WATER MANAGEMENT TECHNOLOGIES TO INCREASE CROP AND INCOME PER DROP WITH REFERENCE TO EFFECTIVE UTILIZATION OF LOW LAND ECO-SYSTEM IN EASTERN REGION

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ABSTRACT

India has got 17.2 million ha of low-lying area out of 38.0 million ha through out world and 75% of low land rice area is situated in eastern India, Bangladesh, Myanmar and Thailand. West Bengal, alone has 4.0 lakh ha of current fallow including the area where nothing could be grown after harvest of pre-kharif crops due to poor drainage, flash flood, occasional flood and submergence. The alluvial zone, itself has got 1.04 lakh ha of such land situation wherein the production of crops was far from satisfactory though the potential productivity of the land is very high. However, a suitable farming system has to be evolved under such situation for effective utilization of water resources and lowland eco-system under multiple use of water. A combination of crop cultivation and animal husbandry including pisciculture has been suggested for such land situation to increase the opportunity of employment as well as to supply protein and fat in the dietary programme. So a combination of fish-rice-vegetable cultivation has been tried in a low-lying risk prone so far unproductive land eco-system to make it productive. Water resource management is an important tool to the researchers to address the issues like climate changes, natural disasters, pollution hazards, environmental degradation, deteriorating soil health for attaining food and livelihood security and mitigating such undesirable situations. In addition to the present status of water availability, rainwater harvesting and its economic utilization coupled with inter basin transfer of water from surplus to deficit basin needs to be executed to maximize full water resources potential. Adoption of proven and cost-effective water management technologies are essential to maximize crop production and minimizing gap between irrigation potential created and utilized. Application of water to minimize conveyance losses; methods and scheduling of irrigation, selection of crop(s) and crop sequence(s) also played an important role for enhancement of water use efficiency. Conservation, distribution and utilization of irrigation water are the basic parameters of on-farm water management. Optimum scheduling of irrigation, choice of suitable method, conjunctive use of rain, surface and ground water for crop cultivation, provision of drainage and use of improved agro-production technology is the basic need of successful on-farm research. Application of proper amount of water at proper time increased the water use efficiency and crop yield and reduced the evaporation and deep percolation losses. The participatory action research is an effective and communicative measure in the developmental processes and involves the users in systemic process of change to make the socio-technical system more viable. On-farm participation encouraged the farmers to adopt irrigation technologies for growing crops on the basis of cost-benefit approach. On-farm water management practices proved to be efficient for dissemination of the location specific technologies to the farmer's field wherein active involvement of the farmers at every stage were ensured. A series of on-farm water management research activities in collaboration with Indian Council of Agricultural Research under the aegis of AICRP on Water Management (BCKV) were conducted in selected deep tube well commands of West Bengal and developed a package of intervention or component technology for different field crops. The results of these studies revealed that there were positive impacts of irrigation water on crop productivity, cropping intensity, input use efficiency, farmers' income and employment generation on adoption of water management technologies with active participation of the farmers.

INTRODUCTION

India is the seventh largest having 329.73 million ha of geographical area and second most populous country having more than a billion population in the world. There is no other substitute other than to use every square inch of land and every drop of water effectively and efficiently. Though there was markedly increase in annual food grain production from 51 (1950-51) million tones t0 206 million tones (2000-01), still the death on hunger is visualized.

The demand for food is increasing with ever-increasing population growth rate. So there is no option other than to increase food production. There is very little or no scope of horizontal expansion due to land limitation, the question of vertical expansion is the only way to fit with the situation. Genetically improved crop variety, hybrids, mechanized agriculture, higher rate of fertilizers and chemicals application may give one or two more green revolution, but the question lies how far it can sustain greenness?

Adoption of improved crop cultivars, cropping system, increasing cropping intensities, precision farming can hold good to get out of this situation where whole system is to be considered.

The cropping intensities in the states like Assam, Bihar, MP, Orissa, UP and West Bengal are 137.7, 137.8, 125.6, 154.6, 148.6 and 159.6 percent, respectively. This indicated that a vast majority of lands remain fallow during dry season due to lack of proper technologies, which are under rainfed conditions, neglected. Except West Bengal, more than half of the arable land remains fallow during rainless period. Increasing cropping intensities in rainfed uplands is not easily achievable but there is great potential of intensification of cropping in rainfed lowland by utilizing natural resources and conserved residual moisture. Pulses like black gram, green gram, lentil, lathyrus, chick pea and oilseeds like linseed, groundnut and rapeseed could not only increase the cropping intensities but also come forward to increase national productivity. The demand for food is increasing with ever-increasing population growth rate. So there is no option other than to increase food production. There is very little or no scope of horizontal expansion due to land limitation, the question of vertical expansion is the only way to fit with the situation. Genetically improved crop variety, hybrids, mechanized agriculture, higher rate of fertilizers and chemicals application may give one or two more green revolution, but the question lies how far it can sustain greenness?

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India has got 17.2 million ha of low-lying area out of 38.0 million ha through out world and 75% of low land rice area is situated in eastern India, Bangladesh, Myanmar and Thailand. West Bengal, alone has 4.0 lakh ha of current fallow including the area where nothing could be grown after harvest of pre-kharif crops due to poor drainage, flash flood, occasional flood and submergence. The alluvial zone, itself has got 1.04 lakh ha of such land situation wherein the production of crops was far from satisfactory though the potential productivity of the land is very high. However, a suitable farming system has to be evolved under such situation for effective utilization of water resources and lowland eco-system under multiple use of water. A combination of crop cultivation and animal husbandry including pisciculture has been suggested for such land situation to increase the opportunity of employment as well as to supply protein and fat in the dietary programme. So a combination of fish-rice-vegetable cultivation has been tried in a low-lying risk prone so far unproductive land eco-system to make it productive.

METHODOLOGY ADOPTION IN MODEL DEMONSTRATION

Having similar to several water logged situations in the country, in a village under Nadia district of West Bengal, a vast low lying area remains submerged in 2.0 to 2.5 m deep water during entire rainy season. Several cultivars of semi-deep water rice trials were conducted during the season, where rice failed to produce adequate yield as the onset of submergence and draining out of the accumulated water varied considerably from year to year. After the drainage of accumulated water one crop of summer (*boro*) rice is grown with unsatisfactory yield return. One farm family has a piece of land with an area of 1.36 ha in that low-lying situation, who compelled to keep the land fallow due to flash flood and poor drainage conditions that led inundation of the area during rainy season. That several semi-deep situations rice cultivars like *Sabita, Jogen* and *Bipasha* failed to give an optimum yield. The entire area were used to be sub-merged under water up to 2.0 to 2.5 m from beginning of the rainy season at least up to the month of October. As such there was no way to use the land during June to December in the year. Hence, the agro-technology was contemplated for effective utilization of such risk prone ecosystem.

On restructuring the land under such situation the field experimentation was carried out started from the year 1998 and on-ward. The area used to receive a high amount of annual rainfall of which more than 85% falls during July-September. The entire area used to be inundated and occasional floods with higher frequencies caused to keep the lands fallow during the period. Growing of a single summer rice crop was only possibility at sub-optimal

productivity level. The soil of the experimental site contained organic carbon 0.5 to 1.5 %, available N and P (mg/100g) 25 to 60 and 3.0 to 6.0, respectively with pH ranged from 6.5 to 7.5 (1:2 soil: water suspension).
Soil was drag out from a portion of land on the lower position up to a depth of a meter during dry season and it was spread out along the perimeter to form an embankment all round. This presented the ingress into the plot during rainy season. After reshaping the different portions of the land, the plot marked C (0.30 ha), lower terrace B (0.79 ha) and embankment A (0.27 ha). Thus the net available water area was come to 1.09 ha from June to December having deep ditch of 0.30 ha at the side of the pond and an embankment area of 0.27 ha was formed. The area for growing rice during summer season was made available that was 0.79 ha. The year 1998 and onward, a new dimension was given to land utilization pattern incorporating fish and vegetables farming as components along with summer rice under such specific risk prone low land ecosystem as field experimentation based on farmers participation. It appeared to be an integrated approach for increasing farm income and sustaining crop productivity. Thus, the venture visualized as a model demonstration and opened a new vista of best utilization of low land eco-system.

Indian major carps (mixed), *catla, rohu, mrigal* were stocked in the month of June at the rate of 6000 fingerlings /ha. The fishes were fed rice bran and cow-dung at the rate of 1:1. The fishes were reared up to the end of December at the B and C portion of land. The B portion was gradually dried up and the remaining fishes were transferred to deep ditch in C area constructed for the purpose. High yielding rice of 120 days duration (*Gotra* I/ IET 4786) was transplanted in the third week of January following standard practices under irrigated condition. The fertilizer application to summer rice was followed the recommended ratio of N: P: K at the rate of 100:50:50 during first year, that was reduced to almost half as 50:26:26 during second year and about one-forth as 25:13:13 during third year of field experimentation. Prior to application of plant protection chemicals to control the insects-pests-diseases of rice and to prevent the drainage of washing, the dykes were made along with the periphery of the B area to prevent run off from the area containing residues of plant protection chemicals to C area.

The hybrid tomato *(Abhinas-2*) was sown in seedbed on 9-15 August and transplanted in the area A at a distance of 50 cm row-to-row and plant-to-plant on last week of August or first week of September accommodating 6000 plants in the first and second year. In the third year, it was replaced by local variety of cowpea to cover the embankment area. The plant protection measures of tomato/cowpea were taken appropriately. The bitter gourd and cucurbits were also grown after harvesting of tomato/cowpea in December.

RESULTS OF THE FIELD DEMONSTRATION

The fishes were harvested periodically from the month of August up to December. An average of 1.31 tons fishes of various categories was obtained from the entire water body. The summer (*boro*) rice (IET 4786) gave on an average yield of 6.25 tons of grain excluding the straw. The model reduced irrigation water of rice to an amount of 10-15 cm required for seedbed and land preparation. The embankment having hybrid tomato (*Abhinas-2)* gave an average yield of 9.87 tons for 2-year whereas cowpea gave an average yield of 7.33 tons for the area during third year. Being eco-friendly, the rice cultivation derived benefit from fish farming as it was observed a reduction of 14 to 20% of cultivation cost of summer rice without any adverse effect on grain yield of rice. The fertilizer application at the ratio of N:P:K at the rate of 100:50:50 during first year, that was reduced to almost half as 50:26:26 during second year and about one-forth as 25:13:13 during third year of field experimentation did not had any adverse effect on grain yield of rice. The main advantage of the integrated approach of farming with rice, fish and vegetables was an effective utilization of low land eco-system under multiple use of water as a model of integrated water resource management for sustainable agriculture.

AVAILABLE WATER RESOURCES IN THE COUNTRY

The annual global flow of water ranges from 4000 to 4700 million ham, out of which 1400 m ham is utilizable for irrigation and other purpose. The present level of utilization of this available potential is just around 25%., out of which irrigation constitutes about three-forth (Harswarup Singh, 1990). As per estimate of National Commission of Agriculture (1976), the average annual rainfall over the geographical area of the country is 370 m ham (112 cm). An amount of 20 m ham could be added, which is brought in form of catchment areas lying outside the country. It is estimated that about 85 m ham of water soaks into the soils (contributing to profile storage/groundwater). And 130 m ham evaporates into atmosphere. The remaining 180 m ham constitutes the average annual flow in different rivers, of which only 70 m ham is utilizable owing to the topographical, hydrological, climatic, soil and other limitations (Harswarup Singh, 1990). The available data on groundwater potential in AP shows the groundwater balance for development to be round 2.7 million ha. Distribution of groundwater reveals that the canal command districts of coastal areas as well as Rayalseema and Telengana, 33 in Rayalseema and 15 on the coastal districts largely in the non-ayacut areas (Siddique, 1995), if policy decision is taken on groundwater development in command areas, an additional areas of 0.5 to 1.0 million ha in Andra Pradesh, Tamil Nadu, West Bengal, Orissa, Bihar and Assam could be brought under crop cultivation during *rabi* season, and summer rice could be grown. Even other crops like groundnut, maize, potato and linseed could successfully be grown in this rainfed lowland ecology after rainy season rice harvested on availability of profile moisture.

CROPPING SYSTEM UNDER RAINFED LOWLAND ECOLOGY

The cropping system in these areas is highly influenced by rainfall pattern and amount of precipitation, soil type, topography within lowlands, time of rice harvesting and resourcefulness of the farmers. Despite their adequate skill for managing crops, farmers could be provided tools at the levels of crop germ plasm, crop management and cropping system to minimize losses due to vagaries of nature. With the objective to produce more quality food grain with less water in the forthcoming decade, rainfed agriculture has its pivotal role in meeting the daunting challenge.

PROFILE MOISTURE IN VARIOUS SOILS

The lowland rice growing imposes high demand on time and energy for conversion of lowland soil to freely drained upland soil. This turn around time required for conversion to upland environment discourages the use of rice fallows. The vast majority of rainfed lowland rice of eastern India is kept fallows due to this reason. The raising of non-rice crops on residual moisture in lowland rice fallows depends on -

1. The rapidity with which the soil dries up and become amenable for tillage in a crumb soil structure of a garden soil;
2. Availability of irrigation after rice crop harvested;
3. Severity of aridity and mildness of temperature in post-rice season;
4. Sensitivity of the crops to a saturated soil condition; and
5. Length of time the soil remains moist.

HARVESTING TIME OF *KHARIF* RICE

Utilization of residual moisture under rainfed lowland through various crops depends on the time of *kharif* rice harvest. In general, rice crop occupied in lowland field even up to December and thus crop planning could be done to sow other crop in December-January.

TILLAGE OPERATIONS

Under rainfed lowland situation, after *kharif* rice harvest, it is most important to establish next crop at earliest opportunity. There would be problem for land preparation in light and medium textured soils than that with heavy clay soils, which generally occurs in lowlands. Several pulses like green gram, black gram and lentil and oilseeds like linseed and sunflower could be raised under heavy soil condition through zero tillage and dibbling of seeds in rows. The time consuming and energy demanding tillage operations is totally dispensed with and the seed broadcast either in standing crop ready for harvest pr in the stubble soon after harvest is followed. The crop so sown used to thrive on receding moisture regime. The non-rice crop is a bonus in such farming system. Surprisingly, this opportunity could not be availed of in many situations, particularly in eastern India.

Crop options for the no-till farming on residual moisture are: sun hemp for hay where soils are heavy and the non-rice growing season is short, black and green gram when whether is mild and rape seed when ambient temperature is low for grain legume. Research agenda for no-till residual moisture farming in lowland would entail, selection of benchmark sites, development of seeding techniques, screening of crops and suitable varieties and evaluation of soil moisture conserving techniques. Besides, there is need for screening the crops towards sensitivity to tilth regarding their germinibilty and growth. It was observed that sesame required fine tilth, sunflower cloddy seddbed and black gram and *khesari* required muddy fields. The crops may also be evaluated for root penetrability. Experiments conducted at CRRI shown that the reduced tillage or shallow tillage at 0-5 cm surface conserved adequate soil moisture to grow successful crop of groundnut. Study on soil moisture profile revealed that under non-tillage treatment, the profile progressively dried, where as under reduced tillage such drying was effectively checked due to soil mulch effect. Sharma *et. al.*, (1985) observed the shallow tillage of surface soil (3-5 cm depth) during dry season and use of 1.5–2 cm thick layer of wheat straw mulch on wet black soil reduced evaporation by 30% and signicantly increased water use efficiency and grain yield of non-irrigated wheat , wheat, safflower, chick pea, lentil, linseed, *taramira*, mustard and toria could be established well on the residual moisture in black soil with applied minimum tillage or animal drawn improved blade harrow, bullock-drawn sweeps with tool frame.

SOWING METHODS AND PROSPECT OF POST RAINY SEASON CROPS

In rainfed lowland areas, deep sowing (5-7 cm) provides good opportunity for better germination and stand establishment of pulse crops. It is well known that for sustaining the productivity of chick pea sowing should be done taking opportunity of first available shower when soil would have sufficient moisture at seeding depth to ensure good germination. Pulses like chickpea, lentil, lathyrus, could be advocated in rice fallows under such situations. Seed treatment, such as soaking of seeds in potassium dihydrogen orthophosphate (KH_2PO_4) before sowing or even seed soaking in water facilitates the germination and early establishment. During the period of November-February, the temperature is low and provided good scope for growing a number of winter crops under rainfed lowland conditions like lentil, gram, safflower, sunflower, linseed, niger and peas depending upon topographical and agro-climatic conditions. They also reported that where winter in mild and short with possibilities of receiving some rainfall during February-March, the sequence of rice-groundnut and rice-sesame appeared to be very profitable.

MULCHING

Mulching is an important technique for conserving residual soil moisture especially in the no-tillage plots under rainfed lowland conditions. Besides conserving moisture, it also suppresses weed growth. Chatterjee and Sen (1977) reported that mulching the crop fields with 5 cm thick straw could increase the yields of winter crops. They observed yield improvement with mulching in case of linseed, safflower and lentil because of increased water use efficiency. MandaI *et al.* (1990) observed that a good crop of safflower can be harvested under late sown condition after the harvest of lowland paddy even without giving any irrigation with the help of residual soil moisture and with a lower dose of each of N, P_20_5 and K_20 @ 30 kg/ ha provided that the soil moisture is conserved with the help of straw mulch @ 7 t/ha at sowing.

PAIRA CROPPING

Paira cropping is another useful practice for raising winter crops in rainfed lowlands. Roysharma et al. (1982) reported that lentil give grain yield of 15.9, 16.3 and 10.5 q/haI at Dholi, Kanpur and Barielly, respectively with inoculated seeds and top-dressing *of* 20 kg N and 30 kg P20S h-I (twice at 40 and 80 DAS) with paira cropping. Gangasaran (1990) reported that paira cropping *of* linseed is certain parts of U.P. and West Bengal. Linseed is broadcast in the standing crop *of* rice 10-20 days before harvest. In an experiment on *paira* cropping, rice seedlings were transplanted on 15^{th} July and chickpea, oilseed flax and lentil were broadcast into the standing rice crop on 25^{th} November at normal and one and half times the normal seed rate without and with 20 kg N + 18 kg P h^{-I} for chickpea and lentil and 30 kg N + 9 kg P h^{-I} for flax. Oilseed flax intercrop with rice gave the highest rice yield equivalent of 5.1 t/h when fertilizers were applied.

PHYSICAL IMPROVEMENT IN SOIL STRUCTURE

Physical soil health is an important consideration in seed germination and conservation. Utilization of residual soil moisture in *rabi* pulses and oilseeds after rice in rainfed lowlands is depended on physical health of the soil. Biswas (1982) has conclusively suggested three practices for improvement of soil physical condition leading to increased soil productivity *viz.* (1) Judicious use of organic manure, (2) use *of* phosphates and (3) legume cultivation in crop rotation. It has reported that long term manuring with FYM or sun-hemp green manuring in red and laterite soils at Bhubaneswar and Ranchi improved water stable aggregates percentage, water storage capacity and available water content. The results obtained from All India Coordinated Project on long-term Fertilizer Experiments revealed that available water holding capacity of soil increased from 18.8% with N alone to 19.5% with combined use of NPK + FYM for 11 years in 8.8% was reported in laterite soils of Bhubaneswar. Long-term fertilizer experiments conducted at CRRI for17 years showed that continuous combined application of inorganic N (44.8 kg/ha) and compost (9.2 t/ha/year) significantly improved soil aggregation , however, for sustainability in production, it is neither chemical fertilizers nor the organic manures alone but their integrated use is highly beneficial (Patnaik *et al.*, 1989).

SOIL FERTILITY IMPROVEMENT

All India Coordinated Project on Long-term fertilizer experiments clearly showed declining trend of productivity even with application of N, P and K fertilizer due to emergence of deficiency of S and Zn. Available S (Morgan's extractable S) decreased to around 3-5 mg/kg in plots where DAP had been applied but increased in plots where SSP had been continuously applied. This effect was quite spectacular at Barrackpore, Jabalpur and Bhubaneswar (Nambiar and Abro, 1989). In the context of growing pulses and leguminous oilseeds after rice in rainfed lowlands, supply of P, S and Ca is very important to improve crop productivity.

EFFECTIVE UTILIZATION OF WATER

In lowland areas of eastern India, because of high rainfall there is a rise reserve of ground water at shallow depth. But, except in Uttar Pradesh and some parts of West Bengal, in rest of the eastern region, the ground water utilization is very poor (Patnaik, 1994). Although in semi-arid and arid regions of the country, indiscriminate use of ground water lowers the water table and is expected to eventually create the problems of drought, there is less chance of and deep tube wells should be developed depending on the position of the aquifers and quality of water. This may help in providing life saving irrigation to the crops grown after rice. Lowland areas of eastern India also provide great scope for storage of rainwater in ponds, ditches or trenches at one site or at comer of the field for adoption of the water-harvested structures (Sinhababu and Venkateswarlu, 1995).

CONCLUSION

Adoption of this system of mixed farming of fish-rice-vegetables in the stated piece of land with marginal productivity has opened up a possibility of instituting a sustainable form of agriculture with a net return of Rs. 1.06 to 1.08 lakhs per annum. The economic aspects of the system, item-wise expenditure incurred towards model demonstration under the system and variable operational cost of pisciculture including fish seeds and sale prices were analyzed and found highly remunerative. The initial effort of utilizing the risk prone eco-zone can be taken as a model based on which further modifications might be incorporated and could be tried for the most gainful combinations. Moreover, the involvement of the farmers of the area through farmers’ cooperative society could render potentially fertile but circumstantially low productive region in to highly remunerative with increased farm income, more employment as well as better nutrition for the people.

FUTURE STRATEGIES OF RESEARCH AND DEVELOPMENT

The extent of occurrence of rainfed lowland, particularly in eastern India is large. But cropping intensity in this ecosystem is low, most probably due to the lack of technology of efficient utilization of residual soil moisture during dry season. In fact, intensification of cropping with the utilization of this rice-natural reserve in rainfed lowlands of eastern India is possible and can provide food security to the growing population of this region. To achieve this objective, the following research and development strategies may be pursued.

- Improvement in soil moisture storage and regulation of upward flux of water through soil structural manipulations;
- Multi-locational evaluation of cropping systems, introduction of new crop species and varieties of different pulses and oilseeds in dry season under rainfed lowland situations along with their screening for sensitivity to soil tilth and soil/air temperature and for root penetrability;

- Genetic improvement in pulses, oilseeds and other crops with particular reference to residual soil moisture utilization;
- Identification of specific limiting factors of crop production (bio-physical and socio-economic factors) and their mitigation options.
- Integrated approaches of nutrient management, water management and plant protection measures.

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Table 1 Farm-end produce of different components from field of an area having 1.36 ha

Year	Component	Total yield (tons)	Rate/ton (Rs)	Sale Price (Rs)
1998-99	Fish	1.025	40341	41350
	Tomato	12.000	5550	66600
	Rice	6.750	7000	47250
	Straw	6.750	300	2025
	Total			157225
1999-00	Fish	1.215	42263	51350
	Tomato	7.730	6600	51018
	Rice	5.750	9000	51750
	Straw	5.750	350	2013
	Total			156131
2000-01	Fish	1.685	44617	75180
	Cowpea	7.330	48200	35330
	Rice	6.120	5500	33660
	Straw	6.000	320	1920
	Total			146090

Table 2 Crop responses under different residual soil moisture ecology

Crop	Variety	Yield t/ha		Place of work	Source
		Residual moisture	Irrigated Ecology		
Mustard	Pus a Bold	0.37	0.37	Cuttack	Chandra, 1993
	Pusa Bahar	0.37	1.03	Cuttack	-do-
Raimash	PDR 14	0.53	1.07	Cuttack	-do-
Peanut	ICGS 44	0.71	1.36	Cuttack	Chandra *et al*.l988
Mungbean	PDM 11	0.11	0.10	Cuttack	-do-
Urdbean	PDU 54	0.15	0.18	Cuttack	-do-
Wheat	Swati	3.72	4.16	Bilaspur	Parihar *et aI*., 1955
Chickpea	JG74	2.02	1.88	Bilaspur	-do-
Indian mustard	Baruna	1.05	1.22	Bilaspur	-do-
Sunflower	Modem	1.91	2.11	Bilaspur	-do-

Table 3 Increasing demand of food at the end of 9th and 10th 5-year plans along with production trends

Crops	Production (in million tones)		
	1998-99	2001-02	2006-07
Rice	84.74	94.00	103.50
Wheat	71.01	75.07	84.30
Coarse Cereals	30.90	32.60	34.40
Total Cereals	186.65	202.30	222.20
Pulses	15.89	18.20	21.00
Food grains	203.54	220.50	243.20
Oilseeds	25.60	28.00	33.80
Sugarcane	295.70	287.00	352.80
Vegetables	87.53	93.60	110.70
Fruits	44.04	53.70	70.50

Source: Kumar, 1996 and The Hindu Survey of Indian Agriculture 2000

Table 4 Profile moisture storage of different soils:

Soil type	Storage (cm)
Clay	76.20
Silt loam	60.96
Sandy loam	45.72
Fine sand	30.48
Coarse sand	15.24

Table 5 Time of *kharif* rice harvest in different states

State	Time of harvest
Orissa	Mid-December
Bihar	Last week of November
Eastern UP	First week of December
Eastern MP	Second week of December
West Bengal	Second week of November
Assam	Last week of October

BRIEF PROFILE OF THE AUTHORS

A. Zaman graduated in Agricultural Science in 1976, completed his M. Sc. (Agril) in 1978 and Ph.D. (Agronomy) in 1986 from BCKV, West Bengal. He joined in the University in 1979. He worked as Officer-in-Charge of Project on Resource Development based on Watershed Management at Bankura, West Bengal (1988-93) since joining as Reader. He deputed and worked as the Head, Irrigation Expatriate Team, Government of Uganda, East Africa (1994-96), and Agronomist at Hill Zone, Kalimpong (1996-97), before assuming the charge as ADR of RRS, Old Alluvial Zone in 1997. He has been working as Professor and Chief Scientist (Water Management) since August 2002 and also took over charge the Head, Department of Agronomy since April, 2008 to October 2011. Joined as Sirector of Research, BCKV in the month of November 2011 and subsequently joined as Dean, Faculty of Agriculture, BCKV on 1st of February 2012 and continuing. He worked primarily with irrigation requirement and water management and water use efficiency of different agronomic crops.