CHAPTER V

DISCUSSION
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Because of high yielding ability with high oil content in seeds and thermo-photo neutral growing nature, sunflower cultivation as an important oilseed crop during *rabi* season under irrigated agro-ecosystems has drawn the attraction of farmers in the state since last 10 years. An adequate water supply to this crop is of prime importance for its substantial production. Therefore, rational use of irrigation to schedule irrigation intervals is an important aspect of water economy in its cultivation. To determine the efficient irrigation schedules for *rabi* sunflower, different irrigation schedules based on important approaches of deciding irrigation frequencies were tested under present investigation. The research findings are elucidated in the previous chapter. The salient features of these findings are critically discussed in this chapter with the support of data recorded and opinions of researchers on the concerned field. Besides the effect of irrigation treatments tried during the investigation, the influence of existing edaphic and meteorological conditions on growth and yield of crop can not be ignored. Hence, they were also described here.

**Edaphic Conditions:**

The soil of the experimental field was homogenous in fertility status prior to using under the present investigation. Texturally
it was clay loam with medium depth, black colour, neutral reaction and normal electrical conductivity. The organic carbon as well as available N and P contents were low in the soil, while K content was high. The water holding capacity and wilting coefficient of the soil at 0-15 cm depth ranged between 33.60 to 32.14 and 26.11 to 22.20% respectively in the two consecutive years. The soil parameters of the experimental field are representative for the majority of the soils in Kymore plateau zone of the state. Hence, the finding of the present investigation may be applicable for such farming situation of the region.

Weather Conditions:

Most of the weather parameters viz. maximum and minimum temperature, relative humidity, wind velocity and sunshine hours were almost normal in both years as compared to 25-year mean data during the crop season. However, rainfall and evaporation rate were high in first year and normal in second year of experimentation when compared with average data of these parameters. Rains occurred during the entire growing season of the crop in first year, nullified the effect of different irrigation schedules tested for their efficiency on the crop growth and yield. But in next year, the rainfall and evaporation rate were almost similar to average data of pervious years. Therefore, the effect of irrigation schedules were compared critically. Almost the weather conditions were congenial
for growth and yield of crop and they did not cause adverse effects on the crop.

**Crop Stand and Growth in General:**

Plant population was uniform under all treatments, as a result of sowing of the crop with uniform seed rate and maintaining the uniform plant population by thinning of the additional seedlings after germination or gap filling by reseeding of the fresh seeds in the gaps looked after completion of the germination of seeds.

Plant-height continuously increased till 75-day growth stage under all treatments and then the elongation of plant stalks ceased and even a little reduction was observed in the plant height. The crop variety grown was "Morden" which matured in 110 days. It required nearly 50 days duration for completion of vegetative phase, 50 to 75 days for reproductive phase and there after for grain development phase (Fig. 3). Plant height rapidly increased after 25 DAS because of grand growth phase of the crop. The rate of elongation in height was maximum during 50 to 75 DAS because of reproductive phase resulting transfer of source to sinks. As the crop reached to grain development phase after 75-day growth stage, the absorption of food materials from the roots and the translocation of food materials and photosynthates to development of cells and cell division in the plant stopped which ceased the elongation of plant height. A little reduction in the plant
height at maturity might be due to the senescence.

The thickness of plant stalks successively increased till the final stage of the crop under all treatments in both years. The rate of increase in girth of stems was most rapid during 25 to 50 DAS in first year because of sufficient availability of moisture due to rains. But in the next year, the increase in stem girth continued at steady rate till the final stage of crop.

Number of functional leaves (active leaves)/plant increased gradually till 75-day growth of the crop under all treatments in both years and then declined at maturity. The formation of new leaves ceased immediately after 50 DAS because of development of reproductive phase. Consequently, number of functional leaves/plant was maximum at 75 DAS. After this, the older leaves dried, hence the leaf counts reduced at maturity.

**Effect on Morphological Characters:**

Application of irrigation water in sunflower with different irrigation frequencies on the basis of soil moisture depletion pattern or IW/CPE ratio or phenological growth stages of the crop significantly varied the morphological parameters viz plant-height (Table 3) stem-thickness (Table 4) and functional leaves/plant (Table 5) at all growth stages after 25 DAS during the second year of experimentation. But in first year, the effect of these irrigation frequencies was not
remarkable because of sufficient rainfall as per need of the crop during the entire crop-season. In second year, the highest irrigation frequency under each criterion for scheduling the irrigation had marked superiority in these morphological features of the plants over the lower irrigation frequencies, but the variations in close frequencies were not appreciable (See plates 1 to 8). All these growth parameters were inferior with the lowest irrigation frequency (only one irrigation) when irrigation was given at 50% depletion of soil moisture or 0.4 IW/CPE ratio. The poor growth parameters with lowest irrigation frequency may be due to the stress on absorption of nutrients, photosynthesis, respiration, metabolic processes and reproductive activities etc. in the plants. The physiological processes of the plants are primarily the function of the water status of the plant and only indirectly affected by soil water stress (Kramer, 1969). Thus, the final effect on growth parameters will depend on the frequency and duration of the water stress. Cell division and cell-enlargement probably decreased with moisture stress because of reduced protein synthesis and enzymic activities related to nitrate metabolism. The moisture stress with reduced irrigation frequency probably caused dehydration of the protoplasm associated with loss of turgor which reduced the expansion of cells and cell division and ultimately decreased the plant height, stem-girth and leaves/plant. These growth parameters increased appreciably by receiving adequate moisture with higher irrigation
Plate 1. Showing initial growth with irrigations at 20% soil moisture depletion

Plate 2. Showing initial growth with irrigations at 30% soil moisture depletion

Plate 3. Showing initial growth with irrigations at 50% soil moisture depletion
Plate 4. Showing initial growth with irrigations at 1.0 IW/CPE

Plate 5. Showing initial growth with irrigations at 0.8 IW/CPE

Plate 6. Showing initial growth with irrigations at 0.4 IW/CPE
Plate 7. Showing initial growth with irrigations at 8-9 leaf + flowering + grain filling stages (no stress)

Plate 8. Showing initial growth with irrigations at flowering + grain filling stages
frequencies. These results are in close conformity with the finding of To mar et al. (1977), Patel and Singh (1980), Thosar et al. (1991); Chaudhary and Patel (1994) and Tomar and Sharma (1994).

The morphological growth parameters of plant did not differ due to different irrigation schedules based on the critical growth stages at all growth during first year and upto maximum vegetative phase (25 to 50 DAS) in second year. However, at advanced growth stages in second year these growth parameters were significantly superior by irrigating the crop at all the 3 important growth stages than missing irrigation at any one of these stages. The growth parameters were almost comparable when irrigation was missed at 8-9 leaf or flowering or grain filling stages. This reveals that the loss in growth parameters after the crop due to delaying the irrigation upto grain filling stage revived by supplementing the irrigation (Rawson and Turner, 1982; Hegde, 1988 A).

**Effect on Physiological Characters**: 

Physiological growth parameters viz. DM accumulation/m² gradually increased at a steady rate (Table 7) till the maturity of the crop under all treatment. The CGR and LAI also successively increased upto 75 DAS and then declined till maturity (Table 8 and 6). In general, RGR and NAR (Table 9 and 10) were maximum at early growth stage (25 DAS) and thereafter these values successively
decreased till the maturity. Gradual increase in morphological growth parameters (plant height, stem-girth and leaves/plant) with the advancement of crop season resulted into production of increased photosynthates and reservation of plant food nutrients. Thus, DM accumulation enhanced during advanced growth stages till the maturity. Increased DM production at advanced growth stages contributed to higher CGR. The CGR relatively reduced at maturity over preceding stage (75 DAS), because the longer interval of time between 75 DAS to maturity (35 days) than the common interval of time (25) at the preceding stages. DM accumulation rate over the DM already accumulated was relatively reduced with the advancement in crop growth which resulted into declined trend of RGR. The LAI was minimum at early stage (25 DAS) which gradually increased at advanced growth stages till 75 DAS and then declined at maturity. Therefore, NAR was maximum at early stages and then it reduced successively up to maturity. The reduced LAI at maturity over 75 DAS attributed to lesser NAR at maturity because of longer interval of time (35 day) between 75 DAS maturity. These results are in close conformity with the views of Andhale and Kalbhor (1980).

The irrigation schedules did not cause significant influence on LAI at all growth stages during first year (1995-96) and at early stage during second year (1996-97), but the highest irrigation
frequency had significantly maximum LAI during advanced growth stages after 25 DAS under each criterion for scheduling in second year (Table 6). The LAI correspondingly reduced with decreasing the irrigation frequencies. The production of bigger sized leaves in more number with adequate availability of water at increased irrigation frequency or attributed to increased LAI.

Taller plants alongwith more thickness and photosynthetic area (LAI) due to application of adequate irrigation water under increased irrigation frequencies resulted to produce more DM yield. Water is a major constituent of tissues, a reagent in photosynthetic and hydrolytic processes, the solvent for nutrients and mode of translocation for metabolites and minerals within plants. Thus, water is essential for cell enlargement and growth. Cell enlargement is correlated with turgor pressure which is increased with supply of irrigation water. Soil moisture stress with reduced frequency of irrigation resulted severe water deficit in the plants.

consequence upon above facts, DM accumulation/m² by sunflower significantly varied due to irrigation schedules at all growth stages after 25 DAS including at maturity in both years (Table.7). During first year, irrigation at 50% depletition of soil moisture faced moisture stress during vegetative phase of crop. Hence it significantly produced the lowest DM production among all the irrigation schedules under different approaches of scheduling.
irrigation. The other irrigation schedules exhibited inconsistent trend of DM production during this year because of rains at different growth stages of the crop. But in second year of experimentation, the highest irrigation frequency under each criterion for determining irrigation schedules significantly produced maximum DM yield at all growth stages beyond 25 DAS. The DM production correspondingly reduced with decreasing levels of irrigation frequencies and the values reached to the minimum with the lowest irrigations frequency under the same criterion of irrigation schedules. Each irrigation schedules followed the same trend of CGR as to followed for DM production in both years. Beneficial effects of water for maintaining cell-division, cell-turgity, photosynthesis, respiration, uptake of water and essential nutrients; and translocation of photosynthates due to higher irrigation frequencies than lower frequencies almost at all growth stages might have resulted into greater RGR under each criterion of scheduling the irrigation. Because of inconsistent trend in DM production under varying irrigation frequencies during first year, the RGR and NAR also exhibited inconsistency due to different irrigation schedules. Like RGR, NAR values were also greater with higher irrigation frequencies than lower ones because of increased DM production. Several workers showed the similar effects of irrigation schedules on different physiological growth parameters of sunflower (Unger, 1982; Jana et al., 1982; Tomar and Sharma, 1994; Reddy and Kumar, 1997).
Effect on Yield Attributing Characters:

Economic yield of crop plants depends upon source-sink relationship and also on different components of source viz., the leaves, plant height, stem-thickness and finally DM accumulation and sinks viz., head-size, number of seeds/plant, shelling percentage, chaffiness percentage, seed index and ultimately, seed yield/plant. Different irrigation schedules decided on the basis of soil moisture depletion pattern or IW/CPE ratio or critical growth stages of crop did not exert their marked influence on these sinks (Table 11 and 12) in first year because of sufficient rains during the crop season. Exceptionally, crop irrigated with 50% depletion of soil moisture produced significantly lower number of seeds/head which attributed to lower seed yield/head also than remaining irrigation schedules in first year. The harvest index (Table 14) values were also higher with increased irrigation frequency. The lower LAI, DM accumulation due to moisture stress at very initial growth stage of crop with irrigation at 50% soil moisture depletion resulted to produce lower seed yield. However, in second year these yield attributes significantly varied due to different irrigation schedules under all criteria of schedules irrigations.

On having a look on over all picture in respect of different irrigation schedules on yield attribute during second year of investigation, the higher irrigation frequency had marked superiority.
in head-size, number of seed/head, chaffiness of seeds, shelling percentage, seed index and seed yield/plant over the lower irrigation frequencies. Improvement in these yield determinants might be the resultant of accelerated production of photosynthates through favorable effect of irrigation water on leaf water potential, leaf turgor, opening of stomata and more LAI resulting in higher photosynthesis and efficient translocation of photosynthates to sink. Besides, accelerated growth, the reproductive growth cycle also run effectively in timely and adequately irrigated treatments.

It was remarkable that the crop receiving 3 irrigations at all critical growth stages (8-9 leaf, flowering and grain filling) was comparable to the crops irrigated with 4 irrigations with either 1.0 IW/CPE or 50% soil moisture depletion for above yield attributes. Similarly two irrigations applied at 8-9 leaf and flowering stages (missing at grain filling) produced the yield attributes equally good as to produced by three irrigations applied with 30% soil moisture depletion or 0.8 IW/CPE. Treatments receiving 2 irrigations viz at 40% soil moisture depletion or 0.6 IW/CPE or 8-9 leaf + grain filling stages or flowering + grain filling stages were almost comparable with regard to yield attributing characters of sunflower. These results reveal that optimum water supply has growth promoting effects on most of the physiological processes in sunflower and consequently, the growth and yield attributes increased with the
presence of adequate moisture. It is also discernible from these results that deciding irrigation schedules on the basis of critical growth stages of the crop was more effective than the other approaches for deciding the irrigation intervals viz soil moisture depletion pattern or IW/CPE ratio. It is also obvious from these results that 8-9 leaf and flowering stages were the most critical stages for scheduling irrigation in sunflower because irrigating crop at these stages probably not only stimulated the vegetative growth of the plants, but also improved the reproductive cycle. Meanwhile superimposing one irrigation at grain filling stage further improved these yield attributes. The significant response of sunflower for yield attributes to the irrigation schedules based on various approaches for deciding the efficient irrigation intervals has been reported by Jadhav and Jadhav (1978), Hegde (1988 A), Thosar et al. (1991), Vivek and Chakor (1992), Sarkar and Chakraborty (1995), Singh et al. (1995) and D’Andria et al. (1995).

Effect on Seed and Haulm Yields:

Seed yield per unit area is the interplay of yield/plant and number of plants per unit area. The later character was almost alike under all irrigation schedules decided on the basis of several approaches i.e. critical growth stages of crop, soil moisture depletion pattern and IW/CPE ratio. Hence, the role of former had great concern for improving the seed yield per unit area under
present investigation. As discussed in the previous heading that seed yield/plant is function of yield attributing characters like head-size, chaffiness percentage, number of seeds/head, shelling percentage, seed index etc. These yield determinants are positively associated with physiological growth parameters like DM accumulation and NAR (Unger, 1982; Bhattacharya et al., 1991; Gangappa and Viupakshappa, 1994), LAI and crop duration (Rawson and Turner, 1983; Hegde, 1988 A and Naga Reddy et al. 1995); and morphological characters like stem-thickness, head-size (Hegde 1988 A; Chaudhary and Patel, 1994; Tomar and Sharma, 1994 and Sudhakar Babu et al., 1997). However, chaffiness percentage had strong negative relationship with seed yield/plant (Hegde, 1988 A and Sudhakar Babu, 1997). Both seed and haulm yields significantly varied due to different irrigation schedules during both years (Table 13).

While comparing the effect of irrigation schedules based on varying soil moisture depletion pattern, the highest frequency (4 irrigation) at 20% soil moisture depletion produced maximum seed and haulm yields in both years which reduced with decreasing the irrigation frequencies as 30% (3 irrigations), 40% (2 irrigations) and 50% (1 irrigation) depletion of soil moisture. But the differences in yields between 20 to 40% soil moisture depletion during first year were not significant. The lowest irrigation frequency with 50% soil moisture depletion (1 irrigation) significantly produced the
lowest yields in both years. The non-significant variations in seed and haulm yields between the irrigation schedules at 20 to 40% depletion of soil moisture in first year was due to rains which resulted to produce almost similar growth characters and yield attributes. But at 50% soil moisture depletion, crop faced severe moisture stress during initial crop growth stage which resulted to poor growth and ultimately produced the lowest yields. In some cases, the rains occurred immediately after irrigating the crop as per schedule based on soil moisture depletion (irrigation at 30% depletion of water) which also caused adverse effect on the growth because of excessiveness of soil moisture. As a consequence, the effect of treatments during first year did not show the consistency of the results due to different irrigation schedules. During second year, maximum irrigation frequency (4 irrigations with 20% soil moisture depletion) produced the highest seed (11.45q/ha) and haulm (60.11q/ha) yields which significantly reduced by each decrease in irrigation frequency at 30, 40 and 50% depletion of soil moisture. Growth parameters of individual plants with higher irrigation frequency were apparently superior which might possibly stimulated the production of superior growth and yield attributes (see plates 9,10,11) and ultimately gave higher yields. Similar results have been reported by Patel and Patel (1993), Vivek et al. (1994), Singh et al. (1995) also from their studies on the effect of irrigation schedules based on soil moisture depletion pattern.
Plate 9. Showing growth at reproductive phase with irrigations at 20% soil moisture depletion

Plate 10. Showing growth at reproductive phase with irrigations at 30% soil moisture depletion

Plate 11. Showing growth at reproductive phase with irrigations at 50% soil moisture depletion
Different irrigation schedules based IW/CPE ratio did not show remarkable influence on seed and haulm yields in first year because of rainfall during the crop season. But in second year, the highest irrigation frequency (4 irrigations) at 1.0 IW/CPE produced maximum seed (10.51 q/ha) and haulm (55.42 q/ha) yields among all irrigation schedules based on IW/CPE. The yields significantly reduced by decreasing the irrigation frequency as irrigations at 0.8 (3 irrigations), 0.6 (2 irrigations) and 0.4 (1 irrigation) IW/CPE. Timely application of irrigation with higher irrigation frequency improved the plant growth which resulted to produce superior yield attributes (see plates 12,13 and 14). It indicates that timely supply of irrigation water maintained the normal growth function of the plant which produced the healthy and heavier seeds resulting in higher harvest index. The production of more seeds/plant with higher weight due to increased irrigation frequency attributed to higher seed yields. Findings of many other workers from different agro-climatic conditions also reveal that application of irrigation water to sunflower on the basis of proper IW/CPE gave maximum yields (Tomar et al., 1977; Vivek and Chakor, 1992; Venkanna et al., 1994 and Reddy and Kumar, 1997).

When the irrigation schedules based on critical growth stage of the crop were taken into consideration, crop irrigated with three irrigations at 8-9 leaf, flowering and grainfilling stages produced
Plate 12. Showing growth at reproductive phase with irrigations at 1.0 IW/CPE

Plate 13. Showing growth at reproductive phase with irrigations at 0.8 IW/CPE

Plate 14. Showing growth at reproductive phase with irrigations at 0.4 IW/CPE
the highest seed (11.06 q/ha) and haulm (61.18 q/ha) yields during second year of the experimentation. The yields markedly reduced when irrigation missed at any of the above three important growth stages and the reduction was maximum by missing the irrigation at flowering stage. However, the differences in seed and haulm yields were not appreciable when irrigation missed at 8-9 leaf or flowering stages of the crop. During first year the effect of irrigation schedules based on critical growth stages of the crop was nullified because of adequate rains during entire crop season. These results reveal that irrigations at all the three growth stages (8-9 leaf, flowering and grain development) was most promising. When only two irrigation are possible, it could be missed at grain filling stage (see plates 15 and 16). Irrigating crop at all critical growth stages significantly improved growth parameters which may be responsible for production of superior yield attributes which finally gave higher yields. The growth and yield attributing parameters like plant height, number of leaves/plant, stem-girth and head size had direct positive relationships with haulm yield while seed yield is directly and positively correlated with head-size, number of seeds/head, seed index, harvest index, shelling percentage. Seed yield is also negatively related with chaffiness percentage. Several workers reported similar positive effects of irrigation to sunflower at critical growth stages.
Plate 15. Showing growth at reproductive phase with irrigations at 8-9 leaf + flowering + grain filling stages (no stress)

Plate 16. Showing growth at reproductive phase with irrigations at flowing + grain filling stages
on seed and haulm yields (Mahapatra and Singh, 1974; Suryanarayana, 1975; Bhan, 1976; Rao et al. 1977; Bajpai et al. 1978; Raghu and Sharma, 1978 and Unger, 1982).

On looking on the over all picture of seed and haulm yields under different approaches for deciding the irrigation frequency to sunflower on the basis of two year mean data, it is obvious to conclude that 3 irrigations at all the critical growth stages was comparable to 4 irrigations given either at 1.0 IW/CPE or at 20% depletion of soil moisture. Like wise, 2 irrigations at 8-9 leaf and flowering stages gave almost same seed and haulm yields which were obtained with 3 irrigations at 0.8 IW/CPE or 30% soil moisture depletion. However, the yields with 2 irrigations given at 0.6 IW/CPE or 40% soil moisture depletion or missing irrigation at 8-9 leaf or flowering stages out of the 3 critical physiological growth stages were at par with regard to seed and straw yields. Thus, it could be said that deciding the irrigation intervals in sunflower based on the critical growth stages of the crop was more practicable and efficient than that of on the basis of soil moisture depletion pattern or IW/CPE ratio.

Effect on Oil Content and Oil Yield:

Oil content did not differ due to different irrigation schedules during first year of the experimentation, while it markedly varied due to various irrigation intervals in second year (Table 15).
The rains occurred during crop season in first year may be the reason for similar oil contents in seeds of sunflower. In the next year, oil contents in seeds were maximum with the highest irrigation frequencies which markedly reduced by decreasing the irrigation frequencies with non-significant differences in between the closer frequencies of irrigation under the same criterion of scheduling irrigation.

In sunflower oil oleic and linoleic acids are the major fatty acids. Their desired ratio is possible by genetic manipulations. However, the degree of unsaturation also depends largely upon the environment (both natural and artificial). The availability of water to the crop during seed development affect the fatty acid composition in seeds. Thus, inadequate water content in plants at seed development stage probably reduced the oil content under the irrigation schedules having moisture stress.

Oil yield is directly related to the seed yield and oil content of the seeds. During first year, both these factors were unaffected due to different irrigation schedules, hence oil yields were almost comparable among all the irrigation schedules. Exceptionally crop irrigated at 50% soil moisture depletion significantly produced the lower oil yield than remaining irrigation schedules because of minimum seed yield. During the second year of experimentation, oil yield was significantly maximum with the highest irrigation
frequency under each criterion for scheduling irrigation which reduced correspondingly with each decrease in the irrigation frequency under the same approach of irrigation schedules. These results also corroborated the findings of Robertson and Green (1981); Jayakumar et al. (1988); Patil et al. (1988); Gupta and Wagle, (1989); Shinde et al., (1990) and Nalayini and Sankaran (1993).

On looking the over all picture of oil yield, 3 irrigations applied at all the important physiological growth stages (8-9 leaf, flowering and grainfilling) produced almost the same oil yield as to produced by 4 irrigations applied at 20% soil moisture depletion or 1.0 IW/CPE. Similarly two irrigations at 8-9 leaf + flowering stages also produced oil yield equivalent to those produced under 3 irrigations either at 30% soil moisture depletion or 0.8 IW/CPE. Hence, it is obvious, that scheduling irrigation on the basis of physiological stages was most promising among all the criteria for deciding the irrigation schedules.

**Effect on Consumptive Use of Water and Water Use Efficiency:**

The seasonal consumptive use of water (CUW) under different irrigation schedules did not differ during first year of investigation except to irrigations scheduled at 50% depletion of soil moisture (Table 14). All the treatments received atleast one irrigation as per treatments and then no irrigation was given due
to rains. Therefore, CUW was similar for these treatments. Exceptionally, no any irrigation could be given for the treatment irrigations at 50% soil moisture depletion. Hence, its CUW was less. In second year, the rains did not affect the scheduling of irrigation as per treatments, therefore number of irrigation varied for each treatment. As a consequence, the highest irrigation frequencies needed more water for irrigation resulting in increased CUW. The CUW values reduced correspondingly by decreasing the irrigation frequencies. Similar number of irrigation with different criteria of scheduling irrigation water required similar quantity of water.

The water use efficiency (WUE) was comparable among all irrigation schedules except to irrigations at 30% and 50% depletion of soil moisture in first year (Table 14). The crop growth and yield suffered due to excessive soil moisture at 30% depletion of soil moisture, because the rains immediately after irrigating the crop as per schedule which resulted to reduced WUE. But the crop faced moisture stress at initial and final stage of crop due to soil moisture depletion between 40 to 50% which restricted the application of irrigation and resulted to less WUE due to poor growth and yield of crop. The irrigation schedules based on either critical growth stages of crop or IW/CPE did not show marked variation in WUE in both years. On the basis of two year mean data, 3 irrigations at critical growth stages (8-9 leaf, flowering and
grain filling) resulted to higher WUE than other irrigation schedules and even with 4 irrigations at 1.0 IW/CPE or 20% depletion of soil moisture. The increased crop yield with irrigations at critical growth stages because of efficient utilization of water resulted to higher WUE. These results are in close conformity with the finding of Hegde and Havanagi (1980); Pawar et al., (1991) and Nimbalkar and Doddamani (1993).

**Uptake of Major Nutrients (N,P,K):**

In sunflower, N uptake was more by the haulms than seeds while uptake of P and K was higher by seeds than haulms (Table 16). The total uptake of N was maximum followed by P and K uptakes in descending order by the sunflower under all treatments.

**N-uptake:**

The total N-uptake was almost comparable under all the irrigation schedules during first year of experimentation because of similar seed and haulm yields. Exceptionally, crop irrigated at 50% soil moisture depletion significantly removed the lowest N from the soil. There was sufficient rains during entire crop season except to a very initial stage. Hence the growth and yield of crops under all irrigation schedules was at par. consequently, the N-uptake was unaffected due to different irrigation schedules. When irrigation was proposed on the basis of 50% soil moisture depletion,
no irrigation was given in early growth stage which resulted into lowest yield and thus, the N uptake was minimum with this irrigation schedule. The uptake of nutrients depends on its concentration in the produce and weight of the produce. As neither N contents in seeds and haulms nor weight of seeds and haulms changed due to different irrigation schedules except to irrigations at 50% soil moisture depletion during first year, hence the uptake of N also did not vary between different irrigation schedules.

During second year, seed and haulm yields were maximum with the highest irrigation frequency under each criterion of irrigation schedules which reduced with corresponding decrease in irrigation frequencies. Though N contents in seeds and haulms were unchanged due to different irrigation schedules in this year, total N-uptake varied due to variation in seed and haulm yields. Therefore, the highest frequency of irrigation under each approach of scheduling irrigation removed maximum N from the soil which decreased by decreasing the irrigation frequency under the respective approach with non-significant differences between the closer irrigation intervals.

P-uptake:

P contents in seeds and haulms did not change due to different irrigation schedules in both years. But P-uptake significantly varied due to different irrigation schedules in both years because of variations in seed and haulm yields. Like in case of N uptake,
crop irrigated at 50% soil moisture depletion had the lowest seed and haulm yield in first year which resulted to the minimum P uptake among all the irrigation schedules. Remaining irrigation schedules under each criterion of scheduling irrigation had almost comparable P-uptake by the sunflower. But in second year, the highest frequency significantly produced maximum seed and haulm yields which reduced by decreasing the irrigation frequencies under all criterion for scheduling the irrigation. Therefore, the P-uptake was maximum with highest irrigation frequencies and reduced correspondingly with every decreasing in the irrigation numbers. However, the differences in closer levels were not much. Better absorption of nutrient and then its translocation in the plants under adequate supply of water resulted to superior growth which increased the uptake. Hence, three irrigations given at important growth phases of the crop resulted to more P-uptake than 4 irrigations applied at 1.0 IW/CPE or 20% depletion of soil moisture.

**K-uptake:**

The K-uptake by sunflower did very due to different irrigation schedules during first year because similar seed and haulm yields and K-contents there in. But crop irrigated at 50% soil moisture depletion had significantly the lowest K-uptake during this year because of the minimum seed and haulm yields. In second year, the highest irrigation frequency significantly removed
maximum K by the plants as a results of highest seed and haulm yields which reduced by each decrease in irrigation frequencies under each criterion of scheduling the irrigation.

As a whole, the moisture stress by decreasing the irrigation frequencies probably decreased the root growth and ability of root surface to absorb the nutrients by affecting the metabolic activity of the plants. Under moisture stress conditions, soil becomes progressively drier and water film around the soil particles becomes thinner, thereby the rate of diffusion of certain elements to root decreases. Because of moisture stress at reproductive phases, root growth retarded or ceased at the time when demand of nutrient is high, plants become increasingly dependent on the flow of nutrient through soil to root surface. Conclusively, irrigating crop as per need of water increases the active life period of leaves and evapo-transpiration rate causing higher absorption by plants which in turn results in increased nutrient uptake. These results also corroborated the findings of Dhaka and Agrawal,(1981); Patel et al. (1988); Tripathi and Sawhney (1989) and Nalayini and Sankaran (1993).

**Effect on Economic Viability:**

Analysis of economic factors of the treatments have the importance of practical value in agricultural investigations. Monetary gain under a particular treatment could be assessed in
two ways. In one way to obtain the maximum monetary returns per unit area of land and per unit time. This assessment is considered to be good for rich farmers and for national production and economy points of view. Another way for assessment of monetary advantages is net monetary return per unit area or profitability (benefit-cost ratio) which is considered a good assessment for medium and poor categories of farmers who can not afford much investment on crop production. For the first way of assessment, the high production technology with high investment can be adopted, while for second assessment, most remunerative production technology of a crop according to availability of funds for investment can be chosen to adopt the practice. Therefore, consideration of cost of cultivation for each treatment is essential. On the basis of existing market price of different inputs used under a particular treatment, the cost of cultivation for each treatment was determined. Sunflower cultivation required a common expenditure of Rs. 6080/- except to investment on irrigation (Table 17). An additional investment of Rs. 265/ha was needed for using only one irrigation and for each subsequent irrigation further required an investment of Rs. 190/ha.

**Gross monetary return:**

Application of 4 irrigations at 20% soil moisture depletion led to register the maximum gross monetary return (Rs. 10340/ha) which was at par to those obtained with 4 irrigations at 1.0 IW/
CPE (Rs. 9810/ha) and 3 irrigations at 8-9 leaf + flowering + grain filling stages (Rs. 10090/ha). Three irrigations with 0.8 IW/CPE fetched the gross monetary return of Rs. 9470 /ha which was at par to 4 irrigations at 1.0 IW/CPE (Rs. 9810 /ha). The difference in gross profit between the closer frequencies was not much appreciable and it reduced with decrease in irrigation numbers under each criterion of scheduling the irrigation. Only one irrigation with 0.4 IW/CPE resulted the gross monetary return of Rs. 7810/ha which was significantly higher when one irrigation with 50% soil moisture depletion (Rs. 6500/ha). Scheduling 2 irrigations at any two important physiological growth stages resulted to the gross monetary return of Rs. 9060 to 9140/ha which was at par to those obtained with 3 irrigations at 30% soil moisture depletion (Rs. 8990/ha) and with 1.0 IW/CPE (Rs. 9470/ha). Thus, it could be said that scheduling irrigations on the basis of critical growth stages of the crop was most promising on economic point of view.

Net monetary return:

Net monetary return is the actual monetary gain by a particular treatment, as it is determined by subtracting the cost of cultivation of the treatment from the values of output realized. It is evident from the results that 4 irrigations at 20% depletion of soil moisture led to record the maximum net profit of Rs. 3425/ha closely followed by 3 irrigations applied at critical stages of crop
(Rs. 3365/ha). Four irrigation at 1.0 IW/CPE (Rs. 2895/ha) proved to be less remunerative than 4 irrigations at 20% soil moisture depletion and even 3 irrigations at important physiological growth stages. The net profit reduced markedly by decreasing the irrigation frequencies under each criterion of scheduling irrigation intervals. Only one irrigation with 50% soil moisture depletion resulted into the lowest net profit (Rs. 155/ha), while one irrigation with 0.4 IW/CPE resulted in to increased net profit of Rs. 1465/ha.

When the net profit under 2 irrigations was compared, irrigations applied at 8-9 leaf + flowering stages gained the maximum net profit of Rs. 2615/ha which was at par to those obtained by irrigating the crop at flowering + grainfilling or 8-9 leaf + grainfilling stages (Rs. 2535/ha), 0.6 IW/CPE (2275/ha) and at 40% soil moisture depletion (Rs. 2375/ha). Thus, it further confirmed that scheduling irrigation on the basis of critical growth stages of sunflower was most economical than other criteria of scheduling the irrigation.

**Profitability:**

It also refers as benefit-cost ratio. It gives an idea about the profit over each rupee of investment on irrigation. The profitability was maximum (1.50) with 3 irrigations applied at 8-9 leaf + flowering + grain filling stages of the crop, which was comparable to 4 irrigations at 20% depletion of soil moisture
(1.49). Though the gross and net profit per hectare was higher with 4 irrigations at 20% soil moisture depletion than 3 irrigations at critical growth stages, the later had higher profitability because of less cost of cultivation almost with the comparable seed yield. Two irrigations applied at critical growth stages had the benefit-cost ratio between 1.38 to 1.39 which was at par to those obtained with higher irrigation frequencies based on soil moisture depletion pattern (1.33) and IW/CPE ratio (1.40). The profitability of 2 irrigations at critical growth stages was higher than two irrigations with other criteria of scheduling irrigation.

On looking the overall picture of the economic analysis, it could be summed up that irrigating sunflower on the basis of critical growth stages was most remunerative, and 8-9 leaf and flowering stages appeared to be most important for increasing the monetary profit.