INFLUENCE OF IRRIGATION ON GERMINATION, GROWTH AND YIELD OF SESAMUM

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DECLARATION

I hereby declare that this thesis entitled "Influence of irrigation on germination, growth and yield of sesamum" is a bona fide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me any degree, diploma, associateship, fellowship or other similar title at any other University or Society.

Vellayani,
November, 1985.

THOMAS MATHEW

CERTIFICATE

Certified that this thesis,entitled "Influence of irrigation on germination, growth and yield of sesamum" is a record of research work done independently by Shri. THOMAS MATHEW, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to him.

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INTRODUCTION

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India is having the largest area under oil seed crops in the world. At present it occupies about ten per cent of the total cropped area constituting 16.83 million hectares with an annual production of 9.01 million tonnes. The annual internal demand for edible oil is estimated as 3.80 million tonnes, while only 2.70 million tonnes are available within the country. Consequently the country is forced to import 1.10 million tonnes of vegetable oil valued at Rs.700 crores annually (Kondap et al., 1983). In course of time the anticipated production will be much lower when we take into account of the anticipated demand of oil. This situation calls for concerted research efforts to increase the production of oil seeds in the country.

Sesamum or gingelly is regarded as one of the oldest oil yielding plants known to man. In India, the white seed is known as 'Safed til' and the black one as 'Kale til'. Sesamum ranks third in area with 14 per cent of the total area under oil seed crops. Each year it is grown to an area of 2.40 lakh hectares and rolls out 4.50 lakh metric tonnes of oil rich seeds. The average yield level at farmer's field condition is 2.77 quintals per hectare (Rai et al., 1984). The major constraints confronted with low level of yields are many. The crop is largely grown in marginal and sub marginal lands with low moisture contents and fertility, where the risks of cultivation are very high. However, the investigations going on in this crop in different centres indicate that yield levels of 8 to 10 quintals per hectare could be obtained if the agronomic potential is fully exploited. The potential of oil seed crop is much greater under irrigated conditions and possibilities exist to increase the production of oil seed crops by increasing the area under irrigation.

In Kerala, sesamum covers an area of 14,153 hectares with an annual production of 3648 tonnes of seeds. The current state average yield per hectare is 257 kg per hectare (Anon., 1985). It is mainly grown as a catch crop during the summer season in the rice fallows of Onattukara tract utilizing the residual moisture and fertility. 'Onattukara' is an important rice growing tract of Kerala covering an area of 68340 hectares. Systematic crop rotation is being followed in this tract where sesamum is invariably raised after the second crop of rice.

The soil of the tract is sandy loam and is well drained. As the crop is raised with the residual soil moisture, often it becomes a major problem for attaining the required soil moisture for proper germination, establishment and growth of the plants. The excess or inadequate soil moisture at the time of sowing leads to very poor plant density. Since the crop is raised under rainfed condition, lack of sufficient soil moisture during the critical stages of growth also results in poor yield. Hence the optimum soil moisture at the time of sowing and during the later stages of growth are considered as the major requirements in increasing the production of sesamum in Kerala.

Preliminary research conducted at R.R.S. Kayamkulam has revealed that this crop responds very well to irrigation. Similarly studies conducted under laboratory conditions have shown that under optimum soil moisture conditions, uniform germination is obtained. It is also noticed that either an excess or deficiency of soil moisture affects the germination of sesamum seeds resulting in poor stand (Kunju and Salam, 1980). Sharma and Reddy (1983) reported that first irrigation should be done immediately after sowing to aid germination and seedling growth and a second irrigation is given when the plants are about 15 cm in height. Subsequent irrigation may be practised at an interval of 15-20 days depending upon the soil type and weather conditions.

Scheduling of irrigation is decided based on one or other criteria, such as soil moisture tension, soil moisture depletion in the root zone, actual evaporation, physiological stages of plants and climatic approach.

Taking into consideration of all these aspects, the present investigation was undertaken with the following objectives.

1. To determine the optimum soil moisture level for obtaining uniform germination of sesamum under field conditions.

2. To study the effect of initial soil moisture conditions on growth and yield of sesamum.

3. To find out the influence of irrigation at the vegetative and reproductive stages on the growth and yield of sesamum.

4. To work out the economics of sesamum cultivation in the rice fallows of 'Onattukara' under different soil moisture regimes.

REVIEW OF LITERATURE

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An experiment was conducted to determine the influence of irrigation on germination, growth and yield of sesamum in Onattukara tract with main treatments as sowing the seeds at different intervals after the initial irrigation. The sub plot treatments consisted of no irrigation during the growth phase, one irrigation during vegetative phase, and two irrigations, one at vegetative and the other at reproductive phases. Research done on the effects of irrigation on growth yield and quality of sesamum was reviewed and presented below. Relevant works done on other similar crops are also included in the review wherever the review is insufficient in sesamum.

Effect of irrigation

Soil moisture is one of the most limiting factors in crop production. Higher yields can be expected when there is adequate soil moisture during cropping period.

One of the basic requirements of germination of a seed is moisture. Other conditions like favourable temperature and oxygen supply are also essential. Germination is the crucial and final event in the life of a seed and it brings about convenient means of distributing plant population throughout the area of adaptation.

Moisture is required for rehydration of the seed for breaking down the reserve materials and to support the increased respiratory activity. Seed moisture content required for germination varies with the species. Several field conditions can reduce the availability of water to the extent that critical moisture content for germination cannot be attained. Excessive soil moisture displaces the oxygen and causes poor germination. Hence determination of optimum soil moisture for uniform germination becomes very important.

1. Germination

Triplett and Tesar (1960) showed that detrimental effects of soil moisture deficit on seedling emergence could be somewhat alleviated by compacting the seedbed. Bhat (1966) observed highest percentage of germination in alluvial soil at 18 per cent in the case of linseed and it was lowest at 13.5 per cent. Kaufmann (1969) found that the seeds of sunflower have taken three days for attaining 50 per cent of germination at constant soil water potential of zero bar and 8 days at a soil water potential of -4.1 bars. The germination was slowed down at -8 bars.

In studies conducted with chickpea, pea and vetch on water uptake under stress conditions, Hadas and Russo (1974) revealed that the amount of water taken up decreased with decrease in osmotic potential and germination was unaffected at osmotic potential ranging from zero to -3.8 bars. Manohar and Mathur (1975) observed 92.5 per cent germination in pea seeds where there was no water stress. The germination percentage was decreased when the moisture stress was increased.

Rao et al. (1975) obtained higher germination percentage in sorghum, bengalgram, cotton and safflower at 28 per cent moisture content in the top ten cm layer of black soil than that at 32 per cent moisture content.

Agarwal and Batra (1977) observed that rate of germination of mustard seeds in sandy loam soil was not affected by moisture content of 10 - 15 per cent in the uncrusted condition, but it was greatly reduced at the ten per cent moisture content where the soil was crusted.

El-Sharkawi and Springueli (1977) conducted studies on germination of crop plant seeds under reduced water potential and found that in the case of wheat, barlery and sorghum, the seeds responded differently to reduced water potential. The germination parameters including plumule emergence and elongation as well as radicle emergence behaved differently to the reduced water potential. The plumule emergence is generally more sensitive to reduced water potential than radicle emergence. The response of plumule elongation to moisture tension was most critical of all. The threshold value for plumule elongation was -7 bars in wheat while in barley and sorghum it was -13 and -10 bars respectively.

Delouche (1980) reported that species of graminacious family require a moisture content of 32 to 35 per cent for germination, while in cotton, soyabean and pea nut 50 to 55 per cent moisture is required.

Adwi et al. (1981) studied the effect of different soil moisture regime on the germination and seedling growth of oil seed crops and found that in the case of flax, safflower and oil seed rape, the seed germination and seedling growth varied between cultivars and with differing soil moisture regimes.

Singh et al.(1981) obtained highest germination percentage by soaking seeds in water for 24 hours prior to sowing in the case of large sunflower seeds.

Sesamum is a drought tolerant crop, but the shortage or excess soil moisture at the time of sowing may seriously affect the seed germination and subsequent establishment of the crop (Weiss, 1971).

Vora et al. (1975) observed that moderate moisture stress at germination decreased the catalase activity in sesamum seedlings at 48 hours of germination but increased at 24 hours and 72 hours.

Kunju and Salam (1980) studied the germination of sesamum seeds under different soil moisture regimes namely zero, 10, 20, 30 and 40 per cent moisture in laboratory conditions and obtained a maximum germination of 97.5 per cent at 20 per cent soil moisture content. Germination decreased beyond 20 per cent moisture. No germination was observed at zero and ten per cent soil moisture. On the contrary, Krishnakumar (1981) found that maximum germination was obtained at 12 per cent soil moisture oontent. But when the moisture content was increased to 18 per cent a reduction in germination was started. Similarly decrease in soil moisture to 11 per cent also causes reduction in germination.

Heikal *et al*. (1982) studied the effect of water stress on germination of sesamum seeds and found that the rate of germination and final germination percentage and water uptake by sesamum seeds decreased by increasing osmotic stress from zero to -8 x 105 pa.

2. Growth and Growth Components

The growth and development of plants depend on the availability of soil moisture. Water stress conditions cause considerable damages to plants and the extent of damage depends upon the physiological stages and degree of water stress.

Miltrope (1945) reported that leafarea was reduced in flax under soil moisture stress due to rapid drying off of leaves, while there was no reduction in leaf size.

Clarkson and Russel (1976) noticed that dry weight of annual Medicago sp. was reduced by moisture stress.

Sivakumar and Shaw (1978) presented the relationship between leaf water potential and R.G.R. of soyabean. Relative growth rate increased as leaf water potential increased. They also observed reduction in growth rates with low water potential.

Matlock (1955) reported that the water requirement of groundnut reached maximum during the stages of flowering and pod development in which most of the dry matter gets accumulated.

The response of potted groundnut plant to different moisture levels at 3 stages of growth has been reported by Ochs and Wormer (1959). The three growth stages studied were (a) germination to flowering (b) flowering to pod formation and (c) pod maturity period. The different moisture levels tried were 25, 50, 75 and 100 per cent of available soil moisture before it was restored to field capacity. In all stages it was found that plants growing in soil at field capacity produced the highest dry matter. The total number of flowers produced by the plants was reduced considerably by drought conditions of flowering period.

Lin et al. (1963) reported that due to drought during the first 50 days before flowering in groundnut, all the plants were shorter and showed poor root distribution, less branching and smaller leaves containing less water than well watered plants. The number of flower and flowering also reduced. There was a positive correlation between the number of flowers and final yield.

Reddy et al. (1968) conducted an experiment with C-301 variety of groundnut in sandy loam soils during kharif and reported that flowering and fruiting stages were very sensitive for moisture stress.

Lingam (1969) conducted an experiment on sandy loam soils at Rajendranagar during rabi season to study the response of groundnut to varying phosphorus and potash levels at different levels of soil moisture depletion (25, 50 and 75 per cent in A.S.M.). He observed that plant height and dry matter production per plant and the pod yield increased with higher level of moisture.

Decrease in total dry matter yield in groundnut due to increase in moisture tension was recorded by Vivekanandan and Gunasena (1976).

Boote and Hammond (1981) studied the effect of drought on vegetative development of pea nut and revealed that groundnut varieties grown without water during early peg and pod formation showed 3-5 nodes shorter than normal plants even when the stressed plants were subjected to rewatering. The number of pegs and pods 77 days after sowing were 51 per cent less than the normal plants and pod maturity was delayed by 10 - 11 days.

Studies carried out on watering intervals on flowering, growth and yield components in pea nut by Ishaq (1982) revealed that pod losses were smaller with longer watering intervals. Number of pod per plant was the yield component most severely affected by watering intervals. LAI increased with frequent watering and reached 5.8. N.A.R. decreased at first and increased with the pegging of gynophores.

Robelin (1967) conducted an experiment to study the effects and after effects of drought on growth and yield of sunflower. Dry matter accumulation in the head was reduced by drought, this being greater for all treatments applied from the small flower bud stage to maturity.

Rollier and Pierre (1972) have reported that sunflower, when subjected to moisture stress for 1-6 weeks after the beginning of flowering, transpiration rate showed rapid adaptation to moisture stress. Transpiration did not return to the level of control after the period of moisture stress. LAI was one of the characters most sensitive to moisture stress. Significant yield reduction was observed with stress period extending for a full week.

Battacharya and Sarkar (1978) observed from the trials conducted in sunflower with irrigation at 20, 40, 60 or 80 per cent A.S.M. that the value for LAI, R.G.R. and N.A.R. increased with increase in soil moisture. The values obtained with irrigation at 60 per cent A.S.M. were LAI = 0.81, R.G.R. = 0.49 g/g/day and N.A.R. = 7.8×10^{-4} g/cm^2/day.

Dry matter production was highest with irrigation at 60 per cent A.S.M. (Pal, 1979).

Somasundaram and Iruthayaraj (1979) observed that the LAI and C.G.R. in sunflower were higher with irrigation scheduled at an IW : C.P.E ratio of 1.05 than with irrigation at other IW : C.P.E ratios. The effects of irrigation regimes on N.A.R. and R.G.R. were not significant.

Andhale and Kalbhor (1980) reported that irrigation increased dry matter accumulation from 24 to 158 g/plant and seed yield from 28 to 54 g/plant.

Maro (1981) studied the physiology of shoot growth and found that when the young seedlings were subjected to a brief period of water stress, the pattern of leaf growth in sunflower changed.

Merrien *et al*. (1981) reported that leaf area, L.A.D. and seed production all increased with increasing water supply. It was further confirmed by measurements of photosynthesis and transpiration that leaf area was much more dependant on water status of the plant than N.A.R.

There were no cytological changes in leaves with relative water content 55 per cent. Leaves with R.W.C. 45 per cent did not recover on rewatering and the cells were completely disrupted. Between 45 to 55 per cent R.W.C., isolated parenchyma cells showed minor cytoplasmic alterations in mesophyll and vascular tissues and resulted in the formation of abnormal material in the xylem vessels (Robb and Busch, 1982).

Unger (1983) observed that sunflower plants irrigated at budding were 19 cm taller than irrigated at flowering or late flowering. Irrigation at flowering or late flowering was important for seed development. Highest seed and total dry matter yields were obtained with full irrigation treatment. Irrigation at budding favoured leaf and stem dry matter production.

Lazim and Nadi (1974) conducted an irrigation trial with sesamum cultivars and found that there were differences among the cultivars in plant height, number of branches per plant, number of nodes per plant and leaf area. They also found that increase in plant density decreased the leaf area and leaf dry weight.

Vora et al. (1975) reported that in the case of sesamum grown under soil moisture stress, the amount of ascorbic acid bound to macro molecules increased, but its utilization decreased, and decreased the dry matter production.

Youssef at al. (1982) made anatomical studies of sesamum at flowering and found that stem diameter increased with increase in water supply and was associated with increased vascularization and cortex development. Low water supply induced xerophytic modifications. It was concluded that variation in the supply of moisture led to quantitative but not qualitative anatomical modifications.

The above review brings about the fact that soil moisture stress causes deleterious effects on growth thereby reducing the leaf number, leaf size, number of branches etc and results in the reduction of seed yield.

3. Root Growth and Development

Moisture stress affects growth rate at various stages from germination of the seeds to the grain filling stage.

The root system of a plant varies in its extent in terms of weight and length according to the availability of soil moisture.

Kmoch et al. (1957) in wheat, obtained a dense shallow root system in soil receiving no irrigation. Roots developed under soil moisture stress were thin and had more branches. However, the root weight was reduced. Bennet and Doss (1960) and Doss et al. (1960) reported that the forage crops receiving supplemental irrigation were having shallow root system.

Muhammed et al. (1965) had correlated the extent of root growth with the availability of soil moisture in crops like oat, barley and wheat. On the contrary, Peters and Runkles (1967) reported that the rate of root growth decreased with increase in water stress, however the growth of root was less affected by water shortage than that of aerial parts so that the overall root: shoot ratio was increased.

The growth of the tap root of Sinapis alba took place under low soil moisture contents and high relative humidity (Vartarian, 1967).

Yu et al. (1969) found that in the case of sunflower and tomato grown under flooded condition showed significantly reduced growth rate, dry weight, and root length as compared with those under unflooded conditions. Flooding damage was less severe in sunflower than in the other plants.

In green gram maximum root dry weight was obtained at an optimum moisture content of 50 per cent (Varma and Rao, 1975).

Kramer (1978) reported that larger root system was produced in soils containing abundance of soil moisture in situations of good aeration. Root : shoot ratio was found to be larger under limited supply of water.

Sheelavanthar et al. (1980) studied the rooting pattern of indigenous and exotic varieties of safflower and found that under dry land condition the L.V.A -1 had deep and well extended root system with numerous secondary and brace roots for adaptation to dry land conditions.

The root tissues of sunflower contracted as much as 25 per cent of their turgid volume when the leaf water potential fell down to -15 bar (Faiz and Weatherley, 1982).

Studies were carried out on root porosity of groundnut with irrigations at IW : C.P.E ratios of 0.45, 0.60, 0.75 and 0.90 to depths of 2, 4 and 6 cm. Root porosity increased with increase in depth of irrigation and increasing IW : C.P.E ratio (Khan, 1983).

It is quite evident from the review that the rate and extent of root growth are controlled by soil moisture. The overall growth of the plant declines with increase in moisture stress, but the root growth is less influenced than shoot growth.

4. Yield and Yield Components

Mazzani and Allievi (1969) concluded from experiments in Venezuela that sesamum yields were closely related to hydrologic balances. A deficiency in the balance during the growth cycle affects the seed production adversely. Phadmis et al. (1969) reported that the highest contribution to total seed yield per plant in sesamum was made by number of capsules per plant and capsule length.

Abdou et al. (1970) observed from field trials that the frequency and quantity of irrigations influenced the seed yield of sesamum. Thirteen irrigations of 450 cubic metre/ac at 6 day interval produced the highest yield. But irrigation of 150 m^3/ac at 6 day interval was the most economic method.

Garcia et al. (1971) in a study of the agroclimatic requirements of sesamum, reported that yields were reduced by an excess or a deficiency of water, an excess caused an abrupt drop in yield, but with a small excess yields remained at a high level.

Dabral and Holker (1971) reported that the seed yield per plant in sesamum was positively correlated with the number of capsules per plant, capsule length, weight of seeds per capsule and 100 seed weight.

Ramachandran _et al_. (1972) observed that yield of sesamum variety TMV-3 grown under irrigation was closely correlated with the number of branches per plant.

In sesamum the leaf diffusion resistance increased markedly as the humidity gradient increased (Camacho _et al_. 1974).

Osman and Khidir (1974) studied 14 characters in a collection of 42 sesamum cultivars during two years and concluded that number of seeds per pod, number of pods per plant, plant height, days to flowering and to maturity were highly positively correlated with seed yield and with one another.

Nicastro (1977) studied the relations between rainfall and growth and yield of sesamum. The cases in which the deficiency or excess of rainfall occurred were determined for periods from sowing to flower formation, from flower formation to greatest plant weight, and from greatest plant weight to maturity.

El-Serogi *et al*. (1977) from the field trials in Egypt observed that irrigation at 25 to 30 per cent available soil moisture depletion decreased the seed yield. Irrigation at 45 to 50 per cent A.S.M. depletion had given the highest yield of 3.69 andeb/Fedden and it has given the highest water use efficiency.

Providing adequate soil moisture at critical stages was found to be conducive for getting maximum yield in sesamum at Chalakudy (Anon., 1978).

Trials conducted on the effects of frequency and level of irrigation of sesamum indicated that seed yields increased with irrigation, but reduced by high level of nitrogen (Farah, 1978).

Rheenen (1979) conducted pot culture experiments on sesamum with frequent saturation of soil with water from once in every 1.5 week to 5 times per week. The treatment with application of water once in every 1.5 week to 1 week showed water stress symptoms from 7 to 8 weeks after sowing. The frequent saturation of soil with water had got a great influence over the yield of sesamum.

Hack (1980) found that in a season of low rainfall prevention of surface run off and one later irrigation in the absence of presowing flooding gave 43 per cent increase in yield over that from plots irrigated only at sowing and with surface drainage.

Results of crop water requirement studies conducted in Middle East and Africa over 20 years have shown that sesamum with 10 cm irrigation every 14 days or 15 cm irrigation every 21 days increased the seed yields (Dallyn, 1983).

Vasiliu and Negomireanu (1970) observed from the trials at Braila and Fundulea that sunflower irrigated at 50 per cent A.S.M. had given seed yields of 3.65 and 3.79 t/ha respectively.

It is found that in sunflower during summer, irrigation at heading and full flowering increased seed yields by 25 per cent and oil yields by 0.18 to 0.25 t/ha compared with unirrigated treatments (KocoDhima and LiambroGjergji, 1973)

Delibaltov and Ivanov (1973) with field trials on the effects of irrigation and fertilizer application on yield and quality of sunflower revealed that irrigating the crop when the soil moisture content was 70 per cent of field capacity; at the early stage of growth, at 80 per cent during the stage between budding and full flowering and 70 per cent from flowering to seed development produced higher yields.

Experiments conducted at ICRISAT indicated that sunflower in kharif season gave significantly high seed yields with two irrigation than no irrigation (Anon., 1974).

Vitkov et al. (1974) observed the highest average yield of 3.99 t seeds and 1.82 t oil/ha by maintaining the soil moisture at 70 per cent of field capacity upto head formation, 80 per cent upto the initiation of heads and 70 per cent up to harvesting.

Kaliappa (1974) reported that irrigating sunflower at 60 per cent soil moisture depletion from the top 30 cm layer of soil gave the highest seed yields while irrigating at zero per cent has given the lowest yield.

In a field trial conducted in Bulgaria on the irrigation regime for sunflower revealed that irrigation to maintain the soil moisture content at 70, 80 and 70 per cent of field capacity at early bud formation, at flower head development and at full flowering was found to be the optimum for high yields of seed and oil (Mikhov,1974).

Field trials were carried out in Cordoba to study the effect of different rates of water application to sunflower given during the whole growth period supplementing 100 per cent of the water lost by evapo-transpiration had given maximum yields (Gimenez et al., 1975).

Muriel et al. (1975) reported that irrigation given to replace 100 per cent of the volume of evapo-transpiration has given maximum seed yield and 100 seed weight when compared with irrigation at 25 per cent, 50 per cent or without irrigation.

Sipos and Paltineau (1975) conducted trials at Fundulea and observed that application of irrigation to maintain soil water content at more than 50 per cent to a depth of 80 cm of soil increased sunflower seed yields from 2.60 t (without irrigation) to 3.03 to (with irrigation).

Malykhin (1976) observed that irrigation supplemented to maintain the soil moisture at 80 per cent of field capacity increased average seed yield from 2.18 to 3.41 t/ha.

Lgov (1976) reported that when the soil moisture did not fall below 80 per cent of the field capacity at a depth of 1m, the increase in yield with non fertilized plot varied between 850-890 kg/ha and the figures were 1.16 to 1.19 t/ha with fertilized plots.

Karami (1977) obtained highest yield with irrigation every 6 days. Plant height,head diameter and 1000 seed weight decreased with increased irrigation intervals. The harvest index and seed oil content decreased and percentage of unfilled seeds increased with long irrigation intervals.

Subramanian <u>et al</u>. (1979) obtained a maximum yield of 1.13 t/ha with irrigations at IW : C.P.E. ratio of 0.75 compared with ratios of 0.60 and 0.90. Water use efficiency was found to be 31 kg grain/ha.cm.

The water use efficiency and seed yields of sunflower were higher with irrigation scheduled at an IW : P.E ratio of 0.70 than at IW : P.E ratios of 0.50, 0.90 or 1.1 (Patel and Singh, 1979).

Bhan and Khan (1980) studied the frequency and method of irrigation and found that sunflower gave highest seed yields with irrigation applied at IW : C.P.E ratio of 1 with 5 cm water per irrigation, but water use efficiency was highest with irrigations at a ratio of 0.75.

The results of trials with irrigation at 20, 40, 60 or 80 per cent A.S.M. from 0 to 30 cm soil depth with no fertilizer as NPK showed that maximum yields were obtained at 60 per cent A.S.M. (Pal, 1981).

Jana et al. (1982) observed increase in head diameter, number of seed/head, 1000 seed weight, seed and oil content with irrigation. Water use efficiency was 13.66 kg/mm of water with two irrigations, one at flowering and the other at seed development stages.

Prunty (1983) studied the influence of soil water and population on hybrid sunflower yield and uniformity of stand. It was found that seed and oil yields and percentage of oil in seed were increased significantly when irrigation rates were increased. The soil water potentials were in the range of -35 to -105 J/kg.

Seydlitz (1962) on experiments with safflower concluded that water deficiency during flowering and ripening markedly reduced the seed yields and vegetative period.

In a field trial with 4 irrigation treatments, the highest yield of safflower seed was obtained with a pre-sowing irrigation plus irrigations at the bud and early flowering stages (Fischer et al., 1967).

Erie and French (1969) obtained highest yield with 7 irrigations and the last one being applied at the end of flowering. Yields were reduced by giving the last irrigation at the beginning of flowering. Irrigations were given when 60 to 72 per cent of the available water in top 120 cm of soil got depleted.

Application of 50 mm irrigation water after 60 mm can evaporation gave the highest seed and oil yield of 2.08 t and 585 kg/ha respectively and highest water use efficiency of 4.56 kg seed per mm. The consumptive use of water for economic returns was about 450 mm at an interval of 15 days (Suryanarayana, 1975).

Mahapatra and Singh (1975) reported that safflower gave the highest seed yields with 3 irrigation in Madhya

Pradesh and with 4 irrigation at Delhi and Rajastan and 2 irrigations under wet and mild climatic conditions of the Terai region of Uttar Pradesh.

Abel (1976) observed a significant reduction in seed yield when irrigation was withheld until plants had utilized 90 per cent of available water than when soil water depletion was limited to 60 to 70 per cent.

Raghu and Sharma (1978) obtained seed yield of safflower without irrigation as 1.35 t/ha and 1.93 to 1.94 t/ha with irrigation applied at the branching or seed formation stage. Yields were slightly increased with 2 to 3 irrigations.

Itwal et al. (1979) found that seed yields were increased from 1.41 to 1.97 t/ha in safflower with two irrigations, one at the vegetative and the other at the grain or seed formation stage.

The seed yields of safflower grown with 1,2,3 and 4 irrigations were 29, 44, 58 and 76 per cent higher than those without irrigation. Similar trends were observed in oil yield also. Water use efficiency was highest with one irrigation at rosette stage (Yusuf et al., 1981).

According to Banerjee et al. (1967) highest yields of toria were obtained from two irrigations followed by one irrigation and three irrigations. The unirrigated treatment has shown the lowest yield.

Nathawat *et al*. (1969) studied the yield and yield components of mustard under the influence of soil drought and concluded that grain yield was positively connected with number of pods per plant.

Singh *et al*. (1977) observed from the trials conducted at West Rajastan that seed yields of sarson and raya were not significantly influenced by different levels of pre-sowing irrigation and the application of 0 - 50 kg/ha each of N and P_2O_5. But the increase in N and P rates and in the level of presowing irrigation produced significant increase in yields when an irrigation of 25 mm was given at flowering and seed filling stage.

Reddy and Pandey (1980) reported that seed yields in mustard were higher with irrigations scheduled at 0.5 atmospheric tension during pre and post flowering stages, than with irrigation scheduled at 1 or 1.5 atmospheric tension.

Bajpai *et al*. (1981) observed maximum number of pods per plant when irrigated at IW : C.P.E ratio of 0.50.

Seed yields of mustard were similar with 5 irrigations at 25 day interval and 7 irrigations at 15 day interval but it was higher than 5 irrigations at 35 day interval (Chaniara and Damor, 1982).

Mantella and Goldin (1964) reported a frequency of 30 day interval for sprinkler irrigation in groundnut with application intensity of 6 mm per hour tended to give higher yields. The consumptive use from a soil depth of 150 cm was about 670 mm.

Prevet et al. (1966) in groundnut observed reduction in yield upto 20 per cent indicating crop susceptibility to drought conditions at all the 3 stages of crop growth. The most damaging effect occurred when drought treatment was applied at peak flowering period causing a reduction in yield upto 50 per cent.

Higher yields were obtained when irrigation was given at 60 per cent of field capacity than irrigating at 40 to 80 per cent of field capacity in groundnut (Mohan, 1970).

Joshi and Kabaria (1972) studied the effect of rainfall during different stages of groundnut from full pegging to pod development stage. A decrease in 1cm rainfall at full pegging to early pod development stage reduced yields by 3.27 kg/ha.

Sandhu et al. (1972) reported that two irrigations, one at flowering and the other at fruiting in addition to the two normal irrigations given during the first and the third months after sowing gave higher yields as compared to no irrigation and one irrigation at flowering.

Gopalaswamy et al. (1974) obtained yields of 1.61 to 2.25 t of unshelled nuts per ha under irrigated conditions compared to 0.97 to 1.41 t per ha under rainfed condition.

Ali et al. (1974) observed higher yields when irrigation was supplemented at 60 per cent A.S.M. in top 30 cm layer of soil.

Irrigation increased pod yield from 1.61 t/ha (with no irrigation) to 2.36 (with irrigation at 10 per cent A.S.M. Irrigation also increased the number of pods per plant, 100 pod weight and shelling percentage (Cheema et al., 1977).

MacGillivray et al. (1981) reported that drought in late flowering and pod formation had the greatest effect on seed yield and quality. Pod yields ranged from 1.41 t/ha in the driest regime to 3.61 t/ha in the wettest with a corresponding increase in seed quality.

Raju *et al*. (1981) conducted studies on productivity of rainfed groundnut under moisture stress and revealed that, moisture stress during vegetative, flowering, pegging, pod setting and early pod development stages reduced pod yield. However, moisture stress at pod development and maturation stages did not affect the pod yield.

Khan and Datta (1982) made studies on scheduling of irrigation for summer peanuts. Pod yield and 100 seed weight increased with increasing frequency of irrigation.

Reddy *et al*. (1982) observed maximum pod yield with 5 cm irrigation at 5 day interval.

Yao *et al*. (1982) observed that drought at seed development stage for 30 days decreased the 100 seed weight by 25.1 per cent, drought at flowering for 30 days caused decrease in 100 seed weight by 24.7 per cent while at ripening 14.6 per cent.

Application of 8 irrigations with 0.9 cm water per irrigation at 11 day interval gave the highest pod yield and highest water use efficiency (Bharambe and Varade, 1982).

Zalwadia and Patel (1983) found that increasing rates of irrigation significantly increased growth rate and nutrient uptake.

Damato and Giordano(1983) obtained higher seed and oil yields with irrigation and they increased with increase in irrigation volume.

A model was developed for groundnut yield prediction over a range of moisture regimes. The critical stages for irrigation were germination, vegetative development and full pegging and pod development. It was suggested that this model could be useful in scheduling irrigation for groundnut (Khatri and Patel, 1983).

Groundnut cv. J-11 (bunch) and M-13 (spreading) were used for irrigated treatment during 4th, 6th and 8th weeks after anthesis of the 1st flower. Irrigation between 4th and 7th week produced more flowers than unirrigated plants. With irrigation 64 and 75 per cent of flowers formed gynophores and 46 to 67 per cent without irrigation in J-11 and M-13 (Bhatia <u>et al</u>., 1984).

Rochester <u>et al</u>. (1984) reported that irrigation at 40 centibar gave 520 lb/ac, more pod yield than non irrigated treatments.

Doss <u>et al</u>. (1974) conducted conventional irrigation experiments and rainfall distribution studies in soyabean and indicated that insufficient water during flowering and pod filling stages limited the yields.

Pande <u>et al</u>. (1970) reported that in trials in 1963-65 with oil seed flax, average seed yields were increased from 0.69 t/ha in unirrigated plots to 0.92 t/ha in those given one irrigation.

Yusuf *et al*. (1978) observed that oil seed flax sown in winter season with presowing irrigation followed by 4 irrigations at different growth stages, like seedling, branching, flowering and seed maturation gave the highest average seed yields of 2.59 t/ha.

Maximum yields were obtained with irrigation at flower initiation and pod development stages in rape seed (Bhan *et al*., 1980).

The above review gives the importance of irrigation under stress condition for getting higher yields. Also indicates the efficient use of water, its efficient management under limited supply by following certain methods of irrigation. Moisture stress condition invariably reduces the yield components and seed yield.

5. Quality characters

Water stress conditions have got qualitative as well as quantitative effects on plant constituents. It affects the economic yield and quality of the product.

(i) Protein

Lahri and Singh (1970) showed that plants grown under low soil moisture regime contained high concentration of total nitrogen as well as protein at all stages of growth as compared to plants under higher soil moisture conditions.

Nutall (1973) reported increased protein content in rape seed under moisture stress. Narasimhan et al. (1978) observed a depression in protein content with increased soil moisture in groundnut while Mac Gillivray et al. (1981) reported that drought in late flowering and pod formation stages had greatest effect on seed quality. Seed quality increased in wettest regime.

Pal (1981) observed decrease in protein content with increasing soil moisture in sunflower.

Yao et al. (1982) observed that drought treatment at flowering reduced protein content whereas drought at the seed development and ripening stages gave higher protein.

With irrigation the seeds had higher protein and phytin contents and lower fat content, when examined at 7 day interval for 6 weeks after flowering than without irrigation (Popov and Kozhevnikova, 1982).

Rochester et al. (1984) reported that peanut quality under irrigation was equal or slightly better than seed quality of non irrigated peanuts.

It can be concluded from the above review that there is a relationship between soil moisture and protein content of the seed. It may increase or decrease with increase in soil moisture.

(ii) Oil

Seydlitz (1962) on experiments with safflower observed that water stress condition at flowering induced reduction in percentage of oil.

Yusuf et al. (1981) also observed increase in oil content with frequency of irrigation.

Delibaltov and Ivanov (1973) reported that irrigation increased seed oil content by 1.17 to 5.92 per cent in sunflower.

According to Vitkov et al. (1974), irrigation increased seed oil contents from 45.95 to 46.55 per cent. Seed oil content from irrigated plots were significantly higher than unirrigated plots. Gimenez et al. (1975) reported that irrigation increased seed oil content and oil yield. Karami (1977) obtained decreased seed oil content with long irrigation interval. Jana et al. (1982) also reported that irrigation increased seed oil content. Prunty (1983) observed increase in percentage of oil in seed and oil yields when irrigation rates were increased in sunflower.

Banerjee et al. (1967) observed that one irrigation gave the highest oil content of 40.04 per cent and 3 irrigations, the lowest 39.2 per cent in mustard. Reddy and Pandey (1980) obtained from the trials conducted in mustard revealed that different soil moisture regime imposed at any stage had no significant effect on seed oil content.

Nutall (1973) noticed that the oil content was reduced due to soil moisture stress in rape seed. Bhan et al. (1980) noticed highest oil content in rape seed with one irrigation at flower initiation than two irrigations. In sesamum the oil content was not significantly affected by soil moisture supply (El-Serogi et al., 1977). Yusuf et al. (1978) noticed that seed oil contents were not affected by either the stage or frequency of irrigation in lin seed. Studies of Narasimhan et al. (1978) have revealed that higher soil moisture content tended to depress the oil content in groundnut whereas Shanmugasundaram et al. (1979) recorded the maximum oil content in situations where moisture status is more when compared to conditions where moisture status is less.

Yao et al. (1982) reported that drought treatment at seed development stage reduced oil content.

The foregoing review shows that soil moisture has got great impact on oil content. It may either increase or decrease with variation in soil moisture.

6. Nutrient uptake

Bennet *et al*. (1964) reported that the nitrogen and potassium in plants decreased with increase in soil moisture, but the total uptake was higher with sufficient soil moisture because of enhanced yields. Studies by Lahri and Singh (1968) revealed that increase in total nitrogen content in the water deprived plants could be due to unrestricted nitrogen uptake and greater translocation from root to the serial organs. Rajagopal (1969) observed a significant decrease in total nitrogen with increase in soil moisture status at all stages of plant growth as well as in the grain. But the phosphorus and potassium contents were significantly increased in the plant and grain as the soil moisture status was increased. Highest uptake of N, P and K with 10 irrigations of 450 m^3/ac at 6 day interval in sesamum was observed by Abdou *et al*. (1970). Varma and Rao (1975) noticed a moisture level of 50 per cent appeared to be optimum for maximum nitrogen content and it was reduced at 100 per cent moisture level. Abel (1976) found that cessation of irrigation at the earlier stages of growth reduced the nitrogen uptake in safflower. Plants growing in soil with adequate moisture content tended to have higher nitrate nitrogen and potassium, while phosphorus content was lower (Koter and Samoyek, 1976) Dudde et al. (1979) reported that 25 per cent depletion of soil moisture resulted in highest concentration of nitrogen and phosphorus at all physiological stages of plant growth. The uptake of nitrogen, phosphorus and potassium was increased with increasing levels from 0 - 60 per cent A.S.M. (Singh and Singh, 1980).

Reddy et al. (1982) reported that N and P uptakes were greatest with irrigation at 5 day interval in groundnut. Zalwadia and Patel (1983) studied the effect of irrigation and P application on concentration and uptake of N, K, Ca, Mg and S at various stages of groundnut and revealed that increasing rates of irrigation significantly increased the growth rate and nutrient uptake, but reduced the concentration of all nutrients except for Mg and S at pod development stage.

It is seen from the above review that irrigation favourably influences the uptake of N, P and K. A decrease in soil moisture invariably increase the nitrogen content, but in the case of phosphorus and potassium varying results are reported.

MATERIALS AND METHODS

MATERIALS AND METHODS

The experiment entitled "Influence of irrigation on germination, growth and yield of sesamum" was undertaken to find out the optimum soil moisture for getting uniform germination and to study the effect of irrigation on the performance of the crop.

The materials used and methods adopted are detailed below.

Materials

Location

The experiment was taken up in the summer rice fallows of the Rice Research Station, Kayamkulam, which comes under the Onattukara tract. The elevation of the farm is 3.05 m above MSL. The station is located at 9^{o} - 10' N latitude and 76^{o} - 3' E longitude.

The soil of the experimental area is typical sandy loam. Data on physical and chemical analysis are given in Table 1. The soil is acidic in reaction, low in nitrogen, medium to high in available phosphorus and very low in available potassium.

Season

The experiment was undertaken during the summer season of 1983-84. Sowing was started on 1-2-84 as per treatment schedule and continued upto 10-2-84. The harvest was started on 15th April and completed by 24th April 1984.

Table 1. Soil characteristics of the experimental area

A. Physical properties

1. Mechanical composition		
Coarse sand	56.10	per cent
Fine sand	30.90	,,
Silt	6.00	,,
Clay	5.80	,,
2. Field capacity	16.05	,,
3. Permanent wilting point	3.86	,,

B. Chemical characteristics

1. Total N	0.05	per cent
2. Total P_2O_5	0.129	,,
3. Available P_2O_5	52.00	kg/ha.
4. Total K_2O	0.0181	per cent
5. Available K_2O	76.00	kg/ha.
6. Organic carbon	0.5	per cent
7. pH	5.1	

Climatic conditions

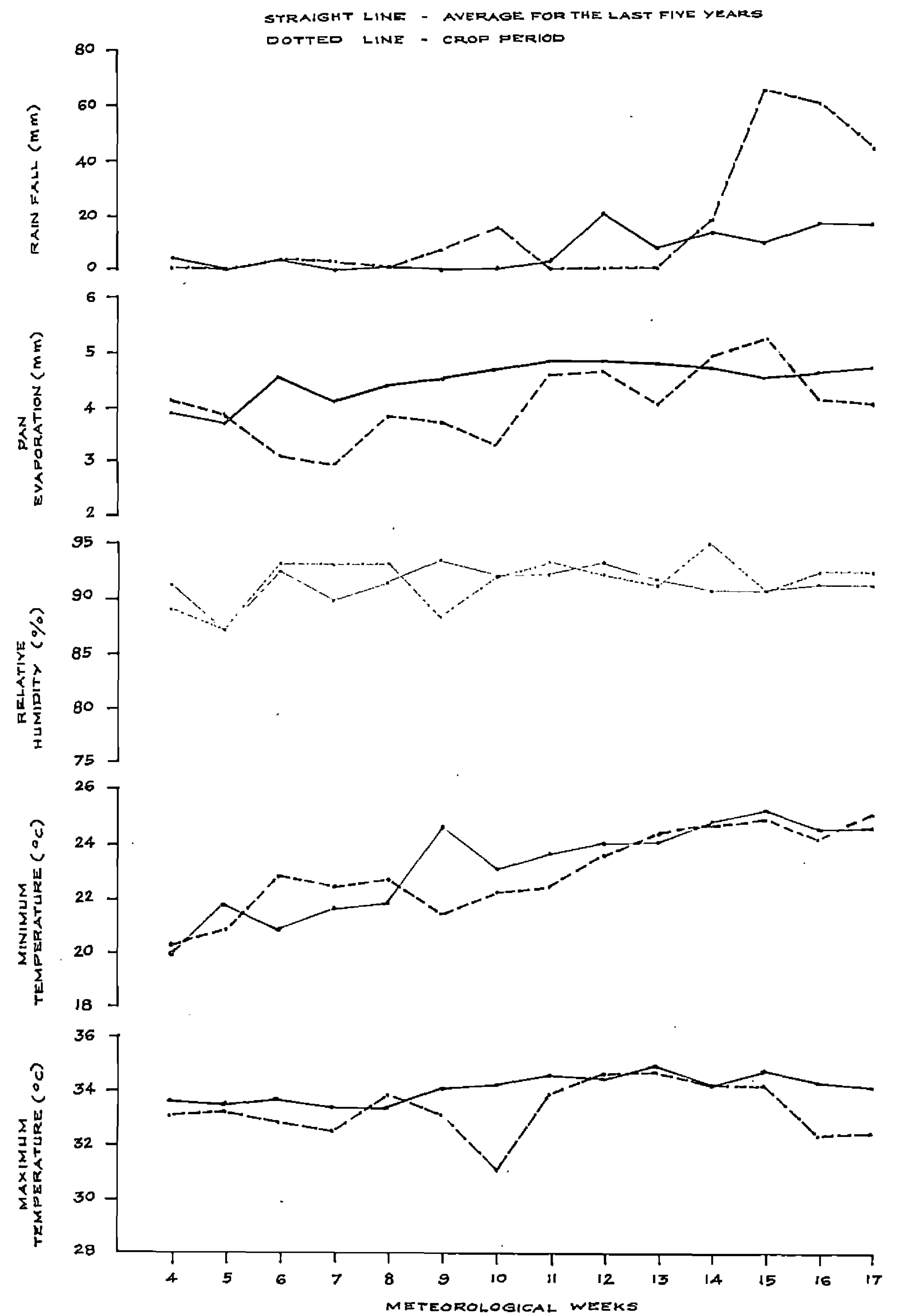
The weekly averages of temperature, relative humidity, pan evaporation and weekly total of rainfall during the crop period and during the past five years collected from the meteorological observatory, C.P.C.R.I., Kayamkulam and R.R.S., Kayamkulam are presented in Table 2 and Fig.1.

The variation in maximum temperature during the crop period, from the average, ranged between -3.6°C to +0.1°C and that of minimum temperature from -2.9°C to +0.9°C. The variation in relative humidity ranged between -3.4 to +4.4 and it was maximum during the 14th standard week. In the case of pan evaporation, the variation ranged between -2.2 to +0.7 mm from the average. The total rainfall received during the experimental period was 170.00 mm and majority of the rainfall was received during the last stage of experimentation. It could be seen that the variation in meteorological parameters during the experimental period from that of the average of the previous five years was more or less negligible and the season was almost normal.

Cropping history of the field

The experiment was conducted in the 'E' block of the experimental farm of R.R.S. Kayamkulam. The plot was under bulk crop of rice during the first and second crop seasons

FIG. 1. WEATHER CONDITIONS DURING THE CROP PERIOD AND AVERAGE FOR THE LAST FIVE YEARS.



of 1983-'84 and received usual cultural and manurial practices.

Variety

The sesamum variety Kayamkulam-2 (Thilothama) was selected for the study. It is a cross between Kayamkulam-1 and P.T.58-5. This is a newly evolved variety and it is highly suitable for the summer rice fallows of Onattukara tract. It comes to maturity within 75-80 days with an average yield of 550 to 600 kg/ha. It contains about 53-54 per cent oil and 23-24 per cent protein.

Seed material

The seed material for the experiment was obtained from the Rice Research Station, Kayamkulam.

Fertilizers

The fertilizers used for the experiment were urea, super phosphate and muriate of potash analysing 46 per cent N, 16 per cent P_2O_5 and 60 per cent K_2O respectively.

Methods

Design and lay out

The experiment was laid out in Split Plot Design. The lay out plan of the experiment is given in Fig.2.

FIG. 2. LAY OUT PLAN

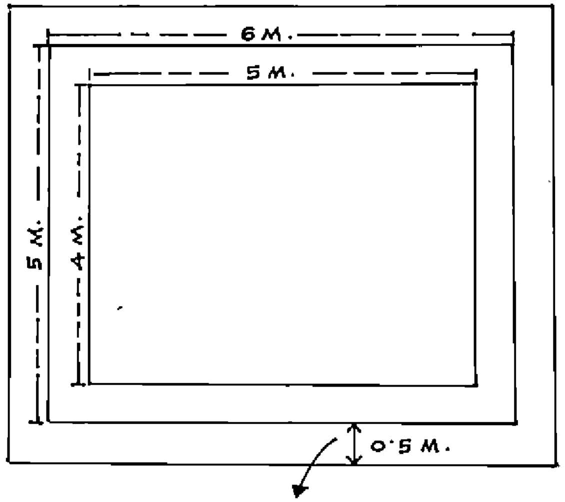
6 M. × 5 M.

Replication - 1		
T_SI_2	T_SI_1	T_SI_0
T_0I_0	T_0I_2	T_0I_1
T_5I_1	T_5I_0	T_5I_2
T_8I_1	T_8I_2	T_8I_0
T_7I_0	T_7I_1	T_7I_2
T_1I_2	T_1I_0	T_1I_1
T_4I_1	T_4I_2	T_4I_0
T_2I_0	T_2I_1	T_2I_2
T_9I_2	T_9I_1	T_9I_0
T_6I_1	T_6I_2	T_6I_0
T_3I_0	T_3I_1	T_3I_2

Replication - 2		
T_1I_0	T_1I_2	T_1I_1
T_6I_2	T_6I_1	T_6I_0
T_0I_1	T_0I_0	T_2I_2
T_3I_2	T_3I_1	T_3I_0
T_SI_2	T_SI_0	T_SI_1
T_9I_0	T_9I_1	T_9I_2
T_5I_2	T_5I_0	T_5I_1
T_4I_1	T_4I_2	T_4I_0
T_8I_1	T_8I_0	T_8I_2
T_7I_0	T_7I_2	T_7I_1
T_2I_2	T_2I_1	T_2I_0

Replication - 3		
T_3I_1	T_3I_0	T_3I_2
T_4I_2	T_4I_1	T_4I_0
T_8I_0	T_8I_2	T_8I_1
T_7I_2	T_7I_0	T_7I_1
T_0I_0	T_0I_1	T_0I_2
T_SI_2	T_SI_0	T_SI_1
T_1I_1	T_1I_0	T_1I_2
T_6I_0	T_6I_1	T_6I_2
T_5I_1	T_5I_2	T_5I_0
T_2I_2	T_2I_1	T_2I_0
T_9I_0	T_9I_2	T_9I_1

SINGLE PLOT ENLARGED



MAIN PLOT TREATMENTS.

T_0	SOWING WITHOUT IRRIGATION
T_S	SOWING ON THE SAME DAY OF IRRIGATION
T_1	SOWING ONE DAY AFTER IRRIGATION
T_2	SOWING TWO DAYS AFTER IRRIGATION
T_3	SOWING THREE DAYS AFTER IRRIGATION
T_4	SOWING FOUR DAYS AFTER IRRIGATION
T_5	SOWING FIVE DAYS AFTER IRRIGATION
T_6	SOWING SIX DAYS AFTER IRRIGATION
T_7	SOWING SEVEN DAYS AFTER IRRIGATION
T_8	SOWING EIGHT DAYS AFTER IRRIGATION
T_9	SOWING NINE DAYS AFTER IRRIGATION

SUB-PLOT TREATMENTS.

I_0 NO IRRIGATION DURING THE GROWTH PHASE.

I_1 ONE IRRIGATION DURING THE VEGETATIVE PHASE (15 DAYS - AFTER SOWING)

I_2 TWO IRRIGATIONS ONE IN THE VEGETATIVE AND ANOTHER IN THE REPRODUCTIVE PHASE (45 DAYS AFTER SOWING)

DESIGN

11 x 3 SPLIT PLOT EXPERIMENT WITH 3 REPLICATIONS.

<u>Treatments</u>

This was laid out in split plot experiment with 11 main plot treatments and 3 sub plot treatments.

i) Main plot treatments : Time of sowing

T_0 sowing without irrigation.

T_S sowing on the same day of irrigation.

T_1 sowing one day after irrigation.

T_2 sowing two days after irrigation.

T_3 sowing three days after irrigation.

T_4 sowing four days after irrigation.

T_5 sowing five days after irrigation.

T_6 sowing six days after irrigation.

T_7 sowing seven days after irrigation.

T_8 sowing eight days after irrigation.

T_9 sowing nine days after irrigation.

ii) Sub plot treatments : Irrigation during growth stages.

I_0 No irrigation during the growth phase.

I_1 One irrigation during the vegetative phase (15 days after sowing).

I_2 Two irrigations, one in the vegetative phase and another in the reproductive phase (45 days after sowing).

Treatment combinations

1) T_0I_0
2) T_0I_1
3) T_0I_2
4) T_SI_0
5) T_SI_1
6) T_SI_2
7) T_1I_0
8) T_1I_1
9) T_1I_2
10) T_2I_0
11) T_2I_1
(12) T_2I_2
(13) T_3I_0
(14) T_3I_1
(15) T_3I_2q
(16) T_4I_0
(17) T_4I_1
(18) T_4I_2
(19) T_5I_0
(20) T_5I_1
(21) T_5I_2
(22) T_6I_0
(23) T_6I_1
(24) T_6I_2
(25) T_7I_0
(26) T_7I_1
(27) T_7I_2
(28) T_8I_0
(29) T_8I_1
(30) T_8I_2
(31) T_9I_0
(32) T_9I_1
(33) T_9I_2

Number of replications : 3

Total number of plots : 99

Plot size

Gross 6 x 5 metres

Net 5 x 4 metres

Border rows : A band of ½ metre width was left as border rows all around the sub plot.

Field culture

1) Preparation of the field

Power tiller was used for ploughing the experimental plots. After ploughing, the stubbles were removed and plots were laid out as per the experimental design.

2) Fertilizer application

A uniform dose of nitrogen, phosphorus and potassium @ 30:15:30 kg/ha was applied as basal as per the package of practices recommendations, Kerala Agricultural University.

3) Seeds and sowing

The seed rate used was 5 kg/ha. The plots were irrigated to field capacity uniformly except the control plot and sowing was done from the day of irrigation and continued at one day interval upto the 9th day after irrigation as per the treatment schedule. The seeds were mixed with dry sand for uniform distribution and sowing was done by broadcasting.

4) After cultivation

First intercultural operation with 'Onattukara hoe' was done 14 days after sowing. In the sub plot treatments I_1 and I_2 irrigation was given to a depth of 3 cm during the vegetative phase (15 days after sowing). The second intercultural operation and weeding with 'Onattukara hoe' were carried out 25 days after sowing. At the reproductive phase (45 days after sowing) a 3 cm irrigation was given to plots coming under I_2 treatments.

5) Plant protection

B.H.C. (5%) was dusted uniformly to control the leaf caterpillar. Dithane M-45 was also applied to control the fungal diseases.

6) Harvesting and threshing

The crop was harvested 75 days after sowing. Harvesting was commenced on 15-4-1984 and completed on 24-4-1984. The plants were uprooted and the root portions were removed. They were bundled and stacked for 3 days so as to shed the leaves. Later the bundles were spread, dried in the sun and threshed. The seeds were separated and cleaned.

Observations recorded

The biometric observations and other characters studied are detailed below.

The sampling procedure for taking biometric observations consisted of selecting five plants according to random cluster sampling method. These plants were tagged and biometric observations were recorded till harvest. These plants were also used for taking post harvest observations. For leaf area and dry matter accumulation studies, plants earmarked from destructive sampling unit were used.

A. Growth characters

i) Germination percentage

Four sampling units of 50 cm x 50 cm size were marked in each plot at random and plant counts were taken from these areas 10 days after sowing. Based on the total number seeds sown per unit area, the germination percentage was worked out.

(ii) Number of plants per plot

Total number of plants per plot was counted at harvest and recorded.

(iii) Height of plants

The height of the plants from the ground level to the top was measured at three stages of growth ie. 30^{th} and 60^{th} day of sowing and at harvest. The mean height per plant was worked out and recorded.

(iv) Number of leaves per plant

Number of leaves produced by the observational plants was counted at 30^{th}, 60^{th} and at harvest. The average number per plant was worked out.

(v) Internodal length

The length between the first and the second nodes was measured in the sample plants on the 30^{th} and 60^{th} day and average worked out.

(vi) Number of branches per plant

The total number of branches on the sample plants was recorded at 30th and 60th day and at harvest. The mean number of branches per plant was worked out.

(vii) Number of nodes per plant

The total number of nodes produced by the sample plants was counted at three stages and the average number was worked out.

(viii) Leaf area per plant

The leaf area per plant was recorded at 3 stages of observation. It was worked out by the punch method (Winter *et al*., 1956) using the five plants uprooted from the area earmarked for destructive sampling.

(ix) Length of tap root and lateral spread of roots

At harvest five plants were selected at random from each plot and were dug out carefully. The roots were washed free of soil particles and the maximum length of tap root and lateral spread were measured and the average worked out.

(x) Dry weight of roots

The total dry weight of roots for the five plants were taken and the average worked out after oven drying at

70 ± 10°C till constant weight was obtained.

(xi) Dry matter production and distribution

The plants up rooted for leaf area determination were utilized for dry matter accumulation studies. The pattern of dry matter production and its distribution into different parts was worked out by taking separately the weight of stem, leaves and capsules after oven drying at 70 ± 10°C till constant weight was obtained. From this, percentage distribution of dry matter in different plant parts was worked out.

(xii) Number of days for first flowering

The number of days taken for first flower opening was recorded.

B. Yield and yield components

(1) Number of capsules per plant

Total number of capsules produced by the five observational plants at 60th day and at harvest was counted and the average worked out.

(2) Weight of capsules per plant

Total dry weight of capsules produced by the five observational plants was recorded and the mean weight per plant calculated.

(3) Number of seeds per capsule

Total number of seeds in each capsule was counted and the average per capsule worked out.

(4) Seed weight per plant

Seeds from the sample plants were separated and the dry weight recorded, after oven drying at $70 \pm 10^{\circ}C$ till a constant weight was obtained. From this the average seed weight per plant was worked out.

(5) 1000 seed weight

From the seed yield of each plot, 1000 seeds were counted, oven dried at $70 \pm 10^{\circ}C$ and weight recorded.

(6) Seed yield

The plants harvested from the net plot, were cured, threshed and seeds separated. The seeds were dried, winnowed and cleaned. The seed weight was recorded after sun drying.

(7) Haulm yield

The seeds were separated from the capsules by threshing and the remaining haulm was sun dried uniformly and their weight recorded.

(8) Shelling percentage

It was calculated from the dry weight of seeds and pods in the following manner.

$$\text{Shelling percentage} = \frac{\text{Dry weight of seeds}}{\text{Dry weight of capsules}} \times 100$$

(9) Harvest index

From the yield data of net plot the harvest index was calculated using the formula

$$\text{Harvest index} = \frac{\text{Economic yield}}{\text{Biological yield}}$$

C. Chemical analysis

I. Quality characteristics

(1) Protein content of seeds

This was worked out by estimating the nitrogen content of the seeds following the Micro kjeldhal method and multiplying the nitrogen of the seeds with the factor 6.25 (Simpson *et al.*, 1965).

(2) Oil content

The oil content of seed was estimated by using Soxhlet Ether Extraction Method (Chopra and Kanwar, 1976).

(3) Oil yield

The oil yield was calculated from the oil content and total dry weight of seeds.

II. Analysis of plant samples

Five sample plants at harvest were oven dried at $70 \pm 10^{\circ}C$, ground in Wiley Mill and used for chemical studies. Nitrogen, phosphorus and potassium contents present in the plant were analysed at 30^{th} day, 60^{th} day and harvest.

(1) Uptake of nitrogen

Total nitrogen content in the plant was determined by the modified Micro kjeldahl method (Jackson, 1967) and the total uptake of nitrogen at 30th day, 60th day and at harvest was calculated based on the content of this nutrient in plants and the dry matter produced at these stages.

(2) Uptake of phosphorus

The phosphorus content in plant was determined by using triple acid ($HNO_3 + H_2SO_4 + HClO_4$) extraction method (Jackson, 1967). Klett Summersion Photoelectric Colorimeter was used for reading the intensity of the colour developed by Vanado - molybdic phosphoric acid. Based on the phosphorus content in plants and the dry matter produced at 30th day, 60th day and at harvest, the uptake was worked out.

(3) Uptake of potassium

The potassium content in plant was determined by using the triple acid extraction method and by reading in an EEL Flame Photometer and the uptake was calculated based on the potassium content in plants and dry matter produced at 30th day, 60th day and harvest.

III. Soil analysis

The physical and chemical characteristics of the soil were assessed using the following standard procedures.

i) Soil moisture status at sowing, at 5 day interval till 15th day and 45 days after sowing (0 - 15 cm depth)	Gravimetric method
ii) Total nitrogen	Micro kjeldahl method
iii) Available phosphorus	Bray's No. 1 method
iv) Available potassium	Ammonium acetate method
v) Organic carbon	Walkely and Black method (Jackson, 1967)

Chemical analysis of soil for N, P_2O_5, K_2O and organic carbon was done on a composite sample collected prior to the experiment and on soil samples collected from each plot after the experiment.

D. Statistical analysis

The data obtained were statistically analysed by employing the methods described by Panse and Sukhatme (1978) and important correlations were also worked out.

The data were analysed with the help of a Micro 2200 Hindustan Computer.

RESULTS

RESULTS

A field study was undertaken to find out the influence of irrigation on germination, growth and yield of sesamum in the Onattukara tract of Kerala. The experiment was conducted at the Rice Research Station, Kayamkulam during the summer season of 1983-84 in the rice fallows. Observations were made on germination, growth, yield and yield attributes, quality aspects and soil moisture contents. The results are presented below.

4.1. Germination

The data on germination percentage recorded on 10 days after sowing are presented in Table 3 and analysis of variance in Appendix I.

The Table shows that the germination percentage was influenced by time of sowing. Sowing seeds one day after irrigation (T_1) recorded the maximum germination percentage and it was significantly superior to all other treatments and was followed by sowing on the same day of irrigation (T_S).

4.2. Soil moisture status

Data on soil moisture status of the soil in the experimental plots recorded at sowing and then at 5 day interval till the 15th day and on the 45th day after sowing are presented in Tables 4 a-e and their analysis of variance in Appendix I.

Table 3. Germination percentage at 10 days after sowing

Time of sowing	Irrigation			
	I_0	I_1	I_2	Mean
T_0	17.26	17.05	16.54	16.95
T_S	50.66	51.16	50.92	50.91
T_1	57.90	57.89	58.88	58.22
T_2	26.07	26.14	25.33	25.85
T_3	21.14	21.51	21.70	21.45
T_4	17.71	17.25	17.92	17.63
T_5	17.83	17.50	16.94	17.42
T_6	16.36	16.60	16.21	16.39
T_7	14.24	14.77	14.08	14.36
T_8	14.36	14.38	14.11	14.28
T_9	17.87	17.72	17.72	17.77
Mean	24.67	24.72	24.58	

C.D. (0.05) for time of sowing = 0.958

(a) At sowing

The Table reveals that soil moisture was significantly varied at the time of sowing. Sowing the seeds on the same day of irrigation recorded the maximum soil moisture content and was significantly superior to all the other treatments. It was followed by T_1, T_2 and T_3. T_3 is on par with T_4, T_5 and T_6. Similarly T_7, T_8, T_9 and T_0 were on par.

(b) 5 days after sowing

Soil moisture was significantly differed at 5 days after sowing. The treatment T_S recorded maximum soil moisture and was on par with T_1 whereas T_8 and T_9 were having the lowest values.

(c) 10 days after sowing

It is seen that there was significant difference in soil moisture at 10 days after sowing T_2 and T_S showed higher moisture contents and were on par at this stage.

(d) 15 days after sowing

The Table shows that there was significant difference in soil moisture content at 15 days after sowing and the treatment T_S gave the highest moisture content and it was on par with T_1 and T_2. T_8 recorded the lowest soil moisture.

(e) 45 days after sowing

The Table reveals that different treatments and their

Table 4. Soil moisture at different stages of growth

(a) At sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	8.53	8.45	8.51	8.50
T_S	16.05	16.05	16.05	16.05
T_1	12.90	12.62	12.65	12.72
T_2	10.71	10.82	11.17	10.90
T_3	10.32	10.13	10.28	10.24
T_4	9.72	9.80	9.51	9.68
T_5	9.86	10.08	9.72	9.89
T_6	10.23	8.89	8.90	9.34
T_7	8.89	8.86	8.66	8.80
T_8	8.26	8.30	7.99	8.18
T_9	8.09	8.55	8.18	8.27
Mean	10.32	10.23	10.15	

C.D. (0.05) for time of sowing = 0.843

Table 4 contd. .....

(b) 5 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	9.07	8.96	9.15	9.06
T_S	11.26	11.37	11.11	11.24
T_1	10.73	10.82	10.80	10.78
T_2	9.97	9.75	10.06	9.92
T_3	8.74	8.50	9.13	8.79
T_4	8.92	8.73	8.87	8.84
T_5	8.92	8.32	8.94	8.73
T_6	8.02	8.04	8.04	8.03
T_7	9.32	9.20	8.80	9.11
T_8	7.91	7.70	8.11	7.91
T_9	7.98	7.87	7.89	7.91
Mean	9.17	9.02	9.18	

C.D. (0.05) for time of sowing = 0.516

Table 4 contd. .....

(c) 10 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	7.53	7.91	8.02	7.82
T_S	9.70	9.69	9.80	9.73
T_1	9.26	9.48	9.35	9.36
T_2	9.86	9.95	9.79	9.86
T_3	8.67	8.63	8.73	8.67
T_4	8.55	7.92	8.34	8.27
T_5	8.45	7.93	8.39	8.26
T_6	7.45	7.50	7.75	7.56
T_7	8.06	8.11	8.07	8.08
T_8	7.59	7.24	7.51	7.44
T_9	7.78	7.76	7.74	7.76
Mean	8.44	8.37	8.50	

C.D. (0.05) for time of sowing = 0.336

Table 4 contd. .....

(d) 15 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	7.28	7.56	7.27	7.37
T_S	8.67	8.64	8.71	8.67
T_1	8.43	8.69	8.39	8.50
T_2	8.68	8.62	8.32	8.54
T_3	8.13	8.14	8.26	8.17
T_4	8.08	7.70	8.03	7.93
T_5	8.19	7.89	8.09	8.06
T_6	7.39	7.49	7.70	7.52
T_7	7.68	7.87	7.91	7.82
T_8	7.34	6.95	7.09	7.12
T_9	7.51	7.26	7.22	7.33
Mean	7.94	7.89	7.91	

C.D. (0.05) for time of sowing = 0.346

Table 4 contd. .....

(e) 45 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	6.41	8.19	8.37	7.65
T_S	6.78	8.72	9.01	8.17
T_1	6.50	7.75	7.88	7.37
T_2	6.40	7.41	7.64	7.15
T_3	6.30	7.32	7.43	7.02
T_4	6.26	7.25	7.33	6.95
T_5	6.21	7.21	7.35	6.92
T_6	6.17	7.13	7.25	6.85
T_7	6.15	7.12	7.17	6.81
T_8	6.00	6.96	7.03	6.66
T_9	5.90	6.87	6.88	6.55
Mean	6.28	7.45	7.57	

C.D. (0.05) for time of sowing = 0.230

C.D. (0.05) for frequency of irrigation = 0.105

C.D. (0.05) for T x I interaction : a* = 0.349

b** = 0.279

* At same level of main plot treatment.

** At different levels of sub plot treatment.

Table 5. Number of plants per plot at harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	183.66	186.66	184.33	184.88
T_S	634.00	636.33	632.33	634.22
T_1	638.00	637.00	646.00	640.33
T_2	415.33	422.33	424.33	420.66
T_3	315.66	323.66	331.00	323.44
T_4	182.66	184.66	186.33	184.55
T_5	180.33	177.33	182.33	180.00
T_6	175.00	179.66	182.33	179.00
T_7	155.00	154.33	154.66	155.66
T_8	157.33	153.66	154.66	155.22
T_9	185.66	182.00	181.00	182.88
Mean	292.96	294.33	296.57	

C.D. (0.05) for time of sowing = 7.523

interaction influenced the soil moisture status.

The treatment T_S recorded maximum soil moisture and was significantly superior to others. With respect to frequency of irrigation I_0 was significantly inferior to I_1 and I_2.

The T x I interaction shows that I_1 and I_2 treatment combinations were significantly superior to I_0 treatment combinations. T_SI_1 and T_SI_2 recorded maximum soil moisture contents at this stage.

4.3. Number of plants per plot

The number of plants per plot counted at harvest is presented in Table 5 and the analysis of variance in Appendix I.

It is seen from the Table that the plant population was significantly influenced by the time of sowing whereas the frequency of irrigation and their interactions were not significant. The treatments T_1 and T_S were on par and significantly superior to other treatments. It was followed by T_2 and T_3.

4.4. Growth Characters

4.4.1. Height of plant

The plant heights recorded at 30th day, 60th day and at harvest are presented in Tables 6 a-c and the analysis of

Table 6. Height of plant (cm) at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	21.40	23.13	24.00	22.84
T_S	20.40	22.73	25.20	22.78
T_1	21.00	22.40	22.00	21.80
T_2	19.00	20.60	20.47	20.02
T_3	29.46	30.73	30.27	30.16
T_4	19.60	23.40	22.13	21.71
T_5	15.07	18.13	19.00	17.40
T_6	12.13	15.87	15.73	14.58
T_7	22.33	29.73	27.47	26.51
T_8	18.27	19.87	20.27	19.47
T_9	27.33	30.00	28.07	28.47
Mean	20.55	23.33	23.14	

C.D. (0.05) for time of sowing = 7.367

C.D. (0.05) for frequency of irrigation = 1.387

Table 6 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	89.20	99.87	96.93	95.33
T_S	86.93	94.27	82.53	87.91
T_1	96.40	102.27	101.50	100.05
T_2	86.40	97.67	97.40	93.80
T_3	105.40	106.67	108.13	106.73
T_4	91.20	101.07	105.83	99.37
T_5	99.80	99.73	95.13	98.22
T_6	98.27	86.73	91.47	92.16
T_7	85.67	98.93	98.00	94.20
T_8	106.00	105.13	106.07	105.73
T_9	97.40	104.33	101.33	101.02
Mean	94.79	99.70	98.57	

C.D. (0.05) for frequency of irrigation = 3.846

Table 6 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	90.60	100.87	98.20	96.56
T_S	89.07	97.53	83.00	89.87
T_1	97.33	103.87	102.67	101.29
T_2	87.07	98.33	98.60	94.67
T_3	105.40	106.67	108.13	106.73
T_4	91.20	101.07	105.83	99.37
T_5	99.80	99.73	95.13	98.22
T_6	98.27	86.73	91.46	92.16
T_7	85.93	98.93	98.00	94.29
T_8	105.73	105.13	106.07	105.64
T_9	97.40	104.33	101.33	101.02
Mean	95.25	100.29	98.95	

C.D. (0.05) for frequency of irrigation = 3.867

variance in Appendix I.

During the first stage of observation, the plant height was significantly influenced by the time of sowing and frequency of irrigation. The treatment T_3 showed maximum height and it was on par with T_9 and T_7 and it was significantly superior to T_1 and T_2. With regard to frequency of irrigation, I_1 and I_2 were on par and significantly superior to I_0. The T x I interaction was not significant at this stage.

At the 60th day and harvest the plant heights were significantly influenced by frequency of irrigation. The treatments I_1 and I_2 were on par and significantly superior to I_0. The time of sowing and T x I interactions were not significant. T_3 recorded maximum plant height at these stages.

4.4.2. Number of leaves

The data representing the number of leaves at different stages of observation are presented in Tables 7 a-c and their analysis of variance in Appendix I. The number of leaves produced per plant at all stages of observation varied significantly with different treatments and the T x I interaction was found only at the second and final stages of observation. During the first stage, the treatment T_3

produced maximum number of leaves and it was on par with T_7 and T_9. With regard to frequency of irrigation I_1 and I_2 were on par and I_0 was significantly inferior to the former two treatments.

In the second stage of observation, the treatment T_3 was having the highest number of leaves and it was on par with T_9, T_8 and T_7 and significantly superior to others. In the case of frequency of irrigation, I_2 produced maximum number of leaves and it was on par with I_1, but significantly superior to I_0.

While comparing the T x I interaction at the same level of main treatment, it was found that the treatment combinations with I_1 and I_2 were having higher number of leaves than the I_0 treatment combinations within the main treatments. The treatment combination T_3I_1 recorded maximum number of leaves among all the different treatment combinations.

At harvest, the treatment T_3 was on par with T_S and T_1 and significantly superior to other treatments. With reference to frequency of irrigation I_2 was significantly superior to I_0 and I_1.

The T x I interaction was significant. The T_3I_2 combination recorded the maximum number of leaves followed by T_3I_1 and T_2I_1. In general, the I_1 and I_2 treatment combinations recorded

Table 7. Number of leaves at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	11.73	17.60	17.00	15.44
T_S	12.47	18.33	17.13	15.98
T_1	16.53	15.87	17.33	16.58
T_2	17.87	15.40	15.33	16.20
T_3	24.33	22.47	21.93	22.91
T_4	15.07	19.53	18.93	17.84
T_5	9.20	12.13	11.60	10.98
T_6	10.07	10.87	11.00	10.64
T_7	17.73	21.27	20.53	19.84
T_8	15.20	16.20	16.87	16.09
T_9	17.53	19.13	18.47	18.38
Mean	15.25	17.16	16.92	

C.D. (0.05) for time of sowing = 5.187

C.D. (0.05) for frequency of irrigation = 0.867

Table 7 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	38.47	77.73	84.03	66.74
T_S	50.20	58.80	54.60	54.53
T_1	52.60	63.53	60.53	58.89
T_2	72.27	98.33	98.60	89.73
T_3	106.53	135.40	134.93	125.62
T_4	101.80	114.07	105.67	107.17
T_5	84.77	104.47	99.33	96.19
T_6	73.27	58.80	121.40	84.49
T_7	96.80	103.00	101.53	100.44
T_8	103.40	110.60	107.53	107.18
T_9	104.87	104.47	119.40	109.58
Mean	80.45	93.56	98.87	

C.D. (0.05) for time of sowing = 26.08

C.D. (0.05) for frequency of irrigation = 5.807

C.D. (0.05) for T x I interaction : a = 19.26

b = 37.46

Table 7 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	39.0	45.50	43.33	42.62
T_S	34.60	65.53	60.13	53.42
T_1	36.47	56.00	54.47	48.98
T_2	15.30	34.73	55.43	35.16
T_3	25.53	67.60	72.67	55.27
T_4	18.33	25.07	24.80	22.73
T_5	30.00	30.07	35.00	31.69
T_6	22.40	27.87	45.13	31.80
T_7	32.20	36.40	35.93	34.84
T_8	25.00	30.13	28.33	27.82
T_9	44.07	48.20	47.00	46.42
Mean	29.35	42.47	45.66	

C.D. (0.05) for time of sowing = 8.113

C.D. (0.05) for frequency of irrigation = 1.224

C.D. (0.05) for T x I interaction : a = 4.060

b = 2.075

comparatively higher values than those with I_0 combinations.

4.4.3. Length of internode

The internodal length of plant recorded at 30^{th} day and 60^{th} day are presented in Tables 8 a-b and their analysis of variance in Appendix I.

It is seen that internodal length was not influenced by the frequency of irrigation at the two stages of observation. But time of sowing recorded significance only at 30^{th} day and the treatment T_7 gave the highest internodal length which was on par with T_1 and T_8. The T x I interaction was not significant at both the stages of observation.

4.4.4. Number of branches per plant

The number of branches recorded at 30^{th} day, 60^{th} day and at harvest are given in Tables 9 a-c and the analysis of variance in Appendix I.

It is seen from the Table that this character was significantly influenced by the time of sowing and frequency of irrigation at all stages of observation. The T x I interaction was found significant only at the second stage of observation.

During the 30^{th} day the treatment T_3 recorded maximum number of branches and was on par with T_4 and T_2. At the 60^{th} day and harvest also the treatment T_3 recorded the maximum number of branches.

Table 8. Internodal length (cm) at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	5.66	4.66	3.93	4.75
T_S	4.40	4.46	4.80	4.55
T_1	5.86	5.13	4.60	5.20
T_2	4.93	4.26	4.13	4.44
T_3	4.73	4.60	3.26	4.20
T_4	4.66	4.40	4.26	4.31
T_5	3.66	4.13	3.93	3.91
T_6	3.76	3.06	3.33	3.38
T_7	4.20	7.26	7.13	6.20
T_8	5.40	5.26	5.06	5.24
T_9	5.26	5.00	4.26	4.84
Mean	4.74	4.75	4.43	

C.D. (0.05) for time of sowing = 1.046

Table 8 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	7.80	6.93	7.73	7.51
T_S	7.60	8.80	6.66	7.68
T_1	7.86	7.20	7.40	7.48
T_2	5.53	6.73	6.06	6.11
T_3	7.06	6.53	6.76	6.78
T_4	6.73	7.80	7.46	7.33
T_5	8.46	8.33	8.26	8.35
T_6	4.20	7.26	7.13	6.20
T_7	8.06	9.53	8.40	8.66
T_8	7.93	7.20	8.00	7.71
T_9	7.40	7.53	5.80	6.91
Mean	7.15	7.62	7.24	

F - Test not significant

Table 9. Number of branches per plant at different stages of growth.

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	2.56	5.06	4.66	4.10
T_S	3.33	4.73	4.40	4.15
T_1	4.13	5.06	5.46	4.88
T_2	5.33	4.73	5.46	5.17
T_3	4.93	5.53	5.33	5.26
T_4	4.60	5.86	5.26	5.20
T_5	1.86	3.80	4.20	3.28
T_6	2.40	3.36	3.13	2.96
T_7	2.53	4.13	4.53	3.73
T_8	2.86	4.33	4.46	3.88
T_9	4.33	5.06	4.53	4.64
Mean	3.53	4.70	4.67	

C.D. (0.05) for time of sowing = 1.117

C.D. (0.05) for frequency of irrigation = 0.396

Table 9 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	2.90	5.53	6.26	4.90
T_S	3.80	5.53	5.40	4.91
T_1	4.43	5.86	6.40	5.56
T_2	5.33	5.53	5.60	5.48
T_3	6.06	6.86	6.33	6.42
T_4	5.53	5.86	5.66	5.75
T_5	4.60	3.35	4.60	4.55
T_6	5.06	5.13	5.20	5.13
T_7	3.80	5.33	5.80	4.97
T_8	4.60	5.46	5.26	5.11
T_9	5.20	5.73	5.66	5.53
Mean	4.66	5.57	5.67	

C.D. (0.05) for time of sowing = 0.782

C.D. (0.05) for frequency of irrigation = 0.353

C.D. (0.05) for T x I interaction : a = 1.173

b = 0.945

Table 9 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	2.60	4.36	5.00	4.15
T_S	3.33	4.40	4.06	4.93
T_1	3.66	3.60	5.33	4.33
T_2	3.80	4.00	4.86	3.22
T_3	4.93	6.33	5.73	5.66
T_4	4.00	5.06	4.86	4.64
T_5	3.93	4.73	4.46	4.37
T_6	5.06	4.00	4.60	4.55
T_7	3.26	4.60	4.93	4.26
T_8	3.60	4.13	3.93	3.38
T_9	4.26	4.93	5.00	4.73
Mean	3.86	4.60	4.83	

C.D. (0.05) for time of sowing = 0.769

C.D. (0.05) for frequency of irrigation = 0.375

Effect of irrigation was significant. I_1 and I_2 were significantly superior to I_0 and they were on par at all stages of observation.

The interaction effect was significant during 60^{th} day, but it was not significant at 30^{th} day and at harvest. The treatment combination T_3I_1 gave the highest value during the above stages of observation.

4.4.5. Number of nodes per plant

The data on the number of nodes per plant at the three stages of observation are presented in Tables 10 a-c and the analysis of variance in Appendix I.

The Tables reveal that this character was significantly influenced by time of sowing and frequency of irrigation at all stages of observation. The T x I interaction effect was found significant only at the harvest stage.

During the first stage, the treatment T_3 produced significantly higher number of nodes and was followed by T_9 and T_8. But at the second and final stages the treatment T_3 producted maximum number of nodes and was on par with T_4 and significantly superior to other treatments.

With reference to the frequency of irrigation, the I_1 and I_2 treatments were on par and significantly superior to I_0 at all the three stages of observation.

Table 10. Number of nodes at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	4.23	4.67	4.73	4.54
T_S	4.13	4.60	4.47	4.40
T_1	4.27	5.00	4.53	4.60
T_2	4.50	4.53	4.47	4.50
T_3	4.67	5.40	5.13	6.07
T_4	4.20	4.60	4.67	4.49
T_5	3.73	4.20	4.00	3.98
T_6	3.87	3.87	3.80	3.84
T_7	4.27	4.60	4.60	4.49
T_8	4.93	5.13	5.07	5.04
T_9	5.09	5.67	5.40	5.38
Mean	4.36	4.76	4.63	

C.D. (0.05) for time of sowing = 0.436

C.D. (0.05) for frequency of irrigation = 0.219

Table 10 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	20.93	52.67	53.13	42.24
T_S	26.53	37.00	36.47	33.33
T_1	35.00	46.13	43.40	41.51
T_2	39.60	44.00	43.33	42.31
T_3	65.20	68.47	72.47	68.71
T_4	52.13	66.27	66.47	61.62
T_5	44.80	48.00	46.53	46.44
T_6	28.60	33.87	37.40	33.28
T_7	44.60	66.13	67.87	59.53
T_8	49.13	52.90	57.07	53.03
T_9	46.27	56.40	61.60	54.76
Mean	41.16	51.98	53.25	

C.D. (0.05) for time of sowing = 8.849

C.D. (0.05) for frequency of irrigation = 2.790

Table 10 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	22.73	54.60	54.53	43.95
T_S	29.73	37.60	38.00	35.17
T_1	33.03	47.66	42.90	41.20
T_2	39.66	44.80	44.36	42.94
T_3	65.20	68.46	72.46	68.71
T_4	53.66	66.26	67.46	62.46
T_5	44.80	48.00	47.06	46.62
T_6	29.60	34.53	37.40	33.84
T_7	44.60	66.40	67.86	59.62
T_8	49.80	52.90	57.26	53.32
T_9	47.26	57.40	61.60	55.46
Mean	41.82	52.60	53.73	

C.D. (0.05) for time of sowing = 8.903

C.D. (0.05) for frequency of irrigation = 3.213

C.D. (0.05) for T x I interaction : a = 10.656

b = 9.709

The interaction effect of T x I was found to be significant at harvest. The treatment combination T_3I_2 recorded the maximum value and T_0I_0 the minimum.

4.4.6. Leaf area per plant

The leaf area per plant recorded at the three stages of observation are presented in Tables 11 a-c and the analysis of variance in Appendix I.

It is observed from the Tables that the main and sub plot treatments significantly influenced the leaf area per plant during all the stages of observation while the interaction effects were significant only at the later two stages. At all stages of observation the treatment T_3 recorded the maximum leaf area.

With reference to the frequency of irrigation I_2 gave the maximum leaf area and was on par with I_1 and significantly superior to I_0 at all the three stages of observation.

4.4.7. Length of tap root and lateral spread of roots

The length of tap root and lateral spread of roots recorded at harvest are presented in Tables 12 a and b respectively and their analysis of variance in Appendix I.

The Table (a) reveals that the length of tap root was significantly influenced by the time of sowing and frequency of irrigation. The treatment T_0 recorded maximum length and

Table 11. Leaf area per plant (cm^2) at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	233.37	348.13	342.85	308.12
T_S	232.75	351.27	336.15	306.72
T_1	322.59	328.39	340.08	330.35
T_2	311.41	254.30	291.74	280.82
T_3	367.43	383.95	364.95	372.11
T_4	260.80	331.09	329.63	307.17
T_5	160.91	215.49	206.25	194.21
T_6	182.41	196.36	197.45	192.07
T_7	312.11	380.67	366.55	353.11
T_8	275.12	273.37	315.74	288.08
T_9	296.30	314.99	318.93	311.08
Mean	268.67	307.36	310.03	

C.D. (0.05) for time of sowing = 84.105

C.D. (0.05) for frequency of irrigation = 23.698

Table 11 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	525.87	909.48	1016.80	817.38
T_S	654.39	778.27	733.74	722.13
T_1	743.76	903.44	847.47	831.56
T_2	947.41	1038.39	1056.99	1014.27
T_3	1258.16	1383.78	1426.24	1356.07
T_4	1194.11	1293.90	1227.85	1238.62
T_5	1021.44	1271.57	1231.07	1174.62
T_6	936.34	764.99	1432.52	1044.62
T_7	1118.04	1182.44	1148.34	1149.61
T_8	1115.85	1209.97	1149.53	1158.45
T_9	1104.25	1103.17	1241.76	1149.72
Mean	965.42	1076.29	1137.48	

C.D. (0.05) for time of sowing = 292.639

C.D. (0.05) for frequency of irrigation = 66.696

C.D. (0.05) for T x I interaction : a = 221.206

b = 263.365

Table 11 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	437.43	522.72	497.47	485.87
T_S	515.67	801.53	778.33	698.50
T_1	347.25	790.92	876.73	671.64
T_2	200.58	372.33	594.49	389.14
T_3	450.49	855.39	820.82	708.90
T_4	215.05	290.49	290.91	265.48
T_5	361.50	364.85	425.95	384.09
T_6	286.27	362.54	467.08	371.97
T_7	383.17	429.81	424.37	412.45
T_8	273.50	328.20	311.43	304.38
T_9	464.87	508.99	495.78	489.88
Mean	357.80	511.62	543.94	

C.D. (0.05) for time of sowing = 98.114

C.D. (0.05) for frequency of irrigation = 35.473

C.D. (0.05) T x I interaction : a = 117.649

b = 107.089

Table 12. (a) Length of tap root (cm) at harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	15.30	12.83	12.60	13.57
T_S	9.26	8.53	8.86	8.88
T_1	12.13	9.53	8.66	10.11
T_2	12.30	8.63	8.26	9.73
T_3	11.80	10.30	9.50	10.53
T_4	12.40	8.93	9.66	10.33
T_5	12.26	8.60	8.20	9.68
T_6	12.00	9.06	10.40	10.48
T_7	12.73	8.60	10.13	10.48
T_8	11.40	9.93	8.66	10.00
T_9	12.80	8.40	9.26	10.15
Mean	12.21	9.39	9.47	

C.D. (0.05) for time of sowing = 2.756

C.D. (0.05) for frequency of irrigation = 0.485

Table 12 contd. .....

(b) Lateral spread of roots at harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	7.68	9.13	8.83	8.55
T_S	8.13	13.60	13.76	11.83
T_1	7.36	15.26	14.83	12.48
T_2	9.30	12.93	12.23	11.48
T_3	12.13	13.80	15.00	13.64
T_4	9.96	13.66	13.06	12.23
T_5	13.63	13.00	12.83	13.15
T_6	9.86	13.60	12.16	11.87
T_7	10.30	14.06	15.23	13.20
T_8	8.46	14.30	12.93	11.90
T_9	10.53	13.80	15.00	12.17
Mean	9.76	13.22	13.16	

C.D. (0.05) for time of sowing = 1.720

C.D. (0.05) for frequency of irrigation = 0.665

C.D. (0.05) for T x I interaction : a = 2.410

b = 1.934

it was significantly superior to all other main treatments. With regard to frequency of irrigation the I_0 treatment produced maximum tap root length and was significantly superior to I_1 and I_2 where the latter two were on par. The T x I interaction was not significant.

The Table (b) shows that the different treatments influenced the lateral spread of the roots. The main treatment T_3 recorded maximum lateral spread. T_0 recorded the lowest value. In the case of frequency of irrigation I_1 and I_2 were on par and significantly superior to I_0.

While the interactions were concerned, the treatment combinations with I_2 and I_1 were showing higher values than the I_0 treatment combinations. Among the combinations, T_1I_1 recorded the highest value.

4.4.8. Dry weight of roots

Dry weight of roots recorded at harvest is presented in Table 13 and their analysis of variance in Appendix I.

The Table shows that the dry weight of root was significantly influenced by the time of sowing, frequency of irrigation and their interaction. The treatment T_3 produced maximum dry weight and it was significant to all other treatments.

With respect to frequency of irrigation, the treatments

Table 13. Dry weight of roots (g) at harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	2.73	3.10	4.24	3.35
T_S	1.77	3.00	3.35	2.70
T_1	1.66	2.70	1.74	2.03
T_2	3.66	4.40	3.90	3.98
T_3	8.86	10.89	9.86	9.86
T_4	4.68	4.80	5.19	4.89
T_5	5.60	7.93	7.13	6.88
T_6	2.36	3.13	3.53	3.00
T_7	7.13	7.20	10.76	8.36
T_8	4.20	6.20	4.66	5.02
T_9	4.54	6.26	5.20	5.33
Mean	4.29	5.41	5.41	

C.D. (0.05) for time of sowing = 1.151

C.D. (0.05) for frequency of irrigation = 0.404

C.D. (0.05) for T x I interaction : a = 1.330

b = 1.239

I_1 and I_2 produced the maximum dry weight and were found significantly superior to I_0 where the former two were on par.

It was also noticed that the treatment combinations with I_1 and I_2 were superior to those with I_0. The treatment combinations T_3I_1, T_7I_2 and T_3I_2 were found to be on par.

4.4.9. Dry matter production

Data on dry matter (kg/ha) produced at different stages of observation are presented in Tables 14 a-c and the analysis of variance in Appendix I.

It is seen from the Tables 14 a-c that the dry matter production was significantly influenced by different treatments and their interactions at all the three stages of observation. The treatment T_1 produced maximum dry matter and was significantly superior to all other main treatments during the first, second and final stages of observation. It was followed by T_S and T_2.

With regard to frequency of irrigation, I_1 and I_2 were found significantly superior to I_0 and the former two were on par.

While the T x I interactions were considered, the treatment combinations with I_1 and I_2 were found significantly superior to the corresponding combinations with I_0.

Table 14. Dry matter production (kg/ha) at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	211.91	260.00	261.66	244.52
T_S	435.66	565.91	576.83	526.13
T_1	481.16	611.75	616.40	573.11
T_2	368.25	454.25	450.58	424.36
T_3	166.33	241.08	238.75	215.38
T_4	161.16	213.08	215.00	196.41
T_5	127.83	173.41	179.91	160.38
T_6	113.16	155.08	161.08	143.11
T_7	91.58	136.58	142.25	123.47
T_8	98.08	141.75	137.66	125.83
T_9	97.50	150.50	140.33	130.44
Mean	213.87	282.12	284.86	

C.D. (0.05) for time of sowing = 23.845

C.D. (0.05) for frequency of irrigation = 8.956

C.D. (0.05) for T x I interaction : a = 29.704

b = 26.436

Table 14 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	869.83	1114.58	1123.58	1036.00
T_S	3286.00	3849.91	3886.83	3674.24
T_1	3571.08	4069.08	4123.83	3920.66
T_2	2886.66	3106.83	3139.50	3044.33
T_3	2195.16	2702.66	2771.16	2556.33
T_4	929.25	1157.41	1124.41	1070.36
T_5	869.58	1052.50	1031.66	984.58
T_6	753.58	898.58	919.08	857.08
T_7	636.08	853.41	840.41	776.63
T_8	735.16	843.16	843.66	807.33
T_9	869.83	1027.91	1026.41	974.72
Mean	1600.20	1879.64	1893.50	

C.D. (0.05) for time of sowing = 52.045

C.D. (0.05) for frequency of irrigation = 26.555

C.D. (0.05) for T x I interaction : a = 88.073

b = 66.550

Table 14 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	891.33	888.00	920.66	900.00
T_S	2646.00	2834.83	2826.50	2769.11
T_1	2725.16	3077.16	3128.33	2976.88
T_2	1723.66	1888.66	1880.00	1830.77
T_3	1177.16	1599.00	1598.66	1458.27
T_4	985.66	1104.83	1103.00	1064.50
T_5	822.83	1177.66	1216.16	1070.88
T_6	806.33	844.16	841.66	830.72
T_7	535.83	663.33	639.50	612.88
T_8	782.33	901.50	853.16	845.66
T_9	744.00	840.33	840.33	808.27
Mean	1258.21	1438.13	1440.36	

C.D. (0.05) for time of sowing = 68.318

C.D. (0.05) for frequency of irrigation = 22.404

C.D. (0.05) for T x I interaction : a = 74.307

b = 71.530

The treatment combination T_1I_2 recorded maximum value and was on par with T_1I_1.

4.4.10. Percentage distribution of dry matter in different parts

The percentage distribution of dry matter in different plant parts at 30th day, 60th day and at harvest are shown in Tables 15 a-c, 16 a-c and 17 a-b respectively and their analysis of variance in Appendix I.

(a) Stem

The Tables 15 a-c show that all treatments and their interactions significantly influenced the dry matter distribution in stem during the first and final stages. But at the second stage the frequency of irrigation was not significant.

At 30th day of observation the treatment T_8 recorded the highest percentage of dry matter in stem and it was significantly superior to all other treatments. In the case of frequency of irrigation, I_0 was significantly superior to I_1 and I_2 where the latter two were on par.

I_0 treatment combinations were significantly superior to I_1 and I_2 treatment combinations except in T_0 and T_8 treatment combinations. Among the combinations, T_7I_0 showed the highest value which was on par with T_8I_1, T_8I_2, T_9I_0 T_8I_0 and T_4I_0.

During the 60th day, the treatment T_8 resulted in the

Table 15. Percentage distribution of dry matter in stem at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	28.99	27.96	28.40	28.45
T_S	32.34	25.92	25.82	28.02
T_1	32.71	24.98	25.81	27.53
T_2	33.16	27.47	29.07	29.90
T_3	33.74	26.07	25.40	28.40
T_4	37.16	27.34	26.00	30.17
T_5	33.92	27.85	25.46	29.08
T_6	35.74	27.85	26.89	30.16
T_7	38.99	26.07	25.94	30.33
T_8	36.84	37.92	37.69	37.48
T_9	36.86	27.29	27.54	30.56
Mean	34.59	29.88	27.64	

C.D. (0.05) for time of sowing = 2.291

C.D. (0.05) for frequency of irrigation = 1.038

C.D. (0.05) for T x I interaction : a = 3.444

b = 2.771

Table 15 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	33.90	27.89	28.85	30.21
T_S	35.34	29.36	33.68	32.79
T_1	33.30	29.77	36.63	33.23
T_2	40.85	27.98	25.18	31.32
T_3	42.42	39.95	31.17	37.84
T_4	46.83	41.47	38.52	42.27
T_5	46.09	43.77	41.61	43.62
T_6	35.12	54.70	56.12	48.65
T_7	33.36	43.31	42.29	39.98
T_8	42.71	55.39	53.79	50.63
T_9	42.84	50.97	51.09	48.30
Mean	39.34	40.41	39.99	

C.D. (0.05) for time of sowing = 2.700

C.D. (0.05) for T x I interaction : a = 4.780

b = 3.530

Table 15 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	34.34	29.36	33.71	32.47
T_S	31.56	27.89	28.85	29.43
T_1	40.18	27.98	25.10	31.12
T_2	31.30	29.77	36.36	32.57
T_3	42.42	39.95	31.17	37.84
T_4	42.16	41.47	38.52	40.72
T_5	43.42	43.77	41.61	42.93
T_6	33.36	32.97	31.92	32.54
T_7	35.12	38.36	37.81	37.10
T_8	45.35	44.07	41.79	43.73
T_9	47.84	40.97	41.75	43.52
Mean	38.82	36.05	35.30	

C.D. (0.05) for time of sowing = 3.133

C.D. (0.05) for frequency of irrigation = 1.294

C.D. (0.05) for T x I interaction : a = 4.292

b = 3.631

highest percentage of dry matter accumulation in stem and it was on par with T_6 and T_9 while the frequency of irrigation was not significant. The T x I interaction was also significant.

At harvest the treatment T_8 recorded maximum dry matter accumulation in stem and was on par with T_9 and significantly superior to others. With regard to frequency of irrigation, I_0 was found significantly superior to I_1 and I_2 treatments where the latter two were on par.

(b) Leaf

The Tables 16 a-c reveal that all the treatments and their interactions significantly influenced the dry matter accumulation in leaf at 30^{th} day and at harvest. But at 60^{th} day, the frequency of irrigation was not having any significant effect on this character.

During the first stage the treatment T_4 recorded highest percentage of dry matter accumulation in leaf and it was on par with T_3. The frequency of irrigation showed that I_2 and I_1 were on par and significantly superior to I_0 treatment. The treatment combinations with I_1 and I_2 were showing higher values than I_0 treatment combinations. The treatment combination T_4I_1 resulted in the highest percentage of dry matter accumulation in leaf at this stage.

Table 16. Percentage of distribution of dry matter in leaves at different stages of growth

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	49.30	60.06	59.20	56.22
T_S	45.72	57.89	56.08	53.22
T_1	49.35	62.32	60.91	57.53
T_2	53.98	57.77	58.80	56.85
T_3	59.30	65.86	65.52	63.56
T_4	61.84	68.84	68.17	66.28
T_5	55.70	59.38	60.35	58.48
T_6	58.14	60.01	55.80	57.98
T_7	55.93	54.20	60.75	56.96
T_8	59.39	63.45	62.92	61.92
T_9	49.99	52.80	59.43	54.07
Mean	54.42	60.24	60.72	

C.D. (0.05) for time of sowing = 3.553

C.D. (0.05) for frequency of irrigation = 1.681

C.D. (0.05) for T x I interaction : a = 5.577

b = 4.385

Table 16 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	32.85	27.26	28.80	29.63
T_S	30.04	31.39	32.71	31.38
T_1	28.26	32.03	32.25	30.85
T_2	33.89	37.62	34.08	35.19
T_3	28.92	33.79	33.39	32.03
T_4	37.69	35.65	32.74	35.36
T_5	29.87	34.40	33.64	32.63
T_6	29.31	37.08	34.40	33.60
T_7	53.48	33.18	34.24	40.30
T_8	27.99	33.45	34.28	31.91
T_9	28.03	31.80	33.56	31.13
Mean	32.76	33.42	33.10	

C.D. (0.05) for time of sowing = 2.835

C.D. (0.05) for T x I interaction : a = 4.597

b = 3.552

Table 16 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	21.80	22.68	11.78	20.44
T_S	22.40	22.93	22.17	21.50
T_1	6.41	13.33	16.30	12.02
T_2	23.57	22.84	14.22	20.21
T_3	11.13	11.12	10.81	11.02
T_4	11.23	9.09	8.28	9.53
T_5	16.44	8.80	9.20	11.48
T_6	16.73	13.16	14.55	14.81
T_7	26.38	10.96	12.23	16.52
T_8	16.61	10.78	12.94	13.44
T_9	12.95	15.69	18.24	14.96
Mean	16.88	14.67	13.98	

C.D. (0.05) for time of sowing = 2.481

C.D. (0.05) for frequency of irrigation = 1.484

C.D. (0.05) for T x I interaction : a = 4.922

b = 3.420

At 60^{th} day the main treatment T_7 recorded the highest percentage of dry matter in leaves and it was followed by T_4, T_2 and T_6. The treatment T_0 recorded the lowest value. The frequency of irrigation was not significant. However, I_1 and I_2 were showing higher values than I_0. The T x I interaction showed that the I_1 and I_2 treatment combinations were having higher values than I_0 treatment combinations.

In the final stage the main treatment T_S recorded maximum percentage of dry matter accumulation in leaves. With reference to frequency of irrigation, the treatment I_0 was significantly superior to I_1 and I_2. The I_0 treatment combinations were showing higher values than I_1 and I_2 combinations. The treatment combination T_7I_0 recorded the highest value.

(c) Capsule

The data presented in Tables 17 a and b showed that the dry matter distribution in capsule was significantly influenced by time of sowing and frequency of irrigation. The T x I interaction was significant during the 60^{th} day and was not significant at harvest. The treatment T_1 recorded the maximum accumulation of dry matter in capsule and it was on par with T_S on the 60^{th} day, while at harvest T_1 was followed by T_6, T_3, T_2 and T_4.

With reference to frequency of irrigation, the treatments

Table 17. Percentage of distribution of dry matter in capsules at different stages of growth

(a) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	27.91	35.51	35.34	32.92
T_S	28.72	36.08	35.25	33.35
T_1	27.71	37.42	35.21	33.68
T_2	25.38	28.59	29.51	27.85
T_3	28.46	34.17	33.91	32.18
T_4	18.49	30.24	32.02	26.92
T_5	28.75	34.29	35.01	32.68
T_6	23.93	29.31	28.26	27.17
T_7	5.04	22.41	20.74	16.07
T_8	24.99	33.38	33.41	30.59
T_9	23.72	30.82	30.69	28.41
Mean	23.92	32.02	31.83	

C.D. (0.05) for time of sowing = 3.262

C.D. (0.05) for frequency of irrigation = 1.200

C.D. (0.05) for T x I interaction : a = 3.982

b = 3.587

Table 17 contd. .....

(b) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	37.17	43.31	43.89	41.46
T_S	40.11	43.17	43.35	42.21
T_1	45.53	51.96	51.96	49.82
T_2	38.84	41.61	43.53	41.32
T_3	36.22	43.58	48.10	42.63
T_4	35.49	45.01	45.89	42.13
T_5	29.00	35.86	38.59	34.50
T_6	41.95	47.44	45.88	45.09
T_7	26.30	37.61	38.03	33.98
T_8	23.89	35.18	34.48	31.98
T_9	28.37	34.72	34.05	32.38
Mean	34.81	41.72	42.52	

C.D. (0.05) for time of sowing = 8.069

C.D. (0.05) for frequency of irrigation = 1.326

I_2 and I_1 were on par and was significantly superior to I_0 at both the stages.

While comparing the T x I interaction at 60th day, the I_0 treatment combinations were found significantly inferior to I_1 and I_2 combinations. Among the T x I interaction, the treatment combination T_1I_1 showed the highest accumulation of dry matter in capsules and it was on par with T_1I_2, T_SI_1, T_0I_1, T_0I_2, T_SI_2 and T_3I_2.

4.4.11. Number of days for first flowering

It is seen from the Table 18 that the time of sowing and frequency of irrigation influenced the number of days taken for first flowering. The T_0 plots recorded the minimum number of days for first flowering which was significantly different from the remaining treatments. In the case of irrigation treatments, no irrigation in the growth phase accounted for the minimum number of days for first flowering while there was no difference in this character between I_1 and I_2. The interaction effects were not significant.

4.5. Yield and yield components

4.5.1 Number of capsules per plant

The data on the number of capsules produced per plant at 60th day and harvest are presented in Tables 19 a and b and their analysis of variance in Appendix I.

Table 18. Number of days for first flowering

Time/Frequency	I_0	I_1	I_2	Mean
T_0	26.33	28.66	29.33	28.11
T_S	28.33	29.66	30.66	29.55
T_1	28.66	29.66	30.00	29.44
T_2	29.00	30.00	30.33	29.77
T_3	29.66	30.33	29.66	29.88
T_4	28.66	30.00	30.33	29.66
T_5	28.00	30.33	30.00	29.44
T_6	29.00	29.33	30.33	29.55
T_7	29.66	30.33	30.00	30.00
T_8	28.33	30.33	29.66	29.44
T_9	30.00	30.33	30.00	30.11
Mean	28.69	29.90	30.03	

C.D. (0.05) for time of sowing = 0.913

C.D. (0.05) for frequency of irrigation = 0.508

Table 19. Number of capsules per plant at different stages of growth.

(a) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	49.40	83.53	85.06	72.66
T_S	37.66	52.40	49.20	46.42
T_1	38.40	52.80	52.06	47.75
T_2	61.60	72.80	63.86	66.08
T_3	61.00	82.40	80.06	77.15
T_4	61.86	77.80	72.06	70.57
T_5	50.66	67.20	63.40	60.42
T_6	35.73	41.93	42.46	39.20
T_7	34.20	45.93	37.46	40.04
T_8	46.33	54.26	53.46	51.35
T_9	41.20	49.80	48.46	46.48
Mean	47.09	61.89	59.80	

C.D. (0.05) for time of sowing = 8.289

C.D. (0.05) for frequency of irrigation = 4.097

Table 19 contd. .....

(b) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	50.73	92.16	91.13	78.01
T_S	39.53	55.73	53.13	49.46
T_1	43.46	61.80	59.06	54.77
T_2	63.73	79.20	78.86	73.93
T_3	67.66	86.66	87.20	80.51
T_4	65.13	81.20	74.40	73.57
T_5	51.60	67.33	65.73	61.55
T_6	36.06	42.60	46.40	41.68
T_7	37.93	45.73	43.33	42.33
T_8	47.64	59.33	57.40	54.79
T_9	45.20	51.00	48.93	48.37
Mean	49.88	65.70	64.14	

C.D. (0.05) for time of sowing = 6.298

C.D. (0.05) for frequency of irrigation = 3.398

C.D. (0.05) for T x I interaction : a = 11.270

b = 7.825

It is seen from the Tables that the time of sowing and frequency of irrigation had significant influence over capsule production at both stages of observation. The T x I interaction was found significant only at the harvest and it was not significant at 60th day of observation.

The treatment T_3 produced maximum number of capsules and was on par with T_0 and T_4 at 60th day of observation. During harvest, similar trend was observed. The frequency of irrigation showed that I_1 and I_2 were significantly superior to I_0 and the former two were on par at the two stages of observation. Among the T x I interactions the treatment combination T_0T_1 recorded maximum number of capsules and was on par with T_0I_2, and T_3I_1.

4.5.2. <u>Weight of capsules per plant</u>

The data on weight of capsule are furnished in Table 20 and their analysis of variance in Appendix I. It is seen that the effects due to time of sowing, frequency and their interactions were significant. The treatment T_3 accounted for the maximum capsule weight and it was on par with T_2 and significantly superior to all other treatments.

With reference to frequency of irrigation I_1 and I_2 were on par and significantly superior to I_0. The treatment combination T_3 I_2 recorded the maximum value and it was

Table 20. Weight of capsules (g) per plant

Time/Frequency	I_0	I_1	I_2	Mean
T_0	5.11	7.90	7.83	6.94
T_S	4.08	6.10	6.16	5.45
T_1	4.80	6.06	6.23	5.70
T_2	5.83	8.66	8.22	7.57
T_3	6.66	8.61	9.35	8.21
T_4	5.03	7.90	7.10	6.67
T_5	4.42	5.84	5.85	5.37
T_6	3.15	4.38	5.22	4.25
T_7	3.70	4.59	4.63	4.31
T_8	3.40	5.63	5.45	4.20
T_9	4.68	4.64	4.64	4.63
Mean	4.62	6.39	6.42	

C.D. (0.05) for time of sowing = 0.952

C.D. (0.05) for frequency of irrigation = 0.097

C.D. (0.05) for T x I interaction : a = 0.322

b = 0.698

significantly superior to all other treatment combinations.

4.5.3. Number of seeds per capsule

The data on number of seeds per capsule are given in Table 21 and the analysis of variance in Appendix I.

From the Table it is seen that the number of seeds per capsule was significantly influenced by the time of sowing and frequency of irrigation. The T x I interaction was not significant. Among the main treatments the treatments T_1 and T_3 produced maximum number of seeds per capsule and they were on par with T_2 and T_S.

The irrigation treatment I_1 was on par with I_2 and significantly superior to I_0.

4.5.4. Seed weight per plant

The data on the weight of seeds produced per plant are furnished in Table 22 and the analysis of variance in Appendix I.

It is seen that the time of sowing and frequency of irrigation and their interaction effects influenced the seed weight per plant. The treatment T_3 accounted for the maximum seed weight per plant and was on par with T_2 and T_0. When the frequency of irrigation was considered, I_0 was significantly inferior to I_1 and I_2 and the latter two were on par.

The treatment combinations T_3I_1 and T_0I_1 recorded maximum seed weight per plant among all the treatment combinations.

Table 21. Number of seeds per capsule

Time/Frequency	I_0	I_1	I_2	Mean
T_0	51.40	57.00	55.06	54.48
T_S	50.13	59.20	58.33	55.88
T_1	51.80	60.46	58.80	57.02
T_2	51.80	56.53	59.46	55.93
T_3	53.33	59.66	58.06	57.02
T_4	49.80	52.00	49.80	50.53
T_5	47.73	52.66	52.73	51.04
T_6	45.86	48.86	45.90	46.87
T_7	45.53	49.20	49.86	48.20
T_8	48.40	50.93	49.66	49.66
T_9	59.20	53.46	52.70	52.13
Mean	49.63	54.54	53.67	

C.D. (0.05) for time of sowing = 3.600

C.D. (0.05) for frequency of irrigation = 1.703

Table 22. Seed weight (g) per plant

Time/Frequency	I_0	I_1	I_2	Mean
T_0	2.55	3.95	3.91	3.47
T_S	2.14	3.01	3.08	2.74
T_1	2.40	3.03	3.08	2.83
T_2	2.64	3.91	3.86	3.47
T_3	3.08	3.95	3.86	3.63
T_4	2.44	3.75	3.42	3.20
T_5	2.02	2.81	2.72	2.52
T_6	1.33	2.07	2.53	1.98
T_7	1.70	2.16	2.19	2.02
T_8	1.83	2.73	2.65	2.40
T_9	2.06	2.20	2.16	2.14
Mean	2.20	3.05	3.04	

C.D. (0.05) for time of sowing = 1.870

C.D. (0.05) for frequency of irrigation = 0.102

C.D. (0.05) for T x I interaction : a = 0.338

b = 1.336

4.5.5. 1000 seed weight

Data on 1000 seed weight recorded at harvest are presented in Table 23 and the analysis of variance in Appendix I.

It is seen from the Table that the different treatments and their interactions were not significant for this character. However, the treatments T_S and T_1 recorded higher values.

4.5.6. Seed yield

The result on seed yield is presented in Table 24 and analysis of variance in Appendix I. The Table shows that seed yield was significantly influenced by the time of sowing and the frequency of irrigation and their interactions. The treatment T_1 produced the maximum yield (785 kg/ha) and it was significantly superior to all other treatments. This was followed by T_S (729.66 kg/ha). T_2 and T_3 were on par. The treatments T_4, T_5 and T_0 were also on par and significantly superior to T_6, T_7, T_8 and T_9. The treatments T_8 and T_9 recorded the lowest yields.

With regard to frequency of irrigation, the treatment I_1 produced maximum yield (373.60 kg/ha) and was significantly superior to I_0. I_1 was on par with I_2.

The T x I interaction was significant and the treatment combinations with I_1 and I_2 were significantly superior to I_0 treatment combinations. Among the T x I interaction, the

Table 23. 1000 seed weight (g)

Time/Frequency	I_0	I_1	I_2	Mean
T_0	3.296	3.299	3.300	3.298
T_S	3.303	3.301	3.304	3.307
T_1	3.294	3.305	3.302	3.300
T_2	3.296	3.298	3.298	3.297
T_3	3.298	3.298	3.301	3.299
T_4	3.300	3.301	3.297	3.299
T_5	3.298	3.301	3.298	3.299
T_6	3.296	3.299	3.298	3.298
T_7	3.300	3.297	3.297	3.298
T_8	3.298	3.300	3.297	3.299
T_9	3.298	3.298	3.300	3.299
Mean	3.298	3.300	3.299	

F. test not significant

Table 24. Seed yield (kg/ha)

Time/Frequency	I_0	I_1	I_2	Mean
T_0	187.00	303.33	304.66	265.00
T_S	633.33	777.33	778.33	729.66
T_1	646.00	850.00	859.00	785.00
T_2	352.66	424.00	420.00	398.88
T_3	331.00	414.33	414.33	386.66
T_4	243.33	296.00	291.33	276.88
T_5	248.33	290.66	286.33	275.11
T_6	205.00	250.33	253.66	236.33
T_7	127.33	184.66	180.00	164.00
T_8	128.00	158.66	158.00	148.22
T_9	126.66	160.00	158.66	148.44
Mean	293.51	373.60	373.12	

C.D. for time of sowing		= 12.500
C.D. for frequency of irrigation		= 4.736
C.D. for T x I interaction :	a	= 15.707
	b	= 13.930

treatment combination T_1I_2 produced the maximum yield (859 kg/ha) which was on par with T_1I_1 (850 kg/ha).

4.5.7. Haulm yield

Data on haulm yield are presented in Table 25 and the analysis of variance in Appendix I. The Table reveals that the sowing time, irrigation frequency and T x I interaction made significant influence on haulm yield. The treatment T_1 produced maximum yield followed by T_S, T_2 and T_3 and it was significantly superior to all other treatments.

With regard to frequency of irrigation, I_2 accounted for the maximum haulm yield and was on par with I_1. But they were significantly superior to I_0 treatment.

Among all the treatment combinations, T_1I_2 recorded the maximum haulm yield and it was on par with T_1I_1.

4.5.8. Shelling percentage

The data on shelling percentage are given in Table 26 and the analysis of variance in Appendix I.

The Table reveals that the shelling percentage differed with time of sowing and frequency of irrigation. The T x I interaction was not significant. The treatments T_0, T_S and T_1 recorded higher shelling percentage (50) and found significantly superior to other treatments.

Similarly in the case of frequency of irrigation, the

Table 25. Haulm yield (kg/ha)

Time/Frequency	I_0	I_1	I_2	Mean
T_0	704.33	584.50	616.00	634.94
T_S	2012.66	2033.50	2048.16	2031.44
T_1	2079.16	2227.16	2269.33	2191.88
T_2	1387.33	1477.00	1460.00	1441.44
T_3	846.16	1185.66	1184.33	1072.05
T_4	742.33	808.83	811.66	787.61
T_5	574.50	883.66	925.83	794.66
T_6	601.33	600.50	588.00	596.11
T_7	408.50	478.66	459.60	448.88
T_8	654.33	742.83	695.16	697.44
T_9	617.33	680.33	681.66	659.77
Mean	966.18	1063.87	1067.24	

C.D. (0.05) for time of sowing = 70.28

C.D. (0.05) for frequency of irrigation = 21.27

C.D. (0.05) for T x I interaction : a = 70.54

b = 70.87

Table 26. Shelling percentage

Time/Frequency	I_0	I_1	I_2	Mean
T_0	50.00	50.00	50.00	50.00
T_S	50.00	50.00	50.00	50.00
T_1	50.00	50.00	50.00	50.00
T_2	45.33	47.11	47.10	46.51
T_3	45.00	46.77	47.32	46.36
T_4	45.73	47.80	47.80	47.11
T_5	45.74	48.24	46.34	46.77
T_6	47.53	47.91	48.39	47.94
T_7	45.98	48.90	47.54	47.47
T_8	44.20	48.16	48.36	46.90
T_9	43.97	47.33	46.70	46.05
Mean	46.68	48.38	48.00	

C.D. (0.05) for time of sowing = 1.748

C.D. (0.05) for frequency of irrigation = 0.710

treatment I_1 and I_2 were significantly superior to I_0.

4.5.9. Harvest index

The data on harvest index are presented in Table 27 and the analysis of variance in Appendix I.

The Table reveals that the harvest index was significantly influenced by the time of sowing, frequency of irrigation and T x I interaction. T_0 recorded the highest harvest index and it was on par with T_6 and significantly superior to other treatments. With reference to frequency of irrigation, the treatment I_1 and I_2 were on par and significantly superior to I_0.

Among the treatment combinations, T_0I_1 resulted in the highest value and it was on par with T_0I_2.

4.6 Chemical analysis

4.6.1. Quality characteristics

4.6.1.1. Protein content of seeds

The data on the protein content of seeds recorded at harvest are furnished in Table 28 and analysis of variance in Appendix I.

It is seen from the Table that the protein content of the seed was significantly influenced by frequency of irrigation and the treatment I_0 was found significantly superior to I_1 and I_2 whereas the latter two were on par. The time of sowing

Table 27. Harvest index

Time/Frequency	I_0	I_1	I_2	Mean
T_0	0.209	0.343	0.331	0.294
T_S	0.239	0.274	0.275	0.263
T_1	0.236	0.278	0.276	0.263
T_2	0.199	0.224	0.223	0.215
T_3	0.281	0.259	0.259	0.266
T_4	0.252	0.271	0.266	0.263
T_5	0.302	0.247	0.233	0.261
T_6	0.255	0.307	0.301	0.288
T_7	0.240	0.278	0.281	0.266
T_8	0.163	0.176	0.185	0.175
T_9	0.170	0.190	0.188	0.183
Mean	0.231	0.259	0.256	

C.D. (0.05) for time of sowing = 0.0206

C.D. (0.05) for frequency of irrigation = 0.0056

C.D. (0.05) for T x I interaction : a = 0.0180

b = 0.0190

Table 28. Protein content of seeds (percentage)

Time/Frequency	I_0	I_1	I_2	Mean
T_0	23.06	21.78	20.50	21.78
T_S	22.41	21.77	20.49	21.56
T_1	22.41	21.78	20.50	21.56
T_2	23.06	21.13	20.49	21.56
T_3	21.77	21.13	19.85	20.92
T_4	23.04	20.58	19.94	21.18
T_5	21.41	21.13	20.49	21.34
T_6	21.13	20.49	20.50	20.70
T_7	22.41	21.77	19.22	21.13
T_8	22.40	21.13	20.49	21.34
T_9	22.40	20.50	21.12	21.34
Mean	22.41	21.20	20.32	

C.D. (0.05) for frequency of irrigation = 1.166

and T x I interaction were not significant.

4.6.1.2. Oil content

The data on oil content at harvest are given in Table 29 and the analysis of variance in Appendix I.

The Table shows that the oil content was significantly influenced by the frequency of irrigation. But the time of sowing and T x I interaction were not significant. However, the treatment T_1 recorded maximum oil content. In the case of frequency of irrigation, the treatment I_2 resulted in the highest oil content and it was significantly superior to I_0 while I_2 and I_1 were on par in this character.

4.6.1.3. Oil Yield

The data on oil yield recorded at harvest are presented in Table 30 and the analysis of variance in Appendix I.

The Table reveals that the oil yield was significantly influenced by the time of sowing, frequency of irrigation and their interactions.

The treatment T_1 gave the maximum oil yield (410.47 kg/ha) and it was significantly superior to all other treatments. T_1 was followed by T_5, T_2 and T_3. The minimum oil yield was recorded by T_9.

In the case of frequency of irrigation the treatment I_1 and I_2 were on par and it was significantly superior to I_0.

Table 29. Oil content (percentage)

Time/Frequency	I_0	I_1	I_2	Mean
T_0	50.70	51.80	52.26	51.58
T_S	51.20	52.40	52.90	52.16
T_1	51.20	52.30	53.06	52.18
T_2	50.86	51.80	52.00	51.55
T_3	50.80	51.33	52.10	51.41
T_4	51.16	51.73	52.40	51.76
T_5	51.16	52.13	52.26	51.85
T_6	50.86	51.33	52.03	51.40
T_7	51.00	52.06	52.26	51.77
T_8	51.20	51.60	52.20	51.66
T_9	51.00	51.66	52.13	51.59
Mean	51.01	51.83	52.33	

C.D. (0.05) for frequency of irrigation = 0.544

Table 30. Oil yield (kg/ha)

Time/Frequency	I_0	I_1	I_2	Mean
T_0	94.80	157.04	159.28	137.04
T_S	324.27	407.30	411.91	381.16
T_1	330.72	444.84	455.87	410.47
T_2	179.39	219.68	218.37	205.81
T_3	168.10	213.17	216.15	199.14
T_4	124.08	153.15	152.64	143.29
T_5	127.06	151.53	149.62	142.73
T_6	104.26	128.49	132.02	121.59
T_7	64.94	96.14	94.07	85.05
T_8	65.51	82.01	82.38	76.63
T_9	64.60	82.32	82.71	76.54
Mean	149.79	194.15	195.91	

C.D. (0.05) for time of sowing = 6.558

C.D. (0.05) for frequency of irrigation = 2.753

C.D. (0.05) for T x I interation : a = 9.132

b = 9.820

Among the treatment combinations, T_1I_2 recorded the maximum yield (455.87 kg/ha) and it was on par with T_1I_1.

4.7. Nutrient uptake

4.7.1. Uptake of nitrogen

Data on uptake of nitrogen at 30th day, 60th day and at harvest are given in Table 31 a-c and the analysis of variance in Appendix I.

It is seen that the uptake of nitrogen was significantly influenced by the time of sowing and frequency of irrigation. The treatment T_1 recorded the highest uptake of nitrogen at the three stages of observation and significantly superior to other treatments except in harvest where it was on par with T_S.

In the case of frequency of irrigation, I_1 and I_2 were on par and significantly superior to I_0 during all the three stages of observation. The T x I interaction was not significant in any of the stages of observation.

4.7.2. Uptake of phosphorus

Data on phosphorus uptake at 30th day, 60th day and at harvest are furnished in Table 32 a-c and the analysis of variance in Appendix I.

The Tables reveal that phosphorus uptake was significantly influenced by the time of sowing, frequency of irrigation and their interactions during the three stages of

Table 31. Uptake of nitrogen (kg/ha) at different stages of growth.

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	8.63	9.58	9.62	9.27
T_S	15.19	18.51	18.28	17.33
T_1	15.76	19.43	19.89	18.36
T_2	13.20	15.85	15.24	14.76
T_3	6.46	8.87	8.55	7.96
T_4	6.59	7.63	7.67	7.30
T_5	4.97	6.20	6.24	5.80
T_6	3.95	4.91	5.23	4.69
T_7	3.19	4.19	4.07	3.82
T_8	3.30	4.20	4.23	3.91
T_9	3.38	4.32	4.25	3.99
Mean	7.69	9.42	9.39	

C.D. (0.05) for time of sowing = 0.847

C.D. (0.05) for frequency of irrigation = 0.426

Table 31 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	24.91	29.51	29.92	28.12
T_S	67.34	76.78	77.26	73.79
T_1	73.19	83.14	84.28	80.20
T_2	56.43	60.47	61.11	59.34
T_3	49.52	61.38	59.57	56.82
T_4	27.61	32.01	30.06	29.89
T_5	26.75	31.28	30.64	27.55
T_6	24.01	28.54	27.41	26.65
T_7	18.86	22.74	22.52	21.37
T_8	20.38	21.58	20.75	20.90
T_9	21.42	23.14	23.12	22.56
Mean	37.31	42.78	42.42	

C.D. (0.05) for time of sowing = 4.074

C.D. (0.05) for frequency of irrigation = 1.562

Table 31 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	19.28	18.17	18.87	18.77
T_S	46.12	49.41	49.19	48.24
T_1	47.50	52.87	53.49	51.28
T_2	33.58	36.28	36.05	35.30
T_3	24.07	31.18	31.14	28.80
T_4	20.33	23.40	21.49	21.74
T_5	19.34	24.10	24.59	22.68
T_6	18.91	21.59	22.76	21.06
T_7	13.69	16.57	16.20	15.48
T_8	16.83	19.04	18.90	18.25
T_9	17.55	19.81	20.72	19.36
Mean	25.20	28.40	28.49	

C.D. (0.05) for time of sowing = 4.655

C.D. (0.05) for frequency of irrigation = 0.912

Table 32. Phosphorus uptake (kg/ha) at different stages of growth.

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	2.54	3.01	3.04	2.67
T_S	2.88	5.09	5.20	4.39
T_1	4.34	5.50	5.70	5.18
T_2	3.36	4.15	4.15	3.89
T_3	2.00	2.70	2.70	2.46
T_4	2.04	2.55	2.55	2.38
T_5	1.66	2.08	2.16	1.97
T_6	1.46	1.89	1.89	1.75
T_7	1.20	1.77	1.83	1.60
T_8	1.20	1.68	1.65	1.51
T_9	1.23	1.75	1.72	1.57
Mean	2.17	2.92	2.96	

C.D. (0.05) for time of sowing = 0.395

C.D. (0.05) for frequency of irrigation = 0.172

C.D. (0.05) for T x I interaction : a = 0.571

b = 0.468

Table 32 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	9.80	12.41	12.36	11.52
T_S	31.56	37.21	37.17	35.31
T_1	34.41	39.06	39.60	37.69
T_2	28.08	30.20	30.23	29.50
T_3	21.57	26.38	26.88	24.94
T_4	10.54	12.08	12.47	11.70
T_5	9.79	11.18	11.24	10.74
T_6	8.55	9.75	9.76	9.35
T_7	7.37	8.91	8.77	8.35
T_8	8.12	9.34	9.09	8.85
T_9	9.44	10.88	10.75	10.35
Mean	16.20	18.85	18.94	

C.D. (0.05) for time of sowing = 0.880

C.D. (0.05) for frequency of irrigation = 0.358

C.D. (0.05) for T x I interaction : a = 1.189

b = 1.013

Table 32 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	7.40	7.74	8.91	8.02
T_S	20.66	22.90	23.01	22.19
T_1	21.19	23.66	24.25	23.03
T_2	14.16	15.61	15.85	15.20
T_3	11.27	14.31	13.88	13.15
T_4	8.08	10.14	10.00	9.40
T_5	7.81	10.71	10.31	9.61
T_6	7.82	8.12	8.48	8.14
T_7	5.98	7.10	6.77	6.62
T_8	7.77	8.98	8.58	8.44
T_9	7.74	8.43	8.48	8.21
Mean	10.90	12.51	12.59	

C.D. (0.05) for time of sowing = 1.551

C.D. (0.05) for frequency of irrigation = 0.309

C.D. (0.05) for T x I interaction : a = 1.026

b = 1.326

observation. The treatment T_1 showed maximum uptake of phosphorus at all the stages of observation and it was significantly superior to other treatments. But at harvest T_1 was on par with T_S and found significantly superior to all other treatments. In the case of frequency of irrigation, I_1 and I_2 were on par and significantly superior to I_0.

The T x I interaction showed that the I_1 and I_2 treatment combinations were having higher values than the I_0 treatment combinations. Among all the treatment combinations, T_1I_2 recorded the maximum uptake of phosphorus.

4.7.3. Uptake of potassium

Data on the uptake of potassium at three stages of observation are furnished in Table 33 a-c and the analysis of variance in Appendix I.

There was significant variation in the uptake of potassium among different treatments and their interactions. The treatment T_1 recorded the maximum uptake of potassium and significantly superior to other treatments at all stages of observation.

With regard to the frequency of irrigation, the I_1 and I_2 treatments were significantly superior to I_0 and they were on par.

Table 33. Uptake of potassium (kg/ha) at different stages of growth.

(a) 30 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	7.28	9.26	9.49	8.67
T_S	12.62	17.34	18.26	16.07
T_1	14.45	18.75	19.83	17.67
T_2	12.39	15.73	15.47	14.53
T_3	5.60	8.19	8.03	7.27
T_4	5.15	7.88	7.87	6.97
T_5	4.43	6.42	6.78	5.87
T_6	3.57	5.06	5.37	4.67
T_7	3.04	5.07	5.38	4.50
T_8	3.04	4.63	4.49	4.05
T_9	2.96	5.23	4.97	4.38
Mean	6.77	9.41	9.63	

C.D. (0.05) for time of sowing = 0.847

C.D. (0.05) for frequency of irrigation = 0.292

C.D. (0.05) for T x I interaction : a = 0.971

b = 0.905

Table 33 contd. .....

(b) 60 days after sowing

Time/Frequency	I_0	I_1	I_2	Mean
T_0	17.84	24.41	24.19	22.15
T_S	46.01	59.02	59.41	54.81
T_1	50.03	63.73	63.23	58.99
T_2	45.23	50.74	51.26	49.07
T_3	35.22	44.14	44.35	41.24
T_4	17.96	23.92	23.16	21.68
T_5	17.38	22.83	22.34	20.85
T_6	16.05	20.09	20.17	18.77
T_7	12.50	17.89	17.70	16.03
T_8	14.67	18.82	18.55	17.34
T_9	18.47	21.92	22.22	20.87
Mean	26.49	33.41	33.32	

C.D. (0.05) for time of sowing = 1.961

C.D. (0.05) for frequency of irrigation = 0.942

C.D. (0.05) for T x I interaction : a = 3.127

b = 2.438

Table 33 contd. .....

(c) At harvest

Time/Frequency	I_0	I_1	I_2	Mean
T_0	10.41	11.85	12.24	11.50
T_S	28.22	33.07	33.88	31.72
T_1	30.87	35.88	35.44	34.06
T_2	20.09	23.91	23.16	22.39
T_3	14.89	19.72	20.26	18.29
T_4	14.43	16.25	16.14	15.60
T_5	12.61	18.84	18.97	16.81
T_6	12.14	14.06	14.03	13.41
T_7	7.86	10.86	10.89	9.86
T_8	11.20	15.63	15.34	14.06
T_9	11.66	14.84	14.54	13.68
Mean	15.85	19.53	19.53	

C.D. (0.05) for time of sowing = 1.278

C.D. (0.05) for frequency of irrigation = 0.555

C.D. (0.05) for T x I interaction : a = 1.844

b = 1.516

Among all the treatment combinations, T_1I_1 recorded the maximum uptake and it was significantly superior to other treatments during the first stage. But as the second stage and at harvest T_1I_1 was on par with T_1I_2 and significantly superior to others.

4.8. <u>Soil analysis</u>

4.8.1. <u>Total nitrogen content of the soil after the experiment.</u>

Data on total nitrogen content in soil after the harvest are furnished in Table 34 and their analysis of variance in Appendix I.

The Table shows that the total nitrogen content in the soil after the experiment was not influenced by any of the soil after the experiment was not influenced by any of the treatments or their interactions. However, treatments T_1 and T_S gave the lower values when compared to T_5, T_6 and T_0.

4.8.2. <u>Available phosphorus oontent of the soil after the experiment.</u>

The data on available P_2O_5 content in the soil after the experiment are furnished in Table 35 and the analysis of variance in Appendix I.

It is seen from the Table that there was no significant

Table 34. Total N content of the soil (kg/ha) after experiment.

Time/Frequency	I_0	I_1	I_2	Mean
T_0	1340.00	1340.00	1340.00	1340.00
T_S	1086.66	1000.00	1036.66	1057.77
T_1	1086.66	1006.66	1000.00	1031.11
T_2	1340.00	1253.33	1253.33	1282.22
T_3	1340.00	1253.00	1340.00	1311.11
T_4	1333.33	1340.00	1253.33	1308.88
T_5	1420.00	1333.33	1333.33	1362.22
T_6	1420.00	1333.33	1333.33	1362.22
T_7	1340.00	1253.33	1253.33	1252.22
T_8	1340.00	1253.33	1340.00	1311.11
T_9	1340.00	1253.33	1340.00	1311.11
Mean	1307.87	1238.18	1253.33	

F. test not significant

Table 35. Available P_2O_5 content of the soil (kg/ha) after the experiment.

Time/Frequency	I_0	I_1	I_2	Mean
T_0	41.89	41.05	40.21	41.05
T_S	41.04	40.21	41.88	41.04
T_1	41.88	39.37	40.20	40.48
T_2	41.05	40.21	40.21	40.49
T_3	39.37	41.89	41.05	40.77
T_4	41.05	41.05	41.89	41.33
T_5	41.05	41.88	40.21	41.05
T_6	41.95	41.89	42.05	41.96
T_7	41.05	41.95	41.89	41.63
T_8	40.95	41.89	41.80	41.54
T_9	42.85	41.88	41.89	42.11
Mean	41.25	41.20	41.21	

F. test not significant

difference due to different treatments and their interactions.

4.8.3. Available potassium content of the soil after the experiment.

The data on available potassium in the soil after harvest are given in Table 36 and their analysis of variance in Appendix I.

The Table shows that there was no significant difference in the available potassium content of soil due to time of sowing, frequency of irrigation or their interactions.

4.8.4. Organic carbon content in soil

The data on the organic carbon content of the soil after the harvest are presented in Table 37 and the analysis of variance in Appendix I.

The Table reveals that the organic carbon content in the soil was not influenced by time of sowing. But it was influenced by the frequency of irrigation. The treatment I_0 recorded the highest value and it was on par with I_1 and these two were significantly superior to I_2 treatment.

4.9. Correlation studies

The correlation coefficients of important plant characters have been worked out and presented in Table 38.

Table 36. Available K_2O content of the soil (kg/ha) after the experiment.

Time/Frequency	I_0	I_1	I_2	Mean
T_0	60.80	57.60	59.20	59.20
T_S	60.80	62.40	59.13	60.77
T_1	60.80	59.13	60.00	60.24
T_2	59.20	59.20	62.40	60.26
T_3	60.80	62.40	59.20	60.80
T_4	62.40	59.20	62.13	61.24
T_5	59.33	60.80	59.13	59.75
T_6	57.60	57.60	59.13	58.11
T_7	60.00	59.06	62.13	60.66
T_8	62.26	62.40	60.80	61.82
T_9	60.80	62.40	59.20	60.80
Mean	60.50	60.20	60.29	

F. test not significant

Table 37. Organic carbon content of soil (percentage) after the treatment.

Time/Frequency	I_0	I_1	I_2	Mean
T_0	0.579	0.570	0.575	0.574
T_S	0.560	0.560	0.544	0.555
T_1	0.579	0.587	0.527	0.564
T_2	0.580	0.575	0.570	0.575
T_3	0.575	0.567	0.547	0.563
T_4	0.563	0.560	0.553	0.558
T_5	0.580	0.580	0.542	0.567
T_6	0.568	0.552	0.547	0.556
T_7	0.550	0.543	0.558	0.550
T_8	0.560	0.568	0.555	0.561
T_9	0.558	0.573	0.564	0.565
Mean	0.568	0.567	0.553	

C.D. (0.05) for frequency of irrigation = 0.011

Table 38. Correlation coefficients of different plant characters.

Sl. No.	Characters correlated	Correlation coefficient
1.	Height of plants x Number of leaves per plant	0.483562**
2.	Height of plants x Number of capsules per plant	0.357339*
3.	Plant population x Number of capsules per plant	-0.078000
4.	Plant population x Number of seeds per plant	0.612103**
5.	Protein content x Oil content	-0.090545
6.	Seed yield x N uptake	0.930278**
7.	Seed yield x P uptake	0.936471**
8.	Seed yield x K uptake	0.930270**
9.	Seed yield x Dry matter production	0.933384**

* Significant at 0.05 level

** Significant at 0.01 level

DISCUSSION

DISCUSSION

The results of the investigation to find out the influence of irrigation on germination, growth and yield of sesamum are discussed below.

5.1. Germination

It is seen that germination percentage is influenced by soil moisture content (Table 3 and Fig. 3 a - b). The data recorded in Table 3 show that maximum germination is obtained by sowing the seeds one day after irrigating the plot to field capacity (T_1). The maximum germination of 58.22 per cent is obtained at a soil moisture content of 12.72 per cent (Table 4) at the time of sowing. It is also observed that sowing the plots on the same day of irrigation ie. at field capacity has given the second heighest value of germination percentage.

It is quite clear that sesamum required certain optimum soil moisture for its germination. When the soil moisture exceeds this optimum level, the germination is found to decrease. Similarly below 12 per cent soil moisture content, a decreasing trend is observed in this character and thereby giving uneven population. As seen from Table 4, the soil moisture content at the time of sowing is decreasing as the days advance and a similar trend has been observed in

FIG. 3a. EFFECT OF TIME OF SOWING ON GERMINATION.

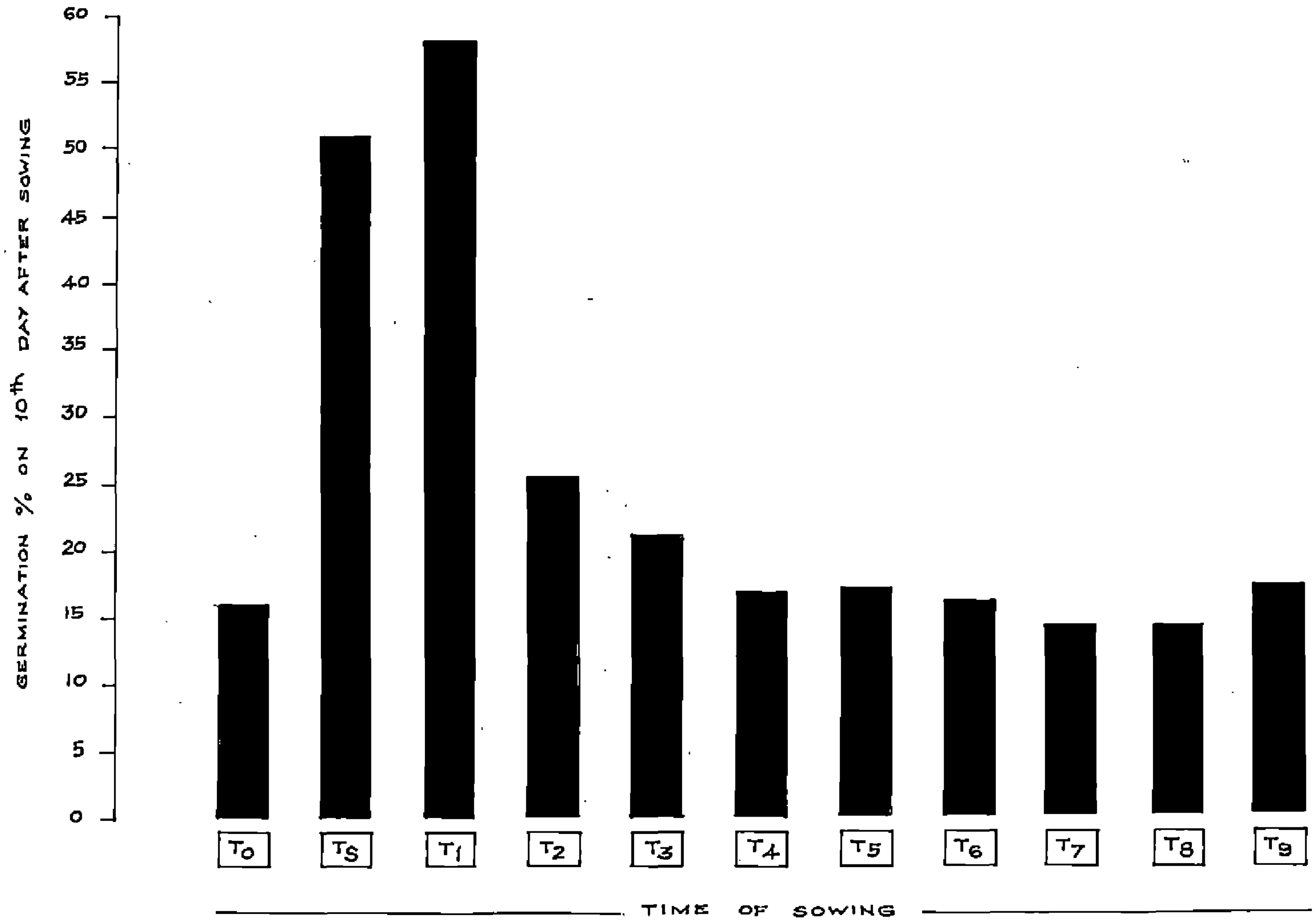
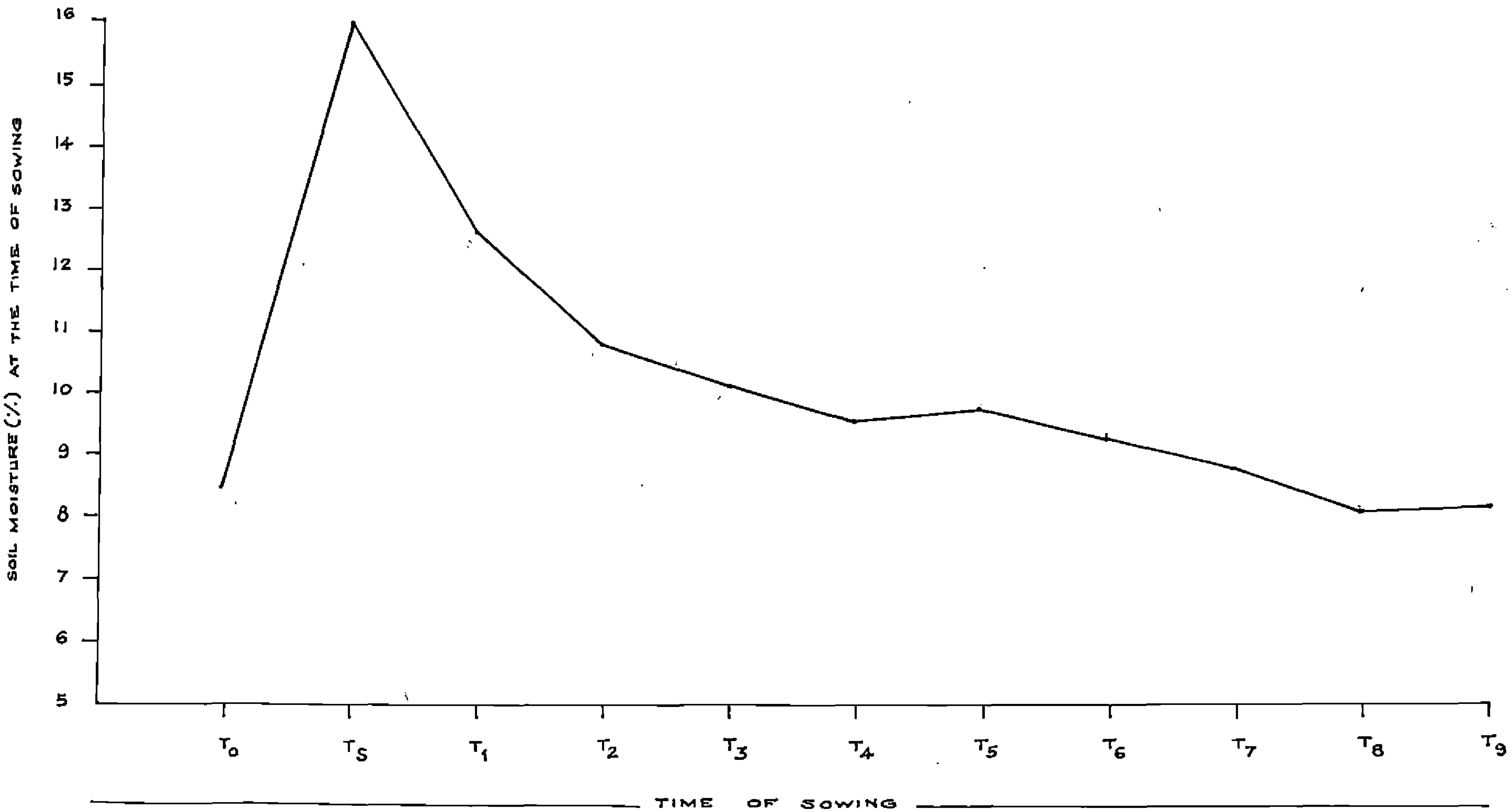


FIG. 3b. EFFECT OF TIME OF SOWING ON SOIL MOISTURE STATUS.

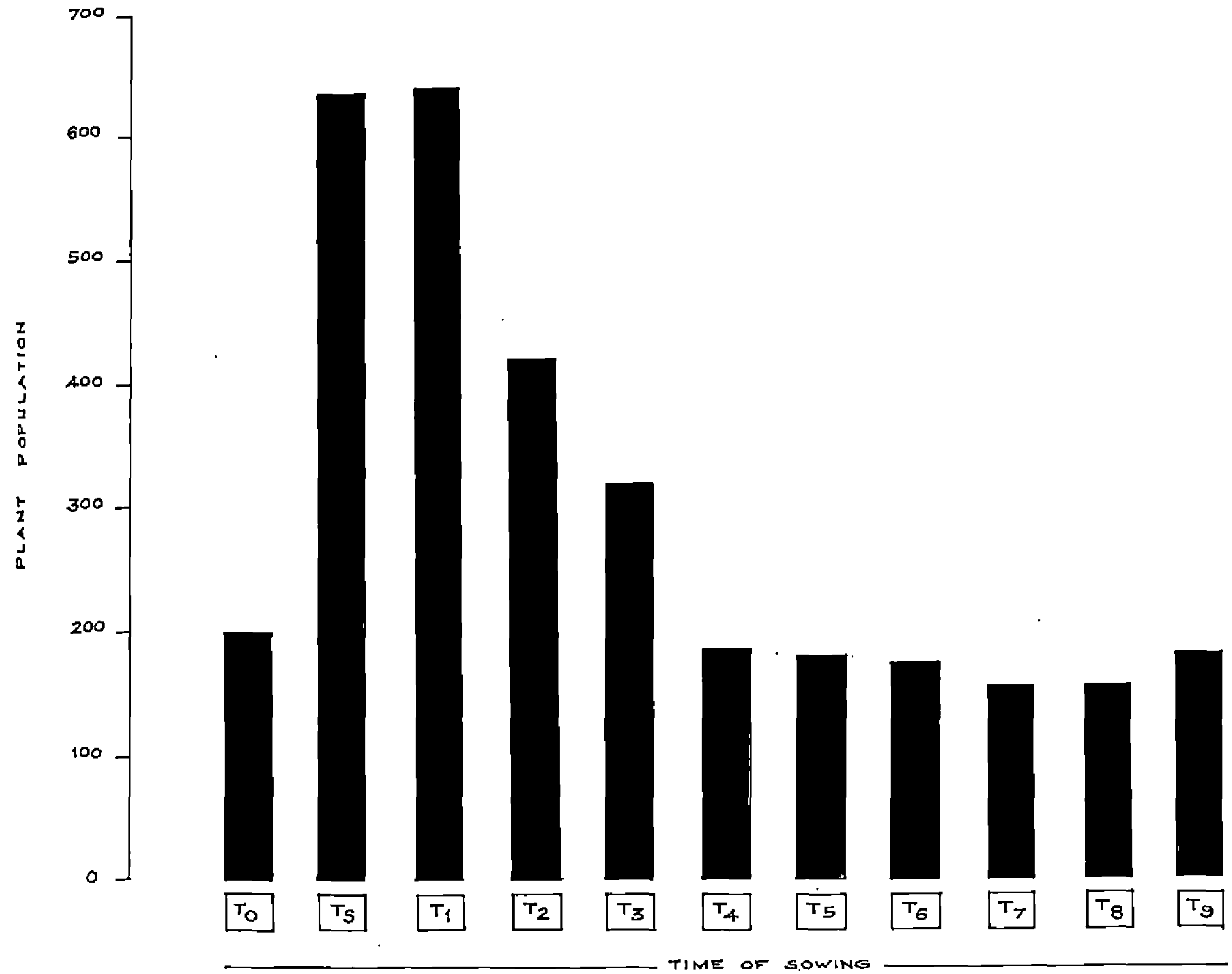


germination percentage also establishing the direct relationship between soil moisture and germination. It can be concluded that a soil moisture content of 12.72 per cent is optimum for getting maximum germination. Soil moisture content above or below this level has got deleterious effects on germination of seeds. These results are in accordance with the findings of Rao et al. (1975), Kunju and Salam (1980), Krishnakumar (1981) and Heikal et al. (1982). Such optimum soil moisture requirements can be attained by irrigating the plot to field capacity and sowing the seeds one day after irrigation in sandy loam soils during summer.

5.2. Plant population

It is seen from the Table 5 and Fig. 4 that plant population is influenced by the time of sowing. Sowing the seeds on the same day of irrigation (T_S) and one day after irrigation (T_1) has given the maximum plant population. This is due to the optimum soil moisture content present at the time of sowing. As the time has advanced, there has been depletion in the soil moisture status right from the day of irrigation which has resulted in bringing down the germination percentage of the seeds sown during the subsequent days after the initial irrigation leading to lesser

FIG. 4. PLANT POPULATION AT HARVEST AS INFLUENCED BY TIME OF SOWING.



plant population. The results obtained in the present study are in conformity with the findings of Krishnakumar (1981) in sandy loam soils.

5.3. Growth characters

5.3.1. Plant height

The data on height of the plant presented in Tables 6a-c show that this character is significantly influenced at all the stages by the frequency of irrigation. One irrigation during the vegetative phase (I_1) and two irrigations one at the vegetative and the other at the reproductive stages (I_2) have shown maximum height than those without irrigation (I_0). The effect of time of sowing on plant height is found significant only at the first stage of observation. However, sowing three days after irrigation (T_3) has given maximum height at all stages of observation.

The moisture status of soil taken at different periods also indicates that the irrigated plots have significantly higher soil moisture content than those without irrigation during the growth phase.

Plant height is generally the result of cell division and cell enlargement and the latter is more sensitive to moisture stress than the former (Begg and Turner, 1976). The reduced soil moisture content may be insufficient for the plant to put forth the required height and the reduced plant height in I_0 treatment may be due to the effect of soil moisture stress on cell enlargement. Similar trends were earlier observed by Lin *et al*. (1963), Boote and Hammond (1981) and Unger (1983).

The lesser plant density in T_3 (Table 5) might have helped the plant to grow without much competition for light, water and space and this situation might have favoured for increasing plant height. This is again in conformity with the findings of Lazim and Nadi (1974).

5.3.2. Number of leaves per plant

The number of leaves presented in Tables 7 a-c show that this character is influenced by different treatments and their interactions. The interaction effect is found only at the 60^{th} day and at harvest.

Sowing three days after irrigation (T_3) has given the maximum number of leaves at all stages of observation. The comparatively lower plant density coupled with appreciable amount of soil moisture in the early stages might have favoured for producing more number of leaves in this treatment.

It is seen that the irrigation treatments have given better effect than the control. Irrigation at the vegetative phase (I_1) and irrigations at vegetative phase as well as reproductive phase (I_2) have produced significantly higher number of leaves than those without irrigation during the growth phases.

Irrigation during the growth phases of the plant might have favoured the growth characters like plant height. In the plots receiving one or two irrigations during the growth period of the crop, soil moisture might not be a limiting factor for plant growth which in turn might have influenced to produce more number of leaves in those treatments. Water stress conditions make changes in the pattern of leaf growth and leaf ontogeny (Marc., 1981). Jacob (1960) reported that the leaves influence the elongation of adjacent internodes through modulation of the rate and amount of transport of the growth substances such as sucrose.

The unirrigated treatment (I_0) has shown comparatively lesser soil moisture than I_1 and I_2. Hence, this might have resulted in the production of lower number of leaves. This is again in accordance with the findings of Lin et al. (1963) and Unger (1983).

Sowing three days after irrigation (T_3) has given maximum number of leaves at all stages of observation. The Table also reveals that T_3 has recorded maximum plant height. The increased plant height might have favoured the plant to carry out the cell division, cell elongation and cell enlargement at greater rate resulting in the differenciation of developing primordia into leaves. A positive correlation is also obtained (Table 38) between the plant height and number of leaves which again substantiates the above observation.

5.3.3. Internodal length

The internodal length presented in Tables 8 a-b reveals that this character is influenced by time of sowing only at the first stage of observation. The frequency of irrigation is not found to be significant in any of the stages of observation.

Sowing seven days after irrigation has recorded maximum internodal length at all stages.

5.3.4. Number of branches per plant

The Tables 9 a-c indicate that the number of branches per plant is significantly influenced by the time of sowing and frequency of irrigation. The T x I interaction is found significant only at the second stage of observation. Sowing three days after irrigation (T_3) has recorded maximum number of branches. Similarly irrigation given during the vegetative phase (I_1) and irrigation at both the vegetative and reproductive phases (I_2) have shown significantly higher number of branches than the unirrigated plots (I_0). Irrigation given during the growth phases might have favoured in the development of growth characters through increased photosynthesis. The increase in the number of branches per plant with irrigations given during the growth phases obtained in the present investigation is in accordance with the findings of Ramachandran et al. (1972).

5.3.5. Number of nodes per plant

The Tables 10 a-c show that this character is significantly influenced by time of sowing and frequency of irrigation at all stages of observation.

Sowing on the 3rd day after irrigation (T_3) has recorded maximum number of nodes. The Tables 7 a-c also reveal that T_3 has recorded maximum number of leaves. This might have led to the production of more number of nodes.

Jacob (1960) also reported that increase in node number is a result of the increase in leaf number. According to Shubeck et al. (1967) an increase in plant population per unit area results in a cooler temperature in the plants surroundings with consequent reduction in the number of nodes. Similarly Table 14 shows that sowing three days after irrigation (T_3) has lesser plant density compared to T_S, T_1 and T_2. This might be the reason for this treatment to produce more number of nodes and leaves which is in accordance with the finding of Lazim *et al*. (1974).

Irrigation at the vegetative phase (I_1) and irrigation scheduled during the vegetative phase as well as reproductive phase (I_2) have resulted in the production of significantly higher number of nodes than those without irrigation during the growth phase (I_0). As stated earlier the irrigated treatments both I_1 and I_2 have recorded maximum number of leaves (Tables 7 a-c) and this might have resulted in the production of more number of nodes per plant.

5.3.6. Leaf area per plant

The data presented in Tables 11 a-c reveal that leaf area is significantly influenced by time of sowing and frequency of irrigation. Interaction effect is found significant at the second and third stages of observation.

Sowing three days after irrigation (T_3) has recorded maximum leaf area at all stages of observation.

As observed earlier, T_3 has recorded maximum number of leaves (Tables 7 a-c). This might have contributed higher leaf area per plant. It is also noticed that increase in plant density decreases the leaf area per plant

(Lazim et al., 1974). Hence the lesser plant density in sowing three days after irritation (T_3) might have contributed more number of leaves resulting in maximum leaf area per plant.

Irrigating at vegetative as well as reproductive phases (I_2) has shown maximum leaf area and it is on par with irrigation at vegetative phase (I_1) and they are found significantly superior to that without irrigation during the growth phases (I_0).

The reduction in leaf area under unirrigated condition may be due to the sensivity of cell enlargement to moisture stress conditions leading to smaller leaf area (Begg and Turner, 1976). Lin et al. (1963) also observed the production of smaller leaves under moisture stress conditions. Similarly Merrien et al. (1981) also observed that leaf area increased with increase in water availability.

The interaction effects found at the second and final stages of observation also reveal that the treatment combinations with irrigation (I_1 and I_2) are showing higher leaf area than the unirrigated combinations. This is in accordance with the observations made by Battacharya and Sarkar (1978), Pal (1979) and Ishaq (1982).

5.3.7. Length and spread of roots

The length of tap root presented in Table 12 a shows that this character is significantly influenced by time of sowing and frequency of irrigation. Sowing without irrigation (I_0) has given maximum length of tap root while in the irrigated plants, it is significantly lesser. It is also seen that irrigation at the vegetative phase (I_1) and irrigation during the vegetative and reproductive phases (I_2) have produced significantly lesser root length compared to the unirrigated treatment (I_0). The treatments without irrigation (I_0) have produced the maximum length of tap root. The difference in the length of roots noticed may be attributed to the soil moisture status of the field during the growth period. In plots where more soil moisture is present, the root penetration is not so deep. This is in conformity with the findings of Bennet and Doss (1960), Doss *et al*. (1960), Muhammed *et al*. (1965) and Vartarian (1967). Elliot (1924) also observed that plants could not extend their roots deeply in saturated soil and this encouraged shallow rooting.

The Table 12 b representing the lateral spread of root shows that this character is influenced by different treatments and their interactions.

Sowing three days after irrigation (T_3) has recorded maximum lateral spread of roots and sowing without irrigation (I_0) has given the lowest value. The Tables 6 a-c, 7 a-c and 10 a-c reveal that T_3 has recorded maximum plant height, number of leaves and number of nodes respectively. This might have favoured the plant to produce more lateral spread of roots in T_3 plots.

Irrigation given at vegetative phase (I_1) and at vegetative and reproductive phases (I_2) have shown significantly higher lateral spread of roots, than those without irrigation (I_0). The I_1 and I_2 treatment combinations are also showing higher lateral spread than I_0 treatment combinations. This may be due to the influence of soil moisture. Adequate supply of water during the growth phase of the crop might have favoured the lateral spread of roots rather than going downwards. But in the case of I_0 treatment combinations the soil moisture content was less. Hence rooting depth was more (Table 12 a) and lateral spread was less.

5.3.8. <u>Dry weight of roots</u>

The data on dry weight of roots show that this character is influenced by all the treatments and their interactions. Sowing three days after irrigation (T_3) has recorded maximum root weight and it is significantly superior to all other treatments. The Table 12 b on lateral spread of roots also reveals that this treatment has given the maximum spread of lateral roots. Therefore, it is to be presumed that the weight is determined by the spread of primary roots rather than the depth of the tap root.

The density of plant population presented in Table 5 shows that the above treatment (T_3) has recorded significantly lesser plant density, compared with T_1 (sowing one day after irrigation) and T_S (sowing on the same day of irrigation). This might have given more land space per plant resulting in more root spread per plant.

Irrigation given during the growth phases ie. irrigation at vegetative phase (I_1) and at vegetative and reproductive phases (I_2) have produced significantly higher root weight than those without irrigation (I_0). The I_1 and I_2 treatments have shown higher lateral spread of roots (Table 12 b) which might have resulted in higher root weight. This is again in agreement with the findings of Kmoch et al. (1957), Peter and Runkles (1967) and Kramer (1978).

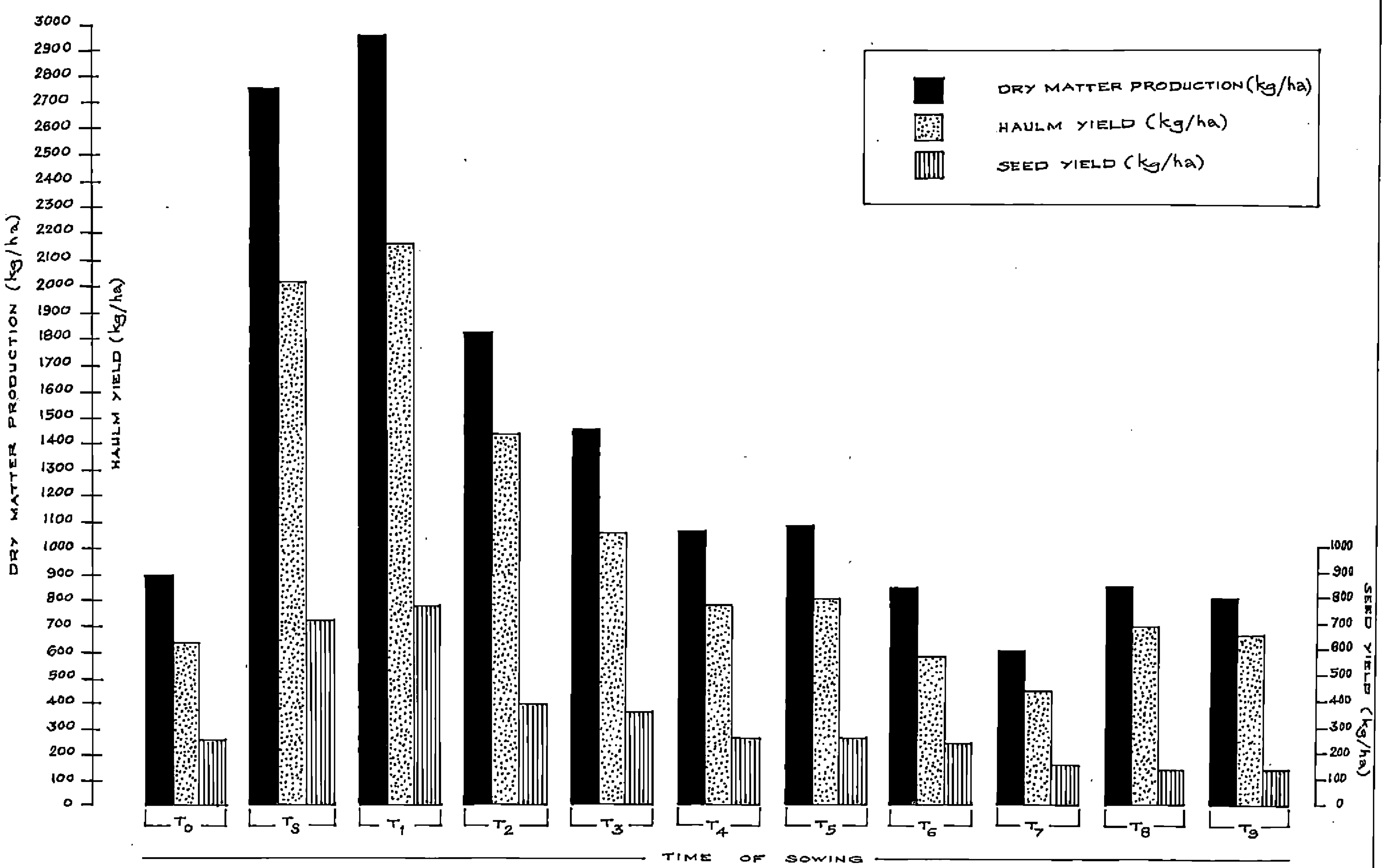
5.3.9. Dry matter production per unit area

Dry matter production presented in Tables 14 a-c and

Fig. 5 a-b reveals that it is significantly influenced by different treatments and their interactions. Sowing one day after irrigation (T_1) has produced maximum dry matter and it is significantly superior to all other treatments. It is followed by sowing same day of irrigation (T_S) and sowing two days after irrigation (T_2). The higher dry matter production in these treatments may be due to the high plant density obtained as a result of the optimum soil moisture conditions prevailed at the time of sowing. In the case of T_S, though it has plant density similar to that of T_1, dry matter production is found to be lesser than T_1. It is already seen that the soil moisture content in T_S plots are high and the excess soil moisture at the time of sowing might have given less vigourous seedlings. The dry matter production in the late sowing treatments are also significantly lesser even though the per plant vegetative growth is quite higher which can be due to low plant density and consequent larger land area per plant.

Irrigation during the vegetative phases(I_1) and irrigation at vegetative as well as reproductive phase (I_2) have shown same effect but it is significantly superior to treatments with no irrigation during growth phase (I_0). It is also noticed that all the I_1 and I_2 treatment combinations

FIG. 5a. EFFECT OF TIME OF SOWING ON DRY MATTER PRODUCTION, HAULM YIELD AND SEED YIELD.



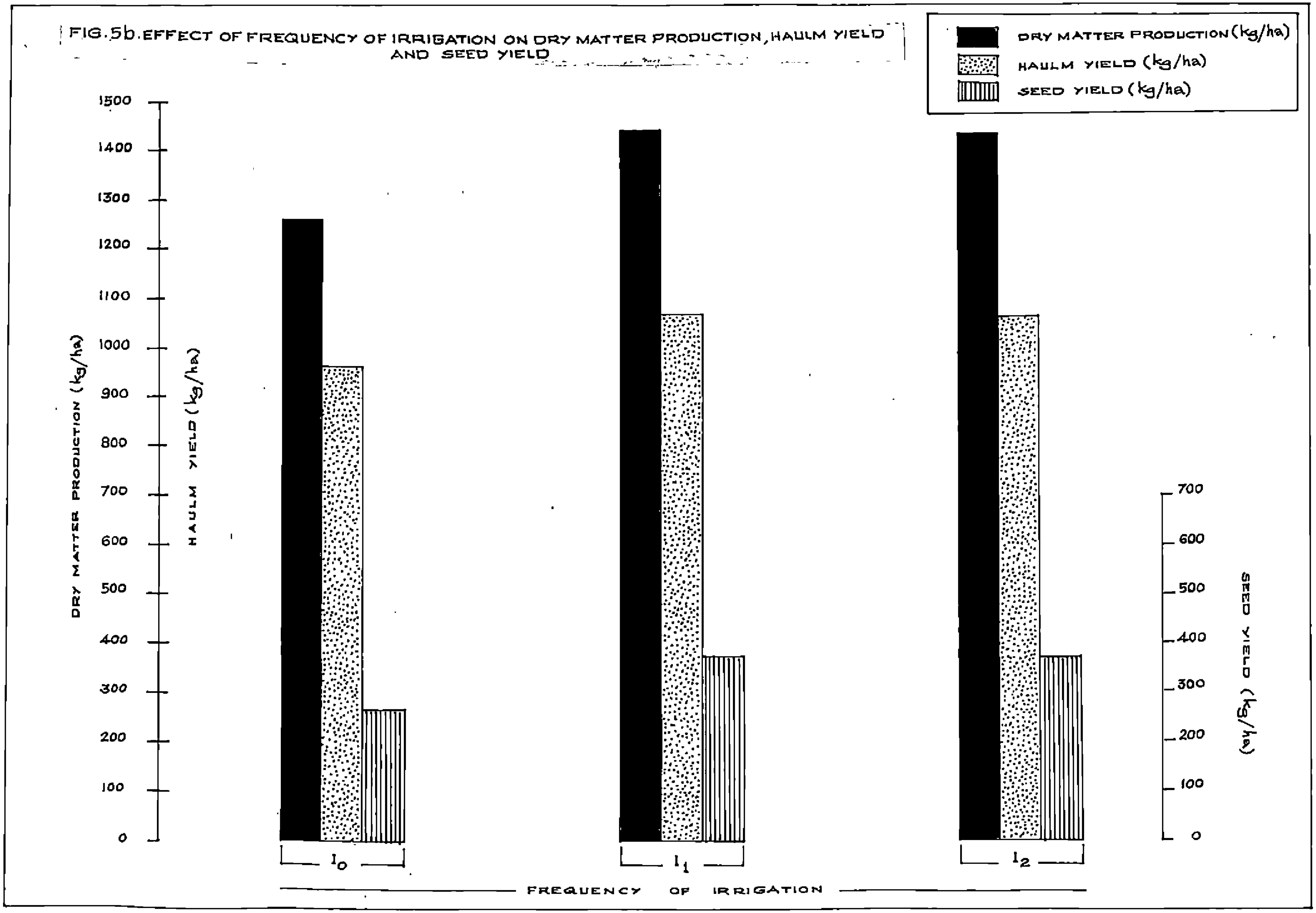


FIG.5b. EFFECT OF FREQUENCY OF IRRIGATION ON DRY MATTER PRODUCTION, HAULM YIELD AND SEED YIELD
DRY MATTER PRODUCTION (kg/ha)
HAULM YIELD (kg/ha)
SEED YIELD (kg/ha)
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
DRY MATTER PRODUCTION (kg/ha)
HAULM YIELD (kg/ha)
700
600
500
400
300
200
100
0
SEED YIELD (kg/ha)
I_0
I_1
I_2
FREQUENCY OF IRRIGATION

have given higher rates of dry matter production as compared to all the unirrigated treatment combinations. Irrigations given during the growth phasesmight have provided adequate soil moisture favouring the plant to put forth better vegetative growth and maximum dry matter production. It is also noticed that irrigation has influenced the plant height (Tables 6 a-c), number of leaves (Tables 7 a-c), number of nodes (Tables 10 a-c), number of branches (Tables 9 a-c) and dry weight of roots (Table 13). All these parameters might have resulted in giving significantly higher dry matter production than those treatments without irrigation during the growth phases. It is again in conformity with the findings of Ochs and Wormer (1959), Rajagopal (1969) Lingam (1969), Vora et al. (1975), Vivekanandan and Gunasena (1976), Andhale and Kalbhor (1980), Youssef et al. (1982) and Unger (1983).

A significant positive correlation is also observed between seed yield and dry matter production (Table 38).

5.3.10. Percentage distribution of dry matter in different plant parts

(a) Stem

The Tables 15 a-c show that the dry matter distribution in stem is significantly influenced by time of sowing at all stages of observation. The frequency of irrigation is significant only at the first and final stages of observation. The T x I interaction is also significant at all stages.

Sowing eight days after irrigation (T_8) has resulted in accumulating maximum percentage of dry matter in stem and it is followed by sowing nine days after irrigation (T_9). The unirrigated treatments I_0 have shown significantly higher percentage of dry matter in stem than those with irrigation during the growth phases. Under water stress conditions the plants are subjected to xerophytic modifications (Youssef et al., 1982). Hence the increased percentage of dry matter distribution in stem may be for thriving the adverse soil conditions for want of moisture and thereby inducing quantitative anatomical changes.

(b) Leaf

The percentage of dry matter distribution in leaf presented in Tables 16 a-c shows that sowing four days after irrigation (T_4) has resulted in the maximum accumulation of dry matter in leaf and it is on par with sowing three days after irrigation (T_3) during the first stage of observation. However, sowing on the same day of irrigation (T_S) has resulted in maximum dry matter accumulation in leaf during the final stage of observation.

Irrigation given during the vegetative phase (I_1) and at vegetative as well as reproductive phases (I_2) have shown higher values than those without irrigation (I_0). The Tables 7 a-c also reveal that the irrigated plots have produced maximum number of leaves than unirrigated treatment combinations (I_0). This might have resulted in the higher percentage distribution of dry matter in leaf in treatments which received irrigation during the growth phases (I_1 and I_2).

(c) <u>Capsule</u>

The Tables 17 a and b reveal that the percentage distribution of dry matter in capsule is significantly influenced by time of sowing and frequency of irrigation at all stages of observation. The T x I interaction is found significant only at 60th day.

Sowing one day after irrigation (T_1) has given the maximum percentage of dry matter in capsules. It is also noticed that (Table 15 and 16 a-c) treatment T_1 has only moderate percentage distribution of dry matter in stem and leaf. This might have favoured for the plant to divert more dry matter to capsule as compared to the stem and leaf.

Irrigation scheduled during the vegetative phase and both at vegetative and reproductive phases have resulted in accumulating more dry matter in capsules than those with no irrigation during the growth phase. The irrigations scheduled during the growth phases might have helped for increasing the photosynthetic activity and thereby increasing the growth and development of the plant resulting in the production of more number of flowers and distribution of dry matter in capsule at higher rate through increased rate of translocation of photosynthates from source to sink. Sowing one day after irrigation and irrigation during vegetative phase (T_1I_1) have given the highest value. Similar observations were made by Matlock (1955), Ochs and Wormer (1959) and Reddy et al. (1968).

5.3.11. Number of days for first flowering

The data presented in Table 18 show that number of days taken for first flowering is significantly influenced by time of sowing and frequency of irrigation. Sowing without irrigation has taken significantly lesser number of days for flowering. Similarly the irrigated treatments have taken more number of days for flowering compared to unirrigated treatments. The unirrigated treatment (I_0) has come to flowering earlier. The water stress conditions might have made the plants to cut short the vegetative stage and enter into reproductive stage. It is also observed previously that the growth characters have been expressed at a significantly lesser degree in the unirrigated treatments (I_0).

5.4. <u>Yield components and yield</u>

5.4.1. <u>Number of capsules per plant</u>

The number of capsules per plant is presented in Tables 19 a and b. It is seen that the number of capsules per plant is significantly influenced by time of sowing and frequency of irrigation. The T x I interaction is observed only at harvest.

Maximum number of capsules has been produced in treatment (T_3) ie. sowing three days after irrigation. Irrigation at vegetative phase (I_1) and irrigation both at vegetative and reproductive phases (I_2) have produced significantly higher number of capsules than those which have not received any irrigation (I_0).

It is already noticed that T_3 has recorded maximum plant height, maximum number of branches and leaves per plant. The same trend has been observed in irrigated treatments (I_1 and I_2) also. This would have contributed to higher photosynthetic efficiency resulting in higher number of capsules. It is also noted from Table 17 a and b that irrigated treatments (I_1 and I_2) are showing higher percentage distribution of dry matter in capsule. The Table 38 shows a significant positive correlation between plant height and number of capsules which again substantiates the above observation. Adequate supply of water during the critical stages of growth, through irrigation and the performance of the crop especially with reference to the growth characters might have favourably influenced the capsule number which again is in accordance with the results of experiments conducted at Chalakudy (Anon., 1978), Boote and Hammond (1981) and Ishaq (1982) have made similar observations earlier. Another point to be considered in this context is the influence of population on the production of capsules and other growth characters. Weiss (1971) has reported that the density of population influences the number of capsules. A perusal of the data on population (Table 5), indicates that maximum population is observed in T_1 and T_S. T_3 has recorded lesser plant density, which influenced higher rate of capsule production per plant. The correlation worked out between plant population and capsule number shows a non significant negative relationship between them (Table 38) which again supports the above findings.

The relationship between moisture supply and the number of capsules and capsule weight has been established by Thompson (1978).

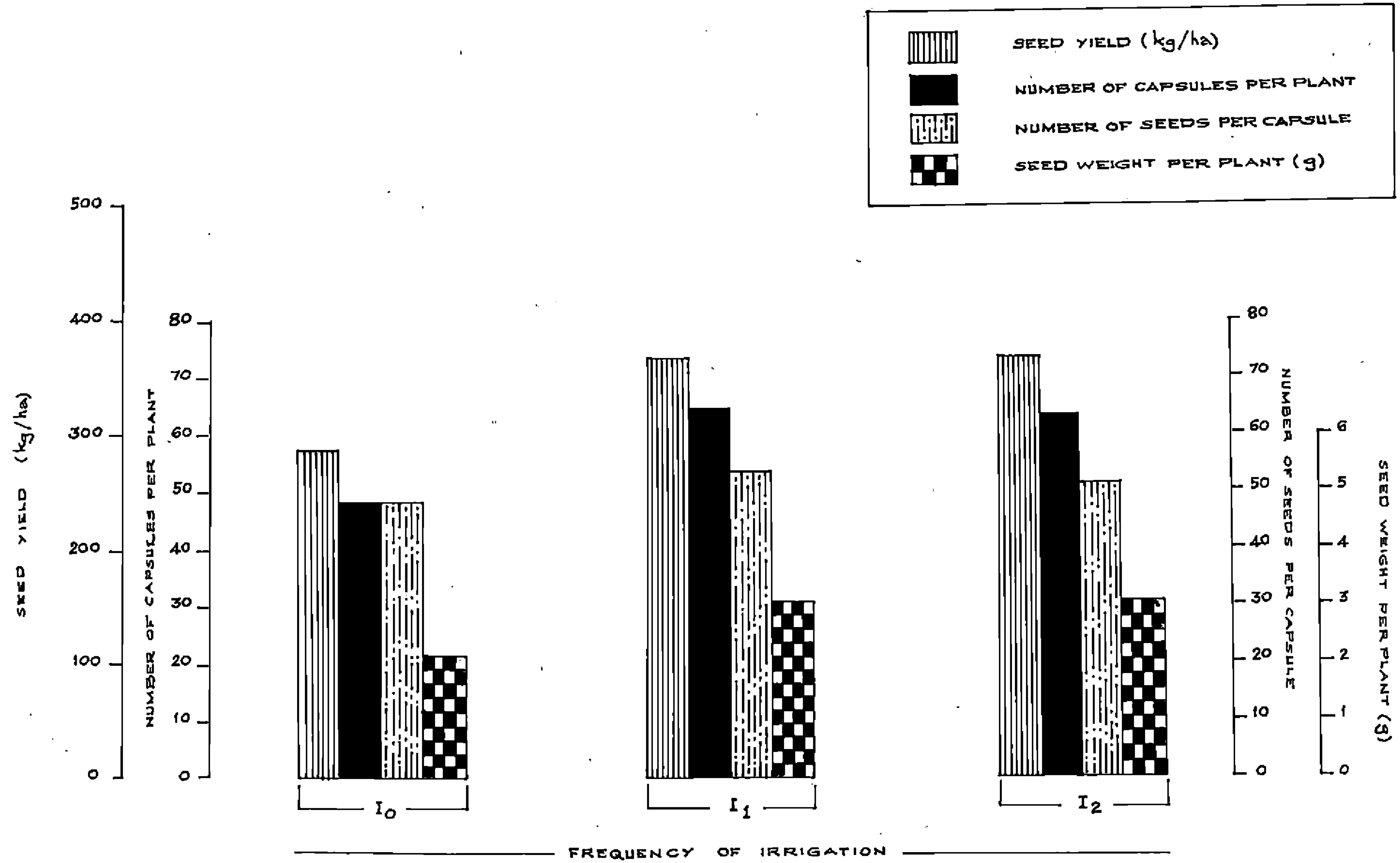
5.4.2. Capsule weight and seed weight per plant

The Tables 20 and 22 and Fig. 6 show that these characters are significantly influenced by time of sowing, frequency of irrigation and their interactions.

Sowing three days after irrigation (T_3) has recorded maximum capsule weight and it is on par with sowing two days after irrigation (T_2). With regard to seed weight per plant the same treatment has produced maximum seed weight. From the Tables 19 a-b, it can be observed that the T_3 has recorded the maximum number of capsules per plant. Similarly the irrigated plots ie. irrigations at vegetative phase (I_1) and at vegetative and reproductive phases (I_2) are found significantly superior to those without irrigation during the growth phases (I_0) for this character. The higher number of capsules per plant might have resulted in higher capsule weight and seed weight per plant.

Weiss (1971) has stated that an increase in plant population correspondingly decreases the seed weight and capsule weight per plant. Similar observations were earlier made by Krishnakumar (1981).

FIG. 6. EFFECT OF FREQUENCY OF IRRIGATION ON YIELD AND YIELD ATTRIBUTES.



5.4.3. Number of seeds per capsule

The Table 21 and Fig. 6 show that the number of seeds per capsule is significantly influenced by the time of sowing and frequency of irrigation.

Sowing the seeds three days after irrigation (T_3) and one day after irrigation (T_1) have recorded higher number of seeds per capsule. The increased weight of capsules in the above treatments might have been due to the higher number of seeds per capsule.

Irrigating the plants at the vegetative phase or at vegetative and reproductive stages has given increased number of seeds per capsule. It is to be noted that these two treatments have given increased weight of capsules which may be due to the higher number of seeds per capsule.

5.4.4. 1000 seed weight

The 1000 seed weight recorded in Table 23 reveals that this character is not influenced by any of the treatments and their interactions. However, it may be seen that sowing on the same day of irrigation (T_S) and one day after irrigation (T_1) have recorded maximum 1000 seed weight. It is also observed that the irrigated treatments ie. irrigation during the vegetative phase (I_1) and irrigation both at vegetative and reproductive phases (I_2) have recorded maximum values than those without irrigation.

5.4.5. Seed yield per ha.

Seed yield presented in Table 24 and Fig. 5 a-b and 7 a-b show that it is significantly influenced by time of sowing, frequency of irrigation and their interactions.

Sowing one day after irrigation (T_1) has produced significantly higher yield and it is superior to all other treatments. It is followed by T_S, T_2 and T_3. Seed yield varied with plant density.

It is already noticed, that sowing one day after irrigation has shown maximum germination (Table 3). It is also observed that sowing on the same day of irrigation (T_S) and one day after irrigation (T_1) have recorded higher plant population (Table 5). The plant density in other treatments has decreased according to the time of sowing and depletion of soil moisture right from the irrigation given at the beginning. The seed yield recorded by different treatments is in accordance with the plant density. Hence, plant density is an important factor in sesamum which determines the seed yield.

As observed earlier, sowing three days after irrigation (T_3) has shown maximum influence over all growth characters and yield attributes. In spite of these growth characters and higher expression of yield attributes per

FIG. 7a. SEED YIELD, OIL YIELD AND OIL CONTENT AS INFLUENCED BY TIME OF SOWING.

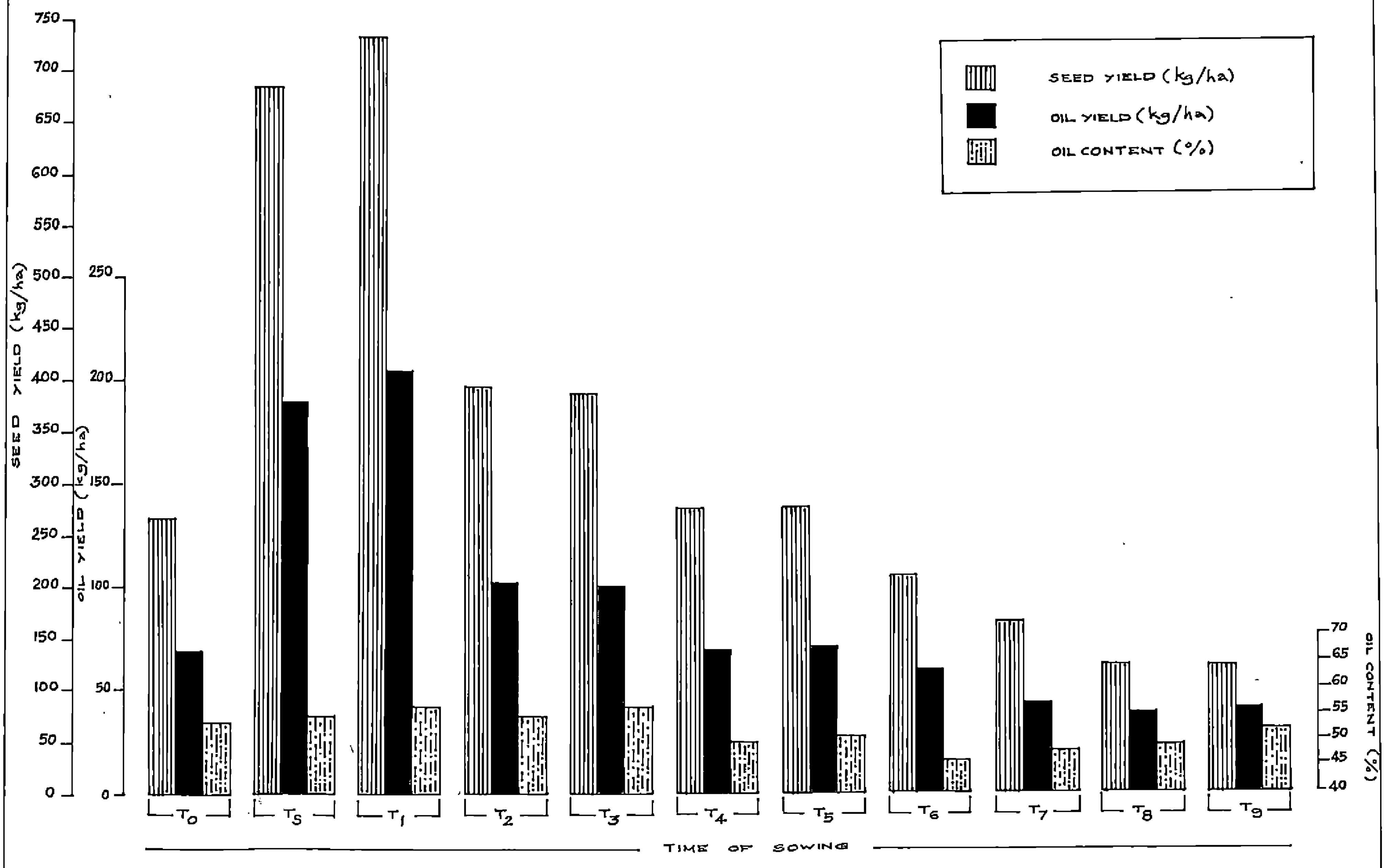
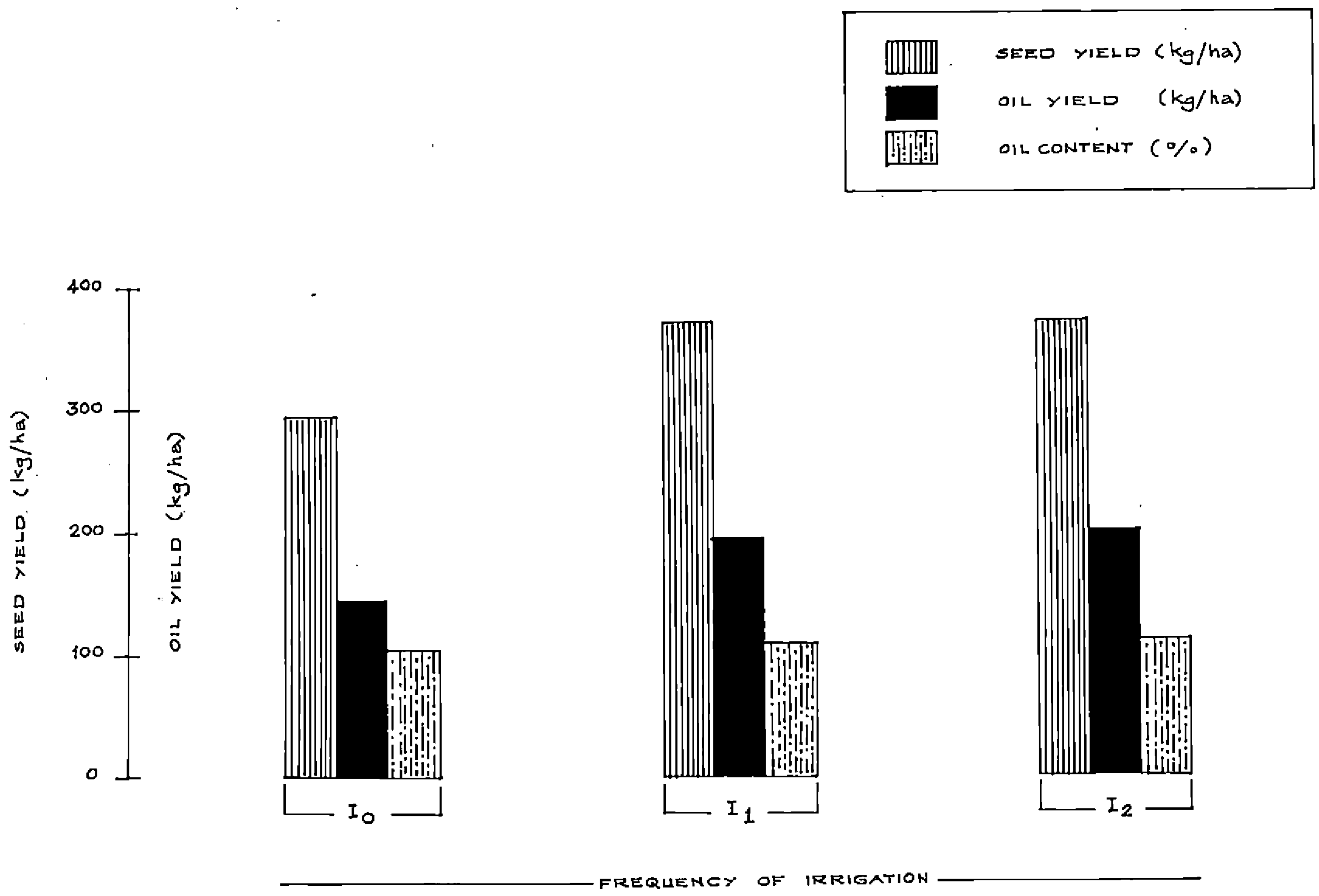


FIG. 7b. SEED YIELD, OIL YIELD AND OIL CONTENT AS INFLUENCED BY FREQUENCY OF IRRIGATION.



plant, it has failed to express in terms of yield per ha. as the plant density is comparatively and significantly lesser than T_1 (Table 5). The dry matter production in T_3 is significantly lesser than T_1 (Tables 14 a-c) and T_3 has reached fourth in rank with reference to seed yield and plant population.

Sowing one day after irrigation has given significantly higher dry matter at all stages of observation (Tables 14 a-c). Donald (1962) stated that the economic yield of a crop could be expressed on certain fraction of the total dry matter at harvest and it might be expected that level of yield would be closely related to the amount of dry matter produced. T_1 has also accounted for maximum seed weight per plant (Table 22), 1000 seed weight (Table 23) more number of seeds per capsule (Table 21) and higher shelling percentage (Table 26).

The uptake of N, P and K is also found maximum with treatment T_1 (Tables 31 a-c, 32 a-c and 33 a-c).

It is already observed that the irrigated treatments during the growth phase ie. irrigation at vegetative phase (I_1) and irrigation both at vegetative as well as reproductive phases (I_2) have shown greater influence over all growth characters and yield attributes. Maximum plant height

(Table 6 a-c), maximum number of leaves (Table 7 a-c), branches (Table 9 a-c) and nodes (Table 10 a-c) might have resulted in higher dry matter production with irrigated plots during the growth phases(I_1 and I_2). It is also seen that yield attributes like number of capsules (Table 19 a and b), seed weight per plant and number of seeds per plant (Tables 22 and 21) are found significantly superior with irrigation (I_1 and I_2). The uptake of nutrients is also found more with I_1 and I_2 treatments. The uptake of nutrients along with their influence on growth and yield attributes might have resulted in higher yields in I_1 and I_2 treatments. Irrigation at vegetative phase (I_1) and irrigation at both vegetative and reproductive phases (I_2) are on par in almost all cases.

The interaction effect reveals that the I_1 and I_2 treatment combinations are significantly superior to I_0 treatment combinations. Among the T x I interaction, sowing one day after irrigation and two irrigations during the growth phases (one at vegetative and the other at reproductive phase) have recorded maximum seed yield (T_1I_2) and it is on par with sowing one day after irrigation and one irrigation during the growth phase ie. at vegetative phase (T_1I_1). A significant positive correlation is obtained with seed yield and dry matter production and seed yield and uptake of N, P and K (Table 38). The results obtained in the present investigation are in accordance with the findings of Mazzani and Allievi (1969), Abdou et al. (1970), Garcia et al. (1971), El-Serogi et al. (1977), Anon. (1978), Farah (1978), Hack (1980), Dallyn (1983) and Sharma and Reddy (1983).

5.4.6. Shelling percentage

The data on shelling percentage presented in Table 26 reveal that this character is significantly influenced by time of sowing and frequency of irrigation.

The treatment T_0 (sowing without irrigation), T_S (sowing on the same day of irrigation) and T_1 (sowing one day after irrigation) have recorded maximum shelling percentage.

Similarly the irrigated treatments ie. irrigation at vegetative phase (I_1) and irrigation at vegetative as well as reproductive phases(I_2) have shown significantly higher values than those without irrigation (I_0).

5.4.7. Haulm yield

The Table 25 and Fig. 5 a-b shows that haulm yield is significantly influeced by time of sowing, frequency of irrigation and T x I interaction.

Sowing one day after irrigation (T_1) has produced maximum haulm yield. Table 5 shows that this treatment has recorded higher number of plants per plot. Dry matter production per unit area is also maximum in this treatment. These factors might have resulted in giving higher haulm yield in T_1 treatment. One irrigation during the vegetative phase (I_1) and two irrigations, one at vegetative phase and the other at the reproductive phase (I_2) have recorded significantly higher haulm yield than those without irrigation (I_0).

It is already observed that the irrigated treatments have shown greater influence over all growth characters resulting in higher dry matter production when compared to unirrigated treatments. This might have favoured for the irrigated treatments (I_1 and I_2) to record higher rate of haulm yield which is in agreement with the findings of Rajagopal (1969), Andhale and Kalbhor (1980) and Unger (1983).

5.4.8. Harvest index

The Table 27 shows that this character differs with different treatments and their interactions. Sowing without irrigation (T_0) has recorded maximum harvest index while sowing eight and nine days after irrigation has resulted in the lowest values.

It is seen that sowing one day after irrigation (T_1) has recorded maximum dry matter production (Tables 14 a-c), seed yield (Table 24) and haulm yield (Table 25). When compared with the haulm yield, the seed yield is less in T_1 treatment, whereas the T_0 treatment has given more seed yield when compared to haulm yield thereby resulting in high harvest index.

Sowing eight days and nine days after irrigation (T_8 and T_9) has produced the lowest seed yield and the reduction in harvest index in these treatments might be due to higher rate of biological yield in comparison with the grain yield. The data on percentage distribution of dry matter in capsules (Tables 17 a-b) also show that these treatments (T_8 and T_9) have recorded lesser values which again substantiates the reason for low harvest index.

In the irrigated plots the percentage distribution of dry matter in capsule (Tables 17 a-b) is comparatively high resulting in high harvest indices.

5.5. <u>Chemical analysis</u>

5.5.1. <u>Quality characters</u>

5.5.1.1. <u>Protein content of seeds</u>

Protein content of seeds presented in Table 28 shows that this character is significantly influenced by the frequency of irrigation. The treatments with no irrigation during the growth phase (I_0) have recorded maximum protein content and it is significantly superior to irrigation given at vegetative phase (I_1) and irrigation given at vegetative phase as well as reproductive phase(I_2).

The irrigated treatment (I_2) has recorded the lowest protein content. Similar observations were made by Narasimhan et al. (1978) and Pal (1981). This may be due to the dilution effeot (Mahanta, 1967 and Muthuvel and Krishnamoorthy, 1981). Bennet et al. (1964), Lahiri and Singh (1968), and Koter et al. (1976) have also reported that plants grown under moisture stress condition have more nitrogen content and protein than those grown under high soil moisture conditions. This is again in accordance with the above observations.

5.5.1.2. Oil content

The data on oil content furnished in Table 29 and Fig. 7 b show that frequency of irrigation influences this character. Irrigation given at vegetative as well as reproductive phases (I_2) has reoorded the maximum oil content and it is followed by irrigation scheduled at vegetative phase (I_1) only. The unirrigated treatment (I_0) has given signifioantly less value.

Loof (1960) stated that oil seeds contain a very little amount of carbohydrate, while protein and oil are the two major constituents present in major proportion and thus there exist an inverse relationship between these two constituents. The Table 28 shows that the unirrigated treatment (I_0) has recorded maximum protein content, whereas the irrigated treatments I_1 and I_2 have shown lesser values. The decreased oil content observed in unirrigated treatments (I_0) might have resulted from the inverse relationship existing between oil content and protein. Many workers (Seydlitz, 1962; Delibaltov and Ivano, 1973; Gimnez et al., 1975; Yao et al., 1982 and Prunty, 1983) have reported that oil content increase with irrigation which is again in conformity with the above observation. A negative correlation is obtained between oil content and protein content (Table 38).

5.5.1.3. Oil yield (kg/ha)

Oil yield presented in Table 30 and Fig. 7 a-b show that it is significantly influenced by time of sowing, frequency of irrigation and T x I interaction.

Sowing one day after irrigation has shown maximum oil yield and it is significantly superior to all other treatments. The same treatment (T_1) has shown maximum seed yield

(Table 24) and oil content (Table 29). Similar trends were observed with irrigation at later stages of growth.

Since the oil yield is determined by percentage of oil and total seed yield, oil yield has also behaved in the same pattern of seed yield and oil content.

5.5.2. Analysis of plant samples

5.5.2.1. Uptake of nitrogen, phosphorus and potassium

The data on the uptake of N, P and K presented in Tables 31 a-c, 32 a-c and 33 a-c reveal that it is significantly influenced by time of sowing, frequency of irrigation and T x I interaction.

Sowing one day after irrigation (T_1) has shown maximum uptake of N, P and K at all stages of observation. While in the case of frequency of irrigation the irrigated treatments I_1 and I_2 have recorded maximum uptake of nutrients. The uptake of nutrients is generally decided by the nutrient content and total dry matter production. The Table 14 a-c on dry matter production also reveal that maximum value is observed in T_1 among the time of sowing and I_2 and I_1 among the frequency of irrigation. This would have contributed for the higher total uptake of nutrients by those treatments. This is again in accordance with Abdou *et al*. (1970), Singh and Singh (1980), Reddy *et al*. (1982) and Zalwadia and

Patel (1983) in different annual oil seed crops.

5.5.3. Soil analysis

5.5.3.1. Total nitrogen content of the soil after the experiment.

The Table 34 on total nitrogen content of soil after the experiment shows that it is not influenced by any of the treatments or their interactions. However, sowing one day after irrigation (T_1) and the irrigation treatments I_1 (irrigation at vegetative phase) and I_2 (irrigation at vegetative as well as reproductive phases) have shown comparatively lesser values.

The Tables 31 a-c on the uptake of nitrogen show that maximum uptake was found with T_1 among different time of sowings and I_1 and I_2 among the frequency of irrigation. This might have resulted for these treatments to show comparatively lesser values than other treatments.

5.5.3.2. Available phosphorus and potassium contents of soil after the experiment

The Tables 35 and 36 show that there is no significant difference between treatments in the available phosphorus and potassium contents of the soil after the experiment. However, sowing eight days after irrigation (T_8) and the unirrigated treatments (I_0) have shown higher values. The

Tables 32 a-c and 33 a-c on the uptake of P and K show that the uptake is comparatively less and records lowest values with treatments T_8 and I_0. The low uptake of P and K might have resultedin showing higher values of P and K in the soil with these treatments.

5.5.3.3. Organic carbon content of the soil after the experiment

The Table 37 on organic carbon content of the soil reveals that it is significantly influenced by frequency of irrigation. The treatments without irrigation (I_0) has recorded the maximum organic carbon content and it is significantly superior to irrigation given both at vegetative and reproductive phases (I_2).

The Table 34 on total nitrogen content of soil after experiment shows that the treatment I_0 has recorded the highest value and data on the uptake of nitrogen show that treatment without irrigation during the growth phase (I_0) has recorded comparatively the lowest uptake. These may be the possible reasons for the unirrigated treatment (I_0) for recording higher organic content in the soil after the experiment.

5.6. Economics of sesamum cultivation under different treatments.

The economics worked out on the cultivation of sesamum based on different treatment combinations is presented in Appendix II. It is observed that the treatment combination T_1I_2 has given the highest returns (Rs.8288/-) followed by T_1I_1 (Rs.8240/-). The treatment combinations with T_8 and T_9 have given very low returns. The plant population was minimum in these treatments. Thus it is evident that plant density which is influenced by soil moisture status at the time of sowing plays an important role for obtaining higher returns.

SUMMARY

SUMMARY

An experiment was conducted at Rice Research Station, Kayamkulam during the summer season of 1983-84 after the harvest of second crop rice to find out the influence of irrigation on germination, growth and yield of sesamum. The experiment comprised of 11 main plot treatments and three sub plot treatments. The main plot treatments consisted of sowing without irrigation, sowing on the same day of irrigation, one day after irrigation, two days after irrigation, three days after irrigation, four days, five days and upto nine days after initial irrigation. Sub plot treatments were (1) no irrigation during growth phase (2) one irrigation at vegetative phase and (3) two irrigations, one at the vegetative and the other at the reproductive phases. Observations were made on germination, growth, yield and quality characters and the results of the study are summarised below.

1. Maximum germination was obtained by sowing one day after irrigating the plots to field capacity (T_1) followed by sowing on the same day of irrigation (T_S). The optimum soil moisture for maximum germination was found to be 12.72 per cent. Delay in sowing resulted in the depletion of soil moisture status and thereby reducing the germination.

2. Maximum plant density was observed in treatment where sowing was done one day after irrigation (T_1) followed by sowing on the same day of irrigation (T_S).
3. The height of the plant was significantly influenced by frequency of irrigation. One irrigation at vegetative phase (I_1) and two irrigations, one at vegetative and the other at reproductive phases were on par and produced maximum plant height.
4. Sowing three days after irrigation (T_3) produced maximum number of leaves. I_1 and I_2 were on par and produced more number of leaves than those without irrigation (I_0).
5. Sowing seven days after irrigation (T_7) has recorded the highest internodal length at 30 days of observation and this character is not influenced by frequency of irrigation.
6. Sowing three days after irrigation (T_3) recorded the maximum number of branches per plant. Irrigation at vegetative phase (I_1) and irrigations both at vegetative and reproductive phases (I_2) have produced more number of branches.
7. Sowing three days after irrigation (T_3) has given more number of nodes per plant. Similarly irrigation at vegetative phase (I_1) and irrigations both at vegetative

and reproductive phases (I_2) have resulted in producing more number of nodes.

8. Leaf area was significantly influenced by time of sowing. The treatment (T_3) has recorded maximum leaf area per plant. Similarly the I_2 treatment has produced the maximum leaf area.
9. Sowing without initial irrigation (T_0) and no irrigation during the growth phase (I_0) have recorded maximum length of tap root.
10. Sowing three days after irrigation (T_3) has shown maximum lateral spread of roots. The irrigation treatments I_1 and I_2 have also recorded higher lateral spread of roots.
11. Sowing one day after irrigation (T_1) and the irrigation treatments I_1 and I_2 have produced higher amounts of dry matter. The unirrigated treatment I_0 has recorded the lowest dry matter production.
12. Sowing three days after irrigation (T_3) have recorded the highest dry root weight whereas the irrigation treatments I_1 and I_2 have recorded more dry weight of roots.
13. Irrigation treatments I_1 and I_2 have shown higher percentage distribution of dry matter in capsule while the unirrigated treatment I_0 has recorded the lowest value.

14. The plants in the unirrigated treatment flowered earlier than the irrigated plants.

15. Sowing three days after irrigation (T_3) has given the highest number of capsules per plant. The irrigation given at vegetative phase (I_1) and irrigation at vegetative as well as reproductive stages (I_2) have also produced higher number of capsules.

16. Sowing three days after irrigation (T_3) has recorded maximum capsule weight and seed weight per plant. Similar trends were observed with I_1 and I_2 also.

17. Sowing one day after irrigation (T_1) and sowing three days after irrigation (T_3) have shown higher number of seeds per capsule. The irrigation treatments I_1 and I_2 have also shown the same trend.

18. 1000 seed weight is not influenced by any of the treatments.

19. Among the main plot treatments, sowing one day after irrigation (T_1) has recorded the maximum seed yield. The treatment combination $T_1 I_2$ has given an yield of 859 kg of seed per ha.

20. Sowing one day after irrigation (T_1) has shown maximum haulm yield (2191.88 kg/ha). Giving irrigations during growth phases have also contributed to higher haulm yields.

21. The irrigated treatments I_1 and I_2 have recorded higher harvest indices.

22. Protein content was found maximum in plots without irrigation.

23. The irrigation treatments I_1 and I_2 have shown higher oil content in seeds.

24. Sowing one day after irrigation (T_1) has recorded maximum oil yield. Irrigation at vegetative phase (I_1) and irrigation at vegetative phase as well as reproductive phase (I_2) have also recorded higher values.

25. Maximum uptake of N, P and K was found with sowing one day after irrigation (T_1). The irrigation treatments I_1 and I_2 have also recorded higher uptake of N, P and K when compared to no irrigation during the growth phases of the plant.

26. The total nitrogen, available phosphorus and available potassium contents of the soil after the experiment were not influenced significantly by any of the treatments.

27. The treatment with no irrigation during the growth phase (I_0) has recorded higher values of organic carbon in the soil after the experiment.

28. The treatment combination T_1I_2 has given the highest net returns followed by T_1I_1.

Thus, from the above studies it can be concluded that for getting uniform germination and optimum plant population, sesamum seeds may be sown one day after irrigating the prepared field to field capacity. Further two irrigations, one at the vegetative phase and the other at the reproductive phase result in maximum economic returns to the farmer. Considering the availability of water in summer single irrigation at the vegetative phase is sufficient for getting economic yie

Future line of investigation

The present study was carried out with relevance to the sandy loam soils of Onattukara region. Since sesamum is also grown under upland and garden land conditions, further studies can be undertaken to determine the optimum soil moisture required for germination and uniform plant stand.

In this experiment two irrigations, one at 15 days and the other at 45 days after sowing were on par with single irrigation given at 15 days after sowing. Hence detailed investigation can be carried out to study whether a second irrigation scheduled at 30 days after sowing has got any economic significance in sesamum production in different cropping conditions existing in the State.

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* Original not seen.

APPENDICES

APPENDIX I

Abstract of Analysis of Variance Table

Sl. No.	Characters studied	Mean square					
		Block (2)	T (10)	Error a (20)	I (2)	T x I (20)	Error b (40)
1.	Germination	0.28	2086.43**	0.95	0.18	0.37	0.64
2.	Plant population	57.64	318105.38**	58.53	109.40	33.52	44.63
3.	Soil moisture						
a.	At sowing	0.397	47.03**	0.736	1.38	0.908	0.583
b.	5 days after sowing	0.04	11.14**	0.27	0.23	0.09	0.21
c.	10 days after sowing	0.02	0.66**	0.11	0.12	0.08	0.11
d.	15 days after sowing	0.01	2.53**	0.12	0.02	0.07	0.09
e.	45 days after sowing	0.18	2.00**	0.05	16.84**	0.15**	0.04
4.	Plant height						
a.	30 days after sowing	251.56	193.88**	56.12	79.905**	3.74	7.78
b.	60 days after sowing	862.52	292.69	197.26	218.36*	62.92	59.80
c.	At harvest	847.99	255.20	201.07	224.46*	67.65	60.45
5.	Number of leaves						
a.	30 days after sowing	12.53	111.61**	23.34	35.88*	7.70	7.07
b.	60 days after sowing	1170.29	4658.98**	704.95	2966.21**	446.20**	136.37
c.	At harvest	328.27	1050.28**	68.07	2463.44**	249.99**	6.06

Figure in paranthesis indicates degrees of freedom

*Significant at 0.05 level
**Significant at 0.01 level

Appendix I contd. .....

Sl. No.	Characters studied	Mean square Block (2)	T (10)	Error (a) (20)	I (2)	T x I (20)	Error(b) (40)
6.	Internodal length						
a.	30 days after sowing	2.529	5.050**	1.133	1.103	1.550	1.072
b.	60 days after sowing	9.598	5.759	2.904	2.029	1.890	1.334
7.	Number of branches						
a.	30 days after sowing	5.285	5.771**	1.291	14.627**	0.732	0.635
b.	60 days after sowing	0.209	2.394**	0.634	10.164**	0.998*	0.506
c.	At harvest	0.271	2.141**	0.618	8.584**	0.998	0.569
8.	Number of nodes per plant						
a.	30 days after sowing	1.465	1.844**	0.196	1.378**	0.061	0.195
b.	60 days after sowing	154.72	1217.72**	80.99	1456.06**	83.06	46.24
c.	At harvest	158.39	1161.28**	81.97	1426.18**	82.99*	41.75

Figure in paranthesis indicates degrees of freedom

*Significant at 0.05 level

**Significant at 0.01 level

Appendix I contd. .....

Sl. No.	Characters studied	Mean square					
		Block (2)	T (10)	Error (a) (20)	I (2)	T x I (20)	Error (b) (40)
9.	Leaf area (cm^2) per plant						
a.	30 days after sowing	2369.93	28954.32**	7315.25	17694.45**	2422.17	2271.05
b.	60 days after sowing	115888.43	347400.21**	88562.23	251035.69**	46487.13**	17988.01
c.	At harvest	47836.33	222007.89**	9955.25	326454.25**	30560.59**	5088.29
10.	Length of tap root (cm)	4.15	12.29**	1.56	85.17 **	1.72	0.95
11.	Lateral spread of roots (cm)	6.902	16.150**	3.048	129.352 **	5.901	1.788
12.	Dry weight of roots (g)	3.96	54.42**	1.372	7.545**	1.961**	0.604
13.	Dry matter production (kg/ha)						
a.	30 days after sowing	34.29	251.24**	588.03	53374.14**	1301.91**	824.37
b.	60 days after sowing	5336.00	13962043.4**	2801.23	903678.83**	31066.13**	2851.56
c.	At harvest	7955.10	5955386.4**	4826.86	360562.77**	21127.61**	2029.78

Figure in paranthesis indicates degrees of freedom

*Significant at 0.05 level

**Significant at 0.01 level

Appendix I contd. .....

Sl. No.	Characters studied	Mean square Block (2)	T (10)	Error (a) (20)	I (2)	T x I (20)	Error (b) (40)
14.	Percentage distribution of dry matter in stem						
a.	30 days after sowing	2.414	63.77**	5.432	513.13**	17.20**	4.367
b.	60 days after sowing	8.99	494.66**	7.57	9.67	119.08**	8.40
c.	At harvest	4.695	259.77**	10.15	113.50**	33.40**	6.77
15.	Percentage distribution of dry matter in leaves						
a.	30 days after sowing	5.94	141.14**	13.05	405.85**	23.97*	11.43
b.	60 days after sowing	36.75	79.42**	8.31	3.65	61.04**	7.77
c.	At harvest	31.64	166.06**	6.36	8.47**	44.04**	8.90
16.	Percentage distribution of dry matter in capsules						
a.	60 days after sowing	17.86	232.49**	11.01	705.22**	14.47*	5.83

Figure in paranthesis indicates degrees of freedom
*Significant at 0.05 level
**Significant at 0.01 level

Appendix I contd. .....

Sl. No.	Characters studied	Mean square					
		Block (2)	T (10)	Error (a) (20)	I (2)	T x I (20)	Error (b) (40)
b.	At harvest	16.61	309.41**	9.74	596.33**	10.66	7.11
17.	Number of days for first flowering	0.03	2.52*	0.86	17.93**	0.90	1.04
18.	Number of capsules per plant						
a.	60 days after sowing	106.86	1680.58**	71.107	2093.53**	91.41	67.88
b.	At harvest	92.78	1866.39**	49.64	2509.41**	98.53*	46.71
19.	Capsule weight (g) per plant	0.549	16.45**	9.39	35.26**	8.42*	3.83
20.	Number of seeds per capsule	12.06	118.99**	13.41	226.44**	8.21	11.73
21.	Seed weight (g) per plant	4.271	3.330**	0.247	7.933**	1.526**	0.0412
22.	1000 seed weight (g)	1.2-04	1.72-05	2.46-05	3.40-05	1.53-05	1.86-05
23.	Seed yield (kg/ha)	195.58	435621.22**	161.66	773.25**	3118.50**	90.70
24.	Haulm yield(kg/ha)	9649.73	3210519.21**	5108.01	108730.91**	18440.92**	1829.64
25.	Shelling percentage	0.358	21.46**	3.61	27.99**	2.19	2.04

Figure in paranthesis indicates degrees of freedom

*Significant at 0.05 level

**Significant at 0.01 level

Appendix I contd. .....

Sl. No.	Characters studied	Mean square					
		Block (2)	T (10)	Error (a) (20)	I (20)	T x I (20)	Error (b) (40)
26.	Harvest index	0.00186	0.1433**	0.00043	0.00746**	0.0219**	0.000136
27.	Protein content (%) of seeds	5.20	0.87	3.83	65.6**	0.82	5.50
28.	Oil content (%)	1.40	0.615	0.625	15.2**	0.087	1.225
29.	Oil yield (kg/ha)	131.76	119691.81**	44.48	22551.06**	1050.65**	30.66
30.	Uptake of Nitrogen (kg/ha)						
	a. 30 days after sowing	0.63	270.52**	0.74	32.30**	1.17	7.3
	b. 60 days after sowing	131.76	4458.31**	17.17	308.94**	12.91	9.86
	c. At harvest	57.20	1375.14**	22.41	116.01**	4.86	3.36
31.	Uptake of phosphorus (kg/ha)						
	a. 30 days after sowing	0.17	14.35**	0.16	0.53**	0.30**	0.12
	b. 60 days after sowing	0.19	1181.17**	5.82	74.60**	3.05**	0.52
	c. At harvest	2.42	302.70**	2.48	30.20**	0.97**	0.38

Figure in paranthesis indicates degrees of freedom

*Significant at 0.05 level

**Significant at 0.01 level

Appendix I contd. .....

Sl. No.	Characters studies	Mean square					
		Block (2)	T (10)	Error (a) (20)	I (2)	T x I (20)	Error (b) (40)
32.	Uptake of potassium (kg/ha)						
a.	30 days after sowing	0.11	230.29**	0.74	83.52**	1.63**	0.34
b.	60 days after sowing	14.68	2441.88**	3.98	520.68	12.42**	3.59
c.	At harvest	9.12	572.08**	1.69	119.22**	2.64*	1.25
33.	Total nitrogen content in soil (kg/ha) after the experiment.	103719.19	116297.37	59959.19	44343.00	29770.10	41404.04
34.	Available phosphorus content in soil (kg/ha) after the experiment.	45.85	2.69	5.65	0.026	1.95	5.58
35.	Available potassium content in soil (kg/ha) after the experiment.	148.22	9.32	100.94	0.82	6.69	76.66
36.	Organic carbon content (%) after the experiment	0.00067	0.00055	0.00049	0.00237*	0.00040	0.00049

Figure in paranthesis indicates degrees of freedom

*Significant at 0.05 level

**Significant at 0.01 level

APPENDIX II

Economics of sesamum cultivation under different treatments (Rs./ha.)

Treatment	Seed yield	cost of cultivation	Value of the produce	Profit
T_0I_0	187.00	1760.00	2244.00	484.00
T_0I_1	303.33	1860.00	3639.96	1779.96
T_0I_2	304.66	1920.00	3655.92	1935.92
T_SI_0	633.33	1860.00	7599.96	5739.96
T_SI_1	777.33	1960.00	9327.96	7367.96
T_SI_2	778.33	2020.00	9339.96	7319.96
T_1I_0	646.00	1860.00	7752.00	5892.00
T_1I_1	850.00	1960.00	10200.00	8240.00
T_1I_2	859.00	2020.00	10308.00	8288.00
T_2I_0	352.60	1860.00	4231.92	2371.92
T_2I_1	424.00	1960.00	5088.00	3128.00

APPENDIX II contd. .....

Treatment	Seed yield	Cost of cultivation	Value of the produce	Profit
T_2I_2	420.00	2020.00	5040.00	3020.00
T_3I_0	331.00	1860.00	3972.00	2112.00
T_3I_1	414.33	1960.00	4971.96	3011.96
T_3I_2	414.33	2020.00	4971.96	2951.96
T_4I_0	243.33	1860.00	2919.96	1059.96
T_4I_1	296.00	1960.00	3552.00	1592.00
T_4I_2	291.33	2020.00	3495.96	1475.96
T_5I_0	248.33	1860.00	2979.96	1119.96
T_5I_1	290.66	1960.00	3487.92	1527.92
T_5I_2	286.33	2020.00	3435.96	1415.96
T_6I_0	205.00	1860.00	2460.00	600.00
T_6I_1	250.33	1960.00	3003.96	1043.96
T_6I_2	253.66	2020.00	3043.92	1023.92

APPENDIX II contd. .....

Treatment	Seed yield	Cost of cultivation	Value of the produce	Profit
T_7I_0	127.33	1860.00	1527.96	..
T_7I_1	184.66	1960.00	2215.92	255.92
T_7I_2	180.00	2020.00	2160.00	120.00
T_8I_0	128.00	1860.00	1536.00	..
T_8I_1	158.66	1960.00	1903.92	..
T_8I_2	158.00	2020.00	1896.00	..
T_9I_0	126.66	1860.00	1519.91	..
T_9I_1	160.00	1960.00	1960.00	..
T_9I_2	158.66	2020.00	1903.90	..

The cost of cultivation was worked out based on the existing norms fixed for sesamum cultivation in Onattukara region. The sale price of sesamum seed is taken as Rs.12/- per kg.

INFLUENCE OF IRRIGATION ON GERMINATION, GROWTH AND YIELD OF SESAMUM

By

THOMAS MATHEW

ABSTRACT OF A THESIS
SUBMITTED IN PARTIAL FULFILMENT OF
THE REQUIREMENT FOR THE DEGREE
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ABSTRACT

A field study was undertaken at the Rice Research Station, Kayamkulam, during the third crop season of 1983-84 to find out the influence of irrigation on germination, growth and yield of sesamum, with eleven main plot treatments as time of sowing and three sub plot treatments as frequency of irrigation. There were 33 different treatment combinations.

The study revealed that the optimum soil moisture for maximum germination of sesamum seed is 12.72 per cent. Moisture contents above or below this adversely affect the germination percentage. Optimum soil moisture for germination could be achieved by irrigating the plots to field capacity and sowing one day after the irrigation. Dry matter production, number of seeds per capsule, distribution of dry matter in capsule, seed yield, oil content, oil yield and shelling percentage were highest in the treatment where sowing was done one day after the initial irrigation. Maximum uptake of N, P and K was also observed in this treatment.

One irrigation at the vegetative phase or two irrigations one at the vegetative and the other at the reproductive stages have favourably influenced the growth

characters like plant height, number of leaves, number of branches and nodes, leaf area, dry matter production, number of capsules per plant, capsule weight per plant, number of seeds per capsule, seed weight per plant and seed yield per ha. The oil content, oil yield and the uptake of N, P and K were also maximum in the above irrigation treatments.

The study revealed that irrigating the plot to field capacity and sowing the seeds one day after irrigation has resulted in obtaining maximum germination and optimum plant density. Similarly irrigation during the growth phases have also increased the seed yield. Maximum seed yield of 859 kg/ha. was produced by sowing the seeds one day after initial irrigation followed by giving one irrigation each during the vegetative and reproductive phases.