CHAPTER II

REVIEW OF LITERATURE
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The requirement regarding the number of irrigation and their timings vary widely for different crops. Earlier workers determined the water requirement of crops by considering the transpiration of the potted plants. But the values under potted condition were quite different than those obtained under field conditions. Thus, this concept has not much practical utility so far as irrigation scheduling for field crops was concerned. This work was later on followed by field experimentation in which arbitrarily selected depth of irrigation in cm (delta) and intervals of irrigation were tested for deciding irrigation schedule of crops. This practice also did not prove scientifically correct because soil moisture status at the time of irrigation and rainfall received during crop growing season or irrigation intervals were not taken into account. After this, a real break through in timing of irrigation was made, when field experiment based on the soil moisture regimes concept were conducted for various crops. According to this concept, the water content of soil at field capacity (the upper limit of the regime) was considered as 100% available for the crop growth and that the permanent wilting point as 0% available. The safe limit of available soil moisture depletion (the lower limit of the regime) for a crop was determined by experimentation and it was taken as a criterion for scheduling irrigations. This approach will work under a given soil and climatic
conditions.

**Effect of irrigation Schedule Based on Physiological Growth Stages:**

Artificial application of water to crop is essential to maintain the optimum water balance in crop plants to regulate the vital physiological processes of the plants. Deviations from an optimum plant water balance are commonly manifested as qualitative and quantitative reduction in the yield. Water requirement of crops vary with the stage of its growth, when water supply is limited. Hence, it is necessary to take into account the critical stages of crop growth with respect to decide irrigation schedule. The term critical stage is commonly used to define the stage of growth when plants are most sensitive to shortage of water. Each crop has certain critical stages at which, if there is shortage of moisture, yield is reduced drastically. When there is shortage of water, it is better to take care of the critical stages first to obtain increased water use efficiency. Therefore, it is imperative to delineate the physiological stages those are critical for water needs of the crop so that irrigation schedule could be tailored to avoid moisture stress during such stages.

According to Roblein (1967), flowering phase of sunflower (20 days before and 20 days after flowering) is most sensitive to moisture stress.
On the basis of results of field experiments conducted on safflower a Rabi oilseed crop synonymous to sunflower at different locations, several workers emphasized that seed yield increased substantially over unirrigated control (Suryanarayana, 1975; Mahapatra and Singh, 1974; Bhan, 1976, Rao et al., 1977, Bajpai et al., 1978, Raghu and Sharma, 1980). They added that scheduling of irrigation on the basis of critical growth stages approach would be more appropriate particularly when irrigation facilities are limited.

Alessi et al. (1977) emphasized that irrigation to sunflower at 50% flowering stage was most effective in north central region of U.S.A. They observed significant positive corelations between seed yield and water use at 50% flowering stage of crop.

On the basis of the results of a 3-year field experimentation on sunflower during winter season at Pune (Maharashtra), Jadhav and Jadhav (1978) concluded that two irrigations applied at initial (I) and flowering (FL) stages gave maximum seed yield which was comparable to three irrigations given at I + FL + capitulum initiation (CI) or grain development (GD) stages. These irrigation schedules significantly produced more seed yield as compared to one irrigation given at any one of the above growth stages. Irrigating crop at I+FL stages proved significantly superior than irrigation at CI+GD, CI+FL, I+GD and I+CI stages. Similar results of irrigation schedules
based on growth stages of the crop were also reported by Singh et al. (1974) from Agra (U.P.), Bhan (1976) from Kanpur (U.P.) and Raghu and Choubay (1978) from Jabalpur (M.P.).

Hegde and Havanagi (1980) reported that consumptive use of water increased with increase in number of irrigation at all sensitive physiological growth stages of sunflower. However, water use efficiency exhibited the reversed trend.

Patel and Singh (1980) stated that optimum water supply has growth promoting effects on most of the physiological processes in sunflower and consequently, the growth, yield attributing parameters and seed yield increased with the presence of adequate moisture due to rapid cell division and cell-elongation.

Dhaka and Agrawal (1981) stated that optimum use of irrigation water helped to increase the nutrient availability by sunflower and ultimately produced higher seed yields than unirrigated crop as well as the crop faced moisture stress at important growth stages.

According to Rajput et al. (1981), application of 2 or 3 post sowing irrigations at an interval of 30 days coinciding with early growth, maximum flowering and grain development stages gave significantly higher grain yield of sunflower than irrigating it only one of the above stages or no irrigation at Kernal (Haryana).
Jana et al. (1982) reported that plant height, LAI and DM accumulation/plant and seed yield significantly increased in sunflower by supplying irrigation at early growth, bud formation and full flowering stages than missing the irrigation at any of the above stages.

Lindstrom et al. (1982) reported that sunflower’s capacity to yield well under water stress was due to a drought escape mechanism rather than lower water requirement. They also stated that its flowering stage was more sensitive to moisture stress.

Rawson and Turner (1982) concluded that sunflower had capacity to recoup the loss in reduction of earlier leaf area due to moisture stress once it is alleviated.

Unger (1982) emphasized that early vegetative and flowering phases of sunflower were most critical for irrigation. He also stated that DM production/plant and LAI increased due to irrigation at these stages which had strong positive relationship with seed yield.

Rawson and Turnor (1983) emphasized that moisture stress at flowering phase of sunflower reduced the LAI which could not be recouped in later stages and resulted in reduction of grain yield. They added that LAI at flowering had strong positive association with seed yield.
Nageshwar Rao et al. (1985) reported that moisture stress to peanut (*Arachis hypogea* L.) at flowering stage caused maximum reduction in pod yield at Hyderabad (A.P.)

Pawar et al. (1987) studied the effect of scheduling irrigation on the basis of critical growth stages approach on grain yield of safflower (*Carthamus tinctorius* L.) varieties. They concluded from the results that three irrigations each given at immediately after sowing, branching and flowering stages gave maximum seed yield. If only two irrigations are available, those should be given at sowing and branching stages. Maximum consumptive use of moisture was observed where three irrigations were applied. Irrigation only at sowing recorded the lowest consumptive use of water with the highest water use efficiency (WUE).

Hegde (1988) evaluated the effect of moisture stress during different growth stages on growth and yield of sunflower with particular reference to leaf area survival at Bangalore (Karnataka). Treatments evaluated were (i) no stress, (ii) moisture stress during vegetative (0-21 DAS), (iii) moisture stress during flowering (22 to 43 DAS), (iv) moisture stress during late flowering (44 to 65 DAS) and moisture stress during seed filling (66 DAS to harvest) stages of crop growth. In case of no stress, 5cm depth of irrigation was given whenever cumulative pan evaporation (CPE) totalled to 50 mm. In case of moisture stress treatments, irrigation was given
only when soil moisture content in the top 0-30 cm layer reached to permanent wilting point (4.80%). From the results he concluded that late flowering followed by seed filling stages were the most critical in respect of moisture stress. Yield reduction due to moisture stress at vegetative phase, early flowering, late flowering and seed filling stages was to the extent of 16.4, 14.0, 27.3 and 23.5% respectively over no stress. He underlined that yield parameters like seed yield/plant, seed filling percentage mainly attributed to these variations in seed yields. He also mentioned that sunflower tolerated the moisture stress which experienced during early part of the crop growth, thus it has the capacity to revive the lost leaf area due to moisture stress during early vegetative growth once it is favorably alleviated later. Leaf area index at flowering had positive correlation with seed yield.

According to Hegde (1988 B) late flowering and seed filling stages were the most sensitive in respect of moisture resistance for irrigating sunflower crop.

At Navsari (Gujrat), Chaudhary and Patel (1994) seen that sunflower crop irrigated at 4-5 leaf stage (L)+bud formation (B)+ 50% flowering (F) + grain development (G) stages gave the heighest seed yield which was at par to those obtained with irrigation at L+B+F stages. They also observed that only two irrigations given at any of the two growth stages produced significantly
lesser seed yields than 3 or 4 irrigations. The moisture stress in plant body at any growth stages up to flowering stage resulted in reduced turgidity in plant cell and leaf expansion. They also noted that seed yield was mainly attributed due to increased plant height, leaf are index and D.M. production/plant under adequate availability of water.

Sharma (1994) found that irrigation to sunflower CV EC 68415 at pre sowing, 8-9 leaf (L) and pre flowering (F) stages produced higher seed yield than missing of irrigation either at L or F stages in clay loam soil of Jabalpur during Rabi season.

Kavi et al. (1994) noted that Kharif sunflower grown under rainfed condition at Raichur (Karnataka) suffered badly, when there was moisture stress particularly during flowering and seed development stages.

Tomar and Sharma (1994) stated that four irrigations given at different >growth stages of sunflower including one irrigation given for germination (I₁) gave significantly higher seed yield than irrigating only for germination (I₂). They also added that plant height, DM production/plant, head-diameter and seeds/head significantly higher with I₁ than I₂. The WUE also increased in I₁ over I₂, but difference was not significant.
From Calcutta, Sarkar and Chakraborty (1995) reported that three irrigations (1 each at 30, 40 and 50 day growth stages) for sole and two irrigations (1 each at 30 and 40 days) for intercropped stands of sunflower were optimum irrigation schedules during winter season. They also mentioned that yield attributing characters viz. head-diameter and 100-seed weight were superior with 3 irrigations in sole stand and with 2 irrigations in intercropped stand.

Katare and Bansal (1995) observed that two irrigations (at branching and flowering) was at par to two irrigations at branching +seed setting and 3 irrigations at branching + flowering + seed setting stages and these were significantly superior over only one irrigation given at any of the above stages.

According to Giri (1995), rosette termination and flowering stages were most critical growth stages for irrigation in safflower at New Delhi.

Singh et al. (1995) reported that irrigation based on physiological stages viz. 25 DAS, initiation of flower buds, mid flowering and seed setting stages of sunflower were critical for scheduling the irrigations. They emphasized that application of irrigation water in sunflower improved oil content in seeds. Based upon the above facts, it may be summed up that there should be
adequate soil moisture for germination of sunflower seeds. There
after, this crop should not be faced moisture stress at various
physiological growth stages viz. early vegetative growth, flowering
and grain filling phases. Flowering phase of the crop appeared to
be most critical for irrigation in sunflower

Effect of Irrigation Schedules Based on Climatological
Conditions:

Soil moisture is the main source of water to the plant.
Soil moisture is orderly depleted through the uptake by the crop
plants as well as through evaporation from the soil surface. The
water absorbed by plants is also lost by transpiration besides its
utilization in various physiological processes. When the rate of
transpiration becomes greater than the uptake of water from the
soil, then plants experience water deficit resulting in poor growth
of plants. To maintain the desirable water balance in the plants,
irrigation becomes a must. A concept of irrigating the crop based
upon climatetical conditions influencing evaporation and transpiration
losses of water has been developed. It is the approach of irrigation
which is based upon the ratio of irrigation water and cumulative
pan evaporor-meter. According to climatological approach, water
use by the crops is primarily a function of the evaporation demand
of climate, provided there is an adequate moisture supply ground
is fully covered and the crop is actively growing. This approach
seemed to be most economical and optimum schedule of irrigation.

From Meerut (U.P.), Tomar et al. (1977) reported that irrigations scheduled at 0.8 IW/CPE ratio produced significantly taller plants with more number of leaves and seed yield/plant compared with 0.4 IW/CPE ratio in spring sunflower. Irrigation with 0.8 IW/CPE gave nearly 34.4% higher seed yield over 0.4 IW/CPE.

Bhan et al. (1980) reported that increased number of irrigation (75mm CPE) reduced the percentage of unfilled seeds/head than lower frequency of irrigation in sunflower.

Chavan and Pawar (1980) underlined that irrigation at 1.0 to 1.2 IW/CPE ratio were sufficient for increased dry matter production of wheat in black clayey soil of Parbhani (MS). They also stated that increased dry matter production with adequate irrigation attributed to superior yield attributes and ultimately produced higher grain yield.

After considering climatic factors for scheduling irrigation, D. Amoto and Giordano (1983) suggested that irrigating sunflower with 2 or 3 irrigations at 0.6 IW/CPE gave the best results in Italy.

While studying the relationship between pan evaporation and soil moisture status in wheat at Parbhani (M.S.) Chavan and
awar (1987) emphasized that the relationship between these parameters was significantly negative and quadratic in nature. They stated that soil moisture content reduced with the increase in pan evaporation but the rate of decrease in soil moisture percentage was diminishing with corresponding increase in cumulative evaporation because the moisture is held by soil particles more tightly at low moisture condition. Similar result were reported by Shinde and Pawar (1983) in groundnut at parbhani (M.S.).

From Junagarh (Gujrat), Chaniara et al. (1989) recorded significant increase in seed and stower yields of winter sunflower with irrigations given at 0.7 to 0.9 IW/CPE ratio over 0.5 IW/CPE ratio in medium black soils of Junagarh (Gujrat). They also observed response of sunflower upto 80 kw N/ha under adequate irrigation which dropped to the limit of 60 kg N when crop received irrigation at 0.5 IW/CPE.

Shinde et al. (1990) studied irrigation schedule of 75,100 and 125 mm CPE and as per canal rotation on sunflower varieties during summer season at Rahuri (MS). From the results, they reported that plant height, dry matter accumulation/plant and grain yield/ha did not significantly differ due to these irrigation schedules. They also seen that oil and protein contents in seeds showed rising trend due to increase in the level of irrigation.
Based upon the results of a field experiment conducted to assess the optimum schedule of irrigation for summer sunflower, Thosar et al. (1991) observed that sunflower varieties surya, EC 6844 and Morden gave higher seed yields when irrigated at 75 (10 irrigations) or 90 (9 irrigations) mm CPE than 105 (8 irrigations) or 120 (6 irrigations) mm CPE. There was significant reduction in yield with increasing irrigation intervals. Plant height and yield attributing characters viz. Seed yield/plant and filled seed percentage showed decreasing trend with increasing irrigation intervals. They also concluded that high yielding potential of these varieties can be achieved with 9 and 10 irrigations at 90 and 75 mm CPE respectively during summer season on medium black soils of Vidarbh region of Maharashtra. These results also corroborated the earlier findings of Sinde et al. (1987) from Rahuri in Maharashtra.

Under mid-hill conditions of Himanchal Pradesh, Vivek and Chakor (1992) found that intensive irrigation schedule of 0.9 IW/CPE ratio significantly increased plant height, LAI and number of functional leaves, size of head and number of seeds/head in sunflower over no irrigation and low intensive moisture regimes viz. 0.3 and 0.6 IW/CPE.

According to Dahiphale and Pawar (1993), plant-height, leaf area and dry matter accumulation of winter sunflower was significantly more by scheduling irrigation with 1.0 IW/CPE ratio,
whereas irrigations scheduled at 0.8 and 0.6 IW/CPE ratio were at par and both proved significantly superior over 0.4 IW/CPE at Parbhani (M.S.).

Pawar et al. (1993) found that scheduling irrigation at 75 mm (about 9-10 irrigations each of 6 cm depth) was better for summer sunflower in medium deep clayey soils of Rahuri (M.S.) under semi arid climatic conditions. They underlined that irrigation and seed yield relationship was quadratic.

At Dharwad, Nimbal and Doddamani (1993) recorded maximum WUE (4.1 kg/ha/mm) with irrigations at 0.6 IW/CPE which was significantly higher than irrigations at 0.4 (3.60 kg/ha/mm) and 0.8 (3.58 kg/ha/mm) IW/CPE. Higher WUE of 0.6 IW/CPE as compared to 0.4 and 0.8 IW/CPE was attributed to higher yield levels per unit of water depleted. The oil content in seed increased, correspondingly with increase in irrigation water from 0.4 to 0.8 IW/CPE (37.2 to 40.3%) mainly due to increased seed plumpness in presence of adequate soil moisture.

Patel and Patel (1993) reported a linear increase in seed yield of Rabi sunflower upto 0.6 IW/CPE while testing four IW/CPE ratios (0.30, 0.45, 0.60 and 0.75) on clayey soil of Navsari (Gujrat). After this a slight decrease in yield was recorded. Maximum seed yield (14.3 q/ha) was with 0.60 IW/CPE which was on par
with 0.75 IW/CPE (14.2q/ha). There was progressive increase in consumptive use of water with the increase in irrigation frequency under varying IW/CPE ratios but water use efficiency was reversed.

In clay loam soils of coimbatore (Tamilnadu), the moisture regimes based on climatological approach viz. 0.5, 0.75 and 1.0 IW/CPE were tested during both Kharif and Rabi seasons for two years (Nalayini and Sankaran, 1993). They observed maximum nutrient uptake under high moisture region which was comparable with medium moisture regime. Kharif crop gave higher oil yield than the Rabi crop. The oil content was high in medium moisture regime which was 38.9 and 33.5% during Kharif and Rabi respectively. The protein content was maximum in high moisture regime followed by medium moisture regime.

Vivek et al. (1994) compared three moisture regimes (0.3, 0.6 and 0.9 IW/CPE) with rainfed conditions at Dhaula Kaun (H.P.) and concluded from the results that 0.9 IW/CPE ratio was the best irrigation schedule for sunflower c.v. morden. They underlined that an increase in the intensity of irrigation significantly increased the seed yield over rainfed crop and lower irrigation levels.

Venkanna et al. (1994) found that irrigation scheduled with 0.6 and 0.8 IW/CPE ratio during vegetative phase and 1.0 at later stage gave higher seed yield of sunflower than other schedules.
of irrigation in sandy loam soils of Andhra Pradesh.

From the results of a three year experimentation in sandy loam soil of Sriganga Nagar (Rajasthan), Singh et al. (1995) concluded that post sowing irrigation to sunflower cv. MSCH-8 along with irrigation at 0.8 IW/CPE had superior growth and yield attributes which resulted in higher seed yields with more oil and protein contents. They also added that irrigating crop with 0.8 IW/CPE needed 4 irrigations which normally coincided with important physiological growth stages viz. leg (early growth), flower bud initiation, mid flowering and seed setting stages.

Reddy and Kumar (1997) studied the effect of irrigation schedules based on IW/CPE ratio on the performance of winter sunflower in sandy loam soil of Jagtial (A.P.). From the results they concluded that DM production/plant and Seeds/Head significantly increased with the increase in irrigation frequencies from 0.4 to 1.0 IW/CPE ratio. They also added that WUE was higher under lower frequencies of water supply than higher frequencies. They underlined that 0.8 IW/CPE ratio needed 5 irrigations which normally coincided with seedling, button, flowering, seed filling and grain development stages of the crop.

It is obvious from the above points that scheduling of irrigation sunflower can not be considered in isolation from that of
climatic factors. Irrigating crop based upon IW/CPE ratio seems to be most efficient and economical use of irrigation water. Depending on the growing in season and soil type, sunflower gave better yield with 0.6 to 0.8 IW/CPE irrigation schedules.

**Effect of Irrigation Schedules Based on Soil Moisture Depletion:**

Efficient water management is the most important and dynamic single factor which influences the final yield of crops to an appreciable extent. Soil moisture is a life sustaining factor for the crop and as such has engaged the attention of research workers from time to time. Soil moisture plays an important role in study of the optimum water for a crop. The hygroscopic water in a soil is not available for plant growth and hence disregarded in considering irrigation needs. Only when soil moisture increases beyond 50% above its content of hygroscopic water, it is taken by the plants for economic utilization of water. Water must be delivered to the field in such manner that the water content of the soil within the root zone at time should never fall below the wilting coefficient of soil and shall never exceed the field capacity (Full load capillary capacity) of the soil. The soil water is the main source of water which is not only essential for plant life, but is also helps to absorb the essential food materials. Scheduling of irrigation based on soil-moisture depletion pattern (Soil moisture
regimes) seems to a recent interest, because it helps in economic utilization of water particularly when availability of irrigation water is limited.

Michael (1978) underlined that maintenance of a soil moisture level of 50% in the effective root zone gave the most economical yields of Kharif Sunflower in several experiments.

Andhale and Kalbhor (1980) postulated that increasing irrigation frequencies up to optimum level resulted in increasing the dry matter accumulation in sunflower crop at Rahuri (M.S.). They also added that increased LAI with irrigation mainly attributed to higher DM accumulation.

Lindstrom et al., (1982) reported that sunflower's capacity to yield well under water stress was due to drought escape mechanism rather than lower water requirements.

Sarkar (1985) emphasized that increasing water supply from deficient to optimum range contributed to better growth and yield of sunflower.

Khanvilkar et al. (1987) revealed that seed yield of spring sunflower significantly increased up to two irrigations and oil yield up to only one irrigation in deep alluvial loam soil of New Delhi. They further emphasized that during the year with excess
rainfall neither the growth and yield attributes of plant nor the seed and oil yield were influenced due to irrigation. They also added that CWU by sunflower increased with irrigations but WUE was highest in plots with one irrigation.

At Coimbatore (T.N.) Jaya Kumar et al. (1988) demonstrated that oil yield of irrigated sunflower was comparable with high and medium soil moisture regimes because of high oil content in seeds with medium moisture regime, but seed yield was higher with high moisture regime.

At L unhiana (Punjab), Tripathi and Sawhney (1989) recorded significant increase in N, P and K uptake by sunflower with increase in the available soil moisture content, the difference being more pronounced when crop experienced hot and dry weather conditions during its reproductive phase. Protein content in seeds was not affected by irrigation levels, where as oil content significantly increased under wet regimes over dry regimes.

While studying the response of sunflower to different moisture regimes on sandy loam soils of Jhar gram (West Bengal), Zaman and Das (1990) reported that sunflower responded upto 42.9 cm of water/ha.

Dhavalagi et al., (1990) reported that irrigating sunflower by alternate furrow method reduced the soil moisture depletion
pattern which helped in saving of 40% irrigation in black clay soils of Dharwad (Karnataka).

During studying the effect of saline water irrigation in sunflower grown on coastal saline soils of Sundarban (W.B.), Bhattacharya et al. (1991) recorded that increased irrigation helped to increase LAI and DM accumulation per plant which gave higher seed yields than lower frequencies of irrigation.

From Hyderabad (A.P.), Sundhakar Babu et al. (1997) reported that ground nut plants grown in 20 cm effective soil depth produced significantly higher number and weight of nodules, total (DP) and leaf area/plant than those in plants of 10 and 15 cm depth. Number of pods/plant, kernal weight/plant also increased at 20 cm effective soil depth than shallow depths.

Thus, it is concluded that no systematic attempts were made to study the irrigation schedules of sunflower under varying agroclimatic conditions in the country where water requirement vary with the type of soil; As the moisture regime concepts can suitably be applied to decide the irrigation schedule of sunflower, the study on this aspect is imperative.

It is obvious from the overall picture of above reviews that the soil, the plant and the climatic factors influence the water
need of the crops. Therefore, it is imperative to decide the proper approach as well as scheduling of irrigation for efficient use of irrigation water.