STUDIES ON IRRIGATION MANAGEMENT WITH PLANT INDICATOR AND INFLUENCE OF WEATHER PARAMETERS ON SORGHUM

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Certificate

This is to certify that the thesis entitled "Studies on Irrigation management with plant indicator and influence of weather parameters on Sorghum" submitted in part fulfilment of the requirements for the award of the degree of Doctor of Philosophy to the Tamil Nadu Agricultural University, Coimbatore is a record of bonafide research work carried out by Thiru M. Subbarayalu under my supervision and guidance and that no part of the thesis has been submitted for the award of any other degree, diploma, fellowship or other similar titles and that the work has not been published in part or full in any scientific or popular journal or magazine.

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ABSTRACT

STUDIES ON IRRIGATION MANAGEMENT WITH PLANT INDICATOR AND INFLUENCE OF WEATHER PARAMETERS ON SORGHUM (CO.22)

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Field experiments were conducted during 1978 and 1979 to study the influence of irrigation and nitrogen levels on sorghum (Co.22) as compared to the crop purely raised under rainfed condition and scheduling of irrigation with the help of sunflower as plant indicator. The main and ratoon crops were raised during both the years. The experiments were laid out with three irrigation treatments under main plot and four nitrogen levels under sub-plots, for the main and ratoon crops. The irrigation treatments were rainfed (no irrigation), irrigation at 50 per cent available soil moisture and irrigation with sunflower as plant indicator. Four levels of nitrogen viz., 0, 40, 80 and 120 kg N/ha were tried in the sub plots.

A well distributed rainfall ranging from 480 to 630 mm will be sufficient for stabilising the yield of rainfed sorghum. Application of nitrogen in the presence of adequate moisture is beneficial to rainfed crop.

The water requirement for the main crop was greater than for the ratoon crop of sorghum. A considerable saving in water consumption ranging from 9.9 to 18.8 per cent in the main crop of sorghum and 5.4 to 11.6 per cent in the ratoon crop was observed when irrigation was scheduled with sunflower as indicator plant as compared to that at 50 per cent ASM resulting in greater water use efficiency without affecting the yield.

The N-uptake in both the irrigation treatments viz. irrigation at 50 per cent ASM and irrigation as per plant indicator was higher than that in the rainfed treatment. Irrigation and nitrogen application had no influence on the P-uptake. K-uptake was however, greater in irrigation treatments than in the rainfed treatment.

Summarising, it could be concluded that an evenly distributed rainfall of 550 mm will be sufficient for stabilising the yield of rainfed sorghum. The water requirement is greater for the main sown sorghum than for the ratoon crop.

There is advantage in scheduling irrigation with sunflower as plant indicator by way of lesser water consumption and increased water use efficiency as compared to the recommended irrigation schedule at 50 per cent ASM.

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INTRODUCTION

INTRODUCTION

Inadequate and ill-distributed rainfall is the major constraint for successful crop production under rainfed conditions. The weather parameters that prevail during the crop growth play an useful role. The crop under rainfed conditions normally yields lesser than the irrigated crop. But the yields get boosted sometimes under adequate quantity of well distributed rainfall with judicious application of nutrients during the crop period. Under rainfed conditions, the initial stages of crop growth are affected by non application of fertilisers. In depth study on the factors responsible for the lower yields obtained under rainfed conditions is essential for stabilising the yield of rainfed crop equivalent to that of an irrigated crop.

Our water resources for irrigation are relatively limited and agriculture is generally a gamble with monsoon. Out of 145 million hectares of cultivable land in India, only about 36 million hectares are under irrigation. This is mainly due to wastage and improper use of water (Rao, 1964). However, there is vast scope for improvement in water management for increased production by providing protected irrigation to crops raised under rainfed conditions.

Depth and frequency intervals fixed arbitrarily were the criteria for treatments in irrigation experiments conducted throughout India. In rainfed conditions it has been possible to increase the yield of crops by providing protective irrigation at critical stages by recycling the surplus water stored in farm ponds. There is need for providing means for irrigation with the proper approach in scheduling of irrigation methods on the basis of soil moisture deficit in the root zone.

Timely irrigation and thereby economising irrigation water has been one of the major problems in irrigated agriculture. Various devices such as tensiometer, neutron probes and resistance blocks have been developed to assess the soil moisture. Though useful, they have not been widely adopted by farmers because of their higher cost and lack of technical knowledge in handling.

Use of biological indicators show a great promise in benefitting the farmers (Anon, 1960). Sunflower is an indicator plant and is very sensitive to changes in soil moisture. On account of its capacity to exhibit clearly the symptoms of moisture stress, sunflower has been employed to indicate the soil moisture deficit for field crops which have similar rooting zone.

Sorghum crop needs adequate irrigation and there is scope for economising irrigation water in its present use. Earlier studies have revealed that in sorghum crop, optimum yields were obtained at 50 per cent available soil moisture (ASM) with 10 irrigations during the crop period (Palaniappan *et al.* 1977).

Thus it is felt that there is need for an in-depth study on the water requirements with cheaper devices and adequate nutrients under rainfed conditions.

Hence a study has been made with the following objectives besides scheduling and economising the irrigation water by using biological indicator such as sunflower plant to ascertain

1) the factors responsible for stabilising the yield of rainfed sorghum crop to that of an irrigated crop

2) the differences in water requirements between the recommended supply of water and restricted supply of water

3) the role of nutrients under different situations

4) the amount of sorghum grain obtained per unit quantum of water and

5) the quantum of irrigation water saved for sorghum by using sunflower as plant indicator.

REVIEW OF LITERATURE

2 REVIEW OF LITERATURE

The earth's most abundant compound is water, a vital constituent in all living matter and it may be considered as the life blood of the earth (Russel *et al.*, 1973). It is essential to know the exact water requirement of crops and the efficiency with which water can be applied to obtain most economic utilisation of limited water resources (Kelley, 1954). Inspite of sorghum being tolerant to drought, the high yielding varieties are responsive to good irrigation practices. Rainfed crop of sorghum yields lesser than irrigated crop. But the yields get boosted some times under adequate quantity of well distributed rainfall with judicious application of nutrients during the crop period. In rainfed regions, the low yield of sorghum is due to moisture stress in initial stages of crop growth and non-application of fertilisers. With regard to irrigated conditions, depth and frequency intervals fixed arbitrarily sometimes cause usage of excess irrigation water. Introduction of plant indicators for scheduling irrigation, economises the quantum of irrigation water. A brief review of the past work done on various aspects regarding weather parameters related to water requirement, moisture stress, fertiliser levels, moisture-fertiliser interactions with reference to scheduling of irrigation is made hereunder.

2.1. Weather parameters

The weather characteristics such as rainfall, temperature, relative humidity and sunshine hours effect the crop growth and yield of crops.

Rainfall has profound influence on sorghum production. Ahmed and Dorairaj (1963) reported that farming in rainfed areas and its success and failure depends on the amount and its distribution of rainfall. Krishnamurthy et al. (1973), Sundararaj and Thulasidas (1976) observed that rainfall at the time of flowering affected the yield because of sterility resulting from washing of pollen grains.

Temperature is one of the important factors affecting all the growth phases of the crop. Among the abnormalities, the temperature causes retarded plant growth, lack of anthesis, lack of grain filling and prolongation of ripening. Appadurai (1957) observed that the maximum temperature during the growth period of September sown crop was ranging from 32°C to 38°C and the minimum temperature about 24°C. This seems to be the best for elongation in the height of sorghum. Dethier and Vittum (1963) while expressing the "growing degree days" sometimes called as 'heat units' or growth units, an arithmatic accumulation of daily mean temperature above a certain threshold value, reported that the amount of plant growth approximately proportional to the amount of heat or temperature units accumulated. The heat unit value is obtained by substracting the base or threshold temperature for the specific crop from the mean temperature (average of maximum and minimum temperature of the day). For sorghum, daily mean temperature minus the threshold temperature of 10°C (50°F), summed from the day of emergence to maturity gives the accumulated heat units (Gilmore and Rogers, 1958). Oizumi and Iguchi (1966) found that growth of sorghum hybrids was highly sensitive to temperature. Narayan and Reddi (1968) stated that flowering was delayed as the mean maximum and minimum temperature and humidity from sowing to flowering and found that flowering duration was highly correlated with mean maximum temperature. Vergara et al. (1970) observed that low temperature at grain ripening stage increased the sterility. Place et al. (1971) found an increase in dry matter with increase in temperature from 27°C to 32°C. Mounder (1972) observed that sorghum could not set seed or continue its development at temperature below 18.3°C to 21.1°C. Babadzhanov (1972) stated that optimum conditions for flowering were 18°C to 22°C. Higher temperature 22°C to 26°C and a low temperature 10°C to 15°C delayed flowering. Purseglove (1975) reported that sorghum required an optimum temperature above 30°C for its growth. Mahendra Singh *et al.* (1975) stated that low temperature adversely affected grain setting and reduce the grain productivity. Sundararaj and Thulasidas (1976) stated that sorghum attained maximum growth and development in areas with high temperature and low humidity during the growing season. The minimum temperature for plant growth is about 15°C and the maximum temperature for plant growth is about 40°C, but sorghum thrives best in regions of 26°C. Livera and Carbello (1977) reported that the normal response of sorghum to growing temperature below 27°C was a lengthening of vegetative phase. Choudhury and Wardlaw (1978) opined that in sorghum, the rate of grain development was greater at the higher temperature of 30°C in the day and 25°C in the night.

Low relative humidity effects slow growth rate in summer crop. Duration seems to be the combined effect of humidity and temperature. High relative humidity above 80 per cent seems to shorten the duration and a low humidity below 50 per cent lengthen the duration. Appadurai (1957) and Babadzhanov (1972) stated that optimum condition for flowering was 70 to 80 per cent relative humidity. Higher relative humidity (85 to 95 per cent) and lower relative humidity (44 to 60 per cent) delayed flowering.

2.2. Scheduling of irrigation

Water requirement of a crop should be properly determined for judicial scheduling of irrigation. The determination of water requirement of crops is broadly classified by Dastane and Sharma (1970) as follows.

1. Transpiration ratio approach
2. Depth-interval-yield approach
3. Soil moisture deficit and degree of depletion approach
4. Climatological approach

In addition to the above, the biological indicator approach also helps in scheduling irrigation. Several formulae including Thornthwaite (1948) Penman (1948) and Blaney and Criddle (1950) were evolved but these were found not useful for day to day use in irrigation practices. Smith and Buchholtz (1964) found that open pan water evaporation provided a better estimation of the monthly and seasonal evaporation power of the air than the Thornthwaite method. Brown *et al.* (1964) found 27.5 cm of ET was necessary to produce the first increment of grain or 20 cm water needed. Dastane (1970) devised a soil-cum-sand mini plot technique for scheduling irrigation.

2.3. Biological Indicator

Sunflower is an indicator plant and is very sensitive to changes in soil moisture (Anon 1960). As the soil moisture stress increases beyond certain limit, the young leaves of the plant lose turgidity and drop. They do not recover unless the water deficit is made good. If wilting persists during the early morning hours it indicates real moisture deficit in the soil. A population rate of 30 sunflower plants at random per 1000 sq. meter area is optimum for use as plant indicator. Khan and Nathuram (1947) made extensive studies on corn, sorghum and sunflower and reported that water requirement did not differ much.

2.4. Irrigation needs of sorghum

Raheja (1961) reported that sorghum crop requires about 609.6 mm water for optimum yield while under Tamil Nadu conditions, Chandramohan (1970) reported 488 mm to be sufficient. Kaliappa et al. (1974) reported that at Coimbatore and Bhavanisagar, irrigation at 50 per cent available moisture was found adequate in the rabi season. At Tirupathi (Andhra Pradesh), irrigation at 50 per cent depletion of available soil moisture on sandy loam soils was found adequate for finger millet grain in rabi season (Ramachandra Reddy et al., 1974). Similar observations were made at Coimbatore in Tamil Nadu (Rajagopal, 1969). Yadav (1972) and Palaniappan et al., (1977) reported that hybrid sorghum yields were maximum when the crop was irrigated at 50 per cent ASM in 0 to 30 cm soil layer in the Kharif season (D.A.R.E. 1975; A.P.A.U., 1975). Gopalakrishnan (1966) observed that soil moisture regime at 60 per cent ASM significantly increased the height of plant.

The stages of crop growth are important while giving irrigation. Balasubramanian et al. (1966) reported that initial seedling, preflowering and grain formation stages coinciding with 2,4,12 to 14, 15 to 16 and 17 weeks after sowing respectively were found critical for water demand at Coimbatore. Dastane (1970) reported that timely irrigations during their growth period important than irrigation at definite intervals. Similar results have been reported by Swaminathan (1972). Kanwar (1969) reported that though the total quantity of water might be the same, if available at the right time of the crop growth, it would be many times more productive. Dastane (1974) summing up the water requirements of cereal crops observed germination and emergence, seedling growth, flowering and grain formation stages to be critical for irrigation requirements and higher yield. Singh (1972) observed that early seedling (15 to 20 days growth) and flowering (90 - 110 days growth) stages were most critical in water demands. The results of experiments conducted at Coimbatore on CSH.2 sorghum also confirmed the same wherein the highest yield of 4545 kg/ha was obtained by irrigations at these stages (Palaniappan *et al*. 1977). Increasing soil moisture by supplemental irrigation markedly increased the yield of sorghum (Bielorai *et al*. 1964). It tended to decrease lodging, and increased the water use efficiency (Bond *et al*., 1964). It also increased the vegetative and reproductive plant growth, height of plants, head weight, thousand grain weight and number of kernels per head (Bielorai *et al*., 1964). Mathers *et al*. (1960) reported that higher moisture levels produced greater yield. Increasing moisture levels resulted in higher grain and straw yields in barley (Fedak and Mack 1977). Timing of irrigation had very marked effect on yield and its components (Hagan *et al*. 1957). Bielorai *et al*. (1964) reported that irrigation applied during the period from heading to seed set increased the grain yield of sorghum considerably. Rao and House (1972) reported that inspite of sorghum being tolerant to drought, the high yielding varieties are also responsive to good irrigation practices. Mertia and Bajpai (1975) observed a linear relationship between yield and water used by sorghum. From New Mexico, Malm and David (1968) reported linear response of sorghum grain yield to the number of irrigations. Mertia and Bajpai (1975) also have reported similar results. Finkner and Malm (1971) reported that an irrigation at 50 per cent flowering increased the sorghum grain yield by 2900 kg/ha and an irrigation at the soft dough stage increased the yield by 530 kg/ha but an irrigation when plants were 15 to 20 cm height gave only a small yield increase. Kaliappa *et al*. (1974) reported that moisture supply during preflowering stage was more important than at post flowering stage in deciding the yield of sorghum.

Jacob (1963) reported that adequate moisture during flowering and grain filling stage are most essential to have larger earhead and better filling of grain. He observed that irrigation at 14 days interval significantly influenced the height of sorghum plants and length of earheads. Thangamuthu (1979) reported that in sorghum, there was significant improvement in plant height with normal irrigation than irrigation given at critical stages.

2.5. Influence of moisture on growth components

Crop growth is sensitive to moisture stress particularly because of the physiological effect of stress on production and maintenance of photosynthetic tissue (Fischer and Hagan; 1965). Grain sorghum will almost cease to grow during a period of moisture stress and will recover and continue to grow if moisture becomes available after a reasonable length of time (Thompson 1963). Campbell *et al*. (1969) recorded a negative correlation between moisture stress and plant height and stem diameter. When sorghum plants were subjected to wilting prior to floral initiation, growth in height virtually ceased (Anon. 1975). Generally, the organ growing most rapidly at the time of stress is the one most affected (Aspinall *et al*. 1964).

Water stress at an earlier stage may affect the amount of leaf area at flowering (Fischer and Hagan, 1965). Water stress can also affect the leaf area through its effect in hastening the rate of leaf senescence (Fischer and Hagan, 1965; Fischer and Kohn, 1966). Although, total plant growth is affected during water stress, shoot growth is reduced most. Root growth is generally favoured relative to shoot growth as indicated by height and root to shoot ratio (Pearson, 1966; Davidson 1969 and Elnadi *et al*., 1969). Kmoch *et al*. (1957) reported that the roots developed under limited soil moisture were finer and had larger branches of secondary and tertiary roots. Elnadi *et al*. (1969) and Clements (1964) recorded higher rooting depths under stress conditions. Pharande *et al*. (1973) reported that about 83 per cent of moisture was extracted from the root zone mostly from 0-30 cm depth.

There is accumulating evidence that soil moisture stress at particular stage of plant growth has specific effects on subsequent development in many crops. Skipping irrigation at flowering stage was not so detrimental in sorghum (Palaniappan *et al*. 1977). Stewart (1947) reported that with sorghum, deficits were least tolerated in the vegetative and pollination period. Lewis *et al*. (1974) reported that a moderately severe stress during boot through bloom stage caused 34 per cent reduction in yield of sorghum while the same accounted for only 10 per cent reduction when the stress occurred during milk through dough stage.

Adams and Arkin (1977) observed smaller panicles and shorter heads at the onset of soil water stress during the early stages of panicle development. Inuyama *et al*. (1976) concluded that the critical period for moisture stress in grain sorghum was from boot stage until flowering. Jain (1975) however did not agree with the critical stages concept as he opined that crops needed sufficient moisture throughout the growth period for maximum yield. Fischer and Hagan (1965) found that grain filling was reduced most when the stress arose about 10 days before ear emergence in wheat. It has been concluded that most determinate crops are especially sensitive to water deficits from the time of floral initiation during flowering, and to a lesser extent during seed development (Begg and Turner 1976). The extent of the damage caused to the plants depended on their physiological stage, the degree of water stress and the species concerned (Gates, 1964). Tillering to booting, heading, flowering and grain development phases in that order has been found critical soil water stress period for sorghum (Subramanian 1980).

Robins and Domingo (1953) reported that the moisture stress in early stages might have reduced the plant height by shortening the internodes. Uizumi et al. (1965) stated that the stress at critical stages limited the elongation of stalk and significantly reduced the LAI. Mohiuddin and Yaseen (1973) reported a significant reduction in yield components in CSH.1 sorghum due to stress during flowering and grain filling stages and stress at grain filling period (70 - 100 days) decreased the seed weight. Stress at flowering and grain development stages reduced the yield of sorghum due to decrease in grain number and grain weight respectively (Dastane 1974). Parameswarappa et al. (1975), observed that only 50 per cent of the spikelets opened fully and seeds set in, during the stress at spikelet opening stage in sorghum CS.3541. The effect of moisture stress in sorghum was marked on leaf area index (Krishnamurthy et al. 1973).

The yield component is more sensitive to stress during its period of rapid development (Begg and Turner, 1976). They reported reduction of panicle numbers in sorghum. Inuyama *et al*. (1976) reported that deficit which decreased the number of grains per ear did not decrease thousand grain weight in grain sorghum. Flowering was delayed by water stress in sorghum and other cereals (Brown *et al*. 1964; Campbell *et al*. 1969; Clarkson and Russel, 1976).

Crop yield, depending on the nature of harvested organ and the origin of its constituents, may be more or less sensitive to water stress than crop growth (Fischer and Hagan, 1965). Weight of grain and straw yield were inversely correlated with water stress (Campbell *et al*. 1969).

2.6. Moisture stress and water use efficiency

In sorghum, water use efficiency for grain production was increased as the stored soil moisture increased (Bond *et al*. 1964). Doss *et al*. (1964) reported that the rate of water use varied directly with the amount of available soil moisture. Jain (1971) reported that increased moisture stress decreased the growth rate to a much more extent than its effect on water use efficiency but the degree and rate of water stress determined the yield and rate of E.T. and thereby the water use efficiency. Mertia and Bajpai (1975) obtained an increase in water use efficiency with increasing moisture regimes along with a rise in consumptive use. Alston (1976) observed that water use efficiency was more in dry treatments and the least under all wet treatments where there were greater losses by evaporation from the surface of the soil.

2.7. Influence of moisture on nutrient uptake

Dastane (1974) opined that water controlled the degree of availability, form, rate of movement and extent of uptake of nutrients and hence the responses to applied fertilisers depended on the quantity and frequency of irrigation. Singh (1972) observed that the transport of mineral nutrients in the soil, absorption by the roots, translocation within the plant and their metabolism were all affected by soil moisture availability. Two reasons have been given for the influence of moisture, namely increased availability of nutrients and the utilisation of absorbed nutrients.

Herron *et al.* (1963) reported that both moisture and nitrogen must be adequate for continued uptake of nitrogen throughout the season. Sharma (1969) found that without nitrogen there was little benefit from increased moisture supply but as more nitrogen was applied, the beneficial effect of water became greater.

Painter and Leamer (1953) observed that more frequent irrigation was of no advantage unless adequate amounts of fertilisers were used or fertilisers were more effective in increasing sorghum yields when the crop was supplied with adequate irrigation. Muthuvel (1976) stated that mineralisation of added nitrogen, its mobility in the soil medium and the consequent uptake by the growing plants were largely influenced by the prevailing soil moisture condition. Bennett _et al_. (1964) found that total uptake of N & K in sorghum was usually higher with irrigation. Singh _et al_. (1971) found that the availability of P increased with increasing intensity and frequency of irrigation due to dilution of soil solution. Nitrogen uptake per unit weight of dry matter production decreased under wetter regimes (Arjan Singh _et al_., 1973). Shrotriya _et al_. (1974) concluded that the uptake of nitrogen in plants increased as a result of increased dry matter production with increase in moisture level. Boovendran (1977) concluded that uptake of nitrogen was greater under high moisture supply. Herron _et al_. (1963) observed that inadequate nitrogen, limited the growth from the five weeks after emergence and moisture stress with inadequate nitrogen severely reduced the growth throughout the season.

2.8. Influence of nitrogen on growth and yield

Burleson *et al*. (1956), Raheja and Krantz (1958), Krishnamoorthy (1962) and Anand Rao and Reddi (1972) reported that nitrogen content and uptake increased with increased levels of nitrogen application. Rao and House (1972) concluded that the total uptake of N, P_2O_5 and K_2O was 130-180, 50-65 and 100-130 kg/ha respectively in a grain sorghum variety yielding 50-60 Q/ha. Atar Singh and Bains (1972) found a rapid increase in the uptake of nitrogen from the boot stage to 75 days after sowing. Roy and Wright (1973) studied the nutrient uptake patterns as influenced by N and P levels and concluded that the highest uptake of 148.7 kg N/ha was recorded with the application of 120 kg/ha. A fertiliser dose of 134.4 kg N, 67.2 kg P_2O_5 and 67.2 kg K_2O/ha resulted in maximum grain and straw yield (Ready, 1968).

Application of N had significant effect in increasing the growth and yield components of sorghum. Raheja and Krantz (1958) observed a positive influence of nitrogen on the length of earhead. Krishnamoorthy (1962) reported that there was significant difference in the length of earhead between nitrogen applied plots and no nitrogen plots. Ramachandra Reddy and Mustafa Hussain (1968) and Panda (1972) reported that plant height, number and size of leaves and the leaf area were not influenced significantly by 'N' application. Anand Rao and Reddi (1972) observed that increasing the levels of nitrogen from 0 to 150 kg N/ha increased the dry matter production at all the stages of plant growth. Ramalingam (1975) stated that increasing levels of nitrogen increased the dry matter significantly. Krishnamurthy et al. (1975) reported that plant height and number of leaves per plant were not much influenced by N-levels. Olsen and Santos (1976) reported that the dry matter yields were highest and almost two fold of the control at 150 kg N/ha.

Stewart (1947) reported that the optimum dose of nitrogen might be around 20 to 40 kg/ha in the major sorghum growing tracts of India. Burleson et al. (1956) reported that sorghum responded to very high levels of nitrogen upto 240 kg/ha. Panickkar (1960) showed that there was good response for nitrogen fertilisation upto 80 kg/ha giving an extra yield of 15 per cent over 40 kg N/ha. Mahendra Singh and Mahendra Pal (1969) stated that optimum nitrogen level was between 100 and 150 kg/ha for different places and genotypes.

Shekhawat and Chundawat (1971) stated that grain yield of sorghum increased with increasing levels of nitrogen upto 150 kg and application beyond this level was not beneficial. Rodge and Tek (1975) reported linear response to nitrogen upto 120 kg/ha for various sorghum hybrids. Similar results were reported for CSH.5 and CSH.6 by Surender Reddy and Reddi (1976). Response of sorghum hybrids to nitrogen levels tried in different locations in India under All India Coordinated Sorghum Improvement project indicated that CSH.5 responded upto 120 kg N/ha.

2.9. Economy in water use

The economy in water use could be achieved by increasing crop production per unit volume of water per unit area of cropped land and per unit of time. There is considerable scope in saving the water use in sorghum. Kelley (1954) observed that it is essential to study the efficiency with which water can be applied to obtain most economic utilisation of limited water resources.

Thus from the review, it may be seen that the water requirement of a crop should be properly determined for judicial scheduling of irrigation and introduction of plant indicators while scheduling irrigation economises the quantum of irrigation water. It was also found that water use efficiency was more in dry treatments and the least under wet treatments. There is considerable scope in saving the water use in sorghum.

MATERIALS AND METHODS

3 MATERIALS AND METHODS

Field experiments were conducted to study the influence of irrigation and nitrogen on sorghum (planted as well as ratoon) as compared to the crop raised under rainfed conditions and scheduling of irrigation with the help of sunflower as plant indicator. The experiments were laid out in field No.69, Eastern block of the College Farm, Tamil Nadu Agricultural University, Coimbatore during the years 1978-79 and 1979-80.

3.1. Materials

3.1.1. Location and climatic conditions

The Agricultural College Farm at Coimbatore is situated in the North Western tract of Tamil Nadu at 11°E north latitude and 76.57" East longitude at an altitude of 426.72 metres above mean Sea level. The mean annual rainfall is 644 mm (average of 25 years). The mean maximum and minimum temperature are 36° and 18.5°C respectively. The weather conditions prevailed during the cropping periods are shown in the form of a chart in Fig.1 and the relevant meteorological data are given in Appendix I.

Fig. 1. Meteorological data during crop seasons

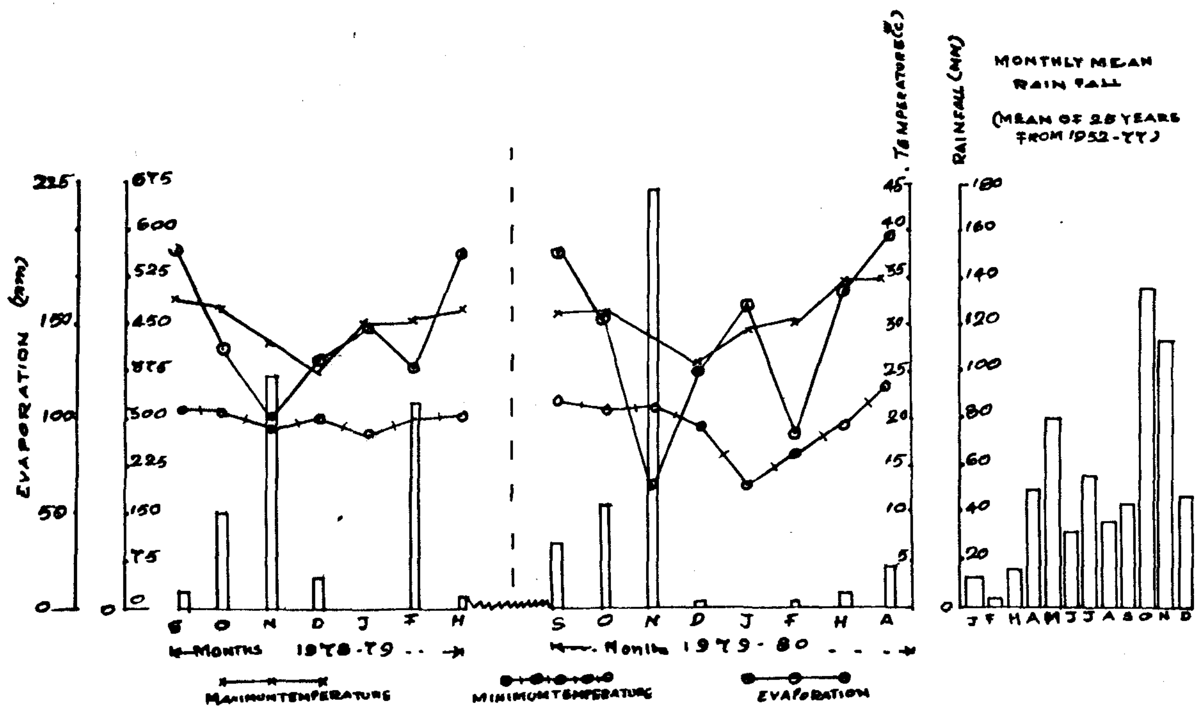


FIG. 1. METEOROLOGICAL DATA DURING CROP SEASONS.

3.1.1.1. Accumulated heat units

The heat unit value is obtained by substracting the base or threshold temperature for the specific crop from the mean temperature (average of maximum and minimum temperature of the day). For sorghum, daily mean temperature minus the threshold temperature of 10°C (50°F), summed from the day of emergence to maturity gives the accumulated heat units (Gilmore and Rogers, 1958).

3.1.2. Soil characteristics

The details regarding the physico chemical properties and analytical data of the soil of the experimental field are presented in Table 1. The soil comes under Perianaickenpalayam series. The soil is of clay loam type.

3.1.3. Water source for irrigation

The crop was irrigated with wet land water available through the intergrid system of the University. The E.C. of the water was 0.89 mmhos/cm.

3.2. Methods

Field experiments were conducted with the sorghum variety Co.22. Three irrigation treatments

Table 1. Initial soil analysis data of the experimental field

Particulars	Soil Depth 0 to 45 cm depth (mean)
Mechanical Composition (Piper, 1966)	
Coarse sand	36.1 per cent
Fine sand	8.6 "
Silt	20.2 "
Clay	34.7 "
Soil Physical properties	
Maximum water holding capacity	44.8 per cent
Pore space (Piper, 1966)	55.1 "
Field capacity (Dastane, 1967)	24.0 "
Permanent wilting point (Richards, 1947)	11.50 "
Bulk density (Sankaram, 1966)	1.38 g/cc
Absolute specific gravity (Piper, 1966)	2.35 g/cc
Available Nutrients	
Nitrogen (Iruthayaraj *et al.*, 1974)	221 kg/ha
Phosphorus (Jackson, 1967)	21.5 "
Potassium (Stanford & English, 1949)	601 "
Other Properties	
E.C. (1:2 water extract)	0.4 mmhos/sq.cm.
pH (1:2 water extract)	8.6

were allotted to the sub plots. There were twelve treatmental combinations replicated six times.

3.2.1. Treatments

3.2.1.1. Main plot treatments (Irrigation treatments)

Treatment symbols	Treatment
I_0	No irrigation - purely rainfed
I_1	Irrigation at 50 per cent available soil moisture (ASM) in the active rooting zone.
I_2	Irrigation given as per the wilting indication shown by the indicator plant sunflower

3.2.1.2. Sub plot treatments (Levels of nitrogen)

N_0	No nitrogen (control)
N_1	40 kg N/ha
N_2	80 kg N/ha
N_3	120 kg N/ha

3.2.2. Plot size

Gross	13.50 m^2
Net	6.48 m^2

3.2.3. Design

A split plot design was adopted as suggested by Panse and Sukatme (1967) for the study. The three irrigation treatments formed the main plot treatments while four nitrogen levels formed the subplot treatments. The layout plan is given in Fig.2.

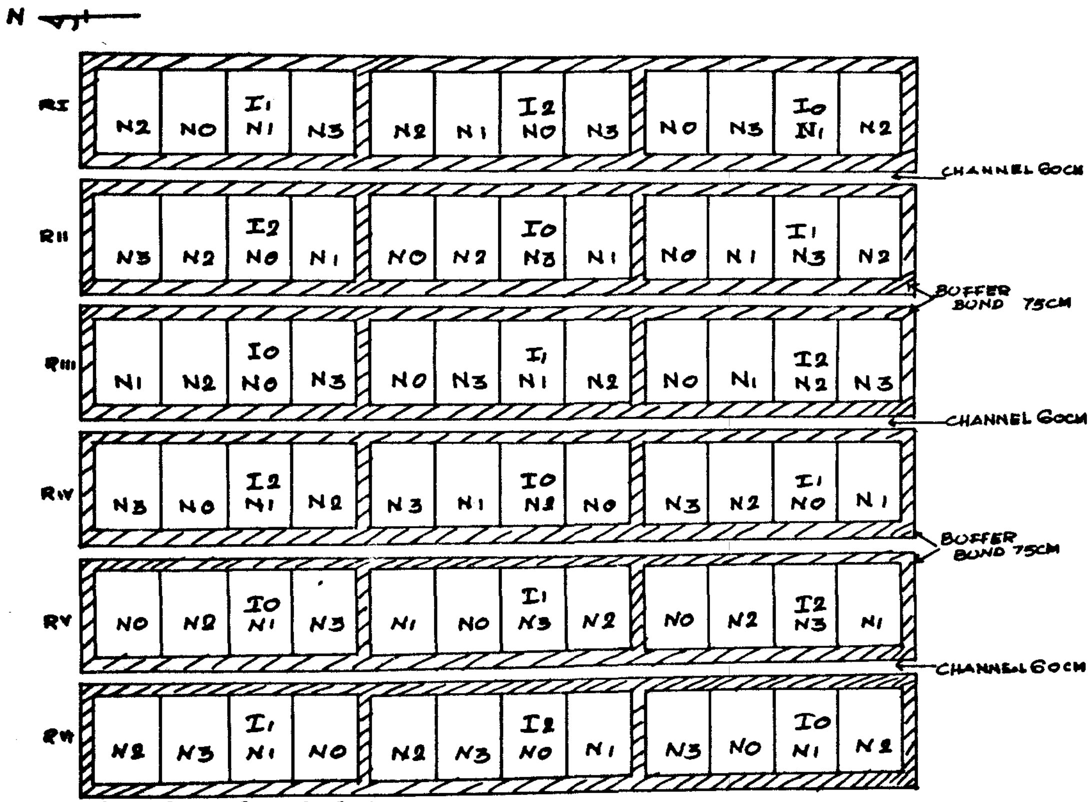
3.2.4. Preparation of the field

The field was prepared by using a tractor drawn mould board plough followed by harrowing. The field was levelled perfectly. Beds and channels with buffer channel of 60 cm all round the beds were formed to prevent seepage of water. A total number of seventy two beds were formed to accommodate all the treatments.

3.2.5. Seeds and sowing

Good viable seeds of sorghum variety with 95 per cent germination were used. Sorghum seeds were treated with Agrosan at two grammes per kilogramme of seed and were sown 15 cm apart with a spacing of 45 cm between two rows by dibbling two to three seeds per hole adopting a seed rate of 10 kg/ha. Before dibbling seeds, soil application of furadon granules at seven kilogrames per hectare was applied along the seed rows. Ten days after sowing, the seedlings were thinned so as to have only one plant per hill. The first year crop was sown on 8.9.78 and the second year crop on 9.10.79.

Fig. 2. Field layout



GROSS PLOT SIZE 4.5 x 3.0 M
NET PLOT SIZE 2.7 x 2.4 M

FIG. 2. FIELD LAYOUT

3.2.6. Fertiliser application

Nitrogen in the form of urea was applied as basal dressing as per the treatments, while 45 kg P_2O_5/ha and 45 kg K_2O/ha were basally applied in the form of superphosphate and muriate of potash respectively. Since one of the treatments is under rainfed conditions, the entire nitrogen was applied as basal dose to all the treatments along with P and K. In the beds, lines were drawn 45 cm apart and fertilisers were applied and covered.

3.2.7. After cultivation

Two hand hoeings, one at 15 days and the second at 30 days after sowing were given. Furadon at seven kelograms per hectare in leaf whorls was applied on the 25th day against sorghum shoot fly. Adequate plant protection measures were taken against pests and diseases as per the recommended doses of Tamil Nadu Agricultural University.

3.2.8. Irrigation

A life saving irrigation was given to all the treatments inclusive of the rainfed treatment for good germination. Afterwards no irrigation to the rainfed treatment I_0 was given, while the rest of the treatments, were irrigated as per treatmental requirements.

Soil moisture measurements were made gravimetrically as suggested by Dastane (1967) from samples taken at three depth intervals viz. 0 to 15 cm, 15-30 cm and 30-45 cm. The average for the three depths were pooled and the mean soil moisture content was utilised for calculating soil moisture depletion. The moisture content of the soil between the field capacity and the permanent wilting point was taken as the available moisture range. The depth of water required at each irrigation was found out by using the formula (Dastane, 1967) namely,

Moisture deficit or Depth of irrigation required =

$$\frac{\text{Field capacity} - \text{Actual moisture content}}{100} \times \text{Bulk Density} \times \text{Depth of rooting zone}$$

This was multiplied by the area of the plot to arrive at the volume of water required for each plot. The measured quantity of irrigation water was supplied through water meter lead through 3 cm polythene tubes directly into the plot. Daily moisture estimates were made in all the treatments.

3.2.8.1. Irrigation to treatment I2 (Plant indicator)

Sunflower is an indicator plant and is very sensitive to changes in soil moisture. On account of its capacity to exhibit clearly the symptoms of moisture stress, the sunflower has been employed to indicate the soil moisture deficit in field crops which have identical rooting zones. Mordan variety of sunflower seed were sown along with the sorghum crop and thinned to have a population of 30 solitary plants at random per 1000 m^2 area. Irrigation was applied when the top most well developed leaves showed loss of turgor. Symptoms were observed at 10 am, when there was no dew on the leaves. Sunflower seeds were sown in between sorghum plants in the treatment where the indicator plant is required.

3.2.8.2. Computation of total water requirement

The water added through irrigation, effective rainfall and the water contents of 0-45 cm. depth of soil profile at sowing and at harvest were considered in computing the total water requirement. Morachan (1978) reported that the consumptive use is equal to the water added plus or minus any change in soil moisture.

3.2.8.3. Effective rainfall

The total receipt of rainfall was recorded separately. But the whole quantity received was not taken into consideration for the moisture availability to the crop, because, out of the total receipt, some might have been lost through run-off and some through percolation. Therefore the effective rainfall, that was the actual quantity utilised for crop growth, was calculated using a lysimeter.

3.2.8.4. Lysimeter

The lysimeter used in this experiment to collect the leachete water consisted of three circular pans with tapering bottoms each having a seperate outlet. These three pans were set one within the other resembling concentric circles and the smallest one was fitted into the 40 cm diameter pan and these two together were fitted into the third and the largest. There were proper apertures and vents on the side walls of the outer, and the outermost to receive the metallic outlet tubes that were connected to collection vessels through flexible tubes. For installation, a pit was dug out and a tunnel was made sideways at the desired level on the pit wall leaving the soil above undisturbed. This three pan lysimeter was set up at 45 cm depth as mentioned above and filled with graded filter to the brim. Then it was pushed into the sideways tunnel and packed around in such a way that the lysimeter top was at a level and horizontal leaving little space between it and the soil. From the water collected from the central pan after the receipt of rain, the effective rainfall was calculated (Nachappan et al. 1974).

3.2.9. Harvest

Two border rows of sorghum were harvested first, later the net plot was harvested. The dates of sowing and harvest of main and ratoon crops in both the years are given in Table 2.

3.2.10. Biometric observations

3.2.10.1. Growth components

In the net plot, five sorghum plants in each treatment were selected at random and labelled for taking the following observations at three stages viz. 30, 60 days after sowing and at harvest stage. From each treatment, plant height, number of functional leaves, leaf area and earhead measurements were recorded at the respective stages.

3.2.10.1.1. Plant height

Plant height was measured from the base of the plant to the tip of the longest leaf stretched and their mean values were recorded in cm.

3.2.10.1.2. Leaf area index

Leaf area was computed using the formula leaf length x leaf breadth x 0.747 as suggested by Stickler *et al.* (1961). The leaf area index was calculated by

Table 2. Details of sowing and harvesting dates

	Particulars	Date of sowing	Date of harvest	Duration in days
1978	Main crop	8.9.78	20.12.78	104
1978	Ratoon crop	20.12.78	1.3.79	72
1979	Main crop	9.10.79	27.1.80	111
1979	Ratoon crop	27.1.80	23.4.80	87

deviding the leaf area by the area of the land occupied by the leaf.

3.2.10.1.3. Dry matter production

At each stage, plants were selected at random from the outer rows, pulled out and the plant samples were kept at 60°C in a hot air oven till constant weight was attained. From the dry weight of the plants, the dry matter production was expressed in kg/ha.

3.2.10.1.4. Root length

Earlier to the laying out of the experiment, seeds of short duration dwarf variety of sorghum (Co.22) and sunflower (Mordan) were sown in pots. Each pot had one sorghum and one sunflower plant in it. The root length of sorghum and sunflower plant at 15 days interval was measured by pulling out the sunflower and sorghum plants from the pot. This was done in duplicate, and the mean value recorded. This study was undertaken to correctly assess the age of the sunflower plant for indicating the wilting point at which stage, irrigation will be given to the treatment I_2.

3.2.10.2. Yield components

3.2.10.2.1. Length of earhead

The length of the earhead was measured from the basal node to the tip of the earhead and expressed in cm.

3.2.10.2.2. Earhead weight

Five earheads, oven dried were weighed and the mean weight was recorded.

3.2.10.2.3. Grain weight per ear

Grains from each oven dried earhead were threshed and weighed and the mean weight recorded.

3.2.10.2.4. Thousand grain weight

One thousand grains from each plot were counted, weighed and expressed in grammes.

3.2.10.3. Yield

3.2.10.3.1. Yield of grain

The grain yield from the net plot was recorded at 14 per cent moisture level and computed to kg/ha.

3.2.10.3.2. Yield of straw

The straw yield from the net plot was sun dried and weighed till consecutive weights were obtained and computed to kg/ha.

3.2.11. Plant nutrient analysis

The plants used for recording dry matter production were chopped into pieces and ground into fine powder in a grinding machine. The powdered material was used for chemical analysis. The nutrient content was multiplied by the corresponding dry matter to calculate the uptake of nutrients and expressed in kg/ha.

3.2.11.1. Nitrogen

Nitrogen content was determined by microkjeldahl method as suggested by Subbiah and Asija (1956).

3.2.11.2. Phosphorus

Phosphorus content was estimated by the method described by Jackson (1973).

3.2.11.3. Potassium

Potassium content was estimated in triple acid extract using EEL flame photometer (Jackson, 1973).

3.2.12. Statistical analysis

Statistical analysis of the data was carried out for the crops in both the years as suggested by Panse and Sukatme (1967). Wherever the result was significant, critical difference was worked out at five percent level.

RESULTS AND DISCUSSION

4 RESULTS AND DISCUSSION

Experiments were conducted for a period of two years (1978 and 1979) with two main sown crops and two ratoon crops to study the influence of weather parameters, irrigation and nitrogen on the growth and yield of sorghum and scheduling of irrigation with sunflower as plant indicator.

4.1. Influence of weather parameters

4.1.1. Rainfall

The weather data during the cropping period of the two year periods are presented in Fig.1 and Appendix 1.

The mean annual precipitation of Coimbatore is 626 mm and the larger amount of rainfall is received from the second week of October to the end of November. Rainfall is generally meagre from the second fortnight of December to the end of March. The mean quantum of rainfall received in summer (Feb-May) is 137 mm, in monsoon season (June-Sep) is 182 mm and in winter (Oct-Jan) is 307 mm.

During the experimental period, a total quantity of 517.4 mm of rainfall (Main crop - 356.4 mm and ratoon crop - 161 mm) was received during 1978, while in 1979, a total quantity of 864.5 mm of rain fall was received during both the main and ratoon crop (main crop - 812.6 mm and ratoon crop - 51.9 mm). The rainfall was less in the first year of 1978 for the main crop as compared to that of 1979. During the first year (1978), the rainfall was fairly distributed during the growth phase of the crop. There was absolutely no rainfall during the vegetative phase of the ratoon crop during the month of January but adequate irrigation was given to the crop at the period of stress. The crop yield in the rainfed treatment I_0 was low since the crop suffered moisture stress at the boot leaf stage. Crop yields would have been boosted if the crop had been given one irrigation at this stage. The rainfall, after sowing of the main crop during 1978 was meagre and the crop suffered by water stress at the seedling stage. Later due to the receipt of heavy showers, the crop has recovered to a great extent and hence the yield was not affected. Rainfall has profound influence on sorghum production (Krishnamurthy *et al.*, 1973). Pollination and fertilisation of the crop were not affected by heavy rain as the flowering escaped the peak rains. The rainfall was very high during the main crop of 1979 and very low and inadequate for ratoon crops.

The lower yield obtained during the second year 1979 main crop may be attributed to the heavy rain fall of 313 mm received during the flowering period due to the late sowing in October. Sundararaj and Thulasidas (1976) also observed that the rainfall at the time of flowering affected the yield because of sterility resulting from washing of pollen grains. The grain yield in the ratoon crops raised during 1978 and 1979 were lower due to the low rainfall during the vegetative and flowering period.

4.1.2. Sunshine hours

There were bright sunshine hours ranging from 5.5 to 7.8 hours per day. Chandler (1963) opined that there was an increasing trend in yield with the increased sunshine hours per day. Park and Lee (1972) observed that the amount of carbohydrate translocated from straw to grain after heading was influenced by sunshine hours per day.

The grain yield of the second year (1979) ratoon crop was greater than the ratoon crop of 1978. The higher yield during 1979 is attributed to the higher heat units during the crop period. The heat units received during 1978 ratoon crop was 580 while the heat units for the second year (1979) was 783.

Loomis and Williams (1963) reported that combinations of favourable temperature and large amount of sunshine hours made possible very high levels of production if moisture supply is adequate and crop management efficient.

4.1.3. Temperature

The temperature is one of the important factors affecting all the growth phases of the crop and the abnormalities in the temperature caused retarded plant growth, lack of anthesis, lack of grain filling and/or prolongation of ripening. Dethier and Vittum (1963) expressed that at temperature above the threshold value, the amount of plant growth was approximately proportional to the amount of heat or temperature. The grain yield during the first year (1978) main crop was better where the mean maximum temperature was 30.7°C during sowing month. Similarly the grain yield of 1979 ratoon crop was higher than the first year (1978) ratoon crop. This may be due to the lower mean maximum temperature of 24.8°C when compared to the higher mean maximum temperature of 29.6°C at the sowing month which recorded higher grain yields. This is supported by the findings of Narayan and Reddi (1968). This is also in confirmity with the findings of Oizumi and Iguchi (1966).

4.1.4. Effect of temperature on crop duration

The duration of the second year ratoon crop (1979) was extended by 15 days as compared to the first year (1978) ratoon crop (Table). Venkateswara Rao and Rama Rao (1969) reporting the mean maximum and minimum temperature and humidity from sowing to flowering found that flowering duration was highly correlated with mean maximum temperature. Babadzhanov (1972) reported that higher temperature delayed flowering. However Livera and Carbello (1977) observed that the normal response of sorghum to growing temperature below 27°C was a lengthening of vegetative phase. The crop duration of the first year (1978) main sown and ratoon crops was (104 days and 72 days respectively) lesser than the duration of the main sown and ratoon crops of the second year (1979) (111 days and 87 days respectively). Rodolfo et al. (1975) reported that abnormalities in the temperature caused prolongation of ripening. The high mean maximum temperature (Table) (33.9°C) prevailed during the cropping period of second year (1979) ratoon delayed the flowering by 15 days as compared to the first year (1978) ratoon crop with mean maximum temperature of 30°C and 70 per cent relative humidity.

4.1.5. Influence of temperature on growth components

Plant height was found to be greater in the second year (1979) ratoon crop (94.9 cm) than that of the first year (1978) ratoon crop (87.3 cm). This may be due to the prevalence of high temperature during the growing season.

The dry matter production was greater during 1979 ratoon crop (8071 kg/ha) as compared to that of 1978 ratoon crop (5269 kg/ha). The higher mean maximum temperature (33.9°C) prevailed during the crop period of 1979 ratoon crop as compared to that of the mean maximum temperature of 1978 ratoon crop might have contributed to the higher dry matter production. Murata (1964) as well as Place <u>et</u> <u>al</u>. (1971) reported that increase in temperature increased dry matter production in rice. Rodolfo <u>et</u> <u>al</u>. (1975) after studying sorghum growth and development under controlled conditions concluded that low temperature condition resulted in low dry matter production.

The lesser grain yield during 1979 main sown crop than that of 1978 may be due to the lower mean minimum temperature (16.1°C) in 1979 compared to 20°C during 1978, at grain ripening stage. Vergara <u>et</u> <u>al</u>. (1970) also observed that low temperature at grain ripening stage of rice increased sterility and thereby reduction in yield.

4.2. Water requirement

The data on the effect of treatments on total water requirements of sorghum are presented in Table 3.

During 1978, the rainfall occured both at the time of sowing (18.9 mm) and after 30 days after sowing. It was fairly distributed during the vegetative phase of the crop. A maximum quantity of 337.3 mm rainfall was received during vegetative and flowering stages. The crop did not get sufficient rains during grain filling stage.

The total water requirement of sorghum under treatment I_1 (50 per cent ASM) during the main crops of 1978 and 1979 were 582 mm and 631 mm while for treatment I_2 (Irrigation as per plant indicator) for 1978 and 1979 were 473 mm and 568 mm. In the case of ratoon crops, the total water requirement of sorghum under treatment I_1 during 1978 and 1979 were 330 mm and 312 mm while for treatment I_2 for 1978 and 1979 it was 310 and 274 mm. It was seen that in general, the total water requirement was greater for main sown crop than ratoon crop. This may be due to longer duration of the main sown crop than the ratoon crop.

Table 3. Number of irrigations and total quantity of water consumed in different irrigation treatments in sorghum

	1978				1979			
	Main		Ratoon		Main		Ratoon	
	I_1	I_2	I_1	I_2	I_1	I_2	I_1	I_2
Number of irrigations	7	3	5	3	5	2	7	4
Total water consumed (mm)	582	473	330	312	631	568	310	274
Saving in water consumption in treatment I_2 (over I_1 (mm)	109		18		63		36	

Treatment I_1 - Irrigation at 50 per cent ASM
I_2 - Irrigation as per plant indicator.

Raheja (1961) found that for optimum yield, sorghum needed 610 mm of water. The water requirement of sorghum at Bhavanisagar was 551 mm (Anon 1973) and 600 mm at Coimbatore (Boovendran 1977).

Among the irrigation treatments of I_1 (50 per cent ASM) and I_2 (Plant indicator) the water requirement was lesser in I_2 (Plant indicator) than I_1 (50 per cent ASM) indicating a saving of 91 mm and 63 mm in the main crops of 1978 and 1979 and a saving of 18 mm and 56 mm in the ratoon crops of 1978 and 1979. In both the main and ratoon crops of both the years of experimentation, the treatment I_1 (50 per cent ASM) consumed more quantity of water than the treatment I_2 (Irrigation as per plant indicator). This is due to more frequency of irrigation under treatment I_1 (50 per cent ASM) than I_2 (Plant indicator). Yadav (1972) reported that sorghum required 8 to 10 irrigations of about 600 mm when applied at 50 per cent ASM.

A total number of 7 and 3 irrigations were given under treatment I_1 (50 per cent ASM) and I_2 (Plant indicator) during 1978 main crop, while 5 and 2 irrigations were given during 1979 main crop. Similarly a total number of 5 and 3 irrigations were given under treatments I_1 (50 per cent ASM) and I_2 (Plant indicator) during 1978 ratoon crop while 7 and 4 irrigations were given under I_1 (50 per cent ASM) and I_2 (Plant indicator treatments during 1979 (Table 3). The lesser number of irrigations during 1979 main crop was due to heavy rainfall received during the period.

The low irrigation regime using sunflower as plant indicator required less quantity of water due to its limited number of irrigations. Musick and Grimes (1963) observed similarly. There is considerable scope for saving the irrigation water in sorghum as per the indications expressed by the indicator plant.

4.3. Irrigation

Dastane (1970) also reported that timely irrigation during their growth period are important than irrigation at definite intervals. Similar findings have been reported by Swaminathan (1972) and Anon (1972).

A total quantity of 582 mm and 631 mm of water was consumed by the crop inclusive of irrigation water and effective rainfall received during 1978 and 1979 main crops respectively under 50 per cent ASM (I_1). A quantity of 473 mm and 568 mm water was consumed under treatment I_2 (Plant indicator) during 1978 and 1979 respectively. Similarly a quantity of 330 mm and 310 mm water was consumed by the ratoon crops during 1978 and 1979 under 50 per cent ASM (I_1) while a quantity of 312 mm and 274 mm water was consumed under treatment I_2 (Plant indicator) during 1978 and 1979.

Raheja (1961) reported that sorghum crop required about 610 mm water for optimum yield while under Tamil Nadu condition, Chandramohan (1970) reported 488 mm to be sufficient.

The quantity of water applied and the number of times each treatment was irrigated are furnished in Table 3. The quantum of water consumed and the water use efficiency in sorghum are presented in Table 4. The data indicated that the quantity of water consumed and the water use efficiency were greater in the treatment I_2 (plant indicator) than the treatment I_1 (50 per cent ASM).

The first year (1978) main crop had seven irrigations while that of second year (1979) main crop had five irrigations. Similarly the first year (1978) ratoon crop had five irrigations while that of second year (1979) had seven irrigations. The number of irrigations among the main crops of 1978 and 1979 varied considerably. A total number of seven

Table 4. Quantity of water consumed and water use efficiency in sorghum (Pooled Mean for 1978 and 1979)

	Main Crop		Ratoon crop		Main crop + Ratoon crop	
	I_1 (50 per cent ASM)	I_2 (Plant indicator)	I_1 (50 per cent ASM)	I_2 (Plant indicator)	I_1 (50 per cent ASM)	I_2 (Plant indicator)
Quantity of water consumed (mm)	606	520	320	293	926	813
Grain yield kg/ha	4043	3653	2753	2588	6796	6241
Water use efficiency kg/ha/mm	6.7	7.0	8.6	8.8	7.3	7.7

irrigations with a total quantity of 582 mm of water was given during 1978 while five irrigations with a total quantity of 631 mm of water was given during 1979. This is due to the different months of sowing and due to the different weather parameters prevailed during the crop growth. The first crop was sown on 8.9.78 and the second crop on 4.10.79. The greater number of irrigations required for the second year ratoon crop was due to lack of receipt and distribution of rainfall after flowering period. Entire quantity of rainfall was received before flowering and dry spell prevailed afterwards. Hence the number of irrigations had increased.

Consequent on the receipt of well distributed rainfall during the first year main crop period, the grain yield was greater than that of 1979. The crop raised under rainfed treatment I_0 also gave comparatively higher yields during 1978 than that of 1979, because of the favourable distribution of rainfall. Ahmed and Durairaj (1963) reported that farming in rainfed areas and its success and failure depended on the amount and the distribution of rainfall. Dastane (1970) reported that timely irrigation during their growth periods important than irrigation at definite intervals. Similar findings have been reported by Swaminathan (1972) and Anon (1972).

4.3.1. Influence of irrigation on growth and yield components

The influence of irrigation on growth components like plant height, leaf area index; dry matter production and yield components like length of earhead, weight of earhead, grain weight per earhead, and thousand grain weight were studied in detail and discussed.

4.3.1.1. Plant height

4.3.1.1.1. Influence of irrigation

The plant height recorded during both the years of experimentation under main and ratoon crops are furnished in tables 5 and 6. They varied from 103 cm to 136 cm in the main crop and from 73 cm to 105 cm in the ratoon crops respectively.

The height of plant was recorded at 30th, 60th day after sowing and at harvest stage. In both the years under main crop there were linear response of plant height to irrigation. The increase in plant height was very sharp from 30th day to 60th day after sowing and the height increase was very meagre from 60th day to the harvest stage. There was more or less cessation of growth during this period. But in the case of ratoon crop, the increase was faster upto 30 days after ratooning and thereafter the increase in

Table 5. Influence of irrigation and nitrogen on Plant height (cm) 1978

Treatments	N_0	N_1	N_2	N_3	Mean
Main Crop					
I_0	103.4	121.9	127.9	123.0	119.0
I_1	120.2	127.7	134.6	135.7	129.5
I_2	117.7	129.5	127.1	131.1	126.3
Mean	113.8	126.4	129.9	129.9	

	S.E.	C.D.(P=0.05)
Irrigation	2.40	5.35
Nitrogen	1.29	2.52
Interaction - N levels at irrigation	1.57	4.36
Irrigation at N - levels	2.27	4.62

Treatments	N_0	N_1	N_2	N_3	Mean
Ratoon Crop					
I_0	79.8	77.7	70.7	72.6	75.0
I_1	92.3	92.1	94.6	86.9	91.5
I_2	95.9	98.6	92.5	94.4	95.4
Mean	89.3	89.5	87.9	84.6	

	S.E.	C.D. (P=0.05)
Irrigation	3.62	8.07
Nitrogen	1.54	3.02
Interaction - N levels at irrigation	N.S.	
Irrigation at N - levels		

Table 6. Influence of irrigation and nitrogen on Plant height (cm) 1979

Treatments	N_0	N_1	N_2	N_3	Mean
Main Crop					
I_0	111.4	121.1	131.7	126.1	122.6
I_1	127.3	132.1	135.4	139.1	133.5
I_2	124.6	129.9	133.2	135.9	130.9
Mean	121.1	127.7	133.4	133.7	

	S.E.	C.D.(P=0.05)
Irrigation	3.87	8.62
Nitrogen	1.38	2.70
Interaction - N levels at irrigation	N.S.	
Irrigation at N - levels		

Treatments	N_0	N_1	N_2	N_3	Mean
Ratoon Crop					
I_0	79.4	91.1	88.8	89.9	87.3
I_1	80.0	99.5	104.6	105.1	97.3
I_2	88.0	102.9	105.2	104.1	100.1
Mean	82.5	97.8	99.5	99.7	

	S.E.	C.D.(P=0.05)
Irrigation	4.01	8.94
Nitrogen	2.31	4.54
Interaction - N levels at irrigation	N.S.	
Irrigation at N - levels		

plant height was not significant. In both the main and ratoon crops of both the years, the plant height at the harvest stage revealed that there was significant increase in irrigation treatments I_1 and I_2 over rainfed treatment I_0. The height of plant at harvest stage under rainfed treatment I_0 was lesser (119 cm) in 1978 and 123 cm in 1979. In the treatment I_1 (50 per cent ASM), the plant height was 130 cm and 134 cm during 1978 and 1979 respectively. The difference in height of plants is mainly due to the irrigation effect. Raheja (1961) stated that sorghum showed increased plant height at higher moisture levels. Abraham Jacob (1963) found that irrigation at 14 days interval significantly influenced the height of sorghum plants. This was supported by Gopalakrishnan(1966) who observed that soil moisture regime at 60 per cent ASM significantly increased the plant height. The rainfed treatment (I_0) suffered in the early stages after sowing for want of rains. The crop was sown on 3.9.78 and only traces of rainfall were received till October first week. This may be one of the reasons for the reduction in plant height. This observation is in line with Robins and Domingo (1953) who reported that moisture stress in early stages might have reduced the plant height by shortening the internodes.

4.3.1.1.2. Influence of nitrogen

The height of plant was measured on 30th, 60th day after sowing and at harvest stage at different levels of nitrogen N_0, N_1, N_2 and N_3 (0, 40, 80 and 120 kg N/ha). The data revealed that there was significant difference in height due to the levels of nitrogen applied in both the main and ratoon crops in both the years. It was seen that 80 kg N/ha and 120 kg N/ha were on par in the main crop while the three levels namely 40 kg, 80 kg and 120 kg N/ha were on par during the ratoon crop.

4.3.1.1.3. Influence of irrigation and nitrogen

The interaction between irrigation and nitrogen levels was significant in the first year main crop only while it was not significant in the next year. The data of the first year main crop revealed that under rainfed treatment (I_0) the three nitrogen levels viz. 40, 80 and 120 kg N/ha were statistically on par but superior over no nitrogen thus indicating that the plant height was influenced by the applied N while the levels did not. Korikanthmath (1975) reported that the plant height was not much influenced by nitrogen levels. Ramachandra Reddi and Mustaffa Hussain (1968) reported similarly.

Under the irrigation treatment I_1 (50 per cent ASM) the nitrogen levels 80 kg and 120 kg N/ha were on par revealing the need for 80 kg N/ha for optimum plant height. Under the irrigation treatment I_2 (irrigation as per plant indicator) all the three levels viz. 40, 80 and 120 kg N/ha were on par indicating that 40 kg N/ha was able to influence the plant height.

4.3.1.2. Leaf area index (LAI)

4.3.1.2.1. Influence of irrigation

The leaf area indices for 1978 and 1979 for both main and ratoon crop are furnished in Table 7 & 8 and Fig. 3. They varied from 1.84 to 3.20 in the main crops and from 0.84 to 2.3 in ratoon crops. The leaf area index was calculated at 30th, 60th day after sowing and at harvest stage.

The leaf area indices increased upto 60th day after sowing while at harvest stage in decreased in both main and ratoon crops in both the years. The leaf area index increased with the time and beyond 60th day, the plant entered into active reproductive phase causing gradual senescence of leaves until harvest. Similar decreases in leaf area index at harvest were reported by Boovendran (1977) and Wahab (1978). The leaf area indices were greater in the main crop than the ratoon

Table 7. Influence of irrigation and nitrogen on Leaf area index 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	3.30	2.98	3.13	2.99	3.10
I_1	3.08	3.17	3.37	3.14	3.19
I_2	3.34	3.11	3.33	3.01	3.20
Mean	3.24	3.09	3.28	3.05	

	S.E.	C.D.(P=0.05)
Irrigation	0.489	N.S.
Nitrogen	0.189	-
Interaction - N levels at Irrigation	N.S.	-
Irrigation at N - levels		

Ratoon Crop

Treatments	N_0	N_1	N_2	N_3	Mean
I_0	0.92	0.69	0.90	0.83	0.84
I_1	0.93	1.25	1.16	1.18	1.13
I_2	1.19	1.32	1.24	1.16	1.23
Mean	1.01	1.09	1.07	1.06	

	S.E.	C.D.(P=0.05)
Irrigation	0.127	0.284
Nitrogen	0.080	N.S.
Interaction - N levels at Irrigation	N.S.	
Irrigation at N - levels		

Table 8. Influence of irrigation and nitrogen on Leaf area index 1979

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	2.03	1.84	2.47	1.93	2.07
I_1	1.98	1.94	2.00	1.70	1.90
I_2	1.70	1.79	1.96	1.92	1.84
Mean	1.90	1.86	2.14	1.85	

	S.E.	C.D.(P=0.05)
Irrigation	0.294	N.S.
Nitrogen	0.141	N.S.
Interaction -		
N levels at Irrigation	N.S.	
Irrigation at N - levels	N.S.	

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	1.5	2.5	1.9	1.5	1.8
I_1	1.8	2.7	2.5	2.3	2.3
I_2	1.7	2.5	2.3	2.0	2.1
Mean	1.7	2.6	2.2	1.9	

	S.E.	C.D.(P=0.05)
Irrigation	0.15	0.34
Nitrogen	0.07	0.13
Interaction -		
N levels at Irrigation	N.S.	-
Irrigation at N - levels	-	-

Fig.3. Influence of irrigation and nitrogen on LAI (Harvest stage)

I_0 Rainfed crop (No irrigation)

I_1 Irrigation at 50 per cent ASM

I_2 Irrigation as per plant indicator

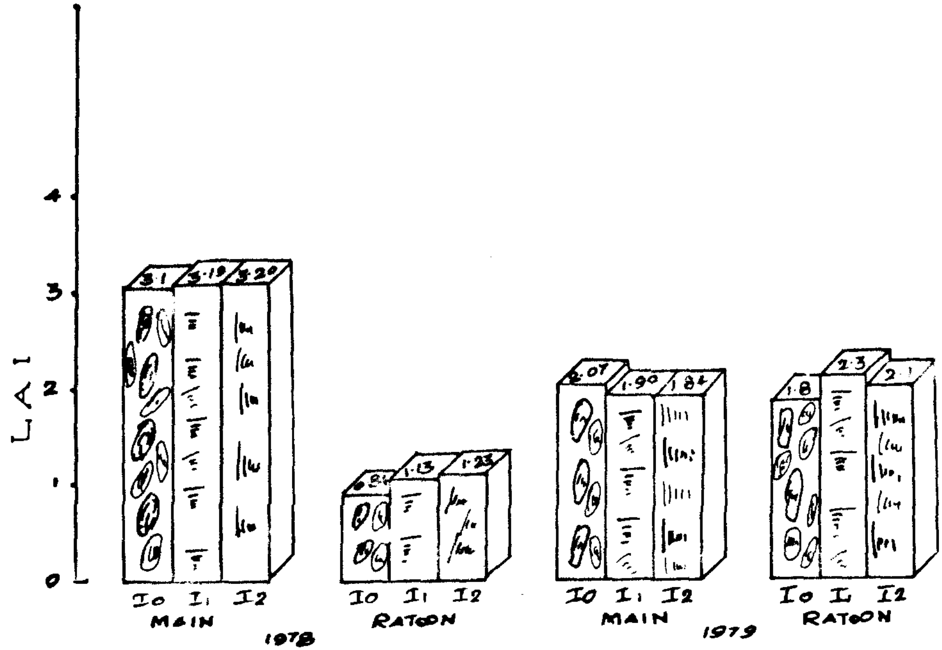


FIG. 3. INFLUENCE OF IRRIGATION AND NITROGEN ON LAI
(HARVEST STAGE)

crop in both the years. The increase in leaf area index in the main crop over the ratoon crop is due to the more number of functional leaves in main crop than in the ratoon crop.

Irrigation at 50 per cent ASM (I_1) and irrigation as per plant indicator (I_2) significantly produced more leaf area index than the rainfed treatment (I_0) in first year main crop. Oizumi et al. (1965) and Kramer (1969) who observed decrease in LAI with water stress plants to the decrease in cell size and intercellular volume. The lack of difference in the LAI during both the year ratoon crops is attributed to the adequate rainfall during the vegetative phases.

4.3.1.2.2. Influence of nitrogen

Leaf area index was calculated on 30th, 60th day after sowing and at harvest stage at different levels of, nitrogen viz. 0, 40, 80 and 120 kg N/ha. The data revealed that there was no difference in leaf area index between different levels of nitrogen at different stages of growth. Ramachandra Reddy and Mustafa Hussain (1968) and Panda (1972) reported that the leaf area index was not influenced by nitrogen levels.

4.3.1.2.3. Influence of irrigation and nitrogen

There was no significant interaction effect between irrigation and nitrogen on leaf area index.

4.3.1.3. Dry matter production (DMP)

4.3.1.3.1. Influence of irrigation

The dry matter production at 30th, 60th day after sowing and at harvest stage was recorded. The data on the effect of irrigation at different stages are presented in Table 9 & 10 and Fig.4 for both the main and ratoon crops in both the years. The dry matter production was more at harvest stage in the main crop than the ratoon crop in both the years. This could be attributed to the more vigorous growth of the crop as revealed through plant height and leaf area index.

The dry matter production increased with increase in moisture supply. Irrigation at 50 per cent ASM (I_1) and irrigation as per plant indicator (I_2) recorded significantly higher dry matter production than the rainfed treatment (I_0) in both main and ratoon crops in both the years. At 30th day after sowing, there was significant reduction in dry matter production due to water deficit in the main crop

Table 9. Influence of irrigation and nitrogen on dry matter production kg/ha 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	8895	8894	8740	8428	8739
I_1	9248	10844	10428	10210	10183
I_2	9812	10479	10364	9648	10076
Mean	9318	10072	9844	9429	

	S.E.	C.D.(P=0.05)
Irrigation	460.0	1024.9
Nitrogen	219.0	429.3
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N - levels	--	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	3501	3901	4168	3568	3785
I_1	5375	6136	6474	6138	6031
I_2	5501	6227	6235	5998	5990
Mean	4792	5421	5626	5235	

	S.E.	C.D.(P=0.05)
Irrigation	259.7	578.5
Nitrogen	126.1	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N - levels	N.S.	--

Table 10. Influence of irrigation and nitrogen on dry matter production kg/ha 1979

Treatments	N_0	N_1	N_2	N_3	Mean
			Main crop		
I_0	7430	7784	7751	7052	7429
I_1	7700	8300	8080	7940	8005
I_2	7609	8822	8017	7571	8054
Mean	7647	8302	7942	7521	
			S.E.	C.D.(P=0.05)	
Irrigation			280.9	625.9	
Nitrogen			112.2	219.9	
Interaction -					
N levels at Irrigation			137.4	380.9	
Irrigation at N - levels			219.2	453.8	
			Ratoon Crop		
I_0	7430	7175	7637	6395	7159
I_1	6388	8308	9523	8958	8294
I_2	7341	9262	9963	8548	8778
Mean	7053	8248	9041	7967	
			S.E.	C.D.(P=0.05)	
Irrigation			554.1	1234.4	
Nitrogen			474.5	930.0	
Interaction -					
N levels at Irrigation			N.S.	--	
Irrigation at N - levels			--	--	

Fig. 4. Influence of irrigation and nitrogen on the dry matter production (Harvest stage)

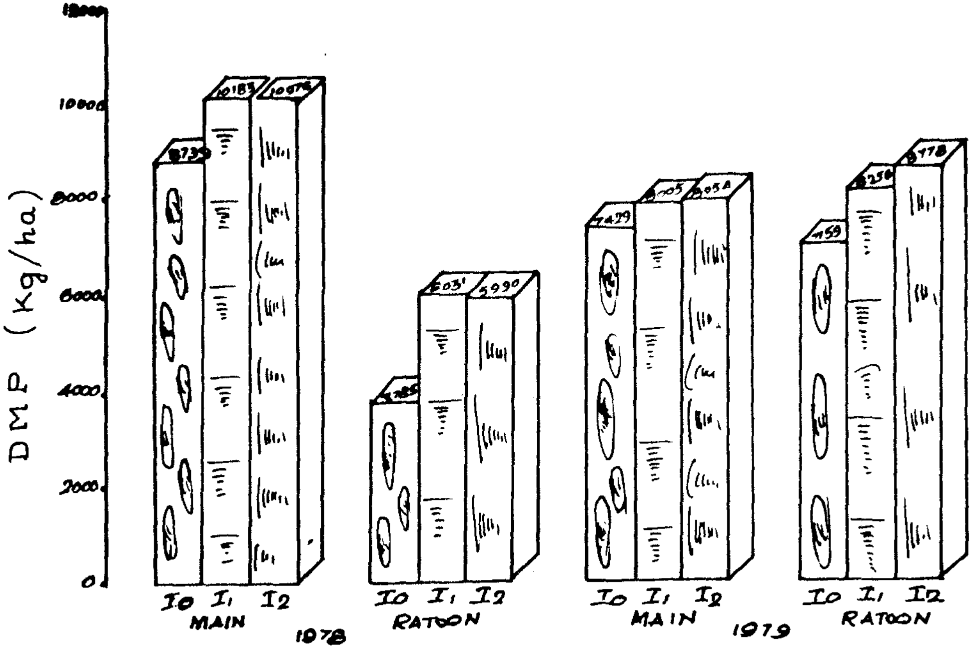


FIG. 4. INFLUENCE OF IRRIGATION AND NITROGEN ON DRY MATER PRODUCTION AT HARVEST STAGE Kg/ha.

than the ratoon crop. The same trend was noticed during the 60th day after sowing and at harvest stage in both main and ratoon crops in both the years. Boovendran (1977) observed a reduction in dry matter production of sorghum due to water deficit. Colman and Lazenby (1975) stated that under severe moisture stress conditions, there was limited leaf growth and much of the moisture use immediately after watering was probably lost by evaporation from the soil and many metabolic functions were affected by moderate moisture stress and it took sometimes to return to normal. Hence the total growth between successive waterings, under low moisture levels was very limited.

There was not any difference in dry matter production between the irrigation treatment I_1 (50 per cent ASM) and I_2 (Plant indicator) in all the three stages of growth viz. 30th, 60th day after sowing and at harvest in both main and ratoon crops in both the years.

4.3.1.3.2. Influence of nitrogen

Dry matter production was worked out on 30th, 60th day after sowing and at harvest stage at four different levels of nitrogen, viz. 0, 40, 80 and 120 kg/ha.

The data revealed that there was a linear response to nitrogen application upto 40 kg N/ha and beyond that, a quadratic response was noted at all the three stages in the main crop, while in ratoon crop, the quadratic response was seen beyond 80 kg N/ha level at 30th day after sowing and at harvest stage. Anand Rao and Reddi (1972) observed that increasing the levels of nitrogen from 0 to 150 kg N/ha increased the dry matter production at all stages of plant growth. Ramalingam (1975) stated that higher levels of nitrogen increased the dry matter production significantly.

4.3.1.3.3. Influence of irrigation and nitrogen

The interaction effect between irrigation and nitrogen levels was not consistant in both main and ratoon crops in both the years. The results were significant during the second year main crop which indicated that under rainfed treatment (I_0), all the four treatments viz. 0, 40, 80 and 120 kg N/ha were on par. It was also seen that the decrease in dry matter production was significant when the nitrogen level was increased from 80 kg/ha to 120 kg N/ha.

Under irrigation treatment I_1 (50 per cent ASM), the three nitrogen levels viz. 40, 80 and 120 kg N/ha were statistically on par revealing that 40 kg N/ha level is optimum. Similar trend was noticed in irrigation treatment I_2.

The above study on growth components of sorghum revealed that the height of the plant was consistantly more at all stages of growth when the available soil moisture increased. In the case of ratoon crop, the difference in height was not significant between different irrigation treatments and stages.

Leaf area index was more under both the irrigation treatments I_1 and I_2 than under rainfed crop upto 60th day after sowing.

Dry matter production increased in all the stages with increase in available soil moisture.

4.3.2. Irrigation and yield components

4.3.2.1. Earhead length

4.3.2.1.1. Influence of irrigation

The influence of irrigation on the length of earhead are furnished in Table 11 and 12 for the main and ratoon crops for both the years. The treatmental differences under irrigation affected the length of earheads. However there was no difference in earhead length between main crop and ratoon crops of both the

Table 11. Influence of irrigation and nitrogen on
Earhead length (cm) 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	20.6	22.4	21.5	21.3	21.4
I_1	23.7	26.2	26.8	25.1	25.4
I_2	22.8	24.5	23.7	23.3	23.6
Mean	22.4	24.4	24.0	23.2	

	S.E.	C.D.(P=0.05)
Irrigation	1.14	2.55
Nitrogen	0.39	0.77
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	--	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	19.0	18.8	20.7	20.5	19.8
I_1	20.2	23.5	22.6	25.8	23.1
I_2	22.5	22.3	22.7	21.5	22.3
Mean	20.6	21.5	22.0	22.6	

	S.E.	C.D.(P=0.05)
Irrigation	1.36	3.03
Nitrogen	0.95	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	--	--

Table 12. Influence of irrigation and nitrogen on Earhead length (cm) 1979

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	18.3	19.9	19.3	18.7	19.0
I_1	20.4	22.0	22.9	21.1	21.6
I_2	20.5	21.5	21.7	21.2	21.2
Mean	19.7	21.1	21.3	20.3	

	S.E.	C.D.(P=0.05)
Irrigation	0.63	1.41
Nitrogen	1.04	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	--	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	18.0	20.5	22.8	24.3	21.4
I_1	20.6	25.4	26.9	26.6	24.9
I_2	20.2	25.4	26.3	25.8	24.4
Mean	19.6	23.8	25.3	25.6	

	S.E.	C.D.(P=0.05)
Irrigation	0.82	1.82
Nitrogen	0.35	0.69
Interaction -		
N levels at Irrigation	0.43	1.19
Irrigation at N levels	0.67	1.38

years. The influence of irrigation on earhead length could be clearly seen by the reduction of the length of earhead in the rainfed treatment I_0 as compared to the irrigation treatments I_1 and I_2. Similar increase in earhead length was observed by Abraham Jacob (1963) and Boovendran (1977). However, no difference in length of earheads was observed between the two irrigation treatments I_1 and I_2.

4.3.2.1.2. Influence of nitrogen

The length of earhead recorded at harvest under different levels of nitrogen is furnished in Table 11 & 12. Significant difference in the length of earhead at different levels of nitrogen in the first year main crop as well as second year ratoon crop was recorded. The earhead was longer with nitrogen applied ~~plots.~~ However the difference in length of earheads between the three different levels of nitrogen viz. 40, 80 and 120 kg N/ha was nonsignificant in 1979 main crop and 1978 ratoon crop. Raheja and Krantz (1958) observed a positive influence of nitrogen on the length of earhead. Krishnamoorthy (1962) reported significant difference in the length of earhead between nitrogen applied plots and no nitrogen plots. Ramachandra Reddy and Mustafa Hussain (1968) observed as increase in the length of earhead with enhancement in nitrogen levels.

4.3.2.1.3. Influence of irrigation and nitrogen

The interaction effect between irrigation and nitrogen levels was nonsignificant in the main crops of both the years as well as the first year ratoon crop. However, during the second year ratoon crop 80 kg N/ha had lengthy ears under the rainfed treatment while the same response was observed with 40 kg N/ha level itself under irrigated treatments (I_1 & I_2).

4.3.2.2. Earhead weight

4.3.2.2.1. Influence of irrigation

The influence of irrigation on the weight of earhead for both the main and ratoon crops for both the years are furnished in Table 13 & 14. Significant effect on the weight of earheads was observed during the second year main and ratoon crops of both the years. Difference in earhead weight between the irrigation treatments I_1 and I_2 was meagre with the main and ratoon crops.

4.3.2.2.2. Influence of nitrogen

The weight of earhead was recorded at the time of harvest at different levels of nitrogen.

Significant difference in earhead weight at different levels of nitrogen in the main and ratoon

Table 13. Influence of irrigation and nitrogen on Earhead weight (g) 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	118.2	123.3	125.3	117.3	121.0
I_1	119.7	125.8	132.0	123.8	125.3
I_2	121.7	127.5	126.8	123.8	124.9
Mean	119.9	125.5	128.0	121.6	
			S.E.	C.D.(P=0.05)	
Irrigation			3.50	N.S.	
Nitrogen			1.64	3.21	
Interaction -					
N levels at Irrigation			N.S.	--	
Irrigation at N levels			--	--	
			Ratoon Crop		
I_0	24.1	32.6	31.6	30.6	29.7
I_1	28.8	38.7	35.7	35.8	34.8
I_2	30.3	35.6	36.7	37.3	34.9
Mean	27.7	35.6	34.7 /	34.6	
			S.E.	C.D.(P=0.05)	
Irrigation			2.84	6.33	
Nitrogen			1.92	3.76	
Interaction -					
N levels at Irrigation			N.S.	--	
Irrigation at N levels			--	--	

Table 14. Influence of irrigation and nitrogen on Earhead weight (g) 1979

Treatments	N_0	N_1	N_2	N_3	Mean
		Main Crop			
I_0	100.5	114.0	113.8	114.2	110.6
I_1	119.7	123.3	125.8	119.2	122.0
I_2	118.0	124.2	120.8	118.3	120.3
Mean	112.7	120.5	120.1	117.2	

	S.E.	C.D.(P=0.05)
Irrigation	3.07	6.84
Nitrogen	1.72	3.37
Interaction -		
N levels at Irrigation	2.10	5.83
Irrigation at N levels	3.00	6.09

Treatments	N_0	N_1	N_2	N_3	Mean
		Ratoon Crop			
I_0	52.5	69.7	73.0	60.8	64.0
I_1	61.3	75.5	76.7	70.0	70.9
I_2	65.8	76.3	75.5	71.7	72.3
Mean	59.9	73.8	75.1	67.5	

	S.E.	C.D.(P=0.05)
Irrigation	4.20	10.07
Nitrogen	2.13	4.17
Interaction -		
N levels at Irrigation	N.S.	—
Irrigation at N levels	N.S.	--

crops of both the years was observed. The weight of earhead was greater in nitrogen applied plots than the no nitrogen plots.

4.3.2.2.3. Influence of irrigation and nitrogen

Significant interaction effect was observed only with the main crop of 1979.

4.3.2.3. Grain weight per ear

4.3.2.3.1. Influence of irrigation

The influence of irrigation on the grain weight per earhead is presented in Table 15 & 16 for the main and ratoon crops of both the years.

Heavier grain weight per earhead was observed with supplemental irrigations (I_1 and I_2) as compared to the rainfed crop. Earheads of the ratoon crop were lighter than that of the main crop.

4.3.2.3.2. Influence of nitrogen

Steady increase in the grain weight per ear was recorded with increase in the level of N upto 80 kg N/ha and whereupon it declined. The decrease in grain weight at 120 kg N/ha may be attributed to the rate of movement and extent of uptake of nutrients.

Table 15. Influence of irrigation and nitrogen on grain weight per earhead (g) 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	52.5	69.7	73.0	60.8	64.0
I_1	61.3	75.5	76.7	70.0	70.9
I_2	65.8	76.3	75.5	71.7	72.3
Mean	59.9	73.8	75.1	67.5	

	S.E.	C.D.(P=0.05)
Irrigation	4.20	10.07
Nitrogen	2.13	4.17
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	18.3	21.6	21.3	20.7	20.5
I_1	21.6	25.6	25.4	26.0	24.6
I_2	21.1	24.0	24.3	24.0	23.3
Mean	20.3	23.7	23.8	23.9	

	S.E.	C.D.(P=0.05)
Irrigation	1.67	3.72
Nitrogen	0.72	1.40
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Table 16. Influence of irrigation and nitrogen on grain weight per earhead 1979

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	45.8	60.5	68.3	62.5	59.3
I_1	61.8	70.5	76.7	64.7	68.4
I_2	62.5	73.5	61.5	60.2	64.4
Mean	56.7	68.2	68.8	62.5	

	S.E.	C.D.(P=0.05)
Irrigation	4.15	9.24
Nitrogen	2.69	5.27
Interaction -		
N levels at Irrigation	5.29	9.13
Irrigation at N levels	4.54	9.16

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	19.8	27.0	28.5	26.0	25.3
I_1	25.2	30.8	29.2	28.0	28.3
I_2	25.5	29.5	29.2	29.2	28.3
Mean	23.5	29.1	28.9	27.7	

	S.E.	C.D.(P=0.05)
Irrigation	0.82	1.82
Nitrogen	0.49	0.97
Interaction -		
N levels at Irrigation	0.61	1.68
Irrigation at N levels	0.85	1.72

Singh (1972) reported that the transport of mineral nutrients in the soil, absorption by roots, translocation within the plant and their mechanism were all affected by soil and water availability.

4.3.2.3.3. Influence of irrigation and nitrogen

The interaction effect was significant in the main and ratoon crops of the second year of experimentation (1979) while it was nonsignificant during the main and ratoon crop of first year. The results revealed that for the main crop, under rainfed and irrigated conditions, 40 kg N/ha itself was found adequate to influence the grain weight per earhead.

4.3.2.4. Thousand grain weight

4.3.2.4.1. Influence of irrigation

The influence of irrigation on 1000-grain weight recorded in the main and ratoon crops in both the years are presented in Table 17 & 18.

There was no variation in thousand grain weight in the main crop of both the years and in the first year ratoon crop due to the effect of irrigation. However there was significant difference between the irrigation treatments in second year ratoon crop.

Table 17. Influence of irrigation and nitrogen on 1000 grain weight (g) 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	30.1	28.4	29.3	29.5	29.3
I_1	31.3	31.9	30.8	31.1	31.2
I_2	30.2	30.2	29.3	30.6	30.1
Mean	30.5	30.2	29.8	30.4	

	S.E.	C.D.(P=0.05)
Irrigation	2.03	N.S.
Nitrogen	0.69	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	--	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	28.7	27.9	28.3	28.0	28.2
I_1	27.5	27.3	28.3	28.1	27.8
I_2	27.4	27.0	28.3	27.5	27.6
Mean	27.9	27.4	28.3	27.9	

	S.E.	C.D.(P=0.05)
Irrigation	1.09	N.S.
Nitrogen	0.64	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	--	--

Table 18. Influence of irrigation and nitrogen on 1000 grain weight (g) 1979

Treatments	N_0	N_1	N_2	N_3	Mean
		Main Crop			
I_0	19.6	21.3	22.3	22.3	21.6
I_1	22.9	24.0	22.3	22.3	22.9
I_2	21.0	21.6	20.3	21.2	21.9
Mean	21.8	22.3	21.6	21.9	

	S.E.	C.D.(P=0.05)
Irrigation	1.93	N.S.
Nitrogen	0.63	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Treatments	N_0	N_1	N_2	N_3	Mean
		Ratoon Crop			
I_0	14.5	17.4	15.8	14.7	15.6
I_1	14.5	17.2	15.4	15.6	15.7
I_2	14.8	14.1	13.8	15.6	14.6
Mean	14.6	16.2	15.0	15.3	

	S.E.	C.D.(P=0.05)
Irrigation	0.87	1.93
Nitrogen	0.59	1.15
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	--	--

Boovendran (1977) observed no difference in thousand grain weight of sorghum under different irrigation treatments.

4.3.2.4.2. Influence of nitrogen

There was no difference in thousand grain weight due to different levels of nitrogen in the main crops of both the years and in first year ratoon crop. However, the difference in thousand grain weight between the nitrogen levels was noticed in the second year ratoon crop. Korikanthimath (1975) observed increase in thousand grain weight of the main crop greater at the corresponding levels of nitrogen than that of the ratoon crop in both the years.

4.3.2.4.3. Influence of irrigation and nitrogen

The interaction effect between irrigation and nitrogen levels was not significant in the main and ratoon crops in both the years.

4.3.3. Uptake of nutrients

4.3.3.1. Nitrogen uptake

4.3.3.1.1. Influence of irrigation

The influence of irrigation on nitrogen uptake is presented in Table 19 & 20 and Fig. 5 for the main

Table 19. Influence of irrigation and nitrogen on Nitrogen uptake (kg/ha) 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	183.6	170.0	179.8	159.1	173.1
I_1	161.8	176.6	188.7	187.9	178.8
I_2	155.8	168.8	188.3	160.9	167.2
Mean	167.1	171.8	185.6	169.3	

	S.E.	C.D.(P=0.05)
Irrigation	N.S.	--
Nitrogen	N.S.	--
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	--	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	64.4	73.7	82.8	66.1	75.9
I_1	65.8	89.3	90.5	102.2	86.9
I_2	72.6	107.9	112.5	96.4	97.3
Mean	67.6	90.3	95.3	88.2	

	S.E.	C.D.(P=0.05)
Irrigation	10.11	22.52
Nitrogen	5.64	11.06
Interaction -		
N levels at Irrigation	6.91	19.16
Irrigation at N levels	9.86	20.02

Table 20. Influence of irrigation and nitrogen on Nitrogen uptake (kg/ha) 1979

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	83.2	103.9	104.7	91.6	95.8
I_1	89.6	112.2	123.0	128.2	113.3
I_2	94.1	107.7	117.3	115.2	108.6
Mean	88.9	107.9	115.0	111.7	

	S.E.	C.D.(P=0.05)
Irrigation	5.17	11.52
Nitrogen	1.58	3.11
Interaction -		
N levels at Irrigation	1.94	5.38
Irrigation at N levels	3.51	7.41

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	78.5	84.1	88.7	76.8	82.0
I_1	112.7	132.9	134.3	131.3	128.0
I_2	118.6	130.4	139.0	124.1	126.3
Mean	103.3	115.8	120.7	110.9	

	S.E.	C.D.(P=0.05)
Irrigation	3.39	7.55
Nitrogen	15.67	--
Interaction -		
N levels at irrigation	N.S.	--
Irrigation at N levels	N.S.	--

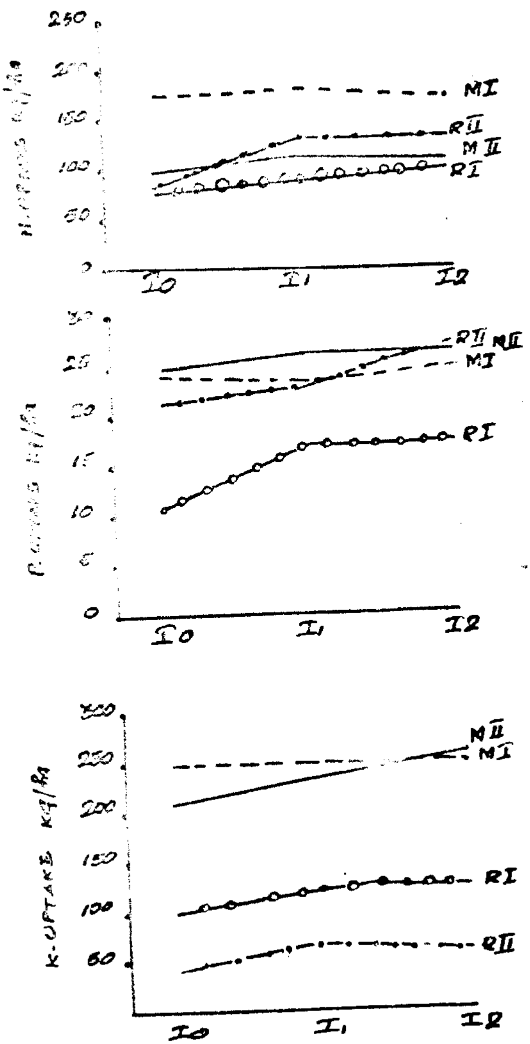
Fig.5. Influence of irrigation on N, P, K uptake (Harvest stage)

I_0 Rainfed crop (No irrigation)

I_1 Irrigation at 50 per cent ASM

I_2 Irrigation as per plant indicator

FIG. 5. INFLUENCE OF IRRIGATION ON N.P.K. UPTAKE (HARVEST STAGE)



1978 MAIN CROP(MI)

and ratoon crops of both the years. The results were significant during the second year main crop and ratoon crops of both the years while there was no difference during the first year main crop. The results during the main crop showed that the nitrogen uptake in the irrigation treatments I_1 (50 per cent ASM) and I_2 (Plant indicator) were on par and the N uptake under the rainfed treatment I_0 was the least. ~~During~~ the ratoon crop, the uptake in all the treatments I_0 (rainfed), I_1 (50 per cent ASM) and I_2 (plant indicator) were similar. Bennet *et al.*, (1964) found that the total uptake of N and K in sorghum was usually higher with irrigation. But Arjan Singh *et al.* (1973) reported that N-uptake per unit weight of dry matter production decreased under wet regimes.

4.3.3.1.2. Influence of nitrogen

The effect of applied nitrogen on nitrogen uptake by sorghum was significant during the second year main crop and first ratoon crop. The results revealed that during the second year main crop, ~~the~~ application of 80 kg N/ha influenced the uptake of nitrogen as seen from the least uptake in no nitrogen plot. During the first year ratoon crop, it was seen that the application of nitrogen increased the uptake of nitrogen but the nitrogen levels 40, 80 and 120 kg N/ha were on par.

The uptake of nitrogen was quadratic in the main and ratoon crop in both the years, at all the stages of crop growth. But at each level of nitrogen there was linear uptake from 30th day after sowing to harvest stage. Burleson *et al.* (1956) Raheja and Krantz (1958), Krishnamoorthy (1962) and Anand Rao and Reddi (1972) reported that nitrogen content and uptake increased at increased levels of nitrogen application.

Uptake of 169 kg of nitrogen per hectare was recorded at harvest stage with the application of 120 kg N/ha. Roy and Wright (1974) reported that the nutrient uptake pattern influenced by N and P levels and concluded that the highest uptake of 148.7 kg N/ha was recorded with the application of 120 kg N/ha.

There was a rapid increase in the uptake of nitrogen from 60th day after sowing to harvest in the main and ratoon crops of both the years. Atarsingh and Bains (1972) also found a rapid increase in the uptake of nitrogen from the boot stage to 75 days after sowing in CSH.1 and Swarna. The total uptake of nitrogen in the experiment in both the years ranged from 89 to 183 kg N/ha in the ratoon crop. Rao and House (1972) concluded that the total uptake of nitrogen in main crop ranged from 130 to 180 kg N/ha in a grain sorghum variety yielding 50 to 60 Q/ha.

4.3.3.1.3. Influence of irrigation and nitrogen

The interaction between irrigation and nitrogen on nitrogen uptake was significant during second year main crop and first year ratoon crop. During the main crop season, the nitrogen levels N_1 and N_2 (40 kg and 80 kg N/ha) were on par but superior to N_0 and N_3 (120 kg/ha) under rainfed treatment I_0 while the levels N_2 and N_3 (80 kg and 120 kg/ha) were on par and superior over N_0 and N_1 under irrigation treatments I_1 and I_2. In the ratoon crop, the nitrogen levels N_1, N_2 and N_3 (40, 80 and 120 kg N/ha) were on par and superior to N_0 under all the three irrigation treatments I_0, I_1 and I_2.

4.3.3.2. Phosphorus uptake

4.3.3.2.1. Influence of irrigation

The influence of irrigation on P uptake for the main and ratoon crops during both the years is presented in Table 21 & 22 and Fig. 5. The results

Table 21. Influence of irrigation and nitrogen on P - uptake kg/ha 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	28.9	23.3	24.2	20.5	24.2
I_1	22.0	25.0	24.3	23.2	23.7
I_2	24.2	28.4	24.8	22.0	24.9
Mean	25.0	25.6	24.4	21.9	

	S.E.	C.D.(P=0.05)
Irrigation	1.94	N.S.
Nitrogen	1.46	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	10.5	11.0	11.6	10.3	10.8
I_1	16.5	17.1	18.1	17.7	17.3
I_2	16.2	18.9	17.8	17.7	17.7
Mean	14.4	15.7	15.8	15.2	

	S.E.	C.D.(P=0.05)
Irrigation	1.21	2.70
Nitrogen	0.84	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Table 22. Influence of irrigation and nitrogen on P - uptake kg/ha 1979

Treatments	N_0	N_1	N_2	N_3	Mean
Main Crop					
I_0	27.2	26.5	20.9	24.1	24.7
I_1	25.3	28.6	23.5	27.9	26.3
I_2	26.6	28.6	27.6	24.3	26.7
Mean	26.4	27.9	24.0	25.4	

	S.E.	C.D.(P=0.05)
Irrigation	2.41	5.36
Nitrogen	1.23	2.41
Interaction -		
N levels at irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Treatments	N_0	N_1	N_2	N_3	Mean
Ratoon Crop					
I_0	23.6	20.3	22.6	19.7	21.6
I_1	19.4	22.1	26.7	24.4	23.2
I_2	23.1	29.6	29.4	26.9	27.2
Mean	22.0	24.0	26.2	23.7	

	S.E.	C.D.(P=0.05)
Irrigation	3.02	6.72
Nitrogen	N.S.	--
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

were significant in the second year main crop and ratoon crops of both the years.

The results showed that the P-uptake under all the three irrigation treatments I_0, I_1 I_2 was statistically on par indicating that the irrigation had no significant influence on P-uptake. However, during the first year ratoon crop, the P-uptake in the irrigation treatments I_1 (50 per cent ASM) and I_2 (plant indicator) was significantly higher than I_0 (Rainfed). Vyas (1964), Greenway et al. (1968) and Boovendran (1977) observed a lower uptake under drier moisture regimes and increased P-uptake at higher soil moisture levels.

4.3.3.2.2. Influence of nitrogen

The P-uptake was very low in the earlier stages of crop growth at all levels of nitrogen. There was no significant difference in P-uptake at all stages at different levels of nitrogen in the main and ratoon crops. However, during the first year ratoon crop, the P-uptake was lower at harvest stage. The total P-uptake in the experiments conducted in both the years under different levels of nitrogen ranged from 22 to 28 kg/ha in the main crop and 14 to 26 kg/ha in the ratoon crop. Rao and House (1972) reviewed the result of a large number of experiments and concluded that the total uptake of P_2O_5 ranged from 50-65 kg/ha in a grain sorghum variety. The results which were significant during the second year main crop showed that the treatments N_0 and N_1 (40 kg/ha) were statistically on par indicating that the nitrogen application had no influence on the P-uptake.

4.5.3.2.3. Influence of irrigation and nitrogen

The interaction between irrigation and nitrogen uptake was not significant in the main and ratoon crops during both the years.

4.3.5.3. Potassium-uptake

4.5.3.3.1. Influence of irrigation

The influence of irrigation on K-uptake is presented in Tables 23 & 24 and Fig.5 for the main and ratoon crops during both the years.

The K-uptake was greater in the irrigation treatments I_1 (50 per cent ASM) and I_2 (plant indicator) compared to that of rainfed treatment (I_0). Wadleigh and Richards (1951) explained the causes of poor uptake by plants. The poor K-uptake was due to moisture stress because of the fact that the rate of

Table 23. Influence of irrigation and nitrogen on K - uptake kg/ha 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	287.8	243.7	239.1	217.4	247.0
I_1	240.2	253.7	243.2	255.0	248.1
I_2	238.6	268.9	248.5	228.2	246.0
Mean	255.5	255.4	243.6	233.5	

	S.E.	C.D.(P=0.05)
Irrigation	26.4	N.S.
Nitrogen	76.7	N.S.
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	122.1	96.7	102.0	85.9	101.7
I_1	117.2	122.8	125.5	122.8	122.1
I_2	121.0	119.8	129.9	125.1	123.9
Mean	120.1	113.1	119.1	111.3	

	S.E.	C.D.(P=0.05)
Irrigation	12.01	26.76
Nitrogen	5.04	N.S.
Interaction -		
N levels at Irrigation	6.17	17.1
Irrigation at N levels	9.65	19.9

Table 24. Influence of irrigation and nitrogen on K - uptake kg/ha 1979

Treatments	N_0	N_1	N_2	N_3	Mean
		Main Crop			
I_0	214.9	198.4	220.9	210.4	211.2
I_1	163.9	220.7	296.5	255.8	234.2
I_2	208.5	265.2	308.6	244.2	256.6
Mean	195.8	288.1	275.3	236.8	
				S.E.	C.D.(P=0.05)
Irrigation				24.67	54.97
Nitrogen				13.80	27.06
Interaction -					
N levels at irrigation				16.91	46.86
Irrigation at N levels				24.10	48.93
		Ratoon Crop			
I_0	34.2	39.6	46.3	42.0	40.5
I_1	60.6	60.9	78.2	72.1	68.0
I_2	50.6	64.7	59.4	62.9	59.4
Mean	48.5	55.1	61.3	59.0	
				S.E.	C.D.(P=0.05)
Irrigation				8.5	19.39
Nitrogen				5.61	N.S.
Interaction -					
N level at Irrigation				N.S.	-
Irrigation at N levels				N.S.	-

entry of K into plant decreased to a greater degree than the rate of dry matter production and utilization of K in the plants. Ahmed and Durairaj (1963) Menzel et al. (1972) and Friboug et al. (1976) reported that the uptake of N, P, K was more under irrigated condition than under dry condition. The quantity of water in the soil affects not only the amounts of nutrients in soil solution but also the rate of movement to the root by diffusion and mass flow as the water is absorbed by the roots, (Viets 1972). The uptake of K at the 60th day after sowing was greater in the first year (1978) while at harvest stage the K-uptake was greater in the main crop of both the years as compared to ratoon crop. The K-uptake in ratoon crop was greater during the first year than in the second year ratoon crop. Baseler et al. (1961) reported a gradual decrease in translocation with a decrease in soil moisture level. Vaadia et al. (1961) and ECK and Musick (1977) observed that the plants growing under moisture stress have relatively lesser amount of P and K. Bielorai et al. (1964), Doss et al. (1964) and Fedak and Mack (1977) reported that an increase by 30-55 per cent and 15 to 35 per cent were noticed for P and K respectively with irrigation.

4.3.3.3.2. Influence of nitrogen

The K-uptake was greater in the main crop than the ratoon crop in both the years. There was variation in the K-uptake in the two earlier stages viz. 30th and 60th day after sowing among the main and ratoon crops in both the years. There was quadratic response of K-uptake in all the stages as the levels of nitrogen increased beyond 40 kg N/ha both in the main and ratoon crops. The total K-uptake in the experiment for different levels of nitrogen in both the years ranged from 196 to 275 kg/ha. in main crop and 48 to 120 kg in ratoon crop. Rao and House (1972) concluded that the total uptake of K_2O ranged from 100 to 130 kg/ha in sorghum.

4.3.3.3.3. Influence of irrigation and nitrogen

The interaction between irrigation and nitrogen on K-uptake was significant in the second year main crop and first year ratoon crop. Under the rainfed treatment I_0, all the nitrogen levels were on par indicating that under rainfed condition, nitrogen has no influence on K-uptake. Under treatment I_1 (50 per cent ASM), 80 kg N/ha had greater influence on the uptake of K over other levels of nitrogen. Under treatment I_2 (plant indicator) both 40 kg and 80 kg N/ha were on par.

In the first year ratoon crop, under all the three irrigation treatments I_0, I_1 and I_2 nitrogen application had no influence on the K-uptake.

4.3.4. Grain yield

4.3.4.1. Stabilisation of yield under rainfed condition equivalent to that of irrigated crop

The crop under rainfed treatment (I_0) and under 50 per cent ASM irrigated treatment (I_1) and irrigated as per plant indicator (I_2) were compared to study the factors or constraints responsible for the lower yield obtained under rainfed treatment (I_0). The results are presented in Table 25 & 26 and Fig. 6 & 7.

The rainfed crop raised under treatment I_0 recorded the least grain yield as compared to the other treatments I_1 and I_2 in the main and ratoon crops in both the years. Crop growth is sensitive to moisture stress particularly because of the physiological effects of stress on production and maintenance of photosynthetic tissue (Fischer and Hagan, 1965) and Campbell et al. 1969).

4.3.4.2. Influence of irrigation

The influence of irrigation on grain yield recorded in the main and ratoon crops in both the years

Table 25. Influence of irrigation and nitrogen on Grain yield kg/ha 1978

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	2995	3340	3305	3175	3204
I_1	3668	4085	4145	4173	4018
I_2	3640	3968	4099	3813	3880
Mean	3434	3798	3850	3720	

	S.E.	C.D.(P=0.05)
Irrigation	169.3	374.6
Nitrogen	67.7	131.2
Interaction -		
N levels at Irrigation	N.S.	--
Irrigation at N levels	N.S.	--

Treatments	N_0	N_1	N_2	N_3	Mean
			Ratoon Crop		
I_0	1525	1455	1402	1336	1429
I_1	2188	2477	2325	2279	2317
I_2	2269	2472	2312	2243	2324
Mean	1994	2128	2013	1952	

	S.E.	C.D.(P=0.05)
Irrigation	112.7	251.5
Nitrogen	32.4	63.3
Interaction -		
N levels at Irrigation	40.1	111.1
Irrigation at N levels	74.1	155.9

Table 26. Influence of irrigation and nitrogen on Grain yield kg/ha 1979

Treatments	N_0	N_1	N_2	N_3	Mean
			Main Crop		
I_0	2438	2600	2459	2258	2439
I_1	3603	4154	4406	4110	4068
I_2	3030	3557	3879	3236	3426
Mean	3024	3437	3581	3201	3311
			S.E.	C.D.(P=0.05)	
Irrigation			254.6	567.9	
Nitrogen			58.6	114.2	
Interaction -					
N levels at Irrigation			72.5	199.1	
Irrigation at N levels			154.3	330.2	
			Ratoon Crop		
I_0	1485	1480	1369	1340	1419
I_1	2504	3510	3432	3309	3189
I_2	2335	3386	2928	2755	2851
Mean	2108	2792	2576	2468	
			S.E.	C.D.(P=0.05)	
Irrigation			139.65	311.0	
Nitrogen			69.82	137.5	
Interaction -					
N levels at Irrigation			86.76	239.0	
Irrigation at N levels			126.96	258.0	

Fig.6. Influence of irrigation and nitrogen on grain yield (1978 and 1979 main crop)

I_0 Rainfed crop (No irrigation)

I_1 Irrigation at 50 per cent ASM

I_2 Irrigation as per plant indicator

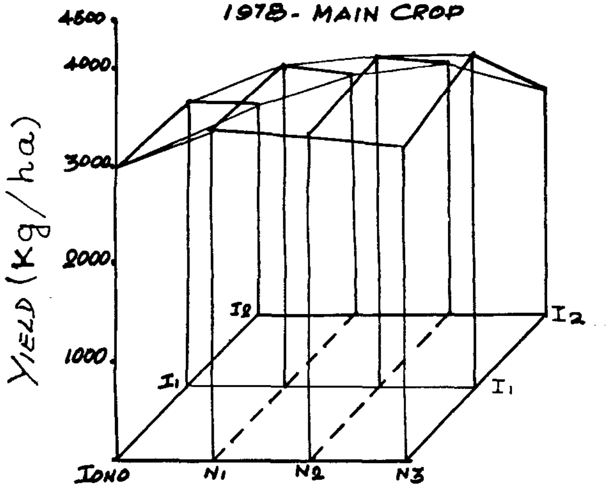
N_0 No nitrogen

N_1 40 kg N/ha

N_2 80 kg N/ha

N_3 120 kg N/ha

FIG. 6. INFLUENCE OF IRRIGATION AND NITROGEN ON GRAIN YIELD



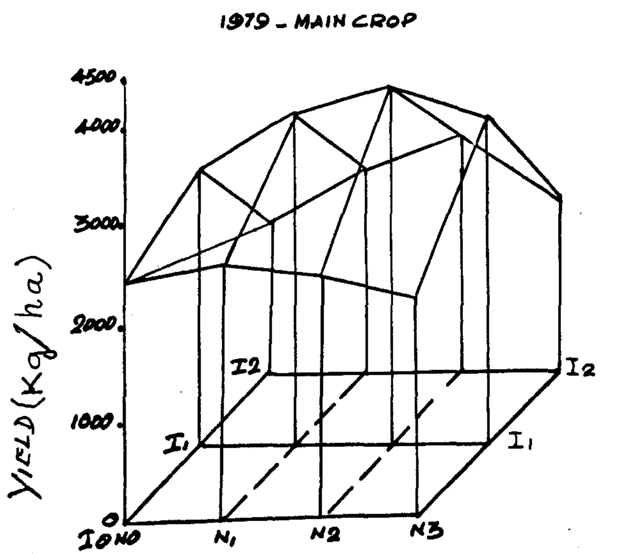
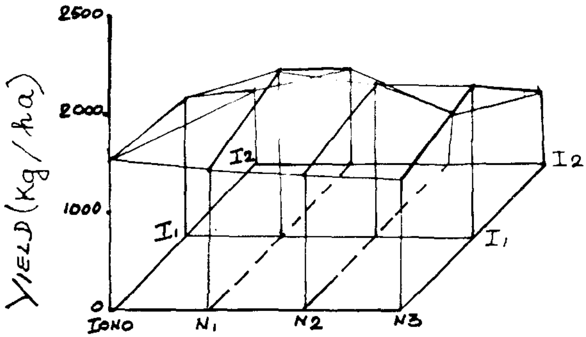


Fig. 7. Influence of irrigation and nitrogen on grain yield (1978 and 1979 ratoon crop)

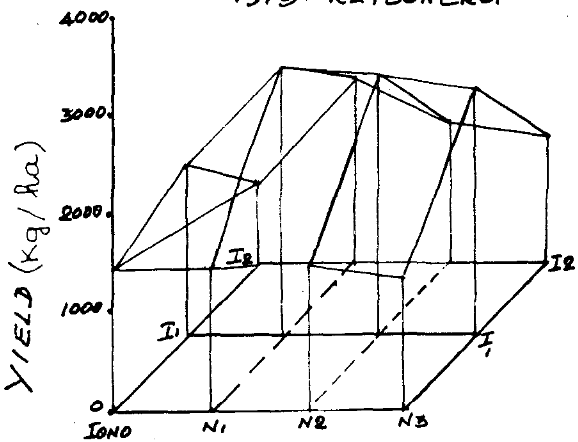
I_0	Rainfed crop (No irrigation)
I_1	Irrigation at 50 per cent ASM
I_2	Irrigation as per plant indicator
N_0	No nitrogen
N_1	40 kg N/ha
N_2	80 kg N/ha
N_3	120 kg N/ha

Fig. 7. INFLUENCE OF IRRIGATION AND NITROGEN ON GRAIN YIELD

1978 - RATOON CROP



1979 - RATOON CROP



1978 and 1979 are presented in Table 25 and 26 and Fig. 6 & 7. The results were significant in both the main and ratoon crops in both the years. Considering the main crop, it was found that during first year (1978), the yields from I_1 and I_2 were on par (4018 and 3880 kg/ha respectively) but significantly superior to I_0 (3204 kg/ha) while during second year, the irrigation treatment I_1 (50 per cent ASM) gave maximum yield of 4068 kg/ha followed by treatment I_2 (plant indicator) with 3426 kg/ha and the treatment I_0 (rainfed) recorded the lowest yield of 2439 kg/ha. Regarding the ratoon crop, in both the years 1978 and 1979, the grain yield obtained in treatments I_1 and I_2 were on par. The yield during 1979 under I_1 and I_2 were 2317 kg/ha and 2324 kg/ha while it was 1423 kg/ha under treatment I_0. During 1979 the yields obtained under treatments I_1 and I_2 were 3189 and 2851 kg/ha respectively, with I_0 treatment the yield was 1419 kg/ha.

The above results indicate the benefit of irrigation to the sorghum crop. Bielorai *et al.* (1964) reported that increasing soil moisture by supplemental irrigation markedly increased the yield of sorghum. The higher yields obtained in the irrigated plots over the rainfed crop may be attributed to the availability and increased uptake of nutrients due to increased moisture available in the soil. Dastane (1974) opined water controlling the degree of availability, form, rate of movement and extent of uptake of nutrients and hence the responses to applied fertilisers depended on the quantity and frequency of irrigations. The lower yield in rainfed treatment I_0 may be attributed to the reason that the transport of mineral nutrients in the soil, absorption by the roots, translocation within the plants and their metabolism are all affected by soil moisture availability and two reasons have been given for the lower yield in rainfed treatment first by decreased availability of nutrients and secondly by the utilisation of obsorbed nutrients to a lesser extent that the irrigated crops.

The grain yield when irrigated at 50 per cent ASM was on par with that irrigated with sunflower as indicator plant during 1978 whereas the yield was higher with I_1 treatment as compared to that with I_2 treatment (plant indicator). Kaliappa *et al*. (1974) and Palaniappan *et al*. (1977) reported that at Coimbatore, sorghum yields were maximum when the crop was irrigated at 50 per cent ASM. At Rahuri (Maharashtra) and Hyderabad, yield did not decrease even when irrigated at 25 per cent ASM (D.A.R.E., 1975; A.P.A.U., 1975).

4.3.4.3. Influence of nitrogen

In the seeded crop, the applied nitrogen increased the grain yield of sorghum. The 40 kg and 80 kg N/ha levels were on par during 1978 while the lower level itself (40 kg N/ha) could bestow greater benefit than the higher level (80 kg N/ha). For the ratoon sorghum, 40 kg N/ha was optimum for higher yields. Stewart (1947) reported that the optimum dose of nitrogen might be around 20 to 40 kg N/ha in the major sorghum growing tracts of India.

4.3.4.4. Influence of irrigation and nitrogen

The interaction between irrigation and nitrogen on grain yield was significant in the second year main crop and ratoon crop of both the years.

The results of the second year main crop revealed that under rainfed treatment I_0, the yield from the three levels of nitrogen 0, 40 and 80 kg N/ha were on par with grain yields of 2438, 2600 and 2459 kg/ha and 120 kg N/ha gave the lowest grain yield of 2258 kg/ha. Thus it indicated that application of nitrogen without adequate moisture may not be remunerative. In fact the grain yield was considerably reduced by 7.4 per cent over the no nitrogen plot. Herron *et al.*

(1963) reported that both moisture and nitrogen must be adequate for continued uptake of nitrogen throughout the season. Bennett *et al.* (1964) found that total uptake of N and K in sorghum was usually higher with irrigation.

When irrigated, the response to applied nitrogen was positive. The 80 kg N/ha level recording higher yield (4152 kg/ha) over that at 40 kg N/ha (3991 kg/ha) as well as 120 kg N/ha (3834 kg/ha). The response to nitrogen when irrigated with sunflower as indicator plant was comparable with that at 50 per cent ASM. Leamer (1953) reported that fertilisers were more effective in increasing sorghum yields when the crop was supplied with adequate irrigation. Panicker (1960) observed that there was good response for nitrogen fertilisation upto 80 kg N/ha giving an extra yield of 15 per cent over 40 kg N/ha. Muthuvel (1976) stated that mineralisation of added nitrogen, its mobility in the soil medium and the consequent uptake by the growing plants were largely influenced by the prevailing soil moisture condition. Rodge and Tek (1975) reported linear response to nitrogen upto 120 kg/ha for various sorghum hybrids.

The interaction effect of irrigation and nitrogen levels on the grain yield of ratoon sorghum was significant. While no response was observed for the applied nitrogen with the rainfed ratoon crop (I_0) application of nitrogen at 40 kg N/ha was able to bring about significant yield increase with the irrigated treatments I_1 and I_2.

4.3.5. Straw yield

4.3.5.1. Influence of irrigation

The influence of irrigation on straw yield was studied through the three treatments viz. Rainfed (I_0), irrigation at 50 per cent ASM (I_1) and irrigation as per plant indicator (I_2). The yield obtained are presented in Tables 27 & 28. The results are discussed below.

The crop under rainfed treatment (I_0), irrigation at 50 per cent ASM (I_1) and irrigation as per plant indicator (I_2) were compared to study the factors or constraints responsible for the lower yield obtained under rainfed treatment I_0. The results showed that the rainfed crop raised under treatment I_0, recorded least straw yield as compared to the other two irrigated treatments (I_1 and I_2) in both the years. It is clearly seen that the main reason is attributed to the moisture stress experienced by the rainfed treatment while the irrigated crops received supplemental

Table 27. Influence of irrigation and nitrogen on straw yield kg/ha 1978

Treatments	N_0	N_1	N_2	N_3	Mean
Main Crop					
I_0	7513	8183	8959	9242	8474
I_1	10123	11005	11429	11217	10943
I_2	10052	11640	11675	10794	11040
Mean	9229	10276	10688	10418	

	S.E.	C.D. (P=0.05)
Irrigation	395.8	882.5
Nitrogen	19.04	38.1
Interaction -		
N levels at Irrigation	249.7	689.9
Irrigation at N levels	364.0	742.9

Treatments	N_0	N_1	N_2	N_3	Mean
Ratoon Crop					
I_0	4527	4270	4475	3987	4315
I_1	5838	6764	6096	6096	6199
I_2	5607	5967	5736	5761	5768
Mean	5324	5667	5436	5281	

	S.E.	C.D. (P=0.05)
Irrigation	347.2	774.7
Nitrogen	121.9	239.2
Interaction -		
N levels at Irrigation	149.7	413.6
Irrigation at N levels	251.5	524.7

Table 28. Influence of irrigation and nitrogen on straw yield kg/ha 1979

Treatments	N_0	N_1	N_2	N_3	Mean
Main Crop					
I_0	5787	5916	5787	6070	5890
I_1	8436	9439	10057	8359	9073
I_2	7922	8411	8256	8153	8185
Mean	7382	7922	8033	7527	

	S.E.	C.D.(P=0.05)
Irrigation	509.3	1137.3
Nitrogen	132.7	260.8
Interaction -		
N levels at Irrigation	163.6	453.7
Irrigation at N levels	324.1	689.8

Treatments	N_0	N_1	N_2	N_3	Mean
Ratoon Crop					
I_0	4868	5256	4727	4621	4868
I_1	6138	8183	8042	8183	7637
I_2	5996	8289	7407	7196	7222
Mean	5667	7243	6725	6667	

	S.E.	C.D.(P=0.05)
Irrigation	0.027	0.061
Nitrogen	0.005	0.010
Interaction -		
N levels at Irrigation	0.087	0.240
Irrigation at N levels	0.135	0.278

irrigation besides rainfall. The straw yields under treatment I_0 in the main and ratoon crops of first and second year are 8474, 5890, 4315 and 4868 kg/ha respectively. The yields were greater in main crop of both the years than that of ratoon crop in all the treatments. Fischer and Hagan (1965) and Campbell et al. (1969) reported that crop growth was sensitive to moisture stress particularly because of the physiological effects of stress on production and maintenance of photosynthetic tissue. Among the straw yields of main crops raised during the two years and in the first year ratoon crop, the yields under I_1 and I_2 were statistically on par while during the second year ratoon crop, the treatment I_1 (50 per cent ASM) comparatively gave higher yield than the treatment I_2 (plant indicator).

4.3.5.2. Influence of nitrogen

Straw yield at different nitrogen levels was significant in the main and ratoon crops of both the years. In the first year main crop, the straw yield at nitrogen level N_2 (80 kg N/ha) was better when compared to the yield at other levels of nitrogen. The no nitrogen plot gave the least straw yield.

But during the second year main crop and the ratoon crops in both the years, the yields under the treatments 40 kg N/ha and 80 kg N/ha were statistically on par. No nitrogen plot gave the least straw yield. Stewart (1947) reported that the optimum dose of nitrogen might be around 20 to 40 kg N/ha in the major sorghum growing tracts of India. Panickkar (1960) showed that there was good response for nitrogen fertilisation upto 80 kg N/ha giving an extra yield of 15 per cent over 40 kg N/ha.

4.3.5.3. <u>Influence of irrigation and nitrogen</u>

The interaction between irrigation and nitrogen on straw yield was significant in the main and ratoon crops of both the years. Under each irrigation treatment, the influence of nitrogen was studied. The results indicated that under I_0 and I_1, the nitrogen levels of 80 and 120 kg N/ha were on par while under I_2 treatment, the nitrogen levels 40 kg and 80 kg/ha were similar. This showed that under different levels of irrigation, a range of nitrogen of 40 to 80 kg N/ha was better for influencing the straw yield in sorghum.

4.4. <u>Economics</u>

The total cost of cultivation and the gross returns for different irrigation treatments and levels of nitrogen were worked out. From this the net return obtained from the various treatments were calculated by deducting the total cost of cultivation from the gross income. The cost of one irrigation was worked out Rs.75/- for each irrigation.

The data revealed (Table 29) that the net returns from both the irrigation treatments I_1 (50 per cent ASM) and I_2 (plant indicator) were on par indicating the advantage of the adoption of the irrigated method by the use of indicator plant. The mean data for 1978 and 1979 reveals that there is a saving in water consumption of 14.2 per cent in main crop and 8.4 per cent in the case of ratoon crop (Table 30).

The data on economics on net return revealed that there was no significant difference between the net returns obtained from irrigation at 50 per cent ASM (I_1) and irrigation as per plant indicator (I_2) in both main and ratoon crops indicating the economy in the use of sunflower as plant indicator in scheduling of irrigation to sorghum crop.

Table 29. Effect of treatments on net return (Rs/ha)

Treatments	Main					Ratoon				
	N_0	N_1	N_2	N_3	Mean	N_0	N_1	N_2	N_3	Mean
I_0	1617	1794	1536	1178	1531	808	574	288	18	422
I_1	2580	3097	3166	2722	2891	1539	2316	1953	1674	1871
I_2	2435	2992	2990	2179	2649	1650	2386	1764	1444	1811
Mean	2211	2628	2564	2026		1332	1759	1335	1045	
Irrigation				S.E.	C.E.			S.E.	C.D.	
				282.9	585.9			169.3	374.6	

Table 30. Economy in water use
(Mean for 1978 and 1979)

Particulars	Main Crop mm	Ratoon Crop mm
Total quantity of water consumed under irrigation treatment (50 per cent ASM)	606.2	320.2
Total quantity of water consumed under irrigation treatment as per plant indicator (I_2)	520.0	293.2
Saving in water consumption	86.2	27.0
Saving in percentage	14.2%	8.4%

4.5. <u>Water use efficiency</u>

The mean grain yield obtained during both the years with the main and ratoon crops was 6796 kg/ha for the treatment I_1 as compared to 6241 kg/ha for treatment I_2 using sunflower as plant indicator. The consumptive use for the treatments I_1 and I_2 were 926 and 813 mm respectively (Table 4). Thus the water use efficiency worked out to 7.3 for treatment I_1 and 7.7 for treatment I_2 which clearly indicate the usefulness of ~~sunflower~~ as indicator plant for scheduling irrigation to sorghum crop for greater water use efficiency.

SUMMARY AND CONCLUSIONS

5 SUMMARY AND CONCLUSION

Irrigation is the prime requirement for successful crop production but at the same time it is one of the costly inputs in crop production. Hence it is essential to economise the utilisation of water for maximum output. Further, under rainfed conditions, crop yields are poor compared to irrigated crop. The weather parameters that prevail during the crop growth play a major role.

The present investigation was taken to assess the factors responsible for stablising the yield of rainfed sorghum crop to that of an irrigated crop, to know the differences in water requirements between the highest yield under the recommended supply of water and restricted supply of water. Attempts were also made to study the role of nitrogen under different situations and the quantity of irrigation water saved by using plant indicator like sunflower.

Experiments were laid out in split plot design with three irrigation treatments viz., No irrigation, Irrigation at 50 per cent ASM and irrigation as per indicator plant in main plots while four nitrogen levels viz., No nitrogen, 40 kg, 80 kg and 120 kg N/ha formed the sub-plot treatments.

The results of the experiments are summarised below:

From the results it could be inferred that a well distributed rainfall ranging from 480 to 630 mm will be sufficient for stabilising the yield of rainfed sorghum. Application of fertilisers in the presence of adequate moisture is benefitial to rainfed crops. Moisture stress in early stages of crop growth will reduce the yield drastically.

The total water requirement of sorghum under treatment I_1 (50 per cent ASM) during the main crop seasons of 1978 and 1979 were 582 mm and 631 mm respectively while it was only 473 and 568 mm under treatments I_2 (Irrigation as per indicator plant). For the ratoon crops raised during 1978 and 1979 the water requirement under treatment I_1 (50 per cent ASM) was 330 mm and 310 mm respectively while under treatment I_2 (Irrigation as per indicator plant) it was 312 mm and 274 mm respectively. Hence it was seen that there was a considerable saving in water requirement by 18.8 per cent in 1978 and 9.9 per cent during 1979 by irrigating the sorghum crop with indicator plant in the case of main crop.

In the case of ratoon, there is a saving of water by 5.4 per cent in 1978 and 11.6 per cent in 1979 by irrigating the sorghum crop with plant indicator.

The nitrogen uptake in the irrigation treatments I_1 and I_2 was higher than that of the rainfed treatment I_0 in the main crop while in the ratoon crop, the uptake in all the three treatments I_1, I_2 and I_0 did not reveal any significant difference in uptake pattern.

There was linear uptake of nitrogen upto 40 kg N/ha beyond which there was quadratic response in both main and ratoon crop. An uptake of 169 kg of nitrogen per hectare was recorded at harvest stage with the application of 120 kg N/ha. There was a rapid increase in the uptake of nitrogen from 60th day after sowing to harvest in both main and ratoon crop.

It was observed that irrigation had no influence on P-uptake. Similarly the results showed that the nitrogen application had no influence on the P-uptake.

K-uptake was greater in the irrigation treatments I_1 and I_2 compared to that of rainfed treatment I_0. There was quadratic response of K-uptake in all the stages of crop growth as the levels of nitrogen increased beyond 40 kg N/ha both in main and ratoon crop.

The water use efficiency is greater (7.7) in irrigation treatment I_2 (plant indicator) that that of the treatment I_1 (50 per cent ASM) which was only 7.3. Thus it clearly indicated the usefulness of sunflower as indicator plant for scheduling irrigation to sorghum crop for greater water use efficiency.

The advantage in the adoption of the irrigation method using sunflower as plant indicator is clearly seen with a saving in water consumption of 18.7 per cent in the main crop and 5.4 per cent in the case of ratoon crop of first year (1978) and 12.6 per cent and 11.6 per cent during second year (1979) as compared to that of irrigation at 50 per cent ASM. There is a saving in the water consumption of 109.4 mm and 63.0 mm in the main crop of 1978 and 1979 respectively.

The influence of irrigation on plant height was clearly seen by the increase in plant height in the irrigated treatments I_1 and I_2 over the rainfed treatment I_0. The rainfed crop in treatment I_0 suffered in the early stages after sowing for want of rains.

There was no significant difference in plant height between 80 kg N/ha and 120 kg N/ha levels of nitrogen applied in both main and ratoon crops.

Irrigation at 50 per cent ASM (I_1) and irrigation as per plant indicator (I_2) significantly produced more leaf area index than the rainfed treatment I_0.

There was no significant difference in LAI between different levels of nitrogen at different stages of growth.

Irrigation at 50 per cent ASM (I_1) and irrigation as per plant indicator (I_2) recorded significantly greater dry matter production than the rainfed treatment (I_0) in both main and ratoon crops. Dry matter production increased in all the stages with increase in ASM. There was not any significant difference in dry matter production between the two irrigation treatments I_1 (50 per cent ASM) and I_2 (Plant indicator).

There was a linear response to nitrogen application upto 40 kg N/ha and beyond that, a quadratic response wasnoted at all the stages of crop growth in the case of main crop while in ratoon crop, the quadratic response was seen beyond 80 kg N/ha at 30th day after sowing and at harvest stage.

The influence of irrigation on earhead length could be clearly seen by the significant reduction of the length of earhead in the rainfed treatment I_0. There was no significant difference in length of earheads between the two irrigation treatments I_1 (50 per cent ASM) and I_2 (plant indicator).

The length of earhead was greater in nitrogen applied plots than no nitrogen plot.

There was significant influence of irrigation on the weight of earhead. But there was not much difference in weight of earhead between the two irrigation treatments I_1 and I_2. There was substantial reduction in weight of earheads in the ratoon crop compared to the main crop.

The weight of earhead was greater in nitrogen applied plots than the no nitrogen plots.

The grain weight per earhead was significantly greater in both the irrigation treatments I_1 (50 per cent ASM) and I_2 (plant indicator) as compared to the rainfed treatment I_0. The grain weight per earhead was greater in the main crop than that of the ratoon crop.

There was steady increase in the grain weight per earhead as nitrogen level increased upto 80 kg N/ha and there after the weight decreased.

There was no significant difference in thousand grain weight under different irrigation treatments, as well as under different levels of nitrogen. The thousand grain weight of the main crop was greater at the corresponding levels of nitrogen than that of the ratoon crop.

In both main and ratoon crops, the grain yields obtained in the two irrigation treatments I_1 and I_2 were similar indicating the irrigation given as per plant indicator is sufficient. The irrigated crop yielded higher than rainfed crop. Further the results revealed that the two levels viz. 40 and 80 kg N/ha were on par in respect of grain and straw yield indicating that 40 kg N/ha is sufficient for sorghum under Coimbatore condition. It was also found that application of nitrogen without adequate moisture is not remunerative.

Summarising the results it could be concluded that a well distributed rainfall ranging from 480 to 650 mm will be sufficient for stabilising the yield of rainfed sorghum crop. The water requirement is greater during the main sown sorghum crop than the ratoon crop.

There is advantage in scheduling irrigation with sunflower as plant indicator with a saving of 18.7 per cent in the main crop of sorghum and 5.4 per cent in the ratoon crop in water consumption without affecting the yield. The water use efficiency is greater in scheduling irrigation with sunflower as plant indicator than irrigation at 50 per cent ASM.

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* Originals not seen

APPENDICES

APPENDIX I

Meteorological data during crop season

(1978 - 79)

Standard week number	Month and date	Mean Temperature °C Maximum	Mean Temperature °C Minimum	Mean relative humidity	Mean Sunshine hours	Rainfall (mm)	Rainy days
1.	2.	3.	4.	5.	6.	7.	8.
36	Sep. 3-9	31.7	21.0	72	6.4	18.9	2
37	10 - 16	31.2	21.1	71	4.8	2.4	-
38	17 - 23	33.2	20.5	60	7.7	0.4	-
39	24 - 30	32.6	21.6	75	8.1	3.1	1
40	Oct. 1-7	31.6	19.2	60	9.5	3.8	1
41	8 - 14	30.9	21.6	70	8.6	21.5	3
42	15 - 21	31.2	21.8	80	5.8	94.3	4
43	22 - 28	29.1	21.3	80	7.0	44.2	3
44	29 - 4	29.6	21.9	82	4.6	38.3	4
45	Nov.5-11	27.7	21.5	84	4.9	115.7	3
46	12 - 18	27.3	19.3	71	10.4	2.7	1
47	19 - 25	27.4	17.1	69	7.8	18.8	1
48	26 - 2	28.3	19.8	71	8.1	1.8	-
49	Dec. 3-9	28.2	19.9	78	5.9	3.4	-
50	10 - 16	28.2	20.7	75	4.2	8.4	1
51	17 - 23	29.5	19.4	69	6.5	-	-
52	24 - 31	28.5	20.1	83	2.7	39.1	3

contd..

Contd..

1.	2.	3.	4.	5.	6.	7.	8.
1	Jan. 1-7	29.1	17.7	68	9.9	-	-
2	8 - 14	29.3	17.3	69	8.7	-	-
3	15 - 21	30.1	18.8	69	8.7	-	-
4	22 - 28	30.4	19.2	67	9.2	-	-
5	29 - 4	32.3	17.8	65	9.6	-	-
6	Feb.5-11	32.2	18.1	63	9.4	1.6	-
7	12 - 18	30.5	20.7	72	6.0	35.8	1
8	19 - 25	30.2	21.3	78	6.2	50.1	2
9	26 - 4	30.1	20.2	73	7.9	34.4	1
10	Mar.5-11	33.4	20.9	69	7.9	16.9	1

APPENDIX II

Meteorological data during crop season

(1979-80)

Standard week No.	Month and date	Mean Temperature °C Maximum	Mean Temperature °C Minimum	Mean relative humidity	Mean sunshine hours	Rain fall (mm)	No. of rainy days
1.	2.	3.	4.	5.	6.	7.	8.
41	Oct.8 - 14	30.9	22.3	94	6.7	46.2	2
42	15 - 21	31.2	20.5	87	10.2	3.4	1
43	22 - 28	29.2	21.3	93	4.1	88.3	4
44	29 - 4	29.6	21.0	95	6.6	56.4	3
45	Nov.5 - 11	27.7	21.3	94	3.2	21.7	3
46	12 - 18	27.3	21.2	96	2.7	283.0	5
47	19 - 25	27.4	21.1	94	2.7	293.6	4
48	26 - 2	28.3	21.6	94	6.0	15.2	1
49	Dec.3 - 9	28.2	20.5	93	6.7	0.7	-
50	10 - 16	28.2	20.8	91	5.2	3.7	1
51	17 - 23	29.5	19.1	91	8.9	-	-
52	24 - 31	28.5	17.2	90	8.9	0.4	-
1	Jan.1 - 7	29.4	16.6	85	10.3	-	-
2	8 - 14	30.0	15.7	88	10.0	-	-
3	15 - 21	29 1	17.4	85	10.0	-	-
4	22 - 28	30.0	14.7	85	10.8	-	-
5	29 - 4	30.8	17.1	81	8.9	-	-
6	Feb.5 - 11	31.5	17.8	88	9.6	9.4	1
7	12 - 18	32.0	16.8	85	10.0	-	-
8	19 - 25	33.0	16.5	81	11.2	-	-

Contd..

1.	2.	3.	4.	5.	6.	7.	8.
9	26 - 4	34.7	16.3	85	10.6	-	-
10	Mar.5-11	34.9	19.5	85	9.0	5.9	1
11	12 - 18	32.3	19.9	86	9.8	19.0	2
12	19 - 25	34.9	11.2	75	11.1	-	-
13	26 - 1	34.4	21.9	78	9.2	-	-
14	Apr.2-8	34.3	23.6	77	7.0	3.3	1
15	9 - 15	35.7	23.1	84	10.4	-	-
16	16 - 22	34.8	23.2	76	7.7	16.9	2
17	23 - 29	34.8	22.5	88	7.2	63.9	4