IRRIGATION STRATEGIES FOR CROP PRODUCTION UNDER WATER SCARCITY

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Introduction

At the most fundamental level, water is absolutely essential to human health and survival. Water makes our fields bloom and brings food to our tables. Indeed, water is life and the history of our society and cultures have been tide inextricably to it.

At the dawn of 21^{st} century, water is once again playing a crucial role in the future of each nation. With rapid urbanization and population growth, we just do not have enough water supplies.

This shortage is felt most by the developing world. The lack of fresh water supply for our daily needs and for our agricultural production is heightened by growing population and changing climate. The global Annual Water Resources are 47196 km3 (IWMI Research Report no. 19, 1998) and demand for this water is increasing especially when urban (drinking) and industrial sectors are competing for it. In most countries, agricultural water use gets low priority. Considering above, water scarcity for agricultural use is inevitable and hence the necessity to focus on irrigation strategies for crop production under water scarcity.

Strategies for Crop Production under Water Scarcity

The challenge is to produce more with less water (Oweis et al., 1999). Yield expressed in terms of production per unit of land has been the traditional measure of productivity in agriculture. But as water is a limited resource, production per unit of water has emerged as an important concept. For a farmer with a scarce supply, strategies to increase the productivity of water may lead to more income and better nutrition (Labhsetwar, 2003). Strategies to increase productivity of water and land may include :

- Use of modern irrigation technology – drip and sprinkler irrigation.
- Application of agricultural bio-technology for crop improvement
- Developing new cropping patterns based on water availability (water efficient crops)
- Use of poor quality water - drainage/brackish water.
- Water harvesting
- Use of waste water in agriculture
- Transfer of surface water from surplus areas.
- Practicing deficit irrigation.

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Practicing Deficit Irrigation

The interval between two irrigations depends primarily on the rate of soil water depletion. Normally, a crop has to be irrigated before soil water is depleted below 50 per cent of its availability in the root zone. The intervals are shorter during summer than in winter. Similarly, the intervals are shorter in the case of sandy soil than in the clay soils. When the water supply is very limited, the intervals are prolonged, the crops are then deficit irrigated only at critical stages.

In this method, irrigations are scheduled at critical stages of crop, grown on the medium to fine textured soils. Singh et al. (1992) identified four critical stages in Sorghum and harvested maximum yield by irrigating at all the four stages. The critical stages are seedling (2-4 weeks), flower premordia (6 weeks), flowering (8-10 weeks) and grain filling stage (10-12 weeks). They observed that seedling and flowering stages were most critical in water demands. Depth of irrigation will depend on soil types. Rodge (1996) harvested maximum yield by supplying two irrigations, one at Premordia initiation and second at boot stage (Table 1).

For high yield adequate water supply is required for Gram as well. Reduction in water supply at pre-flowering stage, flowering and early pod formation stage in general, has an adverse affect on growth and yield. The researchers (Table 2) have identified the critical stages of Gram and reported that the irrigation should be given during those growth stages.

In case of Sunflower Jadhav and Jadhav (1998) scheduled the irrigation by critical growth stage approach and reported that highest yield was obtained by giving irrigations at initial stage, flowering stage and grain filling stage (Table 3).

Irrigation Scheduling under Water Scarcity

Irrigation scheduling in general means application of desired depth of water at right time. The purpose is to assist in maximizing irrigation efficiency by minimizing tail water runoff and deep percolation, and increasing yields significantly.

The irrigation scheduling methods could be based on monitoring soil water, climatical approach, soil – crop – climate approach and critical growth stage (CGS) approach.

The CGS approach is practiced when water is scarce or inadequate. This approach is based on critical stages of crops at which drastic yield reduction occurs, if water is scarce or inadequate. The critical growth stages have been identified and listed in Table 4 to 7. The period of growth stages and the effect of water stress are also included in the table.

In this approach irrigation is given to crops according to their critical stages, whereas depth of irrigation depends on water holding capacity of the soil. The depth of water-applied remains fixed whereas interval will be variable. This technique of irrigation scheduling is recommended when the water holding capacity of the soil is about 200 mm per liter of soil depth or more and a soil depth of 1 metre or more.

Wheat has six critical growth stages and crown root initiation and flowering are priority stages for irrigation (Table 4).

Groundnut has four critical growth stages and flowering and pegging stages are priority stages for irrigation (Table 5).

Cotton has four growth stages and square formation, flowering stage and boll development are priority stages for irrigation (Table 6).

Sunflower has four critical growth stages and bud formation and flowering stage are priority stages for irrigation (Table 7).

This critical growth stage approach of irrigation scheduling is most practical since these critical growth stages are well known to farmers (water user), irrigation and agricultural officials (water supplier). The approach does not involve any high-tech instruments or database and hence very cost effective. It only needs keen field observations and a commitment to release water on time.

Practical Use of Critical Growth Stage Approach in the Field

The use of this approach in the field is complicated because of the diversified cropping pattern and the variable soil types. But on the basis of experimental results it is very clear that on medium to fine textured deep soils, irrigation scheduling by critical growth stage approach is the most efficient method. It greatly economizes the use of irrigation water. The objective should be to increase the total production by supplying deficit irrigation to more area, when irrigation water is inadequate. Under the water scarcity situation more drought resistant crops like Safflower, Sorghum, Gram should be suggested for cultivation.

In Kharif (rainy) season, the crops are selected mostly on the basis of rainfall pattern. The main objective is to harvest more yield with better utilization of rain water. But because of the uncertainty in the rainfall, one or two protective irrigations may be required at critical growth stages. In water scarce zones, whenever there is water scarcity at critical stages of crop, irrigation has to be applied in order to reduce drastic yield reductions. In an irrigation project the first priority for irrigation should be given to Kharif (rainy) crops because only one or two protective irrigation will be required, if water is scarce and the farmers can harvest at least one good Kharif crop. In assured rainfall zones, however, such supplementary irrigations may not be required.

In Rabi (winter) season Sorghum, Gram, Safflower, Wheat, Sunflower and Potato are suggested depending upon availability of irrigation.

If only one irrigation is available in Rabi, Safflower or Sorghum is suggested. The irrigation could be given to Safflower and Sorghum from 10^{th} November (Figure 1). This is the most appropriate time for irrigation, if there is only one irrigation available. At the time of irrigation Sorghum is at flower premordia initiation to flag leaf stage, which is considered as most sensitive stage of Sorghum for water scarcity. Magar et al (1984) harvested satisfactory grain yield by supplying only one irrigation at flower premordia initiation to flag leaf stage. Safflower will be at pre-branching stage during his period. If water is adequate at this stage it increases the number of branches and number of capsules per plant and hence increases the yield.

If two irrigations are available for Rabi, crops like Gram, Safflower and Sorghum are recommended. The first irrigation should be given from 5th November and the second irrigation should be given from 5th December as shown in Figure 2. First irrigation will be helpful in increasing the number of branches in Gram and Safflower whereas the size of earhead will increase by irrigating Sorghum during flower premordia to flag leaf stage. At the time of second irrigation Gram is at flowering stage, Safflower is at capsule development stage and Sorghum is at flowering to grain formation stage. Sondge (1997) reported that two irrigations, one at branching and second at capsule development stage are sufficient for maximum yield. In case of Gram, Patil et al (1990) reported that two irrigations (one at pre-flowering and another at flowering) proved beneficial on clay loam soils. For Sorghum two irrigations (one at premordia initiation and second at flowering stage) are adequate for highest yield on medium black soils (Magar et al, 1984).

If three irrigations are available, crops like Sorghum, Safflower, Gram and Sunflower are suggested in project areas. First irrigation should be given on 5th November (Figure 3) which will be useful for increasing the height of Sunflower, number of branches in Gram and Safflower and size of earhead will increase in Sorghum. Second irrigation should be given from 1st December when Sunflower is at bud formation stage, Gram is at pre-flowering to flowering stage, Safflower is at branching to capsule development stage and Sorghum is at flowering to grain formation stage. Third irrigation should be given from 25th December, when Sunflower is in flowering to grain formation stage, Gram is at for development stage, Safflower is in flowering to grain formation stage and Sorghum is at grain formation stage. Bhan (1995) reported that three irrigations are adequate for maximum yield on sandy loam soils for winter Sorghum.

If four irrigations are available in Rabi (winter) season, Wheat can be included in addition to Sunflower, Rabi Sorghum, Gram and Safflower. Irrigation dates can be decided as suggested in Figure 4. In this case, Gram and Safflower should not be irrigated more than three times. First irrigation should be given from 20th October, which will be useful for better establishment of Sunflower and Sorghum. After pre-soaking, Wheat can be sown in last week of October or first week of November. After first irrigation the interval between two irrigations should be 25 days. In case of Sorghum and Sunflower four irrigations are adequate. Highest yield can be harvested by irrigating four times during their critical growth stages. But for Wheat four irrigations including one pre-soak irrigation is slightly inadequate, still yield will be satisfactory in medium to fine textured deep soils because first irrigation will be at Crown root initiation, second will be at tillering and third will be at flowering stage. Gautam et al., as back as in 1968, reported on sandy loam soils of Delhi, that four irrigations applied at crown root irrigation, tillering, late jointing and flowering yielded as much as intensive irrigation practices with six irrigations.

If five irrigations are available during Rabi (winter), potato can also be included in the cropping pattern in addition to Wheat, Sunflower, Sorghum, Gram and Safflower. Potato is very sensitive crop but short duration varieties (80 days) are available and if five irrigations are available, we can harvest a good yield of Potato on medium textured soils. Scheduling of irrigation at particular dates can be decided as suggested in Figure 5. Rabi Sorghum should not be irrigated more than four times.

If six irrigations are available in Rabi (winter) season, irrigation dates can be decided as shown in Figure 6. In medium to fine textured soils we can take any seasonal Rabi crop, if the irrigation interval is 15 days. If six irrigations are available, water may not be considered scarce any more.

Summary

Water resources have been developed during the last 50 years significantly. At this time, 271 million hectares of lands have been brought under irrigation. But in order to use these water and land resources effectively, Integrated Water Resources Development and Management (IWRDM) needs to be practiced.

During the run-up to the 3rd World Water Forum (Japan), ICID hosted a Virtual Water Forum (VWF) on IWRDM in which the participants acknowledged that the IWRDM helps in producing adequate quantity of food and providing sufficiency at national, regional and global level.

One of the recommendations of ICID-VWF on IWRDM was to increase area under agriculture by increasing water use efficiency and by recycling waste water. Practicing deficit irrigation as described in the paper amounts to increasing water use efficiency, meaning producing more with less water.

Strategies for crop production under water scarcity could be: (1) Use of modern irrigation technology – drip and sprinkler irrigation, (2) Application of agricultural bio-technology for crop improvement, (3) Developing new cropping patterns based on water availability (water efficient crops), (4) Use of poor quality water - drainage/brackish water, (5) Water harvesting, (6) Use of waste water in agriculture, (7) Transfer of surface water from surplus areas, (8) Practicing deficit irrigation.

The Critical Growth Stage (CGS) approach of irrigation scheduling, as a strategy for crop production under water scarcity, has been described as most practical approach since the Critical Growth Stages are well known to farmers (water users) and irrigation and agricultural officers (water suppliers) as well. The CGS approach is practiced when water is scarce or inadequate. This approach is based on critical stages of crops at which drastic yield reduction occurs, if water is scarce or inadequate. The critical growth stages have been identified and listed. The period of growth stages and the effect of water stress on growth and yield has also been dicussed.

In this approach irrigation is given to crops according to their critical stages, whereas depth of irrigation depends on water holding capacity of the soil. The depth of water-applied remains fixed whereas interval will be variable. The choice of crop will depend on number of irrigations available. Given the number of irrigations available, the approximate date/period of irrigation has also been discussed for maximizing yield.

In this way, integrating Critical Growth Stage approach of irrigation scheduling in irrigated agriculture for wider diversity of crops can potentially contribute to solving the problems of food security.

References

Bhan (1995)
Gautam (1968)
Government of India (1979)
IWMI Research Report No. 19 (1998)
Jadhav and Jadhav (1998)
Labhsetwar (2003)
Le Roy Salazaar (1984)
Magar et al (1984)
Musande et al (?)
Oweis et al (1999)
Patil et al (1990)
Raghu & Sharma (1998)
Rodge (1996)
Singh et al (1992)
Sondge et al (1997)

Table 1: Grain yield of rabi Sorghum as influenced by irrigation.

Treatment	Grain yield (kg/ha)			Pooled Mean
	1991-82	1992-83	1993-94	
1. No irrigation	4171	2771	2543	3272
2. One irrigation at primordia initiation	4371	3433	3398	3733
3. One irrigation at boot	4688	3889	3001	3852
4. Two irrigation at primordia initiation and boot	4826	4560	3715	4365
CD at 5%	144	394	323	562

Rodge (1996)

Table 2: Grain yield of Gram as influenced by irrigation.

	Treatment	No. of irrigations	Grain yield (kg/ha)			
			1991-92	1992-93	1993-94	Pooled
1.	No irrigation	0	354	625	238	406
2.	Irrigation at flowering (40 ± 5 days)	1	774	1000	637	804
3.	Irrigation at pod development stage (70 ± 5 days)	1	563	980	620	721
4.	Irrigation at flowering & pod devel. Stage	6	842	1270	838	983
	SE ±	-	33	78	53	38
	CD at 5%	-	96	243	153	106

Rodge (1996)

Table 3: Irrigation scheduling on the basis of critical stages of rabi Sunflower on medium textured soils of Pune.

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Irrigation at critical stages	Grain yield g/ha			
	1993-94	1994-95	1995-96	Pooled Mean
1. Initial stage (15-20 days)	10.96	13.04	15.48	13.16
2. Capitulum initiation (30-35 days)	11.88	15.07	15.89	14.28
3. Flowering (50-60 days)	12.41	14.75	16.88	14.68
4. Grain development (70-80 days)	10.42	14.27	15.16	13.28
5. Capitulum initiation + Grain development	14.58	16.76	17.29	16.21
6. Capitulum initiation + Flowering	12.86	16.28	17.77	15.64
7. Initial stage + Flowering	14.63	17.43	18.15	16.74
8. Capitulum initiation + Flowering + Grain development	15.42	18.11	19.43	17.65
9. Initital stage + Flowering + Grain development	16.95	17.88	19.34	18.06

Jadhav and Jadhav (1998)

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Table 4 : Information on critical growth stages of Wheat

Crop	Critical growth stage	Days after sowing	Effects of moisture stress
Wheat	a. Crown root intiation	20-25	reduced root growth reduced no. of tiller
	b. Tillering	40-45	reduced no. effective tillers
	c. Late jointing	55-60	ear length and no. of grains/ear will be reduced
	d. Flowering	90-95	reduces size of grains
	f. Dough stage	105-110	reduces test weight

Table 5 : Information on critical growth stages of Groundnut

Crop	Critical growth stage	Days after sowing	Effects of moisture stress
Groundnut	a. Seedling stage intiation	30-35	reduced growth rate delayed flowering
	b. Flowering stage	45-50	causes flower drop
	c. Pegging stage	50-55	reduces no. of pods
	d. Pod formation	65-85	reduced pod and test weight

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Table 6 : Information on critical growth stages of Cotton

Crop	Critical growth stage	Days after sowing	Effects of moisture stress
Cotton	a.Vegetative stage	25-35	causes reduced growth and no branching
	b. Square formation	45-50	reduces no. of squares
	c. Flowering stage	85-95	affects flower opening, causes boll shading
	d. Boll development	115-125	boll opening and size
	e. Ripening stage	130-140	affects quality of cotton

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Table 7 : Information on critical growth stages of Sunflower

Crop	Critical growth stage	Days after sowing	Effects of moisture stress
Sunflower	a. Early Vegetative period	35-40	reduced plant height
	b. Late vegetative period	50-55	reduced size of buds
	c. Flowering period	70-75	fewer flowers come to full development
	d. Yield formation	90-100	hollow grains, reduced oil content

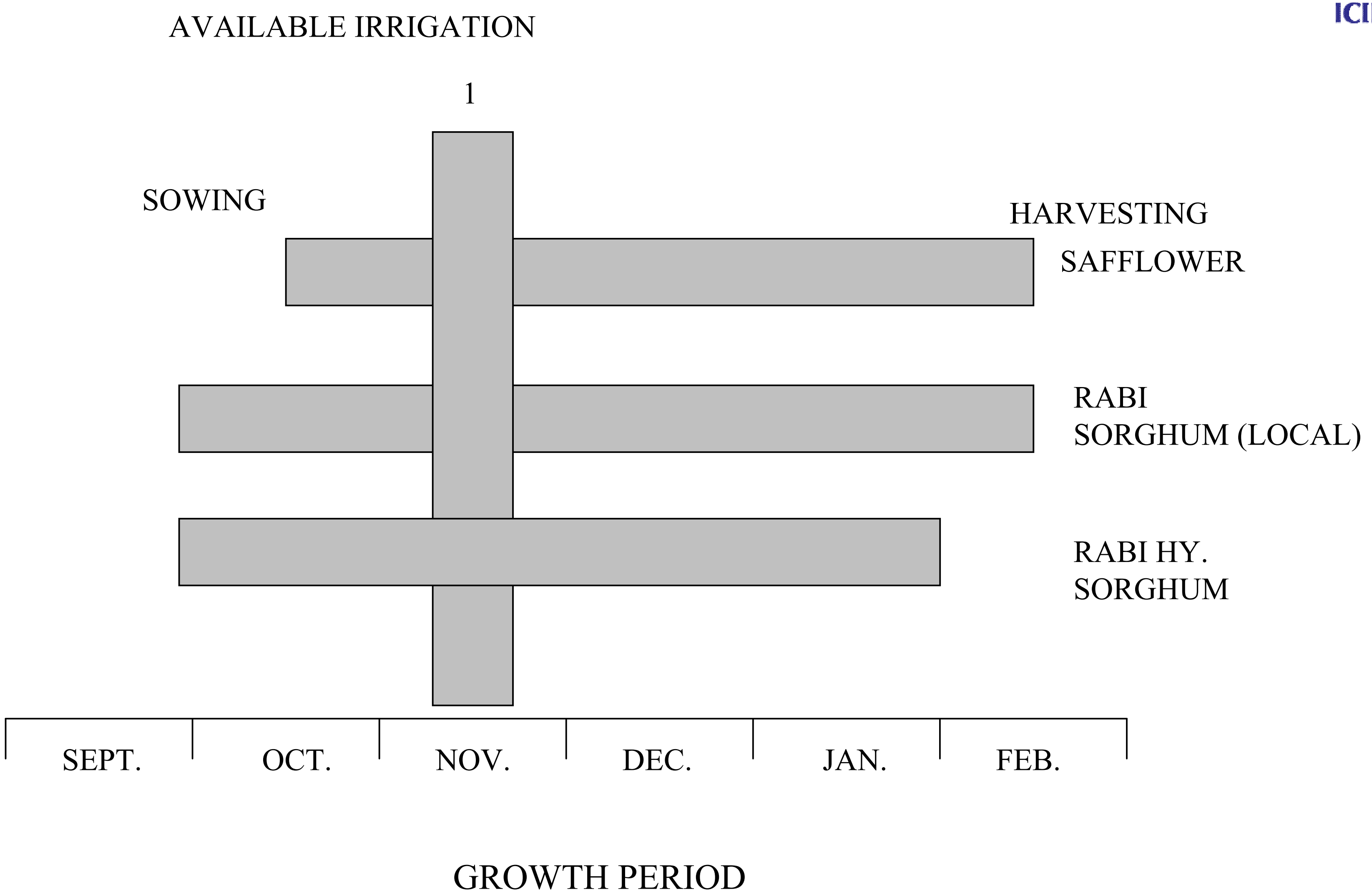


Fig.1. IRRIGATION SCHEDULING AS PER NO. OF IRRIGATIONS AVAILABLE

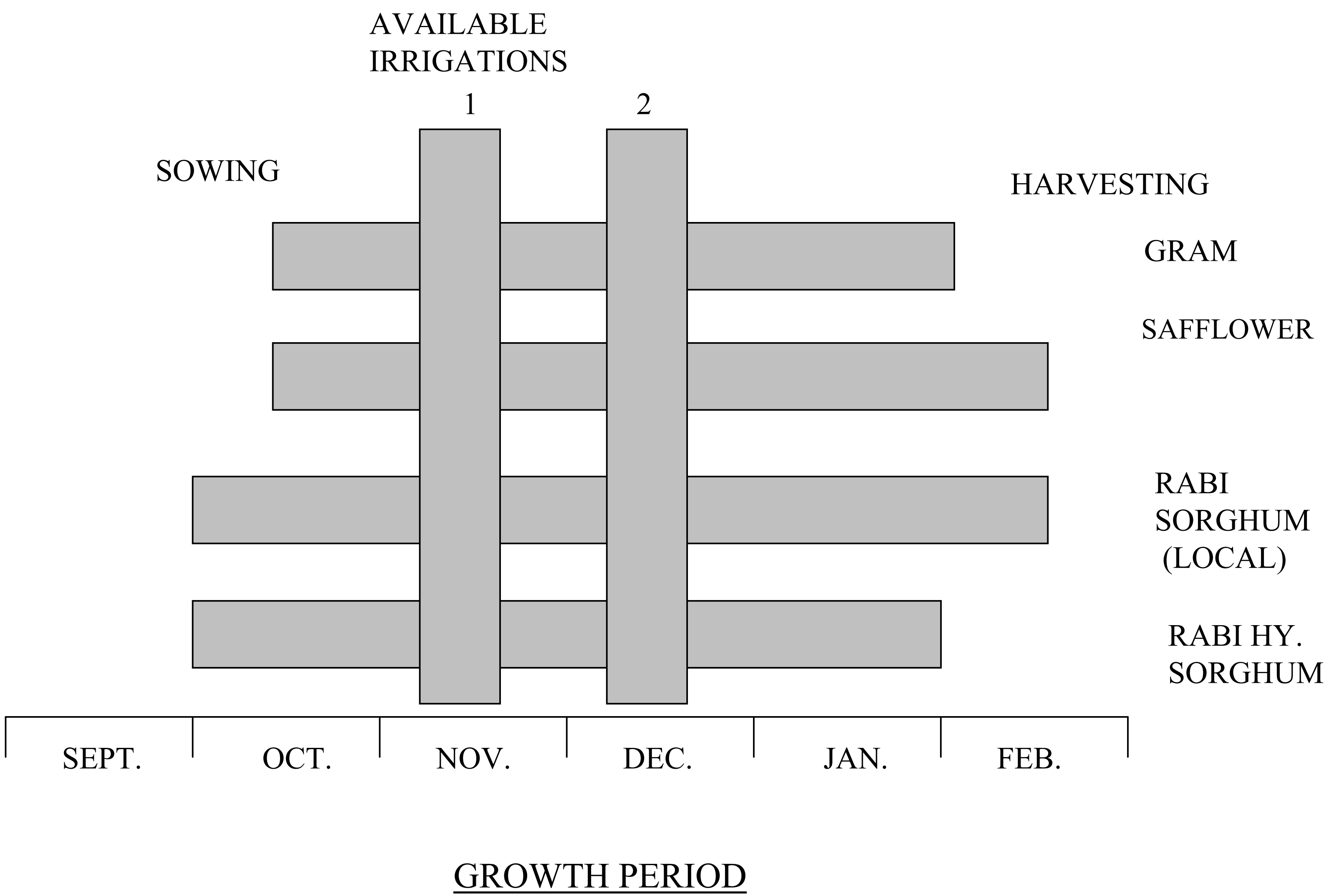
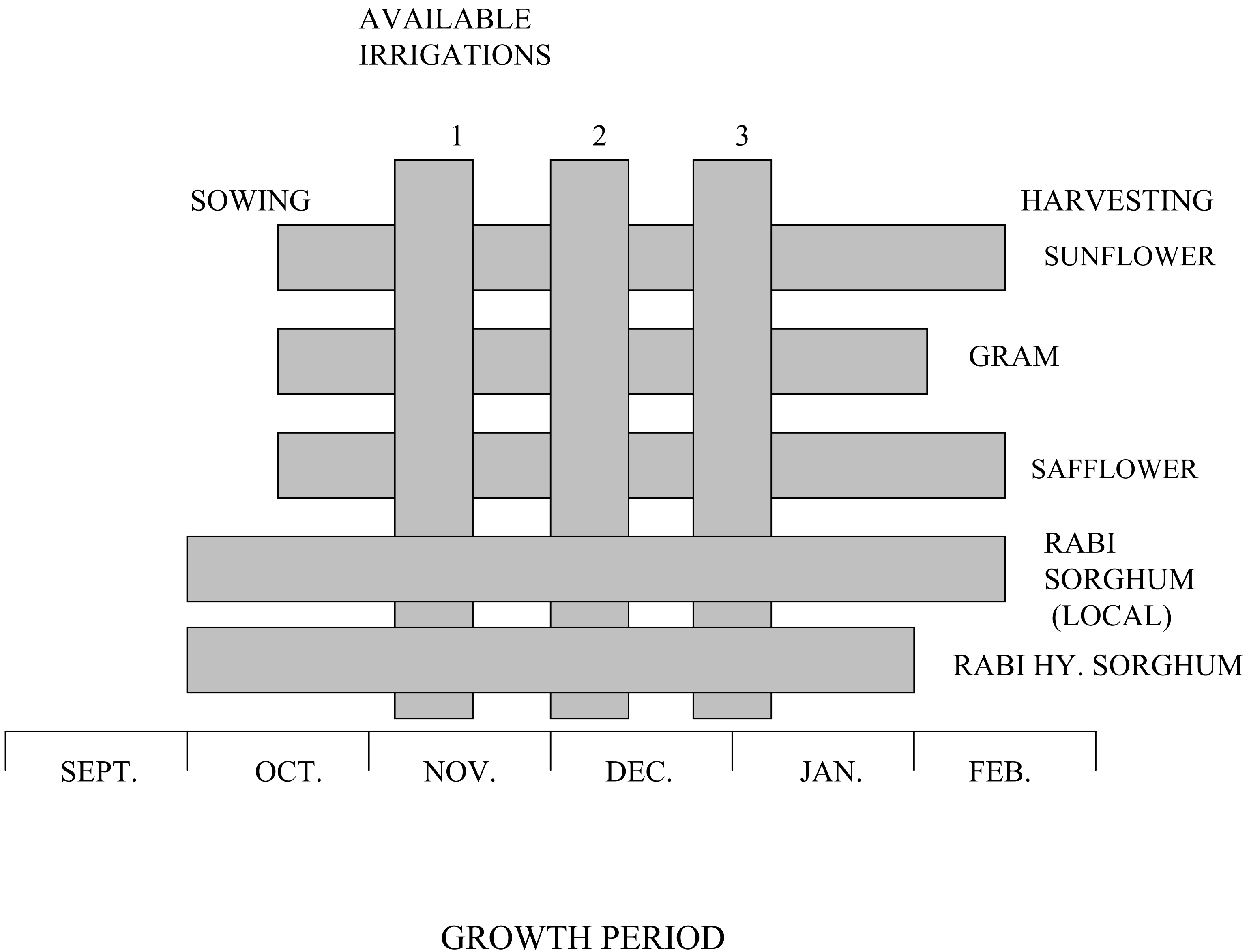


Fig.2. IRRIGATION SCHEDULING AS PER NO. OF IRRIGATIONS AVAILABLE



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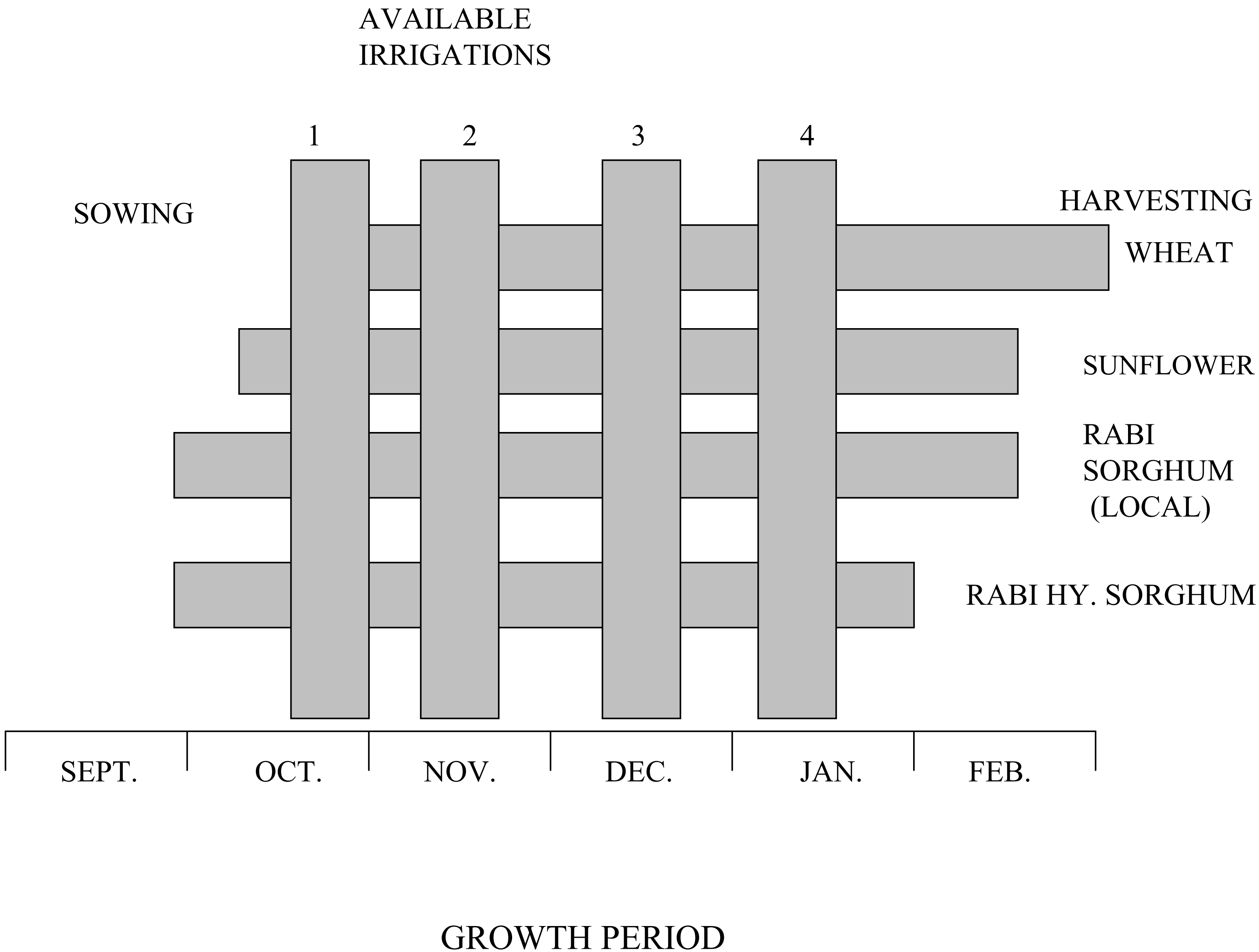

Fig.4. IRRIGATION SCHEDULING AS PER NO. OF IRRIGATIONS AVAILABLE

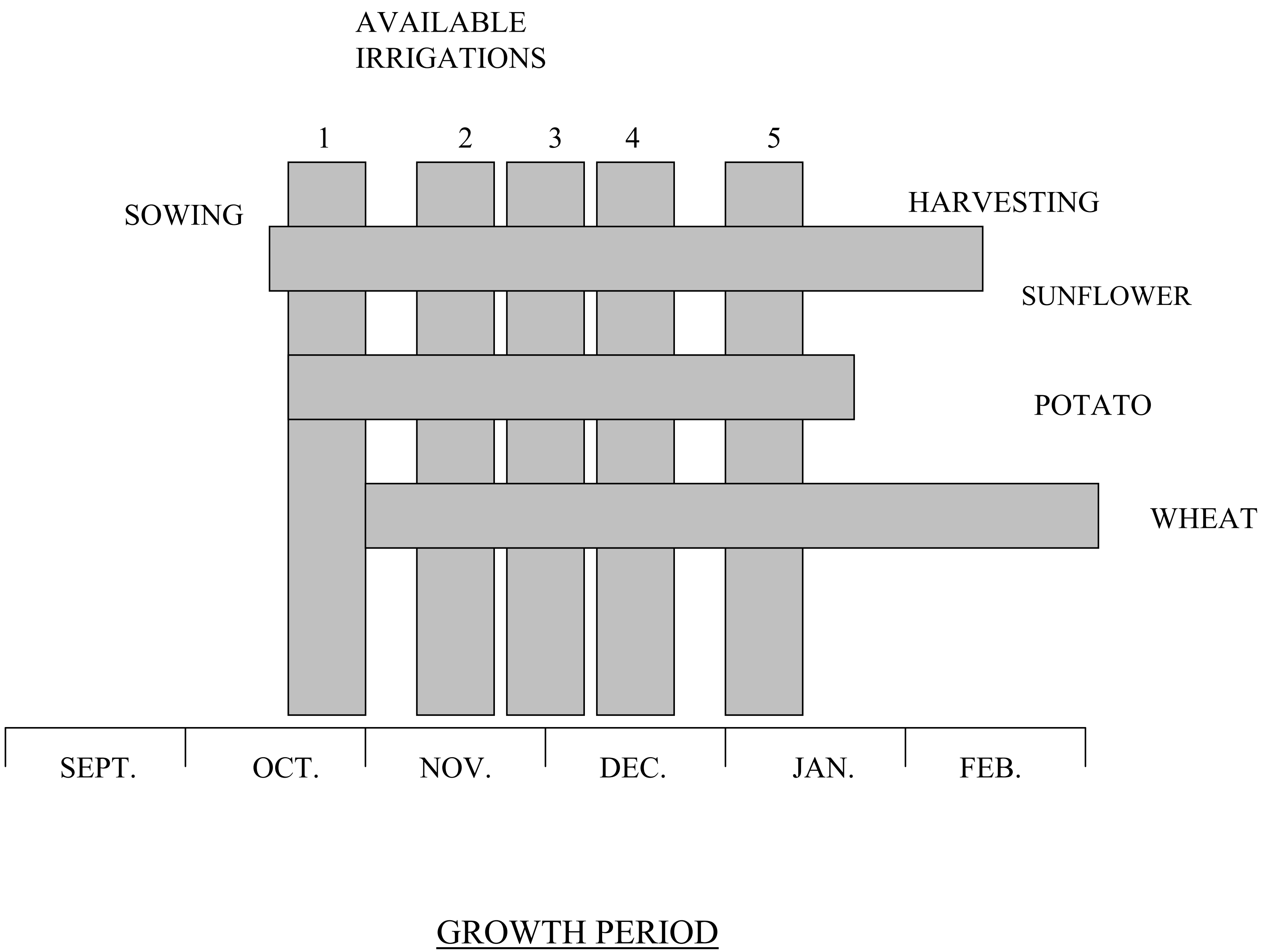

Fig.5. IRRIGATION SCHEDULING AS PER NO. OF IRRIGATIONS AVAILABLE

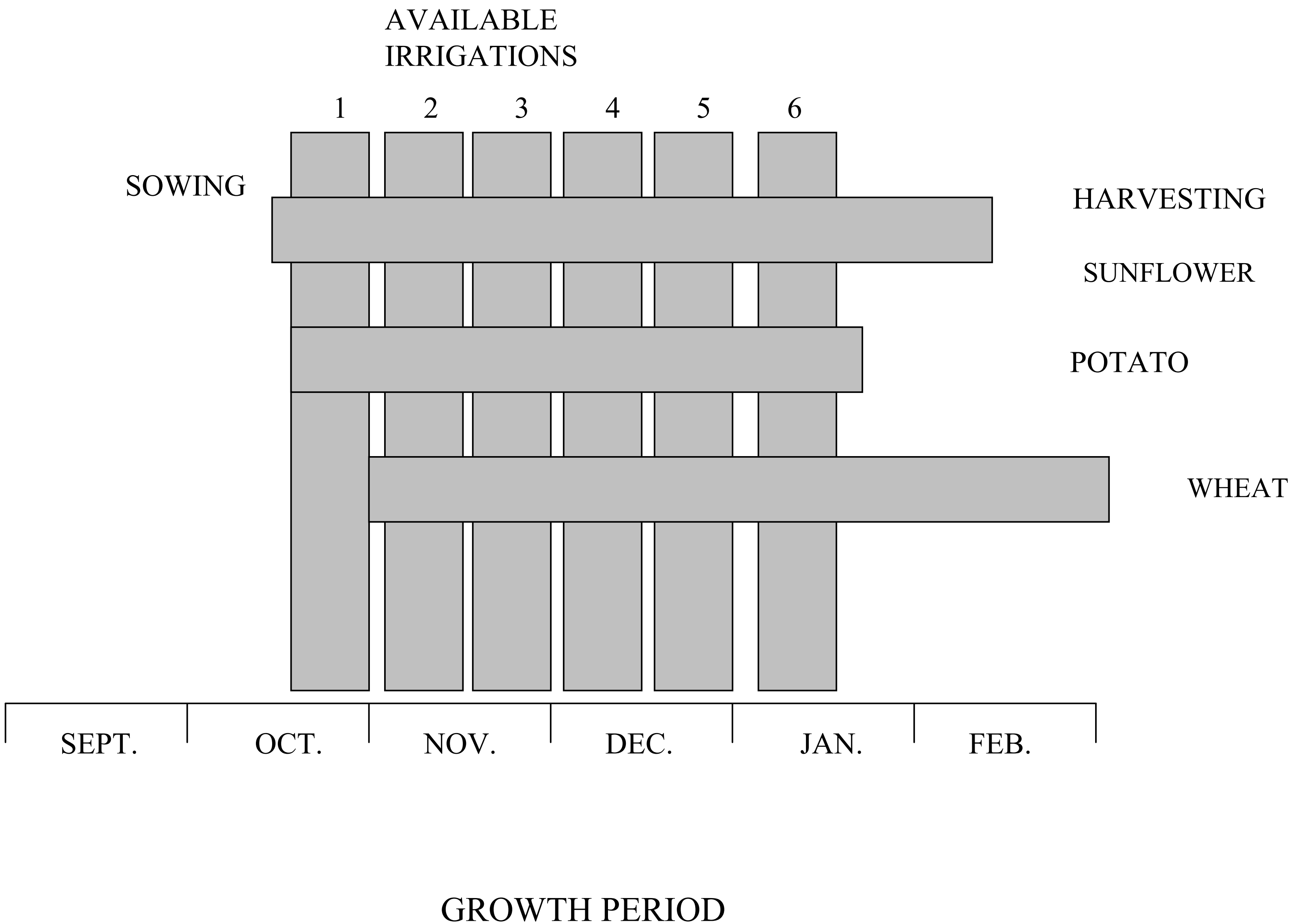

Fig.6. IRRIGATION SCHEDULING AS PER NO. OF IRRIGATIONS AVAILABLE