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CHAPTER 9

Irrigation Practices for Major Field Crops

OBJECTIVES

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Irrigation water is a manageable input in crop production. As such, it should be managed on scientific lines to optimise crop production by avoiding excessive applications leading to waterlogging and wastage of scarce irrigation water. The aim is not necessarily to obtain highest yield per unit land area or even per unit of applied water, but to maximis the net returns, not just for a given season, but also in the long run. Since the soil and climatic conditions under which the crop is grown and the crop management practices differ to a large extent from place to place, there can be no single acceptable recommendation on irrigation water management practices to any crop. Results of experiments on water management practices for major field crops through out the country for the last three decades may serve as a guide for efficient use of scarce irrigation water to optimise crop production. Results of All India Coordinated Research Project on Water Management (AICRPWM), reported by Yadav et al (2000) and others on major field crops from different regions are briefly presented.

9.1. CEREALS AND MILLETS

Rice and wheat are the two major cereals of the country. Rice is cultivated through out the country while wheat is the major crop of relatively cooler parts of north India. Except maize, the area of other millets under irrigation is relatively low.

9.1.1 RICE

Irrigated rice is largely cultivated under conditions of **land submergence** all through the country except in the states of West Bengal, Assam, Kerala and parts of Orissa, Madhya Pradesh and Uttar Pradesh where it is grown as a rainfed crop. Lowland (irrigated) rice requires more water than other crops of similar duration due to land submergence. Depending on the environment in which the crop is cultivated, 50 to 70 per cent of the applied water is lost in deep percolation and about 200 mm of water is necessary for land preparation (Table 9.1).

Table 9.1 Water requirement of irrigated lowland rice (Kung 1971).

Losses	*Quantity*
By water loss	
Transpiration	1.5 to 9.8 mm day^{-1}
Evaporation	1.0 to 6.2 mm day^{-1}
Percolation	0.2 to 15.6 mm day^{-1}
Range of daily loss	5.6 to 20.4 mm day^{-1}
By field operation	
Nursery	40 mm
Land preparation	200 mm
Field Irrigation	1000 mm
Total	1240 mm

The amount of water used at field level is 20,000 m^3 t^{-1} with poor water management and 3,000 m^3 t^{-1} with good management. Irrigation agencies, generally, take only "laissez faire" approach to measurement and control of water in canal command areas where rice is the major crop. A large proportion of the water making up the current system water requirements (Fig. 9.1- cover page) is used in lieu of added control and management (Levine 1965). Most irrigation systems of rice producing nations in Asia are operating at the left hand side of abscissa where the system water requirement is much higher than the actual requirement. It is desirable to incur added (incremental) costs in control and management to save added (incremental) units of water (ha-cm) until last unit of water saved has a cost equal to the cost of a replacement (alternative or new) source of water.

It has been reported that about 5000 l of water is required to produce 1.0 kg rice. Average production of grain (kg ha-mm^{-1} of water) is 3.7 for rice, as against 13.4 for fingermillet, 12.6 for wheat, 9.0 for sorghum, 9.2 for maize and 8.0 for pearlmillet. It is often said and agreed that seasonal water requirement for rice varies from 750 to 1500 mm day^{-1} with an average of 1200 mm. If irrigation period is assumed to be 120 days, the average requirement will be 10 mm day^{-1}, which appears to be reasonable on the condition that land submergence is the usual practice with a minimum of 2 mm day^{-1} percolation and seepage losses (Reddy 2004).

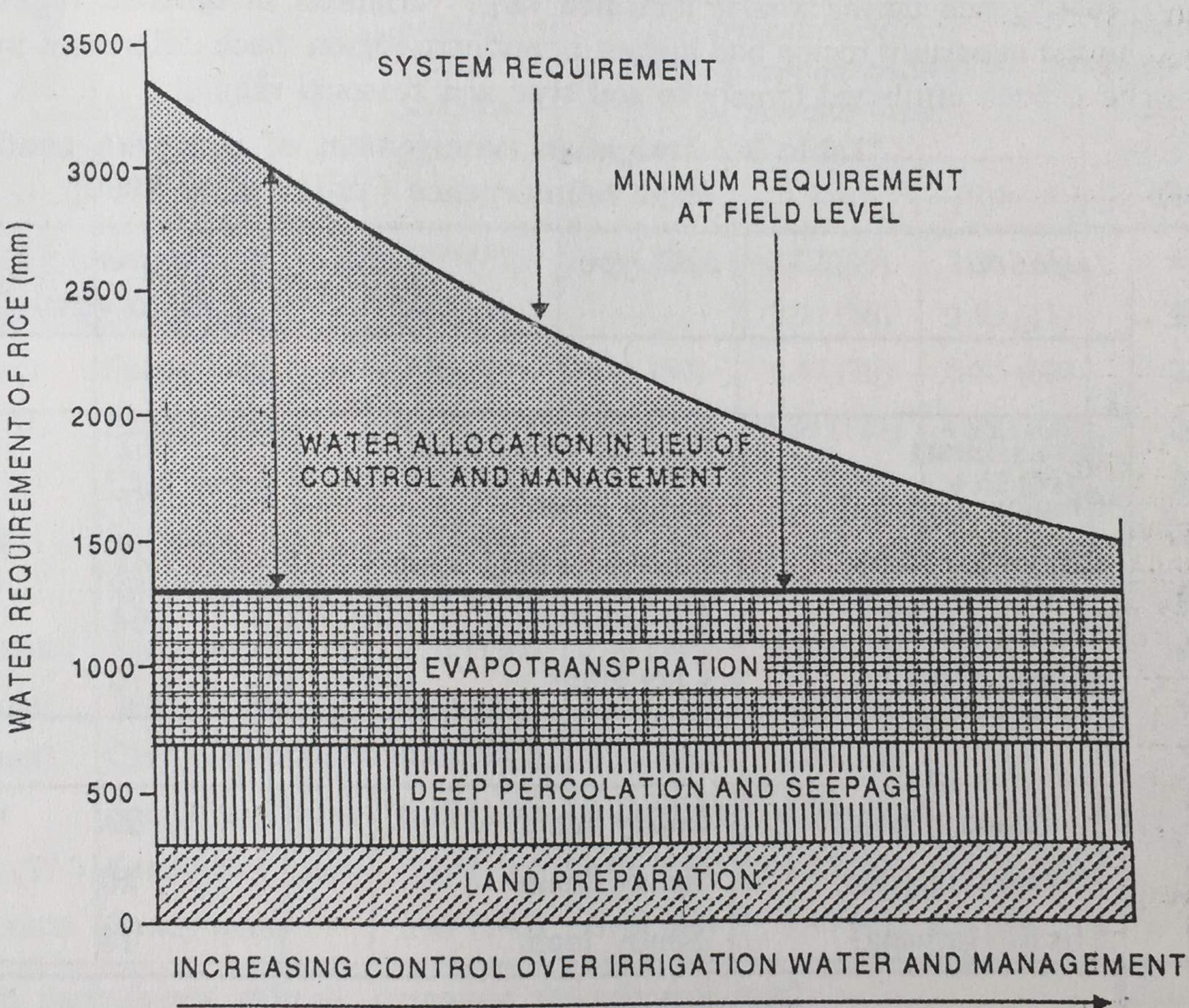

Fig. 9.1 Importance of control and management on system water requirement for rice irrigation (Levine 1965).

As per Kung (1971), the total water loss from rice fields ranges from 5.6 to 20.4 mm day^{-1}. However, most observed losses range from 6 to 10 mm day^{-1}. On an average, a total of 1,240 mm is the water requirement of rice (Table 9.1).

Rice crop has been found to perform better under the conditions of land submergence due to:

- Relatively weed free environment leading to efficient use of inputs by the rice crop
- Increased availability of nutrients, especially phosphorus, potassium, calcium, silicon and iron

- Reduced loss of nitrogen from rhizosphere placed ammonium fertilisers due to reduced soil conditions
- Fixation of atmospheric nitrogen by blue-green algae and other microbes due to favourable environment
- Regulation soil temperature within the rang, ideal for optimum growth and development of the crop.

Weed free environment due to continuous land submergence appears to be the major reason for the preferred land submergence. With increasing scarcity for irrigation water, there is need for a look back on the practice of continuous land submergence for sustainable rice production. Extensive field studies to quantify the irrigation requirement of rice with continuous land submergence during *kharif* indicated large variations in different regions (Table 9.2). It was lowest in eastern region and highest in northern region. Such differences in irrigation requirements have been attributed largely to soil type and seasonal rainfall.

Table 9.2 Irrigation requirement of rice with continuous land submergence (Yadav et al 2000).

Location	*Soil type*	*Seasonal rainfall (cm)*	*Irrigation requirement (cm)*
Eastern region			
Pusa (Bihar)	Alluvial sandy loam	62	81
Chiplam (Orissa)	Sandy loam	57	95
Kharagpur (WB)	Lateritic sandy loam	41	197
Faizabad (UP)	Silt loam	64	65
Bilaspur (MP)	Clay loam	76	98
Northern region			
Ludhiana (Punjab)	Sandy loam	23	190
Karnal (Haryana)	Sandy loam	20	200
Hisar (Haryana)	Sandy loam	18	220
Western region			
Kota (Rajasthan)	Clay loam	30	145
Jabalpur (MP)	Black clay	73	132
Navsari (Gujarat)	Clay loam	29	169
Southern region			
Hyderabad (AP)	Black clay	45	184
Madurai (TN)	Sandy clay loam	38	128
Bhavanisagar (TN)	Sandy clay loam	22	136
Chalakudi (Kerala)	Sandy loam	43	140

In order to bring down the huge irrigation requirement under continuous land submergence, the approach of **intermittent land submergence** (irrigation after 1 to 5 days after the disappearance of ponded water) was tested in all the regions (Table 9.3). Irrigation 3 days after disappearance of ponded water appears to be reasonable in most locations. This schedule resulted in saving of 23 to 60 per cent irrigation water compared with continuous land submergence, without significant reduction in grain yield. If the water table is high, as at Madhepura, irrigation could be 5 days after the disappearance of ponded water. Even one day period considerably saved the irrigation water. Intermittent land submergence enables efficient use of rainfall and enables irrigating larger area with a limited water supply.

Table 9.3 Effect of intermittent irrigation on rice yield (Yadav et al 2000).

Location	*Soil type*	*Yield (t ha^{-1})*				*Saving in irrigation water with 3 days vs. cont sub (%)*
		Continuous land submergence	*Irrigation after disappearance of ponded water*			
			1 day	*3 days*	*5 days*	
Pusa (Bihar)	Sandy loam	3.59 (81)	3.47 (60)	3.22 (46)	2.85 (35)	43
Madhepura (Bihar)	Sandy loam	4.03 (35)	—	3.97 (16)	3.99 (11)	54
Chplam (Orissa)	Sandy loam	7.21 (99)	6.66 (90)	6.47 (76)	5.85 (68)	23
Kharagpur (WB)	Sandy loam	6.11 (197)	5.98 (150)	5.89 (129)	4.99 (108)	34
Bilaspur(MP)	Clay loam	5.86 (98)	5.59 (77)	5.13 (70)	4.62 (56)	29
Faizabad (UP)	Silt loam	3.77 (65)	2.94 (42)	—	—	—
Pantnagar(UP)	Silty clay loam	8.09 (121)	7.57 (112)	7.38 (90)	6.92 (60)	44
Ludhiana (Punjab)	Sandy loam	5.52 (190)	5.44 (145)	5.12 (113)	5.20 (96)	40
Hissar (Haryana)	Sandy loam	5.66 (220)	5.15 (196)	4.69 (126)	—	43
Kota (Rajasthan)	Clay loam	5.41 (145)	5.33 (86)	5.05 (68)	—	53
Madurai (TN)	Sandy clay loam	6.59 (128)	6.66 (104)	6.18 (82)	—	36
Bhavanisagar (TN)	Sandy clay loam	4.57 (136)	5.08 (110)	4.95 (80)	4.16 (55)	41
Chalakudy(Kerala)	Sandy loam	3.47 (140)	3.44 (63)	3.45 (49)	—	55

(Figurs in parentheses indicate irrigation requirement mm)

Recommended Irrigation Practices

Great economy in irrigation water could be achieved if suitable measures are adopted to minimise the deep percolation losses. Some of the recommended practices to economy in irrigation water use in rice cultivation are:

- Rice cultivation on heavy soils with percolation below 5 mm day^{-1}
- Since the seepage is proportional to perimeter of the area, rice should be grown in large blocks instead of in isolated plots
- Puddling to reduce soil permeability
- Subsoil compaction to minimise deep percolation losses

- Addition of bitumen, asphalt etc to the soil
- Application of tank silt to light soils
- Scrupulous land leveling.

Adequate irrigation water availability to meet the crop needs: If irrigation water in not a limiting factor for rice cultivation, continuous shallow land submergence with 5 cm water could be ideal to achieve the benefits of land submergence in *kharif, rabi* and summer seasons.

Limited irrigation water availability: Under the conditions of limited supplies, the following phasic land submergence could be optimum both for *kharif* and *rabi* crops:

- Maintain not more than 2 cm water depth at transplanting
- Up to 3 days after planting (establishment period), 5 cm land submergence is necessary
- Maintain 2 cm depth of land submergence from 3 days after planting to panicle primordial initiation
- From panicle primordial initiation to 21 days after heading, maintenance of 5 cm
- From 21 days after heading to harvest, gradual withholding of irrigation.

If the irrigation water is not adequate meet the above recommended schedule, the following intermittent land submergence could be followed during *kharif* and *rabi*:

- From transplanting to panicle initiation, irrigations could be 3 days after the disappearance of ponded water
- From panicle initiation to 21 days after heading, irrigation should be 2 days after the disappearance of ponded water
- From 21 days after heading to a week before harvest, irrigations may be given 5 days after the disappearance of the ponded water.

Limited irrigation water availability for summer rice crop: A short duration rice crop is transplanted around mid-April under well-irrigation, especially in south India to meet the family needs. The recharging capacity of wells, generally, goes down from April onwards, thus subjecting the crop to soil moisture stress around heading and grain development stages. The following irrigation practices are suggested under such situations:

- Since there is no scope to apply around 5 cm depth of water every day to the entire rice crop, about 2 cm of water may be applied every day to cover the entire area or irrigaton may be given on alternate days to cover the entire area.
- If the above practice could not serve the purpose, the crop may be irrigated 2 or 3 days after the disappearance of the applied water depending on the recharging capacity of the well
- In case the above practices could not serve the purpose, the only alternate to save the standing crop is to irrigating the crop by following check-flooding method of irrigation.

There is no scope for dividing the rice field into beds and channels using machinery or other farm equipment, without causing damage to standing rice crop, for check flooding. An alternative is to use sand to demarcate plots and forming channels for irrigation. This practice can minimise the deep percolation losses relative to wild flooding method of irrigation and aids in irrigating larger area than that with wild flooding.

Irrigation practices for rice crop on saline soils: If irrigation water is not a limiting factor, rice is usually a crop of saline soils. Recommended management practices for rice crop on such soils are:

- Aged seedlings, which can better withstand salinity, may be transplanted in 5 cm standing water
- Deep land submergence (around 8 cm) may be maintained during seedling establishment
- Periodical change of water to minimise salt accumulation
- Mid-season drainage at tillering
- Since flowering period is more sensitive to salinity, deep submergence (up to two-third plant height) should be practiced during flowering phase
- Flowing irrigation (flowing water from field to field) minimises accumulation of soluble salts.

The dwindling water resources suggest irrigated-dry crops during *rabi* and summer seasons instead of a rice crop as at present. Such a shift in cropping system leads to efficient use of scarce irrigation water to meet the increasing food needs of the country.

9.1.2 WHEAT

Wheat season commences after withdrawal of monsoon either as rainfed crop on stored soil moisture or as an irrigated crop. Studies on irrigation requirements of wheat are based on depletion of available soil moisture (DASM), critical growth stages for irrigation and climatological approaches.

On sandy loam soils of Hisar, four irrigations, one each at crown root initiation (CRI), flowering, milking and dough stages produced highest yield as against one irrigation at CRI. At Morena, on the other hand, five irrigations resulted in highest yield (Table 9.4).

Table 9.4 Wheat yield (t ha^{-1}) in relation to irrigation at different growth stages (Yadav et al 2000).

Growth stage	*No. of irrigations (6 cm depth)*	*Hisar, sandy loam*	*Faiza-bad, silt loam*	*Morena, sandy loam*	*Delhi, sandy loam*	*Jharg-ram, sandy loam*	*Irri req (cm)*	*Tot water use (cm)*
CRI	1	2.68	—	—	—	—	6	—
CRI+F	2	2.89	—	—	—	—	12	—
CRI+M	2	—	3.00	—	—	—	12	—
CRI+M+F	3	3.75	—	—	—	—	18	—
CRI+LJ+M	3	—	3.39	—	—	—	18	—
CRI+B+M	3	—	—	—	3.57	—	18	20.9
CRI+F+GF	3	—	—	—	—	1.29	18	19.3
CRI+LJ+M+D	4	—	3.70	—	—	—	24	—
CRI+F+M+D	4	4.4.2	—	—	—	—	24	—
CRI+T+J+F+M	5	—	—	3.30	—	—	30	—

(Irrigation requirement is exclusive of presowing irrigation. CRI = crown root initiation, F =flowering, M = milk, LJ = late jointing, D = dough, T = tillering, B = boot, GF = grain filling, J = jointing)

The IW/CPE approach has been effectively employed for scheduling irrigation to wheat crop. Grain yield of 4.6 t ha^{-1} at Navsari and 4.1 t ha^{-1} at Rahuri was obtained by scheduling irrigation at IW/CPE ratio of 1.05, which required 7 and 5 irrigations of 6 cm deep, respectively (Table 9.5).

Table 9.5 Wheat yield and irrigation needs at optimum IW/CPE ratio (Yadav et al 2000).

Location	*Soil type*	*No. of irrigations (6 cm depth)*	*Optimum IW/CPE ratio*	*Grain yield (t ha^{-1})*	*Irrigationon requirement (cm)*	*Total water use (cm)*
Belvatagi (Karnataka)	Clay	6 – 7	0.90	3.81	39	39
Bikramganj (Bihar)	Sandy loam	3	0.90	2.64	18	23.8
Bilaspur (MP)	Sandy loam	3	0.90	4.01	18	24.5
Chiplam (Orissa)	Sandy loam	4 – 5	1.05	2.70	24 –30	24–30
Faizabad (UP)	Silt loam	4	1.05	4.01	24	24
Hisar (Haryana)	Sandy loam	6	1.05	3.85	36	37
Kharagpur (WB)	Silt loam	5	0.75	2.82	30	33.6
Kota (Rajasthan)	Clay loam	4	0.80	3.98	24	24
Madhipura (Bihar)	Loamy sand	2	0.60	2.40	12	12
Navsari (Gujarat)	Clay	7	1.05	4.60	42	42
Pantnagar (UP)	Silty clay	2	1.05	4.22	12	12
Rahuri (MS)	Clay	5	1.05	4.10	30	30
Parbhani (MS)	Clay loam	6	0.75	2.41	36	41.2
Sriganganagar (Rajasthan)	Sandy loam	4	1.05	5.40	24	24

On light soils, grain yield around 4 t ha^{-1} was obtained at IW/CPE ratios varying from 0.6 to 1.05. On sandy loam soils of Bikramganj and Bilasapur, grain yield of 2.64 and 4.01 t ha^{-1} were obtained at 0.9 ratio, requiring 3 irrigations. Several other studies at different places indicated necessity for irrigation at CRI, CRI and tillering, CRI, tillering and flowering, depending on the availability of irrigation water, for realising optimum wheat yield.

Recommended Irrigation Practices

Based on the results of experiments, the following general conclusions can be drawn on irrigation practices for wheat:

Critical stages approach: In general, 4 to 6 irrigations are needed for optimum yield under different soil and weather conditions as indicated in Table 9.6.

Table 9.6 Critical stages for soil moisture stress and irrigation needs depending on the availability of water.

Available irrigations	*Critical stages*
1	CRI
2	CRI + late jointing (LJ)
3	CRI + boot (B) + milk (M)
4	CRI + late tillering (LT) + LJ + flowering (F)
5	CRI + LT + LJ + F + M
6	CRI + LT + LJ + F + M + dough (D)

Climatololgical approach: As indicated already, this approach has been tested extensively under different conditions.

- Scheduling irrigation at IW/CPE ratios of 0.9 to 1.05 with 6.0 cm depth is ideal for optimum yield. Depending on the climatic conditions, 4 to 6 irrigations may be necessary during the season.
- When the available irrigation water cannot meet the above schedule, irrigation may be scheduled at 0.9 ratio at CRI and at 0.6 during other stages for highest water use efficiency.
- Under situations of acute water shortage, IW/CPE ratio of 0.6 requiring 3 irrigations at critical stages (CRI, boot and milk stages) appears to be the minimum requirement for reasonably good yield.

Depletion of available soil moisture approach: This approach is still the usual approach for scheduling irrigation.

- When irrigation water is not a limiting factor, scheduling irrigation at 25 per cent DASM in the case of light soils and at 40 per cent DASM in the case of heavy soils could be ideal for high yield.
- Under the conditions of limited irrigation water availability, scheduling irrigation at 40 and 60 per cent DASM could be adopted for the crops on light and heavy soils respectively
- The other alternative is to irrigate the crop around 50 per cent DASM at CRI and at 75 DASM during other critical stages.

9.1.3 MILLETS

Among the millets, maize is grown as irrigated crop through out the country, especially during winter and summer seasons. Sorghum, fingermillet and pearlmillet are occasionally grown as irrigated crops during *rabi* and summer seasons, especially in southern parts of the country. As such, work on irrigation needs of millets, except maize, is limited.

Maize: Most critical stage for irrigation is flowering period (15 to 20 days) including tasseling, silking and pollination. Greatest decrease in grain yield is caused by water deficits during this stage, mainly due to reduction in grain number per cob. During the five weeks that follow tasseling, water use is about 50 per cent of the seasonal requirement. It has been shown that when soil moisture is depleted to wilting point, even for a day or two during tasseling or pollination, grain yield will decrease by around 20 per cent and if the stress continuous for a week, yield reduction will be around 50 per cent.

Irrigation schedules based on IW/CPE ratio at Madhepura and Pusa indicated that at 1.0 ratio, winter maize required 4 and 5 irrigations, respectively for grain yield of 3.8 t ha^{-1} (Table 9.6). At Morena, grain yield of 5.22 t ha^{-1} was obtained at 0.9 ratio, requiring 8 to 9 irrigations. Based on the results of experiments, the following conclusions can be drawn on water management practices for maize:

- If irrigation water is adequate, irrigations may be scheduled at 25 per cent DASM or at IW/CPE ratio of 0.9 or 1.0 through out the growth period of the crop. Around 12 irrigations are required depending on the soil type

Table 9.6 Performance of major millets at optimum IW/CPE ratio (Yadav et al 2000).

Location	*Soil type*	*No. of irrigations (depth cm)*	*Optimum IW/CPE ratio*	*Grain yield (t ha^{-1})*	*Irrigation water used (cm)*
		Winter maize			
Pusa (Bihar)	Sandy loam	5 (6)	1.00	3.81	30
Madhepura (Bihar)	Sandy loam	4 (6)	1.00	3.79	24
Rahuri (MS)	Clay loam	2 to 3 (8)	0.60	3.53	20
Faizabad (UP)	Silty loam	5 (6)	0.90/1.20	5.76	30
Morena (MP)	Clay loam	8 to 9 (7.5)	0.90	5.22	64
Hyderabad (AP)	Sandy loam	8 to 9 (5)	0.90	3.70	43
Dharwad (Karnataka)	Black clay	6 to 7 (6)	0.80	5.01	39
Coimbatore (TN)	Sandy clay loam	6 (7.5)	0.60	3.55	36
Kota (Rajasthan)	Clay loam	2 to 3 (6)	0.80	2.67	15
		Sorghum			
Kota (Rajasthan) *Kharif*	Clay	3 (6)	0.75/0.80	3.14	18.0
Navsari (Gujarat) Summer	Black clay	6(8)	0.90	5.13	48.0
Parbhani (MS) *Kharif*	Black clay	1 (6)	0.40	4.02	6.0
Rabi	Black clay	4 (6)	0.60	3.44	24.0
Dharwad (Karnataka)*Rabi*	Black clay	4 (6)	0.40	4.30	24.0
Bhavanisagar (TN) *Kharif*	Sandy loam	5 (5)	0.40	3.01	25.0
Rahuri (MS) *Rabi*	Black clay	5 (7)	1.05	3.73	35.0
		Pearlmillet			
Sriganganagar (Raj) *Kharif*	Sandy loam	3 (6)	0.55/0.60	1.94	18.0
Kota (Raj) *Kharif*	Sandy loam	3 (6)	0.75/0.80	2.84	18.0
Rahuri (MS) *Kharif*	Black clay	4 (5)	0.55/0.60	2.40	20.0
Hyderabad (AP) *Rabi*	Sandy loam	10.5	0.75/o.80	2.20	50.0

- Under conditions of limited irrigation water availability, the above schedules may be followed at flowering period (15 to 20 days) including tasseling, silking and pollination. During other periods, irrigations may be scheduled at 50 per cent DASM or at an IW/CPE ratio of 0.75. This practice may require about 8 irrigations
- Even if irrigation water is adequate, it would be wiser to adopt critical stages approach for increasing the area under irrigation without significant reduction in grain yield.

Sorghum: This crop is mainly a rainy season crop on light soils or a postrainy season crop on stored soil moisture of deep black soils. Very rarely it is grown as an irrigated crop during *rabi* and summer seasons.

Seedling, primordial and flowering stages are the critical stages for soil moisture stress. At Siruguppa (Karnataka), one irrigation at 75 per cent DAMS was adequate for *kharif* crop on heavy soils. However, summer crop gave highest grain yield when irrigations were scheduled at 50 per cent DASM, requiring 550 mm water in 9 irrigations (Dastane et al 1970). Optimum IW/CPE ratio and number of irrigations to sorghum crop varied widely from region to region (Table 9.6). Only one irrigation scheduled at 0.4 ratio produced highest grain yield (4.02 t ha^{-1}) of *kharif* sorghum at Parbhani (Maharastra). On sandy loam soils of Bhavanisagar, grain yield only 3.01 t ha^{-1} at 0.4 ratio, requiring 5 irrigations.

The following general conclusions may serve as a guide for irrigation water management of sorghum under different soil and climatic conditions:

- If irrigation water is adequate, irrigation schedules at 50 per cent DASM or at IW/CPE ratio 0.75, all through the crop period, could be ideal for high grain and fodder yield of sorghum during *rabi* and summer seasons. Depending on soil type and climate, 7 to 9 irrigations may be necessary
- During years of deficit supplies, irrigation schedules at 50 per cent DASM or at IW/CPE ratio 0.75 at seedling, primordial and flowering stages and at 75 per cent DASM or at 0.4 IW/CPE ratio at other stages could be ideal for optimum grain and fodder yield during *rabi* and summer seasons. About 4 irrigations could be adequate with this irrigation schedule.

The following water management practices could also serve the same purpose as that of the above.

- If water supply is adequate for only one irrigation, it should applied at primordial stage
- If water supply is adequate for two irrigations, they should applied at seedling and primordial stages
- If water supply is adequate for three irrigations, they should applied at seedling, primordial and flowering stages
- Four irrigations, one each at seedling, primordial, flowering and grain development stages leads to optimum yield.

Pearlmillet: Area of pearlmillet, both under rainfed and irrigated conditions, has progressively decreased during the last fifteen years due to introduction of more remunerative crops. Still, considerable area exists under irrigation, especially in southern parts of the country during summer season (April-June) as transplanted crop. Much attention has not been paid for irrigation management of the crop. Scheduling irrigation at IW/CPE ratio of 0.75/0.80 required three irrigations for an yield of 2.8 t ha^{-1} during *kharif* at Kota in Rajasthan (Table 9.6). At Hyderabad (AP), *rabi* pearlmillet could produce 2.2 t ha^{-1} with 10 irrigations.

Flowering and grain development stages are most sensitive for soil moisture stress. Scheduling irrigation at 50 per cent DASM during moisture sensitive stages and at 75 per cent DASM during other stages appears to be optimum under several situations (Reddy 2004). Based on the available information, the following conclusions can be drawn on irrigation practices for pearlmillet :

- Under conditions of adequate irrigation water availability, scheduling irrigation at 50 per cent DASM all through the crop period, requiring 5 to 7 irrigations could be ideal for high grain yield of transplanted crop during *rabi* and summer seasons. If scheduling is based on IW/CPE ratio, 0.75 ratio all through the crop period could be as good as the above for optimum grain yield
- At times of deficit water supplies, scheduling irrigations at 50 per cent DASM during moisture sensitive stages and at 75 DASM during other stages or scheduling irrigations at IW/CPE ratio of 0.75 during moisture sensitive stages and at 0.4 ratio during other stages could serve the purpose without significant reduction in grain yield
- For transplanted summer pearlmillet, 6 irrigations, one each at planting, a week after planting, three weeks after planting, panicle initiation, flowering and grain development are ideal, if water supply is not a limiting factor
- Under conditions of deficit supplies, three irrigations (planting, tillering and flowering) can optimise the grain yield during summer season.

Fingermillet: Among the small millets, fingermillet is the only crop grown under irrigation to a considerable extent during *rabi* and summer seasons, especially in south India. During rainy season, one or two supplemental irrigations, at times of drought spells, can double the yield of fingermillet. Tillering, panicle initiation and grain development stages are sensitive to soil moisture stress. The following irrigation schedules may serve as a guide for irrigation water management of fingermillet under different situations:

- If irrigation water is not a limiting factor, 7 irrigations at 10 days interval during *rabi* and 9 irrigations at 8 days interval during summer can meet the crop needs for high grain yield
- Under conditions of limited water supply, a minimum of 3 irrigations (tillering, panicle initiation and grain development) are necessary for economic crop production during *rabi* and summer seasons
- Under conditions of adequate irrigation water availability, scheduling irrigation at 50 per cent DASM all through the crop period could be ideal for high grain yield of transplanted crop during *rabi* and summer seasons. If scheduling is based on IW/CPE ratio, 0.75 ratio all through the crop period could be as good as the above for optimum grain yield
- At times of deficit water supplies, scheduling irrigations at 50 per cent DASM during moisture sensitive stages and at 75 DASM during other stages or scheduling irrigations at IW/CPE ratio of 0.75 during moisture sensitive stages and at 0.4 ratio during other stages could serve the purpose without significant reduction in grain yield

9.2. PULSES

Pulse crops have long tap root system, which aids in soil moisture use from deeper layers. Hence, they can withstand prolonged soil moisture stress and are rarely irrigated during rainy season. Pulses grown after *kharif* rice crop (rice fallow pulses) and those grown on black cotton soils. as postrainy season crops are also not irrigated. Only *rabi* and summer crops, grown to a limited extent, are given limited irrigations depending on the availability of irrigation water. Hence, not much progress has been made in water management practices for pulse crops.

9.2.1 PIGEONPEA

Among the pulse crops, *kharif* pigeonpea may be the only crop, which receives irrigation due to its longer duration, extending up to January – February (postrainy season). The other reason for irrigating the *kharif* sown crop is that it gives 2 or 3 flushes of crop harvests in 6 to 7 months.

On sandy soils of Morena, three irrigations (each 7.5 cm depth) at IW/CPE ratio of 0.9 resulted in seed yield of 2.0 t ha^{-1}. However, at Rahuri, 10 irrigations (each 5 cm deep) scheduled at 0.75 ratio produced optimum yield of 4.34 t ha^{-1} from 3 flushes. At Navsari and Kota, optimum ratio was 0.6 requiring 2 and 4 irrigations respectively (Table 9.7). In the absence of timely rainfall, one irrigation at flower initiation and another at pod development can double the yield of rainy season crop. Response to irrigation is, generally, more consistent in postrainy season crop on stored soil moisture. Three irrigations at monthly intervals can double the yield on light soils, while more than two may not be necessary for the crop on medium and deep soils during postrainy season.

Table 9.7 Seed yield of major pulses at optimum IW/CPE ratio (Yadav et al 2000).

Location	*Soil type*	*No. of irrigations (depth cm)*	*Optimum IW/CPE ratio*	*Seed yield (t ha^{-1})*	*Irrigation requirement (cm)*	*Water use (cm)*
Pigeonpea						
Morena (MP)	Sandy loam. K	3 (7.5)	0.90	2.00	22.5	—
Kota (Rajasthan)	Clay.K	4 (6)	0.75/0.80	1.45	24.0	—
Navsari (MS)	Clay. K	2 (8)	0.60	2.06	16.0	—
Rahuri (MS)	Clay. K	6 (7)	0.75/0.80	4.35	42.0	60.0
Greengram						
Pantnagar (UP)	Silt loam. S	5 (6)	0.60	1.42	30.0	38.2
Dharwad (Karnataka)	Heavy clay. K	1 (6)	0.60	1.32	6.0	6.9
Bhavanisagar (TN)	Silt loam. S	5 – 6 (4)	0.60	1.32	22.0	26.5
Blackgram						
Bhavanisagar (TN)	Sandy loam. K	4 (9)	0.60	1.14	36.0	45.8
Chalakudi (Kerala)	Silty loam. S	5 (3)	0.75	0.65	15.0	20.6

(K = *kharif*; S = summer)

Suggested water management practices for pigeonpea crop during postrainy season are:

- In the absence of adequate rainfall after October, one irrigation at flower initiation (second or third flush of flowering) and another at pod development can double the yield of *kharif* sown crop

- Response to irrigation is, generally, more consistent in postrainy season crop on stored soil moisture. Three irrigations at monthly intervals can double the yield on light soils, while more than two may not be necessary for the crop on medium and deep soils during postrainy season
- Scheduling irrigation at IW/CPE ratio of 0.75 during postrainy season may require two or three irrigations for optimum yield
- If irrigation is scheduled based on DASM, 75 per cent depletion level requiring three irrigations could be adequate for optimum yield.

9.2.2 CHICKPEA

Around 60 per cent of the chickpea area in the country is rainfed, especially as a postrainy season crop on receding soil moisture in black soils. The crop responds to irrigation on light soils of north India, particularly if winter rains are scanty. Even under drought conditions, more than two irrigations are not necessary. Where evaporative demand is high as in Peninsular India, irrigation can double the yield on relatively light soils. However, under conditions of low evaporative demand as in north India, irrigation leads to excessive growth and lodging.

Branching, 45 days after seeding (DAS), and pod formation (75 DAS) are the critical stages for soil moisture stress. Suggested irrigation management practices are:

- If irrigation water is adequate, four irrigations (seeding, branching, flowering and pod filling) appear to be adequate for a crop on light soils. Generally, irrigation is not recommended for a crop on deep black cotton soils
- Under condition of limited availability, two irrigations (branching and pod formation) can give economic yield on light soils
- Scheduling irrigation at 0.5 IW/CPE ratio or at 75 per cent DASM, requiring 2 to 3 irrigations is equally effective as that of critical stages irrigation
- Chickpea is very sensitive to soil salinity. Irrigation water with saline water that has 10 mmhos cm^{-1} can reduce the yield by 60 per cent.

9.2.3 GREENGRAM AND BLACKGRAM

These two crops are grown as rainfed crops during rainy season. As such, they will not respond to irrigation unless there is prolonged dry spell at critical stages for soil moisture stress. Postrainy season crops grown with stored moisture on black cotton soils also will not receive any irrigation. These crops are grown as irrigated crops during summer in northern parts of the country and in winter in southern parts. In delta areas of south India, these crops are grown as relay crops with *kharif* rice without any irrigation.

Flowering and pod development stages are sensitive to soil moisture stress. In general, rainy season crop did not respond to irrigation at several places. Summer crop required 3 to 4 irrigations at IW/CPE ratio of 0.60 for normal yield at different locations. Recommended irrigation practices are:

- Under conditions of adequate irrigation facilities, four irrigations, one each at sowing, branching, flowering and pod development are adequate for optimum yield during winter and summer seasons
- If irrigation water is limiting, a presowing irrigation followed by another irrigation at flowering can result in near optimum yield of winter and summer crops

- Scheduling irrigation at 50 per cent DASM during flowering and pod formation and at 75 per cent DASM during other stages could be as effective as the above, at times of deficit water supplies
- There may not be any necessity for irrigating these crops during rainy season unless prolonged dry spells occur during the critical storages for soil moisture stress.

Other pulse crops like cowpea, kidney bean and lentil are of little importance as irrigated crops. The principle of irrigating these crops is same as that for greengram and blackgram.

9.3. OILSEDS

Oilseed crops are largely *kharif* rainfed. In recent years, considerable emphasis has been laid on growing groundnut, sunflower, soybean and mustard under irrigation.

9.3.1 GROUNDNUT

Groundnut, largely a rainfed crop during *kharif,* is not irrigated in major groundnut producing states. In recent years, however, there is emphasis for *rabi* and summer irrigated groundnut crops, which accounts for about 20 per cent of total production. Water management for groundnut crop is complicated due to prolonged flowering period with two to three flushes of flowering. It is not uncommon to observe the crop with flowers, pegs, developing pods and mature pods at a time, especially when the crop is subjected to soil moisture stress at first or second flush of flowering.

Flowering, pegging and pod developmental stages (flowering to pod development) are considered sensitive to soil moisture stress. Results of experiments indicated necessity for scheduling irrigations at 25 per cent DASM through out the crop period for high pod yield of groundnut on sandy loam soils. Irrigating the crop at 25 per cent DASM from pegging to early pod development and at 50 per cent DASM at other stages appears to be ideal for high water use efficiency without significant reduction in pod yield. An IW/CPE ratio of 1.0 at moisture sensitive stages and at 0.6 during other stages leads to high water use efficiency (Prihar and Sabdhu 1987).

At several situations, 10 to 12 irrigations at 10 days interval resulted in highest pod yield. On sandy loam soils, seven irrigations: presowing, 25, 35, 45, 55, 70 and 90 DAS appears to be optimum for high yield. From the results of experiments at several situations, irrigation practices for groundnut can be summarised as indicated below:

Critical stages approach

- Presowing irrigation (stand establishment) and no irrigation up to three weeks after sowing
- Starting from three weeks after sowing (flowering to pod formation), five irrigations at 10 days interval.
- Last two irrigations (pod development) at 15 days interval.

DASM approach

- Irrigation at 25 per cent DASM, especially for a crop on sandy loam soils, through out the crop period if irrigation water is not a limiting factor
- No irrigation up to three weeks after sowing. From three weeks after sowing up to pod development, irrigation at 50 per cent DASM followed by irrigation schedules at 75 per cent DASM up to pod maturity.

IW/CPE approach

- Irrigation at IW/CPE ratio of 1.0, especially for a crop on sandy loam soils, through out the crop period if irrigation water is not a limiting factor
- No irrigation up to three weeks after sowing. From three weeks after sowing up to pod development, irrigation at IW/CPE ratio of 0.75 followed by irrigation schedules at IW/CPE ratio of 0.6 up to pod maturity.

9.3.2 RAPESEED AND MUSTARD

Brassicas are responsive to irrigation due to scanty winter rainfall. About 60 per cent of the total area under the crop is irrigated. Among the brassicas, *raya* is most responsive to irrigation.

Flowering and pod formation stages of mustard are most sensitive to soil moisture stress. Irrigation at these stages increases the seed yield by 30 per cent (Gangasaran and Giri 1985). Additional irrigation 30 DAS may be given, if irrigation water is not a limiting factor. Scheduling irrigation at 75 per cent DASM was adequate on sandy loam soils of Punjab (Prihar and Sandhu 1987). However, scheduling irrigation at 40 per cent DASM was beneficial. Scheduling irrigations at IW/CPE ratio of 0.6 at Kharagpur and at 0.8 at Pusa resulted in higher mustard yield. As per phonological stages, mustard needed one irrigation 30 DAS at Morena and Ludhiana, one during flowering at Pantnagar and two at flowering and pod development at Navsari. Based on the available information, the following irrigation management practices can be recommended for rapeseed and mustard:

- Mustard crop needs only three irrigations, one each at 30 DAS, flowering and pod formation, for high yield even if irrigation water is not a limiting factor
- If irrigation water is a limiting factor, only two irrigations at flowering and pod development can optimise the mustard yield
- Scheduling irrigation at 50 per cent DASM at the above three stages is ideal. If irrigations are scheduled based on IW/CPE ratio, 0.75 ratio could be optimum at most situations
- Under the conditions of limited irrigation water, scheduling irrigations at 75 per cent DASM or at IW/CPE ratio of 0.6 increases the water use efficiency.

9.3.3 SUNFLOWER

Sunflower is, generally, sown during June in *kharif*, September – October in *rabi* and in January as summer crop. Sunflower will not respond to irrigation during rainy season unless prolonged dry spells occur during critical stages for water deficits. Response to irrigation during *rabi* and summer varies depending on the soil type and weather conditions. Response is more pronounced in summer than in *rabi*.

Critical stages for irrigation are, bud initiation (30 to 40 DSA), flower opening (45 to 55 DAS) and seed filling (60 to 85 DAS). Flower opening stage is the most critical stage for soil moisture stress. Three irrigations (6 cm depth) at these three critical stages resulted in highest yield of 2.5 t ha^{-1} at several locations during *rabi*. Summer crop, however, responded to another irrigation at disc formation stage (60 to70 DAS).

Irrigation at 50 to 60 per cent DASM was optimum both for *rabi* and summer crops at several places (Reddy 2004). During *rabi*, sunflower crop required only two irrigations (7.5 cm depth) at IW/CPE ratio of 0.6 on black soils as against four irrigations (6 cm depth) at 1.2 IW/CPE ratio on light soils (Yadav et al 2000). In general, for a summer crop IW/CPE ratio of 0.80 (6 cm depth) appears to be optimum at several locations. From the results of experiment at different locations, the following irrigation practices can be suggested:

- Under conditions of adequate water availability, irrigation at 12 to15 days interval in black soils and at 10 to12 days interval in light soils is optimum for high yield
- If irrigations are to be scheduled based on DASM, 40 per cent level of depletion will be optimum when water supply is not a limiting factor. If the schedules are based on IW/CPE ratio, 0.75 rato will be optimum
- At times of deficit water supplies, three irrigations (6 cm depth) at three critical stages of bud initiation, flower opening and seed filling could be optimum during *rabi*. Summer crop, however, require another irrigation at disc formation stage.
- Scheduling irrigation at 50 per cent DASM or at 0.75 IW/CPE ratio during the three critical stages and at 75 per cent DASM or at 0.5 ratio during other stages can minimise the irrigation needs at deficit water supplies.

9.3.4 SOYBEAN

Soybean is a *kharif* rainfed crop in northern parts of the country. In central parts, it is largely grown as summer irrigated crop. It is grown as postrainy season crop on stored soil moisture in black cotton soils and as irrigated crop during summer in southern parts of the country.

In general, *kharif* crop may not receive irrigation, except at times of prolonged drought, if facility exists for irrigation. Critical stages for irrigation are flowering and pod development, when the crop needs around 8 mm per day. Soybean has extended period of flowering. The late flowers developing into mature pods can compensate early flower drop due to soil moisture stress. Scheduling irrigation at 50 per cent DASM or at 0.6 IW/CPE ratio is optimum for soybean. At these levels, light soil needs irrigation once in 10 to 12 days and heavy soils once in 18 to 20 days (Reddy 2004). Depending on the level of management, the water use efficiency ranges from 0.4 to 0.7 kg m^{-3}. Recommended irrigation practices are:

- Where irrigation water is not a limiting factor, scheduling irrigation at 50 per cent DASM or at 0.6 IW/CPE ratio is optimum for *rabi* and summer soybean. At these levels, light soil needs irrigation once in 10 to 12 days and heavy soils once in 18 to 20 days
- At times of deficit water supplies, irrigation may be scheduled at 50 per cent DASM or at 0.6 IW/CPE ratio at critical stages and at 75 per cent DASM or at 0.4 ratio during other stages
- If water is available for only one irrigation, it should be applied at late flowering when small pods begin to appear. If there is scope for two irrigations, first irrigation should be a presowing irrigation for adequate stand establishment in addition to the above. A third irrigation where possible will give best results if given at the beginning of pod filling.

9.3.5 CASTOR

Castor is usually a *kharif* rainfed crop and it responds to irrigation at times of prolonged drought spells during the crop season. One or two irrigations during the drought period can double the yield. Supplemental irrigations, if drought persists, must be given at primary spike development or secondary spike initiation. Flowering and seed developmental stages are considered critical stages for irrigation.

Improved varieties and hybrids are grown as irrigated crops during *rabi*, especially in Andhra Pradesh, Gujarat and Maharastra. Castor can extract moisture from deeper soil layers due to its deep root system. As such, it is desirable to give relatively heavy irrigations than frequent light irrigations. Suggested irrigation schedule for *rabi* castor is:

- If the water supply is adequate, first irrigation must be given 50 DAS or around full flowering of primary spike. Subsequent irrigations may be given at an interval of 20 days. A crop of 180 days duration requires around 6 irrigations for optimum yield.
- At times of deficit water supplies, first irrigation must be given at primary spike development or secondary spike initiation followed by one or two irrigations during flowering and seed formation
- If irrigations are to be scheduled based on DASM, 50 per cent level should be at critical stages and 75 per cent level at other stages
- An IW/CPE ratio of 0.6 could be ideal at times of adequate water supply and a ratio of 0.4 appears to be ideal at times of deficit water supplies.

9.4. COMMERCIAL CROPS

Sugarcane and cotton respond to irrigation because of their growth period beyond the rainy season. Wider row spacing for these two crops is conducive to drip irrigation system for efficient use of scarce irrigation water.

9.4.1 SUGARCANE

Water use efficiency of sugarcane under field conditions is low (0.4 to 0.6 t $ha\text{-}cm^{-1}$). It can be increased to 1.0 t cane $ha\text{-}cm^{-1}$ of water with appropriate water management practices. Studies on critical stages of sugarcane of water at IISR, Lucknow indicated that tillering, grand period of growth and early ripening stages are most critical for irrigation (Singh et al 1976). Irrigating February planted cane crop at 25 per cent DASM requires 10 irrigations and at 50 per cent, 7 irrigations. Irrigation at 80 per cent leaf sheath moisture content produced highest cane yield at Caddalore. Scheduling irrigation at IW/CPE ratio of 0. 7 was optimum for high cane yield. Numerous studies conclusively proved beneficial effect of trash mulch in minimising the irrigation needs of sugarcane.

Studies on drip irrigation during late 1980s at Rahuri indicated saving of 64 per cent irrigation water compared to furrow method and produced 12 per cent higher cane yield (Table 9.8).

Table 9.8 Relative efficiency of drip and surface irrigation at Rahuri (Yadav 2000).

Irrigation	*Cane yield (t ha^{-1})*	*Water applied (cm)*
Surface irrigation	130.4	166.0
Drip-one day interval	155.7	93.2
Drip-two day interval	151.4	93.2
Drip-three day interval	146.6	93.2

Irrigation interval of one day with drip method is better than daily irrigation or two to three day's interval. Even three days interval gave higher yield than surface irrigation. Cane yield with paired row planting in drip method was better than all surface treatments, indicating scope for minimising cost for drip system with paired row system. Paired row planting required 26 per cent less water without significant yield reduction. In spite of marginal yield advantage, pit method requires substantial labour and hence not economical. (Yadav et al 2000). Suggested irrigation practices are:

- Premonsoon is the crucial period for irrigation in tropical and subtropical regions
- Tillering, grand growth period and early ripening period are more sensitive to soil moisture stress. At times of deficit water supplies, irrigation must be provided at least during these stages
- If irrigation water is not a limiting factor, sugarcane needs 8 to 12 irrigations during rainy season and 8 to 14 during postrainy period in tropical regions. In subtropical regions, irrigation is not necessary during monsoon period, while 2 to 3 irrigations are needed during postrainy period
- In general, scheduling irrigation at 50 per cent DASM or at IW/CPE ratio of 0.75 is ideal, if there is no scarcity for irrigation water
- Generally, a drying off period of 4 to 6 weeks prior to harvest has to be allowed
- Alternate day drip irrigation increase the cane yield and decrease the irrigation needs by more than 50 per cent compared with surface irrigation. Paired row planting considerably bring down the cost of drip equipment and reduce the irrigation needs by about 25 per cent compared with surface irrigation.

9.4.2 COTTON

More than 75 per cent of the area under cotton in India is entirely depending on rainfall during monsoon period while supplemental irrigation is available for about 25 per cent. Supplemental irrigation is, generally, given for American and hybrid cottons, depending on the availability of irrigation water.

To restrict the excessive vegetative growth during early phase, maintenance of relatively dry soil moisture regime (75 per cent depletion level) is necessary. At flowering, soil moisture regime should be regulated to control vegetative growth in relation to reproductive growth. Water deficit from onset of flowering to peak flowering may cause more negative effect on yield as compared to that occurring after peak flowering. With severe water deficits during late flowering and early boll formation, boll shedding can be excessive. Moderate deficit during flowering to restrict vegetative growth leads to good boll setting and higher yield despite a reduction in flower number. Squaring to peak flowering is considered critical to soil moisture.

The scope for water economy and yield advantage with drip irrigation was studied at Parbhani (Yadav et al 2000). Paired planting pattern (60-60 × 120 cm) was adopted to reduce the cost of drip system and compared with normal planting (90 × 90 cm) for cotton. Scheduling irrigation at IW/CPE ratio of 0.8 by drip system resulted in highest cotton yield (Table 9.9). About 10 per cent saving in irrigation water and 10 to 21 per cent yield advantage was recorded with drip as compared with furrow method. As indicate already, controlled moisture stress is advocated for cotton since stress leads to early maturity. Results of experiments at Hisar indicated that such controlled stress could be better managed with drip system than with furrow system.

Table 9.9 Effect of drip irrigation on cotton yield (Yadav et al 2000).

Treatment	*Yield (t ha^{-1})*	*Water applied (cm)*
Drip irrigation at % PE. Normal planting (90 × 90 cm)		
40	2.44	9.0
60	2.57	13.5
80	2.80	18.1
100	2.63	18.0
Drip irrigation at % PE.Paired planting (60-60 × 120)		
40	2.35	9.0
60	2.65	13.5
80	2.59	18.1
100	2.57	18.0
Alternate furrow irrigation. Normal planting (90 × 90 cm)		
IW/CPE = 0.90	2.32	18.0

From the available information, the following irrigation practices can be advocated for cotton crop:

- Squaring to peak flowering is considered critical to soil moisture
- Irrigations may be scheduled at 75 per cent DASM during vegetative phase to check the excessive vegetative growth. During flowering, 60 per cent depletion level can check vegetative growth without significant reduction in final yield
- Scheduling irrigation at 50 per cent depletion level during squaring (boll formation) and maturation is necessary for high yield and quality fiber
- At times of deficit water supplies, two irrigations during boll filling and maturation can minimise the yield loss due to stress
- Paired row planting and drip irrigation can bring down the irrigation needs considerably.

9.5. PROBLEM SOILS AND WATER MANAGEMENT

Extensive land area in arid and semiarid regions of India has gone out of cultivation due to rise in water table and accumulation of salts leading to unfavourable soil-water-air relationships and decrease in crop productivity. Irrigation aspects of problem soil, waterlogged soils and use of poor quality irrigation water for crop production are briefly discussed.

9.5.1 PRACTICES FOR SALT AFFECTED AND BRACKISH WATER

Unfavourable soil-air relations and accumulation of certain elements in toxic proportions in plants limit crop growth on alkali soils. Alkali soils have low infiltration rates, reduced water availability and poor water transmission to growing roots. These constraints warrant controlled water management practices. On coastal saline soils, 3-4 cm water at CPE of 50 mm resulted in wheat yield advantage over two normal irrigations. At Ludhiana, light and frequent irrigation with 5 cm depth was advantageous than less frequent irrigations (Bhattacharya et al 1995).

Accumulation of salts is closely associated with soil texture. In general, accumulations of salts in a soil under normal drainage increase from coarse to fine textured soils by about two times. Thus, waters with EC of 12 to 16 dS m^{-1} could be used for tolerant and semitolerant crops like wheat, barley and mustard in coarse textured soils with an annual rainfall above 400 mm (Manchanda 1993). However, water with EC of more than 2 dS m^{-1} often create salinity problem in fine textured soils. Saline waters up to 6 dS m^{-1} for pearlmillet and cotton and up to 12 dS m^{-1} for wheat, barley and mustard can be used through sprinklers on undulating light textured soils, provided sprinklers are run during cool hours in summer (Garg and Gupta 1995).

These are situations where limited quantities of good waters are available in addition to saline water resources. These two supplies should either be mixed to bring the EC within permissible limits or used in alternate irrigations. The former option requires mechanism of mixing and several issues relating to decision on the mixing ratios. Potato yields did not differ considerably due to alternate irrigation with canal water and well-water with EC of 6 dS m^{-1} (Yadav 1982). Wheat and rice yields did not differ significantly due to one irrigation with brackish water after two irrigations with canal water of good quality (Gupta et al 1995). Seeding on conserved soil moisture or irrigation with good quality water during seed establishment and poor quality water at later crop growth stages is a good strategy under conditions of limited canal water availability. In areas with brackish groundwater, a reduction in canal water supply by at least 20 per cent would go a long way in reducing harmful effects of high water table, besides saving fresh water for needy areas.

9.5.2 PRACTICES FOR HIGH WATER TABLE, WATERLOGGED AND FLOOD AFFECTED AREAS

Adequate drainage and efficient on-farm water management assume significance to sustain crop production on long term basis. Good quality groundwater at shallow depth considerably minimise supplemental irrigation, provided groundwater table is about 50 cm. Under such situations, one irrigation at crown root initiation is adequate for wheat. If the water table is medium (100-150 cm) two to three irrigations are adequate for wheat. There was significant reduction in irrigation needs of rice at Pantanagar when the water table was 50-100 cm (Agarwal et al 1997).

Choice of crops for flood prone areas is closely related to depth and duration of water stagnation, receding duration of floodwaters, soil type, salt tolerance of crops, quality and quantity of irrigation water and other management practices. Rice and sugarcane crops perform better than other crops in flood prone areas. If the recession time of water is relatively longer, rice is ideal than sugarcane. All the crops need reduced depth and frequency of irrigation depending on duration of flooding. Sprinkler and drip irrigation systems can reduce excessive irrigation relative to flood irrigation.

SUMMARY

- Lowland (irrigated) rice requires more water than other crops of similar duration due to continuous land submergence. Depending on the environment in which the crop is cultivated, 50 to 70 per cent of the applied water is lost in deep percolation. Rice crop has been found to perform better under the conditions of land submergence largely due to relatively weed free environment, increased availability of nutrients and reduced loss of applied nitrogen.

- Great economy in irrigation needs of rice could be achieved if suitable measures are adopted to minimise the deep percolation losses. Intensive puddling to reduce soil permeability is the practical approach to minimise deep percolation losses besides controlling the weed growth. Under the conditions of limited supplies, phasic land submergence or intermittent land submergence could be optimum both for *kharif* and *rabi* rice crops.
- Wheat season commences after withdrawal of monsoon, either as rainfed crop on stored soil moisture or as an irrigated crop. Four irrigations, one each at crown root initiation, flowering, milking and dough stages are necessary for economic yield. In general, 4 to 6 irrigations are needed for optimum yield under different soil and weather conditions.
- In the case of maize, most critical stage for irrigation is flowering period (15 to 20 days) including tasseling, silking and pollination. Under the conditions of limited irrigation water availability, irrigations may be scheduled at 25 per cent DASM or at IW/CPE ratio of 0.9 to 1.0 at flowering period (15 to 20 days) including tasseling, silking and pollination. During other periods, irrigations may be scheduled at 50 per cent DASM or at an IW/CPE ratio of 0.7. This practice may require about 8 irrigations.
- In sorghum, seedling, primordial and flowering stages are the critical stages for soil moisture stress. If water supply is adequate for three irrigations, they should be applied at seedling, primordial and flowering stages. Four irrigations, one each at seedling, primordial, flowering and grain development stages leads to optimum yield.
- Flowering and grain development stages of pearlmillet are most sensitive to soil moisture stress. At times of deficit water supplies, scheduling irrigations at 50 per cent DASM during flowering and at 75 DASM during grain development or scheduling irrigations at IW/CPE ratio of 0.75 during flowering and at 0.4 ratio during grain development could be the minimum requirement.
- Tillering, panicle initiation and grain development stages of fingermillet are sensitive to soil moisture stress. Seven irrigations at 10 days interval during *rabi* and 9 irrigations at 8 days interval during summer can meet the crop needs for high grain yield.
- Among the pulse crops, *kharif* pigeonpea may be the only crop, which receives irrigation due to its longer duration, extending up to January – February (post rainy season). Response to irrigation is, generally, more consistent in postrainy season crop on stored soil moisture. Three irrigations at monthly intervals can double the yield on light soils, while more than two may not be necessary for the crop on medium and deep soils during postrainy season.
- Chickpea crop responds to irrigation on light soils of north India, particularly when winter rains are scanty. Even under drought conditions, more than two irrigations are not necessary. Branching, 45 days after seeding (DAS), and pod formation (75 DAS) are the critical stages for soil moisture stress. Under condition of limited availability, two irrigations (branching and pod formation) can give economic yield
- Greengram and blackgram are grown as irrigated crops during summer in northern parts of the country and in winter in southern parts. In delta areas of south India, these crops are grown as relay crops with *kharif* rice without any irrigation. Flowering and pod development stages are sensitive to soil moisture stress. Summer crop required 3 to 4 irrigations at IW/CPE ratio of 0.60 for normal yield. If irrigation water is limiting, a presowing irrigation followed by another irrigation at flowering can result in near optimum yield of winter and summer crops.

- Groundnut, as *rabi* and summer crop, responds to irrigation. The entire period from flowering to pod development is considered as critical phase for soil moisture stress. After presowng irrigation, there is no necessity for irrigation up to 20 days after sowing (DAS) in the case of light soils and up to 25 DAS in the case of heavy soils. Irrigation at 25 DAS followed by four irrigations at 10 days interval and two irrigations at 15 days interval, making a total of 8 irrigations, is adequate for optimum pod yield of bunch types. When water supply is inadequate, irrigation may be scheduled at 50 per cent DASM from flowering to pod development followed by one irrigation during pod maturation or at 0.8 IW/CPE ratio from flowering to pod development followed by one irrigation at 0.5 IW/CPE rato.
- Flowering and pod formation stages of mustard are most sensitive to soil moisture stress. The crop needs only three irrigations, one each at 30 DAS, flowering and pod formation for high yield even if irrigation water is not a limiting factor. If irrigation water is a limiting factor, only two irrigations at flowering and pod development can optimise the mustard yield.
- In sunflower, critical stages for irrigation are, bud initiation (30 to 40 DSA), flower opening (45 to 55 DAS) and seed filling (60 to 85 DAS). Flower opening stage is the most critical stage for soil moisture stress. At times of deficit water supplies, three irrigations (6 cm depth) at three critical stages of bud initiation, flower opening and seed filling could be optimum during *rabi*. Summer crop, however, require another irrigation at disc formation stage.
- Critical stages of soybean for irrigation are flowering and pod development, when the crop needs around 8 mm per day. If water is available for only one irrigation, it should be applied at late flowering when small pods begin to appear. If there is scope for two irrigations, first irrigation should be a presowing irrigation for adequate stand establishment in addition to the above. A third irrigation, where possible, will give best results if given at the beginning of pod filling.
- Castor can extract moisture from deeper soil layers due to its deep root system. As such, it is desirable to give relatively heavy irrigations than frequent light irrigations. At times of deficit water supplies, first irrigation must be given at primary spick development or secondary spike initiation followed by one or two irrigations during flowering and seed formation.
- Premonsoon period is the crucial period of sugarcane for irrigation in tropical and subtropical regions. Sugarcane needs 8 to12 irrigations during rainy season and 8 to 14 during postrainy period in tropical regions. In subtropical regions, irrigation is not necessary during monsoon period, while 2 to 3 irrigations are needed during postrainy period. Tillering, grand period of growth and early ripening stages are most critical for irrigation. Alternate day drip irrigation increase the cane yield and decrease the irrigation needs by more than 50 per cent compared with surface irrigation. Paired row planting considerably bring down the cost of drip equipment and reduce the irrigation needs by about 25 per cent compared with surface irrigation.
- Supplemental irrigation is, generally, given for American and hybrid cottons, depending on the availability of irrigation water. Squaring to peak flowering is considered critical to soil moisture. Irrigations may be scheduled at 75 per cent DASM during vegetative phase to check the excessive vegetative growth. During flowering, 60 per cent depletion level can check vegetative growth without significant reduction in final yield. At times of deficit water supplies, two irrigations during boll filling and maturation can minimise the yield loss due to stress. Paired row planting and drip irrigation can bring down the irrigation needs considerably.

- In areas with brackish groundwater, a reduction in canal water supply by at least 20 per cent would go a long way in reducing harmful effects of high water table, besides saving fresh water for needy areas.
- Good quality groundwater at shallow depth considerably minimise supplemental irrigation, provided groundwater table is about 50 cm. Under such situations, one irrigation at crown root initiation is adequate for wheat. If the water table is medium (100-150 cm) two to three are adequate for wheat.
- Rice and sugarcane crops perform better than other crops in flood prone areas. If the recession time of water is relatively longer, rice is ideal than sugarcane. All the crops need reduced depth and frequency of irrigation depending on duration of flooding. Sprinkler and drip irrigation systems can reduce excessive irrigation relative to flood irrigation.

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ASSESSMENT

I. *Choose the correct answer for the following?*

1. Irrigated rice is largely cultivated under conditions of land submergence in:
   (*a*) West Bengal (*b*) Assam
   (*c*) Andhra Pradesh (*d*) Kerala
2. Lowland rice requires more water than other crops of similar duration due to:
   (*a*) High ET (*b*) High CU
   (*c*) High yield (*d*) High percolation losses
3. The percentage of applied water lost in rice fields through deep percolation is:
   (*a*) 50 to 70 (*b*) 20 to 40
   (*c*) 75 to 95 (*d*) 10 to 20
4. Huge differences in irrigation requirements of rice from place to place have been attributed largely to:
   (*a*) Weather (*b*) Soil type and seasonal rainfall
   (*c*) Fertiliser use (*d*) Crop duration
5. Which of the following practices is more effective in minimising the irrigation needs of rice crop?
   (*a*) Scrupulous land levelling (*b*) Application of tank silt
   (*c*) Subsoil compaction (*d*) Intensive puddling
6. If irrigation water is available for two irrigations, it should be applied to wheat crop at:
   (*a*) CRI and flowering (*b*) CRI and milk stage
   (*c*) CRI and late jointiong (*d*) CRI and tillering
7. In the case of maize, most critical stage for irrigation is:
   (*a*) Flowering period (*b*) Milk stage
   (*c*) Seed hardening stage (*d*) Seedling establishment stage
8. In the case of sorghum, if water supply is adequate for only two irrigation, it should applied at:
   (*a*) Primordial and flowering stages (*b*) Seedling and primordial stages
   (*c*) Primordial and milk stages (*d*) Primordial and boot leaf stagers
9. In sunflower, most critical stages for irrigation is:
   (*a*) Bud initiation (*b*) Seed filling
   (*c*) Flower opening (*d*) Establishment

10. Paired row planting and drip irrigation is, relatively, well suited to:
    (a) Groundnut
    (b) Millets
    (c) Cereals
    (d) Sugarcane

II. *Fill in the blanks with appropriate answers?*

1. It has been reported that about 5000 l of water is required to produce .... kg rice.
2. As per critical stages approach, the number of irrigations required for optimum yield of wheat under different soil and weather conditions are ....
3. Scheduling irrigation at IW/CPE ratio of .... with 6.0 cm depth is ideal for optimum yield of wheat.
4. In pearlmillet, flowering and .... stages are most sensitive for soil moisture stress.
5. In chickpea, ... and pod formation stages are critical for soil moisture stress.
6. .... to peak flowering phase of cotton is considered critical to soil moisture.

III. *Indicate whether the following statements are True (T) or False (F)?*

1. It is often said and agreed that the seasonal water requirement for rice varies from 750 to 1500 mm day^{-1} with an average around 1200 mm.
2. For rice, the average production of grain in relation to water used (kg ha-mm^{-1} of water) is 13.7.
3. Reduced loss of nitrogen from rhizosphere placed ammonium feartilisers is due to reduced soil conditions with land submergence.
4. Efficient use of applied fertilisers appears to be the major reason for the preferred land submergence to rice crop by the farmers.
5. If irrigation water in not a limiting factor for rice cultivation, continuous shallow land submergence could be ideal to achieve the benefits of land submergence.
6. Critical stage of rice for water deficit is from 21 days after heading to harvest.
7. Deep land submergence during seedling establishment and flowering stages is recommended to rice crop on saline soils.
8. Chickpea crop on heavy soils is more responsive to irrigation than a crop on light soils.
9. Flowering and pod formation stages of mustard are most sensitive to soil moisture stress.
10. Castor can extract moisture from deeper soil layers due to its deep root system. As such, it is desirable to give relatively heavy irrigations than frequent light irrigations.

IV. *Write short notes on:*

1. Intermittent land submergence for rice crop
2. Phasic land submergence for rice crop
3. Water management for rice on saline soils
4. Water management practices for pulse crops
5. Water management practices for cotton crop

V. *Distinguish between the following:*

1. Intermittent and phasic land submergence for rice crop
2. Continuous and phasic land submergence for rice crop
3. Critical stages approach and DASM approach for scheduling irrigation

VI. *Answer the following questions?*

1. How can you minimise the deep percolation losses in lowland rice fields? Suggest appropriate irrigation practices for rice crop for the following situations?

   (*a*) Limited availability of irrigation water during *rabi*

   (*b*) Rice crop on saline soils.

2. What are the recommended irrigation practices for wheat crop based on:

   (*a*) Critical stages approach (*b*) Climatological approach

   (*c*) DASM approach.

3. What are your suggestions for irrigating the following crops at times of deficit water supplies?

   (*a*) Groundnut (*b*) Sunflower

   (*c*) Soybean (*d*) Castor

4. Suggest appropriate irrigation practices for deficit and adequate water supply situations and methods of irrigation for cotton and sugarcane crops? Discuss the scope of drip irrigation for these two crops?

ANSWERS

I. *Choose the correct answer for the following?*

1. (*c*) 2. (*d*) 3. (*a*) 4. (*b*) 5. (*d*) 6. (*c*) 7. (*a*) 8. (*b*) 9. (*c*) 10. (*d*)

II. *Fill in the blanks with appropriate answers?*

1. 1.0, 2. 4 to 6, 3. 0.9 to 1.05, 4. Grain development, 5. Branching, 6. Squaring.

III. *Indicate whether the following statements are True (T) or False (F)?*

1. T 2. F 3. T 4. F 5. T 6. F 7. T 8. F 9. T 10. T

★★★★★★