), Rahman and Paul (1998) and Sarker (1996) in wheat under irrigated condition. Alam *et al.* (2007) and Ahmed *et al.* (2006) in barley, Haque *et al.* (2004) and Paul and Sarker (2003) in wheat. Ahamed *et al.* (1975) stated that seeding wheat in the third week of December reduced the grain yield by 50%. Ahmed *et al.* (2006) added that grain yield and straw yield increased significantly with early sowing (30 November) in all the varieties in both the years.

Paul and Sarker (2003) suggested that wheat cultivars Karan and BL 1183 can be sown by November 15 for maximum grain yield under irrigated condition. Rao *et al.*

(1980) found that November 20 was the optimum time of sowing for the highest grain yield production in wheat and also declared that delayed sowing beyond November decreased grain yield due to high temperature at the grain filling stage like the finding for the third sowing of the present study. Ahmed *et al.* (2006) observed that the optimum sowing time for BARI barley-1 and BARI barley-2 may range from 30 November to 15 December. Sarker and Paul (1993) observed that delayed sowing in mustard resulted in lower seed yield. Singh and Dixit (1985) stated that delayed sowing beyond November decreased grain yield in different wheat varieties. Delayed sowing resulted in a linear decrease in maximum grain yield in winter wheat (Darwinkel *et al.*, 1977) and in winter barley (Green *et al.*, 1985a). Green and Ivins (1985) stated that early sowing (September 22) of winter barley increased the duration of the growth period and increased the opportunity for the absorption of photons that favoured the highest TDM accumulation which ultimately gave the highest yield. Green *et al.* (1985b) added that early sowing induced faster production of tillers and consequently gave higher maximum tillers and tended to accumulate dry matter at a faster rate and provided the highest grain yield led by optimum temperature during the growth period.

Sharma and Singh (1972) stated that the optimum time of sowing was the beginning of November for longer duration varieties and the second half of November for short duration varieties of wheat. Kanani and Jadan (1985) denoted October 5 as early and November 15 as normal sowing. They reported that November 15 sown crop gave the highest grain yield and Shatabdi had higher grain yield with the highest tillering. Ahmed *et al.* (1975) suggested that the optimum time of sowing of wheat as November 9 for the best production. Hossain and Farid (1988) declared that the higher yield was obtained on November 20 sowing due to higher number of spikes per m^2, higher number of grains per spike, higher 100-grain weight to favorable atmospheric condition prevailing from sowing to grain filling period. They also reported that the late sowing (December 20) produced low yield due to shorter growing period at the vegetative phase and steep rise in temperature at the grain filling period. But the early sowing caused reduction (8.8%) in yield due to high temperature at the seedling emergence and tiller formation stages resulting in a lower tiller number per unit area.

Islam *et al.* (1993) also reported that the best time of sowing was November 15, for producing higher grain yield due to higher number of spikes per m^2, number of grains/spike and 100-grain weight for favorable atmospheric condition during growth period. These findings were supported by Torofder and Altab (1991) in barley and Samanta *et al.* (1997) in prosomillet. Hsu and Walfon (1971) reported that the number of grains/spikelet was the main yield components in wheat.

Again Bhuiya and Kamal (1994) showed that grain yield of wheat is the product of four components, viz. number of ears per plant, number of spikelets per ear, number of grains/spikelet and individual grain yield. Perry and Antuono (1989) and Gale (1979) reported that the higher number of grain per unit area was responsible for the yield advantage of wheat. Lupton (1974) stated that grain yield increased with increasing spikes per unit area. Syme (1970) reported grains/spike was dependent on the number of spikelet. Angus and sage (1980) found more grains/spike where spikelet fertility was higher. Many workers corroborated yield on the size and shape of wheat. Several researchers opined that yield and yield components varied depending on the sequenced of environmental conditions at the various stages in the development of the crop.

The plants under irrigated condition produced significantly better performances in all these characters than those of the rainfed plants. The highest plant height, tiller number per plant, fertile tiller number per plant, total dry matter and grain yield (kg/ha) were produced by Shatabdi in both the years and the lowest values were shown by Gaurav. Therefore, the grain yield depended on the kernel number per plant and the number of spikelets per spike. Bingham (1966) reported that the grain yield was dependent on the number of tillers per plant in wheat. In the present investigation, tiller number of plant was highest in Kanchan and Shatabdi produced the highest grain yield per plant and grain yield (kg/ha) in both the years. So it appears that grain yield was dependent on the number of tillers plant.

In the present investigation, it was observed that grain yield was significantly higher in the irrigated plants. Similar results were reported in wheat by Robins and Domingo, 1962; Day and Intalap, 1970; Sairam *et al.*, 1990; Paul and Nahar, 2000 and Rahman, *et al.,* 2001. In wheat El- Nadi (1969) reported that the plant height, number of tillers, dry weight and grain yield were higher in the favorable water regime treatments. El- Rab *et al.* (1988) also reported that water stress at different growth stages had a significant effect on grain and straw yields in wheat. They concluded that maximum grain and straw yields were obtained by increasing irrigation. Robins and Domingo (1962), Day and Intalap (1970) and Sairam *et al.* (1990) reported that number of kernels and grain yield of wheat were generally reduced by soil moisture stress. Singh and Kumar (1976) reported that the number of effective tillers and grain yield increased with an increase in the number of irrigation in barley. Similar results were reported by Rahman *et al.* (2001) and Haider and Paul (2003) in wheat. Wright *et al.* (1983) reported that grain yield, single grain weight and number of grains per plant in the irrigated plants of sorghum had higher values than the rainfed plants. Hsu and Walfon (1971) reported that the grain number per spikelet was the main yield component in wheat. Fischer *et al.* (1977) reported that water stress during grain growth was found to decrease grain size leading to reduction in yield. They also reported that stress in the early stress of growth influenced the number of grain, while stress after anthesis influenced the size of grain. Several authors (Gale, 1979 and Perry and Antaono, 1989) reported that a higher number of grains per unit area were responsible for the yield advantage of wheat. Furthermore, in wheat, the increased grain number has been arisen by spikes per unit area (Lupton *et.al.,* 1974) or more grains per spike (Syme, 1970) caused by a higher spikele number (Rawson, 1971) or a higher spikelet fertility (Angus and Sage, 1980).

In both the years plant height showed significant correlation with all other yield components in all the sowing dates except 1000-grain weight of S_2. The significant correlation was observed in number of total tillers per plant with other yield components in both the years in the first sowing (November 15) except extrusion length and 1000-grain weight in both the experimental years.

Number of fertile tillers per plant, spike length, number of spikelets per spike, 1000-grain weight and grain yield were found to be the most important yield components in the present investigation. These components were significantly correlated with all other yield components irrespective of all sowing dates and years. In both the experimental years, total dry matter was found to be significantly correlated with other yield components except extrusion length of S_1 (November 15) and S_2 (November 30) in the second year.

In the present study, the correlation coefficients showed that plant height, number of total tillers per plant, number of fertile tillers per plant, extrusion length, spike length, number of spikelets per spike. 1000-grain weight and total dry matter had positive correlation with grain yield. Hsu and Walfon (1971) reported that the grain number per spikelet was the main yield component in wheat. Several authors (Gale, 1979; Perry and Antano, 1989) reported that a higher number of grains per unit area was responsible for yield advantage of wheat. Singh and Kumar (1976), Koszanski *et al.,* (1999), Zapotocny and Bizik (1999) and Karczmarczyk *et al.* (1999) reported that the number of effective tillers and grain yield increased with an increase in the number of irrigation in barley. Paul and Sarker (2003) reported that grain yield was positively correlated with number of tillers per plant, number of fertile tiller per plant, number of spikelets per spike and total dry matter but negatively with 1000-grain weight.

Significant and positive correlation among the yield components were observed by many workers in barley. Kandera (1981) found a positive correlation coefficient between yield and 1000- grain weight in barley. Abdel-Raouf *et al.* (1983a) observed that grain yield was positively correlated with plant height at all the growth stages, DM accumulation, leaf area and LAI at the later growth stage. In another experiment, Abdel-Raouf *et al.* (1983b) observed that grain yield was positively correlated with the number of ears/m^2 and 1000-grain weight. Dudas and Pelikan (1985), Saini and Dadhwal (1986) observed similar results in wheat.

Kulik (1985) observed that grain yield was positively correlated with number of ears/m^2, number of productive tillers/m^2 and number and weight of grains/main ear. Chanda *et al.* (1987) found that grain yield was correlated positively with number of ears/m^2 and 1000-grain weight and negatively with ear length. Same finding was observer by Chaudhury (1977).

In the present study, the correlation coefficients showed that plant height, number of total tillers per plants, number of fertile tillers per plants, extrusion length, spike length, number of spikelets per spike, 1000-grain weight and total dry matter had positive correlation with grain yield. Similar result was reported by Fisher (1981) and Chaudhury (1977).

Significant and positive correlation among the yield components were observed by many workers in barley. Kandera (1981) found a positive correlation between yield and 1000-grain weight in barley. Razzaque *et al.* (1981) observed that yield plant showed highly significant positive correlation with ear length, grains per ear and 100-grain weight. Ears per plant, however, did not show any considerable correlation with yield.

Samarrai *et al.* (1987) observed that grain yield was most strongly correlated with harvest index, plant height and total biomass. Kulik (1988) observed that yield was correlated with the number of plants/m^2, number of ears/m^2 and number of grains in the main ears. Gu and Shi (1988) showed that yield was strongly and positively correlated with ears/m^2 and total growth period and negatively with 1000-grain weight, height and grains/ear. They also concluded that ears/m^2 had the greatest direct effect on yield, followed by 1000-grain weight and grains/ear.

Shim *et al.* (1988) reported that yield was significantly correlated with culms length, plant dry weight, number of grains/spike and 1000-grain weight. Manohar *et al.*

(1988) found that yield was correlated with the numbers of effective tillers/m^2 and grains/spike and with N content in the flag leaf before heading.

Hadjichristodoulon (1991) observed that grain yield was positively correlated with yield. Geweifel (1991) reported that variation in grain yield was most closely associated with variation in number of grains per spike. Singh (1989) reported that heritability estimates and correlations among trials indicated that productive tillers per plant, days to flowering, days to maturity and 200-grain weight would be the most useful selection criteria. Rahman *et al.* (2001) observed that grain yield was positively correlated with total dry matter.

Riaz-ud-Din *et al.* (2007) revealed that characters, like number of grains and 1000-grain weight had positive and non-significant correlation with grain yield. Under stress conditions plant height had positive and significant association with 1000-grain weight and negatively correlated with number of spikes/m^2. A positive and significant correlation was recorded between days to anthesis and number of grains per spike. Debnath *et al.* (2008) reported that the correlation coefficient of seed yield (kg/m^2) with inflorescence per plant were positive and highly significant. Grain setting receme per plant also showed significant and positive correlation with seed yield (kg/m^2).

Path coefficient analysis was done. The highest direct positive effect was contributed by number of fertile tillers per plant followed by number of grain per spike, number of spikelets per spike and plant height on grain yield. The highest negative direct effect on grain yield also showed high positive indirect influence through number of tillers per plant, average grain weight of plant and plant height. In such condition indirect causal factors are to be considered simultaneously for selection. Similar result was reported by Singh *et al.* (2008), Amiruzzaman *et al.* (2003), Razzaque *et al.* (1981). Ali Hayder (2006), Ariyo *et al.* (1987), Johnson and Whittington (1977), Dangi and Poroda (1974) and Dayal *et al.* (1972) also noticed a high positive direct effect of number of spikes and dry matter content on grain yield and advocated for giving more importance of these characters during selection to get improvement in grain yield.

Kumar and Reddy (1982) observed that path coefficient values based on phenotypic correlation revealed that plant height, number of spike per plant and average 1000-grain weight of plant had direct positive effect towards grain yield also having positive correlation with grain yield. Therefore, proper attention should be taken on above characters for the improvement of grain yield. Similar results were reported by Yadav *et al.* (1979).

Dokuyucu and Akkaya (1999) concluded that spikes/m^2 had positive direct effect on grain yield. Riaz-ud-Din *et al.* (2007) also observed that higher positive direct effect was for spike/m^2 followed by days to maturity, grains per spike and plant height. Debnath *et al.* (2008) reported that grains per raceme had the highest positive direct effect on yield followed by inflorescence per plant and seed yield per plant.

In the present study, correlation and path coefficient analysis suggest that during selection more emphasis should be given on plant height, total dry matter, fertile tiller number and number of grains per spike. Since these characters have high correlation and high direct effect on grain yield.

In the present investigation phenotypic regression coefficients (bi) and stability parameters $\bar{S}^2_{di}$ were calculated to evaluate highly stable genotype over a wide range of environments. Regression coefficients were found to be highly significant in most cases indicating that the genotypes were highly responsive with the environmental variations. Phenotypic expression of a particular genotype in a specific environment depends on three properties: a mean expression, a linear response to environment and residual deviations from regression. Of the two sensitivity measures the linear sensitivity coefficient is of particular interest since it provides a convenient measure of a genotype's sensitivity and allows prediction across environments to be readily made (Breese, 1969; Jinks and Perkins, 1970; Samuel *et. al.,* 1970). The importance of the genotype in determining mean expression has long been recognized. A number of studies (Anisuzzaman *et al.,* 2007; Islam *et al.,* 2003; Alam *et al.,* 2002; Bucio Alanis and Hill, 1966; Jinks and Perkins, 1970; Paroda and Hayes, 1971; Westerman, 1971; Fripp, 1972) have shown that the determination of the sensitivity aspects of phenotype also involves genetical components.

According to Eberhart and Russell (1996), a stable genotype is characterized by a slope not different from unity (bi =1) and the deviation from regression close to zero ($\bar{S}^2_{di}$=0). Analysis of variance showed that the mean sum of squares due to genotypes (G) and environment (E) difference tested against the G x E interaction were significant for all the traits studied, indicating the presence of wide variability among the genotypes and environment. The significant estimates of G x E interaction indicated that the characters were unstable and may considerably fluctuate with change in environments. The G x E (linear) interaction was significant against pooled deviation suggesting the possibility of the variation for all the characters. These findings are in close agreement with those of Semin *et al.* (1986), Afiash *et al.* (1999) Sarker (2002) and Mohamadi *et al.* (2005).

The linear regression (bi) is considered to be a definite and measurable response to the environment. Genotypes that have relatively the same amount of performance over a wide range of environments would have bi values less than unity and would be least responsive to change in the environments. The standard error of regression coefficients is a measure of 'stability of response' exhibited by each population. Since the linear regression represents very definite and measurable response to the environment, it is no longer profitable to consider this component of genotype environment interaction as a measure of stability in the way proposed by Finlay and Wilkinson (1963).The term 'stability' should now rather be reserved to describe measurements of unpredictable irregularities in the response to environment as provided by the deviations from regression. Lerner (1958) has proposed this deviation.

A stable variety should be one with high mean performance, one with unit regression slope (bi=1.00) and the deviation from regression as small as possible. Thus for a particular character the genotype with higher mean performance and average regression coefficient together with a considerable low $\bar{S}^2_{di}$ value will be suitable for favorable environments. However, even if the genotypes though have high deviation around their regression lines yet they deserve inclusion in suitable environments. These varieties are very sensitive to environmental changes and hence as the environment improves their performance will increase at a rate well above the average of the group. Under the most favorable condition they will be able to express themselves as very high yielding varieties suggesting their exploitation in favorable environments. On the other hand, these genotypes with comparatively low bi and $\overline{S}_{di}^2$ values together with moderate high mean yield are specially adapted to low yielding environments. These varieties are so insensitive that they are unable to exploit in high yielding environments. Lastly, the genotypes that have low bi and $\overline{S}_{di}^2$ values and also low mean performance indicate that they are consistently lower yielder in all environments.

The phenomenon of genotype environment interaction in high yielding varieties of wheat under Bangladesh condition was studied by Islam (1978), Islam *et al.* (1981, 1987) in wheat, Alam *et al.* (1999) in soybean, Sarker (2002) in rice, Anisuzzaman (2003) in barley and Islam *et al.* (2003) in chickpea. In the present investigation, the varieties of wheat showed different combination of performances in different characters and therefore, it is difficult to draw conclusion regarding their stability over a wide range of environments. However, Shatabdi with high mean, one with unit regression slope and low $\overline{S}_{di}^2$ values for plant height, number of grain per spike and thousand grain weight and grain yield, indicating its stability to varying environments. Shourav and Gaurav gave moderate and Kanchan gave lowest grain yield significantly in all the environments. Nanak Chand *et al.* (2008) reported similar results for 1000- grain weight, only one genotype RD2634 had average mean associated with bi=1 and $\overline{S}_{di}^2$ =0, identified for wider adaptation and stability over all sites across environments. These results are in conformity with the findings of Yadav and Rao (1985), Hadjichristodoulon (1992), Shahmohamadi *et al.* (2005) and Verma (2007).

The overall results of the present investigation revealed that the early sowing and irrigated plants showed better than the delayed sowing and rainfed plants. Delayed sowing resulted in reduced grain yield. Result indicated that sowing time in the second and third week of November resulted higher grain yield. The maximum grain yield was obtained in S_1 planting and it was followed by S_2 and S_3. Among the four wheat varieties, Shatabdi showed the higher TDM, LAI, CGR, RGR, SLA, LWR and plant height at all the growth stages. Yield and yield components were also found to be higher in Shatabdi in both the years. Less reduction in yield due to delayed sowing was found in variety Kanchan although it had higher tiller number due to its greater vegetative growth. Again in both the soil moisture levels and sowing dates, the physiological response, growth and yield were moderately higher in Shourav. So, it is treated as most economic with respect to fertilizer application. Among the varieties studied, Shatabdi was comparatively least susceptible one while Kanchan was the highest susceptible. The performances of the remaining two varieties Shourav and Gaurav were not satisfactory. Phenotypic regression analysis also showed that Shatabdi had unit regression slope with low stability value for grain yield, grain number per spike, thousand grain weight and plant height indicating its stability to varying sowing time and soil moisture treatments. So, Shatabdi gave satisfactory results in both the years.

Therefore, to get higher yield, Shatabdi may be recommended for sowing at the middle of November with optimum soil moisture regime in the northern region of Bangladesh.

Chapter 6

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