# EFFECTS OF IRRIGATION LEVELS AT DIFFERENT STAGES OF GROWTH AND SOWING DATE ON THE GROWTH, YIELD AND MALTING QUALITY OF BARLEY (Hordeum vulgare L.)

BY

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## DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my own research work. It has not been presented in any previous application for a higher degree.

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CERTIFICATION

This thesis entitled "Effects of Irrigation Levels at Different Stages of Growth and Sowing Date on the Growth, Yield and Malting Quality of Barley (*Hordeum vulgare* L.)" by Abdulkadir Azarema meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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## D E D I C A T I O N

To M. Y. Ahmed who has done so much for so long.

And wife, Fatsuma and daughter, Samina.

## ABSTRACT

A field experiment was conducted under irrigation at the Irrigation Research Station, Kadawa, in the Sudan savanna ecological zone of northern Nigeria during the 1986/87 dry season to study the effects of different irrigation levels at different stages of growth and sowing date on the growth, yield and malting quality of barley (Hordeurn vulgare L.).

The treatments consisted of four irrigation levels (optimum irrigation water throughout growth period, 50% optimum water at the vegetative stage only, 50% optimum water at the reproductive stage only and 50% optimum water throughout growth period) using IW/CPE ratio; and three sowing dates (early-November, late-November and mid-December),

Barley supplied with optimum irrigation water throughout growth period produced the highest grain yield of 3209 kg/ha which was reduced by about 30, 23 and 48% when 50% optimum water was withheld at the vegetative stage, reproductive stage and throughout growth period, respectively. All growth parameters, yield components and WUE were highest when the crop was supplied optimum irrigation water throughout. However, the grain protein content was lowest when plants were supplied optimum water throughout, while withholding 50% irrigation water throughout growth resulted in the

highest grain protein content. Similarly, all growth parameters, yield and yield components and WUE were highest with late-November sowing, but grain protein content was lowest compared to early-November and mid-December sowings.

The interaction was significant on number of spikes per square meter, length of spike, number of grains per spike, grain yield, straw yield and grain protein content. Most of the parameters measured were significantly and positively correlated to grain yield. Grain protein content was however, negatively correlated to grain yield.

TABLE OF CONTENTS


| Chapter | | Page |
|---|---|---|
| | Title page | i |
| | Declaration | ii |
| | Certification | iii |
| | Acknowledgement | iv |
| | Dedication | v |
| | Abstract | vi |
| | Table of Contents | viii |
| | List of Tables | xi |
| | List of Figures | xiii |
| | List of Appendices | xv |
| 1 | Introduction | 1 |
| 2 | Literature Review | 5 |
| 2.1 | Moisture stress | 5 |
| 2.1.1 | Sensitivity of barley crop to water stress at different growth stages | 5 |
| 2.1.2 | Effect of water stress on yield and yield components | 9 |
| 2.1.3 | Effect of moisture stress on malting quality | 10 |
| 2.1.4 | Recovery from water stress | 11 |
| 2.1.5 | Water-use efficiency | 12 |
| 2.1.6 | Irrigation scheduling | 14 |
| 2.2 | Effect of sowing date on the growth and yield of barley | 18 |
| 2.2.1 | Effect of sowing date on malting quality of barley | 20 |

| Chapter | | Page |
|---|---|---|
| 2.3 | Irrigation and sowing date interactions | 21 |
| 3.0 | Materials and Methods | 23 |
| 3.1. | Experimental site | 23 |
| 3.2 | Soil analysis | 23 |
| 3.3 | Soil moisture relations | 23 |
| 3.4 | Experimental treatments | 24 |
| 3.5 | Frequency of irrigation | 27 |
| 3.6 | Water application to the plots | 28 |
| 3.7 | Water table depth | 29 |
| 3.8 | Experimental design | 31 |
| 3.9 | Cultural practices | 31 |
| 3.10 | Observations recorded | 32 |
| 4.0 | Results | 39 |
| 4.1 | Growth characters | 39 |
| 4.1.1 | Germination count | 39 |
| 4.1.2 | Plant height | 39 |
| 4.1.3 | Leaf area per plant | 43 |
| 4.1.4 | Leaf area index | 46 |
| 4.1.5 | Number of tillers per square meter | 49 |
| 4.1.6 | Leaf dry weight | 52 |
| 4.1.7 | Stem dry weight | 57 |
| 4.1.8 | Total dry matter accumulation | 57 |
| 4.1.9 | Absolute crop growth rate | 60 |
| 4.1.10 | Number of days to 50% flowering and number of days to maturity | 61 |
| 4.2 | Yield and yield components | 64 |

| Chapter | | Page |
|---|---|---|
| 4.2.1 | Grain yield | 64 |
| 4.2.2 | Straw yield | 68 |
| 4.2.3 | Number of spikes per square meter | 70 |
| 4.2.4 | Spike length | 71 |
| 4.2.5 | Number of grains per spike | 72 |
| 4.2.6 | 1000-grain weight | 75 |
| 4.3 | Grain protein content | 77 |
| 4.4 | Water-use efficiency | 79 |
| 4.5 | Correlation studies | 82 |
| 5.0 | Discussion | 84 |
| 5.1 | Effect of Irrigation Levels on Barley | 84 |
| 5.1.1 | Growth | 84 |
| 5.1.2 | Yield and yield components | 86 |
| 5.1.3 | Malting quality | 89 |
| 5.1.4 | Water-use efficiency | 89 |
| 5.2 | Effect of Sowing Date on Barley | 91 |
| 5.2.1 | Growth | 91 |
| 5.2.2 | Yield and yield components | 92 |
| 5.2.3 | Malting quality | 93 |
| 5.2.4 | Water-use efficiency | 93 |
| 5.3 | Interaction Between Irrigation Levels and Sowing Date on Barley | 94 |
| 5.4 | Correlation | 94 |
| 6.0 | Summary and Conclusion | 96 |
| | References | 99 |
| | Appendices | 114 |
| | Biography | 118 |

LIST OF TABLES


| Table | | Page |
|---|---|---|
| 3.1 | Periods of irrigation and cummulative depths of water applied for the four irrigation treatments sown in early-November | 36 |
| 3.2 | Periods of irrigation and cummulative depths of water applied for the four irrigation treatments sown in late-November | 37 |
| 3.3 | Periods of irrigation and cummulative depths of water applied for the four irrigation treatments sown in mid-December | 38 |
| 4.1 | Germination count at 8 days after sowing | 40 |
| 4.2 | Absolute crop growth rate of barley ($gm/m^2/wk$) grown at Kadawa during 1986/87 season as affected by irrigation levels and date of sowing | 62 |
| 4.3 | Number of days to 50% flowering and number of days to barley maturity as affected by irrigation levels and date of sowing at Kadawa during 1986/87 dry season | 63 |
| 4.4 | Grain yield, straw yield and grain protein content of barley grown at Kadawa during 1986/87 dry season as affected by irrigation levels and date of sowing | 65 |
| 4.5 | Spike characteristics of barley grown at Kadawa during 1986/87 as affected by irrigation levels and date of sowing | 66 |
| 4.6 | Interaction of irrigation levels and date of sowing on the grain yield of barley (kg/ha) at Kadawa during 1986/87 dry season | 67 |

| Table | | Page |
|---|---|---|
| 4.7 | Interaction of irrigation levels and date of sowing on the straw yield of barley (kg/ha) at Kadawa during 1986/87 dry season | 69 |
| 4.8 | Interaction of irrigation levels and date of sowing on the number of barley spikes per square meter at Kadawa during 1986/87 dry season | 72 |
| 4.9 | Interaction of irrigation levels and date of sowing on spike length at Kadawa during 1986/87 dry season | 74 |
| 4.10 | Interaction of irrigation levels and date of sowing on the number of grains per spike at Kadawa during 1986/87 dry season | 71 |
| 4.11 | Interaction of irrigation levels and date of sowing on the grain protein content (%) at Kadawa during 1986/87 dry season | 78 |
| 4.12 | Water-use efficiency of barley grown at Kadawa during 1986/87 dry season as influenced by irrigation levels and date of sowing | 80 |
| 4.13 | Interaction of irrigation levels and date of sowing on the water use efficiency of barley (ka/ha/cm) at Kadawa during 1986/87 dry season | 81 |
| 4.14 | Simple correlation coefficients (r) between growth parameters, yield and yield components | 83 |

## LIST OF FIGURES


| Figure | | Page |
|---|---|---|
| A | Samaru plop water level sounder | 30 |
| 1 | Plant height (cm) as affected by irrigation levels at Kadawa during 1986/87 dry season | 41 |
| 2 | Plant height (cm) as affected by date of sowing at Kadawa during 1986/87 dry season | 42 |
| 3 | Leaf area per plant ($cm^2$) as affected by irrigation levels at Kadawa during 1986/87 dry season | 44 |
| 4 | Leaf area per plant ($cm^2$) as affected by date of sowing at Kadawa during 1986/87 dry season | 45 |
| 5 | Leaf area index as affected by irrigation levels at Kadawa during 1986/87 dry season | 47 |
| 6 | Leaf area index as affected by date of sowing at Kadawa during 1986/87 dry season | 48 |
| 7 | Number of tillers per square meter as affected by irrigation levels at Kadawa during 1986/87 dry season | 50 |
| 8 | Number of tillers per square meter as affected by date of sowing at Kadawa during 1986/87 dry season | 51 |
| 9 | Leaf dry weight ($gm/m^2$) as affected by irrigation levels at Kadawa during 1986/87 dry season | 53 |
| 10 | Leaf dry weight ($gm/m^2$) as affected by date of sowing at Kadawa during 1986/87 dry season | 54 |

| Figure | | Page |
|---|---|---|
| 11 | Stem dry weight ($gm/m^2$) as affected by irrigation levels at Kadawa during 1986/87 dry season | 55 |
| 12 | Stem dry weight ($gm/m^2$) as affected by date of sowing at Kadawa during 1986/87 dry season | 56 |
| 13 | Dry matter accumulation in barley ($gm/m^2$) as affected by irrigation levels at Kadawa during 1986/87 dry season | 58 |
| 14 | Dry matter accumulation in barley ($gm/m^2$) as affected by date of sowing during 1986/87 dry season | 59 |

## LIST OF APPENDICES


| Appendix | | Page |
|---|---|---|
| A | Physico-chemical properties of the soil of the experimental field | 114 |
| B | Daily temperature records for Kadawa from November 1986 to March 1987 | 115 |
| C | Total monthly rainfall record for Kadawa for the period March - November 1986 | 117 |
| D | Monthly relative humidity record for Kadawa during the experimental period (November 1986 - March 1987) | 117 |

Chapter 1

# INTRODUCTION

Barley (Hordeum vulgare L.) belongs to the family gramineae. It is believed to be one of the world's oldest domesticated crops and probably shares with wheat the distinction of being the first plant wild form brought under cultivation (Matz, 1969). Though considered a temperate crop, barley is world wide in distribution and adaptation. It is believed to be the most widely adapted cereal crop and is possibly the most extensively grown of the cereals in the world (Kipps, 1970).

In Nigeria, barley cultivation is presently on experimental scale, entirely under irrigation in the savanna ecological zone of the country (between latitudes 10 and 13° N). It is grown during the dry season between the months of November and April. During the growing season, which coincides with the cool dry harmattan period, the optimum temperatures for germination (15 - 20°C), growth (16 - 17°C), and fertilization and grain development (18 - 20°C) are met (Kumar et al. 1982). In this zone, between the months of November and February, the maximum temperatures are consistently below 32.5°C and the minimum mostly around 15.0°C which provides the ideal thermal requirement of the crop.

The principal use of barley in Nigeria, as in most parts of the world, is making malt products. It is regarded as the principal malting grain in the production of beer, whiskey and other malt products including some types of beverages.

Since the local production of barley is practically nil, the existing breweries and distilling industries rely almost entirely on imported barley malt for their raw material. For example, in 1983, the Jos/Breweries International Nigeria Limited alone imported about 88,000 tons of barley malt valued at an estimated cost of ₦40 million (Anonymous, 1984). In order to curb this drain in the country's foreign reserves, the government recently announced the banning of barely importation with effect from 1988. Thus, the breweries and distilling industries are faced with the challenge of obtaining their raw materials locally.

Barley cultivation in Nigeria is entirely under irrigation during the dry season, and irrigation water is often a limited resource, it is therefore essential to determine the optimum quantity of water required by the crop and the appropriate time to apply it in order to optimize yield. It is also necessary to determine the most suitable time of planting to provide the ideal temperature requirements of the crop for optimum yield and malting quality.

Published data on the irrigation practices of this crop in Nigeria are limited. In virtually all the works reported to date, irrigation water was applied at pre-determined intervals of one week, two weeks or three weeks (Ahmed et al. 1977; Falaki, 1978, 1980; Falaki and Ibrahim, 1982). Although this method may be easily understood and simple to adopt by the small scale farmer, it is unscientific and often results in over- or under-irrigation as irrigation water may not be given at the time when it is most required by the crop. A better approach will therefore seem to be one that is based on the soil conditions, prevailing weather of the area, and water use of the crop. This is because irrigation frequency is controlled by the climatic conditions and the available soil water holding capacity of the root zone (Kumar et al. 1977; Choudhary and Kumar, 1981).

Temperature plays a dominant role in determining barley productivity, and is not amenable to direct control. The influence of temperature may, however, be modified by correct choice of sowing date. Furthermore, in order to get the full benefits of irrigation water, it is important to sow barley at the right time. The duration of the cold season suitable for growing barley [illegible] is very short (November - February), and farmers in this zone mostly plant their crops late.

In this study therefore, an experiment was conducted to determine the optimum quantity of irrigation water and its time of application for barley crop sown on three different dates. The general objectives were:

(1) To determine the optimum irrigation water for barley in the Sudan savanna zone of Nigeria.

(2) To investigate the effects of different irrigation levels on the growth, yield and malting quality of barley.

(3) To determine the effect of sowing date on the growth yield and malting quality of barley.

(4) To study the interaction of irrigation levels and sowing date on the growth, yield and malting quality of barley.

Chapter 2

# LITERATURE REVIEW

## 2.1 Moisture stress

Moisture supply plays a dominant role in crop production. Plant growth and yield are often reduced by moisture deficits because the internal water balance of a plant controls the various physiological processes in the plant including quantity and quality of dry matter production (Slatyer, 1973). According to Begg and Turner (1976), deficit of water is the single most important factor limiting crop growth and yield; and the reductions are dependent on the degree and duration of the deficit.

Moisture stress results from imbalance between the supply of moisture furnished by the soil and the amount needed by the plant as determined by atmospheric demand (Shaw and Laing, 1965). The daily cycle of water use is controlled mainly by the rate of transpiration, but long term reductions in plant water potential are controlled by the soil water potential (Slatyer, 1967).

### 2.1.1 Sensitivity of barley crop to water stress at different growth stages

The phenology of barley have been outlined and described by Large (1954). Also, Nimzing *et al.* (1987) have studied the duration of the various growth stages

of barley in relation to growing season at Kadawa and Samaru, and determined the critical stages.

A critical stage for water use has been defined as a distinct stage at which if water is not given, the growth and yield of the crop will be drastically affected (Large, 1954). Singh and Kumar (1979) found that withholding irrigation at any critical stage affected the growth and yield of barley and wheat. Also Kumar and Yayock (1980); Nimzing (1986); Nimzing et al. (1986 and 1987) have observed and reported similar effect of water stress on barley yield.

Adequate moisture supply at germination is very necessary to ensure good sprouts and plant establishment since number of plants per unit area, which is an important yield component is determined at this stage. It is therefore necessary in most cases to irrigate the crop before or immediately after sowing. Hughes and Metcalfe (1972) ascertained that inadequate soil moisture at germination leads to seed rottening in the soil, while Malhotra and Cheema (1977) observed that pre-sowing irrigation increased the yield and water use efficiency of barley.

Aspinall et al. (1964) observed that water stress during the early growth stages of barley has great effect on tillering of the crop. Chowdhary and Kumar (1981) working on wheat subjected the crop to water stress at

maximum tillering to flowering stages and recorded grain yield reduction resulting from fewer grains per ear and a lower 1000-grain weight. On re-watering, they observed that mildly-stressed plants showed recovery in plant height, tiller number and yield. Kumar and Singh (1976) reported a two-year average grain yield of 2.38 t/ha when barley was irrigated only at tillering stage, compared with 1.79 t/ha and 1.74 t/ha when irrigated only at flag-leaf and milk-ripe stages respectively. They concluded that the critical periods for water requirement by a barley crop were from tillering to flag-leaf stage, and from flag-leaf to milk-ripe stage. Similar observations were also reported by Singh et al. (1978). In another finding, Kumar and Singh (1977) reported that water stress between the active tillering stage and the flag-leaf stage of barley was most critical for grain yield.

Stressing barley for water at jointing stage was found by Day and Thampson (1975) to result in shorter plants, reduced lodging, more tillering and more heads per unit area. They further observed that water stress at this stage did not reduce yield, but increased it due to deeper root penetration and development, and a stronger plant which withstood wind actions and resisted lodging more effectively under irrigation. In contrast, Day and Intalop (1970) found that moisture stress at jointing

reduced grain yield of wheat due to reductions in plant size, photosynthetic area, heads per unit area, and seeds per spike.

Navas (1975) reported that the heading stage of barley was one of the most sensitive stages for moisture. He found that water stress during this stage resulted in reduction in the number of spikes per unit area, spikelets per spike and grains per spike. Similarly, in an earlier work with wheat, Robins and Domingo (1962) reported maximum reduction in yield for soil water stress occuring during and after heading. They suggested that moisture stress be avoided from booting to grain filling stage. This view has been corroborated by the findings of other researchers (Aspinall et al. 1964, Fischer, 1973; Singh, 1981).

The reproductive stages of both barley and wheat are highly critical for grain yield with respect to the availability of soil moisture (Singh and Kumar, 1979). Aspinall et al. (1964) and Kumar et al. (1977) also found damaging effects of water stress at grain development stage of barley and wheat. Aspinall et al. (1964) reported that grain number per ear was seriously affected by stress occurring prior to anthesis, an effect associated with the process of spikelet initiation and formation of the gametes. Grain size on the other hand was reduced more by stress at or shortly after anthesis. Day and Intalop (1970) observed that moisture stress

occurring at the flowering and dough stages reduced grain yield due to lighter-seed weight, and it also hastened maturity. Day and Thampson (1975) in their investigation found that moisture stress at flowering stage of barley resulted in fewer seeds per head because some seeds failed to develop at low moisture conditions.

### 2.1.2 Effects of water stress on yield and yield components

Water stress limits crop growth and yield, and the extent of reductions depends on the degree, duration and the timing of the stress, and the proportion of the total yield that comprises the economically useful part of the crop (Sepaskhah and Ardekani, 1976). The components that are influenced by water stress depend largely on the timing of stress in relation to the development of the part of the crop that is economically useful. In general, a plant organ is most sensitive to water stress during its period of rapid development (Sanchez-Diaz and Kramer, 1971 and Choudhury and Kumar, 1981).

Aspinall *et al*. (1964) found that moisture stress in barley prior to anthesis had adverse effects on number of grains per ear, and grain size was reduced more by stress at anthesis or shortly after. They also reported that stress before flowering produced as many ears as the unstressed plants, but a moisture stress beginning during grain filling even reduced grain size significantly.

However, Fischer (1973) observed that the period 5-15 days before ear emergence in wheat was the most sensitive stage for moisture. He found that when the crop was stressed for water, the yield components most affected were the number of grains set per ear.

### 2.1.3 Effects of moisture stress on the malting quality of barley

Water stress influences not only economic yield, but also the quality of a crop. It has been reported that water stress increases the nitrogen percent of small grains such as barley and wheat (Storrier, 1965; Campbell et al. 1969). An increase in the nitrogen content of the grains would increase the feeding and baking qualities of both barley and wheat (Miller, 1938), but this would reduce the malting quality of barley due to excessive enzymatic activity and foaming during malting process, and a haze in the finished product (Chapman and Carter, 1976; Palmer and Bathgate, 1976).

Protein content of the grain is the major quality component in the production of barley for malting (Pomeranz et al. 1976). The best cultural practices for malting barley production are those that combine high yields with low protein contents. A good malting barley should be plump and well filled, free from diseases and broken and skinned kernels, bright in

colour, moderate in protein and capable of vigorous uniform germination (Pomeranz et al. 1976; Palmer and Bathgate, 1976; Rehm and Moomaw, 1980). Protein levels for grains for malting should range between 11.5 - 13.0% for 6-row barley and 10.0 - 12.0% for the 2-row cultivars (Chapman and Carter, 1976).

### 2.1.4 Recovery from water stress

Rewatering stressed plants results in increased water potential of the plant, and thus recovery of turgor. However, stomatal opening and photosynthesis do not normally resume immediately after rewatering (Schneider and Childers, 1941; Stafelt, 1955; Iljin, 1957; Glover, 1959).

Removal of stress was found to result in transitory greater rates of leaf enlargement (Boyer, 1970; Hsio et al. 1970; Acevedo et al. 1971). This effect according to Acevedo et al. (1971) might be due to cell extensibility during water stress. However, according to Boyer (1970), the rate of leaf enlargement was not as rapid as in the well watered plants. Thus, with brief stress, full recovery was possible (Acevedo et al. 1971), but with long or severe stress, full recovery was not observed (Boyer, 1970; Acevedo et al. 1971).

Sanchez-Diaz and Kramer (1971) found that alleviation of water stress during floral development

resulted in a more rapid development of the floral organs whose development was hindered by stress.

2.1.5 Water-use efficiency

Water-use efficiency refers to a parameter of yield, and is defined as the ratio of dry matter or marketable yield of a crop produced per unit area over the delta of water (ET) used to produce the crop. It is represented as:

$$WUE = Y / ET$$

where WUE = water use efficiency
Y = economic yield of crop
ET = evapotranspiration or seasonal water use of crop.

Water use efficiency implies the beneficial utilization of water for producing a commercial crop, while on the other hand, ET implies a water loss which should be reduced to the lowest possible level in order to increase WUE. Therefore WUE can be improved by either increasing dry matter production (Y) or by decreasing water use (ET), or by increasing Y, at the same time decreasing ET (Begg and Turner, 1976).

Water loss from soil and plant surfaces can be reduced through cultural practices such as mulching and use of anti-transpirants. These two methods, however, have little practical significance on crop production

on a large scale. Practices like effective weed control, insects and disease control are very effective in increasing the WUE of crops on field scale.

For most of the grain crops, the general trend of crop water use during the whole period of growth and development is that it starts from a minimum at the beginning of germination, increases continuously to a certain maximum at the flowering stage, and then again decreases continuously until the harvesting stage. In field conditions, crop water use is subject to the changing atmospheric evaporative demand.

Day et al. (1978) reported a linear relationship between yield and water use of barley. They further stated that prolonged drought during the early growth stages had a great effect on both yield and water use.

Kumar and Singh (1976) reported that WUE of barley was maximum with one irrigation at active tillering stage (12.80 kg/ha-mm), closely followed by two irrigations at active tillering and flag-leaf stage (12.45 kg/ka-mm). This indicated that water stress in barley during the active tillering to flag-leaf stage was most harmful.

Hochman (1982) reported that water stress from booting to grain filling stage reduced the grain yield and WUE of wheat by 36% due to reductions in the number of grains per spike and 1000-grain weight. Also

Choudhary and Kumar (1981) have found reductions in the grain yield and WUE of wheat when given stress during seeding to maximum tiller-stage.

Comparing barley and wheat Singh and Kumar (1979) observed that under all levels of stress, leaf water potential of barley was higher than that of wheat, and recovery of leaf water potential was also faster in barley indicating that barley was more resistant to drought than wheat. They also reported that on the average, a decrease in the leaf water potential by - 1 bar at soft dough stage decreased barley and wheat yields by 70 kg/ha and 150 kg/ha respectively indicating higher drought tolerance capacity of barley over wheat.

### 2.1.6 Irrigation scheduling

To achieve better crop productivity, it is important to work out an efficient and economic irrigation schedule for use under any given set of agro-climatic conditions. Since response of a crop to irrigation is influenced by soil, plant and atmospheric factors, the potential advantages of basing irrigation schedule on soil-crop-climate data have been emphasized by many researchers (Sepaskhah, 1978; Singh, 1978; Chari and Maurya, 1980).

Several methods of scheduling irrigation of crops are available and investigations have been made on the effects of each method based on various concepts and approaches on yield and WUE of crops. The common approaches

that have been used for scheduling irrigation of crops include:

i) Irrigation scheduling based on a fixed time interval:
Several researchers have optimized the yield and WUE of barley by applying fixed amounts of irrigation water at fixed intervals (Johanson, 1977). Falaki et al. (1980) and Falaki and Ibrahim (1982) irrigated barley at one, two and three weeks intervals, and they suggested that the crop should be irrigated at 10 days intervals for attainment of maximum yield and WUE in the Sudan savanna zone of Nigeria.

ii) Irrigation scheduling based on critical stages:
This is mainly concerned with irrigation at the critical stage of growth for water need of the crop. This approach has been described as the most practical criterion for scheduling irrigation of small-grain crop like barley (Falaki et al. 1979). Some of the critical stages for water requirement by a barley crop are germination, tillering, jointing, heading, flag-leaf, flowering, and dough stage (Large, 1954).

iii) Irrigation scheduling based on depletion of available soil moisture (ASM) from the soil profile:
This approach is based on the fact that crop growth under irrigation is stimulated by moderate quantities

of soil moisture and retarded by deficient quantities. The ASM in the active root zone is the amount of moisture available for the crop use. Depletion of the ASM from the active root zone is accompanied by loss of moisture for the crop.

Bajpai and Mertia (1977) reported that grain yield and WUE of barley were highest with 50% depletion of ASM irrigation than with 80% or 70% ASM depletion. Also Sepaskhan and Arde Kani (1976) suggested that irrigation at 50% ASM would result in higher grain yields and WUE. Singh et al. (1980) reported that irrigation of wheat at 50% ASM resulted in greatest yield per centimeter of water used by the crop.

iv) Irrigation scheduling based on the ratio of a fixed amount of irrigation water applied (IW) to commulative pan evaporation (CPE):
In this approach, the fixed amount of irrigation water has relevance to available soil moisture capacity, moisture deficit before next irrigation and the effective root zone depth of the crop (Chari and Maurya, 1980). On the other hand, pan evaporation generally has a relation with the crop water requirement or loss of water by the crop through ET - due to atmosphere and crop factors. In this approach, various ratios between the depth of irrigation water and cummulative pan evaporation

are used to find the best irrigation frequency for a particular crop.

v) Irrigation scheduling based on the ratio of actual evapotranspiration (AET) to potential evapotranspiration (PET):
This is a prediction method for crop water requirement. Different ratios between AET to PET are used for a particular crop to get the optimum yield and WUE. A number of researchers have optimized the yield and WUE of barley and wheat using this approach. Ratey et al. (1978) reported that optimum yield and WUE of wheat may be obtained at AET/PET ratios of between 0.5 - 0.7.

Generally, among the several approaches of scheduling irrigation, methods based on fixed time intervals may not be completely satisfactory under all given sets of agro-climatic conditions. This method is unscientific in the sense that irrigation is given too frequently in most cases irrespective of the crop water requirements, the soil type and the prevailing weather conditions. As such the method often results in wastage of water due to excess application.

The critical stage approach too may not be quite appropriate in the arid and semi-arid climate as high ET demand may result in rapid depletion of available soil

moisture thereby drying the root zone before irrigation is due at the next critical stage. This approach can be applied successfully under the conditions of high water holding capacity as in heavy textured soils with low ET.

## 2.2 Effects of sowing date on the growth and yield of barley

Time of planting has a marked effect on the growth, yield and quality of barley (Bockstaele and Maddens, 1965). Yields generally decline with sowings done earlier or later than an optimum period due to effects of environmental factors such as drought (as a result of late start or early ceasation of rainfall under rainfed conditions), solar radiation and temperature (Mark, 1965; Singh et al. 1975).

Kumar et al. (1982) indicated that temperature constitutes the major limiting factor to barley productivity and growing season in Northern Nigeria, because its cultivation in the country is entirely under irrigation during the dry harmattan period. According to these researchers, by late February/mid-March in the savanna, air temperature rises abruptly, and the high maximum temperature (above 35°C) coupled with low relative humidity (about 20%) could adversely affect flowering, grain development and time of maturity of the crop. They concluded that the time of planting of barley during the dry season should be adjusted such that the crop utilizes

as much as possible the favourable growing season (110 - 130 days) to accumulate maximum economic yield.

Some researchers in Nigeria have grown and reported the performance of malting barley varieties to different dates of sowing, and suggested suitable times for planting barley varieties in the barley growing zone of the Nigerian savanna.

Sinha (1982) reported that the best time for sowing barley varieties at Kadawa is mid-November. Sinha and Falaki (1982), working on three barley varieties (Berenice, Ketch and Trampf) sown on five dates at forthnightly intervals beginning late October to late December also observed that November sowings gave higher grain yields than sowings made in October and December. In another report by Asenime and Sinha (1983), sowings done in mid-November to late-December resulted in higher grain yields than early November sowing.

Summarizing all research works on the sowing date of barley in the Nigerian savanna, Asenime and Sinha (1986) recommended that in a normal season when there is no severe and protracted harmattan, sowing barley from the second week of November to first week of December would result in optimum yield. But when harmattan is severe and prolonged, sowing from the second week of November to ~~first~~ week of December is recommended.

Several researchers in different parts of the world have reported decreases in yields of barley with late

Pade

sowing. Park (1975), working on the sowing date of barley in South Korea, reported that timely sowing of the crop gave early emergence, earlier greatest tillering, higher number of tillers per square meter, higher number of ears per unit area, and higher dry matter accumulation.

Kumar and Yayock (1980) in Nigeria also found that timely-planted wheat (mid-November) produced a yield of 4640 kg/ha, while the late-planted (mid-December) crop yielded 59% less grain due to reductions in dry weight, head length, grain number per head and 1000-grain weight.

Apart from yield reductions, late sowing of barley may also encourage the build-up of diseases (Francis, 1974). Johnston (1976) reported a 55% yield reduction in barley due to root rot disease (Cochlioblus sativus) when sowing was delayed by one week. Similarly, Machacek (1943) observed great reduction in the tillering of wheat due to root rot disease as a result of late sowing.

2.2.1 Effect of sowing date on malting quality of barley

Time of sowing has a marked effect on the malting quality of barley grains (Munro et al. 1974; Munro and Ann, 1977; Ondruch, 1977). Bockstaele and Maddens (1965) found that grain protein content was lower in barley sown early; yield of extract during malting was 1.7% lower in the early crop compared with the late sown. Antoszewaska and Ulinski (1966) reported an increase in grain protein,

phosphorus and potassium contents with two weeks delay in sowing. Munro et al. (1974) observed a mean increase in grain nitrogen content of 0.15% when sowing was delayed for 4-6 weeks. Mundy and Page (1972) observed that early sown crops produced grains with a lower nitrogen content compared to late sown crops. Ondruch (1977) found a decrease in the grain malting quality with 10 or 20 days delay in sowing.

Decreases in the malting quality of barley with lateness in sowing have also been reported in Nigeria (Sinha 1982; Sinha and Falaki, 1982; Asenime and Sinha, 1983 and 1984).

## 2.3 Irrigation and sowing date interactions

Crop growth and yield under irrigation with adequate supply of water could perhaps be limited by other environmental factors like temperature, solar radiation and wind movement.

Singh and Kumar (1979) indicated that the interaction between irrigation and time of sowing is due to the effects of differing atmospheric demands. In an experiment in the semi-arid part of India, they found that soil moisture status differed on two dates of sowing (November 11 and December 11) with consequent reductions in the leaf water potentials of both barley and wheat under the late sowing

due to excessive loss of water by evapotranspiration as a result of high evaporative demand of the weather.

Parmer (1978) found that the interaction between irrigation and planting time was significant in the post-flowering period of wheat. He observed greater reduction in grain yield due to infrequent irrigation in the late sown wheat due to the effect of high temperatures (in March) at grain development stage.

The interaction between irrigation practices and sowing date was also found to be highly influenced by cultivar (Anonymous, 1977). It was observed that early maturing varieties of wheat yielded well when sown late by maturing before the onset of damaging by high temperatures in March, while longer season varieties gave their maximum yields at early sowing dates under same irrigation treatments at Kadawa.

Chapter 3

# MATERIALS AND METHODS

## 3.1 Experimental site

The experiment was conducted at the Irrigation Research Station Kadawa (Kano State) of the Institute for Agricultural Research, Ahmadu Bello University, during the 1986/87 dry season. Kadawa is located in the Sudan savanna ecological zone of Northern Nigeria ($11^{o}$ 39' N, $08^{o}$ 02' E and 500m above sea level).

## 3.2 Soil analysis

A composite soil sample was collected from various points on the field at 0-30 cm and 30-60cm depths for analyses for the physico-chemical properties. Results of the analyses are given in Appendix A.

## 3.3 Soil moisture relations

The field capacity (FC) and the permanent wilting point (PWP) levels of the soil were estimated from the moisture characteristic curves of the experimental field as determined by Nwadukwe (1986). The FC was estimated at -0.2 bar and the PWP at -15 bar. From these values, the available soil moisture (ASM) was estimated by the difference. From the curves, moisture content at FC was 38.6% by volume and that at PWP was 18.2% by volume; and therefore the ASM was 20.4% by volume.

The 20.4% moisture content by volume implies 0.204 cc of water/cc of soil, which was multiplied by the depth of the soil profile under consideration for conversion to depth basis. In this experiment, the effective root zone depth of barley was taken as 60 cm (Anonymous, 1979). Therefore for 60-cm soil depth, the ASM was 0.204 x 60 = 12.24 cm of water/60cm soil depth. Assuming 50% allowable depletion of the ASM in this soil profile, irrigation was therefore given when 6.12cm of water was assumed to be depleted, and thus the addition of 6.12 cm depth of irrigation water to the plots was considered as the "optimum irrigation water level".

Optimum water level is a condition whereby the crop was irrigated with just enough water required for its growth, no excess, no stress.

### 3.4 Experimental treatments

The treatments tested included four irrigation levels and three sowing dates. Details of the treatments are as follows:

Irrigation levels

$I_1$ = optimum irrigation level throughout the growth period using $IW/CPE$ ratio as described below.

$I_2$ = 75% of optimum irrigation level at the reproductive stage only.

$I_3$ = 50% of optimum irrigation level at the reproductive stage only.

$I_4$ = 50% of optimum irrigation level throughout the growth period.

Sowing date

$D_1$ = Early - November (November 4).

$D_2$ = Late - November (November 25).

$D_3$ = Mid - December (December 16).

The irrigation treatments were based on the concept of the ratio of irrigation water (IW) to cummulative pan evaporation (CPE), i.e. $^{IW}/_{CPE}$ ratio - (Kumar et al. 1977; Choudhary and Kumar, 1981). Daily pan evaporation data was collected from a class 'A' U.S. open pan evaporimeter installed at the adjoining field in determining when to give irrigation.

The concept of irrigation scheduling using the $^{IW}/_{CPE}$ ratio is based on the fact that cummulative actual evapotranspiration of a crop is given by the equation.

$$CAET = Kc.\ Pc\ \ CPE = IW \quad \text{——————} \quad (1)$$

where CAET = cummulative actual evapotranspiration.

Kc = crop coefficient

Pc = pan coefficient

CPE = cummulative pan evaporation

IW = irrigation water

From equation (1) above:

$$^{IW}/_{CPE} = Kc.\ Pc \quad \text{——————} \quad (2)$$

Pc is usually constant, depending on the nature of the site of the pan, and is taken as 0.7 at Kadawa (Abdulmumin 1988). But Kc changes during the growth season of the crop. It may vary from 0.3 at the establishment stage, to 0.7 at the mid-vegetative stage and 1.0 at peak vegetative to early flowering stage, and to 0.6 at the grain filling stage. These Kc values were established for wheat crop varieties by Abdulmumin (1988), but were used in this experiment because of barley's similarities with wheat in growth and water use (Anonymous, 1979).

From the information above, therefore, the irrigation frequencies of the crop were based on the following ratios at the different growth stages.

Mid-vegetative stage.

$IW/CPE = Kc. Pc$

$= 0.7 \times 0.7 = 0.49$

Peak-vegetative and early flowering.

$IW/CPE = 1.0 \times 0.7 = 0.7$

Grain filling stage.

$IW/CPE = Kc. Pc$

$= 0.6 \times 0.7 = 0.42$

Therefore the crop in $I_1$ plots was irrigated when $^{IW}/_{CPE}$ ratios were 0.47 at the mid-vegetative stage, 0.70 at the peak-vegetative and early flowering stage, and 0.42 at the grain filling to maturity stage by applying 6.12 cm depth of irrigation water at each irrigation as the"optimum irrigation level". Then the subsequent stress treatments of 50% of the optimum irrigation water were given by applying 3.06 cm depth of irrigation water to the stress plots at the appropriate stages.

3.5 Frequency of irrigation

From the equation $^{IW}/_{CPE} = Kc.\ Pc$

$$CPE = \frac{IW}{Kc.\ pc} \qquad \text{(3)}$$

The times of irrigation which were dependent on the CPE at the different growth stages were:

Mid-vegetative $= \frac{6.12}{0.49} = 124.9$ mm

Peak-vegetative and early flowering $= \frac{6.12}{0.7} = 87.4$ mm

Grain filling stage $= \frac{6.12}{0.42} = 145.7$ mm

3.6 Water application to the plots

The irrigation method was by surface flow using check basin system in plots size of 5 x 3 m. Water was conveyed from the supply channel to the plots using calibrated syphon tubes. The quantity of water applied at each irrigation was calculated on volume basis thus:

$$\text{Optimum irrigation level} = 5 \times 3 \times \frac{6.12}{100}$$

$$= 0.918 m^3 \text{ of water/plot.}$$

$$\text{50\% of optimum (stress)} = 5 \times 3 \times \frac{3.06}{100}$$

$$= 0.459 m^3 \text{ of water/plot.}$$

The different volumes of water applied in the different treatment plots at each irrigation were controlled by timing a stopwatch. This was achieved by determining the flow rate (Q) of the syphon tubes in litres/second using a clitrated bucket each time to give an irrigation.

In addition to the initial irrigation given immediately after sowing, two general irrigations were given to all the treatments at 8 and 16 days after sowing to ensure good stand establishment. Thereafter, the different treatments were applied. Tables 3.1, 3.2 and 3.3 showed the records for the periods of irrigation and the cummulative depths of water applied in the

different irrigation treatments for the first, second and third sowings, respectively.

Soil moisture content was determined before each irrigation and two days after at 0-30 and 30-60cm depths.

3.7 Water table depth:

The water table depth was determined at various points of the field before the experiment started. It varied between 100 and 120cm below the soil surface. During the experiment, water table fluctuation was monitored using a locally designed instrument called "Samaru Plop Water Level Sounder" (Nwa, 1982). It was made from kenaf stalk about 1.5cm long and calibrated in centimeters. A small light cork is attached to the bottom end of the stalk so that it can float on water surface and the instrument makes a sound as soon as it touches the water surface (Figure A). This instrument was lowered through the piezometer tubes fixed in each plot and the depth of water level was determined from the point where it made a sound. The water table depth fluctuated between 80 and 90 cm below.

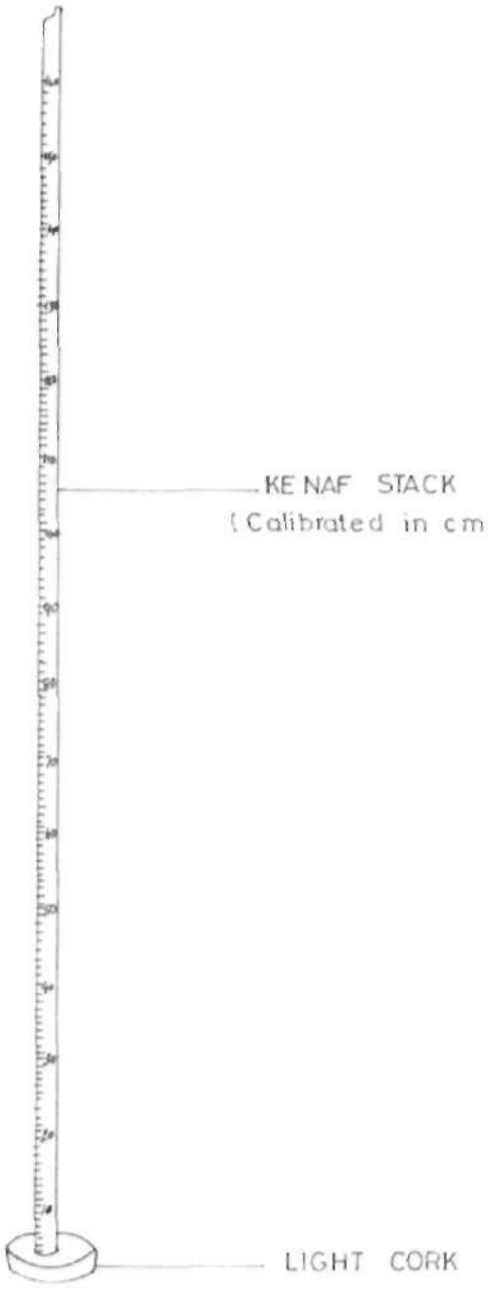



Figure A:

SAMARU PLOP WATER LEVEL SOUNDER

## 3.8 Experimental design

The experiment was laid out as a Randomized Complete Block Design with four replications.

Treatments were allocated as follows:

Irrigation levels = 4

Sowing date = 3

Replications = 4

Total number of treatments = 4 x 3 = 12

Total number of plots = 12 x 4 = 48

Treatment combinations

| | | |
|---|---|---|
| $T_1 = I_1 D_1$ | $T_5 = I_1 D_2$ | $T_9 = I_1 D_3$ |
| $T_2 = I_2 D_1$ | $T_6 = I_2 D_2$ | $T_{10} = I_2 D_3$ |
| $T_3 = I_3 D_1$ | $T_7 = I_3 D_2$ | $T_{11} = I_3 D_3$ |
| $T_4 = I_4 D_1$ | $T_8 = I_4 D_2$ | $T_{12} = I_4 D_3$ |

## 3.9 Cutural practices

The land was prepared by plowing once and harrowing twice to get a fine tilth. The field was then divided into plots of 5 x 3 m size. Irrigation and drainage channels were well constructed for efficient water distribution to the plots. Individual plots were separated by one meter gap to avoid seepage of water from adjacement plots.

Fertilizer at the rate of 60 kg N/ha and 40 kg $P_2O_5$/ha were applied to each plot and incorporated three days before sowing.

Barley (cultivar Berenice), which matures in 100-120 days was hand-drilled in rows of 20 cm apart at a seed rate of 120 kg/ha. There were 12 rows in each plot. The second and eleventh rows were earmarked for sampling, while grain yield was determined from the eight centre rows. Weeding was done by hand pulling whenever necessary.

3.10 Observations recorded

i. Crop emergence: This was recorded at 8 days after sowing. Plants were counted from an area of one square meter.

ii. Tillers: These were recorded at 3 weeks interval beginning 3 WAS until physiological maturity. All plants were counted from a 25-cm row length and then expressed per square meter. The number of ear-bearing tillers was also recorded at harvest.

iii. Plant height: 10 plants were randomly selected and tagged from each plot. The height of each plant was measured from the ground level to the tip of the longest leaf at 3 weeks intervals.

iv. Leaf area per plant: Five plants were taken from each plot. The length and breadth of each functional leaf was measured using a ruler and multiplied by a factor of 0.876 (Rao et al. 1967). The areas of the individual leaves from the five plants were added together and divided by the number of plants.

v. Leaf area index: This was determined by multiplying the leaf area per plant (iv above) by the number of plants in a meter square area and then dividing by the land area.

vi. Dry matter accumulation: This was determined by taking all the plants from a 25-cm row length cut from the base with a sharp knife, and leaves and stems separated and oven-dried at 80°C for 48 hours and then weighed. This was then converted to dry matter accumulation in grammes per square meter.

vii. Number of days to 50% flowering: Days from sowing to the time above 50% of the plants in each plot had flowered.

viii. Number of days to maturity: Days from sowing to the time plant rachis was dried in about 50% of the spikes.

ix. Crop growth rate: It was calculated using the following formula:

$$CGR = \frac{W2 - W1}{t_2 - t_1}$$

where $W_1$ = total dry wt. at $t_1$

$W_2$ = total dry wt. at $t_2$

x. Number of spikes per square meter: This was counted at harvest from each plot.

xi. Length of spike: It was measured at harvest using a ruler by taking 10 spikes from each plot.

xii. Number of grains per spike: This was determined using 10 spikes from each plot and counting the number of grains on each spike.

xiii. 1000-grain weight: 1000-grains were counted from each plot and weighed.

xiv. Grain yield: Weight in grammes of the grains from the plants in 4.0m length of the eight centre rows (i.e 6.4 $m^2$ net plot) was taken and converted to kg/ha. All the plants from the harvest area were cut from the base, bundled and properly sun-dried in a protected area before weighing. The plants were then threshed manually, winnowed, and the grains cleaned and weighed accurately and then converted to kg/ha.

xv. Straw yield: The straw yield was determined by obtaining the difference between the total dry weight and the grain weight from the harvest area of each plot and then converting to kg/ha.

xvi. Grain protein content: This was obtained by estimating the nitrogen content of the grains (%) as described by Jennings (1961). The nitrogen percent was then multiplied by 6.25 to convert it to crude protein content (Jackson, 1962).

xvii. Cummulative water use: The water use was estimated by summing up the depths of irrigation water applied at each treatment for the crop duration.

xviii. Water-use efficiency (WUE): It was estimated using the following formula:

$$WUE = \frac{\text{Grain yield (kg/ha)}}{\text{cummulative depth of water used.}}$$

Data Analysis

All data collected were subjected to statistical analyses for significance of differences as described by Snedecor and Cochran (1967).

Table 3.1: Periods of irrigation and cummulative depths of water applied for the [illegible] irrigation treatments for barley sown in early-November

| Days from sowing | | Depth of water application (cm) per irrigation per plot | | | | Irrigation interval (days) |
|---|---|---|---|---|---|---|
| | | Optimum water throughout | 50% opt. water at veg. stage | 50% opt. water at repr. stage | 50% opt. water throughout | |
| Gen. irrigs. | 8 | 6.12 | 6.12 | 6.12 | 6.12 | 8 |
| | 16 | 6.12 | 6.12 | 6.12 | 6.12 | 8 |
| Kc = 0.7 | 30 | 6.12 | 3.06 | 6.12 | 3.06 | 14 |
| | 44 | 6.12 | 3.06 | 6.12 | 3.06 | 14 |
| Kc = 1.0 | 54 | 6.12 | 3.06 | 6.12 | 3.06 | 10 |
| | 64 | 6.12 | 3.06 | 6.12 | 3.06 | 10 |
| | 74 | 6.12 | 6.12 | 3.06 | 3.06 | 10 |
| Kc = 0.6 | 90 | 6.12 | 6.12 | 3.06 | 3.06 | 16 |
| | 106 | 6.12 | 6.12 | 3.06 | 3.06 | 16 |
| | Total | 55.08 cm | 42.84 cm | 45.90 cm | 33.66 cm | |

Table 3.2: Periods of irrigation and cummulation depths of water applied for the ar irrigation treatments for barley sown in late-November

| Days from sowing | | Depth of water application (cm) per irrigation per plot | | | | Irrigation interval (days) |
|---|---|---|---|---|---|---|
| | | optimum water throughout | 50% opt. water at veg. stage | 50% opt. water at repr. stage | 50% opt. water throughout | |
| Gen. irrigs. | 8 | 6.12 | 6.12 | 6.12 | 6.12 | 8 |
| | 16 | 6.12 | 6.12 | 6.12 | 6.12 | 8 |
| | 29 | 6.12 | 3.06 | 6.12 | 3.06 | 13 |
| Kc = 0.7 | 43 | 6.12 | 3.06 | 6.12 | 3.06 | 14 |
| | 54 | 6.12 | 3.06 | 6.12 | 3.06 | 11 |
| Kc = 1.0 | 65 | 6.12 | 3.06 | 6.12 | 3.06 | 11 |
| | 76 | 6.12 | 6.12 | 3.06 | 3.06 | 11 |
| Kc = 0.6 | 92 | 6.12 | 6.12 | 3.06 | 3.06 | 16 |
| | 108 | 6.12 | 6.12 | 3.06 | 3.06 | 16 |
| | Total | 55.08 cm | 42.84 cm | 45.90 cm | 33.66 cm | |

Table 3.3: Periods of irrigation and cummulative depths of water applied for the four irrigation treatments for barley sown in mid-December

| Days from sowing | | Depth of water application (cm) per irrigation per plot | | | | Irrigation interval (days) |
|---|---|---|---|---|---|---|
| | | Optimum water throughout | 50% opt. water at veg. stage | 50% opt. water at repr. stage | 50% opt. water throughout | |
| Gen. irrigs. | 8 | 6.12 | 6.12 | 6.12 | 6.12 | 8 |
| | 16 | 6.12 | 6.12 | 6.12 | 6.12 | 8 |
| Kc = 0.7 | 29 | 6.12 | 3.06 | 6.12 | 3.06 | 13 |
| | 42 | 6.12 | 3.06 | 6.12 | 3.06 | 13 |
| | 52 | 6.12 | 3.06 | 6.12 | 3.06 | 10 |
| Kc = 1.0 | 63 | 6.12 | 3.06 | 6.12 | 3.06 | 11 |
| | 74 | 6.12 | 6.12 | 3.06 | 3.06 | 10 |
| | 89 | 6.12 | 6.12 | 3.06 | 3.06 | 15 |
| Kc = 0.6 | 104 | 6.12 | 6.12 | 3.06 | 3.06 | 15 |
| | Total | 55.08 cm | 42.84 cm | 45.90 cm | 33.66 cm | |

Chapter 4

# RESULTS

## 4.1 Growth characters

### 4.1.1 Germination count

Regardless of the levels of irrigation, all treatments produced statistically the same number of plants per square meter at 8 days after sowing (Table 4.1).

The late-November sowing produced significantly higher number of plants per square meter at 8 days after sowing than the other two sowings which were statistically at par.

The interaction between irrigation levels and sowing date on the number of plants per square meter at 8 days after sowing was not significant.

### 4.1.2 Plant height

Plant height was highly influenced by the different levels of irrigation given at the different growth stages of barley (Figure 1). Plants supplied with optimum irrigation water throughout the growth period ($I_1$) and those supplied with 50% of optimum water at the reproductive phase ($I_3$) had similar heights. Those plants supplied with 50% of the optimum irrigation water either at vegetative stage only ($I_2$) or throughout the growth period ($I_4$) also had similar heights, but were significantly shorter than plants in treatments $I_1$ and $I_3$.

Table 4.1: Emergence count at 8 days after sowing.

| Treatments | Number of plants/$m^2$ |
|---|---|
| Irrigation levels | |
| $I_1$-- Optimum water throughout | 109.2 |
| $I_2$ - 50% optimum water at vegetative stage only | 106.1 |
| $I_3$ - 50% optimum water at reproductive stage only | 107.8 |
| $I_4$ - 50% optimum water throughout | 110.3 |
| S.E. ± | 2.1 |
| L.S.D. (P = 0.05) | 6.1 |
| Sowing date | |
| $D_1$ - November 4 | 97.3 |
| $D_2$ - November 25 | 121.3 |
| $D_3$ - December 16 | 104.9 |
| S.E. ± | 1.8 |
| L.S.D. (P = 0.05) | 5.3 |

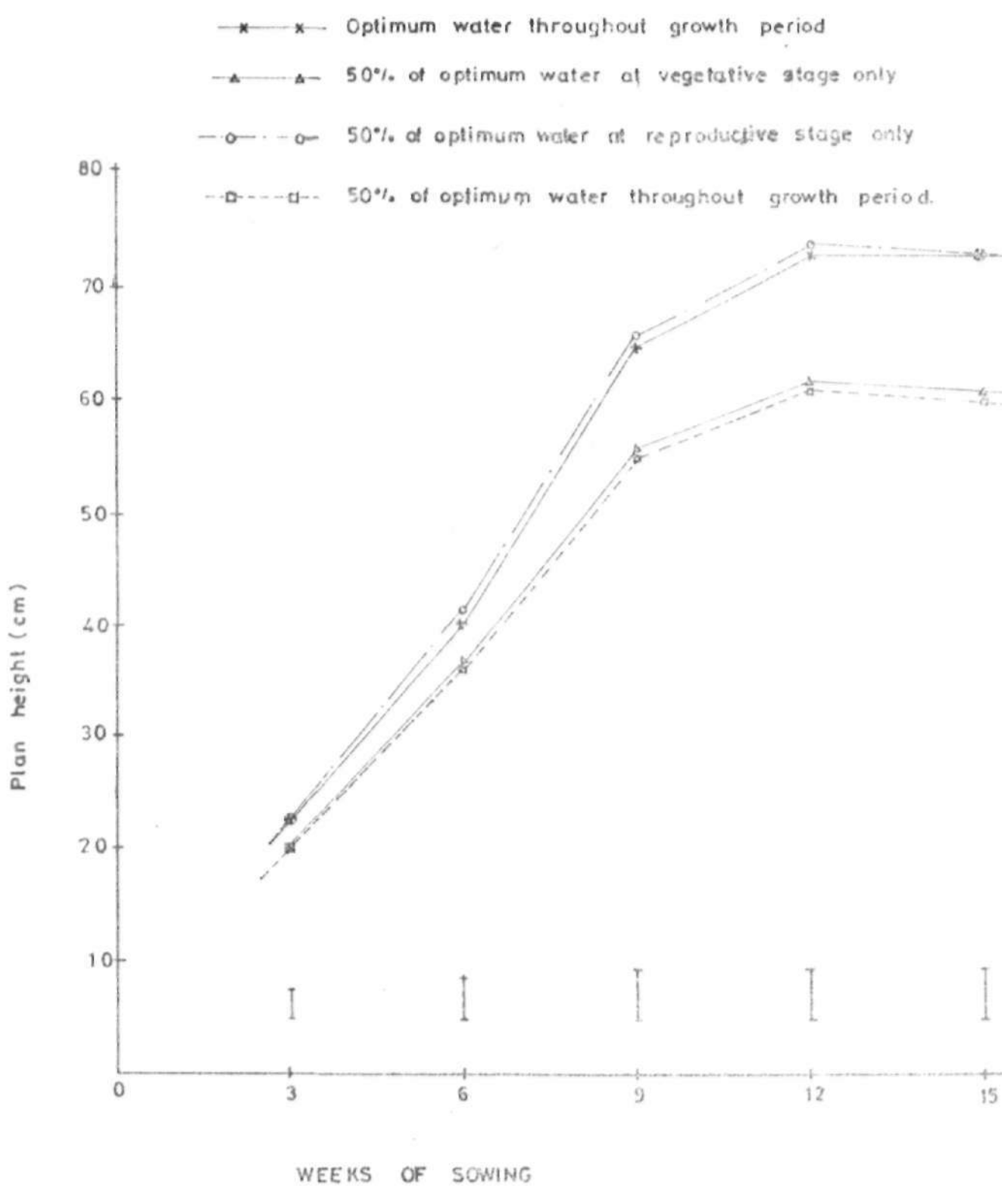



Fig 1: Plant height (cm) as affected by irrigation levels at Kadawa during 1986/87 dry season

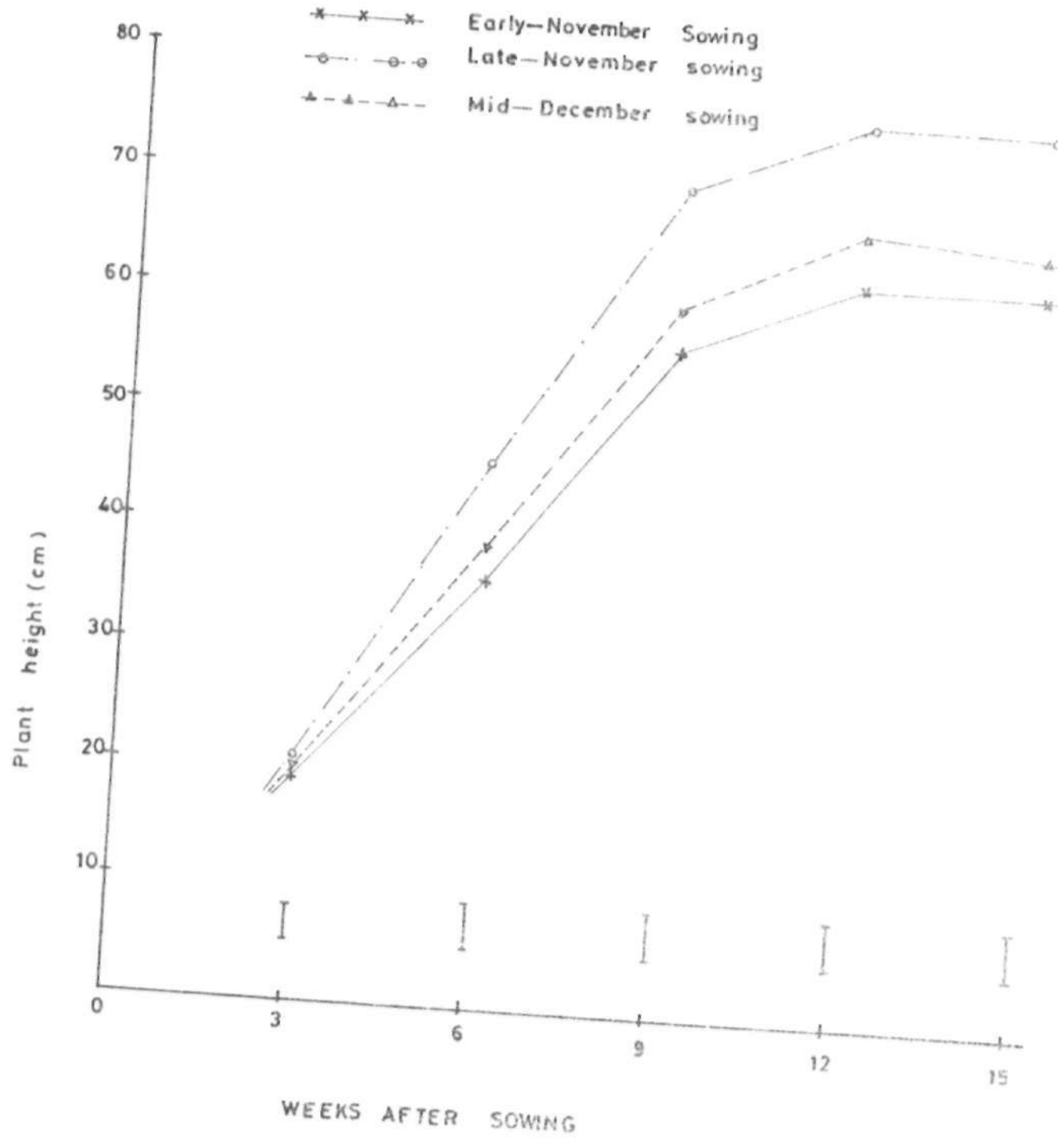



Fig 2: Plant height (cm) as affected by date of sowing at Kadawa during 1986/87 dry season

Significant differences in the height of plants were also observed with the different dates of sowing (Figure 2). Crop sown in late-November ($D_2$) had the tallest heights, while early-November ($D_1$) and mid-December ($D_3$) sowings produced significantly same heights.

The interaction between irrigation levels and sowing date on plant height was not significant.

4.1.3. Leaf area per plant

Treatment supplied with optimum water throughout growth period and those supplied with 50% of optimum water at the reproductive stage only produced larger leaf area than treatments supplied with 50% of optimum irrigation water either at vegetative stage only or throughout the growth period (Figure 3). Leaf area of $I_1$ and $I_3$ were similar up to 12 weeks after sowing (WAS), thereafter, $I_1$ had a larger leaf area. In the same manner, leaf area of $I_2$ and $I_4$ were similar up to 12 WAS, from where $I_4$ showed a more rapid decline and having the lowest leaf area. In all the irrigation treatments, leaf area reached a peak at 9 WAS, thereafter, there was a decline due to leaf senescence.

Mean differences in the leaf area per plant with date of sowing are presented in Figure 4. The late-November sown crop had the largest leaf area per plant,

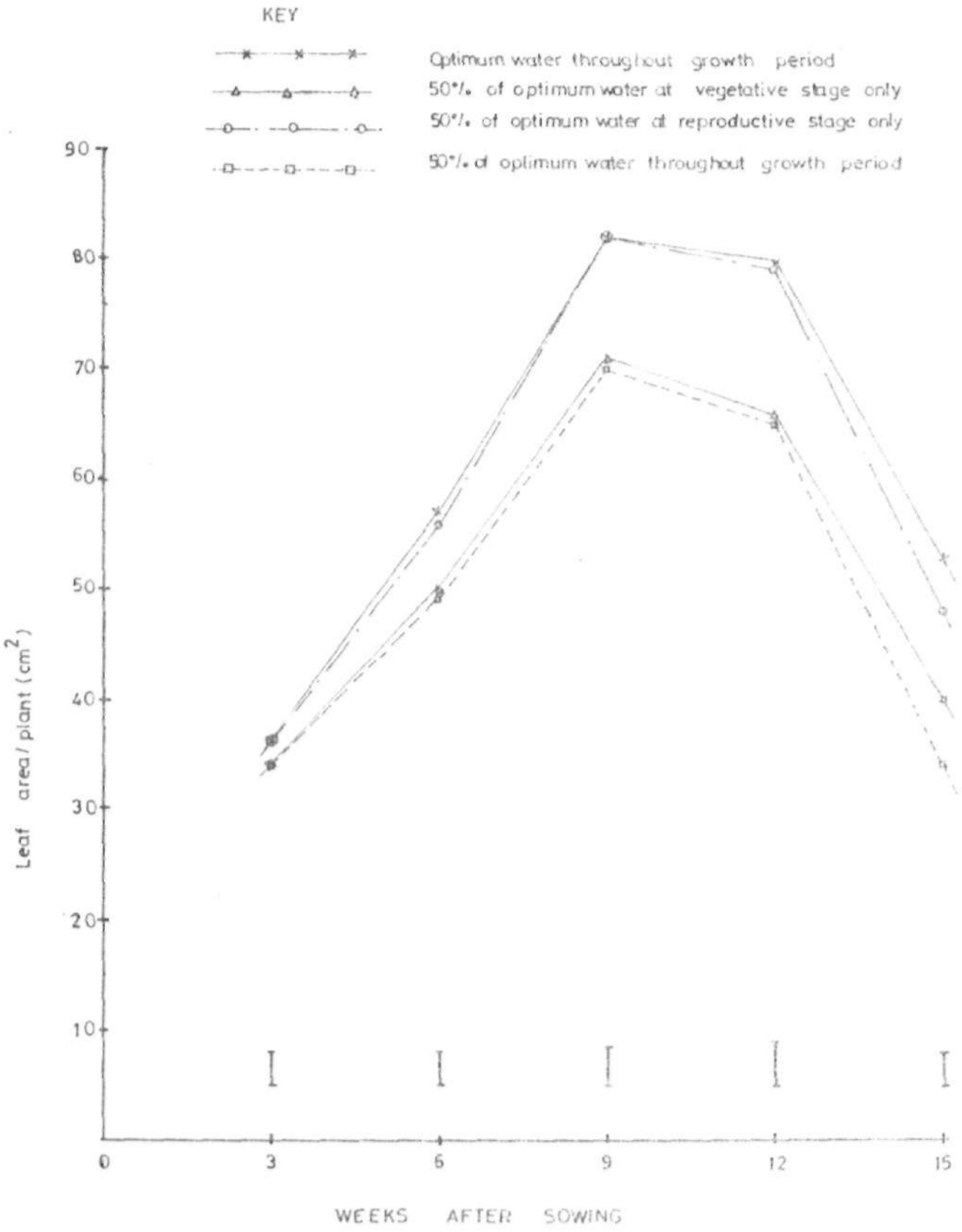



Fig 3: Leaf area/ plant (cm ) as affected by irrigation levels at Kadawa during 1986/87 dry season

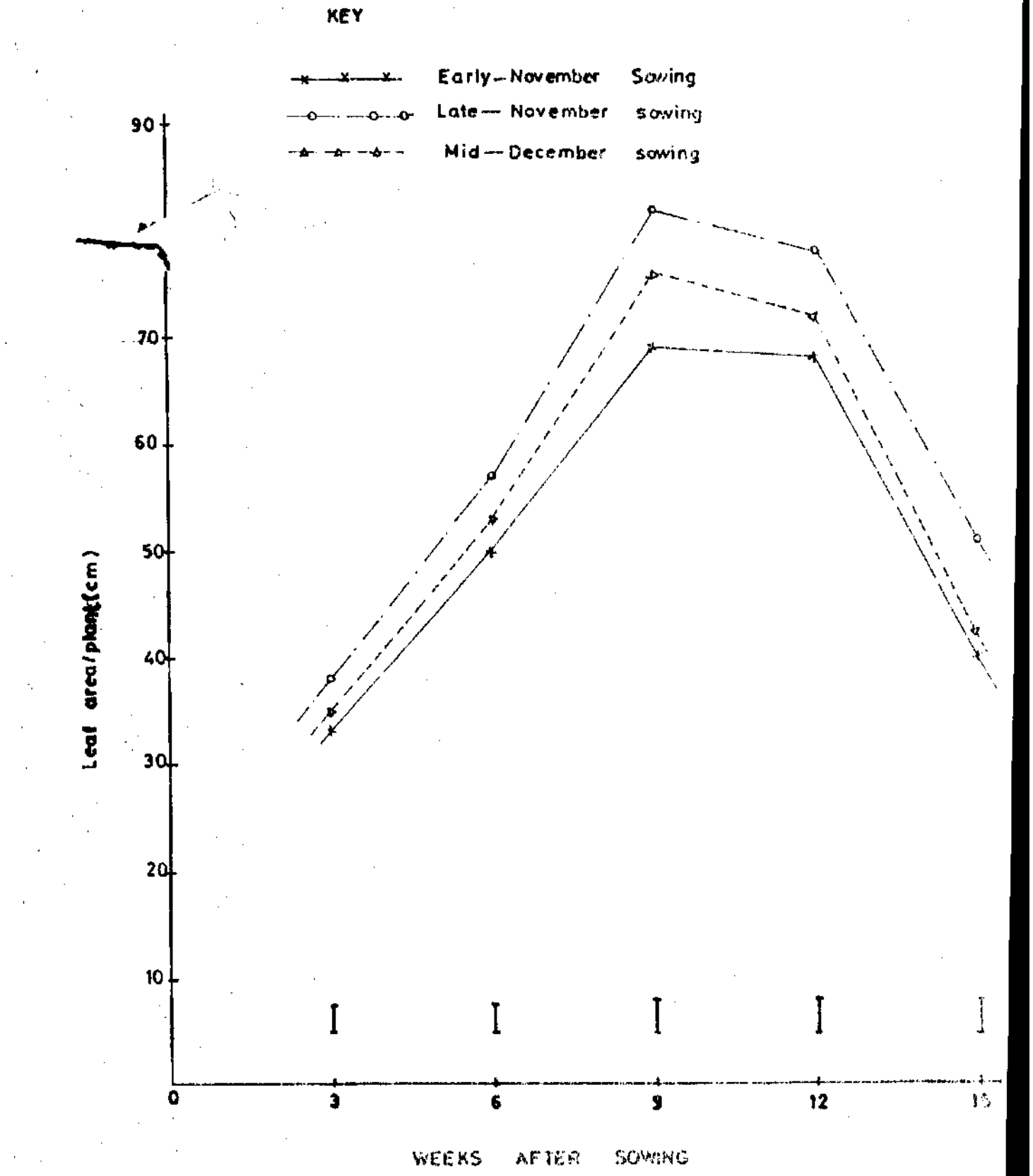



Fig 4: Leaf area/Plant(cm) as affected by sowing date at Kadawa 1986/87 dry season

followed by the mid-December sown crop. Sowing in early-November produced the smallest leaf area per plant. The differences in the leaf area of the early-November and mid-December sown plants were largely insignificant statistically.

The interaction between irrigation levels and sowing date on leaf are per plant was not significant.

### 4.1.4 Leaf area index (LAI)

Irrigation levels and sowing date both influenced the leaf area index (Figures 5 and 6). Treatments $I_1$ and $I_3$ supplied with optimum irrigation water throughout the growth period and during vegetative stage only, respectively had statistically higher and similar LAI up to 12 WAS, thereafter, $I_1$ had the highest. Likewise, $I_2$ and $I_4$ treatments that received 50% of the optimum irrigation water at the vegetative stage only and throughout the growth period, respectively had statistically lower but similar LAI up to 12 WAS compared with the other treatments. From 12 WAS, $I_4$ had the lowest LAI.

Among the dates of sowing, late-November sowing had the highest LAI values at all the sampling dates. This was followed by the mid-December sowing. The early-

sampling dates, the LAI values were significantly different with the different sowing dates except at 3 WAS

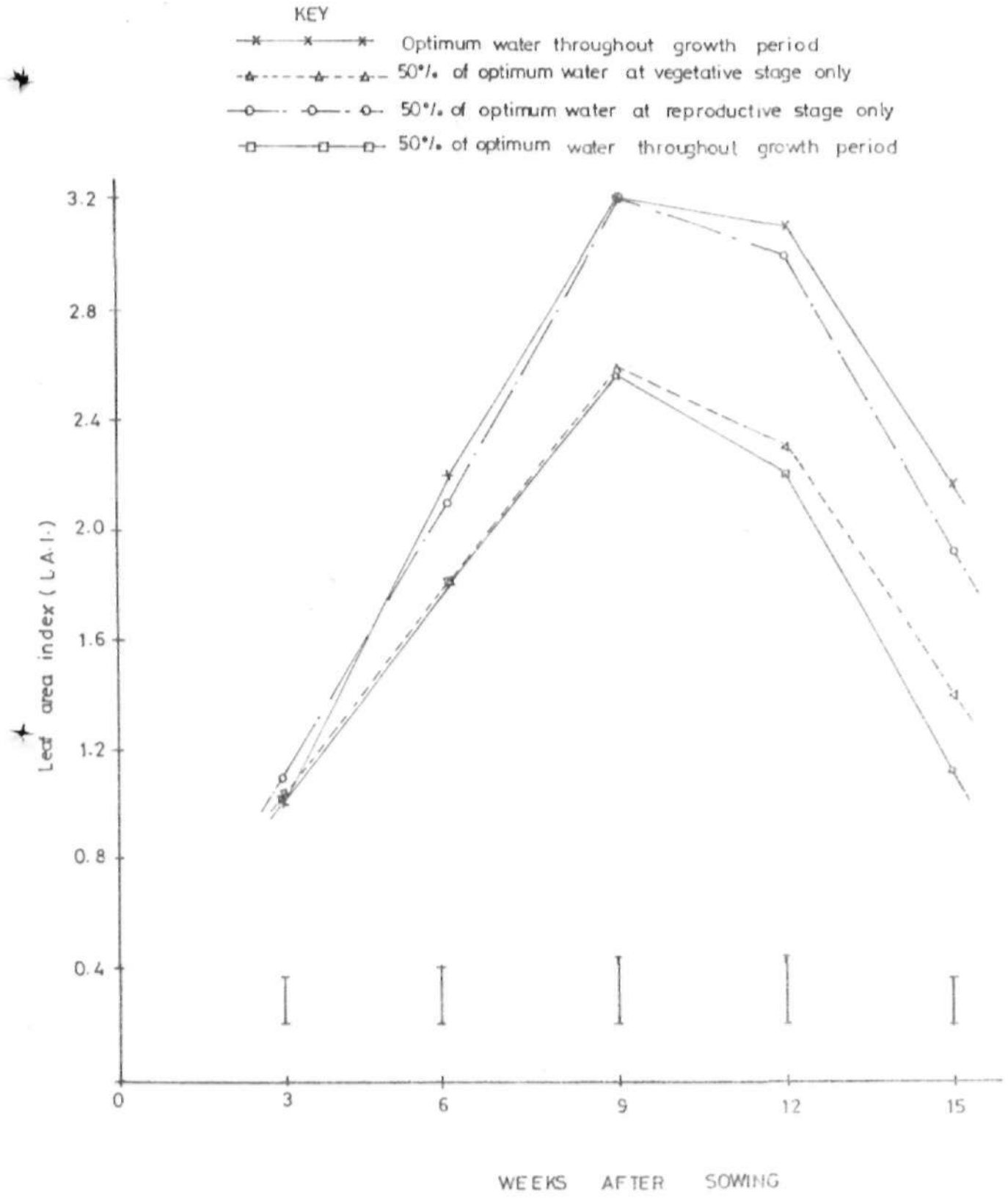



Fig 5: Leaf area index of barley as affected by irrigation levels at Kadawa during 1986/87 dry season

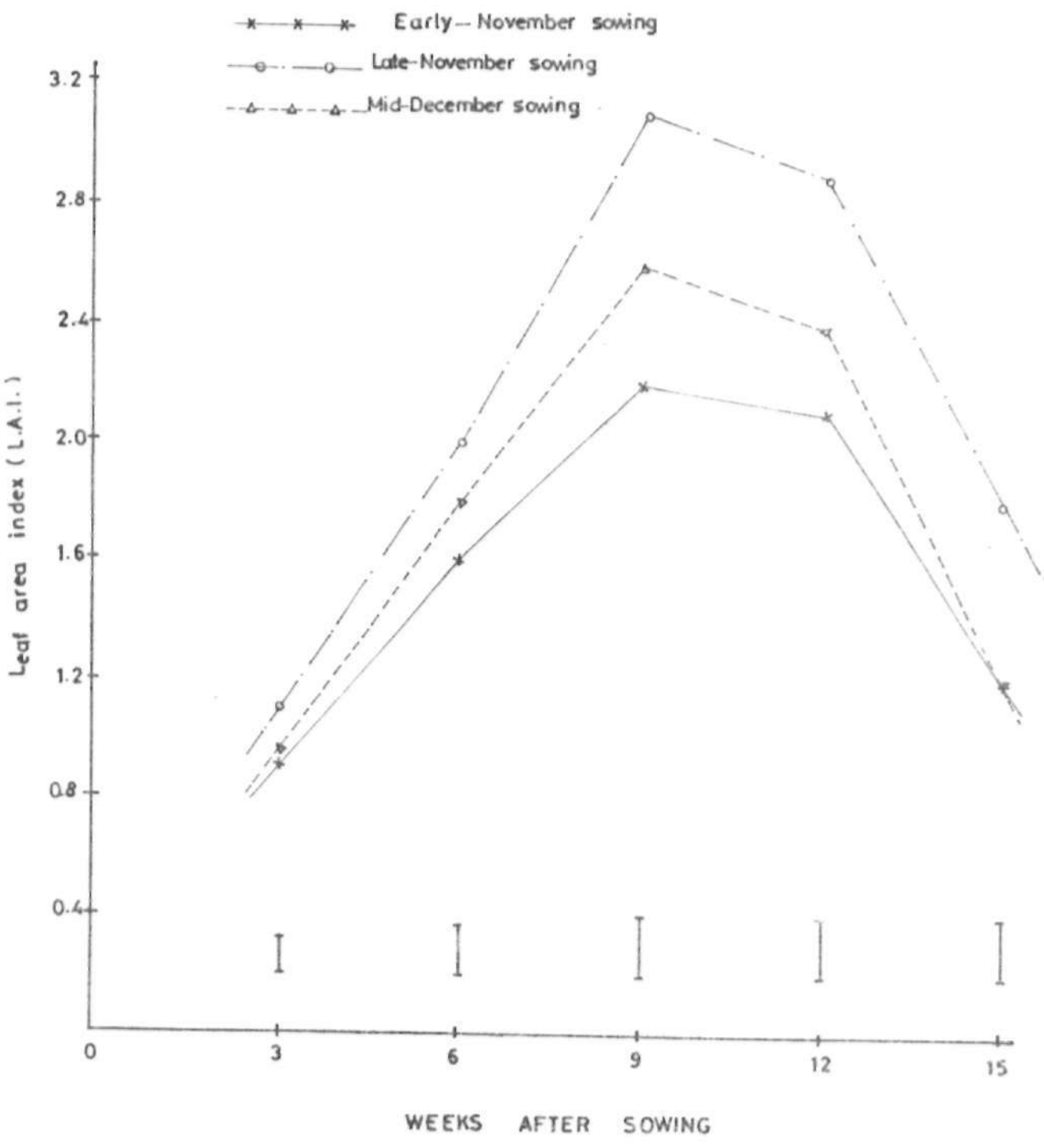



Fig 6: Leaf area index of barley as affected by date of sowing at Kadawa during 1986/87 dry season

and 15 WAS only, where the early-November and the mid-December sowings had statistically the same values.

The interaction between the different irrigation levels and sowing date on LAI was not significant.

4.1.5 Number of tillers per square meter

Plants supplied with optimum irrigation water either throughout the growth period ($I_1$) or at the vegetative stage ($I_3$) produced similar and the highest number of tillers per square meter up to 12 WAS (Figure 7). At 15 WAS, $I_1$ treatment had the highest number of tillers. In the same manner, plants given 50% of the optimum irrigation water either at the vegetative stage only ($I_2$) or throughout the growth period of the crop ($I_4$) had similar and lower number of tillers per square meter up to 12 WAS, thereafter, $I_4$ had the lowest tiller number which was statistically at par with $I_2$.

Among the dates of sowing, the highest number of tillers per square meter was produced by plants sown in late-November at all the sampling dates (Figures 8). This was followed by the mid-December sowing which was significantly higher than the early-November except at 15 WAS.

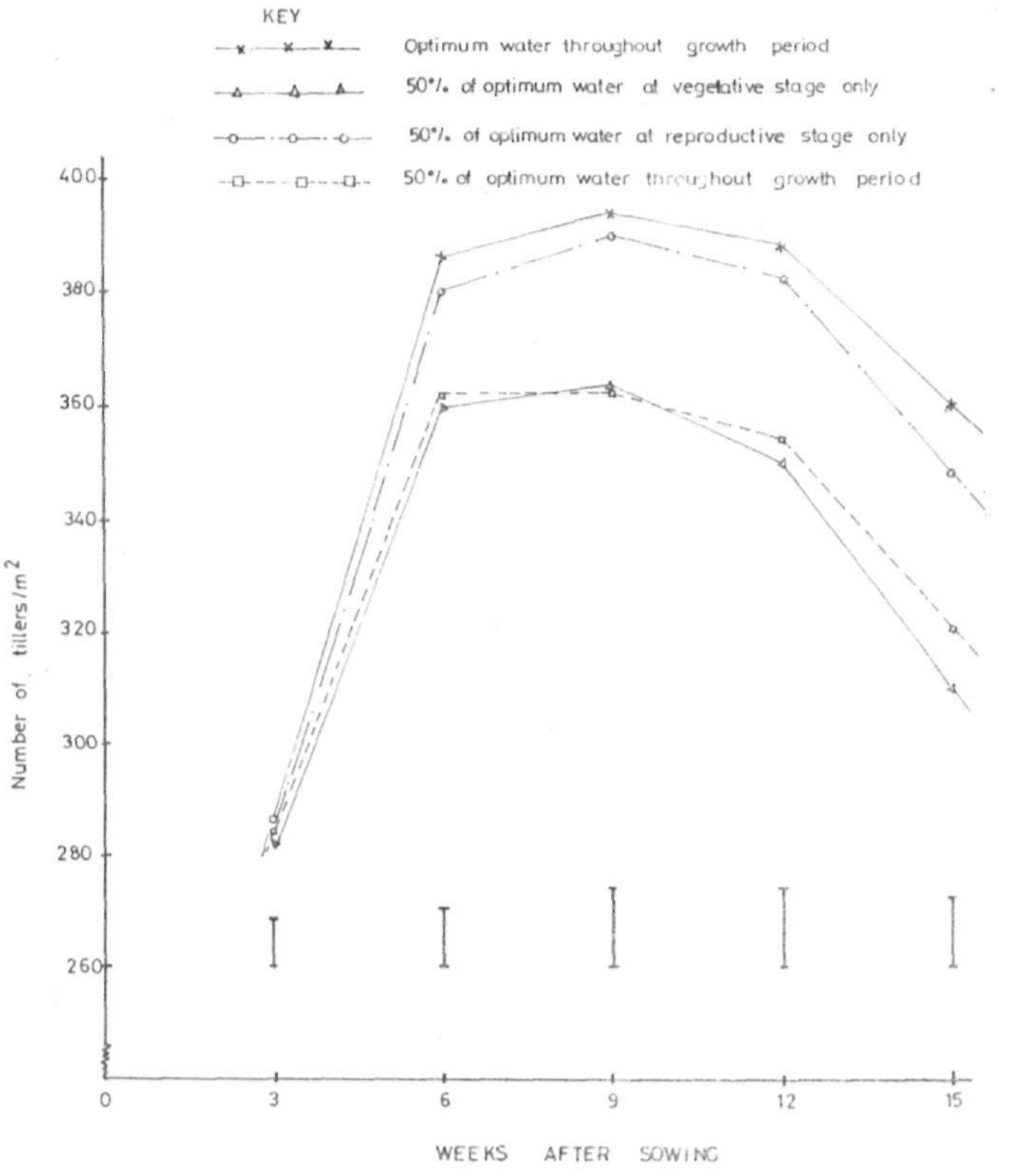



Fig 7: Number of barly tillers per square meter as affected by by irrigation levels at Kadawa during 1986/87 dry season

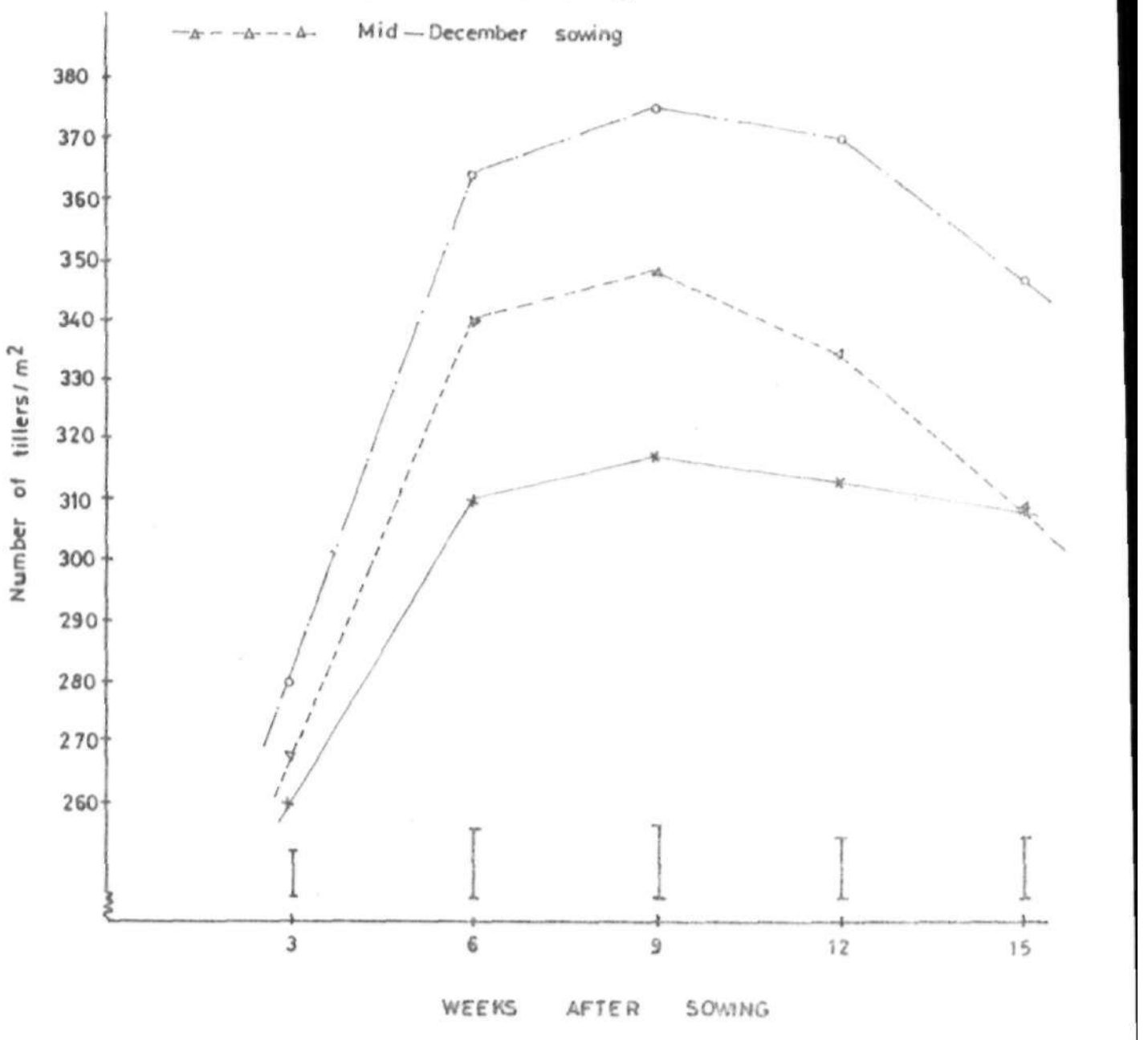



Fig 8: Number of tillers of barley per square meter as affected by sowing date at Kadawa during 1986/87 dry season.

Interaction between the different irrigation levels and sowing date on the number of tillers per square meter was not significant.

### 4.1.6 Leaf dry weight

Leaf dry weight was higher in $I_1$ and $I_3$ treatments that received optimum irrigation water throughout the growth period and during the vegetative stage, respectively (Figure 9). These were followed by the other two treatments that received 50% of optimum irrigation water either at vegetative stage only ($I_2$) or throughout the growth period ($I_4$). $I_1$ and $I_3$ as a group, and $I_2$ and $I_4$ as another were statistically the same at the sampling dates except at 15 WAS, when $I_1$ had the highest leaf dry weight, followed by $I_3$, then $I_2$ and finally $I_4$ which had the lowest. All the treatments were significantly different at 15 WAS.

Late-November sowing of barley produced the highest leaf dry weight, followed by the mid-December sowing which was statistically higher than the early-November sowing at 9 and 12 WAS only, but on the other sampling dates, they were not significantly different.

Interaction between different irrigation levels and sowing date on leaf dry weight was not significant.

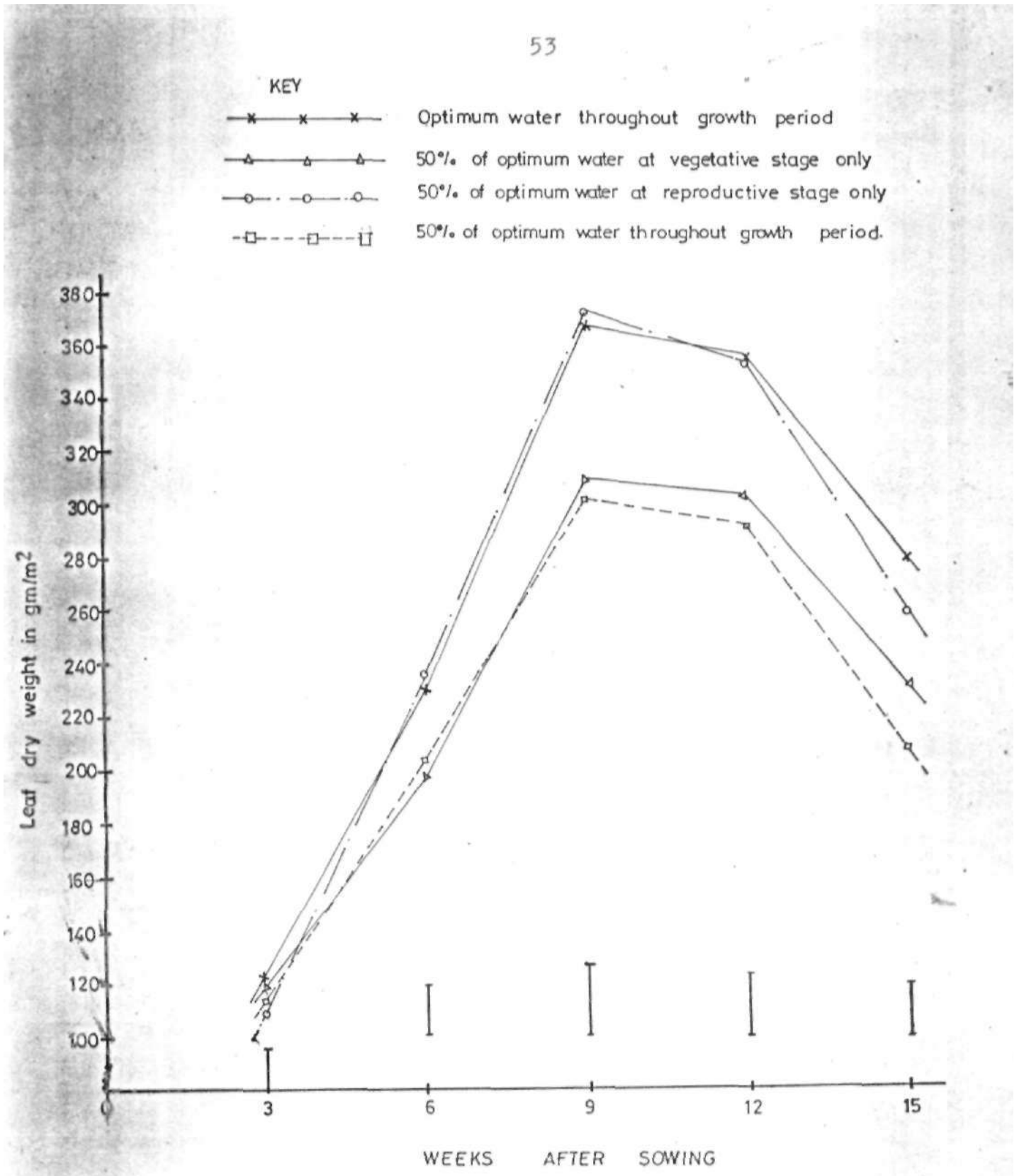



Fig 9: Leaf dry weight ( $gm/m^2$ ) as affected by irrigation levels at Kadawa during 1986/87 dry season

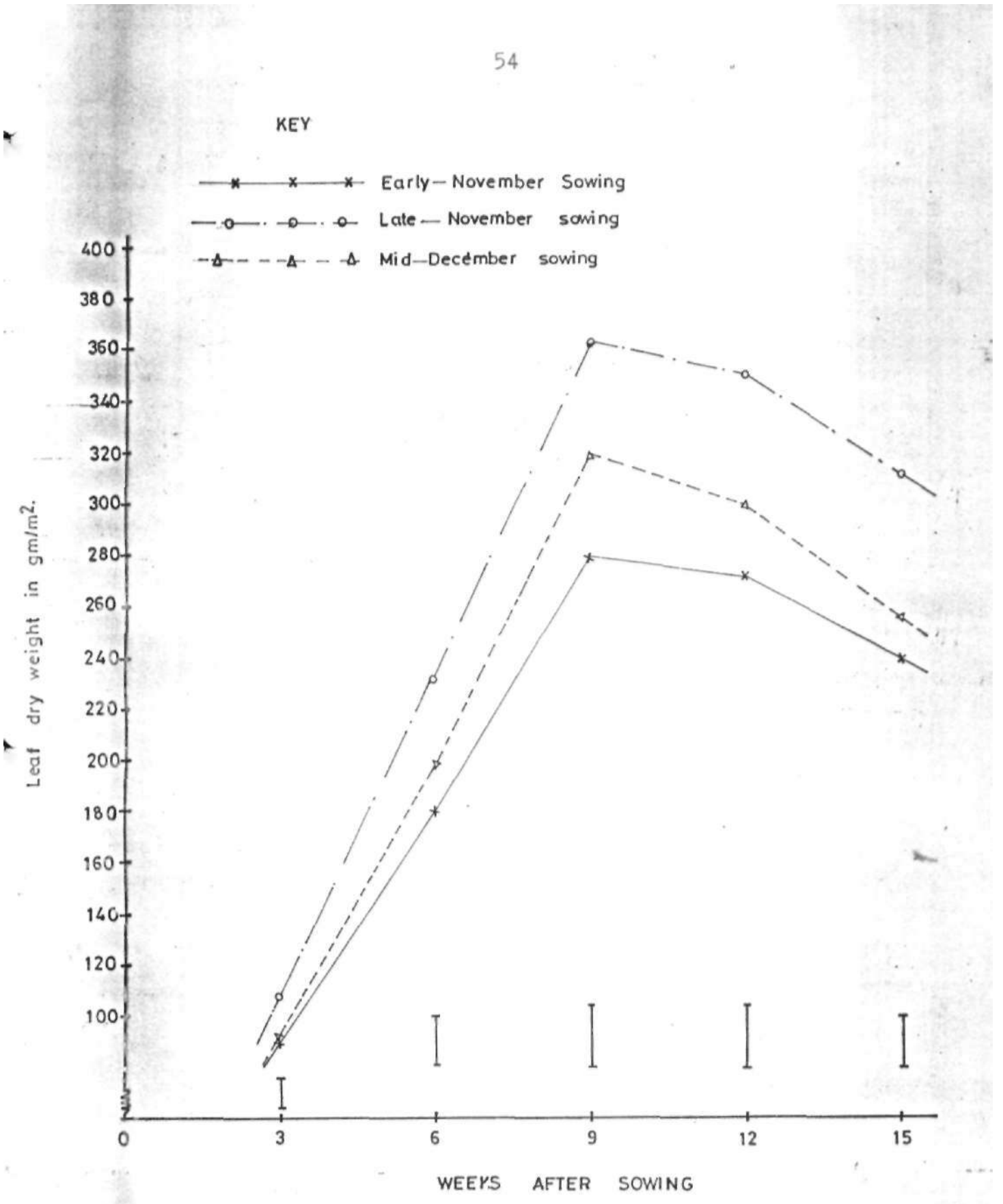



Fig 10: Leaf dry weight( $gm/m^2$ ) as affected by date of sowing at Kadawa during 1986/87 dry season

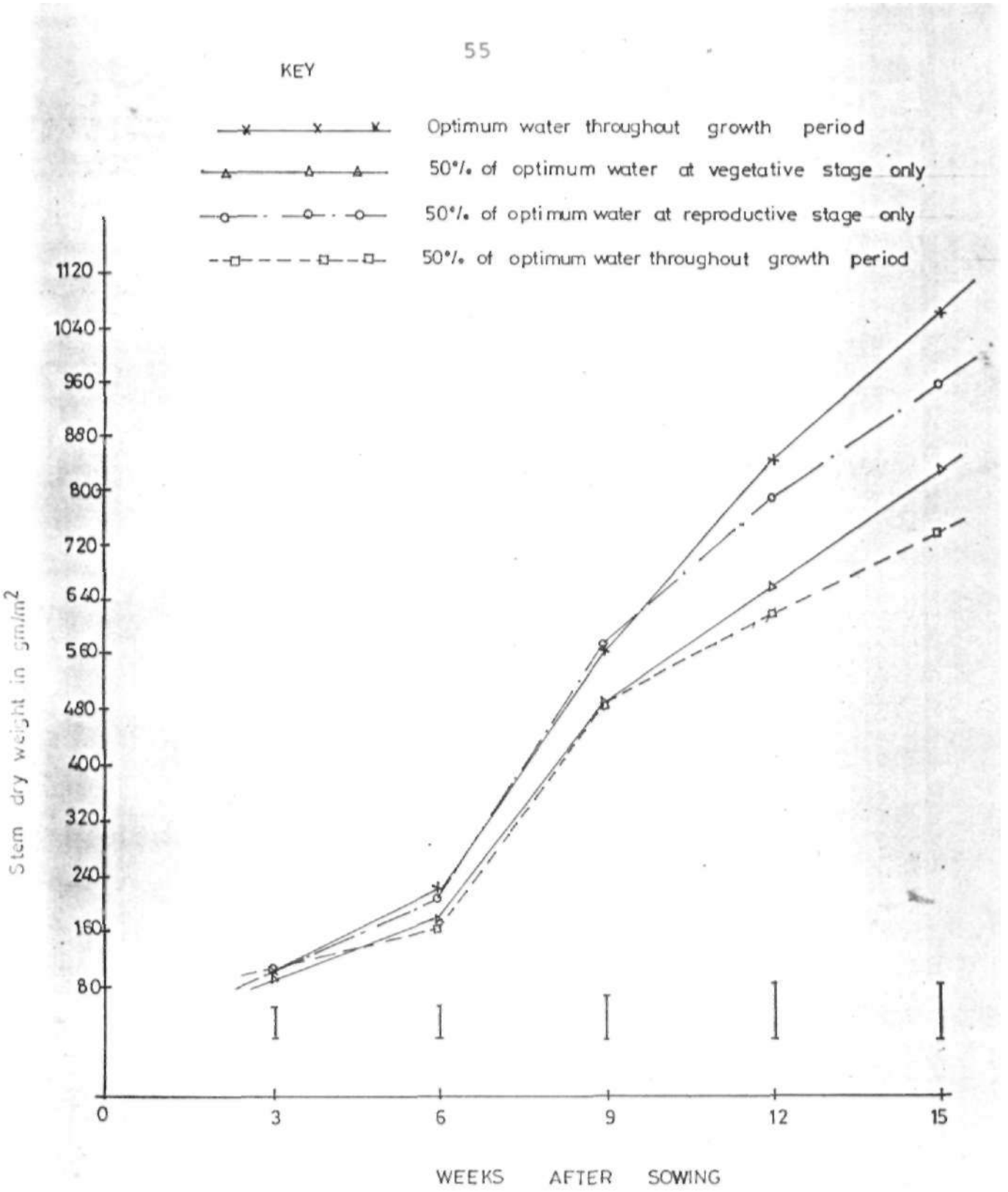



Fig 11: Stem dry weight ($gm/m^2$) as affected by irrigation levels at Kadawa during 1986/87 dry season.

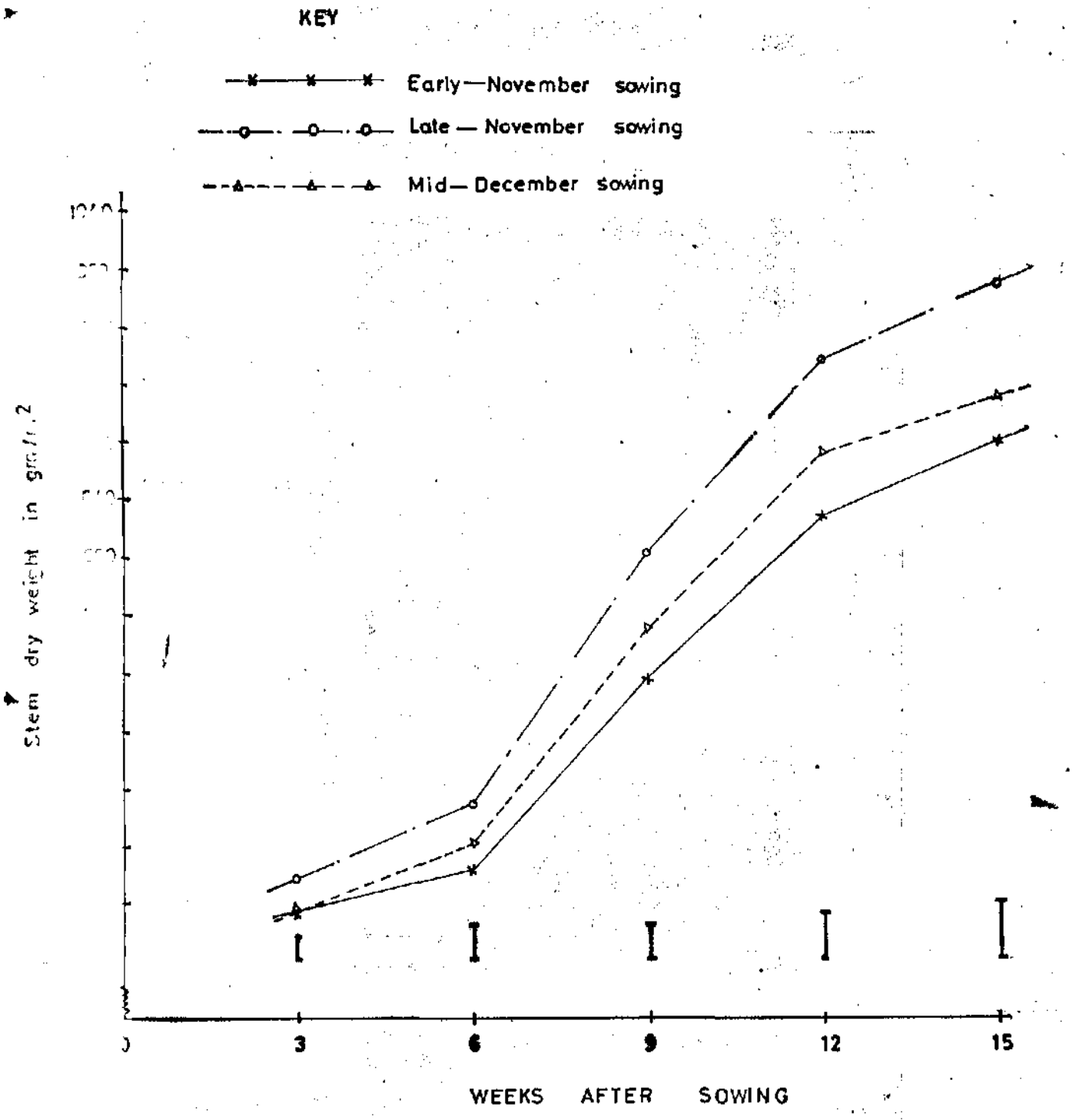



Fig 12: Stem dry weight ( $gm/m^2$ ) as affected by date of sowing at Kadawa during 1986/87 dry season

4.1.7 Stem dry weight

At 3 WAS, all treatments were not significantly different; but from 6 to 12 WAS, $I_1$ and $I_3$ produced higher stem dry weight than $I_2$ and $I_4$, thereafter, $I_1$ had the highest stem dry weight followed by $I_3$. Stem weights of $I_2$ and $I_4$ were similar up to 12 WAS after which $I_2$ produced significantly higher stem dry weight than $I_4$.

At all sampling dates, plants sown in late-November produced the highest stem dry weight. This was followed by the mid-December sowing and then the early-November sowing. These two latter dates were statistically the same except at 9 and 12 WAS when the mid-December sowing had significantly higher stem dry weight than the early-November sowing.

The interaction between the different irrigation levels and sowing date on the stem dry weight was significant only at 15 WAS.

4.1.8 Total dry matter accumulation

Treatments given optimum irrigation water throughout the growth period ($I_1$) and at vegetative stage only ($I_3$) produced the highest dry matter and were statistically

treatments were significantly different, with $I_1$ having higher

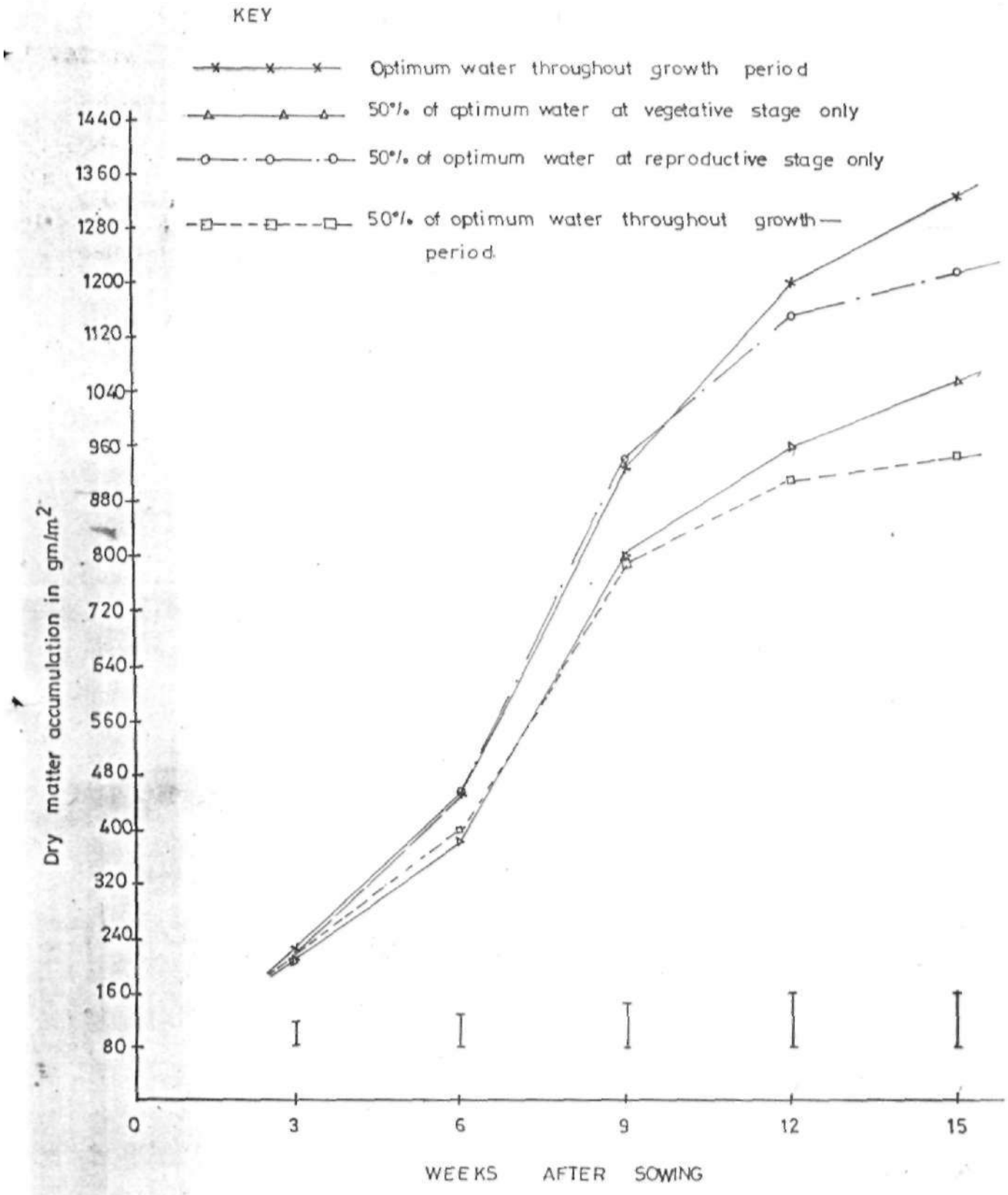



Fig 13: Dry matter accumulation in barley ($gm/m^2$) as affected by irrigation levels at Kadawa during 1986/87 dry season

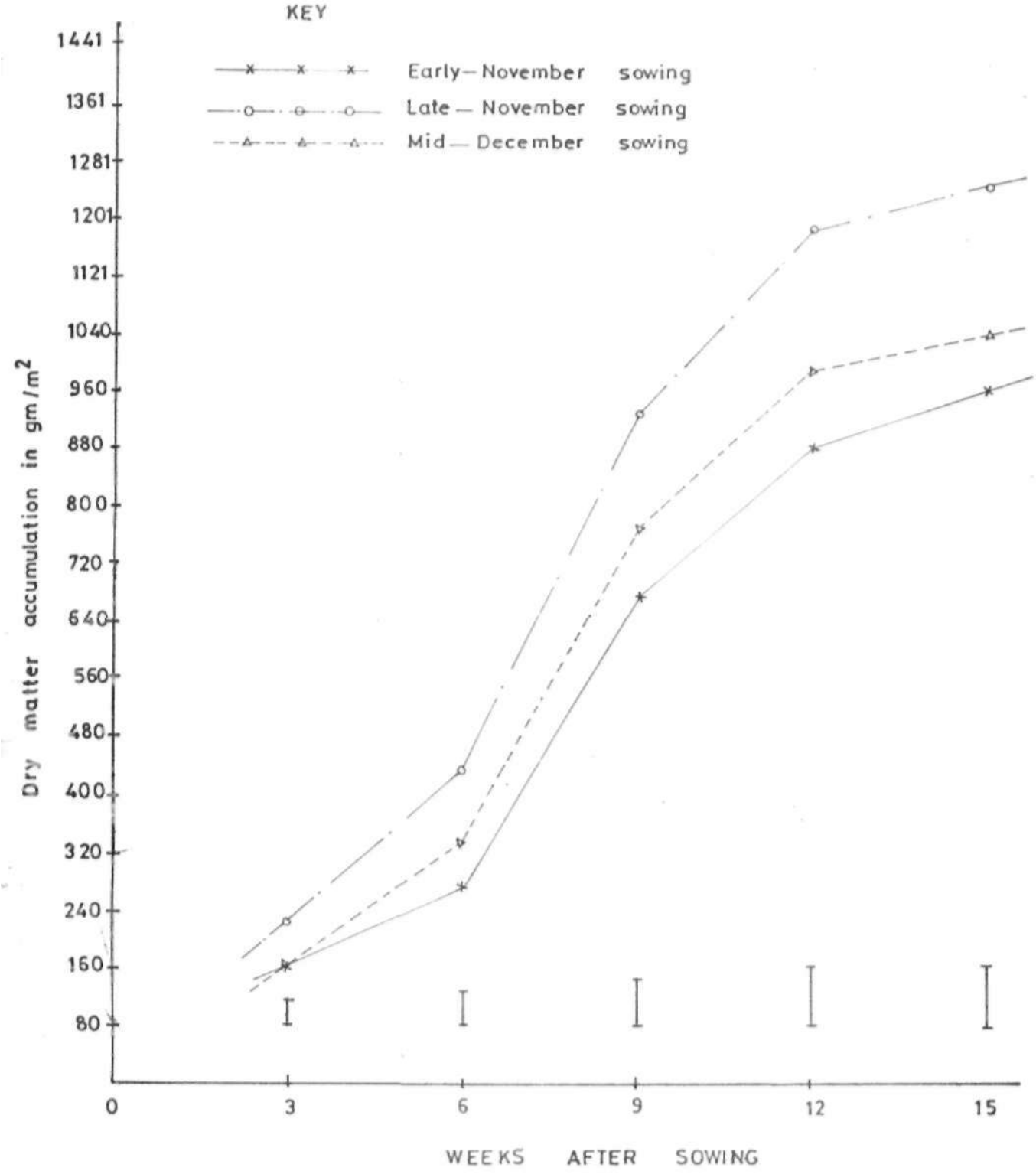



Fig 14: Dry matter accumulation in barley ( gm/ $m^2$ ) as affected by sowing date at Kadawa during 1986/87 season

dry matter. Similarly, withholding 50% of the optimum irrigation water either at the vegetative stage only ($I_2$) or throughout the growth period ($I_4$) had similar and lower total dry matter accumulation up to 12 WAS. At 15 WAS also, the two treatments were significantly different with $I_2$ having higher dry matter accumulation than $I_4$. At this sampling period, all the four irrigation treatments were significantly different.

Sowing barley in the late-November period produced the highest dry matter accumulation throughout the sampling dates (Figure 14). Dry matter accumulation in plants sown in early-November and mid-December periods were significantly different at 6, 9 and 12 WAS with the mid-December sowing having higher. But at 3 and 15 WAS, the two dates were not significantly different.

The interaction of irrigation levels and sowing on the total dry matter production was not significant.

4.1.9 Absolute crop growth rate

In all treatments, maximum crop growth rate was obtained approximately between 6 and 9 WAS (Table 4.2). Those plants supplied with optimum irrigation water either throughout the growth period or at the vegetative stage only had similar growth rates up to approximately 12 WAS. Thereafter, $I_1$ had higher growth rate. Likewise, $I_2$ receiving 50% optimum water throughout the growth period had similar rate of growth until about 12 WAS, after which $I_2$ had higher growth rate than $I_4$.

Date of sowing also affected the rate of barley growth. Throughout the sampling dates, late-November sown plants had the highest growth rate up to about 12 WAS. Between 3 and 9 WAS, mid-December sown plants had higher growth rate than the early-November sown plants, but between 9 and 12 WAS, they had significantly the same rate of growth. Between 12 and 15 WAS, early-November sowing had the highest growth rate, followed by the late-November sowing; while the mid-December sowing had the lowest.

4.1.10 Number of days to 50% flowering and number of days to maturity:

Plants flowered and matured relatively earlier when supplied with 50% of optimum water either during vegetative growth only or throughout growth period compared with those supplied optimum water throughout growth period or supplied 50% optimum water at the reproductive stage only (Table 4.3).

Early-November and mid-December sown crops also flowered and reached maturity relatively earlier than the late-November sown crop.

The interaction between irrigations levels and sowing date on these parameters were not significant.

Table 4.2: Absolute crop growth rate ($gm/m^2$/week) of barley grown at Kadawa during 1986/87 dry season as affected by irrigation levels and date of sowing.

| Treatments | weeks after sowing | | | |
|---|---|---|---|---|
| | 3-6 | 6-9 | 9-12 | 12-15 |
| Irrigation levels | | | | |
| $I_1$ - Optimum water throught | 74.7 | 160.0 | 90.6 | 69.3 |
| $I_2$ 50% optimum water at vegetative stage | 58.6 | 138.2 | 58.3 | 32.0 |
| $I_3$ 50% optimum water at reproductive stage | 77.3 | 165.1 | 69.3 | 21.1 |
| $I_4$ 50% optimum throughout | 61.3 | 128.0 | 42.7 | 14.0 |
| S.E. ± | 4.5 | 6.9 | 5.0 | 4.2 |
| L.S.D. (P = 0.05) | 13.1 | 20.0 | 14.3 | 12.1 |
| Sowing date | | | | |
| $D_1$ - November 4 | 37.6 | 123.2 | 69.8 | 26.0 |
| $D_2$ - November 25 | 69.0 | 165.3 | 88.2 | 21.1 |
| $D_3$ - December 16 | 56.0 | 144.0 | 74.7 | 16.3 |
| S.E. ± | 3.5 | 6.4 | 4.5 | 2.8 |
| L.S.D. (P = 0.05) | 10.2 | 18.4 | 13.0 | 7.9 |

Table 4.3: Number of days to 50% flowering and number of days to barley maturity as affected by irrigation levels and date of sowing at Kadawa during 1986/87 dry season.

| Treatments | Number of days to 50% flowering | Number of days to maturity |
|---|---|---|
| Irrigation levels | | |
| $I_1$ - Optimum water throughout | 78 | 115 |
| $I_2$ - 50% optimum water at vegetative stage only | 74 | 110 |
| $I_3$ 50% optimum water of reproductive stage only | 78 | 115 |
| $I_4$ 50% optimum water throughout | 74 | 110 |
| S.E. ± | 1.3 | 1.5 |
| L.S.D. (P = 0.05) | 3.6 | 4.4 |
| Sowing date | | |
| $D_1$ - November 4 | 74 | 110 |
| $D_2$ - November 25 | 78 | 114 |
| $D_3$ - December 16 | 74 | 110 |
| S.E. ± | 1.1 | 1.4 |
| L.S.D. (P = 0.05) | 3.2 | 3.9 |
| Interaction | N.S. | N.S. |

## 4.2 Yield and Yield Components

### 4.2.1 Grain yield

Plants supplied with optimum irrigation water throughout the growth period produced significantly higher grain yield (Table 4.4). Treatments that received 50% of optimum irrigation water either during vegetative or reproductive phase gave statistically similar grain yields. Withholding 50% of the optimum irrigation water throughout the growth period resulted in the production of the lowest grain yield. There was as much as 48% yield reduction when 50% of the optimum water was withheld throughout the growth period compared with the optimum water treatment throughout growth period, whilst the corresponding yield reductions for 50% optimum water treatments at vegetative and reproductive stages were 30% and 23%, respectively compared to the optimum.

Sowing date also had a significant effect on the grain yield (Table 4.4). Late-November sowing markedly out-yield both early-November and mid-December sowings. Yield reductions were 22% and 20% when sowing of barley was done in early-November and mid-December periods, respectively compared with late-November sowing.

Table 4.4: Grain yield, straw yield and grain protein content of barley grown at Kadawa during 1986/87 dry season as affected by irrigation levels and date of sowing.

| Treatments | Grain yield (kg/ha) | Straw yield (kg/ha) | Grain protein content (%) |
|---|---|---|---|
| Irrigation levels | | | |
| $I_1$ - Optimum water throughout | 3209 | 8929 | 10.0 |
| $I_2$ - 50% Optimum at vegetative stage only | 2243 | 7016 | 11.7 |
| $I_3$ 50% optimum at reproductive stage only | 2467 | 8567 | 11.4 |
| $I_4$ 50% optimum water throughout | 1685 | 6567 | 13.2 |
| S.E. ± | 108 | 146 | 0.1 |
| L.S.D. (P = 0.05) | 310 | 421 | 0.3 |
| Sowing date | | | |
| $D_1$ - November 4 | 2186 | 7168 | 12.0 |
| $D_2$ - November 25 | 2797 | 8514 | 10.8 |
| $D_3$ - December 16 | 2220 | 7627 | 12.0 |
| S.E. ± | 102 | 139 | 0.08 |
| L.S.D. (P = 0.05) | 293 | 400 | 0.22 |
| Interaction | * | * | * |

* Significant at 5% level of probability.

Table 4.5: Spike characteristics of barley grown at Kadawa during 1986/87 dry season as affected by irrigation levels and date of sowing.

| Treatments | No. of spikes/$m^2$ | Length of spike (cm) | No. of grains/ spike | 1000-grain wt.(gm) |
|---|---|---|---|---|
| Irrigation levels | | | | |
| $I_1$ - Opt. water throughout | 344 | 9.5 | 27.6 | 34.4 |
| $I_2$ - 50% opt. at veg. stage only | 292 | 7.9 | 23.7 | 33.0 |
| $I_3$ - 50% opt. at repr. stage only | 319 | 9.4 | 23.9 | 32.2 |
| $I_4$ - 50% opt. water throughout | 284 | 8.0 | 19.1 | 30.8 |
| S.E. ± | 4 | 0.2 | 0.6 | 0.9 |
| L.S.D. (P = 0.5) | 12 | 0.5 | 1.7 | 2.5 |
| Sowing date | | | | |
| $D_1$ - November 4 | 300 | 8.3 | 23.5 | 31.3 |
| $D_2$ - November 25 | 337 | 9.5 | 26.1 | 33.6 |
| $D_3$ - December 16 | 291 | 8.5 | 21.1 | 30.7 |
| S.E. ± | 3 | 0.1 | 0.5 | 0.7 |
| L.S.D. (P = 0.05) | 9 | 0.4 | 1.5 | 2.0 |
| Interaction | * | * | * | N.S. |

* Significant at 5% probability.

Table 4.6: Interaction of irrigation levels and date of sowing on the grain yield of barley (kg/ha) at Kadawa during 1986/87 dry season.

| Irrigation levels | Sowing Date | | |
|---|---|---|---|
| | November 4 | November 25 | December 16 |
| $I_1$ - Optimum water throughout | 2890 bc | 3682 a | 3054 b |
| $I_2$ - 50% optimum water at vegetable stage only | 1900 ef | 2521 ed | 2309 de |
| $I_3$ - 50% optimum water at reproduction stage only | 2263 de | 3020 b | 2118 def |
| $I_4$ - 50% optimum water throughout | 1690 fg | 1965 ef | 1400 g |
| S.E. $\pm$ (174) | | | |

Means followed by same letters within the treatments are not significantly different at 5% level using DMRT.

The interaction between irrigation levels and sowing date was significant (Table 4.6). The grain yields of treatment supplied 50% optimum water at the reproductive stage was significantly higher than that supplied 50% optimum water at the vegetative stage when barley was sown in late-November, whereas, with early-November and mid-December sowings, withholding 50% water either at vegetative or reproductive stage gave similar grain yields.

4.2.2 Straw yield

Straw yield of barley was also influenced by the levels of irrigation given (Table 4.4). Plants that had optimum water throughout and those that had 50% of optimum water at the reproductive stage produced higher straw yields. Supplying 50% of optimum water either at the vegetative stage only or throughout growth period reduced the straw yield or barley significantly. However, straw yield of plants that received 50% optimum water at the vegetative stage was significantly higher than those that had 50% optimum water throughout the growth period.

Highest straw yield was produced by the crop sown in late-November, followed by the mid-December sown crop which in turn produced significantly higher straw yield than the early-November sowing (Table 4.4).

**Table 4.7:** Interaction of irrigation levels and date of sowing on the straw yield of barley (kg/ha) at Kadawa during 1986/87 dry season

| Irrigation levels | Sowing Date | | |
|---|---|---|---|
| | November 4 | November 25 | November 16 |
| $I_1$ - Optimum water throughout | 8089 c | 9871 a | 8827 bc |
| $I_2$ - 50% optimum water at vegetative stage only | 6312 f | 7692 c | 7043 de |
| $I_3$ - 50% optimum water of reproductive stage only | 7999 c | 9423 ab | 8278 c |
| $I_4$ - 50% optimum water throughout | 6270 f | 7069 d | 6360 f |
| S.E. $\pm$ (218) | | | |

Mean followed by same letters within the treatments are not statistically significant at 5% level using DMRT.

Interaction effect between irrigation levels and sowing date was significant (Table 4.7). Straw yields of early-November sown barley were significantly the same when 50% optimum water was withheld at the vegetative growth or throughout growth period; whilst with the later two sowings, withholding 50% optimum water at the vegetative stage resulted in a significantly higher straw yield than withholding 50% water throughout growth.

### 4.2.3 Number of spikes/$m^2$

The data on the effects of irrigation levels and sowing date on the number of spikes per square meter are presented in Table 4.5. Treatments that received optimum irrigation water throughout growth period produced the highest number of spikes per square meter. These were followed by treatments that received 50% optimum water at the reproductive stage only. Lowest number of spikes per unit area was produced by treatments supplied with 50% optimum water either at the vegetative stage only or throughout the growth period.

Date of sowing too had some influence on the number of spikes produced per square meter (Table 4.5). The early-November and the mid-December sowings produced significantly lower number of spikes per square meter compared with the late-November sowing.

Interaction between irrigation levels and sowing date (Table 4.8) indicated that number of spikes of early-November sown barley were statistically similar when the crop was stressed either at the vegetative phase, reproductive phase or throughout growth period. However, with late-November and mid-December sowings, plants supplied 50% optimum water at reproductive stage had a higher number of spikes per square meter than those given 50% optimum water at the vegetative stage or throughout growth period. Furthermore, supplying barley with optimum water throughout or 50% water at reproductive stage only resulted in the production of similar number of spikes per square meter; also supplying 50% optimum water either at the vegetative stage or throughout growth period resulted in the production of similar number of spikes when the crop was sown in late-November; whereas with mid-December sowing, all treatments had different number of spikes per square meter.

### 4.2.4 Spike length

When 50% water was withheld either at the vegetative growth or throughout growth period, it resulted in producing shorter spikes compared to when optimum water was given throughout or when 50% optimum water was given at the reproductive stage only (Table 4.5).

Table 4.8: Interaction of irrigation levels and date of sowing on the number of barley spikes per square meter at Kadawa during 1986/87 dry season.

| Irrigation levels | Sowing Date | | |
|---|---|---|---|
| | November 4 | November 25 | November 16 |
| $I_1$ - Optimum water throughout | 332 b | 365 a | 335 b |
| $I_2$ - 50% optimum water at vegetative stage only | 288 de | 317 bc | 280 e |
| $I_3$ - 50% optimum water at reproductive stage only | 299 cd | 358 a | 299 cd |
| $I_4$ - 50% optimum water throughout | 281 de | 309 c | 251 f |
| S.E. ± (6) | | | |

Means followed by same letters within the treatments are not statistically significant at 5% level using DMRT.

With sowing date, early-November and mid-December sowings had produced spikes which were significantly shorter than the late-November sown crop (Table 4.5).

The interaction of irrigation levels and sowing date on spike length indicated that with early-November sowing, spike lengths of all irrigation treatments were statistically the same, whereas on the two later sowing dates, plants supplied optimum water throughout or 50% optimum water at reproductive stage had statistically longer spikes than those supplied 50% optimum water at either vegetative or throughout growth period (Table 4.9).

### 4.2.5 Number of grains per spike

Number of grains per spike was significantly affected by the quantity of water received (Table 4.5). The highest number of grains per spike was produced by plants that received optimum water throughout. Plants that were given 50% optimum water either at vegetative or at reproductive phase had statistically same number of grains per spike, but significantly higher than in plants supplied with 50% water throughout.

Differences in the mean number of grains per spike recorded for the three sowing dates were also significant (Table 4.5). The late-November sown crop produced the highest number of grains per spike than the early-November sowing which in turn was significantly higher than mid-December sowing.

Table 4.9: Interaction of irrigation levels and date of sowing on the length of barley spike (cm) at Kadawa during 1986/87 dry season.

| Irrigation levels | Sowing Date | | |
|---|---|---|---|
| | November 4 | November 25 | November 16 |
| $I_1$ - Optimum water throughout | 8.6 c | 10.5 a | 9.5 b |
| $I_2$ - 50% optimum water at vegetative stage only | 8.0 cd | 8.5 c | 7.3 d |
| $I_3$ - 50% optimum water at reproductive stage only | 8.4 c | 10.4 a | 9.5 b |
| $I_4$ - 50% optimum water throughout | 8.0 cd | 8.6 c | 7.5 d |
| S.E. $\pm$ (0.3) | | | |

Means followed by same letters within the treatments are not statistically significant at 5% level using DMRT.

The interaction between irrigation levels and sowing date was highly significant (Table 4.10). Barley supplied with optimum water throughout and 50% optimum water at reproductive stage had similar number of grains/spike in the early-November or late-November sowings, but when given 50% of optimum water either at vegetative stage or throughout, was not similar in the late-November sowing. With the mid-December sowing, however, plants supplied with optimum water throughout produced grains more than any other treatment.

### 4.2.6 1000 - grain weight

The 1000-grain weights for all the irrigation treatments were statistically the same except between treatments supplied with optimum water throughout and those supplied with 50% of optimum water throughout (Table 4.5).

With sowing date, late-November sown crop produced significantly heavier grains than early-November and mid-December sown crop which had statistically similar grain weights (Table 4.5).

Interaction between irrigation levels and sowing date was not significant.

Table 4.10: Interaction of irrigation levels and date of sowing on the number of grains per barley spike at Kadawa during 1986/87 dry season.

| Irrigation levels | Sowing Date | | |
|---|---|---|---|
| | November 4 | November 25 | November 16 |
| $I_1$ - Optimum water throughout | 26.7 bc | 29.8 a | 26.3 bc |
| $I_2$ - 50% optimum water at vegetative stage only | 23.0 de | 26.0 bc | 22.1 def |
| $I_3$ - 50% optimum water at reproductive stage only | 24.3 cd | 27.4 ab | 20.0 f |
| $I_4$ - 50% optimum water throughout | 21.1 ef | 21.2 ef | 16.0 g |
| S.E. ± (1.0) | | | |

Means followed by same letters within the treatments are not statistically significant at 5% level using DMRT.

## 4.3 Grain Protein Content

The highest percentage of the grain protein content of barley was obtained in plants supplied with 50% of optimum water throughout growth period (Table 4.4). This was followed by plants that received 50% of optimum water either at vegetative or reproductive stage. The lowest grain protein was produced by plants supplied with optimum water throughout growth period.

Sowing barley in early-November and mid-December periods produced statistically the same and higher grain protein content of barley grains than crop sown in late-November period.

The interaction between irrigation levels and sowing date was significant (Table 4.11). With late-November sowing, withholding 50% of optimum water at vegetative stage resulted in higher grain protein content than withholding at the reproductive stage, whilst for early-November and mid-December sowings, the grain protein contents were not influenced by stressing the crop for water either at vegetative or reproductive stage.

Table 4.11: Interaction of irrigation levels and date of sowing on the **grain protein** content of barley (%) at Kadawa during 1986/87 dry season

| Irrigation levels | Sowing Date | | |
|---|---|---|---|
| | November 4 | November 25 | November 16 |
| $I_1$ - Optimum water throughout | 10.5 ef | 9.3 g | 10.1 f |
| $I_2$ - 50% optimum water of vegetative stage only | 12.3 cd | 11.0 e | 11.8 d |
| $I_3$ - 50% optimum water at reproductive stage only | 12.0 d | 10.2 f | 12.1 d |
| $I_4$ - 50% optimum water throughout | 13.0 b | 12.7 bc | 13.8 a |
| S.E. ± (0.2) | | | |

Means followed by same letters **within** the treatments are not statistically significant at 5% level using DMRT.

## 4.4 Water-use Efficiency

Water-use efficiency was higher when optimum irrigation was given throughout the growth period; whereas plants given 50% of optimum irrigation water either at the vegetative or reproductive stage had statistically similar water-use efficiency (Table 4.12). WUE was lowest when 50% of optimum water was given throughout the growth period, but this was not significantly different from the treatment that received 50% of optimum water at the vegetative stage.

With the date of sowing, water was used more efficiently by sowing barley in late-November compared with the earlier or later sowing (Table 4.12).

There was a significant interaction between irrigation levels and sowing date (Table 4.13). When barley was sown in mid-December and supplied 50% optimum water at vegetative stage, used water more efficiently than those supplied 50% optimum water throughout, whereas with the two earlier sowings, WUE values for plants stressed at vegetative stage or throughout growth period were statistically at par. Furthermore, plants given optimum water throughout and those stressed at reproductive stage had similar WUE when sown in early-November and late-November, whereas with delay in sowing

Table 4.12: Water use efficiency of barley grown at Kadawa during 1986/87 dry season as influenced by irrigation levels and date of sowing.

| Treatments | W.U.E. (kg/ha/cm) |
|---|---|
| Irrigation levels | |
| $I_1$ - Optimum water throughout | 58.3 |
| $I_2$ - 50% optimum water of vegetative stage only | 52.5 |
| $I_3$ - 50% optimum water of reproductive stage only | 54.1 |
| $I_4$ - 50% optimum water throughout | 50.1 |
| S.E. ± | 1.2 |
| L.S.D. (P = 0.05) | 3.4 |
| Sowing date | |
| $D_1$ - November 4 | 49.3 |
| $D_2$ - November 25 | 63.0 |
| $D_3$ - December 16 | 50.4 |
| L.S.D. (P = 0.05) | 2.8 |
| Interaction | * |

* Significant at 5% level of probability.

Table 4.13: Interactions of irrigation levels and date of sowing on the water use efficiency of barley (kg/ha/cm) at Kadawa during 1986/87 dry season.

| Irrigation levels | Sowing Date | | |
|---|---|---|---|
| | November 4 | November 25 | November 16 |
| $I_1$ - Optimum water throughout | 52.5 def | 66.9 a | 55.4 cde |
| $I_2$ - 50% optimum water at vegetative stage only | 44.4 gh | 60.2 bc | 49.9 efg |
| $I_3$ - 50% optimum water at reproductive stage only | 49.3 efg | 65.5 ab | 47.5 fgh |
| $I_4$ - 50% optimum water throughout | 48.2 fg | 58.4 cd | 41.6 h |
| S.E. ± (2.2) | | | |

Means followed by same letters within the treatments are not statistically significant at 5% level using DMRT.

till mid-December, those plants supplied with optimum water throughout made use of water more efficiently than those given 50% of optimum water of reproductive stage.

## 4.5 Correlation studies

Simple correlation studies carried out on the growth parameters, yield and yield components showed that almost all the parameters recorded were significantly and positively correlated to grain yield, except the grain protein content which was negatively correlated to yield (Table 4.14). There was however no significant correlation between plant height and leaf dry weight; leaf area and stem dry weight, number of grains per spike and 1000-grain weight; number of tillers per square meter and spike length; leaf dry weight and number of spikes per square meter, length of spike, number of grains per spike and 1000-grain weight; stem dry weight and grain protein content; number of spikes per square meter and spike length; and straw yield and number of grains per spike.

**Table 4.14** Simple correlation coefficients (r) between growth parameters, yield and yield components

| | Plant height | Leaf area | No. of tillers/$m^2$ | Leaf dry wt. | Stem dry wt. | Total dry matter | No. of spikes/$m^2$ | Spike length | No. of grains/spike | 1000-grain wt. | Grain yield | Straw yield | Grain protein content |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height | 1 | | | | | | | | | | | | |
| Leaf area | 0.580** | 1 | | | | | | | | | | | |
| No. of tillers/$m^2$ | 0.298* | 0.767** | 1 | | | | | | | | | | |
| Leaf dry weight | 0.174 | 0.513** | 0.304* | 1 | | | | | | | | | |
| Stem dry weight | 0.427* | 0.171 | 0.530** | 0.440* | 1 | | | | | | | | |
| Total dry matter | 0.674** | 0.684** | 0.834** | 0.531* | 0.669** | 1 | | | | | | | |
| Number of spikes/$m^2$ | 0.301* | 0.551** | 0.885** | 0.152 | 0.502** | 0.717** | 1 | | | | | | |
| Spike length | 0.854** | 0.375* | 0.203 | 0.148 | 0.300* | 0.448* | 0.201 | 1 | | | | | |
| No. of grains/spike | 0.449* | 0.162 | 0.360* | 0.181 | 0.412* | 0.593** | 0.305* | 0.625** | 1 | | | | |
| 1000-grain weight | 0.362* | 0.147 | 0.353* | 0.202 | 0.401* | 0.613** | 0.359* | 0.642** | 0.549** | 1 | | | |
| Grain yield | 0.425* | 0.390* | 0.801** | 0.301* | 0.400* | 0.701** | 0.847** | 0.639** | 0.875** | 0.602** | 1 | | |
| Straw yield | 0.651** | 0.415* | 0.803** | 0.368* | 0.503** | 0.871** | 0.765** | 0.593** | 0.186 | 0.203 | 0.541** | 1 | |
| Grain protein content | -0.554** | -0.468* | -0.515** | -0.315* | -0.249 | -0.564** | -0.632** | -0.560** | -0.654** | -0.605** | -0.685** | -0645** | 1 |

Chapter 5

# DISCUSSION

## 5.1 Effect of Irrigation Levels on Barley

### 5.1.1 Growth

The results obtained in this experiment revealed that depth of irrigation water application at different growth stages had marked influence on the growth of barley. Plant height, leaf area, LAI, number of tillers per unit area and dry matter accumulation of plant were enhanced by application of optimum irrigation water throughout the growth period of the crop. However, the effect of depth of irrigation water was more pronounced when plants were given less water during the vegetative phase only or throughout growth period where all the growth parameters mentioned above were reduced. Slatyer (1967) has demonstrated that plant growth and development are controlled primarily by adequate supply of soil moisture. This could perhaps account for the fact that though water was applied to all treatments at the same time, yet the growth and development of those plants supplied with optimum water requirement per irrigation superceded those that were supplied with 50% of optimum irrigation water. It appears that the 50% optimum water did not wet the entire soil profile within the root zone of the crop, or that soil moisture in the profile of the root zone was depleted faster in treatments that received

50% optimum water resulting into drying of the root zone before next irrigation. Thus, only the growth stages or the developmental processes taking place at the time irrigation was given or shortly after were probably favoured. Acevodo et al. (1971) have also observed reduced growth in maize with less moisture during the vegetative phase.

Since plants were stressed for water either at the vegetative or reproductive period in the present study, it is possible that the critical stages for water use at the vegetative stage like tillering, jointing, heading, flag-leaf (Kumar et al. 1977) might have been drastically affected. It is well known that inadequate moisture at any of the critical stages could be detrimental to the crop (Singh and Kumar, 1979; Kumar and Yayock, 1980; Nimzing et al. 1986 and 1987). This is probably the reason why treatments that received optimum irrigation water at the vegetative stage had taller plants larger leaf area, higher number of tillers per unit area and higher dry matter accumulation than those that received 50% irrigation water at that stage, though irrigated at the same time. Day and Thampson (1975) have shown that stem elongation in barley was adversely affected by water stress at the tillering and jointing stages. Nimzing (1986) also observed a similar effect and he attributed this to inhibition of nutrient uptake and distribution within the plant.

5.1.2 Yield and yield components

The grain yield of barley and its components were found to be highly affected by the quantity of irrigation water given at the vegetative or reproductive phase of growth. The application of optimum irrigation water throughout growth period produced the highest grain yield which was reduced by about 30, 23 and 48% when 50% of optimum water was withheld at the vegetative stage, reproductive stage and throughout growth period, respectively (Table 4.4). The reductions in the grain yield with water stress at the vegetative stage was mainly due to observed reductions in the number of spikes per square meter and length of spike, while that at reproductive stage could be attributed to reduced number of grains per spike and 1000-grain weight. A combination of reductions in the number of spikes per square meter, length of spike, number of grains per spike and 1000-grain weight accounted for the yield reduction observed when 50% optimum water was withheld throughout growth period. Slatyer (1973) attributed the reductions in the grain yields of crops with water stress at the reproductive stage to reduced fertilization and grain set resulting from dehydration of pollen grains, poor germination of the pollen and failure of the growth of the pollen tube from the stigma to the ovules. Verma et al. (1976) found that adequate

irrigation at the flowering stage enhanced fertilization. They indicated that sound and healthy grain development are only possible when there is sufficient moisture in the soil.

Contrary to the findings of several researchers (Aspinall et al. 1964; Day and Thampson, 1975; Nimzing, 1986) that moisture stress at the reproductive stage of barley was more critical for grain yield than that at the vegetative stage, in this study, with timely sowing (late-November), more reduction in grain yield was observed when stress was imposed at the vegetative than at reproductive growth. On the other two sowing dates, the grain yields of plants stressed at either vegetative or reproductive growth stages were not significantly different. This could be attributed to the problem of high water table at Kadawa (80 - 120cm) caused by the presence of hard pan down below (Kwa, 1982). By the time the plants reached the reproductive stage, they had developed extensive root system which was able to tap water from the rising water table. This yield reduction was therefore not as great as expected when stress was imposed at the redproductive phase. Similar observations had been reported earlier for wheat by Chari and Maurya (1980).

Straw yield, which is a function of vegetative growth was highest in treatments that were supplied optimum water throughout and those given 50% of optimum

at the reproductive stage only because plants from these treatments were taller and produced more tillers which increased the straw yield substantially compared to the treatments supplied 50% optimum water either at the vegetative stage only or throughout growth period (Table 4.4).

The number of spikes per square meter and length of spike were reduced by supplying 50% optimum water either at the vegetative stage only or throughout growth period because the plants did not form many tillers, while the spikes were shorter compared to those plants supplied optimum water throughout or given 50% of optimum water at the reproductive stage only (Table 4.5). Similar effects were also observed by Aspinall et al. (1964): Day et al. (1978) and Kumar and Yayock (1980) who reported that water stress during the vegetative growth of barley and wheat had a detrimental effect on the tillering and jointing which consequently reduced the number of spikes produced per unit area and head length, and hence the grain yield.

The number of grains produced per spike was drastically reduced when plants were stressed at the reproductive stage because many spikelets were unable to fill their grains. Furthermore, those grains that were filled had lighter weight which reduced the 1000-grain weight. This is similar to the findings of Day and Thampson (1975) and Kumar et al. (1977) who reported

damaging effects of water stress on the grain development stage of barley and wheat and an increase in the proportion of small grains which led to lower grain yields.

### 5.1.3 Malting quality

The grain protein content is the principal determinant of the malting quality of barley (Pomeranz et al. 1976). In this study, the protein content of barley was found to be higher in the treatments that produced lower grain yields. Aspinall et al. (1964) observed and reported that barley supplied with sufficient irrigation water had high grain yield with relatively lower grain protein content compared to that stressed which had low grain yield and relatively higher grain protein content. It must be emphasized, however, that even though water stress increased grain protein in this study, the values obtained for all the treatments were within the desirable range for malting as recommended by Chapman and Carter (1976).

### 5.1.4 Water-use efficiency

Highest water-use efficiency was obtained in plants that were supplied optimum water throughout growth period compared with the other treatments (Table 4.12).

This is because in the optimum water treatment, plants produced more grain yield in relation to amount of water used. Day et al. (1978), who observed a linear relationship between grain yield and water-use of barley, stated that prolonged moisture deficit during the early growth stages had a negative effect on the WUE.

An important objective of this study was to device ways of saving irrigation water, especially in a place like the Sudan savanna ecological zone where irrigation water is very limited. Results of previous works could be used to compare the efficiency of the irrigation method used in the present study, $^{IW}/_{CPE}$ ratio with the weekly irrigation generally adopted by farmers in this zone. With weekly application of irrigation water, the variety of barley, Berenice used here would require a total of 84.00 cm of water (6.0cm depth of irrigation water per week for about 14 weeks) from sowing to maturity. However, basing irrigation schedule on the soil, prevailing weather conditions of the area and the water use of the crop, the same variety was given a total of 55.08 cm of water within the same period. It is noteworthy that the highest grain yield of 3682 kg/ha obtained when optimum irrigation water was given in this study (Table 4.6) was similar to the yields of 3271 to 3819 kg/ha earlier reported (Ahmed et al. 1977; Falaki et al. 1980 and Falaki and Ibrahim 1982) at Kadawa for

the same variety when weekly irrigation was applied. Thus, it appears that irrigation scheduling based on the soil, prevailing weather of the area and the water use of the crop as done here was more efficient in terms of water use than weekly irrigation which is generally practiced by farmers in this zone.

## 5.2 Effect of Sowing Date on Barley

### 5.2.1 Growth

The differences in the emergence and growth of barley sown on the three dates could be attributed to variations in temperature within the period from sowing to maturity. Percent emergence was relatively higher when barley was sown in late-November compared to early-November or mid-December. The air temperature records (Appendix B) show that the average minimum and maximum temperature (18.9 and 34.1°C), one week after the early-November crop was sown were relatively higher than the recommended optimum range of 15-20°C for good germination of barley (Kumar et al. 1982). On the other hand, minimum and maximum temperatures one week after the late-November and mid-December sowings were done were closer to the recommended temperature range which favoured the germination and growth of the crop more compared to the early-November sowing.

Plant height, leaf area, LAI, number of tillers per unit area and dry matter accumulation of plant were highest in the late-November sowing, followed by the mid-December sowing. Barley sown in early-November produced the lowest values in all these parameters. Tsala (1985) and Yusuf (1985) also observed differences in maize and millet growth with different dates of sowing at Kadawa due to variations in temperature.

### 5.2.2 Yield and yield components

Grain yield was higher when barley was sown in late-November compared with earlier or late sowing. This is due mainly to favourable temperature, the late-November sown crop enjoyed from sowing to maturity. The mid-December sown crop on the other hand, suffered the adverse effect of high temperatures at the grain filling stage (in late-March). Many spikelets were unable to fill their grains as a result of damaging effect of high temperatures, while number of spikes per unit area were reduced due to tiller mortality which consequently reduced the grain yield. Although temperatures during the grain filling of the early-November sown crop (in February) were close to the optimum range for grain development (18 - 20$^{o}$C), temperatures at the seedling emergence were high resulting in reductions in stand establishment with consequent reduction in number of tillers per unit area and length of spike which contributed to the reduction in the grain yield. These results

are in line with the previous reports of Sinha (1982); Sinha and Falaki (1982) and Asenime and Sinha (1986) indicating that the best time for sowing barley at Kadawa was mid-November to early-December to avoid the damaging effect of high temperatures in March and April on grain development.

5.2.3 Malting quality

Grain protein content increased with decrease in grain yield. Thus, early-November and mid-December sowings which had low grain yields had higher grain protein contents. This can be related to the explanation given by Asenime and Sinha (1983) that fewer number of plants established per unit area with late sowing accumulated more nitrogen which was later transferred to the fewer grains formed.

5.2.4 Water-use efficiency

Water was used more efficiently by crop sown in late-November compared with the two other dates. This is because the late-November sowing had the highest grain yield per centimeter of water used. Even though all the sowing date treatments received same quantities of irrigation water, late-November sowing produced more grain yield. Bengtsson (1977) reported that barley sown at the right time yield more grain per centimeter of water used.

## 5.3 Interaction Between Irrigation Levels and Sowing Date

The interaction between irrigation level and sowing date was not significant for all the growth attributes measured suggesting that irrigation level and sowing date may be acting independently of each other in determining the growth of barley. However, the interaction effects of irrigation level and sowing date on grain yield and yield components except 1000-grain weight were significant. This indicates that the grain yield response of barley to water at different growth stages would vary with time of sowing.

## 5.4 Correlation

Correlation studies indicated that almost all the parameters measured were significantly and positively correlated to grain yield except the grain protein content which was negatively correlated. This is due to the fact that during the process of growth, photosynthates produced were made available for the plant growth and development. The highly significant correlation of number of spikes per square meter, spike length, number of grains per spike and 1000-grain weight to the grain yield indicated that these were very important components and critical determinants of yield. The negative correlation of the grain protein content to the grain yield indicated that the lower the grain yield,

the higher the grain protein content due to accumulation of more nitrogein in the fewer grains.

Chapter 6

## SUMMARY AND CONCLUSION

Barley (Hordeum vulgare L.), variety Berenice was grown under irrigation at the Irrigation Research Station, Kadawa, in the Sudan savanna ecological zone of northern Nigeria during the 1986/87 dry season. Treatments tested consisted of four irrigation levels (optimum irrigation water throughout growth period, 50% optimum water at the vegetative stage only, 50% optimum water at the reproductive stage only and 50% optimum water throughout growth period) using $^{IW}$/CPE ratio; and three sowing dates (early-November, late-November and mid-December). The treatments were laid out in a complete randomized block design replicated four times.

Giving optimum irrigation water throughout growth period produced the highest grain yield. Yield reductions were as much as 48, 30 and 23% when 50% of the optimum irrigation water was withheld throughout growth period, at the vegetative stage only and at the reproductive stage only, respectively. Plant height, leaf area, LAI, number of tillers per unit area and dry matter accumulation by plants were highest with the optimum water treatment throughout growth period. Number of spikes per square meter, length of spike, number of grains per spike and 1000-grain weight were

also highest with the application of optimum irrigation water throughout growth period. This was followed by the 50% optimum water treatment either at the vegetative or reproductive stage only which were statistically at par. The lowest grain yield was obtained when the crop was given 50% optimum irrigation water throughout growth period. Grain protein content on the other hand increased with increase in water stress.

The growth and yield of barley were found to be best when the crop was sown in late-November. Yield decreases were 22 and 20% when sowing was done in early-November and mid-December, respectively. In the late-November sowing, plants grew taller with longer spikes, more spikes per unit area and more grains per spike compared to the other sowing dates. Interactions were significant on the grain yield and its components except the 1000-grain weight.

Based on these results, it can be concluded that stressing barley for water either at the vegetative or reproductive phase was harmful. However, the grain yield was more adversely affected when the crop was stressed at the vegetative compared with reproductive phase under the condition of high water table at Kadawa. Sowing barley between mid-November and early-December period would result to optimum in optimum yield and malting quality in the Sudan savanna ecological zone of northern Nigeria. Likewise, basing irrigation schedule

on the soil conditions, prevailing weather of the area and the water use of the crop would result in optimum grain yield and high WUE with less wastage of water compared to the weekly irrigation.

In this study, the imposition of moderate to severe water stress resulted in drastic reductions in barley yield. Further work would be needed on the effect of mild stress compared with no stress in order to determine whether the limited irrigation water could be conserved by imposing mild stress.

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Appendix A.

Physico-chemical properties of the soil of the experimental plot from a composite sample of 60cm depth.

| Soil properties | Method of analysis | Characteristics |
|---|---|---|
| Physical properties | Hydrometer method | Proportion (%) |
| Sand | | 72.76 |
| Silt | | 14.49 |
| Clay | | 12.75 |
| Bulk density | | 1.69 |
| Texture | | Sandy loam |
| Chemical properties | | |
| pH in water | Glass electrode method | 6.43 |
| pH in 0.01m Cac12 | " | 5.87 |
| $Ca^{++}$ | Atomic absorption Spectrophotometry | 4.52 meq./100gm soil. |
| $Mg^{++}$ | " | 1.16 " |
| $K^{+}$ | Flame photometry | 0.45 " |
| $Na^{+}$ | " " | 0.02 " |
| Organic carbon | Walkley-Black method | 0.23% |
| Total nitrogen | Micro-Kjeldahl " | 0.02% |
| Available phosphorus | Phosphomolybdate method | 57.79 ppm |

Appendix B. Daily temperature records (°C) for Kadawa from November 1986 to March 1987.

| Days | November 1986 | | December 1986 | |
|---|---|---|---|---|
| | Max. | Min. | Max. | Min. |
| 1 | 34 | 21 | 27 | 12 |
| 2 | 34 | 21 | 24 | 14 |
| 3 | 34 | 20 | 25 | 14 |
| 4 | 35 | 20 | 26 | 13 |
| 5 | 35 | 19 | 24 | 14 |
| 6 | 35 | 20 | 24 | 10 |
| 7 | 35 | 18 | 25 | 10 |
| 8 | 35 | 18 | 27 | 11 |
| 9 | 34 | 19 | 28 | 11 |
| 10 | 30 | 17 | 28 | 11 |
| 11 | 29 | 18 | 29 | 10 |
| 12 | 29 | 16 | 29 | 12 |
| 13 | 29 | 11 | 29 | 13 |
| 14 | 29 | 12 | 30 | 11 |
| 15 | 28 | 13 | 27 | 12 |
| 16 | 29 | 15 | 28 | 12 |
| 17 | 30 | 13 | 28 | 12 |
| 18 | 31 | 14 | 25 | 12 |
| 19 | 32 | 13 | 25 | 12 |
| 20 | 33 | 33 | 22 | 14 |
| 21 | 33 | 14 | 21 | 13 |
| 22 | 32 | 15 | 25 | 11 |
| 23 | 33 | 14 | 28 | 11 |
| 24 | 29 | 15 | 31 | 12 |
| 25 | 30 | 14 | 28 | 13 |
| 26 | 30 | 15 | 29 | 11 |
| 27 | 28 | 14 | 33 | 13 |
| 28 | 29 | 14 | 27 | 12 |
| 29 | 30 | 14 | 25 | 11 |
| 30 | 28 | 15 | 22 | 11 |
| 31 | - | - | 26 | 13 |

| Days | January 1987 | | February 1987 | | March 1987 | |
|---|---|---|---|---|---|---|
| | Max. | Min. | Max. | Min. | Max. | Min. |
| 1 | 34 | 12 | 31 | 12 | 33 | 13 |
| 2 | 32 | 13 | 31 | 12 | 30 | 13 |
| 3 | 31 | 13 | 28 | 14 | 27 | 16 |
| 4 | 31 | 11 | 27 | 15 | 29 | 14 |
| 5 | 29 | 12 | 29 | 14 | 32 | 16 |
| 6 | 24 | 12 | 30 | 16 | 33 | 16 |
| 7 | 22 | 11 | 31 | 16 | 33 | 16 |
| 8 | 26 | 11 | 31 | 16 | 34 | 14 |
| 9 | 27 | 11 | 29 | 14 | 33 | 18 |
| 10 | 29 | 11 | 32 | 13 | 33 | 19 |
| 11 | 28 | 11 | 32 | 13 | 33 | 19 |
| 12 | 29 | 12 | 36 | 14 | 34 | 16 |
| 13 | 29 | 11 | 35 | 17 | 34 | 19 |
| 14 | 29 | 13 | 36 | 18 | 34 | 20 |
| 15 | 31 | 12 | 31 | 18 | 36 | 18 |
| 16 | 34 | 11 | 31 | 18 | 37 | 18 |
| 17 | 35 | 12 | 32 | 17 | 37 | 22 |
| 18 | 34 | 12 | 32 | 16 | 38 | 22 |
| 19 | 35 | 12 | 33 | 14 | 39 | 22 |
| 20 | 33 | 12 | 34 | 16 | 39 | 22 |
| 21 | 33 | 15 | 35 | 16 | 40 | 24 |
| 22 | 32 | 16 | 36 | 16 | 37 | 24 |
| 23 | 30 | 14 | 34 | 16 | 33 | 22 |
| 24 | 29 | 13 | 34 | 18 | 37 | 23 |
| 25 | 29 | 13 | 35 | 17 | 35 | 32 |
| 26 | 29 | 13 | 32 | 19 | 34 | 23 |
| 27 | 27 | 12 | 33 | 17 | 33 | 32 |
| 28 | 27 | 13 | 33 | 18 | 31 | 22 |
| 29 | 28 | 13 | - | - | 36 | 25 |
| 30 | 29 | 11 | - | - | 37 | 26 |
| 31 | 29 | 10 | - | - | 36 | 26 |

Source: Meteorological Office, I.A.R./A.B.U. Samaru.

Appendix C. Total monthly rainfall record for Kadawa for the period March-November 1986

| Month | Rainfall (mm) |
|---|---|
| March | 0.0 |
| April | 13.2 |
| May | 71.1 |
| June | 105.6 |
| July | 167.9 |
| August | 234.0 |
| September | 113.7 |
| October | 18.7 |
| November | 0.0 |

Source: Meteorological Office, I.A.R./A.B.U. Samaru.

Appendix D. Mean monthly relative humidity record for Kadawa during the experimental period (November 1986 - March 1987)

| Month | Relative humidity (%) |
|---|---|
| November | 62.9 |
| December | 47.3 |
| January | 48.6 |
| February | 47.6 |
| March | 52.1 |

Source: Meteorological Office, I.A.R./A.B.U. Samaru.

# B I O G R A P H Y

| | |
|---|---|
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| Date and Place of Birth: | 5th January, 1959,<br>Azare, (Bauchi State). |
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| | Graduate Assistant,<br>1984 to date<br>(Abubakar Tafawa Balewa<br>University, Bauchi). |
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| Number of Children: | One |
| Year of Admission for Post-Graduate Studies: | January, 1986 |
| Admission Number: | M.Sc./Agric./7715/85-86 |