13. WATER MANAGEMENT PRACTICES AND RICE CULTIVATION IN INDIA

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Soil Conditions and Water Management:

The cultivation of rice is suggested in those soils where the losses due to seepage and percolation are the minimum. Based on the values of percolation, the limits for evaluating suitability of soils for growing rice under irrigated conditions are as follows (Dastane, 1967).

Soil class	Excellent	Good	Marginal	Unsuitable
Percolation (mm/day)	1–2.5	2.5–5.0	5.0–10.0	above 10.0

Consideration of field for the cultivation of rice in past was based on soil type, which however had the factor of loss of water due to percolation into account. Nevertheless besides soil factors, the loss of water in the rice fields is governed by different soil and water management practices. A suitable cultural practice aimed at reducing the loss of water would outweigh the advantage from suitability of the soils only. The work done on different soil types in the country have suggested that the water requirement varies from 750 to 2500 mm (Dastane, 1971). Of this, at places, as high as 70 per cent of the water is lost due to percolation (Dastane, 1969). Gupta and Bhattacharya (1963); Pande and Mittra (1969) and Shanmugum (1971) studied percolation loss under different soil types and reported that the deep percolation loss was in the order of sandy soil > sandy loam soil > fine sandy loam > heavy clay soil.

Soil physical conditions created by varying soil manipulation treatments, puddling and compaction increased the bulk density and reduced the water loss by reducing macropores, thereby hydraulic conductivity. Pandya (1963) had suggested that reduction in the mean weight diameter of soil aggregates by puddling helped in reducing the water requirement of the crop. Similar observations are also made by Bhole (1963); Pande and Mittra (1969); Ghildyal (1969) and Rao (1970). Besides surface manipulation, creation of subsurface barriers for water movement are also found effective in lowering the percolation loss, thereby reducing the total water requirement without sacrificing the yields.

The surface soil manipulations by puddling and compaction brought almost similar effect to soil physico-chemical properties and hydraulic conductivity. The degree and depth of puddling and extent of compaction under the above, had varying influence on growth, yield and water requirement of the crop. Work conducted in acid lateritic sandy-clay-loam soil revealed that the water loss due to percolation was reduced considerably by increasing the depth of puddling from 10 cm to 15 cm. Subsurface barriers using polythene sheets, bitumen, asphalt or cement have been tried successfully in reducing the percolation loss (Table 1) at Siruguppa on black clay soil and at Kharagpur on sandy-clay-loam soil. However, the economic feasibility of the technique in reducing the loss is yet to be investigated.

Experience over years has shown that paddy is the only crop which is feasible

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Table 1. Influence of puddling, compaction and subsurface barriers on bulk density and hydraulic conductivity of soil and percolation loss.

Treatments	Soil bluk density	Soil hydraulic conductivity 10^{-4} cm/sec	Percolation loss mm/day
Control	1.46	5.7	100—120
Puddling	1.73	0.45	5— 18
Compaction	1.68	0.48	6— 22
Sub-surface barriers	1.48	5.1*	negligible

(Source: Pande et. al., 1973)
* Soil condition remained as that of control.

to grow in standing water, a common feature of rice field. In saline soil submergence desalinises and dilutes the salts present therein. Among the different growth stages of the rice plant, seedling and flowering stages have been identified as more sensitive to salinity or alkalinity. To overcome the above limitations, the practice of transplanting longer duration seedlings in combination with maintaining submergence during seedling to tillering stage has been advocated. The salt tolerance of rice progressively increases with the increase in age up to elongation stage. The reproductive stage is found more adversely affected than the vegetative stage. The relative tolerance of different growth stages to varying levels of salt concentration is given in Table 2 and Fig. 1.

Table 2. Relative salt tolerance at different growth stages of rice

Stages of crop growtth	Tolerance limit upto (ppm)
Safe for all	600
Seedling	1,300
Tillering	1,700
Booting to heading	3,400
Flowering	1,700
Up to maturity	3,400

(Source: Dargon and Abrol, 1971).

It is apparent that dilution of salt concentration by land submergence is essential particularly at seedling and flowering stages. The saline and alkaline soils being mostly ill drained, addition of gypsum has been found beneficial as it increases the permeability of soil (Bhumla, 1968). In the problem soils, effect of soil amendments on the crop had been improved when phasic water management was practiced.

The leaching loss of nitrogen is inevitable in submerged rice field. Attempts have been made to minimize the loss by split application of nitrogen. The loss of nitrogen was considerably reduced in the heavy soils by three split application and that in light soil by four splits, as shown in Appendix I.

Minimizing the percolation loss of water through suitable water management practice seems to be another possibility in reducing the loss of nutrients. Pande and Mittra (1969) observed that besides saturation, shallow depth of submergence brought considerable reduction in percolation loss under all levels of fertilization.

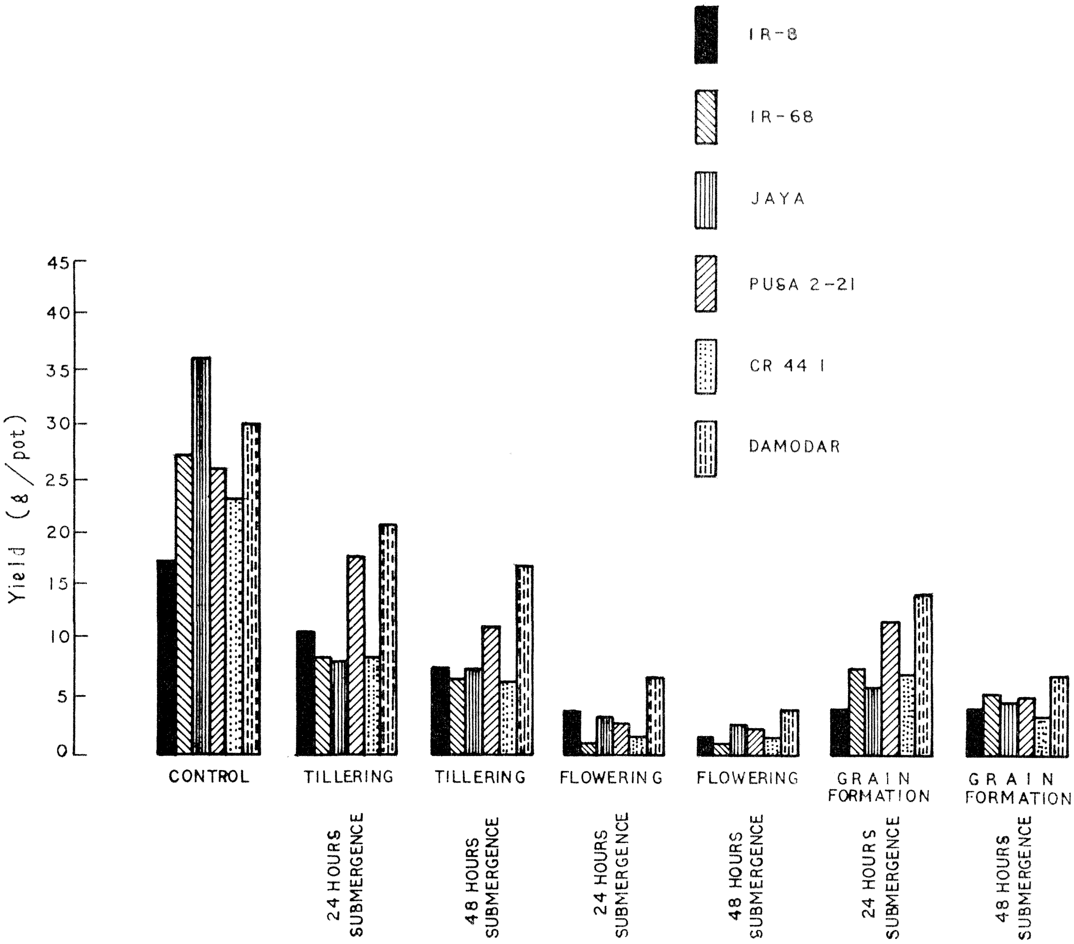


Fig. 1. Effect of saline water submegence at different growth stages on paddy varieties (Source: Yadav, 1973)

Table 3. Water loss due to percolation as affected by the interaction between the level of submergence and fertilization of the soil

Levels of soil submergence	Water loss due to percolation (cm)		
	Levels of soil fertilization (N, P_2O_5 and K_2O kg/ha)		
	Low (50 : 30 : 30)	Medium (75 : 45 : 45)	High (100 : 60 : 60)
Saturation (0—0. 1)	33. 6	33. 7	34. 0
Shallow submergece (5±3 cm)	65. 7	70. 5	71. 2
Deep submergence (10±3 cm)	77. 6	83. 5	80. 6
L. S. D. at 5%		0. 56	
at 1%		0. 62	

(Source: Pande, and Mittra, 1969)

While studying different conditions of soil moisture regimes, like continuous submergence of 15 cm (condition of low land field), just above field capacity and just above 75 per cent availability (conditions resembling upland fields) Sahu and Routh (1969) found that the water use under the above three situations was 1560, 812 and 700 mm respectively. The work done at Cuttack (Yadav, 1973) revealed that there was greater loss of nutrients with the increase in number of drainage cycles, the cumulative loss with increase in drainage was observed in case of *N* and *Mn* whereas in case of *P* and *Fe* there was no further loss after third and fourth drainage cycles respectively.

Rice grown in ill drained soil is subjected to toxic effects of reduced products like sulphide and methane. Further, this problem is more accentuated when the organic matter in the soil is more. To avoid the ill effect of the toxic substances, the drainage is necessitated in poorly drained soil. On the other hand, where natural vertical drainage is good there is no necessity of artificial drainage. On such soil any practice either by keeping the soil submerged or maintaining a shallow water table for keeping the root zone saturated proved equally beneficial to rice (Rangamannar, 1974). Therefore, some workers have drained the field during land submergence with benefit to the plant growth while others found no advantage of drainage. Ramiah (1934) advocated drainage at any time during vegetative growth, but stressed that it should not be long enough to cause soil cracking. The findings of Dastane (1970) are in confirmity with the above. Sahu (1967) observed that on a drained and ill drained field paddy yields were 30 and 20 quintals/hectare respectively. Moreover when farm yard manure was added at the rate of 180 quintals/hectare, the drained plot yielded 37 quintals/hectare while the ill drained plot yielded 18 quintals/hectare only.

Rice Plant Growth and Water Management:

Cultivation of rice under submergence has been taken as an accepted practice with many benefits accrued from it. Since the performance of different varieties varies under varying water management practices and agroclimatic conditions, it would be worthwhile knowing the stage of the crop growth and the duration for which the same may be submerged.

Results of almost all the experiments broadly show that submergence of land is beneficial to rice crop growth. A depth of water upto 10 cm has been reported to be the favourable limit of submergence. However, excess water above 5 cm is of no advantage to most of the varieties grown in India. Adverse effects on yield have been noted with deeper depth of water as well as when the field moisture was below the saturation level for more than 3 days at a stretch. Saturated condition of soil appears to be sufficient to meet the crop requirement under low atmospheric evaporative demand while flooding seems to be essential under high atmospheric evaporative demand (Jana and Ghildyal, 1969; Pande and Singh, 1969; Anon, 1974). In the cultivation of high yielding varieties it had been found that continuous submergence not only caused considerable wastage of water but also brought decrease in yield where the soil was poorly drained.

Depth of Land Submergence:

Effect of land submergence on growth and yield of rice had been studied by several workers for important rice growing tracts in the country (Bal, 1935; Sen, 1937; Narasingha Rao, 1951; Sukanya Bai and Shanmuga Sundaram, 1962; Ghosh and Bhattacharyya, 1959; Chaudhury and Pande, 1968; Ghildyal and Jana, 1967; Ghildyal, 1969; Sen and Datta, 1967; Vamadevan and Dastane, 1967; Pande and Mittra, 1969; Pande and Singh, 1969; Vamadevan and Manna, 1971; Anon, 1974). Their finding indicate that a shallow depth of about 5 cm submergence is essential for rice growth.

Table 4. Effect of moisture regimes on yield of tall and dwarf indica rice

Water regimes	Grain yield q/ha	
	Tall	Dwarf
Bhatia and Dastane (1966)		
Saturation to 0.4 atm. tension	46.10	55.80
4 cm to 0 cm submergence	59.00	71.90
8 cm to 4 cm submergence	57.00	56.10
Pande and Mittra (1969)		
Continuous near saturation	25.81	37.78
Shallow submergence 5±2 cm	32.26	47.11
Deep submergence 10±2 cm	32.23	47.00

A series of trials revealed that (Anon, 1974) during monsoon season the rice crop performance was almost similar under saturation, shallow and deep submergence, which may be attributed to low evaporative demand and frequent wetting of the soil due to rain. Whereas in summer season high evaporative demand lead to significantly poor yield of the crop under saturation as compared to that of shallow and deep submergence.

Table 5. Water regimes affecting rice yields under low and high evaporative demand

Treatment	Monsoon		Summer	
	1st year	2nd year	1st year	2nd year
Near saturation	43.8	39.3	33.0	34.0
Shallow submergence 5±2 cm	40.0	43.2	52.2	51.5
Deeper submergence 10±2 cm	38.7	45.0	50.0	40.1
Level of significance	Not significant		Significant	
L. S. D. at 5%			8.5	

(Source: Anon., 1974)

In low lying areas, the depth of water in the rice field sometimes exceeds the optimum level of submergence due to high rainfall and flood the land at times more than a meter deep. This limits the cultivation of high-yielding semi-dwarf rice varieties under such situation.

It was inferred from the experimental evidences that the early stage of rice crop could not withstand complete submergence beyond 9 days and resulted in the ultimate decay of the plant. The ability of the rice plant to stand against flood increased with the age of the plant (Richharia, 1963). Further, it has been noted that the rice plant could withstand varying level of partial submergence at different stages of its growth. However, early tillering to flowering stage of the crop was found more susceptible to flooding (Pande, et al., 1974), which is given in Appendix II.

Flood resistant varieties have been tried in different parts of the country and responded well even in the situation where the land is submerged to the extent of 2 meters. PLA 2, PLA 3, PLA 4, Ptb 16, IR 13A and FR 43B have come up as suitable varieties for flood affected areas.

Duration of Submergence:

Water being one of the costliest inputs and rice having high water need, whether continuous land submergence is essential, became a vital question in water management studies of this crop. Nevertheless, knowledge regarding the duration of submergence either throughout the growth period or at certain stages only, could be the question for economic utilization of water. Phasic submergence provided condition of favourable soil environment to the crop during monsoon (*kharif*) and that of economy in water use during summer.

For increased tiller and grain production, continuous submergence in the rice field specially during the early plant growth period (Ghosh, 1954 and Ghosh and Bhattacharya, 1958) has been largely emphasized. However, maintenance of shallow water depth just after transplanting has also been argued to be as effective as continuous submergence (Lanka, 1971). On the other hand Chaudhury and Pande (1968); Roy and Pande (1969) and Pande *et al.*, (1971) reported no necessity of continuous stagnation of water for high yield dwarfs and advocated an irrigation schedule of alternate wetting and drying. This practice was found useful in drained and irrigated soils (Dastane *et al.*, 1967). Some of the experimental observations are given in Appendix III and IV.

The above experimental findings conclusively suggest the water management practices for cultivation of semi-dwarf high yield potential rice varieties. A schedule of near saturation condition should be maintained from transplanting to tillering followed by shallow submergence of 5 ± 2 cm from tillering to flowering and either submergence or saturation from flowering till maturity stage of the crop. This would bring higher degree of water use efficiency without sacrificing the yield.

Water Requirement of Rice Crop:

Water requirement of rice crop varies widely due to soil and its management, climate and season, variety, water management and other practices. The data on irrigation and total water requirement of rice given by different workers show that the water requirement of rice varies from 750 mm to as high as 2500 mm. A brief review of the work is presented in Table 6.

Soil Types and Water Management Practices:

It does not need emphasis that in submerged paddy soils having high hydraulic conductivity (light soil), the water loss due to percolation is high which results in high water requirement as compared to the soils of low hydraulic conductivity (heavy soils). A suitable soil manipulation practice helps in reducing the loss of water due to percolation. Even in light soil the crop can be grown successfully with considerably less quantity of water. Using suitable technique for reducing the percolation losses of water in sandy-clay-loam soil having percolation loss as high as 10 cm per day, it had been possible to grow rice with considerably less quantity of water.

Season and Climate:

It is understood that the variation in losses due to evaporation, transpiration including metabolic water use and percolation alter the total water requirement in

Table 6. Irrigation and water requirement of rice

Author	State/Place	Water needs (mm)	Irrigation needs (mm)	Remarks
Basak (1957)	West Bengal	1,143		
Pande and Mittra (1969)	Kharagpur	1,850		Autumn rice
		1,890		Winter rice
		2,150		Summer rice
Sahu and Bout (1969)	Bhubaneswar	1,560		*Kharif*
Chaudhury and Pandey (1971)	Cuttack	884		December-April
Ramiah and Varshney (1951)	Cuttack	1,905		
Pandey (1968)	Bikkramganj	950		*Kharif*
Mittra and Sabnis (1945)	Uttar Pradesh		916	Early varieties
			1,270	Late varieties
Anonymous (1950)	Uttar Pradesh			
Central Board of Irrigation	a) Behaderabad	1,304	347	
and Power	b) Attarah	1,615	615	
	c) Dhanauri	1,600	740	
Gupta and Bhattacharya (1963)	Roorkee	1,615	752	
Patil (1963)	Mysore	1,522	1,168	
Chandra Mohan (1965, 67)	Tamilnadu	1300 to 2500		
Narsimha Rao (1951)	Tamilnadu	1,295		

(Source: Dastane et. al., 1970)

Table 7. Influence of puddling, compaction and subsurface impervious layer on bulk density and hydraulic conductivity of soil in the rice field

Treatments	Water requirement (cm)		
	(January-April)	(April-July)	(July-Nov.)
Control	388.00	317.37	70.67
Puddling	185.40	153.20	—
	(48.04%)	(48.52%)	
Compaction	203.70	164.80	—
	(97.00%)	(93.00%)	
Sub-surface	89.63	75.09	47.90
Impervious layer	(337%)	(322%)	(49%)

(Source: Pande et al., 1973)

the field. The variation is due to environmental factors which change with the season. A year round estimate on the above components for all the rice growing seasons is presented through Fig. 2A and 2B.

Varieties:

As mentioned earlier by the Author in the country report the high yielding varieties are categorized into 3 group (early, medium and late) on the basis of

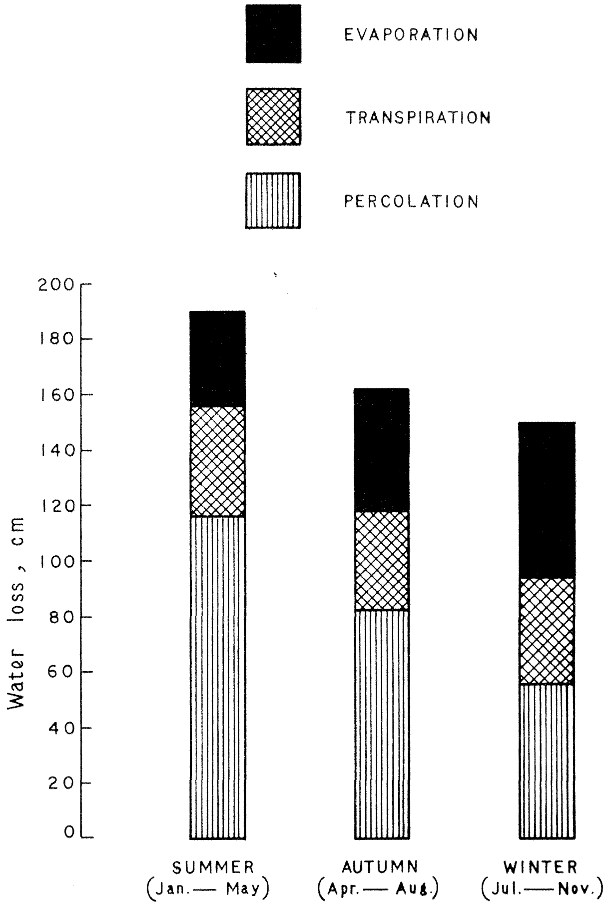


Fig. 2a. Loss of water from low land rice field during three rice growing seasons (Source: Yadav, 1973)

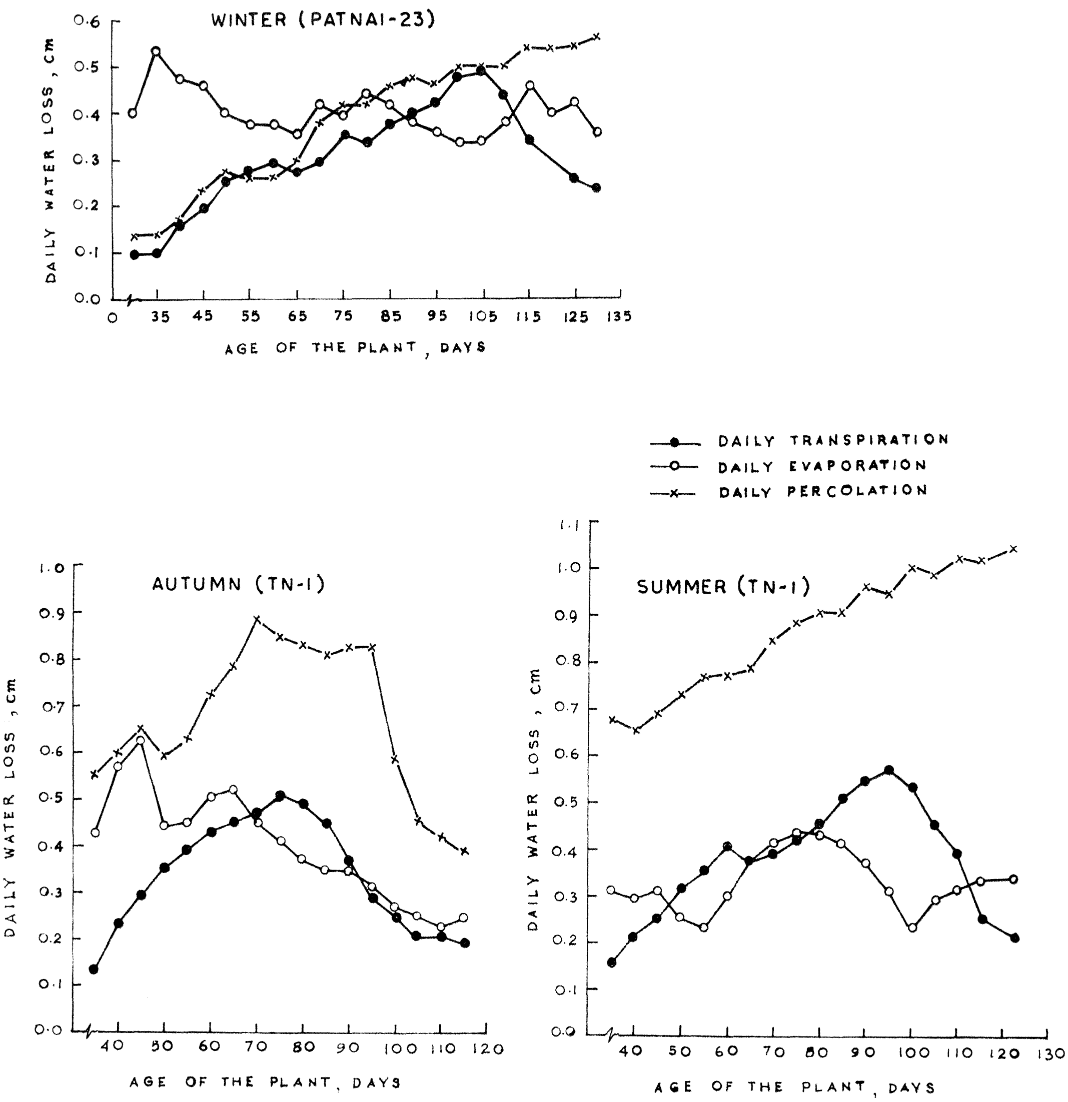
Varieties	Fully irrigated		Partially irrigated	
	Duration (days)	Water requirement (cm)	Duration (days)	Water requirement (cm)
Bala	96	82		
Cauveri	108	92		
Jaya	142	135	131	119
Jagannath	—	—	150	136

(Source: Yadav, 1973)

their life span. Apparently the water requirement also varies as per their duration.

Water Management Practices:

Rice is considered to be an inefficient water user, hence it is imperative to develop judicious water management to achieve higher efficiency by saving water



(Source: Pande and Mitra, 1971.)

Fig. 2b. Daily water loss due to transpiration evaporation and percolation from the rice field during winter, autumn and summer

without sacrificing crop yield. Experiments conducted at various centres in India reveal the fact that there is considerable saving in water, when submergence was maintained only between tillering till flowering and near saturation condition at other growth phases. Through this practice the water requirement of the crop was reduced to the extent of 27 per cent during Kharif (wet season) and 40 per cent during summer (dry season) without any reduction rather an increase in yield (Pande *et al.*, 1973).

A practice of water management in heavy black soil during Kharif season where soil moisture was maintained from saturation to hair cracking proved as good as

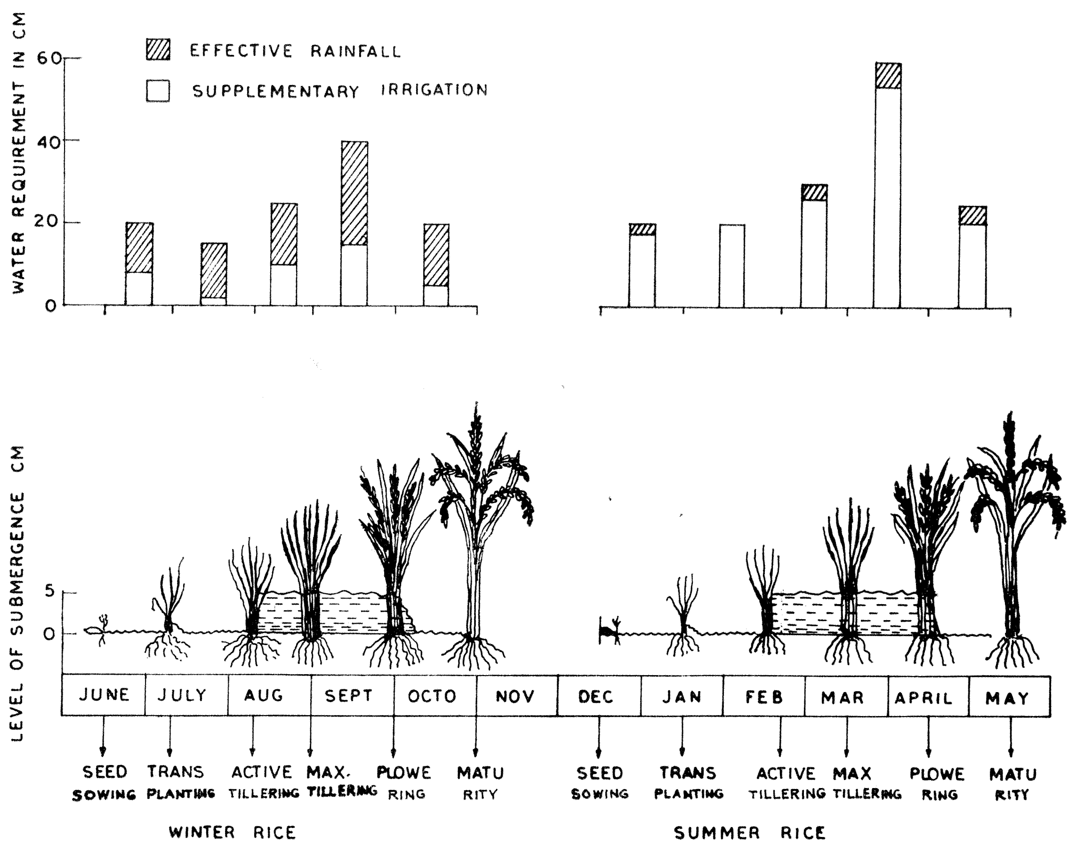


Fig. 3. Year round efficient water management in rice (Source: Pande and Mitra, 1971)

continuous submergence for rice crop with a saving of 40 per cent water (913 mm under saturation to hair cracking, and 1538 mm in submergence) under the former situation, (Table 8).

Table 8. Effect of different water regimes on grain yield and water requirement of rice crop during Kharif

Moisture regimes	I year Grain yield (q/ha)	Water applied (mm)	II year Grain yield (q/ha)	Water applied (mm)
I_1 5-0 cm submergence	57.1	1,538	42.7	1,190
I_2 Saturation to hair cracking	54.7	913	44.6	870
I_3 Saturation to F.C.	53.6	831	44.6	754

(Source: Yadav, 1973)

Considerable saving of water is possible in cultivation of high yielding varieties by adopting suitable soil water management practices (Fig. 4). This brightens the prospect of successful cultivation of high yielding rice varieties which are grown with assured water supply.

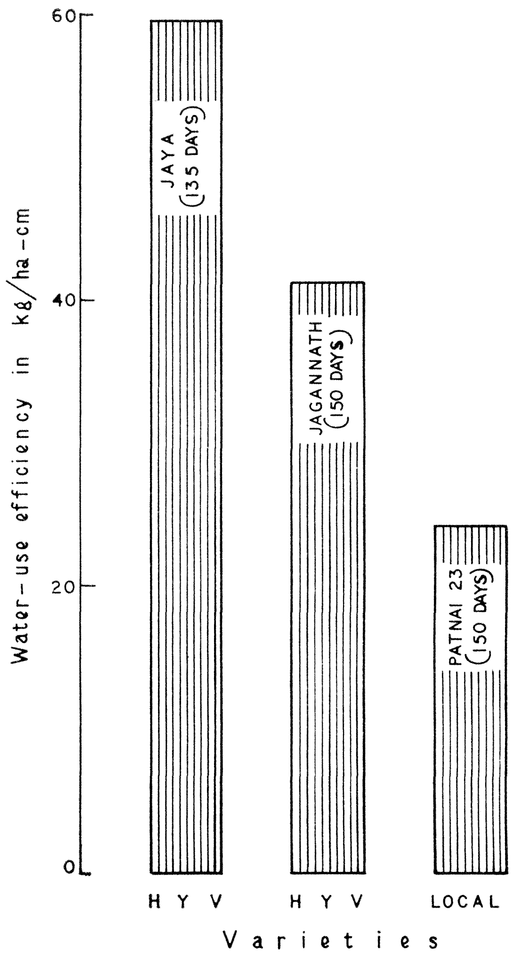


Fig. 4. Water-use efficiency of high yielding and local rice varieties (Source: Water management and salinity scheme, ICAR consolidated report, 1974)

Extension of High Yielding Varieties and Water Management:

A wide choice exists among the high yielding varieties having varying growth duration and sowing time. The range of duration exists from 95–165 days. Among these, the varieties of 130–140 days duration have exhibited high yield potential and are therefore preferred by the growers (Fig. 5) Selection of late or early maturing varieties are decided on the availability and duration of supply of water from a water source. In the areas of limited water supply, varieties of short duration like Bala, Cauveri, Krishna, Pusa 2–21 are preferred while in areas where late rains are accompanied with longer period of land submergence, long duration varieties like Pankaj and Jagannath have been selected. Among the high yielding varieties having varying duration, maximum area is covered by medium duration varieties. As stated earlier, there is considerable increase in irrigation resources, consequently a marked increase is noted in the area under these varieties. Water being the costliest input,

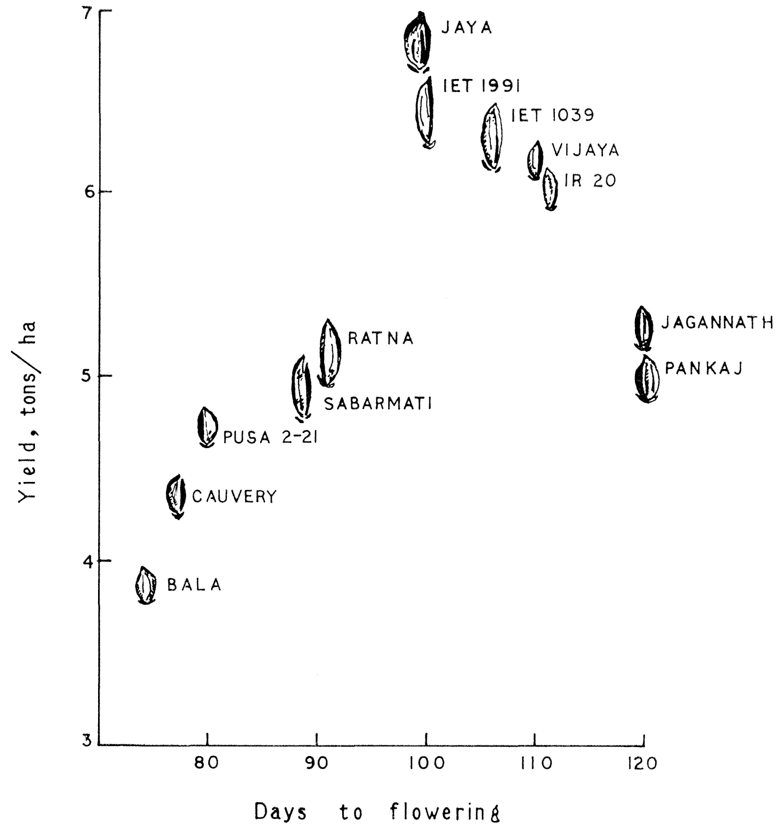


Fig. 5. Among the presently available dwarf varieties those with total duration of 130–140 days have the highest yield potential, earlier and later varieties being lower in yield. Fine grain quality is not incompatible with high yield. (**Schematic**)
(**Source: Shastry, 1972**)

saving of irrigation water has been attempted through suitable water management practices for higher economy, greater water use efficiency and increasing the area of irrigated paddy (Fig. 6).

Multiple Cropping:

Crop diversification in rotational sequence with irrigated rice is a major problem. This has long been felt and is well recognized need in the country especially in the areas which have additional irrigation potential for another crop following the harvest of rice. In recent years, the country in general and the rice producing states in particular are passing through a big change in cropping pattern with the introduction of high yield potential rice varieties which can be grown in all the 3 seasons. In the various parts of the country investigations were initiated to grow more than one crop of rice in sequence in a year. However in multiple cropping programme inclusion of crops other than 2nd or 3rd crop of rice has also been tried with an objective to earn more profit per unit area per unit consumption of water. It has been found that instead of growing 3 crops of rice in sequence, when a crop of rainy season

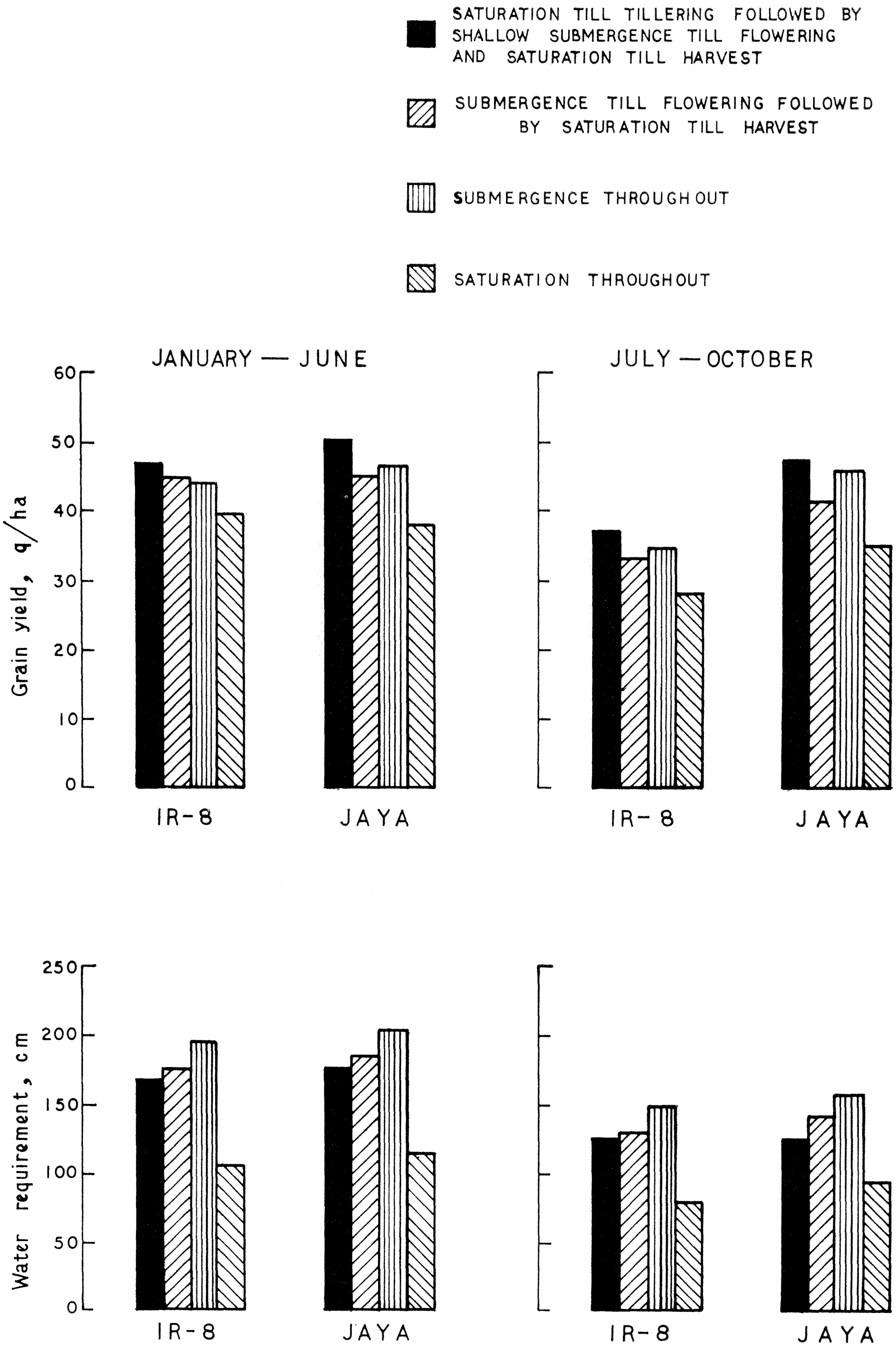


Fig. 6. Influence of phasic submergence and/or saturation on grain yleld requirement and water-use-efficiency of IR 8 and jaya varieties of rice grown during January-June and July October seasons
(Source: Anonynous, 1974)

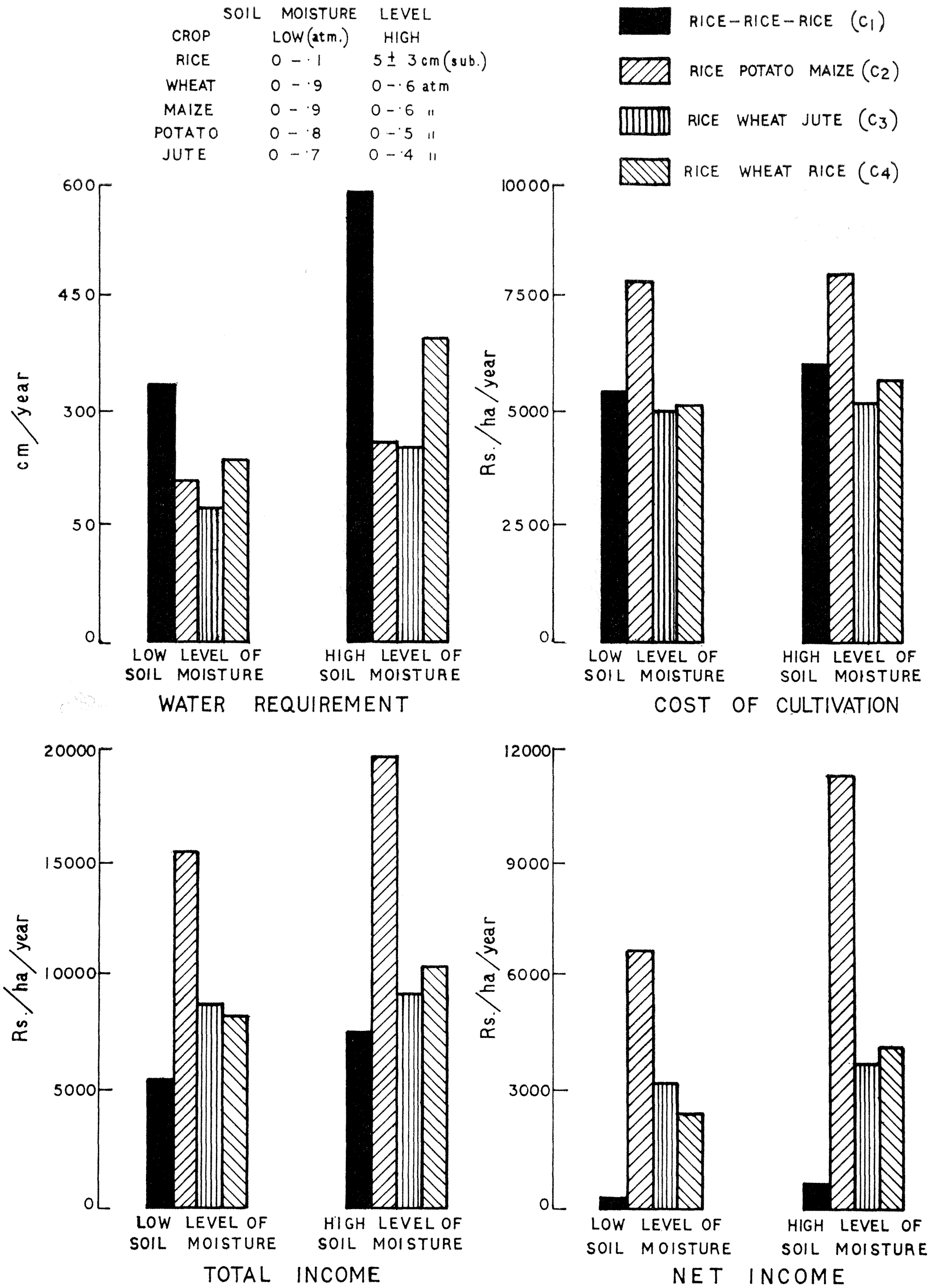


Fig. 7. Comparative efficiency of multiple cropping system with different corps in rotation (Source: Anonynous, 1974)

rice was followed by potato or wheat during winter and maize during summer, a high return varying from 94 to 628 per cent could be achieved and there was a saving of irrigation water from 39 to 128 per cent. When Jute crop was grown in place of autumn rice there was saving of irrigation water to the extent of 390 per cent, though there was not much change in net profit (Fig. 7). In some areas due to specific agro-edaphic conditions farmers are unable to introduce any other crop than rice, inspite of the fact that the cultivation of rice more than once is less remunerative. On the other hand even with the prospect of growing second crop other than rice, the farmers are continuing with their age old practice of growing only rice, one, two or even three crops a year. Nevertheless wherever soil and climatic conditions favour, the cultivation of other crops in rotation with rice is, by and large, getting favour of the farmers.

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APPENDIX I

Leaching loss of Nitrogen as influenced by split application at different stages of crop growth.

Soil	Treatments	Loss of applied N (total—control*)	
		(mg.)	(%)
Alluvial	all at I	790	44.4
	all at II	656	36.8
	at I and II	587	32.9
	at II and IV	417	23.4
	at I, II and IV	362	20.4
	at II, IV and V	238	13.4
	at I, II, IV and V	200	11.3
	at II and IV (Sealed-bottom pot)		
Lateritic	all at I	1,079	60.6
	all at II	828	46.5
	at I and II	993	55.8
	at II and IV	617	34.7
	at I, II and IV	707	39.7
	at II, IV and V	461	25.9
	at I, II, IV and V	583	32.8
	at II and IV (Sealed-bottom pot)		

* Total loss of $N(NH_4+NO_3)$ from control pot (native nitrogen) for stages I, II, III, IV and V respectively was 78, 10, 1, 4 and 2 mg./pot in alluvial soil and 45, 7, 1, 4 and 2 mg./pot in lateritic soil.

Stages of crop growth I, II, III, IV and V=transplanting, active vegetative, lag vegetative, reproductive and ripening stages respectively.

(Source: Pande and Adak, 1971)

APPENDIX II

Yield of variety 'Jaya' under three levels of submergence, 25, 50 and 75 percent of crop height at each of the three growth phases during aman (July–Nov.) and boro (Jan.–April), 1973–74.

Treatments		Grain yield g/drum with 7 clumps	
		1973 (aman)	1974 (boro)
	Control (continuous submergence 5 ± 2 cm)	197.60	255.60
Stage	Height of the plant submerged		
Seedling establishment to maximum tillering	25 percent	162.00	191.11
	50 percent	148.71	157.89
	75 percent	134.22	149.44
Maximum tillering to flowering	25 percent	160.56	189.89
	50 percent	141.11	164.67
	75 percent	143.11	143.44
Flowering to maturity	25 percent	155.44	180.33
	50 percent	150.44	169.67
	75 percent	138.89	149.56
LSD at 5%		16.27	23.24
at 1%		22.54	32.19

(Source: Pande et al., 1974)

APPENDIX III

Yield of IR 8 rice influenced by differential (Saturation and submergence) soil water regimes at various growth stages.

Treatment	Particulars	Grain yield kg/ha
T_1	Saturation at I, II, III, IV and V	4,705
T_2	Submergence at I, II, III, IV and V	6,993
T_3	Saturation at I and submergence at II, III, IV and V	7,016
T_4	Saturation at I, III and V and submergence at II and IV	7,734
T_5	Submergence at I, III and V and saturation at II and IV	4,612
	LSD, 5%	998

Stages of growth: I, II, III, IV and V — seedling establisshment, active vegetative, lag vegetative, reproduction and ripening stages respectively.
(Source: Yadav, 1973)

APPENDIX IV

Effect of moisture regimes on grain yield of paddy (Jaya)

Physiological stages						Grain yield per plant (g)		
Pe	T	E	F	M	D	1971	1972	Average
S	S	S	S	S	X	6. 6	9. 90	8. 25
S	S	S	S	X	S	6. 9	8. 80	7. 85
S	S	S	X	S	S	5. 1	7. 35	6. 22
S	S	X	S	S	S	4. 2	9. 10	6. 65
S	X	S	S	S	S	5. 5	7. 95	6. 72
X	S	S	S	S	S	5. 6	8. 25	7. 22
Sb	Sb	Sb	Sb	Sb	X	8. 2	12. 05	10. 12
Sb	Sb	Sb	Sb	X	Sb	7. 9	11. 15	9. 52
Sb	Sb	Sb	X	Sb	Sb	6. 7	6. 45	6. 57
Sb	Sb	X	Sb	Sb	Sb	4. 9	9. 30	7. 10
Sb	X	Sb	Sb	Sb	Sb	7. 2	9. 00	8. 10
X	Sb	Sb	Sb	Sb	Sb	8. 4	9. 35	8. 87
Sb	S	Sb	S	Sb	S	8. 3	9. 05	8. 67
S	Sb	S	Sb	S	Sb	7. 4	8. 09	8. 15
Sb	Sb	S	S	Sb	Sb	5. 7	9. 30	7. 50
S	S	Sb	Sb	S	S	7. 2	9. 10	8. 15
Sb	Sb	Sb	S	S	S	6. 7	10. 25	8. 47
S	S	S	Sb	Sb	Sb	5. 7	9. 85	7. 78
Sb	Sb	Sb	Sb	Sb	Sb	7. 3	12. 65	9. 97
S	S	S	S	S	S	6. 5	9. 10	7. 80
Irrigation at 80% A S M						4. 6	8. 60	6. 60
L. S. D. at 5%						2. 4	1. 15	1. 88

S=Soil saturation; Sb=Submergence; Pe=Plant establishment; T=Tillering; E=Elongation; F=Flowering; M=Milk and D=Dough stage.
(Source: Singh and Misra, 1974)

APPENDIX V

Yield of rice plant types as influenced by soil moisture systems

Plant type	Grain (kg/ha)			
	Without stress (above saturation)	With stress as vegetative stage	(below saturation)	
			Reproductive	Ripening
Tall-Indica	1, 646	1, 213	1, 608	1, 449
PTB — 10	(100)	(—26. 3)	(—2. 4)	(—12)
Japonica	1, 876	1, 410	1, 804	1, 614
Indica ADT. 27	(100)	(—26)	(—5. 6)	(—15. 4)
Dwarf-Indica	2, 593	1, 894	2, 530	2, 275
Jaya	(100)	(—27)	(—2. 5)	(—12. 3)

The digit in paranthesis represents percent loss in yield due to moisture stress taking the yield without stress, as 100.
(Source: Yadav, 1973)

Question and Answer

S. Okabe, Japan: You have mentioned that in the areas where water available is limited, short duration varieties are preferred, which have less-yielding potential as compared to mid-duration variation. This selection might cause some problems, because they would prefer to grow higher yielding varieties, if available. How does the Government manage the farmers to select appropriate varieties so as to meet the total availability of water?

Answer: There is no compulsion imposed by the Government on the farmers to adopt any specific variety. This is entirely affected by the source of irrigation, whether available or not available. In the former situation i.e. when there is a source of irrigation, invariably a farmer grows mid-duration variety which if HYV are always higher yielder. This is being followed in situation having canal or tube-well irrigation.

M. Araragi, Japan: About Appendix I, I think this values are high, and so I would like to ask. (1) Did you check the nitrogen content of water which passed through soil layer? (2) What is the cm of the depth of soil in this experiment?

Answer: (1) This is the total loss of N (NH_4^+ and NO_3^-) through a column of soil about 45 cm having CEC of 8 me./100 g. soil of lateritic sandy clay loam in nature. Hence when nitrogen was applied as ammonium sulphate, the leachate contain appreciably NH_4^+ ions following simple or two splits of the fertilizer application showing the limited adsorption of the NH_4^+ ions on colloidal complex of the soil, and the excess over being allowed to go through percolating water in the farm of leading. (2) The water applied was drawn from deep tube well having negligible or nil quantity of nitrogen.

J. A. Lewis, Sri Landa: Have you had problem of diversifying crops in the heavy soils where puddling was done for rice?

Answer: The diversification of crops through multiple cropping system as discussed in the technical paper was adopted on sandy clay loam soil having only about 20% clay fractions. These soils after the harvest of paddy when tilled using a soil turning plough followed by two to three harrowings turn to normal tilth to sustain the normal crop of wheat, potato etc. However for heavy soils the same way not hold good. They may need investigation for suitable agronomic practices including suitable crop species for such situation.