Effects of Irrigations Scheduled as per Water Use Factors Under Varying Conditions of Nitrogen Fertilization on Growth, Yield and Quality of Sunflower (*Helianthus annuus* L.) Variety EC 68414 in *Kharif* Season

By

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B. Sc. (Agri.) First Class

A Thesis submitted to the

MAHATMA PHULE KRISHI VIDYAPEETH

(AGRICULTURAL UNIVERSITY)

RAHURI, Dist. Ahmednagar, (Maharashtra State)

in partial fulfilment of the requirements for the degree of

Master of Science (Agriculture)

in

Agronomy

DEPARTMENT OF AGRONOMY

Post Graduate School, Rahuri

May, 1974

DEDICATED

TO

MY LOVING PARENTS

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AGRONOMY

1974

Approved by the Advisory Committee

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CERTIFICATE

This is to certify that the thesis entitled " Effects of irrigations scheduled as per Water Use Factors under varying conditions of nitrogen fertilization on growth, yield and quality of sunflower (Helianthus annuus L.) variety EC 68414 in Kharif season", submitted to the Faculty of Agriculture, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) in partial fulfilment of the requirements for the degree of MASTER OF SCIENCE (AGRICULTURE) in Agronomy embodies the result of a piece of bonafide research work carried out by Shri B.D. Shende, under my guidance and supervision. It is sufficiently of a high standard to warrant its submission to the Vidyapeeth (University) for the award of the said degree. No part of the thesis has been submitted for any other degree, diploma or published in any other form.

The assistance and help received during the course of this investigation and sources of literature referred to have been duly acknowledged.

(Dr.P.N.Kalbhor)
Research Guide.

Rahuri :
Date : 10/6/74

ACKNOWLEDGEMENTS

I consider myself to be extremely fortunate for the opportunity, I got of working under the guidance of Dr. P.N. Kalbhor, M.S. (Utah), Ph.D. (I.A.R.I.), Associate Professor of Agronomy, Department of Agronomy, Post-Graduate School, Rahuri, Dist. Ahmednagar (M.S.) and I have a great pleasure in recording my heartfelt feelings of gratification and indebtedness for suggesting this interesting problem, scholastic guidance, timely suggestions, constructive criticisms, constant inspiration and generous treatment throughout the present investigation.

Heartfelt thanks are also due to Prof. B.N. Narkhede, M.Sc.(Agri.), Head, Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra), and member of the Advisory Committee for his imparting valuable knowledge and versatile advice.

I am greatly indebted to Prof. M.D. Patil, Assistant Professor of Agricultural Chemistry and Soil Science, Mahatma Phule Krishi Vidyapeeth, Rahuri (Maharashtra), and member of Advisory Committee for his versatile suggestions and willing guidance from time to time during the period of this investigation.

I am also thankful to Prof. A.G. Shinde, M.S.(U.S.A.), Assistant Professor of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, for his valuable help during the conduct of this investigation.

Thanks are also due to Prof. V.R. Karandikar, M.Sc. (Agri.) and Prof. S.V. Mahajan, M.Sc.(Stat. & Maths), Associate Professors, Department of Agricultural Statistics, Mahatma Phule Krishi Vidyapeeth, Rahuri, for their valuable suggestions regarding the statistical part of the manuscript.

I shall fail in my duties if I do not place on record my sincere thanks to all the staff members of the Department of Agronomy, Mahatma Phule Krishi Vidyapeeth, Rahuri, as well as sectional and farm staff members of 'C' Block, Mahatma Phule Krishi Vidyapeeth, Rahuri and my colleagues for their kind co-operation during the conduct of this research work.

I must keep on record the sincere efforts made by my parents and brothers in sailing the boat successfully through the fully unfavourable and unstable environment. Also I am heartily acknowledging the timely and physical help that I received from my friends to whom I considered an important mile stones in the lifelong voyage.

Lastly, the venerable thanks are also due to the Kshatriya Mali Educational Society, Malinagar, Dist. Sholapur for awarding me a loan scholarship during the span of the present studies.

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Dated : 8th June 1974

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(S.D. Shende)

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CHAPTER I

INTRODUCTION

CHAPTER I

INTRODUCTION

Sunflower which is popularly called as 'Surajmukhi', has been grown for ornamental purpose in the past. It's use as an oilseed crop however was not commonly known in India. Sunflower (Helianthus annuus L.) a native of north America is now the important oilseed crop of the world and its introduction as a cultivated oilseed crop in India dates back to as early as 1916 in Maharashtra and 1924 in Tamilnadu. The recent revival of interest in this crop is partly due to the reduction in production of groundnut oil per hectare in many states of India and partly due to introduction of high oil yielding varieties from U.S.S.R. Thus its cultivation is taking root in India. It is second only to groundnut as it supplies 19.4 per cent of the total edible vegetable oil production of the world (Trotter and Sivan 1971). The world's farmers now devote some 9.2 million hectares to sunflower which is 20 per cent more than that in 1966. Although the U.S.S.R. still produces the lions share with 52 per cent, the farmers in other countries have increased their share from 35 to 48 per cent since 1966. Argentina is the second largest grower of this crop in the World (Luciano and Mavroux 1967). Total area under sunflower in different states of India was 833 thousand hectares in 1971-72.

Sunflower seed oil, a light yellow colour, is well suited for use as salad and cooking oil, and when hydrogenated, it is used in margarine fat. It is high in poly-

unsaturated fatty acids. It contains 9 to 12 per cent of saturated fatty acids, 60 to 65 per cent linoleic acid, 24 to 31 per cent oleic acid with Iodine number ranging from 125 to 136. Sunflower seed is highly nutritious containing about 20 per cent protein, 40 per cent carbohydrate and 35 to 40 per cent vegetable oil and associated with very high calorific value. The consumption of this oil does not increase the cholesterol in human blood and hence sunflower oil is good for human consumption. Sunflower oil is also a rich source of vitamin 'D' complex.

Sunflower is photo-insensitive crop and can be grown in any season of the year. Being short duration crop, it can be very well suited in the multiple-cropping programme. Sunflower responds very well to irrigation as it is highly sensitive to soil moisture stress during the growth period from flowering to grain development. Also, adequate moisture supply at sowing is highly desirable and may warrant pre-sowing irrigation if the rainfall is not sufficient. Higher yields of sunflower can be obtained by the application of artificial fertilizers and with the timely, adequate moisture supply from soil.

Research work all over the world has now proved that meteorological factors are the primary determinants of water needs of crops. The evapotranspiration by species is a physical process and involves conversion of water into vapour which requires energy. This energy is received from sun and

wind. Values of evapotranspiration by crop - plant can therefore be estimated from the weather data. In this new concept, water loss is governed primarily by meteorological parameters and is independent of crop species as long as the vegetation covers the soil completely and is extensive and also in active growth stage.

Penman (1946) Thronthwaite (1948), Blaney - Criddle (1950) and many others have evolved the empirical formulae for estimation of water use by crop plants, but there are some limitations such as need for precision devices, technical know how, etc. for using these formulae. Recently, several types of evaporimeters which integrate all the meteorological elements causing evaporation of water are being tried as tool for estimating the water loss by plants.

Bathakal (1965) indicated that as the evaporation rates from U.S. standard open pan evaporimeter were very close to the consumptive use of water by crop plant, pan evaporimeter might serve as a better guide for estimation of water needs of crop. Sharma et al (1968) suggested that the use of screened evaporimeter with suitable mesh might be valuable tool, for direct estimation of water loss by crop plant for scheduling irrigation.

As a result of better understanding of these findings, the concept of water use factor is employed in the present investigation. Water Use Factor is the ratio of the actual water evapo-transpired by the crop and the loss of water due to evaporation from U.S. standard open pan evaporimeter (with wire mesh).

Based on these principles, an investigation with ten treatment combinations comprising of irrigation treatments viz., no irrigation, 0.3 Water Use Factor, 0.6 Water Use Factor and nitrogen levels viz., 25, 50, 75 and 100 kg. per hectare was carried out at the main campus, Mahatma Phule Krishi Vidyapeeth Farm, Rahuri.

The main objectives of this investigation were as follows :-

i) To study the effects of different irrigation schedules (according to Water Use Factors) on growth, yield and quality of sunflower (CV EC 68414).

ii) To compare the effects of no irrigation Vs irrigation on growth, yield and quality of sunflower during kharif season.

iii) To evaluate the effects of graded levels of nitrogen with and without irrigation.

iv) To study the effects of interaction, irrigation x nitrogen levels, on the growth, yield and quality of sunflower.

CHAPTER XI

REVIEW OF LITERATURE

CHAPTER II

REVIEW OF LITERATURE

Sunflower as a cultivated oil seed crop is newly introduced to India, and it dates back to as early as 1916 in Maharashtra and 1924 in Tamilnadu. However, the research work in agronomical aspect is rather meagre, in India. The literature on research work carried out on sunflower in foreign countries is available. The relevant literature on this crop is reviewed in brief in this chapter.

1. Effect of irrigation :

1:1 Effect of irrigation on growth :

Heneа and Olteanu (1959), stated that irrigation should be given during the critical phases of growth, namely head-formation, flowering and seed formation. The amount of water applied ranged from 1200-1800 m^3 per hectare according to weather. Nicolae et al. (1958), observed that when period of head formation and flowering is coincided with abundant rainfall the yield of sunflower seed was increased. Casallo and Rodriguez, (1963) reported that the sunflower was a promising crop for spain, in fertile soil under at least 500-600 mm rainfall or under irrigation in less fertile soil when summers were cooler.

Vasiliu and Negomireanu (1968) reported that the mean daily water consumption by sunflower was 1-2 mm. in April, 2.5-2.6 mm. in May, 5.0-5.2 mm. in June, 4.6-5.1 mm. in July and 2.8-3.1 mm. in August, at Fundulae. While conducting the experiment on drought resistance of sunflower, Mirjol et al.

(1969), found that drought induced during vegetative growth period was least detrimental to qualitative and quantitative yields, affecting only growth process. Drought induced at anthesis period proved to be the most detrimental, causing significant yield decrease by forming small number of flowers, but partial fertilization. He further added that drought induced at seed-formation, resulted in high number of flower and seeds developed but filling process was stagnated and this was due to fact that a great part of leaf area was dried out.

Verstermans and Dellenbach (1970) reported from trial with two cultivar that on light soils, irrigation was not required in wet years but in dry years, one early irrigation, if the water table was less than two meters deep and one early irrigation and second at flowering, if water table was more than two meter deep. On heavy and deep soil numerous successive irrigations were invaluable in dry season for sunflower. Daulay et al. (1971), found that total consumptive use was 94 mm and moisture use efficiency was 3.3 kg seed per mm for sunflower in Rajastan as against moisture use efficiency of 1.6 kg seeds per mm and 1.9 kg seeds/mm for groundnut and til respectively at Rajastan.

1.2 Effect of irrigation on yield of Sunflower :

Vucic et al. (1965) reported that sprinkler irrigation increased the infection of sunflower by Septoria helianthi; Puccinia helianthi and Sclerotium bataticola, to such an extent that treatment adversely affected the yield and quality

of sunflower seed. He further stated that furrow irrigation has little effect on disease incidence and improved yield and quality of sunflower seed.

At Braila and Fundulae, sunflower was irrigated at 70 per cent and 50 per cent available moisture and at capitullum formation, seed formation when more than 30 per cent of available moisture remained. From above experiment Vasiliu and Negamireanu (1968) reported that yield of 70 per cent and 50 per cent available soil moisture treatment and irrigation at capitullum and seed formation stages were 3.45, 3.65 and 3.61 tons of seed per hectare as against 2.75 tons of sunflower seed per hectare in 'no irrigation' plot. While conducting field trials with sunflower, cultivar peredovik and Armavirec, Watson, Myhre (1970) found that the average seed yield of sunflower was 2225 and 1600 lbs per acre respectively, even though the rainfall between sowing and harvesting was only six inches. Anonymous (1972) reported that when single irrigation given at beginning of the flowering, resulted in giving significantly higher yield of sunflower to the extent of 19.25 quintals per hectare as against 13.42 quintals per hectare in 'no irrigation' plot and it was as effective as two irrigation given at 5-6 leaf stage and flowering, three irrigations given at 5-6 leaf stage, flowering and at pod filling.

1:3 Effect of irrigation on quality of Sunflower :

1:3:1 Protein :

Trepacev (1952) stated that protein content and other qualitative characteristics of sunflower seed fluctuated

greately depending upon whether the crop was irrigated or not.

Pirjol et al. (1969) reported that when drought was induced at seed formation, a high number of flower heads and seeds were developed but filling process was stagnated giving high percentage of empty seeds and low protein content and this was due to fact that great part of leaf area was dried out.

1:3:2 Oil :

Trepacev (1952) stated that oil content and other qualitative characteristics of sunflower seed fluctuated greately depending on whether the crop was irrigated or not. The results obtained, revealed that oil from irrigated varieties had higher iodine number and increased oleic acid.

Simanskit (1961) reported that water supply was a critical factor for oil formation particularly in the period between flower formation and full ripening of seed. Pirjol et al. (1969) reported that when drought was induced at seed formation a high number of flower head and seed were developed but filling process was stagnated, giving high percentage of empty seed and low oil content and this was due to fact that great part of leaf area was dried out.

2 Effect of Nitrogen :

2:1 Effect of Nitrogen on Growth :

2:1:1 Height :

Salugeanu and Pristavu (1966), observed no increase in height of sunflower by application of ammonium nitrate.

Cornea and Zarav (1969) reported that application of 200 kg ammonium nitrate 300 kg single super phosphate and 150 kg of muriate of potash per hectare resulted in induced vegetative growth of sunflower.

Stevenson (1970) observed an increased growth of sunflower by 30-40 per cent with added nitrogen and phosphate on clay-loam soil. Massey (1971) found that, the application of 56 kg N per hectare to sunflower increased plant height by 11 cms over control.

2:1:2 Number of leaves and leaf area per plant :

Cornea and Zarav (1969) stated that by application of 20 tons of F.Y.M. 150 kg of single super phosphate to sunflower at sowing increased the number of leaves significantly per plant over the control. Golgoezi (1969) reported that the fertiliser treatments significantly increased leaf area of sunflower.

2:1:3 Stem girth :

Massey (1971) observed in field trial with sunflower that 56 kg N per hectare increased the stem diameter by 4 mm as compared to control. Higher doses of nitrogen were found ineffective in increasing the stem diameter of sunflower.

2:1:4 Head diameter :

Golgoezi (1969) observed significant increase in flower head diameter with increasing rate of nitrogen upto 110 kg N per hectare and phosphate and potassium upto 220 kg per hectare applied to sunflower, Cultivar Mishavardai and Peredovik. Massey (1971) stated that there was an increase of flower head

diameter by 2.2 cm with application of 56 kg N per hectare over control.

2:1:4 Weight of seed per head :

Cernea and Tarav (1969) reported that the application of 20 tons of F.Y.M. and 150 kg super-phosphate per hectare to sunflower at sowing increased the weight of seed per head, (Cultivar Vniimik 8931). Lassey (1971) reported in field trials on sunflower that 56 kg N per hectare increased seed weight by 17.79 gm per head as compared to control.

2:1:6 Thousand seed weight :

Limanskit (1961) reported that absolute seed weight and hence the yield was increased by nitrogen fertilisation. Cernea and Tarav (1969) observed significant increase in thousand seed weight of sunflower (C.V. Vniimik 8931) by application of 20 tons of F.Y.M. and 150 kg super-phosphate per hectare.

Lassey (1971) stated that application of 56 kg N per hectare increased seed weight by 1.9 g per 200 seeds as compared to control.

2:2 Effect of Nitrogen on yield of sunflower seed :

Tarancuk (1951) reported that sunflower seed yield were 21.03 centres per hectare on N P K manured plot as compared to 19.98 centres per hectare on unmanured plot (1 centre= 100 kg). Limanskit (1961) obtained significant increased yield of sunflower with application of nitrogen as compared to control. In the field trial carried out by Hera (1966), the yield of sunflower varied from 19.70 quintals to 28.70 quintals per

hectare. He further observed that climate affected the yield of sunflower seed more than did the fertilizer. Onish Chenko (1966) reported that the application of 120 kg N, 120 kg P_2O_5 per hectare to sunflower increased seed yield significantly over control. Pochv (1969) observed that application of 120 kg N per hectare resulted in increased yield from 23.7 h kg per hectare on unmanured soil to 26.1 h kg per hectare on manured soil.

Singh et al. (1970) reported that application of 40 kg N per hectare resulted in increasing the yield at sunflower seed significantly of 30.29 quintals per hectare as compared to 21.43 quintals per hectare in controlled plot. Whereas 80 kg N per hectare did not differ either from 40 kg N or 120 kg N per hectare (CV. Peredovik). Robinson (1971) observed that 75 or 150 kg N per hectare failed to increase the yield of sunflower on fertile silt loam soil. Massey (1971) found that application of 96 kg N per hectare increased seed yield by 653 kg over control, and that no further increase was observed from additional nitrogen. While conducting the solution culture experiment on sunflower, Goic et al. (1972) applied 4-12 meg NO_3 per litre solution to the plant either upto flowering or seed maturity. They observed that N given until flowering resulted in seed yield of 18.4 gm per plant with 4 mg NO_3 per litre solution and 66.9 gm of seed per plant due to application of 12 mg NO_3 per litre solution. They further reported that there were an increase in seed yields upto 27.7 and 72.3 gm for 4 meg NO_3 and 12 meg NO_3 per litre solution respectively

when the NO_3 was given until seed maturity. The manurial experiments were conducted by the All India Co-ordinated Research Project of Sunflower, Digraj (M.S.) at Agricultural Research Station, Digraj, Karad, Gadhinglaj, Niphad, Jalgaon and College of Agriculture, Dhulia and Kolhapur. It was observed that no significant differences in grain yield were obtained due to the application of 25, 50 and 75 kg N per hectare over control at Digraj and Dhulia while at Niphad, Jalgaon and Kolhapur the above levels proved to be effecting by producing significantly higher yields of grain over control. At Karad, grain yield of sunflower increased with increase in levels of nitrogen while at Gadhinglaj all the levels tried were significantly superior over control but no significant difference in grain yield between 25 and 50 kg N per hectare was obtained (Anonymous 1974).

In another experiment conducted by the above project at Digraj , Jeur and Poona (Maharashtra) it was observed that no significant difference in grain yield of sunflower was obtained with the application of 25 to 50 kg N per hectare over control while at Poona, the increased levels of nitrogen i.e. 25 and 50 kg per hectare has given significantly superior yield over no application of nitrogen (Anonymous 1974).

2:3 Effect of Nitrogen on quality of sunflower :

2:3:1 Protein :

Investigating with the elite seeds of sunflower Cultivar Peranjunka 35, Parancuk (1951) found that in N P K manured

plot the seed were of better quality than unmanured plot. Simanskit (1961) reported that N fertilizers lead to increase in protein content of sunflower seed. Onish Chenko (1966) stated that application of 120 kg N and 120 kg P_2O_5 per hectare to sunflower resulted in increasing the protein content of seed. Boic et al. (1972) reported from solution culture experiment that protein content of seed increased upto 37.9 per cen of dry seed with both increased NO_3 application and increased period of application by 4 mg of NO_3 given until flowering.

2:3:2 Oil :

Simanskit (1961) reported that N fertilization lead to reduction in the oil content of sunflower seed. Mera (1966) concluded that the climate affected the oil content of seed more than did the fertilizer application. Onish Chenko (1966) stated that application of 120 kg N and 120 kg P_2O_5 decreased the oil content of sunflower seed. Gruev (1960) reported that nitrogen alone reduced the oil content of seed sunflower.

D'yakov (1969) observed in pot trial and field trial that nitrogen utilization by sunflower plant for oil formation at early stage of development originated from stem and from ageing lower leaves but not from actively growing upper leaves. He further added that the cultivar with low oil content have the upper leaves more longer than those cultivar with high oil content.

It has been observed by Pochv (1969) that the application of 120 kg N per hectare resulted in reducing oil percentage upto 44.8 per cent as against 47.9 per cent in unmanured seeds of

sunflower. He further added that total oil yields were 11.5 h kg per hectare in unmanured sunflower plot as against 11.69 h kg per hectare when crop was manured with 120 kg N per hectare. From the field trials with Vniimik 8931, Cornea and Taray (1969) stated that the application of 200 kg ammonium nitrate alongwith 300 kg super phosphate and 120 kg K_2O per hectare increased the oil production. While conducting solution culture experiment with sunflower, Coic et al. (1972) observed reduction in oil content byboth increased NO_3 application and period of application. The reduction in oil was from 62.8 per cent in 4 mg NO_3 application until flowering to 49.0 per cent in 12 mg NO_3 application until seed maturation.

2:3:3 Oil and protein :

Simanskit (1961) reported that N fertilizer lead to an increase in protein content with consequent reduction in oil content of sunflower seed. Onish Chenko (1968) stated that application of 120 kg N and 120 kg P_2O_5 per hectare to sunflower resulted in increasing the protein contents of seed but decreased the oil content of seed.

Coic et al. (1972) conducted a solution culture experiment with sunflower and he observed that the protein content of seed increased by both increased NO_3 application and period of application. The increase was upto 37.9 per cent of dry seed by the application of 4 mg of NO_3 until flowering but the oil content was reduced from 62.8 per cent in 4 mg NO_3 given until flowering to 49.0 per cent in 12 mg NO_3 application until seed maturation.

3 × Effect of irrigation and nitrogen :

3:1 Effect of irrigation and nitrogen on growth :

Warren (1966) at Deniliquecain (Australia) found that the levels of NAR for sunflower at wider spacing with non-limiting water and nutrient obtained was 2.09 gm per dm^3 per week in clear weather of mid summer. Milic (1967) observed that the sunflower cultivar Vniimk 9345 when grown at the rate of 36000 plants per hectare with three irrigation regime and three rates of N P K , the optimum irrigation requirements were 1-2 applications each of 600-700 m^3 per hectare. Under such conditions the crop consumed 70-100 m^3 water per hundred kg seed of which 20-30 per cent was evaporated in first, 45-60 per cent in the second and 20-25 per cent in the final and third cropping season.

3:2 Effect of irrigation and nitrogen on yield :

Nicolae et al. (1958) observed that ammonium nitrate did increase seed yield of sunflower in one year when the period of head formation and flowering coincided with abandant rainfall. Simanskit (1961) stated that inadequate water supply with and without use of fertilizer resulted in much reduced yield of sunflower. Grver (1968) found near Sofia that by application of 20 tons of F.Y.M. per hectare to irrigated sunflower increased seed yield from 26.7 h kg per hectare in unfertilized plot to 32.7 h kg per hectare in manured plot. He further added that highest yield of 46.0 h kg per hectare was obtained from addition of 120 kg N 120 kg P_2O_5 and

100 kg K_2O per hectare when 25 per cent of these amount applied before sowing and 25 per cent each of remained amount later on as top-dressing. He again reported that when same amount was given in single dose before sowing it resulted in reduced yield upto 39.7 h kg per hectare.

3:3 Effect of irrigation and nitrogen on quality :

Simanskit et al. (1961) observed that water supply was a critical factor for oil formation particularly between flower formation to full ripening of seed. They further added that inadequate water supply with or without use of fertilizer resulted in much reduced oil and the reduction was of 2.5 to 10 per cent in oil. Gruev (1968) observed that the application of 20 tons of F.Y.M. to sunflower with irrigation considerably increased oil content as compared to unmanured plot.

CHAPTER III

MATERIALS AND METHODS

CHAPTER III

MATERIALS AND METHODS

The present studies were carried out during Kharif season of 1973 at the main campus of Mahatma Phule Krishi Vidyapeeth, Rahuri. The details about the materials used and methods followed in the present investigation are described in this Chapter.

1 Experimental site :

The experiment was laid out in the Kharif season of 1973 in Survey number 138 of 'C', block at the main campus of Mahatma Phule Krishi Vidyapeeth, Rahuri. The topography of the experimental plot was fairly uniform and levelled. In order to know the physico-chemical properties of the soil, soil samples from experimental plot were taken at random and mixed together to get a composite soil sample. The soil samples were taken with the help of screw auger from 0-30 cm layer. The results of the physico-chemical properties of the soil are presented in Table 1.

1:1 Physical properties of the soil :

1:1:1 Mechanical analysis :

It was carried out by International Pipette method as described by Piper (1950).

1:1:2 Moisture constants of soil :

The soil moisture constants like Field capacity, Permanent wilting point and Moisture equivalent were determined by field method, sunflower method, and as procedure described

Table 1 : Physical and chemical properties of the soil from experimental plot (0-30 cm depth).

Sr.No.	Characteristics		Particular
A)	**Physical properties :**		
1)	Mechanical composition		
	a) Coarse sand	Per cent	8.15
	b) Fine sand	Per cent	17.25
	c) Silt	Per cent	13.57
	d) Clay	Per cent	55.14
	Textural class		Clayey
2)	Bulk density		1.27 gm/cc
3)	Pore space	Per cent	52.08
4)	Moisture constants		
	a) Field capacity		
	i) 0-30 cm	Per cent	39.77
	ii) 30-45 cm	Per cent	38.12
	b) Permanent wilting point		
	i) 0-30 cm	Per cent	23.06
	ii) 30-45 cm	Per cent	24.13
	c) Moisture equivalent		
	i) 0-30 cm	Per cent	41.34
	ii) 30-45 cm	Per cent	40.15
5)	Depth of Water Table		More than 3 meter from surface.
B)	**Chemical properties :**		
1)	Total nitrogen	Per cent	0.067
2)	Available P_2O_5	Per cent	0.0024
3)	Available K_2O	Per cent	0.014
4)	pH		8.2
5)	Total soluble salt		0.356 mhos/cm^2
6)	Organic Carbon	Per cent	0.66
7)	Organic matter	Per cent	1.13
8)	C/N ratio		11.57

1:2:6 C/N ratio :

The percentage of Organic Carbon was divided by the percentage of nitrogen to get the C/N ratio.

1:2:7 Soil pH :

The soil pH was determined with Blackman's pH meter on 1:2.5 soil : water ratio.

1:2:8 Total soluble salts :

The total soluble salts were determined by electrical conductivity method.

Data in Table 1 revealed that the soil from experimental plot was clayey in texture and it was alkaline in reaction. The soil was medium in nitrogen phosphorus and potassium (Datta, 1960).

2 Climate :

The experimental area was situated at the main campus of Mahatma Phule Krishi Vidyapeeth, Rahuri which is about 30 km. from Ahmednagar on Ahmednagar-Manmad National Highway No. 14. It is 12 km. away on West side of Rahuri Railway Station of Central Railway.

The campus is located in between 19°47' North to 19°57' North lattitude and in between 74°82' North East to 74°19' East longitude. It's height above sea level is variable from 495 m. to 569 m. (1950 - 1850 feet). The area comprises of rolling plain with varying depth, lies on western side of Nagar Manmad highway which divide the campus.

Table 2 : Meteorological data recorded during the cropping period of Kharif 1973.

Meteorological weeks	Dates and months	Mean Temperature °C		Mean U.S.W.B. Class I open pan evaporation (mm)	Rainfall	
		Maximum	Minimum		mm	Rainy days
	August 1973					
33	13-19	28.20	21.60	5.35	-	-
34	20-26	27.50	22.40	4.91	14.0	3
35	27-2	25.00	22.00	6.23	-	-
	September 1973					
36	3-9	23.50	22.60	3.77	-	-
37	10-16	26.50	21.40	6.53	-	-
38	17-23	24.00	21.80	3.75	44.0	3
39	24-30	24.50	22.50	3.63	52.0	2
	October 1973					
40	1-7	23.30	22.30	4.08	5.0	1
41	8-14	24.62	22.48	6.51	-	-
42	15-21	23.20	22.10	5.10	38.0	1
43	22-28	22.20	21.80	3.97	43.0	2
44	29-4	23.60	17.3	4.85	-	-
	November 1973					
45	5-11	27.70	17.08	5.23	-	-
46	12-18	27.80	16.76	5.03	-	-
47	19-25	27.56	16.21	4.33	-	-
48	26-2	28.87	15.57	4.53	-	-
	December 1973					
49	3-9	27-52	17.34	5.74	-	-
					183.0	12

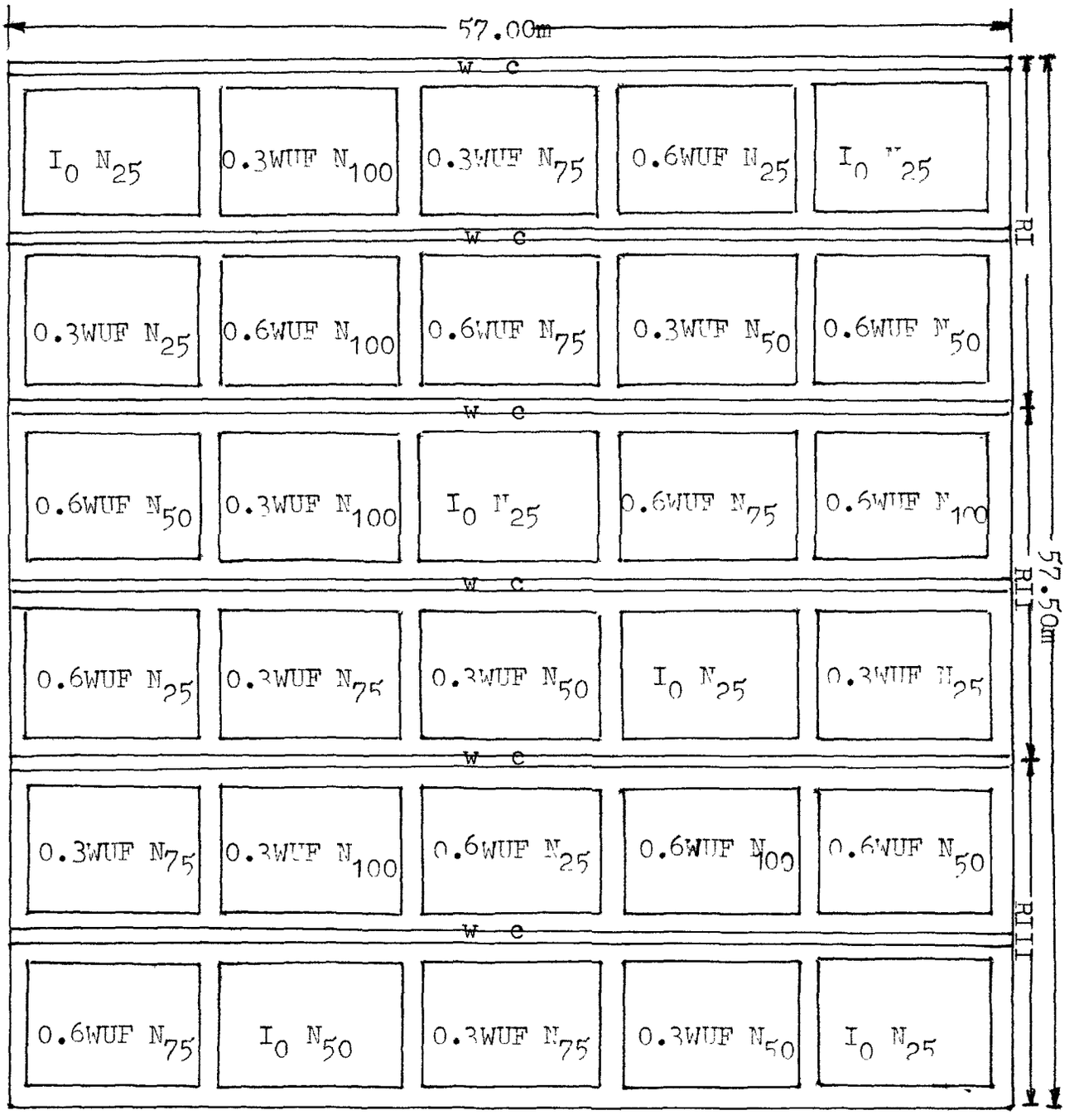
Table 3 : Cropping history of the experimental plot for last three years.

Cr. No.	Year	Season	Crop	Manured and fertilizers		
				N kg/ ha	P_2O_5 kg/ha	K_2O kg/ha
1	1970-71	Kharif	Fallow	-	-	-
		Rabi	Fallow	-	-	-
2	1971-72	Kharif	Fallow	-	-	-
		Rabi	Wheat	50	25	-
3	1972-73	Kharif	Cotton	150	75	50
		Rabi	Maize	50	25	-
4	1973-74	Kharif	Present investigation			

4 Experimental Details :

The experiment was laid out in a factorial randomised block design with ten treatment combinations replicated three times. There were four levels of nitrogen and two schedules of irrigation thus forming 8 treatment combinations. In addition, there were two additional treatment combinations of 2 lower levels of nitrogen with 'no irrigation' treatment. Thus total treatment com-bination were ten. The plan of layout for present investigation is given in Fig. 1. The details of experiment and treatments alongwith symbols used are given below.

PLAN OF LAYOUR FIG.1



(Not to the Scale)

Design = Factorial Randomised block

Gross plot size = 9.60 m x 6.00 m

Net plot size = 8.40 m x 4.80 m

Crop = Sunflower

Variety = EC 68414

Spacing = 60 cm x 30 cm

Design	=	2^4 Factorial /randomised block design
Number of Replication	=	Three
Gross plot size	=	9.60 m x 6.0 m.
Net plot size	=	8.40 m x 4.80 m.
Crop	=	Sunflower
Variety	=	A.C. 68414
Spacing	=	60 cm x 30 cm.

Table 4 : Treatment details along with the symbol used.

Sr.No.	Treatments	Symbol
A)	**Irrigation schedules :**	
	1) To irrigate at Water Use Factor of 0.3	.. 0.3 WUF
	2) To irrigate at Water Use Factor of 0.6	.. 0.6 WUF
B)	**Nitrogen :**	
	1) 25 kg N/ha	.. N_{25}
	2) 50 kg N/ha	.. N_{50}
	3) 75 kg N/ha	.. N_{75}
	4) 100 kg N/ha	.. N_{100}
C)	**Additional two treatment combinations :**	
	N_{25} and N_{50} with no irrigation	
	1) No irrigation with N_{25} kg/ha	.. $Io.N_{25}$
	2) No irrigation with N_{50} kg/ha	.. $Io.N_{50}$
	Total treatment combinations = Ten	-

In respect of irrigation treatments involving the climatological approach as in case of the present investigation,

irrigations were scheduled on the basis of pre-determined Water Use Factors. The Water Use Factor is the ratio between evapotranspiration by the crop and evaporation from U.S.W.B. Class A open pan evaporimeter (with wire mesh).

The cumulative evaporation values, (i.e. total depth of water that should be evaporated from standard U.S.W.B. Class I open pan evaporimeter between two successive irrigation turns) were calculated for each Water Use Factor. The effective root zone for the sunflower was taken as 300 mm. The depth of available moisture was calculated as per the following formula :

$$\text{Depth of available moisture} = \frac{\text{Available moisture} \times \text{bulk density} \times \text{effective root zone}}{100}$$

The available moisture was calculated by determining the difference between field capacity and permanent wilting point. As per the assumption that, next irrigation was to be given, when 50 per cent of the available soil moisture is depleted; the depth of available moisture thus calculated was halved. In order to determine the interval of irrigation, the evaporation values were calculated for each of the Water Use Factor and the schedules of irrigations were fixed. Evaporation values for irrigation treatment are calculated as below.

$$\text{Depth of available moisture} = \frac{(39.77 - 23.06) \times 1.27 \times 300}{100}$$

$$= 16.77 \times 1.27 \times 3$$

$$= 63.66 \text{ mm}$$

50 per cent of the available soil moisture depletion :

$$\frac{63.66}{1} \times \frac{50}{100} = 31.83$$

Thus, the evaporation values were calculated as follows :

1) At Water Use Factor of 0.6 :

$$\frac{31.83}{1} \times \frac{10}{6} = 53.05 \text{ mm}$$

2) At Water Use Factor of 0.3 :

$$\frac{31.83}{1} \times \frac{10}{3} = 106.10 \text{ mm.}$$

Thus irrigation would be given when daily evaporation value from standard U.S.W.B. Class I open pan evaporimeter summed up to about 53.05 mm and 106.10 mm for 0.6 and 0.3 water use factors respectively.

If the rainfall was received at any time during the crop growth period the effective rainfall only was taken into account. If the rainfall is received within 3 - 4 days after irrigation, all the rainfall was taken as ineffective but the pan evaporation values for scheduling next irrigation were calculated by starting from the next immediate day after rainfall and not from the day of previous irrigation. If the rainfall received was just before next irrigation and if it was sufficient enough to

bring the 30 cm soil depth to field capacity then all the rainfall was taken as effective and the irrigation was then scheduled by taking pan evaporation value starting from the next day of rainfall.

5 Irrigation application and measurement of irrigation water :

One common irrigation was given to all plots including " no irrigation " treatment plot at the time of sowing. This helped for easy germination and good stand of crop in all the treatment plots. Subsequent irrigations were given as per irrigation schedules. The source of irrigation was well and it was near the plot. The actual quantity of water to be applied for each plot was calculated on the basis of soil moisture study, 24 hours before irrigation for each plot. The quantity of irrigation water was measured with the help of water meter.

6 Soil moisture studies :

The soil moisture studies were made 24 hours before irrigation and 48 hours after irrigation. The soil moisture percentage were determined from 0 - 30 cm and 30 - 45 cm layer. The soil samples were taken from two spots in each plot and mixed together for their respective depths. The 50 g of weighed samples were taken to determine the moisture percentage. The soil moisture percentage were determined by gravimetric method expressed on oven dry basis at 105°C.

The soil moisture percentage was determined at harvesting. It was also confirmed by taking the soil moistures that whether the field was reached at field capacity after receipt of rainfall.

7 Fertilizer application :

a) Nitrogen :

As per the schedules, the nitrogen was applied through urea analysing 46 per cent nitrogen. The complete dose was splited into two. The first, being the two third quantity of nitrogen, at the time of sowing and the remaining one third qaqntity was applied at 25 days after sowing in 0.3 IW treatment plots and 29 days after sowing in 0.6 IW treatment plots.

However, all the dose of nitrogen was applied to the " No irrigation " treatment plots at sowing.

b) Phosphate application :

The phosphatic fertiliser was applied at the rate of 40 kg P_2O_5 per hectare at the sowing time. It was applied in band placement just by the side of raw marked with marker for dibbling the seed. It was applied as basal dose to all treatment plots.

c) Potash :

The potassic fertilizer was applied as a basal dose to all treatment plots at the rate of 20 kg K_2O per hectare. The method of application was the same as in case of phosphate application.

The phosphate was applied through single super phosphate containing 16 per cent P_2O_5 and potassium was applied through muriate of potash analysing 60 per cent K_2O.

8 Field operations :

The schedule of cultural operations carried out during Kharif 1973 in the experimental plot, are given in Table 5.

Table 5 : Schedule of cultural operations carried out during kharif 1973 season in the experimental plot.

Sr. No.	Name of operations	Frequency	Implements used	Date of operation
A.	Preparing			
1.	Ploughing	1	Tractor drawn plough	1-8-73
2.	Discing	1	Tractor drawn Disc.	9-8-73
3.	Harrowing	1	Deccan blade harrow	10-8-73
4.	Stuble collection	1	Women labour	10-8-73
5.	Preparation of layout	1	-	12-8-73
6.	Preparation of bed and water channals	1	Spade, phawada	13-8-73 14-8-73
7.	Application of fertilizer	1	Ghamela	16-8-73
8.	Marking	1	Marker	16-8-73
B.	Sowing of seeds	1	Women labour	16-8-73
C.	Intercultivation			
1.	Common irrigation	1	-	16-8-73
2.	Gap filling	1	Khurpi, women labour	26-8-73
3.	First thinning	1	Hand, women labour	29-8-73
4.	Second thinning	1	Hand, women labour	3-9-73
5.	Weeding	3	Hand khurpi	8-9-73
			Hand khurpi	27-9-73
			Hand khurpi	9-11-73

Sr. No.	Name of operations	Frequency	Implements used	Date of operation
6.	Fertilizer application	2	Ghamela, khurpi	
	i) In 0.3 WUF treatment plot	1	Ghamela, khurpi	10-9-73
	ii) In 0.6 WUF treatment plot	1	Ghamela, khurpi	14-9-73
7.	Mending of water channels	1	Spade, phawada	11-10-73
8.	Irrigation as per treatment of 0.6 WUF	1	-	30-8-73
9.	Irrigation as per treatment of 0.3 WUF	1	-	10-9-73
10.	Irrigation as per treatment of 0.6 WUF	1	-	14-9-73
11.	Irrigation as per treatment of 0.6 WUF	1	-	14-10-73
12.	Irrigation as per treatment of 0.6 WUF	1	-	11-11-73
13.	Irrigation as per treatment of 0.3 WUF	1	-	20-11-73
14.	Plant Protection			
	i) 10 per cent BHC dusting	1	Hand duster	21-10-73
	ii) Endrin 20 per cent EC spraying	1	Power sprayer	25-10-73
	iii) 10 per cent BHC dusting	1	Hand duster	7-11-73
15.	Watching		Women labour	1-11-73 to 5-12-73
16.	Harvesting		Hand, sickle	5-12-73
17.	Threshing		Hand, women labour	12-12-73

9 Seeds and sowing :

The seeds of sunflower variety E.C. 68414 was obtained from seed store of Mahatma Phule KrishiVidyapeeth, Mahuri. The seeds were treated with agroson 3 g per kg seed. The sowing was accomplished on 16th August, 1973. About 4-5 seeds were dibbled at each hill at 60 cm x 30 cm spacing. Then immediately after sowing the common irrigation was given to all plots.

10 Gap filling :

Gap filling was done on 10th day after sowing i.e. on 26-8-73 and water was applied with bucket to ensure good germination.

11 Thinning :

The thinning operation was carried out on 13th day from sowing. Again on 3-9-73 i.e. 18th day from sowing the second thinning was carried out and only one healthy seedling was kept at each hill where gap filling was done.

12 Plant protectors measures :

There was mild attack of red hairy caterpiller (Amsacta moorei and Amsacta albistrigs). It was controlled by spraying endrin 20 per cent E.C. Also 10 per cent BHC was dusted.

13 Biometric observations :

13:1 Sampling :

In order to record the biometric observations, ten plants were selected at random in each net plot, by using the Tippett's random number Table. These plants were marked by fixing the bamboo pegs near the selected plants and also plants were labled

with paper lable. All the growth and developmental observations were recorded on those plants. The details about the various biometric and other observations recorded during the course of present investigation are presented in Table 6.

Table 6 : Details of the biometric and other observations recorded.

Sr. No.	Particulars	Frequency	Days from sowing	Plant(s) observed
A.	Preharvest study			
1.	Height per plant(cm.)	6	32,46,60,74,88,111	10 plants
2.	Spread per plant(cm.)	5	32,46,60,74,88	10 plants
3.	Number of leaves	6	32,46,60,74,88,111	10 plants
4.	Leaf area per plant (sq.dm.)	6	32,46,60,74,88,111	10 plants
5.	Stem diameter per plant (cm)	6	32,46,60,74,88,111	10 plants
6.	Dry matter per plant(g)	6	32,46,60,74,88,111	10 plants
7.	Days required for flowering		Observation was continued from start of flowering to the day when more than 50 per cent plants flowered.	Two rows in each net plot
8.	Head diameter (cm.)	3	74,88,111	10 plants
9.	Root study	1	111	Two plants in each net plot
10.	Soil moisture studies		24 hours before and 48 hours after each irrigation scheduled according to treatments.	
11.	Plant population	1	111	All plants in net plot

Sr. No.	Particulars	Frequency	Days from sowing	Plant(s) observed
B.	Post harvest studies			
1.	Weight of head along with seeds per plant	1	111	10 plants
2.	Weight of grain per head	1	111	10 plants
3	Weight of reproductive plant parts other than grains per head	1	111	10 plants
4	Dry weight of stalks per plant	1	111	10 plants
5	Thousand grain weight	1	111	Representative sample from produce of net plot
6	Number of filled, unfilled and total number of grain per head	1	111	5 heads
7	Weight of heads per net plot	1	111	Net plot
8	Weight of grains per net plot	1	111	Net plot
9	Weight of straw per net plot	1	111	Net plot
C.	Chemical studies			
1	Total nitrogen in soil at harvest	1	111	Sample from each net plot
2	Plant analysis per nitrogen percentage			
	1st stage :	1	60	Two plants
	i) Stem		60	Two plants
	ii) Leaves		60	Two plants
	iii) Head		60	Two plants

Sr. No.	Particulars	Frequency	Days from sowing	Plant(s) observed
	2nd Stage :	1	60	Two plants
	i) Seed		88	Two plants
	3rd Stage :	1	111	A composite sample
	i) Stem		111	prepared out of
	ii) Leaves		111	10 randomly selected
	iii) Seeds		111	plants in each net
	iv) Disc along with bhusa and unfilled seeds		111	plot
3	Protein percentage in seed (crude protein)	1	111	Sample from each net plot
4	Oil percentage	1	111	

13:2 Preharvest observations :

13:2:1 Stand of crop :

The plant population was recorded by counting all the plants in the net plot at 30 days after sowing and at the time of harvest.

13:2:2 Height of plant :

The height of plant (cm) in each treatment plot was recorded for 10 plants selected at random as in 13:1. The height was measured from ground level to the base of last fully opened leaf upto the capitulum stage, and from ground upto the base of capitulum thereafter.

13:2:3 Spread of plant :

The spread of plant was recorded in cm.

13:2:4 Number of functional leaves per plant :

The total number of fully opened green leaves were counted.

13:2:5 Leaf area per plant :

The plants taken for dry matter studies were first used for measuring the leaf area per plant. The total number of leaves per plant were classified into three groups i.e. small, medium and big sized leaves. The leaf area was measured by tracing the representative leaf margin for each group and with the help of planimeter and subsequently the values for each class were multiplied with class frequency and summed up to get total leaf area per plant.

13:2:6 Stem diameter :

The diameter of stem was recorded with the help of vernier calliper. It was measured at the base of 5th leaf in all observations.

13:2:7 Dry matter study :

For dry matter study, two plants were selected at random from each net plot. The plants were cut at ground level, dried in sun and kept in brown paper bag. The plant samples then were dried in hot air oven at about 70°C. The component parts of plant i.e. stem, leaves and head (if present) were separated and weighed separately. The total dry matter per plant was calculated by totalling the weight of these components.

13:2:8 Days required for flowering :

To asses the period of flowering, two rows in each net plot were selected randomely and the heads which were flowered completely were observed. The counting was started just from start of flowering and continued till 50 per cent plants were flowered.

13:2:9 Diameter of head :

The diameter of head was recorded when 50 per cent plants from net plot were flowered. The diameter was recorded on plants selected at random for biometric observations. It was measured at two places and mean was taken as diameter of the head.

13:2:10 Root study :

The root study was taken at the time of harvest only. Two plants from each net plot were dug out. The pit of 60 cm length, 60 cm breadth and 60 cm depth was dug out carefully. The block of soil with roots was gently washed to remove the soil from roots. The depth of tap root and maximum spread was taken immediately.

13:2:11 Soil moisture studies :

The soil moisture percentage were determined in all the treatment plots including " no irrigation " treatment plots at 24 hours before and 48 hours after each irrigation.

13:2:12 Plant population at harvest :

At harvest all the plants from net plot were counted and the plant population per hectare was calculated for each treatment plot.

13:3 Post harvest observations :

13:3:1 Weight of head alongwith seeds per plant :

The ten observation plats were used for recording the weight of head along with seed per plant.

13:3:2 Weight of grains per head :

The heads used in 13:3:2 were threshed and weights of clean seeds were recorded. The mean of ten plants were recorded as weight of seed per head i.e. plant.

13:3:3 Weight of reproductive plant parts other than grains per head :

The mean weight of seed per plant was deducted from the mean weight of head along with seed per plant to get weight of reproductive plant parts other than seed.

13:3:4 Dry weight of stalks per plant :

The ten observation plants were taken for recording the dry weight of stalk per plant.

13:3:5 Thousand grain weight :

Thousand grains from representative sample of produce in each net plot was taken and weighed to get thousand grain weight.

13:3:6 Number of filled, unfilled and total number of grains per head :

Five plants were selected at random from the observation plants in each treatment and number of filled, unfilled and total number of grains per head were counted. The mean of five observation was recorded as number of filled, unfilled and total number of grains per head.

13:4 Yield data :

13:4:1 Weight of heads per net plot :

The heads from each net plot were dried in sun for seven days and weighed to get weight of head per net plot.

13:4:2 Weight of grains per net plot :

The heads in 13:4:1 were threshed and clean grains were weighed as grain weight per net plot.

13:4:3 Weight of straw per net plot :

The stalks from net plot were cut with sickle from ground level and kept for sundrying for ten days and the heads remained after threshing were included and the dry weight was taken as weight of straw per net plot.

13:4:4 Total grain and straw yield per hectare :

The grain and straw yield from each net plot was multiplied by a factor to get the total grain and straw yield per hectare.

13:4:5 Grain to straw ratio :

The ratio of grain to straw was calculated by dividing the weight of straw by weight of grain on unit area basis.

14 Growth analysis :

In respect of growth analysis, the absolute growth rate (AGR) and relative growth rate (RGR) of dry matter per plant per week were calculated.

14:1 Absolute growth rate (AGR) :

The absolute growth rate of height and total dry matter per plant, per week were computed as per the following formulae :

$$\text{AGR for height} = \frac{H_2 - H_1}{t_2 - t_1}$$

$$\text{AGR for dry matter} = \frac{W_2 - W_1}{t_2 - t_1}$$

Where H_1, H_2 and W_1, W_2 refer to the height per plant and dry matter per plant at times t_1 and t_2 respectively.

14:2 Relative Growth Rate (RGR) :

The relative growth rate at which a plant incorporate new material into its substances is measured and expressed mathematically by the following formulae :

$$RGR = \frac{\log_e W_2 - \log_e W_1}{t_2 - t_1}$$

W_1 and W_2 are total dry matter per plant at times t_1 and t_2 respectively.

15 Chemical analysis :

15:1 Soil analysis per total nitrogen at harvest :

The soil samples from each net treatment plot were taken for analysis. The depth of sampling was 30 cm. The total nitrogen in soil from each treatment plot was estimated, after the harvest of sunflower crop. The nitrogen estimation was carried out by the modified Kjeldahl's method (A.O.A.C. 1958).

15:2 Plant analysis per nitrogen percentage :

The samples taken for dry matter study were used to determine the nitrogen percentage in component parts of the plant viz., stem, leaves, heads, seeds.

15:3 Protein percentage in seed :

The crude protein percentage in grain was computed from the seed samples used for nitrogen percentage determination. The percent nitrogen was multiplied by 6.25 to get protein percentage in seeds.

15:4 Oil percentage in seed :

The seed samples from net plot were used and oil percentage was determined by Soxhlet's ether extraction method (Piper, 1950).

16. Statistical analysis and interpretation of data :

The statistical analysis of the data was done by the standard method known as " Analysis of Variance ". Standard error of means were worked out. Wherever the results were significant, critical differences (C.D.) at 5 per cent level were worked out. The data were suitably illustrated with graphs and figures wherever necessary.

CHAPTER IV

[illegible]

CHAPTER IV

EXPERIMENTAL RESULTS

The present investigation was carried out during kharif season of 1973 at Central Campus, Mahatma Phule Krishi Vidyapeeth Farm, Mahuri. The results obtained are described in this chapter.

1. Number of irrigations and irrigation interval between successive irrigations etc.:

The data regarding the cumulative evaporation values, the number of irrigations and interval between successive irrigations alongwith irrigation treatments are presented in Table 7.

Table 2 : Evaporation values, number of irrigations (excluding first common irrigation) and interval between successive irrigations as affected by irrigation treatments.

Treatments	Evaporation	Number of irrigations	Interval between successive irrigation			
			A	B	C	D
*0	-	-	-	-	-	-
0.3 WUF	106.10	2	25	71	-	-
0.6 WUF	53.05	4	14	15	30	28

A = Sowing to first irrigation.

B = First to second irrigation.

C = Second to third irrigation.

D = Third to fourth irrigation.

The data in Table 7 indicate that the number of irrigations were 2 and 4 as per 0.3 WUF and 0.6 WUF schedule

respectively. The evaporation values (i.e. cumulative evaporation values) were 106.10 and 53.05 cm. for 0.3 WUF and 0.6 WUF schedule respectively.

2. Soil moisture studies :

The data regarding the soil moisture studies are tabulated in Table 8. The soil moisture percentages were determined in all the treatment plots including, ' no irrigation ' treatment plots at 24 hours before and 48 hours after each irrigation. The data on soil moisture studies were not statistically analysed. It should be noted that one common irrigation was given just immediate after sowing to all treatment plots.

2:1 0.3 WUF schedule :

Data in Table 8 indicate that the soil moisture percentages, when determined 24 hours before irrigation, were equivalent to 50 per cent available soil moisture at all irrigation dates. It can also be observed that the soil moisture percentages, at all irrigation dates in ' no irrigation ' treatment was about the same, while in 0.6 WUF treatment plot, it was observed to be much above 50 per cent available soil moisture.

2:2 0.6 WUF schedule :

When irrigation were scheduled to 0.6 WUF plots, it was observed that at first irrigation date, the soil moisture percentage at 24 hours before irrigation were about equivalent to 50 per cent available soil moisture in all treatment plots.

Table 8 : Soil moisture percentages at various soil depths (24 hours) before and (48 hours) after irrigations as affected by different irrigation schedules.

Soil moisture percentage in treatments of	Depth of soil (cm)	At sowing	Irrigations as per 0.3 WUF treatment schedule				Irrigations as per 0.6 WUF treatment schedule								At harvest
			I		II		I		II		III		IV		
			B	A	B	A	B	A	B	A	B	A	B	A	
I_0		Immediately after sowing a common irrigation to all treatment plots including 'no irrigation' treatment plots was given	(25)*		(96)*		(14)*		(29)*		(59)*		(87)*		(111)
	0-30		30.48	30.11	31.48	30.49	33.33	32.85	30.11	29.04	32.95	39.77	32.91	32.42	27.44
	30-45		34.05	33.83	34.93	34.36	34.85	34.75	33.83	33.06	35.94	39.77	36.24	35.62	32.34
0.3 WUF															
	0-30		29.96	39.53	30.88	37.62	32.59	32.28	39.53	38.25	33.10	39.77	32.64	32.01	34.80
	30-45		33.22	39.85	35.07	38.41	34.12	34.03	39.85	38.79	36.36	39.72	36.33	35.71	36.85
0.6 WUF															
	0-30		35.24	34.74	35.38	34.76	33.01	38.76	34.74	39.68	32.71	39.77	32.95	38.28	32.09
	30-45		36.53	35.37	37.22	36.61	34.23	39.56	36.31	39.65	36.30	39.77	36.77	39.35	34.05

B = Before irrigation. A = After irrigation.

* Figures in paranthesis indicates the days after sowing for each irrigation.

At second irrigation, the soil moisture percentage 24 hours before said irrigation were slightly below field capacity in 0.6 WUF treatment plots, while at about 50 per cent available soil moisture in " no irrigation " and at field capacity in 0.3 WUF treatment plots. The soil moisture percentages 24 hours before third irrigation and fourth irrigation were about the same in all the treatment plots i.e. ' no irrigation ', 0.3 WUF and 0.6 WUF treatment plots. When soil moisture percentages were determined 48 hours after irrigation, it was observed that these were at field capacity in 0.6 WUF treatment plots. In 0.3 WUF treatment plots, the soil moisture percentages were about equivalent to 50 per cent available soil moisture at first and fourth irrigation. While it was at field capacity after second and third irrigation. The reason is that the first irrigation to 0.3 WUF treatment plots was given just one day before the second irrigation to 0.6 WUF treatment plots and also after third irrigation there was immediately, a receipt of rainfall. The soil moisture percentages in " no irrigation " treatment plots was about equivalent to 50 per cent available soil moisture at all irrigation dates except after third irrigation, when it was at field capacity due to receipt of rainfall.

3. Plant population :

Data pertaining to the plant population at harvesting is given in Table 9. Data reveal that the differences in the plant population due to various treatments were not significant.

Table 9 : Plant population per hectare as affected by different treatments at harvesting.

Theoretical plant population is 55555 / ha.

Treatments	Plant populations/ha (observed)	Actual plant population (percent of theoretial plant population)
Irrigation schedules		
0.3 IW/CPE	52255	94.05
0.6 IW/CPE	51635	92.94
'F' test	N.S.	-
S.E. ±	332	-
C.D. at 5 %	-	-
'No irrigation' Vs. irrigation		
I_0	51214	92.18
I	51958	93.52
'F' test	N.S.	-
S.E. ±	667	-
C.D. at 5 %	-	-
Nitrogen levels, kg/ha		
N_{25}	51536	92.76
N_{50}	51958	93.52
N_{75}	52454	94.43
N_{100}	51858	93.34
'F' test	N.S.	-
S.E. ±	471	-
C.D. at 5 %	-	-
Nitrogen levels without irrigation		
N_{25}	50668	91.20
N_{50}	51743	93.13
'F' test	N.S.	-
S.E. ±	667	-
C.D. at 5 %	-	-
Interaction (I x N)		
'F' test	N.S.	-
S.E. ±	667	-
C.D. at 5 %	-	-
General Mean	51727.0	-

Sig = Significant. N.S. = Non significant

Actual plant population varied from 91.20 per cent to 94.43 per cent of theoretical plant population.

4. Growth studies :

4.1 Plant height :

Data informating the plant height as affected periodically by various treatments are presented in Table 10 and graphically shown in Fig. 2.

The growth and vigour of the plant can be expressed by its height. The mean maximum plant height was observed to be 153.00 cm at harvesting. The height was increased rapidly from 32 days upto 74 days after sowing and thereafter the magnitude of increase in plant height was not markedly.

Effect of irrigation schedule :

The data on mean plant height given in Table 10 indicate that it was affected significantly at only 46 and 60 days after sowing. The plant height in 0.6 WUF treatment plot was slightly higher than that in 0.3 WUF treatment plot at 46 and 60 days after sowing. Difference in plant height at harvest (111 days) was not significant.

Effect of ' no irrigation ' Vs. irrigation :

It was seen from the data in Table 10 that the plant height was significantly increased due to irrigation treatment over ' no irrigation ' treatment at all the stages of crop growth except at 32 days after sowing.

Effect of nitrogen :

In general, plant height increased significantly with the increase in nitrogen dose. Difference in plant height due

FIG.2

MEAN PLANT HEIGHT (CM)/PLANT AS AFFECTED BY DIFFERENT TREATMENTS

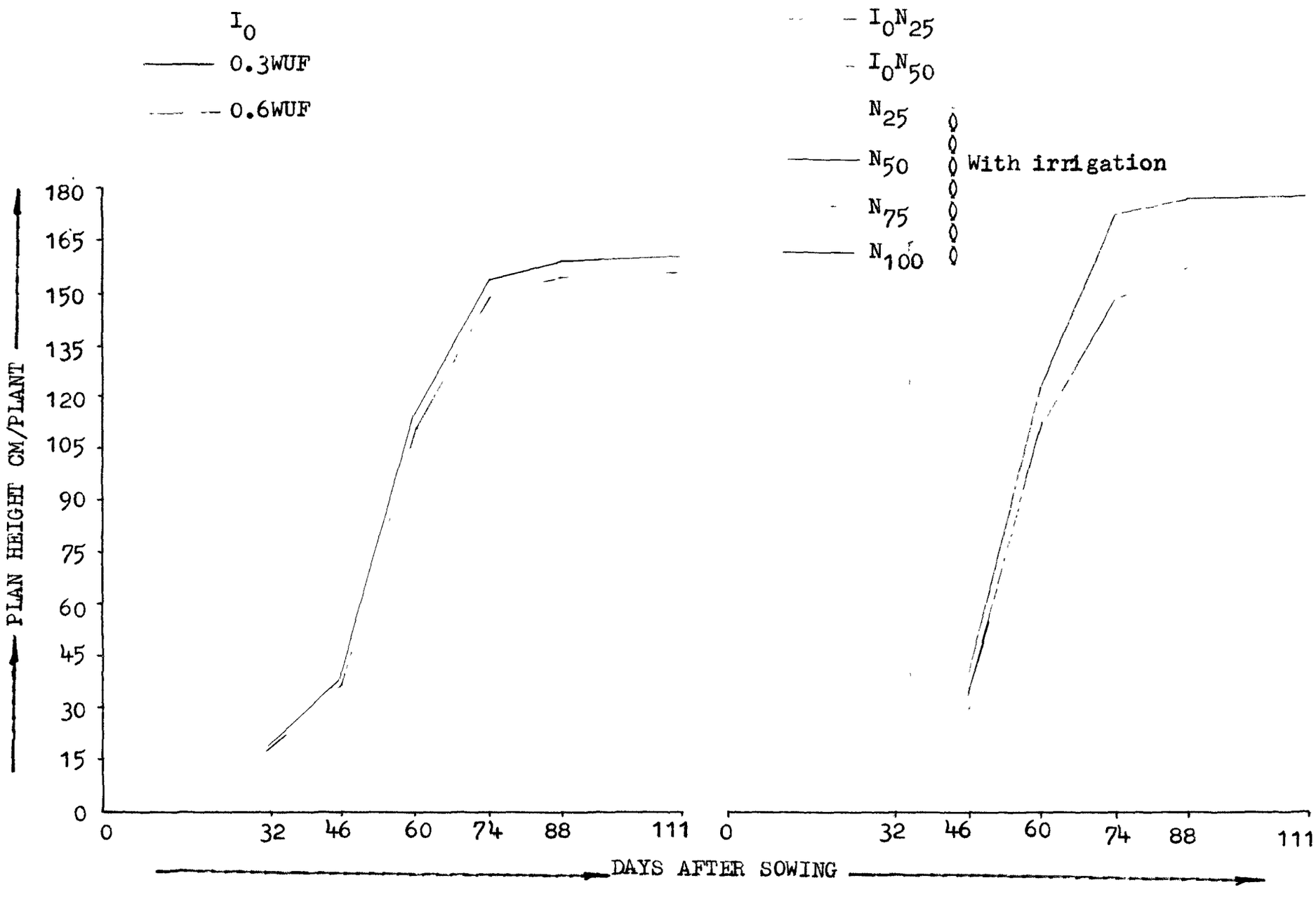


Table 10 : Mean plant height (in cm) as affected periodically by different treatments.

Treatments	Days after sowing					
	32	46	60	74	88	111
Irrigation schedules						
0.3 IW/CPE	17.10	35.36	111.80	148.37	154.82	155.04
0.6 IW/CPE	18.09	36.90	115.66	153.85	160.79	160.89
'F' test	N.S.	Sig.	Sig.	N.S.	N.S.	N.S.
S.E. ±	1.04	0.50	0.52	1.90	2.25	2.29
C.D. at 5 %	-	1.49	1.55	-	-	-
'No irrigation' Vs. irrigation						
I0	16.08	31.65	102.65	135.85	140.40	141.51
I	17.59	36.13	113.73	151.11	157.60	157.96
'F' test	N.S.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	2.09	1.00	1.04	3.81	4.50	4.58
C.D. at 5 %	-	1.67	1.73	6.32	7.47	7.61
Levels of nitrogen kg/ha						
N25	16.25	32.85	106.10	130.73	134.60	134.40
N50	17.15	35.15	112.80	148.91	156.08	156.90
N75	17.91	36.53	118.75	157.18	163.95	163.99
N100	19.06	40.00	123.27	167.63	176.37	176.56
'F' test	N.S.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	1.48	0.71	0.74	2.69	3.18	3.25
C.D. at 5 %	-	2.11	2.19	8.00	9.40	9.63
Nitrogen levels without irrigation :						
N25	15.30	29.50	97.80	128.93	133.70	134.80
N50	16.86	33.80	107.50	142.76	147.10	147.95
'F' test	N.S.	Sig.	Sig.	Sig.	Sig.	N.S.
S.E. ±	2.09	1.00	1.04	3.81	4.50	4.58
C.D. at 5 %	-	2.99	3.10	11.31	13.30	-
Interactions (I x N)						
'F' test	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.E. ±	2.09	1.00	1.04	3.80	4.50	4.58
C.D. at 5 %	-	-	-	-	-	-
General Mean	17.13	34.78	110.40	146.53	152.56	153.00

Sig. = Significant. N.S. = Non significant.

to I_{50} and I_{75} however were not significant at 46, 88 and 111 days after sowing. Similarly differences in plant height due to levels of nitrogen were not significant at 32 days after sowing.

Effect of nitrogen without irrigation :

It was observed that the application of 50 kg nitrogen per hectare without irrigation increased plant height significantly over 25 kg nitrogen application per hectare at all stages except at 32 and 46 days, when they were at par.

Effect of interaction :

The effects of interaction between irrigation and nitrogen were not found to be significant at all stages of crop growth.

4.2 Absolute Growth Rate (AGR) :

With view to get idea about the absolute growth rate of height, the data for the same is given in Table 11. The mean maximum AGR of the height was at 46 to 60 days after sowing. Values of AGR at 0 to 32 days was only 3.74 and it was increased with the advance in age of crop. These values were 8.86, 37.79, 18.07, 3.00 and 0.137 cm per plant per week during period between 32 to 46, 46 to 60, 74 to 88 and 88 to 111 days after sowing respectively.

Effect of irrigation schedules :

The AGR values were not affected considerably by the different irrigation schedules at various growth stages of crop. The mean maximum value of AGR was observed during 46 to 60 days after sowing.

Table 11 : Mean absolute growth rate (AGR) height (cm) per plant per week during different growth periods as affected by different treatments.

Treatments	Days after sowing					
	: 0-32	: 32-46	: 46-60	: 60-74	: 74-88	: 88-111
Irrigation schedules						
0.3 WUE	3.74	9.13	38.22	18.28	3.22	0.0669
0.6 WUE	3.95	9.40	39.38	19.09	3.47	0.0304
No irrigation Vs. irrigation						
I_0	3.51	7.78	35.50	16.60	2.27	0.3560
I	3.84	9.27	38.62	18.87	3.24	0.1095
Levels of nitrogen kg/ha						
N_{25}	3.55	8.30	33.62	15.31	1.63	0.1217
N_{50}	3.75	9.00	38.82	18.05	3.98	0.0060
N_{75}	3.92	9.71	41.11	19.21	3.38	0.0121
N_{100}	4.16	10.47	41.63	22.18	4.34	0.0760
Nitrogen levels without irrigation						
N_{25}	3.34	7.10	34.15	15.56	2.38	0.3340
N_{50}	3.68	8.47	36.85	17.63	2.17	0.2580
General Mean	3.74	8.86	37.79	18.07	3.00	0.1370

Effect of 'no irrigation' Vs. irrigation :

The data regarding AGR values in Table 11 revealed that irrigation treatment has given higher AGR values than "No irrigation" treatment.

Effect of nitrogen :

It was observed that the AGR or plant height was increased at all stages of crop growth with increasing the levels of nitrogen. The difference in the AGR value due to N_{25} and N_{50} per hectare were considerably higher.

Effect of nitrogen without irrigation :

There was no much more difference in the AGR value due to levels of nitrogen without irrigation.

4:3 Spread of plant :

Data regarding the mean spread of plant as affected periodically by different treatments are presented in Table 12. It was observed that mean minimum spread of plant was only 12.07 cm at 32 days, however it was increased gradually and attained mean maximum spread of 69.40 cm at 88 days after sowing.

Effect of irrigation schedules :

It would be observed from the data given in Table 12, that the spread of plant was not affected significantly by irrigation schedules at all stages of crop growth.

Effect of 'no irrigation', Vs. irrigation :

Data in Table 12, revealed that the mean spread of plant was significantly increased due to irrigation over "no irrigation" at all stages of crop growth.

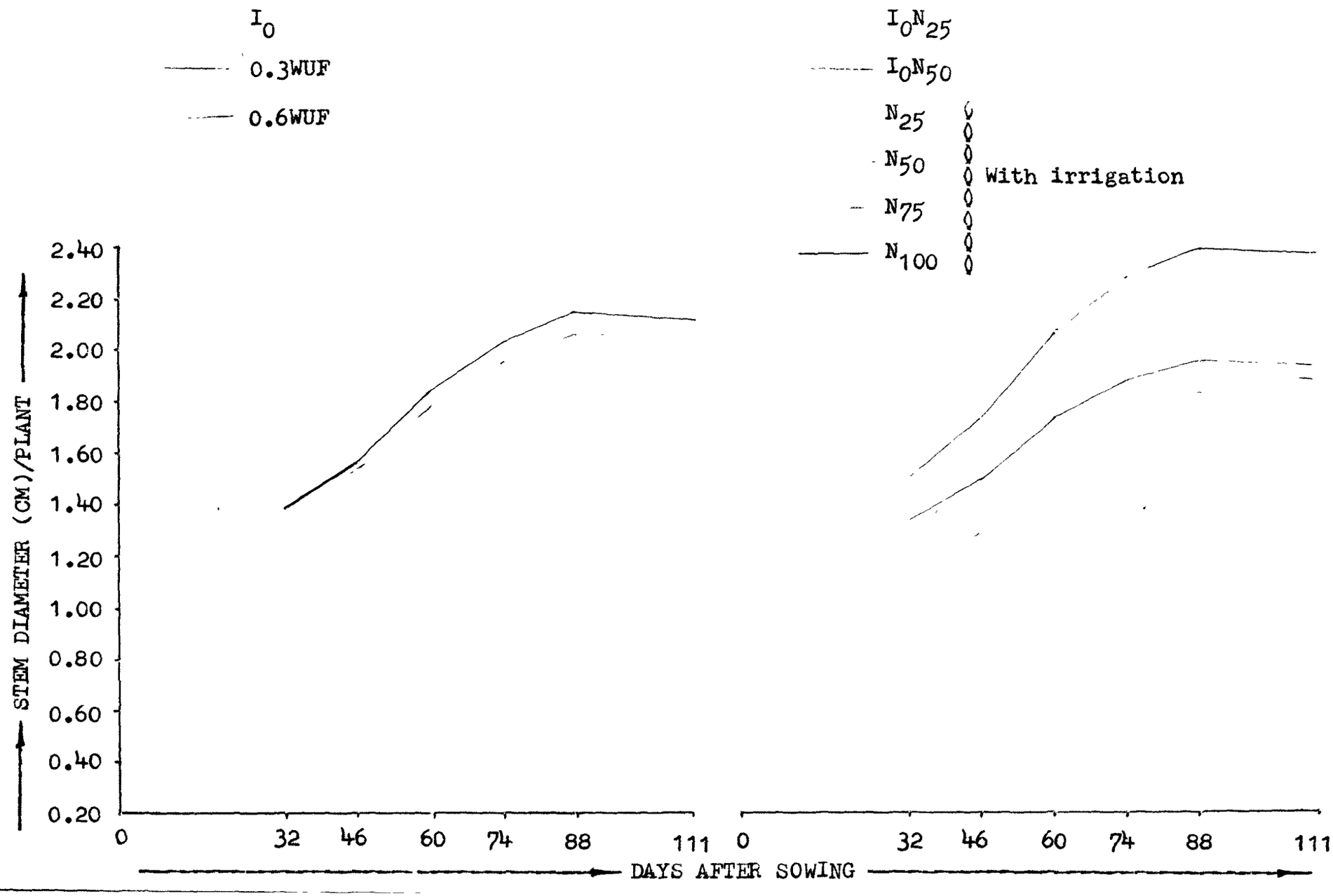
Table 12 : Mean spread of plant (cm) as affected periodically by different treatments.

Treatments	Days after sowing				
	: 32	: 46	: 60	: 74	: 88
Irrigation schedules					
0.3 IW/CPE	12.05	42.95	61.77	69.82	70.85
0.6 IW/CPE	12.45	44.01	62.67	72.06	73.12
'F' test	N.S.	N.S.	N.S.	N.S.	N.S.
S.E. ±	0.18	0.48	0.71	0.82	0.81
C.D. at 5 %	-	-	-	-	-
'I$_0$ irrigation' Vs. irrigation					
I	11.31	39.03	54.05	62.45	63.60
I$_0$	12.46	43.46	62.72	70.94	71.98
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.37	0.97	1.42	1.64	1.63
C.D. at 5 %	0.63	1.62	2.35	2.73	2.72
Levels of nitrogen, kg/ha					
N$_{25}$	11.45	38.83	55.55	64.35	65.66
N$_{50}$	12.16	43.13	60.76	68.48	69.81
N$_{75}$	13.07	45.08	65.20	72.46	73.50
N$_{100}$	13.16	46.90	69.36	78.48	78.96
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.26	0.68	1.00	1.16	1.15
C.D. at 5 %	0.79	2.04	2.98	3.45	3.44
Nitrogen levels without irrigation					
N$_{25}$	10.80	36.16	50.53	58.76	59.70
N$_{50}$	11.83	41.90	57.53	66.13	66.90
'F' test	N.S.	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.37	0.97	1.42	1.64	1.63
C.D. at 5 %	-	2.89	4.22	4.89	4.86
Interaction (I x N)					
'F' test	N.S.	N.S.	N.S.	N.S.	N.S.
S.E. ±	0.37	0.97	1.42	1.64	1.63
C.D. at 5 %	-	-	-	-	-
General Mean	12.07	42.14	60.11	68.39	69.40

Sig. = Significant. N.S. = Non significant.

FIG.3

MEAN STEM DIAMETER OF PLANT (CM) AS AFFECTED BY DIFFERENT TREATMENTS



Effect of nitrogen :

Data in the Table 12 shows that in general, plant spread increased significantly with the increase in nitrogen dose at all stages of crop growth.

Effect of nitrogen without irrigation :

The mean plant spread was found to be not affected significantly at 32 days due to the application of nitrogen without irrigation. Thereafter, at all stages of crop growth, the plant spread was significantly higher due to 50 kg nitrogen application over 25 kg nitrogen application per hectare without irrigation.

Effect of interaction :

The mean plant spread was not significantly affected at all stages of crop growth due to interaction between irrigation and nitrogen.

4.4 Stem diameter :

Data pertaining to the mean stem diameter (cm) as affected periodically by different treatments are presented in Table 13 and graphically dipicted in Fig. 3.

It was observed that mean stem diameter affected significantly due to all treatments under study at one or other crop growth stages. The mean maximum stem diameter was 2.025 cm at 88 days after sowing and it was declined at 111 days i.e. at harvesting.

Effect of irrigation schedules :

The stem diameter per plant was not significantly affected at 32, 46 and 60 days after sowing due to irrigation

Table 13 : Mean stem diameter of plant (cm.) as affected periodically by different treatments.

Treatments	Days after sowing					
	32	46	60	74	88	111
Irrigation schedules						
0.3 IW/CPE	1.355	1.545	1.781	1.950	2.052	2.022
0.6 IW/CPE	1.372	1.551	1.837	2.020	2.134	2.105
'F' test	N.S.	N.S.	N.S.	Sig.	Sig.	Sig.
S.E. ±	0.023	0.024	0.021	0.019	0.021	0.0211
C.D. at 5 %	-	-	-	0.059	0.062	0.062
No irrigation Vs. irrigation						
I_0	1.191	1.356	1.591	1.761	1.868	1.831
I	1.363	1.548	1.809	1.985	2.093	2.063
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.047	0.048	0.043	0.039	0.042	0.042
C.D. at 5 %	0.079	0.080	0.072	0.066	0.070	0.086
Levels of nitrogen, kg/ha						
N_{25}	1.200	1.355	1.575	1.751	1.876	1.831
N50	1.316	1.495	1.715	1.865	1.948	1.921
N75	1.445	1.620	1.890	2.061	2.181	2.150
N100	1.493	1.723	2.058	2.265	2.385	2.351
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.033	0.034	0.030	0.028	0.029	0.029
C.D. at 5 %	0.099	0.101	0.091	0.083	0.088	0.088
Nitrogen levels without irrigation						
N25	1.140	1.286	1.513	1.713	1.830	1.786
N50	1.243	1.426	1.670	1.810	1.906	1.876
'F' test	N.S.	N.S.	Sig.	N.S.	N.S.	N.S.
S.E. ±	0.047	0.048	0.043	0.039	0.042	0.042
C.D. at 5 %	-	-	0.129	-	-	-
Interaction (I x N)						
'F' test	N.S.	N.S.	N.S.	N.S.	Sig.	Sig.
S.E. ±	0.047	0.048	0.043	0.039	0.042	0.042
C.D. at 5 %	-	-	-	-	0.125	0.125
General Mean	1.312	1.490	1.743	1.918	2.025	1.994

Sig. = Significant. N.S. = Non significant.

schedules. Thereafter, the 0.6 IW schedule increased the stem diameter significantly over the 0.3 IW schedule. The increase in the stem diameter due to 0.6 IW schedule was 0.7 mm, 0.8 mm and 0.8 mm over 0.3 IW schedule at 74, 88 and 111 days respectively.

Effect of 'no irrigation' Vs. irrigation :

The difference in the stem diameter was found to be significantly higher due to irrigation over "no irrigation" treatment at all crop growth stages. The increase in stem diameter due to irrigation application were, 1.8, 1.9, 2.1, 2.2, 2.2, and 2.3 mm over "no irrigation" treatment at 32, 46, 60, 74, 88 and 111 days respectively.

Effect of nitrogen :

The data in Table 13 revealed that the stem diameter was found to be increased significantly with increasing levels of nitrogen at all stages of crop growth.

Effect of nitrogen without irrigation :

Data from the Table 13, indicate that the application of nitrogen without irrigation resulted into increased stem diameter at all stages, but the difference was only significant of 60 days due to 50 kg nitrogen over 25 kg nitrogen application per hectare without irrigation.

Effect of interaction :

Data in Table 13, indicate that the interaction effects between irrigation and nitrogen were found to be significant in affecting the stem diameter at only 88 and 111 days after sowing. The relevant data is given in Table 14 and Table 15 respectively.

Table 14 : Mean stem diameter per plant (cm) as affected by interaction between irrigation and nitrogen at 88 days after sowing.

Irrigation	Nitrogen				
	N_{25}	N_{50}	N_{75}	N_{100}	Mean
0.3 WUF	1.846	1.943	2.046	2.373	2.052
0.6 WUF	1.870	1.953	2.316	2.396	2.134
Mean	1.858	1.948	2.181	2.385	2.093

'F' test = Sig. S.E. ± = 0.042 C.D. at 5 % = 0.125.

It is seen from Table 14 that in general, at each of irrigation treatment viz., 0.3 WUF and 0.6 WUF, the stem diameter increased. Similarly at each nitrogen level, 0.6 WUF increased the stem diameter at 88 days after sowing as compared to that at 0.3 WUF treatment. Stem diameter at 88 days after sowing in treatment of 0.6 WUF combined with 75 to 100 kg nitrogen per hectare and 0.3 WUF combined with 100 kg nitrogen per hectare was significantly higher than that in all other treatment combinations.

Table 15 : Mean stem diameter per plant (cm) as affected by interaction between irrigation and nitrogen at 111 days after sowing.

Irrigation	Nitrogen				
	N_{25}	N_{50}	N_{75}	N_{100}	Mean
0.3 WUF	1.806	1.903	2.016	2.363	2.022
0.6 WUF	1.856	1.940	2.280	2.340	2.105
Mean	1.831	1.921	2.150	2.351	

'F' test = Sig. S.E. ± = 0.042, C.D. at 5 % = 0.125.

Similar trend as in case of stem diameter at 88 days after sowing was observed in case of the stem diameter at 111 days after sowing (Table 15).

4.5 Number of functional leaves per plant :

The data in respect of mean number of functional leaves per plant as affected periodically by different treatments are given in Table 16. The mean maximum number of functional leaves per plant were 22.66 at 74 days after sowing.

Effect of irrigation schedules :

The data in Table 16 revealed that mean number of functional leaves were found to be increased significantly at only 46 and 60 days after sowing.

Effect of "no irrigation" Vs. irrigation :

It could be observed from the data given in Table 16 that application of irrigation resulted into increased mean number of functional leaves per plant over "no irrigation" treatment.

Effect of nitrogen :

In general, increasing the level of nitrogen application found to be significantly effective in increasing the functional leaves per plant at all crop growth stages except at 111 days after sowing. However, at 32 and 88 days after sowing, the levels of 50 and 75 kg nitrogen per hectare were at par.

Effect of nitrogen without irrigation :

It is seen from data given in Table 16 that 50 kg nitrogen application per hectare was significantly effective in

Table 16 : Mean number of functional leaves per plant as affected periodically by different treatments.

Treatments	Days after sowing					
	32	46	60	74	88	111
Irrigation schedules						
0.3 IW/CPE	8.52	15.98	21.64	22.95	21.77	11.04
0.6 IW/CPE	8.89	16.78	22.59	23.71	22.17	11.96
'F' test	N.S.	Sig.	Sig.	N.S.	N.S.	N.S.
S.E. ±	0.14	0.24	0.22	0.26	0.18	0.41
C.D. at 5 %	-	0.74	0.67	-	-	-
No irrigation Vs. irrigation						
I_0	7.53	14.23	19.51	21.11	20.68	10.65
I_1	8.70	16.38	22.11	23.36	21.90	11.50
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	N.S.
S.E. ±	0.28	0.49	0.45	0.53	0.37	0.83
C.D. at 5 %	0.48	0.82	0.75	0.89	0.62	-
Levels of nitrogen, kg/ha						
N25	7.75	14.30	19.56	21.16	20.08	11.30
N50	8.43	15.75	21.32	22.71	21.68	11.26
N75	8.86	16.86	22.55	24.06	22.45	11.20
N100	9.78	18.61	25.03	25.38	23.68	12.25
'F' test	Sig.	Sig.	Sig.	Sig.	Sig	N.S.
S.E. ±	0.20	0.35	0.32	0.37	0.26	0.59
C.D. at 5 %	0.60	1.04	0.94	1.12	0.79	-
Nitrogen levels without irrigation						
N25	7.40	13.80	18.60	20.50	20.13	10.63
N50	7.66	14.66	20.43	21.70	21.23	10.66
'F' test	N.S.	N.S.	Sig.	N.S.	N.S.	N.S.
S.E. ±	0.28	0.49	0.45	0.53	0.37	0.83
C.D. at 5 %	-	-	1.34	-	-	-
Interaction (I x N)						
'F' test	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
S.E. ±	0.28	0.49	0.45	0.53	0.37	0.83
C.D. at 5 %	-	-	-	-	-	-
General Mean	8.35	15.73	21.33	22.66	21.57	10.24

Sig. = Significant. N.S. = Non significant.

increasing the functional leaf number per plant at only 60 days after sowing. However before, and following 60 days, the nitrogen levels were ineffective in increasing the functional leaf number per plant.

Effect of interaction :

Interaction effects between irrigation and nitrogen were found to be absent.

4:6 Leaf area per plant :

Data with information on mean leaf area per plant as affected periodically by different treatments are presented in Table 17 and graphically shown in Fig. 4.

Data revealed that sunflower plant attained maximum leaf area of 36.899 sq. dm at 74 days after sowing, while it hardly produced 12.344 sq dm leaf area up to 32 days. Following 74 days of peak period of leaf area per plant, there was gradual decrease in leaf area and it was 17.844 sq dm per plant at harvesting.

Effect of irrigation schedules :

Mean leaf area per plant was significantly increased due to 0.6 WUR schedule over 0.3 WUR schedule at all crop growth stages except at 32 days after sowing, when difference was not significant.

Effect of 'no irrigation' Vs. irrigation :

It was observed that irrigation application resulted in increased leaf area significantly over "no irrigation" treatment. The mean maximum values were 40.30 sq dm and

MEAN LEAF AREA (SQ DM) PER PLANT AS AFFECTED BY DIFFERENT TREATMENTS

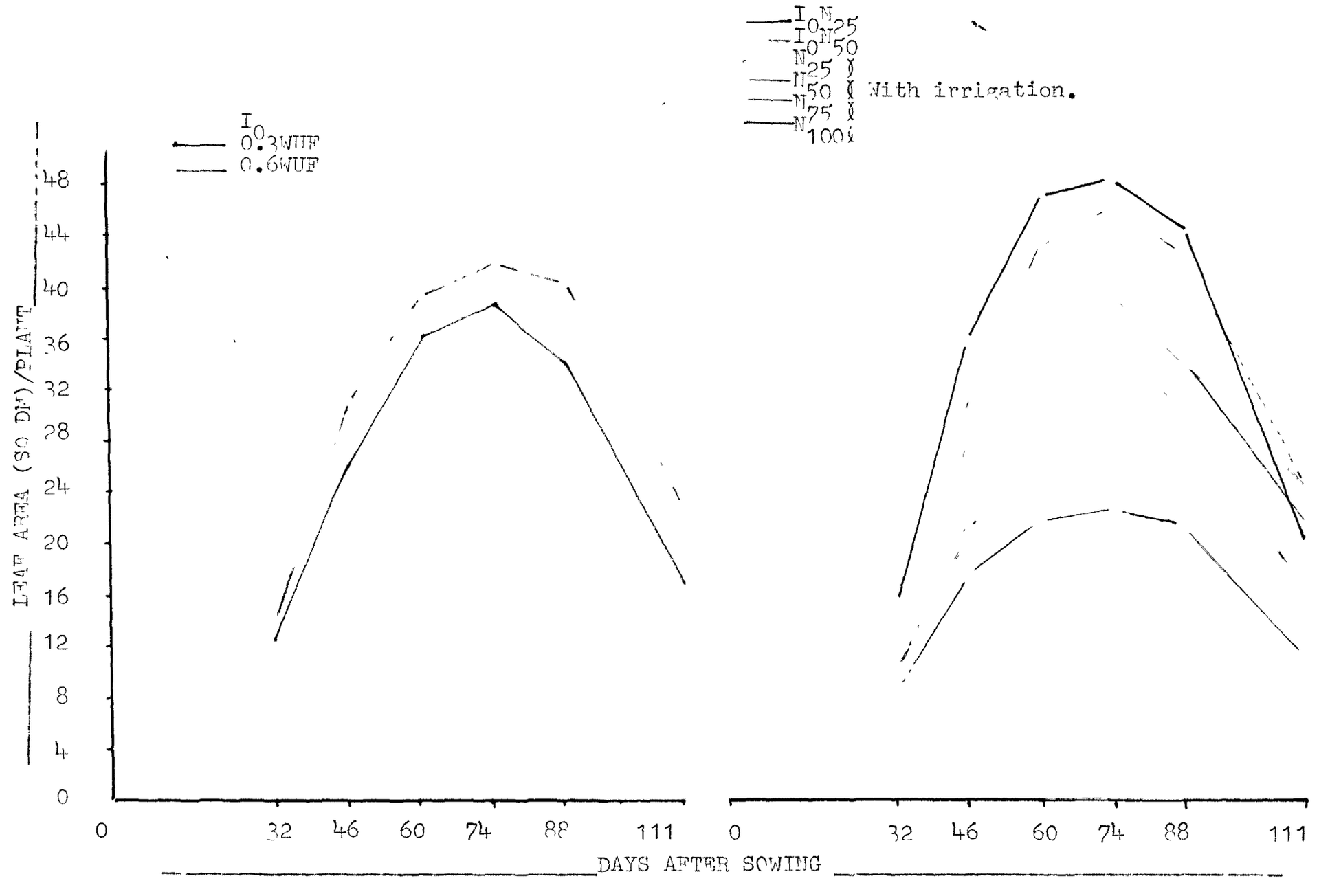


Table 12 : Mean leaf area (sq dm) per plant as affected periodically by different treatments.

Treatments	Days after sowing					
	32	46	60	74	88	111
Irrigation schedules						
0.3 IW/F	12.733	26.777	36.926	38.737	34.143	17.619
0.6 IW/F	14.009	31.766	39.369	41.871	40.545	23.125
'F' test	N.S.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.905	0.475	0.615	0.795	0.703	0.424
C.D. at 5 %	-	1.411	1.828	2.363	2.088	1.258
No irrigation Vs. irrigation						
No	9.948	19.177	28.093	28.950	26.105	11.939
I	13.371	29.272	38.148	40.300	36.593	20.377
'F' test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	1.810	0.950	1.251	1.590	1.406	0.847
C.D. at 5 %	3.006	1.578	2.045	2.642	2.335	1.407
Levels of nitrogen, kg/ha						
N25	10.856	21.419	24.670	27.701	25.474	15.777
N50	12.497	27.778	36.975	39.131	33.945	21.393
N75	14.584	31.869	43.635	46.056	42.677	24.336
N100	15.544	36.022	47.312	48.327	44.278	20.002
'F' test	N.S.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	1.280	0.672	0.870	1.125	0.994	0.599
C.D. at 5 %	-	1.996	2.586	3.342	2.954	1.779
Nitrogen levels without irrigation						
N25	9.265	17.729	21.956	22.782	21.584	11.521
N50	10.632	20.625	34.231	35.135	30.622	12.356
'F' test	N.S.	Sig.	Sig.	Sig.	Sig.	Sig.
S.E. ±	1.810	0.950	1.231	1.590	1.406	0.847
C.D. at 5 %	-	2.823	3.657	4.725	4.177	2.517
Interaction (I x ...						
'F' test	N.S.	N.S.	N.S.	N.S.	Sig.	Sig.
S.E. ±	1.810	0.950	1.231	1.590	1.406	0.847
C.D. at 5 %	-	-	-	-	4.177	2.517
General Mean	12.344	26.243	35.131	36.899	33.597	17.844

Sig. = Significant. N.S. = Non significant.

28.958 sq dm at 74 days after sowing in irrigation treatment and "no irrigation" treatment respectively.

Effect of nitrogen :

It was observed that the increasing level of nitrogen were significantly effective in increasing leaf area per plant at all stages of crop growth except at 32 days, when they were not significant.

Effect of nitrogen without irrigation :

From data given in Table 17, it would be seen that the application of 50 kg nitrogen per hectare without irrigation gave significantly higher leaf area per plant over 25 kg nitrogen application per hectare without irrigation.

Effect of interaction :

The interaction effects between irrigation and nitrogen levels were significant at 88 and 111 days after sowing. The data are given in Table 18 and 19 respectively.

Table 18 : Mean leaf area (sq dm.) per plant as affected by interaction between irrigation and nitrogen at 88 days after sowing.

Irrigation	Nitrogen				
	N_{25}	N_{50}	N_{75}	N_{100}	Mean
0.3 IW/CPE	23.125	31.654	40.758	41.034	34.142
0.6 IW/CPE	27.823	36.236	33.597	47.521	39.045
Mean	25.474	33.945	42.677	44.777	-

'F' test = Sig. C.D. ± = 1.406 C.D. at 5 % = 4.177

It is seen from the Table 18 that leaf area increased with the increase in level of nitrogen at each WUF treatment. Similarly, at each level of nitrogen, leaf area increased in 0.6 WUF as compared to that in 0.3 WUF. Irrigation scheduled as per 0.6 WUF combined with 100 kg nitrogen per hectare increased the leaf area significantly as compared to all other treatment combinations except treatment combination of 0.6 WUF and 75 kg nitrogen per hectare.

It can be observed from the Table 19 that, at harvest, leaf area per plant in 0.3 WUF treatment as well as in 0.6 WUF treatment increased with the increase in level of nitrogen up to 75 kg per hectare only. At each nitrogen level, 0.6 WUF treatment increased the leaf area per plant as compared to 0.3 WUF treatment.

Table 19 : Mean leaf area (sq dm) per plant as affected by interaction between irrigation and nitrogen at harvest i.e. 111 days after sowing.

Irrigation	Nitrogen				
	N_{25}	N_{50}	N_{75}	N_{100}	Mean
0.3 WUF	13.701	17.521	20.821	18.472	17.628
0.6 WUF	17.852	25.265	27.852	21.532	23.125
Mean	15.776	21.393	24.336	20.002	-

't' test = Sig. S.E. ± = 0.847 C.D. at 5 % = 2.517

It is seen from the data given in Table 19 that the treatment combinations of 0.6 WUF with 50 and 75 kg nitrogen per hectare increased the leaf area significantly as compared to all other treatment combinations.

4:7 Leaf Area Index (LAI)

With view to get comparative idea about the leaf area produced by a plant and land area kept for a plant, the leaf area indices were calculated. The data is not statistically analysed and inferences are based on means. The relevant data is given in Table 20. It was observed that the mean maximum LAI was 2.049 at 74 days after sowing. The leaf area indices were very negligible at 32 days, but following this slow growth period, the leaf area indices were increased gradually and attained maximum value at 74 days after sowing, indicating the full canopy at the stage. Thereafter, the leaf area indices were decreased and became negligible not in all but in some treatments at harvest.

Effect of irrigation schedules :

A glance at Table 20 would indicate that mean LAI were affected by irrigation schedules much more at latter stages of crop growth. The differences in the mean leaf area indices were negligible at 32 and 60 days after sowing, but considerable difference was found at 46, 74, 88 and 111 days after sowing.

Effect of nitrogen :

From Table 20, it would be seen that there was increasing trend in LAI values resulted from different nitrogen levels up to 88 days. At 111 days, however, no regular trend was observed.

Effect of nitrogen without irrigation :

It could be observed from Table 20 that 50 kg nitrogen application per hectare without irrigation resulted into higher

Table 20 : Mean leaf area index as affected periodically by different treatments.

Treatments	Days after sowing					
	32	46	60	74	88	111
Irrigation schedules						
0.3 WUF	0.707	1.487	2.051	2.152	1.897	0.979
0.6 WUF	0.778	1.764	2.187	2.326	2.252	1.284
No irrigation Vs. irrigation						
I_0	0.552	1.065	1.560	1.608	1.450	0.663
I	0.742	1.626	2.119	2.238	2.032	1.132
Levels of nitrogen, Kg/ha						
N_{25}	0.603	1.189	1.370	1.538	1.415	0.876
N_{50}	0.694	1.543	2.048	2.173	1.885	1.188
N_{75}	0.810	1.770	2.424	2.558	2.370	1.352
N_{100}	0.863	2.001	2.628	2.684	2.459	1.111
Nitrogen levels without irrigation						
N_{25}	0.514	0.984	1.214	1.265	1.199	0.640
N_{50}	0.590	1.145	1.901	1.951	1.701	0.686
General Mean	0.685	1.457	1.950	2.049	1.866	0.991

leaf area indices than that due to 25 kg nitrogen per hectare without irrigation.

4:8 Dry matter per plant :

Data on dry matter production (g) per plant and its distribution in different plant parts, as affected periodically by different treatments are presented in Table 21 and graphically shown in Fig. 5. From the data in Table 21, it would be seen that dry matter per plant was increased with the advance in age of crop. The mean maximum value for dry matter per plant was 147.18 g at 111 days after sowing i.e. at harvesting. During first 32 days growth period, a plant has accumulated 3.45 g dry matter. Upto 46 days, the plant had accumulated dry matter in vegetative parts but following 46 days, plant had accumulated dry matter in reproductive plant parts as well.

Effect of irrigation schedules :

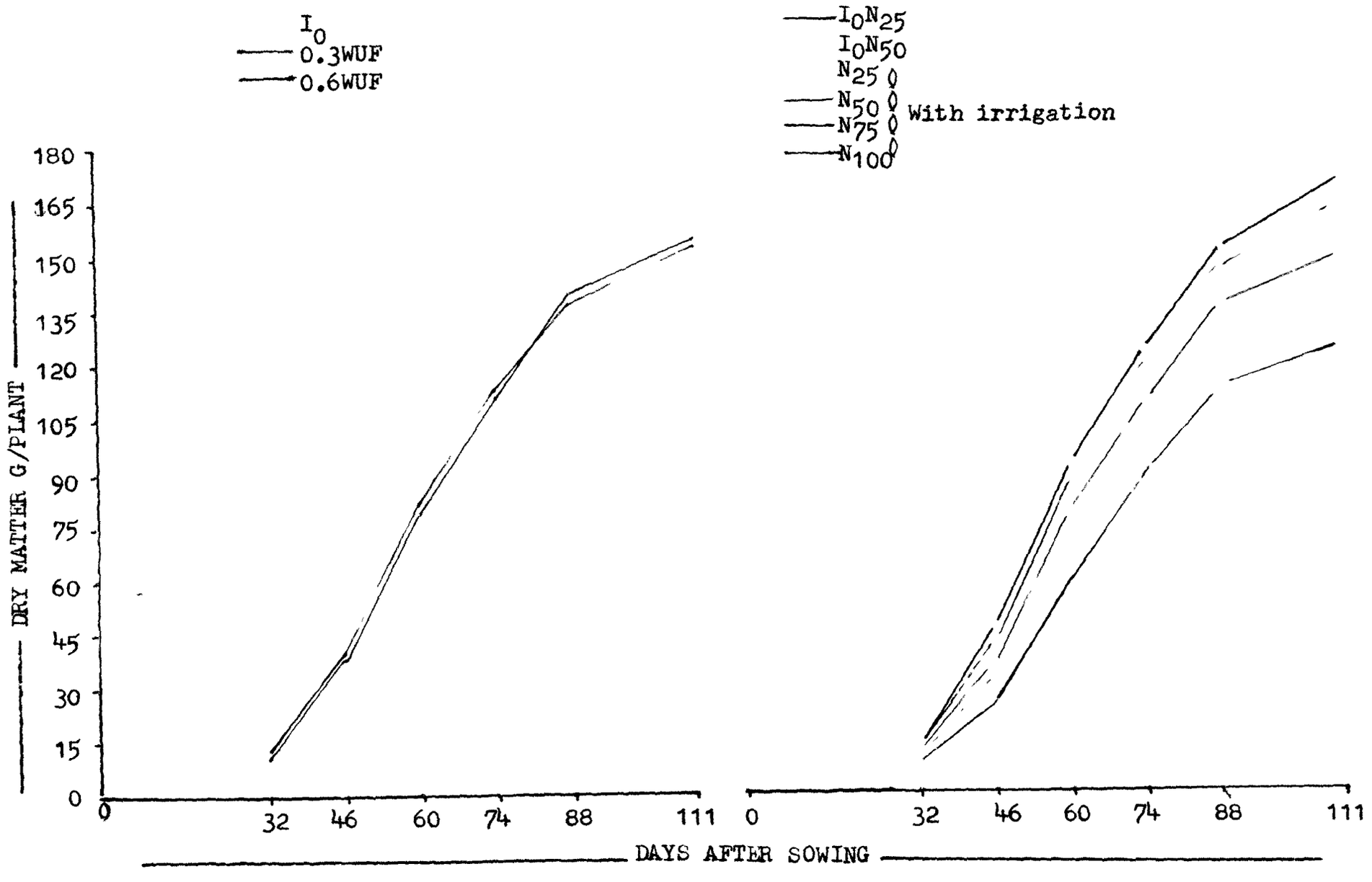
It would be seen from the data in Table 21 that the total dry matter per plant and its distribution in component plant parts were accumulated significantly higher in amount due to 0.6 WUR than due to 0.3 WUR schedule at 32 days after sowing. Following 32 days, the irrigation schedules were ineffective in increasing the dry matter per plant as well as in its component plant parts except at 111 days (i.e. at harvesting) where the seed weight per plant was significantly higher due to 0.6 WUR than 0.3 WUR schedule.

Effect of 'no irrigation' Vs. irrigation :

It was observed that application of irrigation resulted

MEAN TOTAL DRY MATTER (G)/PLANT AS AFFECTED BY DIFFERENT TREATMENTS

FIG.5



into significant increase in dry matter production per plant, and in its component plant parts, at all stages. Except at 74 days (in head and stem) and at 111 days (in reproductive plant parts other than seed) the dry matter production was not significantly higher due to irrigation over "no irrigation" treatment.

Effect of Nitrogen :

Data in Table 21 show that the dry matter production per plant increased significantly with the increase in nitrogen dose up to 75 kg per hectare at all crop growth stages.

Effect of nitrogen without irrigation :

The total dry matter production per plant was increased significantly due to 50 kg nitrogen application per hectare over 25 kg nitrogen application without irrigation at all crop growth stages except at 46 days, where they were not significant (vide Table 21).

Effect of interaction :

It is seen from data given in Table 21 that interaction effects between irrigation and nitrogen were not significant at all crop growth stages.

4.9 Growth analysis :

4.9.1 Absolute Growth Rate (AGR) :

Data pertaining to the AGR of dry matter in g per plant per week during different growth periods as affected by different treatments are presented in Table 22. Data were not statistically analysed and inferences are based on means.

Table 22 : Mean absolute growth rate (AGR.) of total dry matter per plant (g) per week during different growth periods as affected by different treatments.

Treatments	Days after sowing					
	0-32	23-46	46-60	74-88 / 60-74	74-88	88-111
Irrigation schedules						
0.3 WUE	2.16	14.055	20.225	18.320	13.250	2.249
0.6 WUE	2.56	12.820	21.270	14.965	14.040	4.620
'No irrigation' Vs. irrigation						
I_0	1.84	10.540	16.260	15.025	12.700	3.865
I	2.36	13.725	20.810	15.500	13.635	3.433
Levels of nitrogen, kg/ha						
N_{25}	1.88	9.860	17.325	15.335	13.150	3.682
N_{50}	2.24	12.590	21.545	14.775	13.655	3.965
N_{75}	2.56	15.905	21.795	16.000	13.830	0.672
N_{100}	2.77	16.835	22.330	16.460	13.890	5.417
Nitrogen level without irrigation						
N_{25}	1.54	9.685	15.865	15.450	11.935	3.582
N_{50}	2.14	11.400	20.650	15.300	12.730	4.169
General Mean	2.20	12.70	21.42	15.51	13.28	3.56

Mean maximum AGR recorded was 21.42 g per plant per week during 46 to 60 days after sowing. It was only 2.20 g per plant per week during 0 to 32 days and increased rapidly upto 12.70 g during 32 to 46 days after sowing. Following 60 days, the AGR was reduced and approached the value of 3.56 g per plant per week.

Effect of irrigation schedules :

The AGR value was increased due to 0.6 WUR schedule over 0.3 WUR schedule at all crop growth stages, except during 32 to 46 and 60 to 74 days after sowing.

Effect of "no irrigation" Vs. irrigation :

It is seen from the data given in Table 22 that the AGR values due to irrigation application were higher than that due to "no irrigation" treatment at all crop growth stages except duri 88 to 111 days after sowing.

Effect of nitrogen :

It is indicated from data given in Table 22, that AGR values were increased during 0 to 32, 32 to 46 and 60 to 74 days after sowing with increasing levels of nitrogen upto 75 kg per hectare. However during 46 to 60 and 74 to 88 days, the AGR values were found to be about the same due to 50, 75 and 100 kg nitrogen application per hectare. During 88 to 111 days, the AGR were very less.

Effect of nitrogen without irrigation :

It is seen from the given data in Table 22 that AGR values were increased with increasing dose of nitrogen in

"no irrigation" treatment. Higher difference was found during period between 46 to 60 days after sowing due to levels of nitrogen without irrigation.

4:9:2 Relative Growth Rate (RGR) :

Data on RGR or dry matter (g) per plant per week during different growth periods as affected by different treatments are presented in Table 23. Data is not statistically analysed. Sunflower has recorded maximum RGR of 0.631 g per plant per week during 32 to 46 days after sowing. Following 46 days the RGR was decreased with the advance in age of crop.

Effect of irrigation schedules :

Irrigation schedules did not show higher influence on RGR values worked out periodically. However, during 0 to 32 and 88 to 111 days after sowing, the RGR values were greater due to 0.6 IW:CPE than that due to 0.3 IW:CPE schedule.

Effect of "no irrigation" Vs. irrigation :

It is seen from data given in Table 23 that application of irrigation resulted in increasing RGR values over "no irrigation" treatment during period of 0 to 32 days and 32 to 46 days after sowing. Thereafter application of irrigation did not show increased RGR value over 'no irrigation' treatment.

Effect of nitrogen :

A glance at Table 23 indicate that the RGR was increased at 0 to 32 days period and 32 to 46 days after sowing, with the increase in level of nitrogen. Thereafter RGR were progressively decreased with increasing levels of nitrogen at all stages except during 88 to 111 days after sowing, when it was maximum

Table 23 : Mean relative growth rate (RGR) of total dry matter (g) per plant per week during different growth periods as affected by different treatments.

Treatments	Days after sowing					
	0-32	32-46	46-60	60-74	74-88	88-111
Irrigation schedules						
0.3 IW/CPE	0.501	0.672	0.364	0.172	0.107	0.026
0.6 IW/CPE	0.538	0.598	0.369	0.157	0.113	0.520
No irrigation Vs. irrigation						
I_0	0.466	0.626	0.403	0.187	0.117	0.049
I	0.520	0.634	0.366	0.164	0.110	0.039
Levels of nitrogen, kg/ha						
N_{25}	0.471	0.593	0.401	0.196	0.124	0.048
N_{50}	0.508	0.621	0.398	0.159	0.113	0.046
N_{75}	0.538	0.657	0.347	0.156	0.104	0.007
N_{100}	0.555	0.648	0.337	0.154	0.101	0.055
Nitrogen levels without irrigation						
N_{25}	0.427	0.660	0.394	0.213	0.119	0.049
N_{50}	0.449	0.600	0.409	0.173	0.108	0.050
General Mean	0.502	0.631	0.379	0.173	0.112	0.088

due to 100 kg nitrogen application while minimum due to 75 kg nitrogen application per hectare.

Effect of nitrogen without irrigation :

It is seen from data given in Table 23 that NGR of dry matter (g) per plant per week was increased during period of 0-32 days, due to 50 kg nitrogen application per hectare over 25 kg nitrogen application per hectare without irrigation. Following 32 days NGR were decreased with increasing levels of nitrogen without irrigation except during period of 46 to 60 days and 88 to 111 days after sowing.

4:10 Root study :

4:10:1 Root length :

Data regarding the mean tap root length in cm per plant as affected by treatments at harvest are given in Table 24, and graphically shown in Fig. 6 and shown in plate 1. It would be seen from the data in Table 24 that mean tap root length at harvest was 30.74 cm.

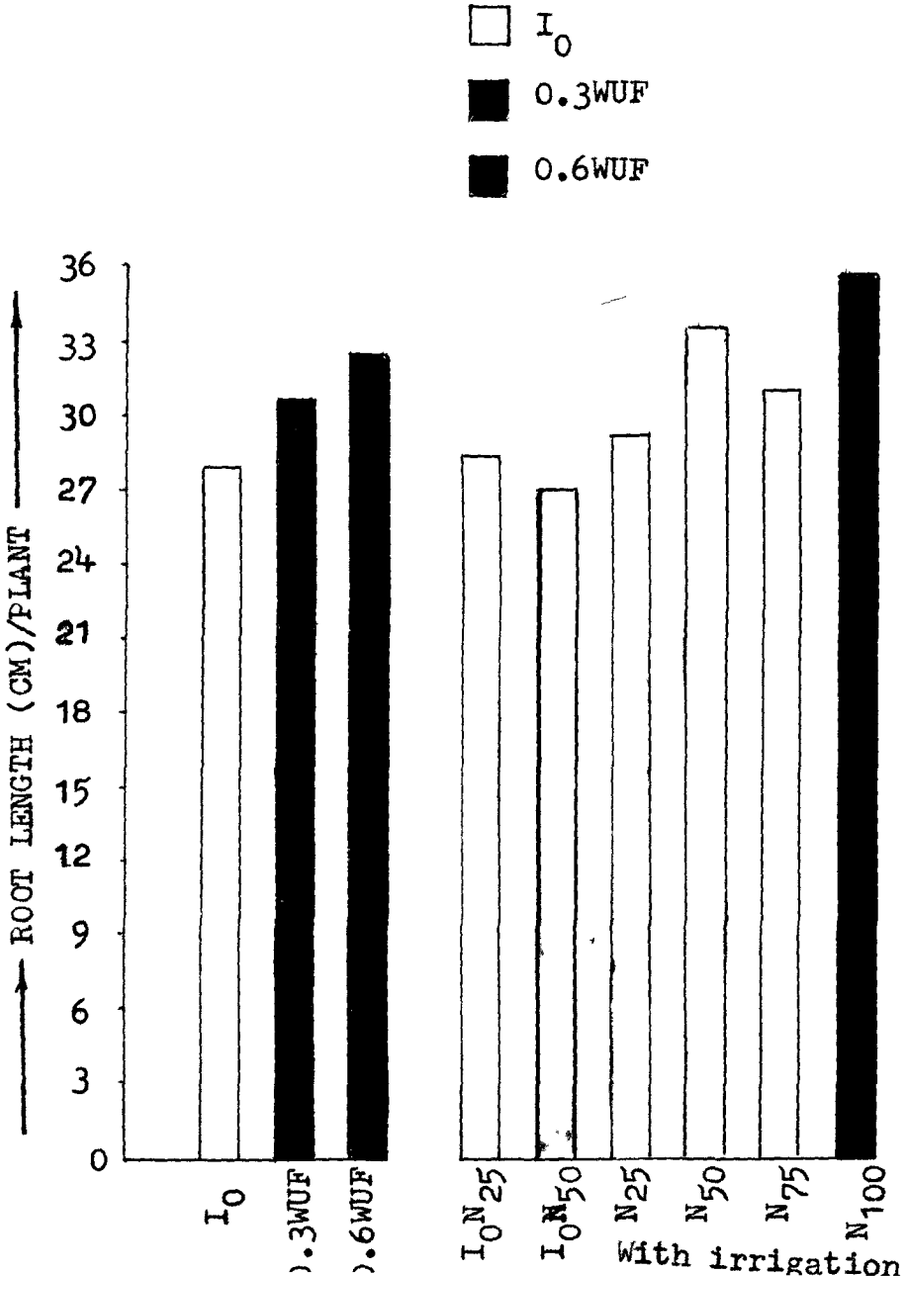
Effect of irrigation schedules :

The data given in Table 24 would indicate that though the tap root length per plant was increased due to 0.6 WUF schedule over 0.3 WUF schedule, the difference was not found to be significant.

Effect of 'no irrigation' Vs. irrigation :

The effect of irrigation over "no irrigation" treatment was found to be increasing the tap root length per plant, though the difference was not significant.

MEAN ROOT LENGTH (CM)/PLANT AS AFFECTED BY DIFFERENT TREATMENTS



MEAN ROOT SPREAD (CM)/ PLANT AS AFFECTED BY DIFFERENT TREATMENTS

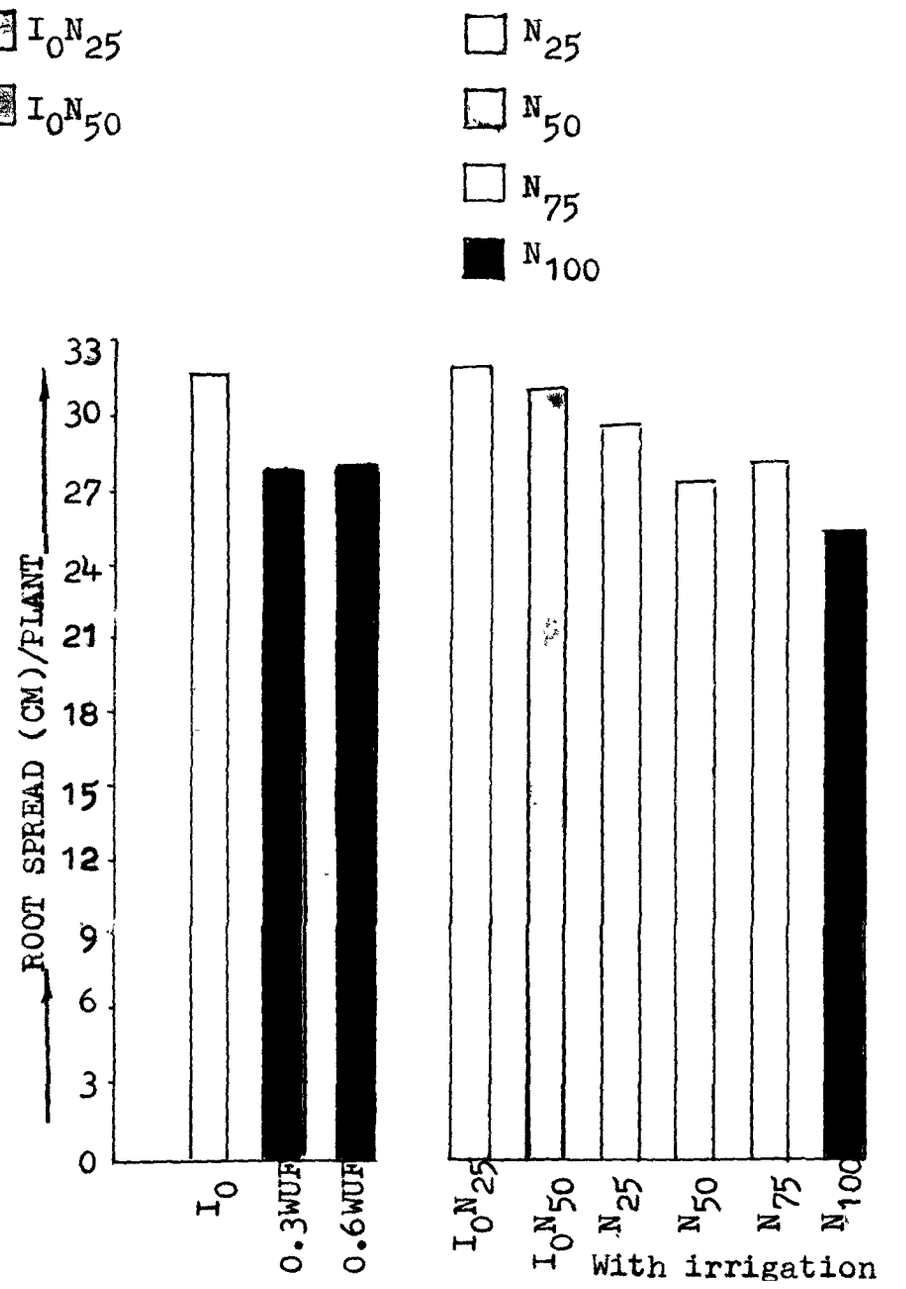


Table 24 : Mean root length and root spread (cm) per shoot as affected by different treatments at harvest.

Treatments	Root length(cm)	Root spread(cm)
Irrigation schedules		
0.3 IW/E	30.75	27.46
0.6 IW/E	32.36	27.57
'F' test	N.S.	N.S.
S.E. ±	1.99	0.64
C.D. at 5 %	-	-
No irrigation Vs. irrigation		
I0	27.86	31.68
I	31.55	27.52
'F' test	N.S.	Sig.
S.E. ±	3.99	1.29
C.D. at 5 %	-	2.15
Levels of nitrogen, kg/ha		
N25	29.21	29.41
N50	33.58	27.30
N75	30.91	27.96
N100	35.91	25.40
'F' test	N.S.	Sig.
S.E. ±	2.82	0.91
C.D. at 5 %	-	2.72
Nitrogen levels without irrigation		
N25	28.50	32.00
N50	27.23	31.36
'F' test	N.S.	N.S.
C.D. at 5 %	-	-
Interaction (I x N)		
'F' test	N.S.	N.S.
S.E. ±	3.99	1.29
C.D. at 5 %	-	-
General Mean	30.74	28.76

Sig. = Significant N.S. = Non significant.

Effect of nitrogen :

Application of nitrogen with increasing levels found to be effective in increasing the tap root length per plant, however, the differences were not significant.

Effect of nitrogen without irrigation :

Data in Table 24 revealed that application of 50 kg nitrogen per hectare did not show any significant difference in tap root length per plant over 25 kg nitrogen per hectare without irrigation.

Effect of interaction :

The interaction between irrigation and nitrogen was found to be absent.

4:10:2 Root spread :

Data on the mean spread of roots per plant is given in Table 24 and dipicted in Fig. 6. The data revealed that mean root spread per plant was found to be 28.76 cm per plant at harvesting.

Effect of irrigation schedules :

The data given in Table 24 indicate that irrigation schedules did not show any significant difference in the mean root spread per plant.

Effect of "no irrigation" Vs. irrigation :

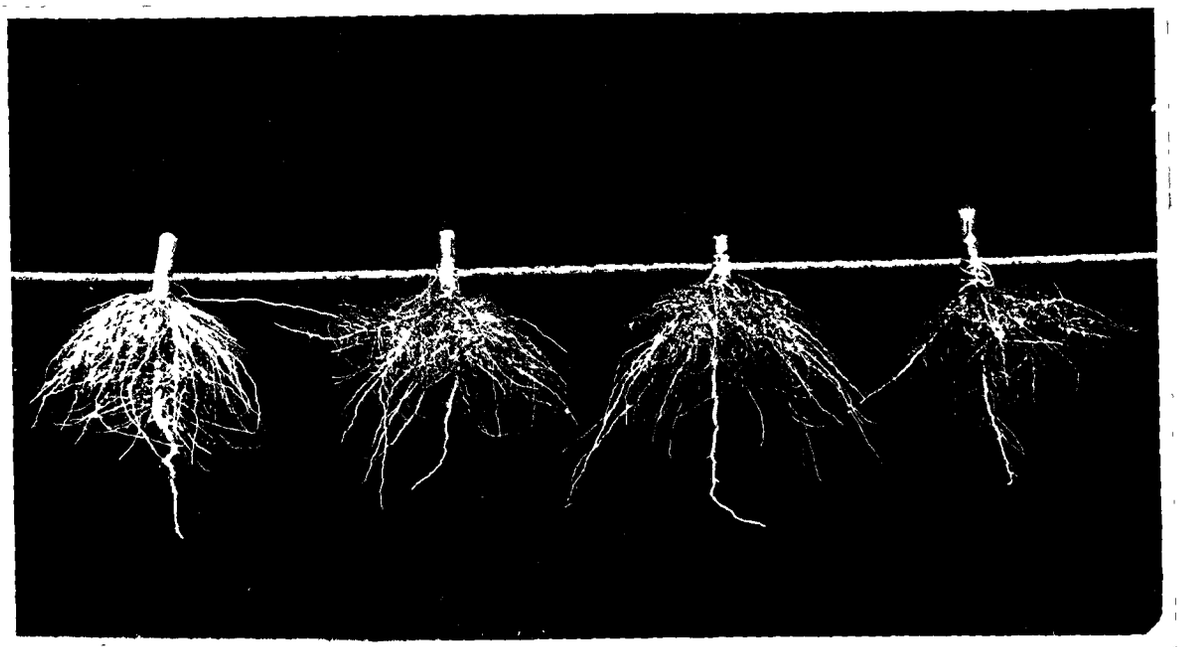
From the data in Table 24, it could be seen that application of irrigation resulted into reduced root spread per plant to the extent of 4.16 cm over "no irrigation" treatment.

Effect of nitrogen :

Data from Table 24 would show that with the increase in

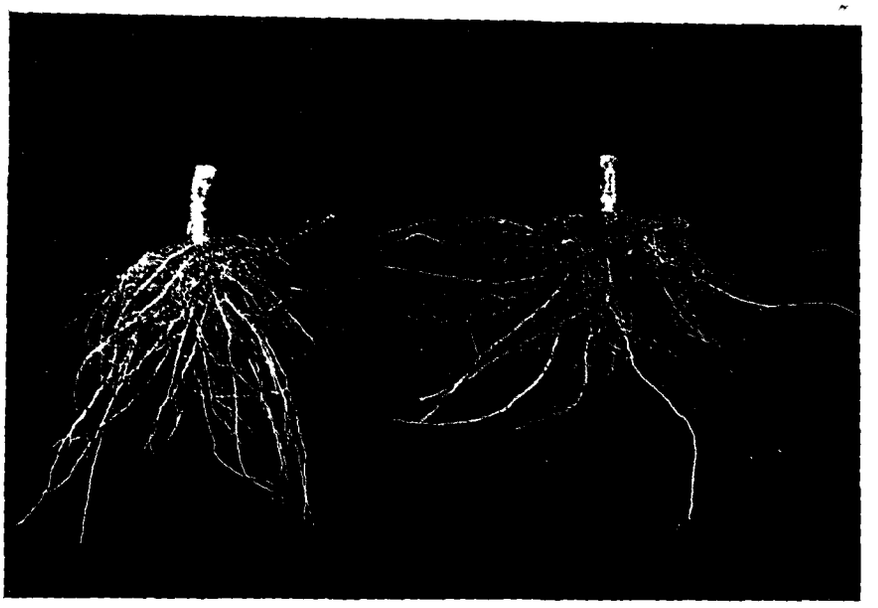
PLATE-1

1.A THE EFFECT OF NITROGEN LEVELS (WITH IRRIGATION) ON ROOT DEVELOPMENT AT HARVEST



N_{100} N_{75} N_{50} N_{25}

1.B THE EFFECT OF NITROGEN LEVELS (WITHOUT IRRIGATION) ON ROOT DEVELOPMENT AT HARVEST



N_{50} N_{25}

levels of nitrogen, the root spread was found to be reduced significantly. Application of nitrogen at the rate of 100 kg per hectare significantly decreased the root spread as compared to other lower levels of nitrogen.

Effect of nitrogen without irrigation :

It could be seen from Table 24 that though the 50 kg nitrogen application per hectare did reduce root spread per plant over 25 kg nitrogen application without irrigation, the difference was not significant.

Effect of interaction :

Interaction between irrigation and nitrogen was not found to be significant.

5. Developmental studies :

5.1 Days required for flowering :

Data pertaining to the number of days (after sowing) required for flowering as affected by different treatments are given in Table 25 and graphically dipicted in Fig. 7. The data indicate that the mean number of days (after sowing) required for flowering were 66.7.

Effect of irrigation schedules :

It could be seen from the data given in Table 25 that irrigation schedules did not affect the number of days required for flowering.

Effect of 'no irrigation' Vs. irrigation :

Data given in Table 25 indicate that application of irrigation delayed the flowering significantly by 1.29 days as compared to "no irrigation" treatment.

FIG.7

MEAN NUMBER OF DAYS REQUIRED FOR FLOWERING

AS AFFECTED BY DIFFERENT TREATMENTS

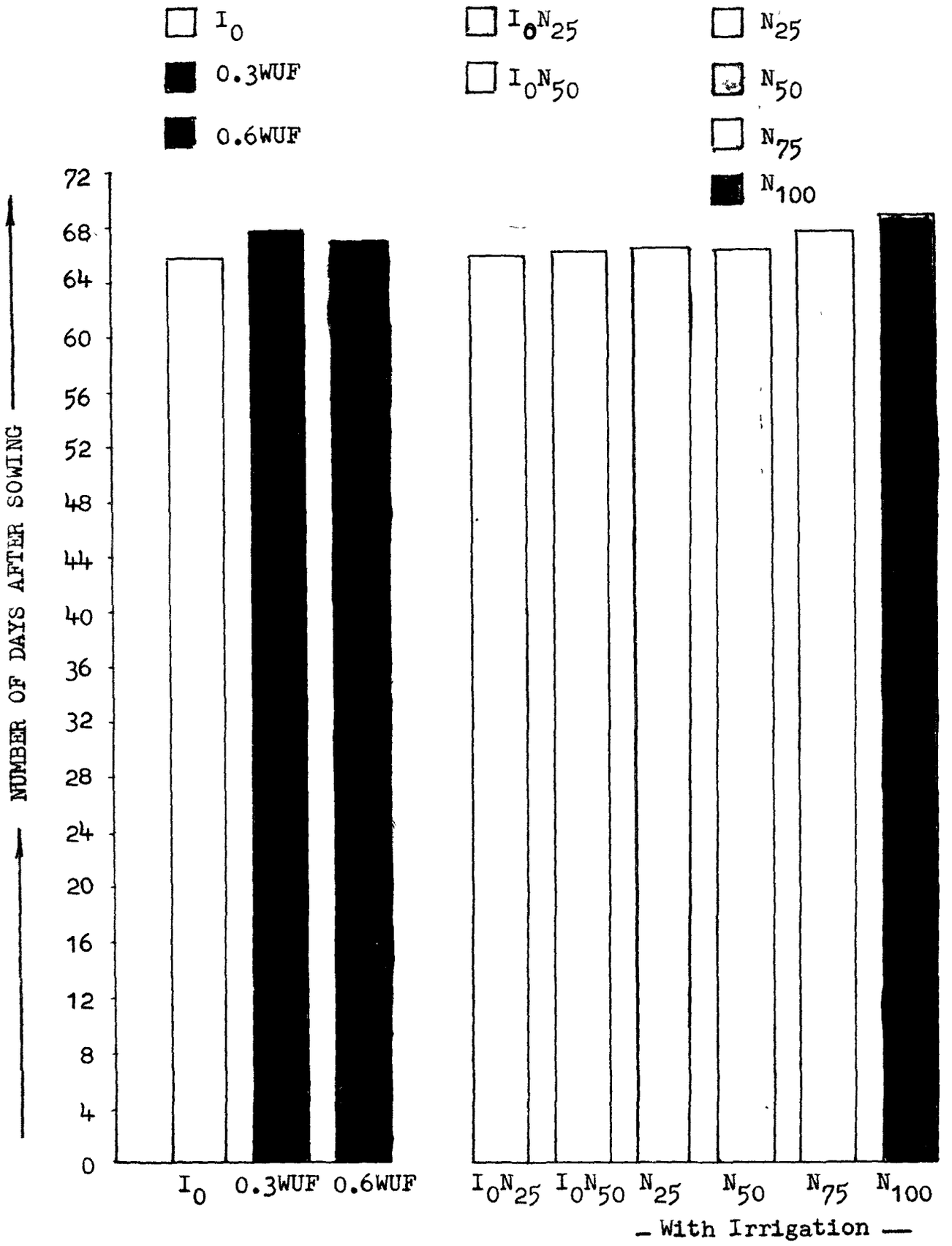


Table 25 : Number of days after sowing required for flowering as affected by different treatment.

Treatments	Days after sowing
Irrigation schedules	
0.3 WUE	67.50
0.6 WUE	66.75
'F' test	N.S.
S.E. ±	0.30
C.D. at 5 %	-
No irrigation Vs. irrigation	
I_0	65.83
I_1	67.12
'F' test	Sig.
S.E. ±	0.61
C.D. at 5 %	1.01
Levels of nitrogen, kg/ha	
N_{25}	66.16
N_{50}	66.16
N_{75}	67.66
N_{100}	68.50
'F' test	Sig.
S.E. ±	0.43
C.D. at 5 %	1.20
Nitrogen levels without irrigation	
N_{25}	65.66
N_{50}	66.00
'F' test	N.S.
S.E. ±	0.61
C.D. at 5 %	-
Interaction	
'F' test	N.S.
S.E. ±	0.61
C.D. at 5 %	-
General Mean	66.73

Sig. = Significant. N.S. = Non significant.

Effect of nitrogen :

A glance at a Table 25 would indicate that with the increase in levels of nitrogen application, the days required for flowering were increased. However, differences between 25 and 50 kg nitrogen per hectare as well as 75 and 100 kg nitrogen per hectare were found to be not significant. The dose of 75 kg nitrogen and 100 kg nitrogen per hectare, significantly prolonged the period of flowering by 1.50 and 2.34 days, respectively as compared to that of 25 kg nitrogen application per hectare.

Effect of nitrogen without irrigation :

Nitrogen levels without irrigation did not show any significant difference in days required for flowering.

Effect of interaction :

Interaction between irrigation and nitrogen was found to be not significant.

5:2 Head diameter :

Data regarding the head diameter (cm.) at various growth stages as affected by various treatments are given in Table 26 and shown in plate 2. The data indicate that the mean head diameter was 8.83 cm at 74 days after sowing and it was increased rapidly with the advance in head development and attained maximum head diameter of 12.98 cm at 88 days and it again found to be reduced at harvesting when the heads were dried out.

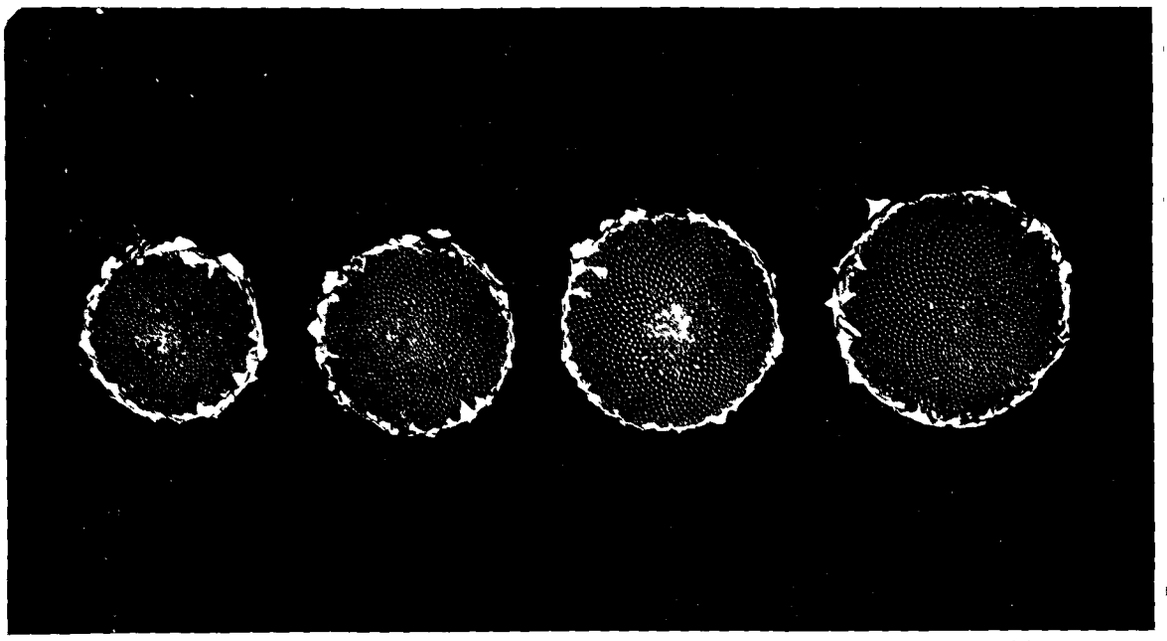
Effect of irrigation schedules :

Data given in Table 26 indicate that irrigation schedules

PLATE-2

THE EFFECT OF NITROGEN LEVELS (WITH IRRIGATION)

ON HEAD DEVELOPMENT AT HARVEST



N_{25} N_{50} N_{75} N_{100}

Table 26 : Mean diameter of the head (cm) as affected by different treatment at various stages of head development.

Treatments	Days from sowing		
	74	88	111
Irrigation schedules			
0.3 WUE	8.90	13.39	13.18
0.6 WUE	9.06	13.38	13.34
'F' test	N.S.	N.S.	N.S.
S.E. ±	0.15	0.14	0.11
C.D. at 5 %	-	-	-
No irrigation Vs. irrigation			
I_0	8.46	12.06	12.06
I	8.98	13.38	13.26
'F' test	N.S.	Sig.	Sig.
S.E. ±	0.31	0.29	0.22
C.D. at 5 %	-	0.40	0.36
Levels of nitrogen, kg/ha			
N25	8.28	11.93	11.56
N50	8.82	12.70	12.65
N75	9.27	13.95	13.90
N100	9.54	14.96	14.94
'F' test	Sig.	Sig.	Sig.
S.E. ±	0.22	0.20	0.15
C.D. at 5 %	0.65	0.61	0.45
Nitrogen levels without irrigation			
N25	8.16	11.66	11.67
N75	8.81	12.45	12.46
'F' test	N.S.	N.S.	Sig.
S.E. ±	0.31	0.29	0.22
C.D. at 5 %	-	-	0.65
Interaction (I x L)			
'F' test	N.S.	N.S.	N.S.
S.E. ±	0.31	0.29	0.22
C.D. at 5 %	-	-	-
General Mean	8.83	12.98	12.90

Sig. = Significant. N.S. = Non significant.

were ineffective in increasing the head diameter at all stages of head development.

Effect of 'no irrigation' Vs. irrigation :

Application of irrigation significantly increased the head diameter at later stages (i.e. at 88 and 111 days) over no "no irrigation" treatment. However, the difference in head diameter due to "no irrigation" and irrigation treatment was not significant, at 74 days after sowing.

Effect of nitrogen :

Data given in Table 26 show that nitrogen levels increased the head diameter significantly at all stages of head development. Application of 75 kg nitrogen and 100 kg nitrogen per hectare was found to be significantly superior over 25 kg nitrogen per hectare in increasing the head diameter. At 88 and 111 days after sowing, head diameter increased significantly with the increase in level of nitrogen upto 100 kg per hectare.

Effect of nitrogen without irrigation :

Head diameter was found to be not significantly higher at 74 and 88 days after sowing due to levels of nitrogen without irrigation. However, 50 kg nitrogen application found to be increasing the head diameter significantly by 0.79 cm over than that of 25 kg nitrogen application per hectare without irrigation at 111 days after sowing.

Effect of interaction :

Interaction between irrigation and nitrogen was found to be not significant.

6. Yield contributing characters :

6:1 Weight of grains per head :

Data regarding the mean weight of grains per head as affected by different treatments are given in Table 27 and graphically shown in Fig. 8. The mean weight of grains per plant was found to be 32.12 g per head.

Effect of irrigation schedules :

Data given in Table 27 indicate that the mean weight of grains (g) per head was significantly increased by 0.6 cm over 0.3 cm treatment.

Effect of 'no irrigation' Vs. irrigation :

It was found that application of irrigation resulted in significant increase in mean grain weight per head by 5.83 g as compared to that in "no irrigation" treatment.

Effect of nitrogen :

Data given in Table 27 indicate that the mean weight of grains was increased significantly with the increase in level of nitrogen. Applications of 50, 75 and 100 kg nitrogen per hectare were found to be resulted in significantly increased grain weight per head by 5.23, 7.53 and 9.77 g over that of 25 kg nitrogen application per hectare. The grain yield per head due to 50 and 100 kg nitrogen per hectare were significantly higher as compared to that due to 25 and 50 kg nitrogen per hectare respectively.

Effect of nitrogen without irrigation :

It is seen that application of 50 kg nitrogen per hectare yielded significantly more weight of grains per head

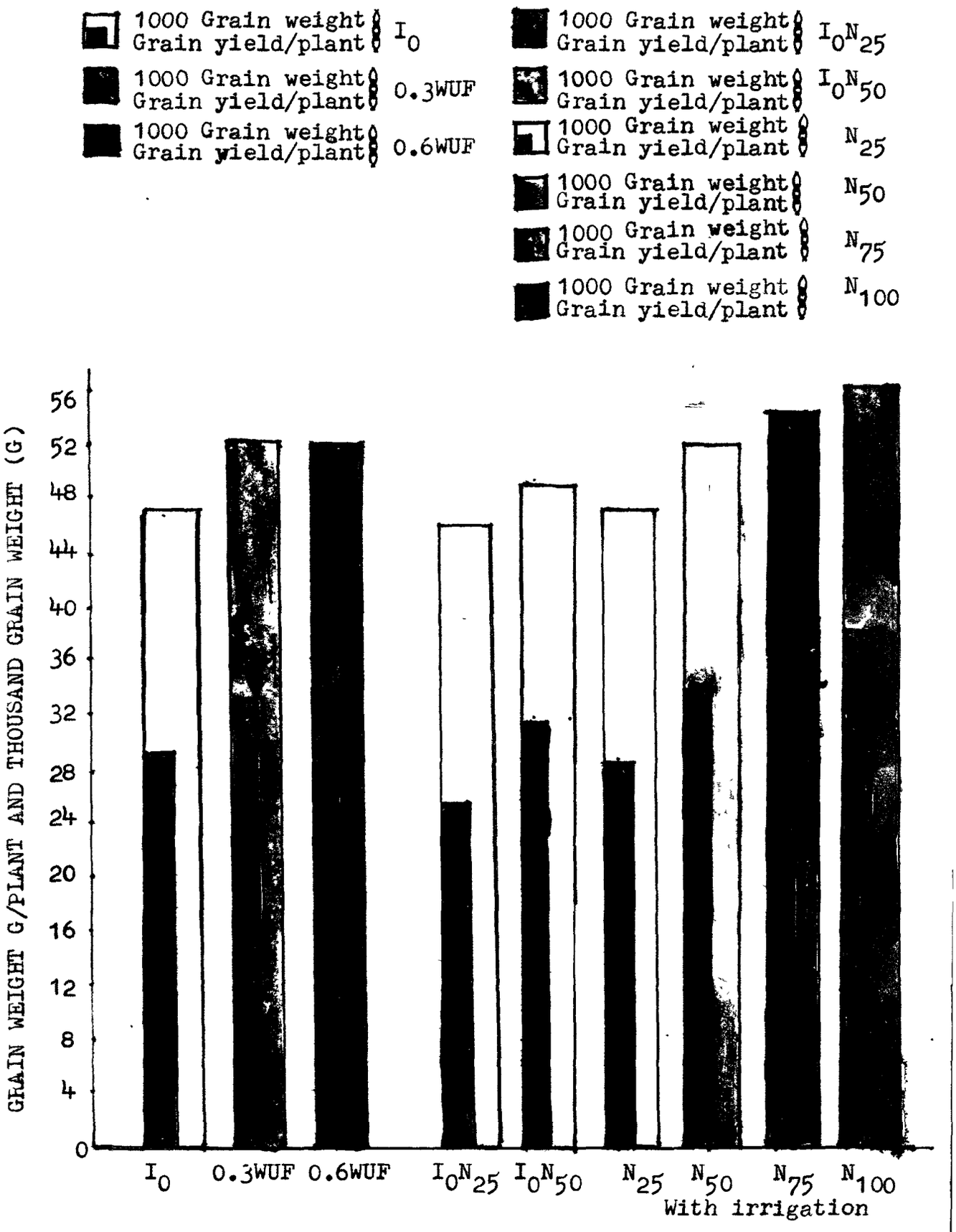
Table 27 : Mean grain yield (g) per plant and thousand grain weight (g) as affected by different treatment.

Treatments	Grain yield per plant (g)	Thousand grain weight (g)
Irrigation schedules		
0.3 IW/CPE	32.45	52.43
0.6 IW/CPE	35.32	52.03
'F' test	Sig.	N.S.
S.E. ±	0.85	1.50
C.D. at 5 %	2.52	-
No irrigation Vs. irrigation		
I_0	28.05	47.25
I^0	33.88	52.23
'F' test	Sig.	Sig.
S.E. ±	1.70	3.00
C.D. at 5 %	2.82	4.99
Levels of nitrogen kg/ha		
N25	28.25	47.24
N50	33.48	51.68
N75	36.78	54.02
N100	38.02	55.98
'F' test	Sig.	Sig.
S.E. ±	1.20	2.12
C.D. at 5 %	3.57	6.31
Nitrogen levels without irrigation		
N25	25.09	45.76
N50	31.02	48.93
'F' test	Sig.	N.S.
S.E. ±	1.70	3.00
C.D. at 5 %	5.06	-
Interaction		
'I' test	N.S.	N.S.
S.E.±	1.70	3.00
C.D. at 5 %	-	-
General Mean	32.13	50.75

Sig. = Significant N.S. = Non significant.

FIG.8

GRAIN YIELD G/PLANT AND THOUSAND GRAIN WEIGHT (G) AS AFFECTED BY DIFFERENT TREATMENTS



than that due to 25 kg nitrogen application without irrigation, indicating thereby, that there is a scope for increasing level of nitrogen application without irrigation over and above 50 kg per hectare.

Effect of interaction :

The interaction between irrigation schedule and nitrogen was found to be not significant.

6:2 Thousand grain weight :

Data pertaining to thousand grain weight as affected by different treatments are tabulated in Table 27 and graphically shown in Fig. 8. Data from Table 27 show that the mean thousand grain weight was 50.75 g.

Effect of irrigation schedules :

Data from Table 27 indicate that the difference due to different irrigation schedules were not significant.

Effect of 'no irrigation' Vs. irrigation :

Data given in Table 27 would indicate that thousand grain weight was significantly more in treatments which received irrigation than as compared to "no irrigation" treatment.

Effect of nitrogen :

The data given in Table 27 indicate that differences in the mean thousand grain weight due to nitrogen levels were significant. The thousand grain weight due to 75 kg nitrogen application per hectare was significantly higher than that due to 25 kg nitrogen application per hectare.

Effect of nitrogen without irrigation :

The difference in the thousand grain weight due to

nitrogen levels without irrigation was not significant.

Effect of interation :

Effect of interaction between irrigation and nitrogen was not significant.

6:3 Number of filled, unfilled and total number of grains per head :

Data showing the filled, unfilled and total number of grains per head as affected by different treatments, are given in Table 28 and graphically shown in Fig. 9. Data indicate that mean number of filled, unfilled and total number of grains per head were 427.5, 748.5 and 1176.0 respectively.

Effect of irrigation schedules :

The difference due to irrigation schedules was not significant in increasing the filled, unfilled and total number of grains per head.

Effect of "no irrigation" Vs. irrigation :

Application of irrigation according to water Use Factor in addition to the receipt of rainfall (188.8 mm) increased significantly, unfilled and total number of grains per head over "no irrigation" treatment. However, difference in filled due to irrigation treatment over 'no irrigation'was not significant.

Effect of nitrogen :

A glance at a Table 28 indicate that the nitrogen legels did not show significant differences in the filled grains per head. However, the mean number of unfilled and total number

FIG.9

NUMBER OF FILLED, UNFILLED AND TOTAL NUMBER OF GRAINS/HEAD AS AFFECTED BY DIFFERENT TREATMENTS

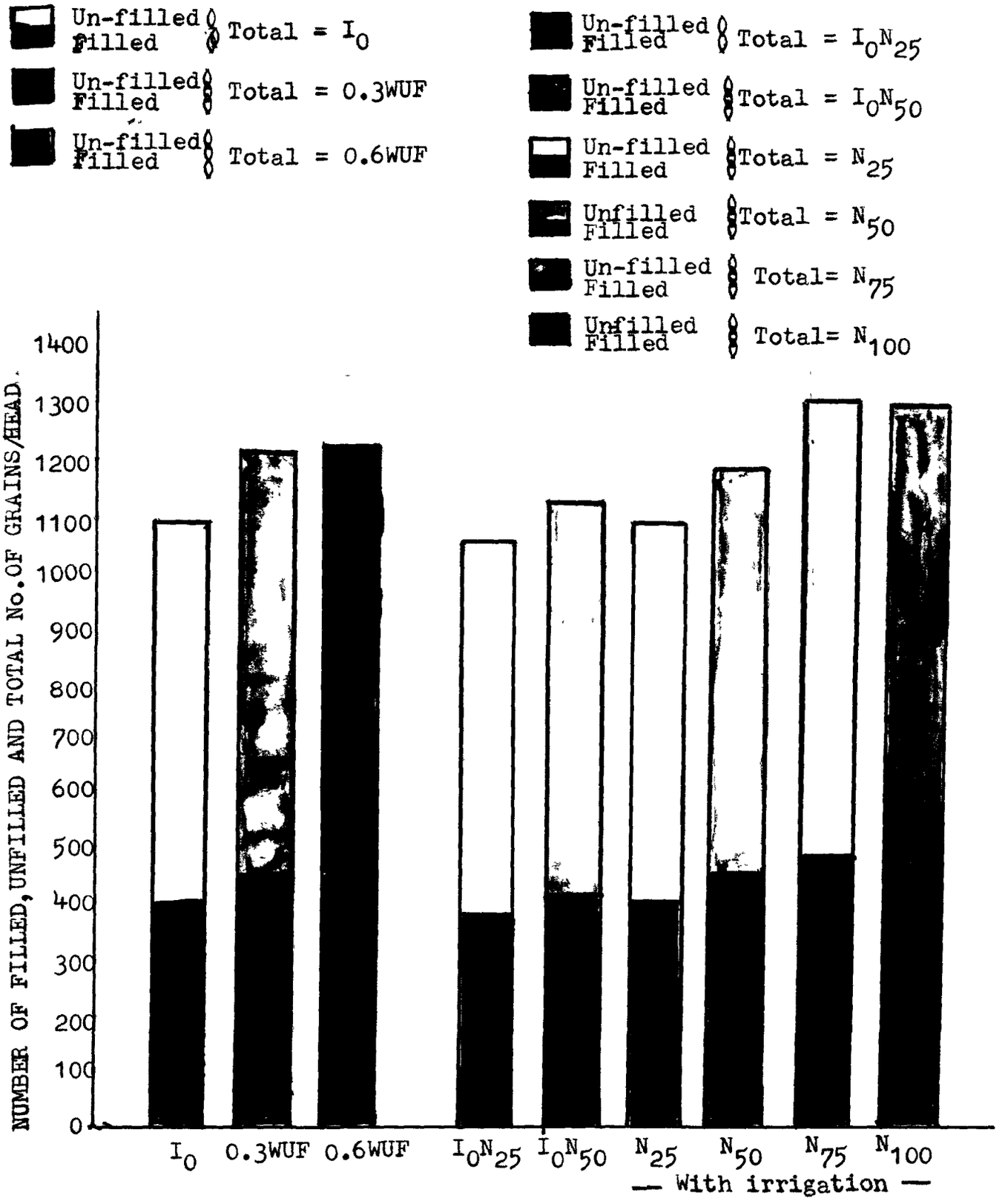


Table 28 : Mean number of filled, unfilled and total number of grains per head as affected by different treatments.

Treatments	Filled grains/ head	Unfilled grains/ head	Total number of grains/ head
Irrigation schedules			
0.3 WUF	439.6	772.7	1212.4
0.6 WUF	441.7	783.1	1224.9
'F' test	N.S.	N.S.	N.S.
S.E. ±	19.04	18.50	22.70
C.D. at 5 %	-	-	-
No irrigation Vs. irrigation			
Io	397.0	680.0	1077.0
I	440.7	777.9	1218.0
'F' test	N.S.	Sig.	Sig.
S.E. ±	38.09	37.07	45.57
C.D. at 5 %	-	81.55	75.69
Levels of nitrogen, kg/ha			
N25	390.3	686.5	1076.8
N50	446.5	738.5	1185.3
N75	481.0	828.3	1309.3
N100	445.0	858.1	1303.0
'F' test	N.S.	Sig.	Sig.
S.E. ±	26.93	26.2	32.2
C.D. at 5 %	-	77.2	95.7
Nitrogen levels without irrigation			
N25	383.6	653.0	1036.6
N50	410.3	707.0	1117.3
'F' test	N.S.	N.S.	N.S.
S.E. ±	38.9	37.0	45.57
C.D. at 5 %	-	-	-
Interaction (I x N)			
'F' test	N.S.	N.S.	N.S.
S.E. ±	28.9	37.0	45.5
C.D. at 5 %	-	-	-
General Mean	427.5	748.5	1176.0

Sig. = Significant. N.S. = Non significant.

of grains were significantly increased with the increase in nitrogen levels. Application of 75 and 100 kg nitrogen per hectare increased the unfilled grains by 141.8 and 171.6 over 25 kg nitrogen application and by 89.8, 119.6 unfilled grains over 50 kg nitrogen application per hectare respectively. However, 25 and 50 kg as well as 75 and 100 kg nitrogen levels per hectare were at par. Data given in Table 28 regarding the total number of grains per head revealed that with the increase in level of nitrogen application per hectare upto 75 kg, the total number of grains per head increased significantly.

Effect of nitrogen without irrigation :

Nitrogen levels without irrigation did not significantly affect the filled, unfilled and total number of grains per head.

Effect of interaction :

Effect of interaction between irrigation and nitrogen was found to be absent.

7. Yield per hectare :

7:1 Grain yield per hectare :

The data regarding the mean grain yield per hectare in quintals as affected by various treatments is given in Table 29 and graphically dipicted in Fig. 10. The mean yield of grain was 16.25 quintals per hectare.

Effect of irrigation schedules :

Difference in the mean grain yield quintals per hectare due to irrigation schedules was not significant.

Effect of no irrigation Vs. irrigation :

The increase in grain yield due to application of

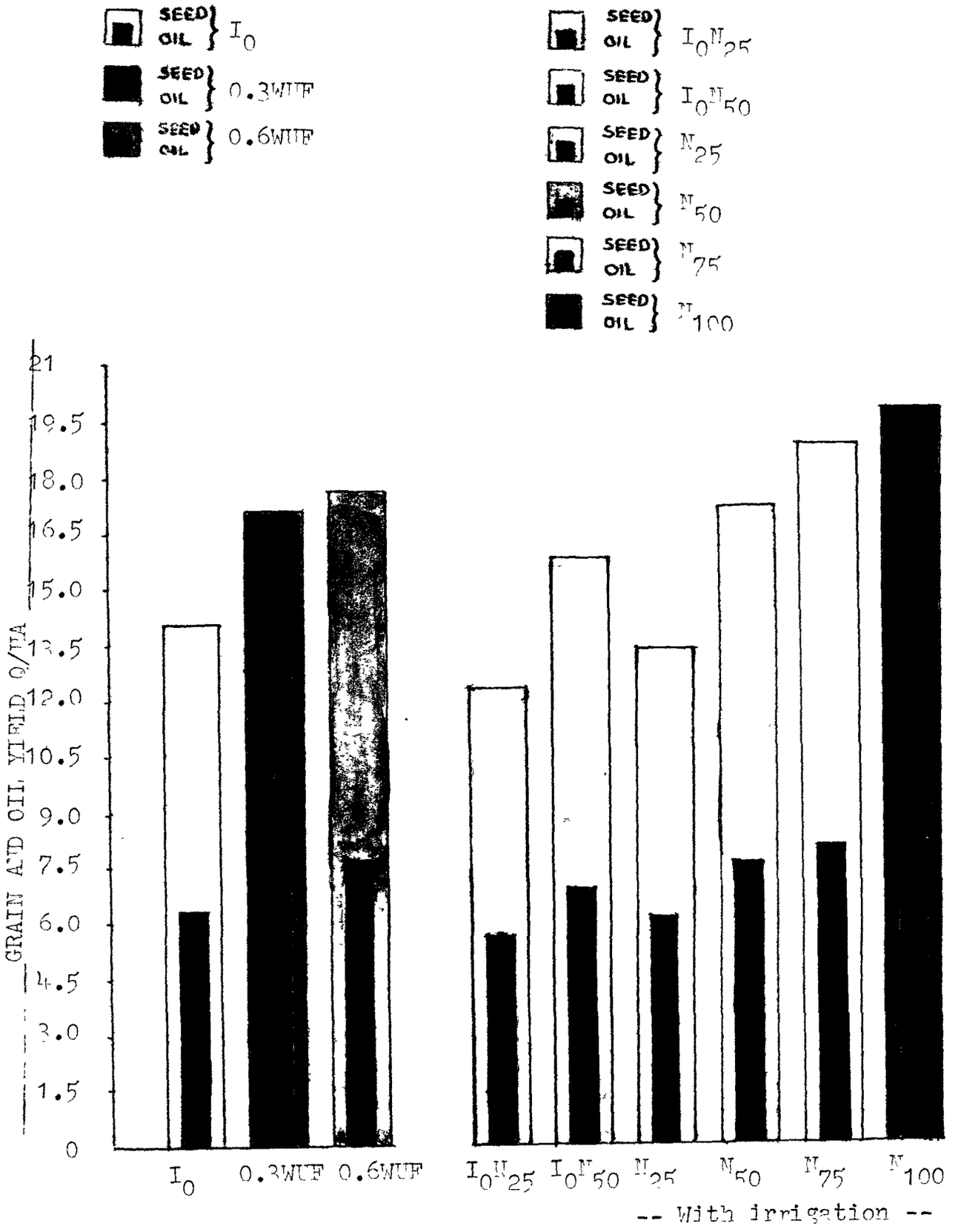
Table 29 : Mean grain yield, straw yield and oil yield (quintal) per hectare and grain/straw ratio as affected by different treatments.

Treatments	Grain yield Q/ha.	Straw yield Q/ha.	Oil yield /ha.	Grain/ straw ratio
Irrigation schedules				
0.3 WUF	16.91	43.25	7.28	2.545
0.6 WUF	17.50	44.70	7.63	2.572
'F' test	N.S.	N.S.	N.S.	N.S.
S.E. ±	0.28	1.62	0.13	0.004
C.D. at 5 %	-	-	-	0.012
No irrigation Vs. irrigation				
I_0	14.03	35.09	6.27	2.496
I	17.21	43.97	7.45	2.559
'F' test	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.56	3.24	0.27	0.008
C.D. at 5 %	0.94	5.39	0.46	0.013
Levels of nitrogen, kg/ha				
N_{25}	13.39	33.59	6.18	2.506
N_{50}	17.06	43.48	7.54	2.546
N_{75}	18.72	47.56	7.99	2.576
N_{100}	19.67	51.29	8.11	2.606
'F' test	Sig.	Sig.	Sig.	Sig.
S.E. ±	0.40	2.29	0.19	0.0057
C.D. at 5 %	1.19	6.82	0.58	0.017
Nitrogen levels without irrigation				
N_{25}	12.35	30.84	5.63	2.476
N_{50}	15.71	39.54	6.92	2.516
'F' test	Sig.	N.S.	Sig.	Sig.
S.E. ±	0.56	3.24	0.27	0.008
C.D. at 5 %	1.68	-	0.82	0.024
Interaction (I x N)				
'F' test	N.S.	N.S.	N.S.	N.S.
S.E. ±	0.56	3.24	0.27	0.008
C.D. at 5 %	-	-	-	-
General Mean	16.25	41.31	7.30	2.539

Sig. = Significant. N.S. = Non significant.

FIG.10

MEAN GRAIN AND OIL YIELD IN Q/HA AS AFFECTED BY DIFFERENT TREATMENTS



irrigation over "no irrigation" treatment was found to be significant. The increase due to application of irrigation in grain yield per hectare was 3.18 quintals over "no irrigation" treatment.

Effect of nitrogen :

Data given in Table 29 indicate that the grain yield was significantly increased with the increase in level of nitrogen upto 75 kg per hectare only. Application of 50 and 75 kg nitrogen per hectare found to be increasing the grain yield significantly to the extent of 3.67 and 5.33 quintals per hectare than that due to 25 kg nitrogen application respectively. At the same time, the increase in grain yield due to 75 kg nitrogen per hectare over 50 kg nitrogen per hectare was 1.66 quintals.

Effect of nitrogen without irrigation :

Application of 50 kg nitrogen per hectare significantly increased the grain yield to the extent of 3.36 quintals per hectare over 25 kg nitrogen application per hectare without irrigation.

Effect of interaction :

The interaction between irrigation and nitrogen was found to be not significant.

7:2 Straw yield per hectare :

The data regarding the mean straw yield per hectare as affected by different treatments are given in Table 29.

Effect of irrigation schedules :

A glance at a Table 29 revealed that difference in the

straw yield per hectare due to irrigation schedules was not significant.

Effect of "no irrigation" Vs. irrigation :

The difference in the straw yield per hectare due to application of irrigation over "no irrigation" was found to be significant. The increase in the straw yield due to application of irrigation over "no irrigation" was 6.88 quintals per hectare.

Effect of nitrogen :

Data given in Table 29 indicate that with the increase in nitrogen level upto 100 kg per hectare, the straw yield was increased significantly, except that the difference due to 50 and 75 as well as due to 75 and 100 kg nitrogen per hectare were not significant.

Effect of nitrogen without irrigation :

Data given in Table 29 indicate that, though the 50 kg nitrogen application resulted in increased straw yield by 8.90 quintals per hectare over 25 kg nitrogen application without irrigation, the difference was not found to be significant.

Effect of interaction :

The interaction between irrigation and nitrogen was not found to be significant in increasing the straw yield per hectare.

7.3 Oil yield per hectare :

The data pertaining to the mean oil yield per hectare as affected by different treatments are presented in Table 29

and graphically shown in Fig. 10. The mean oil yield per hectare was 7.30 quintals.

Affect of irrigation schedules :

Data in Table 29 indicate that though, the 0.6 IW/F schedule increased the oil yield by 0.35 quintals per hectare than that of 0.3 IW/F schedule, the difference was not found to be significant.

Affect of "no irrigation" Vs. irrigation :

Application of irrigation significantly increased oil yield per hectare as compared to that in "no irrigation" treatment.

Affect of nitrogen :

Data presented in Table 29 would indicate that with the increase in level of nitrogen, the oil yield per hectare was found to be increased significantly. Oil yield per hectare increased significantly upto 50 kg nitrogen per hectare only. Further addition of nitrogen did not increase the oil yield significantly.

Affect of nitrogen levels without irrigation :

The data given in Table 29 revealed that the application of 50 kg nitrogen per hectare increased the oil yield than that of 25 kg nitrogen application per hectare without irrigation. The increase over 25 kg nitrogen application was 1.29 quintals of oil per hectare.

Affect of interaction :

The interaction between irrigation and nitrogen was not found to be significant.

7.4 Grain/Straw ratio :

Data pertaining to grain to straw ratio are given in Table 29. The mean grain to straw ratio was found to be 2.539.

Effect of irrigation schedules :

Data pertaining to the mean grain to straw ratio given in Table 29 indicate that difference in the grain to straw ratio due to different irrigation schedules was significant.

Effect of "no irrigation" Vs. irrigation :

It is observed from the data given in Table 29 that the difference in grain to straw ratio due to "no irrigation".

Effect of nitrogen :

From the data given in Table 29, it is seen that the values of grain to straw ratio increased significantly with the increase in level of nitrogen application upto 100 kg per hectare.

Effect of nitrogen without irrigation :

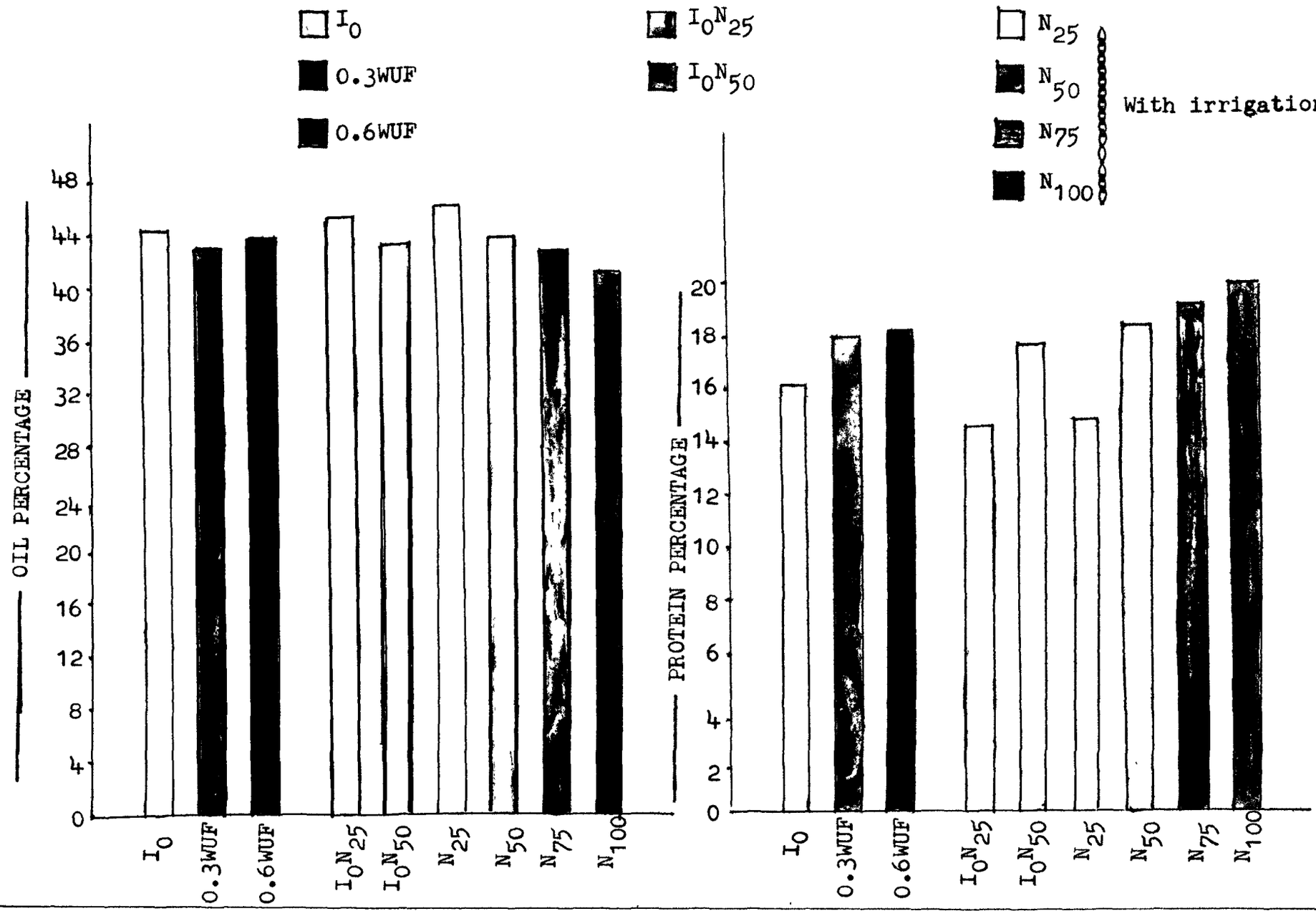
The data from Table 29 revealed that the value of grain to straw ratio was significantly increased with the increase in level of nitrogen upto 50 kg per hectare without irrigation, indicating thereby that the nitrogen level may be increased over and above 50 kg per hectare in "no irrigation" treatment.

Effect of interaction :

The values of ratio between grain and straw were found to be not affected significantly by the interaction of irrigation and nitrogen.

FIG.11

OIL AND PROTEIN PERCENTAGE OF SEED AS AFFECTED BY DIFFERENT TREATMENTS



8. Quality studies :

8:1 Oil percentage :

Data regarding the mean oil percentage as affected by various treatments are given in Table 30 and dipicted graphically in Fig. 11. On an average, the mean oil percentage of sunflower (E.C. 68414) seed was 43.86.

Effect of irrigation schedules :

From the data given in Table 30, it could be seen that mean oil percentage was not affected significantly due to different irrigation schedules.

Effect of "no irrigation" Vs. irrigation :

It was observed that difference between "no irrigation" and irrigation treatment was not significant in affecting the oil percentage of sunflower seed.

Effect of nitrogen :

The data given in Table 30 indicate, with the increase in level of nitrogen the oil percentage was found to be decreased significantly upto 75 kg nitrogen per hectare. The lowest dose i.e. 25 kg nitrogen per hectare has given highest percentage of oil in sunflower (EC 68414) seed, while the highest dose, i.e. 100 kg nitrogen per hectare has given the lowest percentage of oil in sunflower seed.

Effect of nitrogen without irrigation :

Application of 50 kg nitrogen per hectare resulted in decreasing the oil percentage of sunflower as compared to that of 25 kg nitrogen application per hectare in "no irrigation" treatment. However, the decrease in oil percentage was not significant.

Table 30 : Mean oil percentage and protein percentage of seed as affected by different treatments.

Treatments	Oil percentage	Protein percentage
Irrigation schedules		
0.3 WUE	43.31	17.975
0.6 WUE	43.85	18.310
'F' test	N.S.	N.S.
S.E. ±	0.36	0.179
C.D. at 5 %	-	-
No irrigation Vs. irrigation		
I_0	44.54	16.165
I	43.53	18.142
'F' test	N.S.	Sig.
S.E. ±	0.73	0.358
C.D. at 5 %	-	0.595
Levels of nitrogen, kg/ha		
N25	46.24	14.368
N50	44.22	18.386
N75	42.66	19.266
N100	41.24	20.048
'F' test	Sig.	Sig.
S.E. ±	0.51	0.253
C.D. at 5 %	1.53	1.752
Nitrogen levels without irrigation		
N25	45.60	14.593
N50	43.47	17.736
'F' test	N.S.	Sig.
S.E. ±	0.73	0.358
C.D. at 5 %	-	1.064
Interaction (I x N)		
'F' test	N.S.	0.358
S.E. ±	0.73	0.358
C.D. at 5 %	-	-
General Mean	43.86	17.548

Sig. = Significant. N.S. = Non significant.

Effect of interaction :

The interaction between irrigation and nitrogen was not found to be significant.

8:2 Protein percentage :

The data regarding the mean protein percentage in Sunflower (EC 68414) seed as affected by different treatments are presented in Table 30 and graphically dipicted in Fig.11. On an average the protein percentage of sunflower (EC 68414) seed was 17.54%.

Effect of irrigation schedules :

It is seen from the data given in Table 30, that mean protein percentage was not affected significantly due to different irrigation schedules.

Effect of "no irrigation" Vs. irrigation :

It is seen that application of irrigation was found to be significantly effective in giving higher protein percentage in seed than that due to 'no irrigation' treatment.

Effect of nitrogen :

It is seen that with the increase in levels of nitrogen upto 100 kg per hectare the protein percentage in sunflower seed was significantly increased.

Effect of nitrogen without irrigation :

The data from Table 30 revealed that 50 kg nitrogen application per hectare was found to be significant in increasing the protein percentage than that due to 25 kg nitrogen per hectare.

Effect of interaction :

The interaction between irrigation and nitrogen was not found to be significant.

9. Chemical studies :

9:1 Nitrogen percentage in different plant parts at different stages of crop growth :

9:1:1 Nitrogen percentage in different plant parts at 60 days :

Data pertaining to the percentage of nitrogen in the different plant parts as affected by different treatments at 60 days after sowing are tabulated in Table 31. The data were not statistically analysed and the inferences are based on mean values. It would be observed from the data that the percentage of nitrogen in the stem, leaves and head (reproductive part) at 60 days crop growth were 0.981, 2.497 and 1.921 respectively. The leaf was richer in nitrogen content than the stem. Also, leaf was richer in nitrogen content than reproductive parts at 60 days.

Effect of irrigation schedules :

The mean percentage of nitrogen in different plant parts at 60 days of crop growth were affected due to different irrigation schedules. The nitrogen percentage in stem was lesser which received irrigation according to 0.6 WUE schedule than those which received irrigation according to 0.3 WUE schedule. But the nitrogen percentage was higher in leaves from the plots which received irrigations according to 0.6 WUE schedule than that which received irrigations according 0.3 WUE. The nitrogen

Table 31 : Nitrogen percentage in different plant parts at different stages of growth as affected by treatments.

Treatments	at 60 days			88 days seeds	111 days(at harvest)			
	Stem	Leaves	Head		Stem	Leaves	Reproductive parts other than seed	Seeds
Irrigation schedules								
0.3 WUF	1.035	2.485	1.967	2.215	0.469	0.643	0.330	2.849
0.6 WUF	1.020	2.562	1.946	2.230	0.442	0.631	0.347	2.927
No irrigation Vs. irrigation								
I_0	0.875	2.430	1.838	2.078	0.373	0.560	0.273	2.587
I	1.024	2.520	1.957	2.223	0.455	0.637	0.338	2.888
Levels of nitrogen, kg/ha								
N_{25}	0.885	2.373	1.805	2.073	0.378	0.508	0.263	2.319
N_{50}	0.968	2.531	1.920	2.161	0.428	0.600	0.310	2.884
N_{75}	1.098	2.553	2.008	2.293	0.480	0.690	0.373	3.083
N_{100}	1.161	2.638	2.095	2.365	0.536	0.750	0.408	3.208
Nitrogen levels without irrigation								
N_{25}	0.816	2.390	1.763	2.023	0.350	0.520	0.263	2.335
N_{75}	0.933	2.490	1.913	2.133	0.396	0.600	0.283	2.839
General Mean	0.981	2.497	1.921	2.179	0.428	0.614	0.319	2.792

percentage in the reproductive plant parts also were influenced by irrigation schedules. However, the difference in nitrogen percentage of reproductive part (i.e. head) due to irrigation schedules was very less as compared to the difference in nitrogen percentage of leaves due to different irrigation schedules.

Effect of "no irrigation" Vs. irrigation :

The mean nitrogen percentages in different plant parts i.e. stem, leaves and head were comparatively muchhigher which received irrigations according to WUE schedules as compare to that in "no irrigation" treatment.

Effect of nitrogen :

The data from Table 31 revealed that [redacted] increase in the nitrogen level from 25 to 100 kg per hectare, the nitrogen percentage in all plant parts i.e. reproductive as well as vegetative plant parts, was found to be increased. The increase in nitrogen percentage in stem due to 50, 75 and 100 kg nitrogen per hectare over their corresponding lower levels of nitrogen were 0.083, 0.130 and 0.063 per cent respectively. In case of the head i.e. reproductive part the increase in nitrogen percentage due to 50, 75 and 100 kg nitrogen per hectare over their corresponding lower level of nitrogen were 0.115, 0.088 and 0.087 per cent respectively. The corresponding values for leaves were 0.153, 0.022 and 0.085 per cent respectively.

Effect of nitrogen without irrigation :

The data given in Table 31 revealed that application of 50 kg nitrogen per hectare resulted in increased nitrogen

percentage in all plant parts over that of 25 kg nitrogen application, without irrigation. The increase in the nitrogen percentage of stem leaves and head were 0.117, 0.100 and 0.150 per cent due to 50 kg over 25 kg nitrogen application per hectare respectively.

9:1:2 Nitrogen percentage in sunflower seed at 88 days :

Data pertaining to the nitrogen percentage in sunflower seeds at 88 days as affected by different treatments are tabulated in Table 31. On an average, the nitrogen percentage in seeds at 88 days was 2.179.

Effect of irrigation schedules :

The nitrogen percentage in sunflower seeds was found to be affected due to irrigation schedules. The increase in the nitrogen percentage of sunflower seeds due to 0.6 IW:CPE schedule over 0.3 IW:CPE schedule was 0.015 per cent.

Effect of "no irrigation" Vs. irrigation :

The increase in the nitrogen percentage of sunflower seeds due to application of irrigation over "no irrigation" was to the extent of 0.148 per cent.

Effect of nitrogen :

It would be seen from the data given in Table 31 that with increase in the nitrogen level from 25 kg upto 100 kg per hectare, the nitrogen percentage in sunflower seeds was found to be increased.

Effect of nitrogen levels without irrigation :

It was observed that the application of 50 kg nitrogen

per hectare resulted in increased nitrogen percentage of sunflower seeds by 0.11 per cent as compared to that of 25 kg nitrogen application without irrigation.

9:1:3 Nitrogen percentage in different plant parts at harvest :

Data regarding the nitrogen percentage in different plant parts at harvest are tabulated in Table 31. From the data, it is seen that the nitrogen percentage in stem, leaves, reproductive parts other than seeds and seeds at harvest were 0.428, 0.614, 0.319 and 2.792 per cent respectively.

Effect of irrigation schedules :

It is observed that the data given in Table 31 that nitrogen percentage in stem and leaves were lesser due to 0.6 WUR schedule as compared to 0.3 WUR schedule, but reverse is the case in respect of nitrogen percentage in the seeds and reproductive parts other than seeds.

Effect of "no irrigation" Vs. irrigation :

It is seen from data given in the Table 31 that the nitrogen percentage in all plant parts were much higher due to application of irrigation as compared to that due to "no irrigation" treatment.

Effect of nitrogen :

From the data given in the Table 31, it is seen that with the increase in level of nitrogen, the nitrogen percentage in all plant parts was increased. The application of 100 kg nitrogen per hectare gave highest nitrogen percentage in all plant parts and the values were 0.536, 0.750, 0.408

and 3.208 for stem, leaves, reproductive parts other than seeds and seeds respectively.

Effect of nitrogen levels without irrigation :

The nitrogen percentage in all plant parts were higher due to 50 kg nitrogen application per hectare as compared to 25 kg nitrogen application per hectare without irrigation.

9.1.4 Total nitrogen percentage in soil at harvest :

Data regarding the percentage of total nitrogen at harvest as affected by different treatments are presented in Table 32.

The data presented in Table 32 would show that the percentage of total nitrogen in soil at harvest was 0.0607 and it was observed that the total nitrogen percentage at harvest was decreased than that at initial total nitrogen percentage in soil.

Effect of irrigation schedules :

It is seen from the data given in Table 32 that total nitrogen percentage in the soil at harvest was affected significantly by the irrigation schedules. The total nitrogen percentage in 0.3 WUF treatment plot was significantly higher than that in 0.6 WUF treatment plot.

Effect of "no irrigation" Vs. irrigation :

The difference in the total nitrogen percentage in soil at harvest was not found affected significantly due to 'no irrigation' Vs. irrigation treatment.

Table 32 : Mean percentage of total nitrogen in soil as affected by different treatments at harvest.

(0-30 cm)

Treatments	Percentage of total nitrogen
Irrigation schedules	
0.3 IW/CPE	0.0620
0.6 IW/CPE	0.0602
'F' test	Sig.
S.E. ±	0.0004
C.D. at 5 %	0.0013
No irrigation Vs. irrigation	
I0	0.0598
I	0.0611
'F' test	N.S.
S.E. ±	0.0010
C.D. at 5 %	0.0017
Levels of nitrogen, kg/ha	
N25	0.0570
N50	0.0595
N75	0.0622
N100	0.0658
'F' test	Sig.
S.E. ±	0.0007
C.D. at 5 %	0.0021
Nitrogen levels without irrigation	
N25	0.0573
N50	0.0623
'F' test	Sig.
S.E. ±	0.001
C.D. at 5 %	0.0031
Interaction (I x N)	
'F' test	N.S.
S.E. ±	0.001
C.D. at 5 %	0.0031
General Mean	0.0607

Sig. = Significant. N.S. = Non significant.

Effect of nitrogen :

It was observed that the total nitrogen percentage in soil at harvest was significantly increased with the increase in nitrogen level upto 100 kg per hectare.

Effect of nitrogen without irrigation :

It was observed that the total nitrogen percentage in soil at harvest was significantly higher due to 50 kg nitrogen application than that due to 25 kg nitrogen application per hectare without irrigation.

Effect of interaction :

The interaction between irrigation and nitrogen was not significant in affecting the total nitrogen percentage in soil at harvest.

[redacted]

CHAPTER V

DISCUSSION

The results of present investigation are discussed in this chapter.

1. Soil, weather and crop development :

The physico-chemical properties of the soil from experimental plot are presented in Table 1. Also the data on weather conditions etc. are presented in Table 2. The data in these two tables are scrutinised with a view to get broad outlook of growth pattern and development of crop under the soil and environmental conditions at Vaburi. It is revealed from the data given in said Tables that the soil under present experimentation was clayey in texture. The per cent pore space indicates the good drainability of soil. The chemical analysis of soil indicate that soil was medium in nitrogen, available phosphate and available potash, (Datta 1960). The pH of soil showed that the soil was alkaline in reaction.

The data given in Table 2 indicate that the the mean maximum temperature during entire growth period ranged from 22.20°C to 28.87°C, while minimum temperature ranged from 13.82°C to 22.60°C. The mean maximum U.S.W.B. Class I open pan evaporation was 6.53 mm in the 37th meteorological week after which, there was a receipt of rainfall. The mean minimum value for U.S.W.B. Class I open pan evaporation was 3.63 mm in the 39th meteorological week. Thus the values of

pan evaporation varied from 3.63 mm to 6.53 mm during the entire period of crop growth.

From the data given in Table 2, it is seen that the total rainfall received during whole crop growth period (16th August 1973 to 5th December 1973) was 188.8 mm with 12 rainy days. The rainfall received in the second week (34th meteorological week) after sowing resulted in easy emergence of seedlings and into very good stand of crop. However, a month thereafter there was no rainfall and the crop growth in "no irrigation" treatment was adversely affected.

Scrutinity of the data presented in Table 8 on soil moisture percentages 24 hours before and 48 hours after each irrigation, revealed that, the soil moisture percentages before irrigation were equivalent to 50 per cent available soil moisture at all irrigation dates in 0.3 IW/CPE treatment plot. Also in "no irrigation" treatment plots it was about the same while that in 0.6 IW/CPE treatment plots, it was much above 50 per cent available soil moisture. These facts were again observed in the plots before application of irrigations as per 0.6 IW/CPE schedule. Also the soil moisture percentages 48 hours after irrigation were at about field capacity in plots receiving irrigation while these were equivalent to 50 per cent available soil moisture which did not received irrigation. These facts indicate that the soil moisture were equivalent to or above 50 per cent available soil moisture throughout the crop growth period.

In order to get idea about the general performance of the Sunflower (EC 68414) under the environmental and soil conditions, the general means of important growth attributes are studied. The relevant data are presented in Table 33.

From the extract of relevant information showing effects of soil and environmental condition on sunflower at Rahuri, it is seen that the growth and development of crop as measured in terms of height was 153.00 cm, having maximum plant spread of 69.40 cm with 22.66 leaves and 36.899 sq dm leaf area per plant. At harvest, total dry matter of 147.18 g was accumulated per plant. Absolute growth rate of height was maximum during 46 to 60 days after sowing. AGR and RGR of total dry matter were maximum during 46 to 60 and 32 to 46 days respectively and decreased gradually with the age of crop.

Sunflower (EC 68414) plant required 66.70 days for completion of flowering at Rahuri and produced head having diameter of 12.98 cm at 88 days. The mean maximum stem diameter was 2.025 cm at 88 days after sowing. It was observed that sunflower plant was having 30.74 cm tap root length and 28.76 cm root spread at harvest. The yield contributory characters viz. grain weight per plant, number of filled, unfilled and total number of grains per (head) plant, thousand grain weight were, 32.13 g 427.5, 748.5, 1176.0 and 50.75 g respectively. Such a plant was capable enough to produce 16.25 quintals of grain yield with 41.31 quintals of straw per hectare. The total oil yield that can be obtained from the said grain yield was 7.30 quintals per hectare. The oil and protein percentage in sunflower seed were 43.86 and 17.540 respectively.

Table 33 : Influence of season on performance of some important characters of sunflower (EC 68414).

Sr. No.	Particulars	Effect of season
1	Maximum height of plant at harvest (cm)	153.00
2	Maximum AGR of height in cm per plant per week during 46 to 60 days	37.79
3	Maximum plant spread (cm) at 88 days after sowing	69.40
4	Maximum functional leaf number per plant at 74 days	22.66
5	Maximum leaf area (sq dm) per plant at 74 days	36.899
6	Maximum stem diameter (cm) at 88 days	2.025
7	Maximum leaf area index at 74 days	2.049
8	Total dry matter (g) at harvest	147.18
9	AGR of dry matter (g) per plant per week during 46 to 60 days	21.42
10	AGR of dry matter (g) per plant per week during 32 to 46 days	0.631
11	Tap root length at (cm) harvest	30.74
12	Root spread (cm) per plant at harvest	28.76
13	Days required for flowering	66.70
14	Head diameter (cm) at 88 days	12.98
15	Grain yield (g) per plant	32.13
16	Thousand grain weight (g)	50.75
17	Number of filled grains per head	427.5
18	Number of unfilled grains per head	748.5
19	Total number of grains per head	1176.0
20	Grain yield (quintals) per hectare	16.25
21	Straw yield (quintals) per hectare	41.31
22	Oil yield (quintals) per hectare	7.30
23	Grain to straw ratio	2.539
24	Oil percentage in seed	43.86
25	Protein percentage in seed	17.548
26	Nitrogen percentage in stem at 60 days after sowing	0.981
27	Nitrogen percentage in leaves at 60 days after sowing	2.497
28	Nitrogen percentage in head at 60 days after sowing	1.921
29	Nitrogen percentage in seed at 88 days after sowing	2.179
30	Nitrogen percentage in stem at harvest	0.428
31	Nitrogen percentage in leaves at harvest	0.614
32	Nitrogen percentage in reproductive plant parts other than seed at harvest	0.319
33	Nitrogen percentage in seed at harvest	2.792

At 60 days after sowing, the chemical analysis of different plant parts indicate that the nitrogen percentage in stem, leaves and head were 0.981, 2.497 and 1.921 respectively. The analysis of seeds at 88 days indicate that the nitrogen percentage was 2.179 per cent.

The data indicate that the nitrogen percentage in stem and leaves was reduced at harvest as compared to that at 60 days after sowing. The nitrogen percentage of seed was increased at harvest as compared to that at 88 days. These facts indicate that the nitrogen was mobilized from vegetative plant parts to reproductive plant parts during later stages of growth. These findings are in confirmity of those found out by D'Yakow, (1969) and Robinson (1970).

In order to throw more light on nature of growth of sunflower crop (EC 68414), it was considered to be worthwhile to scrutinize the data on growth of plant measured in terms of height, plant spread, functional leaf number, leaf area, stem diameter, total dry matter etc. at various growth stages of sunflower (EC 68414). The relevant data are presented in Table 34, that show the slow growth period of sunflower upto 32 days. By 32 days, a plant had produced 11.19 per cent of its height with 36.85 per cent leaves having 33.45 per cent leaf area and plant spread of 17.39 per cent of the total. Even though the plant had attained 64.79 per cent of its total stem diameter, the total dry matter accumulated was only 6.85 per cent. At this stage, the foliage expansion was hardly

Table 34 : An extract of relevant information showing percentage of total mean height, plant spread, functional leaf number, leaf area, stem diameter, and total dry matter, per plant recorded periodically.

Days after sowing	Height per plant (cm.)		Plant spread per plant (cm.)		Functional leaves per plant		Leaf area per plant (sq dm.		Stem diameter per plant (cm.)		Total dry matter per plant (g)	
	Absolute	% of total	Absolute	% of total	Absolute	% of total	Absolute	% of total	Absolute	% of total	Absolute	% of total
32	17.13	11.19	12.07	17.39	8.35	36.85	12.344	33.45	1.312	64.79	10.09	6.85
46	34.78	22.73	42.14	60.72	15.73	69.41	26.243	71.12	1.490	73.58	35.70	24.25
60	110.40	72.15	60.11	86.61	21.33	94.13	35.134	95.21	1.743	86.07	75.10	51.43
74	146.53	95.77	68.39	98.54	22.66	100.00	36.899	100.00	19.18	94.71	106.74	72.52
88	152.56	99.71	69.40	100.00	21.57	95.18	33,597	95.05	2.025	100.00	133.24	90.52
111	153.00	100.00	-	-	10.24	45.18	17.844	48.35	1.994	98.46	147.18	100.00

about 0.685 times, more than that land area kept for plant. (Table 20).

The first phase of slow growth was followed by a second phase of 32 to 74 days growth period after sowing. During this phase, plant was growing at a faster rate and completed its flowering completely to switch on the further reproductive phase. By 74 days of crop growth, a plant was having its 95.77 per cent height, 98.54 per cent plant spread with 100 per cent leaves and leaf area. At this stage plant attained 94.71 per cent stem diameter with 72.52 per cent dry matter which was sufficient to the crop to switch on to reproductive phase. During third phase of crop growth, following 74 days after sowing, the rate of dry matter accumulation remained fairly high. However, other growth characters viz., height showed slow growth rate. Following 74 days, the leaf number and consequently leaf area per plant and LAI were decreased.

It is to be noted that the number of functional leaves and leaf area per plant were the two growth characters to attain its maximum value at 74 days followed by plant spread and stem diameter at 88 days and in succession. The dry matter accumulation and plant height followed at harvesting.

2. Effects of irrigation schedules :

An extract of the relevant information on growth, yield contributory characters, yield and quality of sunflower (LC 68414) as affected by irrigation schedules is presented in Table 35, with a view to scrutinize the effects of irrigation

Table 35 : An extract of relevant information showing the effects of irrigation schedules on growth, yield contributory characters and yield of sunflower (LC 69414).

Sr. No.	Particulars	Irrigation schedules	
		0.3 IW/CPE	0.6 IW/CPE
1	Mean maximum height of plant in cm at harvest	155.840	160.890
2	Mean maximum AGR of height in cm per plant per week during 46 to 60 days	38.220	39.380
3	Mean maximum plant spread (cm) at 88 days	70.850	73.120
4	Mean maximum function leaves per plant at 74 days	22.950	23.710
5	Mean maximum leaf area in sq dm per plant at 74 days	38.737	41.871
6	Mean maximum stem diameter (cm) at 88 days	2.052	2.134
7	Mean maximum leaf area index at 74 days	2.152	2.326
8	Mean maximum total dry matter(g) at harvest	152.130	154.180
9	AGR of dry matter(g) per plant per week during 46 to 60 days	20.225	21.270
10	RGR of dry matter(g) per plant per week during 32 to 46 days	0.672	0.598
11	Tap root length in cm at harvest	30.750	32.360
12	Root spread in cm at harvest	27.460	27.970
13	Days required for flowering	67.500	66.750
14	Head diameter in cm at 88 days	13.390	13.380
15	Grain yield in g per plant	32.450	35.320
16	Thousand grain weight in g	52.430	52.030
17	Number of filled grains per plant	439.500	441.700
18	Number of unfilled grains per plant	772.700	783.100
19	Total number of grains per plant	1212.400	1224.900
20	Grain yield in quingals per hectare	16.910	17.500
21	Straw yield in quintals per hectare	43.250	44.700
22	Oil yield in quintals per hectare	7.280	7.630
23	Grain to straw ratio	2.545	2.572
24	Oil percentage in seed	43.310	43.850
25	Protein percentage in seed	17.975	18.310
26	Nitrogen percentage in stem at 60 days	1.035	1.020
27	Nitrogen percentage in leaves at 60 days	2.485	2.562
28	Nitrogen percentage in head at 60 days	1.967	1.946
29	Nitrogen percentage in seed at 88 days	2.215	2.230
30	Nitrogen percentage in stem at harvest	0.469	0.442
31	Nitrogen percentage in leaves at harvest	0.643	0.631
32	Nitrogen percentage in reproductive plant parts other than seeds at harvest	0.330	0.347
33	Nitrogen percentage in seed at harvest	2.849	2.927

schedules under the soil and climatic conditions prevailed during the investigation.

In addition to the common irrigation given just after sowing to all treatment plots, 10 mm and 4 mm rainfall was received on 6th and 10th day after sowing respectively. It was quite timely rainfall for seed germination. However, 25, 17 and 2 mm rainfall received on 33rd, 34th and 35th days i.e. immediately after second irrigation as per 0.6 WUF, and 30 mm rainfall on 61st day after sowing i.e. immediately after third irrigation as per 0.6 WUF, played very important role in making the irrigation treatments (0.3 WUF and 0.6 WUF) ineffective. The rainfall (52 mm and 5 mm) received on 45th and 46th day respectively, in addition to that mentioned above was at right time i.e. at start of flowering. Also on 72nd and 73rd day, the rainfall (20 mm and 23 mm) at seed formation was quite sufficient for making the irrigation treatments ineffective.

The growth characters namely stem diameter at 88 days leaf area at 74 days and yield contributory characters such as grain yield per plant, grain to straw ratio were significantly higher in 0.6 WUF treatment as compared to those in 0.3 WUF treatment. All other growth characters viz. plant height, number of functional leaves, leaf area etc. per plant were significantly higher due to 0.6 WUF schedule as compared to 0.3 WUF schedule on dry matter accumulation at 32 days was found to be significantly higher due to 0.6 WUF schedule as compared to 0.3 WUF schedule. Following 46 days, most of the

growth charactors and yield contributory characters were not affected differentially by irrigation schedules. Ultimately the grain yield per hectare was not differentially affected by these two irrigation schedules. As mentioned above, the rainfall received during the crop growth period was sufficient in amount and was well distributed. Sunflower requires comparatively less amount of water (Doulay et al. 1971) as the consumptive use of water for sunflower crop in Rajastan was observed to be 94 mm. Receipt of sufficient rainfall and comparatively less water requirements of sunflower, made the irrigation schedules ineffective.

3. Effect of "no irrigation" Vs. irrigation :

In order to compare the effects of irrigation application with that of 'no irrigation', an extract of relevant information on the effects of no irrigation Vs. irrigation on, growth, yield contributory characters, quality of sunflower, (AC 68414) and nitrogen percentage in the different plant parts at various growth stages are presented in Table 36.

The growth characters viz. mean plant height, plant spread, functional leaves, leaf area, stem diameter, total dry matter per plant were significantly higher to the extent of 16.45 cm, 8.38 cm, 1.45, 11.342 sq dm, 0.225 cm, 18.97 respectively than that in 'no irrigation' treatment at harvest. The studies on growth analysis indicate that the AGR of plant height was 38.62 cm per plant per week during 46 to 60 days as compared to that 35.50 cm per plant per week in 'no irrigation' treatment. The AGR of dry matter was 20.810 g per

Table 36 : An extract of relevant information showing the effects of nitrogen Vs. irrigation on growth yield contributory characters and yield of sunflower (LC 60414)

Sr. No.	Particulars	No irrigation	Vs. irrigation
1	Mean maximum height of plant (cm)at harvest	141.510	157.960
2	Mean maximum AGR of height (cm) per plant per week during 46 to 60 days	35.500	38.620
3	Mean maximum plant spread in cm at 80 days	63.600	71.980
4	Mean maximum function leaves per plant at 74 days	21.410	23.360
5	Mean maximum leaf area in sq dm per plant at 74 days	28.958	40.300
6	Mean maximum stem diameter in cm at 88 days	1.868	2.093
7	Mean maximum leaf area index at 74 days	1.600	2.238
8	Mean maximum total dry matter(g)at harvest	134.100	153.150
9	AGR of dry matter(g) per plant per week during 46 to 60 days	16.260	20.810
10	NGR of dry matter(g) per plant per week during 32 to 46 days	0.626	0.634
11	Tap root length in cm at harvest	27.860	31.550
12	Root spread in cm at harvest	31.600	27.520
13	Days required for flowering	65.830	67.120
14	Head diameter in cm at 88 days	12.060	13.380
15	Grain yield in g per plant	28.050	33.880
16	Thousand grain weight in g	47.250	52.230
17	Number of filled grains per plant	397.000	440.700
18	Number of unfilled grains per plant	680.000	777.900
19	Total number of grains per plant	1077.000	1218.000
20	Grain yield in quintals per hectare	14.030	17.210
21	Straw yield in quintals per hectare	35.090	43.970
22	Oil yield in quintals per hectare	6.270	7.450
23	Grain to straw ratio	2.496	2.559
24	Oil percentage in seed	44.540	43.530
25	Protein percentage in seed	16.165	18.142
26	Nitrogen percentage in stem at 60 days	0.875	1.024
27	Nitrogen percentage in leaves at 60 days	2.430	2.520
28	Nitrogen percentage in head at 60 days	1.838	1.957
29	Nitrogen percentage in seed at 88 days	2.078	2.223
30	Nitrogen percentage in stem at harvest	0.373	0.455
31	Nitrogen percentage in leaves at harvest	0.560	0.637
32	Nitrogen percentage in reproductive plant parts other than seeds at harvest	0.273	0.338
33	Nitrogen percentage in seed at harvest	2.587	2.888

plant per week due to irrigation as against the AGR of 16.260 g per plant per week in 'no irrigation' treatment during 46 to 60 days after sowing. The value for RGR of dry matter was 0.634 g per/plant week due to irrigation application, while it was only 0.626 g per plant per week in 'no irrigation' treatment at 32 to 46 days after sowing. The tap root length was increased by 3.69 cm due to irrigation over 'no irrigation' treatment but the increase was not significant. The mean root spread was significantly higher (31.68 cm) due to irrigation treatment as compared to 27.52 cm in 'no irrigation' treatment. The mean number of days required for flowering were significantly higher due to irrigation treatment (67.12 days) as compared to that (65.83 days) due to 'no irrigation' treatment.

The head diameter was significantly higher upto 13.38 cm due to irrigation treatment as against 12.06 cm due to 'no irrigation' treatment at 88 days. It is seen that the mean grain weight per plant was 33.88 g due to irrigation treatment as compared to 28.05 in 'no irrigation' treatment. The difference was significant. The mean thousand grain weight was significantly higher upto 52.23 g due to irrigation application as compared to 47.25 g in 'no irrigation' treatment. The filled grains per plant were not significantly increased due to irrigation application while the unfilled and total number of grain per plant were found to be significantly higher (777.9 and 1218.0 grains per head) respectively due to irrigation application as compared to that in 'no irrigation'

treatment (680.0 and 1077.0 grains per head respectively).

The mean grain yield, straw yield and total oil yield per hectare as well as the grain to straw ratio, i.e. all the attributes were significantly increased due to irrigation treatment over 'no irrigation' treatment. The mean grain yield, straw yield and total oil yield per hectare was 17.21, 43.97, 7.45 quintals per hectare due to irrigation as compared to that 14.03, 35.09 and 6.27 quintals per hectare respectively under 'no irrigation' treatment. The grain to straw ratio was also found to be significantly higher due to irrigation (2.559) over 'no irrigation' (2.496) treatment.

In respect of quality studies, the oil percentage was increased due to 'no irrigation' treatment over irrigation treatment but the increase was not significant. Reverse was the case as regards to the protein percentage in sunflower seed (EC 68414). The protein percentage was significantly increased due to irrigation (18.142 per cent) as compared to that in 'no irrigation' (16.165 per cent) treatment. The chemical analysis of different plant parts for nitrogen percentage at various stages, indicate the higher nitrogen percentage due to irrigation treatment as compared to that in 'no irrigation' treatment. At 60 days after sowing, the nitrogen percentage in stem, leaves and head were 1.024, 2.520 and 1.957 per cent as against, 0.875, 2.430 and 1.838 per cent respectively in 'no irrigation' treatment. At 88 days, the seed analysis for nitrogen percentage indicate that, due to irrigation application

the nitrogen percentage was much higher (2.223 per cent) in sunflower seeds (EC 68414) as compared to that in 'no irrigation' treatment (2.078 per cent).

At harvesting, the nitrogen percentage in stem, leaves, reproductive plant parts other than seed and seed were 0.455, 0.637, 0.338 and 2.888 per cent due irrigation treatment as compared to 0.373, 0.560, 0.273 and 2.587 per cent respectively due to 'no irrigation' treatment respectively.

Thus a glance at a Table 36 revealed that all the attributes namely, growth characters, growth functions, developmental studies, yield contributory characters and yields were significantly increased due to irrigation application as compared to that in 'no irrigation' treatment. However, the characters namely root length at harvest, number of filled grains per plant and oil percentage in sunflower seed (EC 68414) were not increased significantly due to irrigation.

It should be noted that the mean values of all the attributes presented in Table 36 as the effects of 'no irrigation' treatment are emerged of average of 25 and 50 kg nitrogen application per hectare under 'no irrigation' treatment, while those effects of irrigation treatment are emerged of average of 25, 50, 75 and 100 kg nitrogen per hectare with 0.3 WUF and 0.6 WUF treatment. Thus the comparison is in between the groups i.e. 25 and 50 kg nitrogen per hectare under 'no irrigation' with 25, 50, 75 and 100 kg nitrogen under irrigation treatments. As a result of group comparison

as described above, the effects of irrigation treatment on all attributes namely growth characters, growth function, developmental studies, yield contributory characters and yields were dominated by the inclusion of higher doses under irrigated condition as compared to lower doses with 'no irrigation' treatment.

4. Effect of nitrogen :

An extract of the relevant data on growth, yield contributory characters, yield and quality of sunflower (EC 68414) alongwith nitrogen percentage in different plant parts at various growth stages as affected by nitrogen fertilisation with and without irrigation are presented in Table 37 with a view to evaluate the effects of nitrogen fertilisation under varying conditions.

It is seen from Table 37 that nitrogen fertilisation of sunflower was reflected on growth, yield contributory characters, yield, quality and nitrogen percentage in plant parts. The growth characters namely, plant height, plant spread, stem diameter, functional leaf number, leaf area, dry matter per plant were enhanced significantly by application of nitrogen. The vegetative growth was slow in the beginning. The response to second dose over first was very markedly. With further addition of 25 kg nitrogen per hectare (i.e. 75 kg N/ha), these character no doubt showed increase in their values than that due to preceeding lower dose of nitrogen (i.e. 50 kg nitrogen) per hectare, but magnitude of response

in individual character was not to the extent as observed due to first incremental dose. The mean maximum height due to 100 kg nitrogen application per hectare and that due to the lowest level were 176.56 cm and 134.40 cm per plant respectively. These results are in confirmity with those observed by Massey (1971).

The leaf area per plant and leaf number has been considered to be reliable index of crop response to fertilizer application. The leaf number and leaf area per plant and consequently, the leaf area indices observed in the present investigation are increased significantly by nitrogen application. The increase was observed with each increase in the dose of nitrogen from 25 to 100 kg per hectare.

It is to be noted that the leaf number and leaf area were ultimately responsible for making the foliage size of the crop. These were affected by nitrogen application, thereby indicating superior growth with each higher level of nitrogen over its corresponding lower level of nitrogen. The vigorous growth made by the plant due to nitrogen application reflected in increased dry matter production per plant. This increased dry matter production is responsible for increased yield with the increased dose of nitrogen.

Nitrogen fertilization to sunflower not only favoured in stimulating vegetative growth, but also enhanced the crop yield. With a view to throw more light on effects of nitrogen

fertilization, on dry matter production, yield contributory characters, yield and quality of sunflower, it was considered worthwhile to scrutinise data more thoroughly. The relevant data information is given in Table 38.

Table 38 : An extract of relevant information showing per cent increase in the growth and yield contributory characters of sunflower (EC 68414) due to each higher level of nitrogen over its lower.

Sr. No.	Particulars	Percentage increase due to		
		N_{50} over N_{25}	N_{75} over N_{50}	N_{100} over N_{75}
1	Dry matter per plant	12.88	10.02	3.82
2	Head diameter	6.45	9.84	7.24
3	Grain yield per plant	18.51	6.06	6.26
4	Thousand grain weight	9.39	4.52	3.62
5	Number of filled grains per plant	14.34	7.72	7.49 *
6	Number of unfilled grains per plant	7.57	12.15	3.59
7	Total number of grains per plant	10.07	10.46	0.49 *
8	Grain yield per hectare	27.40	9.73	5.07
9	Straw yield per hectare	29.44	9.38	7.84
10	Oil yield per hectare	22.00	5.96	1.50
11	Oil percentage	4.37 *	3.53 *	3.33 *
12	Protein percentage	23.66	4.78	4.05

* Percentage decrease.

Evidently, the response of nitrogen to dry matter production was graded. The percent increase in dry matter production per plant was 12.88, 10.02 and 3.62 due to 50, 75 and 100 kg nitrogen over 25, 50 and 75 kg nitrogen per hectare respectively. The diameter of head was also increased by nitrogen fertilisation. The percent increase in number of filled seed per plant was 14.34, 7.72 due to 50 and 75 kg nitrogen over 25 and 50 kg nitrogen level respectively. However, there is reduction in percentage of filled seed of 7.49 per cent due to 100 kg nitrogen over 75 kg nitrogen application. The increase in filled seeds due to nitrogen fertilisation was not significant. The unfilled and total number of grains were significantly increased with increase in the dose of nitrogen, except that there was decrease in total number of grains per head due to 100 kg nitrogen over 75 kg nitrogen application per hectare.

As discussed above, the significant increase in all yield contributory character might have resulted into significant increase in yield per hectare. The seed yield was significantly increased upto 75 kg nitrogen application. The percentage increase in seed yield was 27.40, 9.73 and 5.07 due to 50, 75 and 100 kg nitrogen over 25, 50 and 75 kg nitrogen per hectare respectively.

The percentage increase in straw yield also showed same trend as that of seed yield. It is seen that the oil

yield was significantly increased upto 50 kg nitrogen application per hectare. The percentage increase in oil yield was 22.00, 5.96 and 1.50 per cent due to 50, 75 and 100 over 25, 50 and 75 kg nitrogen per hectare respectively. With 50, 75 and 100 kg nitrogen application per hectare, oil percentage was decreased by 4.37, 3.53 and 3.33 per cent over that of 25, 50 and 75 kg nitrogen per hectare. The trend as regards to the protein percentage was different than that observed in oil percentage. The protein percentage was increased significantly and the percentage increase was 23.60, 4.78 and 4.05 due to 50, 75 and 100 kg nitrogen over 25, 50 and 75 kg nitrogen per hectare. The nitrogen percentage in different plant parts was higher at 60 days after sowing but it went on decreasing with advance, in the age of crop, indicating flow of nitrogen from stem and leaves to the reproductive parts.

5. Effect of nitrogen without irrigation :

Two levels of nitrogen viz. 25 and 50 kg nitrogen per hectare were tried under unirrigated conditions in order to get additional information for optimum dose of nitrogen under rainfed conditions. It may be noted that during the crop growth period, rainfall received was 188.8 mm which was quite well distributed. A relevant information regarding the effects of nitrogen levels without irrigation on growth, yield contributory characters, yield and quality are given in Table 37.

It was observed that growth of plant measured in terms of height, number of leaves, stem diameter was not affected significantly, due to 50 kg nitrogen application per hectare,

as compared to 25 kg nitrogen per hectare with 'no irrigation' treatment. However, other growth characters namely plant spread, leaf area and consequently leaf area index, total dry matter were increased significantly due to 50 kg nitrogen over 25 kg nitrogen application per hectare with 'no irrigation' treatment.

Root spread and root length was also not affected significantly. Flowering period was remained same due to 50 and 25 kg nitrogen application per hectare. The grain yield per plant was significantly higher (31.02 g per plant) due to 50 kg nitrogen per hectare as compared to that (25.09 g per plant) due to 25 kg nitrogen per hectare.

Detailed scrutinity of data in Table 39 indicates that the dry matter production was 15.20 per cent more due to 50 kg nitrogen when compared with that in 25 kg nitrogen per hectare. The grain yield per plant was 23.63 per cent higher due to 50 kg nitrogen over 25 kg nitrogen application per hectare. The number of filled, unfilled and totals number of grains per plant were not affected significantly and the percentage increase due to 50 kg nitrogen was 6.96, 8.26, and 7.78 respectively over 25 kg nitrogen per hectare. The grain yield per hectare due to 50 kg nitrogen application was 27.20 per cent more as compared to that in 25 kg nitrogen application without irrigation. The value for straw yield was 29.04 per cent. However, this increase was not significant. The oil yield per hectare was 22.91 per cent higher due to 50 kg nitrogen over 25 kg nitrogen application per hectare without

Table 39 : An extract of relevant information showing percentage increase in dry matter yield contributory characters yeild and quality of sunflower due to 50 kg nitrogen over 25 kg nitrogen per hectare with 'no irrigation' and irrigation treatment.

Sr. No.	Particulars	Percentage increase due to 50 kg N/ha over 25 kg N/ha	
		Unirrigated	Irrigated
1	Dry matter per plant	15.20	12.88
2	Head diameter	6.76	6.45
3	Grain yield per plant	23.63	18.51
4	Thousand grain weight	6.92	9.39
5	Number of filled grain per plant	6.96	14.34
6	Number of unfilled grains per plant	8.26	7.57
7	Total grains per plant	7.78	10.07
8	Grain yield per hectare	27.20	27.40
9	Straw yield per hectare	29.04	29.44
10	Oil yield per hectare	22.91	22.00
11	Oil percentage	4.68 *	4.37 *
12	Protein percentage	21.53	23.66

* Percentage decrease

irrigation. In respect of quality studies, it was observed that oil percentage was reduced due to 50 kg nitrogen as compared to that in 25 kg nitrogen treatment with consequent increase in the protein content of sunflower seed. However, the decrease in oil percentage due to 50 kg nitrogen applicatio

was not significant while the increase in protein content of sunflower seed was significant due to 50 kg over 25 kg nitrogen application per hectare with 'no irrigation' treatment.

Thus it should be noted that with the receipt of sufficient and well distributed rainfall, the grain yield of sunflower and consequently the total oil yield per hectare was significantly increased with 50 kg nitrogen application under unirrigated condition. These findings indicate that there is scope for increasing dose of nitrogen beyond 50 kg per hectare, provided that there is sufficient and timely rainfall.

In order to see the comparative effects of two lower levels of nitrogen viz. 25 and 50 kg nitrogen per hectare under irrigated and unirrigated conditions, the relevant data are given in Table 39.

Scrutinity at data in Table 39 indicate that percentage increase in the yield contributory characters, yield and quality of sunflower due to 50 kg nitrogen over 25 kg nitrogen per hectare with irrigation and without irrigation were not differentially affected (Table 39). This is due to the fact that the rainfall received during whole crop growth period was sufficient in amount and was well distributed. These findings thus revealed that with the receipt of sufficient rainfall, application of irrigation was not essential in increasing the yield of sunflower when fertilized upto 50 kg nitrogen per hectare.

CHAPTER VI

SUMMARY AND CONCLUSION

CHAPTER VI

SUMMARY AND CONCLUSION

An investigation was carried out to study the " effects of irrigations scheduled as per Water Use Factors under varying conditions of nitrogen fertilization on growth, yield and quality of sunflower (Helianthus annuus L.) variety EC 68414 in Kharif season ", of 1973 at the Central Campus, Mahatma Phule Krishi Vidyapeeth Farm, Rahuri. The experiment was conducted with two irrigation schedules (0.3 and 0.6 Water Use Factors) and four levels of nitrogen (25, 50, 75 and 100 kg per hectare). Additional two treatment combinations of 25 and 50 kg nitroge.. per hectare with 'no irrigation' treatment were included. The total treatment combinations, thus were ten. The experiment was laid out in factorial randomised block design with three replications. As a basal application, 40 kg P_2O_5 and 20 kg K_2O per hectare were applied at the time of sowing. The dose of nitrogen was completely applied at the sowing time in 'no irrigation' treatment plots. For 0.3 WUF and 0.6 WUF treatment plots, the nitrogen dose was splited up. Two third dose of nitrogen was applied at the time of sowing in all irrigation plots. Remaining one third dose was applied at 25 and 29 days after sowing in 0.3 and 0.6 WUF treatment plots respectively. The important findings are summarized below.

1. The receipt of rainfall (44 mm) on 33rd day and (30 mm) on 61st day immediately after second and third irrigations respectively, given as per 0.6 WUF schedule, played important role

in making the irrigation treatments (0.3 WUF and 0.6 WUF) ineffective. The rainfall (52 mm) received at 45 days, in addition to that mentioned above was at right time i.e. at start of flowering and 20 and 23 mm at 72nd and 73rd day after sowing i.e. at seed formation, was also sufficient. Thus, the timely, adequate and well distributed rainfall received during the investigation, was sufficient for normal crop growth. Due to these conditions prevailed during investigation, differences in most of the growth, yield and quality characters of sunflower (EC 68414) due to irrigation treatments (i.e. 0.3 and 0.6 Water Use Factor) were not found to be significant.

2. It was however observed that the irrigation treatment gave significant difference in growth, yield and quality of sunflower (EC 68414) as compared to that in 'no irrigation' treatment. But it should be noted that 'no irrigation' Vs. irrigation was the group comparison and the higher levels of nitrogen included in the later group of treatment dominated the effects of irrigation treatment over 'no irrigation' treatment. If the group comparison was found to be significant then the further object, aimed at, was to find out the treatment, giving significant results within the respective group.

3. It has been observed that the differences in all the growth characters such as plant height, plant spread, functional leaf number and consequently leaf area, etc. were found to be affected significantly due to levels of nitrogen. The significan

increased growth due to graded levels of nitrogen was reflected in production of increased dry matter. Ultimately, the grain yield per plant, thousand grain weight, number of unfilled and total number of grains per plant increased significantly with the increase in level of nitrogen except that the number of filled grain per plant were not affected significantly due to levels of nitrogen. The days required for flowering were increased significantly with the increase in levels of nitrogen application. The tap root length was not affected but root spread was significantly decreased with the increase in levels of nitrogen application. Thus, nitrogen fertilisation to sunflower (EC 68414) was beneficial and produced higher grain yield, straw yield and oil yield per hectare significantly. The seed yield was significantly increased upto 75 kg nitrogen application per hectare. The oil percentage significantly decreased with the increase in levels of nitrogen upto 75 kg per hectare. However, oil yield in quintals per hectare increased significantly upto 50 kg nitrogen application per hectare only. Protein percentage in sunflower seed increased significantly with the increase in levels of nitrogen application upto 100 kg per hectare. Thus, the protein percentage increased while the oil percentage decreased with the increase in levels of nitrogen application.

4. It was observed that nitrogen fertilisation at the rate of 50 kg per hectare with 'no irrigation' treatment gave significant increase in all the growth attributes namely plant height, plant spread, leaf area and dry matter per plant as

compared to those at the rate of 25 kg nitrogen per hectare. The tap root length was not affected due to these two levels of nitrogen viz. 25 and 50 kg per hectare. The number of days required for flowering was not affected due to increased nitrogen fertilization in 'no irrigation' treatment. The root spread was also not found to be affected. As regards the yield contributory characters, the grain yield per plant was increased significantly by 50 kg nitrogen over 25 kg nitrogen without irrigation. However, other characters, namely thousand grain weight, number of filled, unfilled and total number of grains per plant were not affected due to 50 kg nitrogen over 25 kg nitrogen application per hectare. Other yield contributory characters, namely seed yield and oil yield per hectare were significantly increased due to 50 kg nitrogen per hectare over 25 kg nitrogen per hectare without irrigation. The straw yield was not affected, but the grain to straw ratio was significantly increased due to 50 kg nitrogen over 25 kg nitrogen application per hectare without irrigation.

The oil percentage was not significantly affected but protein percentage was significantly increased with the 50 kg nitrogen over 25 kg nitrogen application per hectare without irrigation.

In respect of nitrogen percentage in different plant parts of sunflower, leaf was the richest in nitrogen content among all the plant parts at 60 days after sowing. At harvest the nitrogen percentage was reduced from all plant parts i.e. stem and leaves and the seed was the richest in nitrogen content.

It can be said that with the receipt of sufficient and well distributed rainfall, application of 50 kg nitrogen per hectare with 'no irrigation' gave significantly higher yields and there is scope for increasing the dose of nitrogen beyond 50 kg to get additional higher yields.

Thus, it may be said that under sufficient and well distributed rainfall conditions, supplementary irrigation is not necessary to sunflower. The seed yield of sunflower increased by 75 kg nitrogen application per hectare, while the oil yield increased only by 50 kg nitrogen application per hectare. When irrigation is not given and the rainfall is satisfactory, nitrogen application to the extent of 50 kg per hectare is advantageous. As these findings are obtained for one season these treatments should be tried for some more season in order to confirm the results.

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