Farmer's Participatory Action Research for Water Management Interventions in Canal Command

R.K. Sahu, A.K. Pali and Jitendra Sinha
Department of Soil and Water Engineering, Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh – 492006

Abstract : Efficiency of water use in canal command areas in Chhattisgarh is often quite low, estimated to be around 30%. Field to field irrigation is prevalent which not only reduces irrigation and nutrient efficiency, but also makes crop diversification difficult. Farmer's Participatory Action Research Programme was implemented in 4 villages of Dhamtari and Durg districts (two villages in each) of Chhattisgarh state, in the years 2007-08 to 2009-10. This programme was sponsored by Central Water Commission, Ministry of Water Resources, Government of India and implemented by Faculty of Agricultural Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur. The objectives of the research conducted here include: 1. Conjunctive use of surface and groundwater through SFR and shallow dug wells. 2. Irrigation scheduling as per the ET requirement of crops and at critical crop growth stages. 3. Demo trial on full submergence, partial submergence and intermittent submergence at critical crop growth stages, and 4. Provision of drainage system in rice fields.

Canal irrigation water is quite unreliable in regard to its supply during critical crop growth stages. Therefore, construction of secondary reservoirs in the form of small farm reservoirs (SFR) in conjunction with shallow dug well to facilitate conjunctive use of surface and groundwater was found to be useful for assured water supply and to alienate water logging. This technology in the study area was found to increase the main product rice yield by 12.7 q ha^{-1} and that of by product yield by 21.0 q ha^{-1}. Besides, some farmers by fish rearing, were able to get extra remunerations to the tune of Rs. 3000/- Drum sticks on pond bund and vegetables using SFR water provided farmers an additional remuneration around Rs. 9000/-. Thus, the land lost due to digging out SFR was not only compensated but promoted farmers to adopt crop diversification

Irrigation scheduling as per ET requirement of crops helped satisfactorily to develop seasonal irrigation plan/ schedule. Though theoretically, the rains at flowering and late reproductive phase were higher than ET requirement, either due to various water losses or the location of field at disadvantage position (tail enders), two irrigations each 50 mm at these stages are required to realize full potential of rice, particularly to late duration photosensitive rice varieties.

Three levels of submergence of rice fields were attempted in the study. Higher yield of rice main product was achieved in deep submergence 56.2-59.7 q ha^{-1} as compared to intermittent submergence and partial submergence, however, higher water use efficiency was observed in intermittent submergence (0.72-0.75 kg ha^{-1} m^{-3}). The relative saving of water ranged from 1000 to 1500 m^{3} ha^{-1} (12.3% to 16.1%) in intermittent submergence over deep submergence.

Drainage congestion as well as surface flooding in canal commands, pose serious threat to sustainable irrigation agriculture in Chhattisgarh. Appropriate drainage system incorporating preventive and curative measures were demonstrated to farmers. This drainage system had outlet in SFR which acts as sink to store the excess water that was further recycled as supplemental irrigation to rice during flowering and late reproductive stages. This drainage effluent stored in SFR was used by some farmers for fish rearing giving them extra remuneration. Provision of drainage system in rice fields increased rice yield by 4.9-5.7 q ha^{-1} and that of by product by 7.8-9.4 q ha^{-1} worth Rs. 5200 ha^{-1}.

INTRODUCTION

Water, the unique resource on the planet earth is the elixir for sustaining all forms of life. Fresh water is a retreating resource worldwide. Water has always been scarce and people as a matter of habit have been mismanaging it resulting in wastage and severe pollution of water bodies. Due to its multiple benefits and the problems created by its excesses, shortages and quality deterioration, it is all the more necessary to conserve these resources within the fields, rather than allowing it to flow to the sea, causing floods and devastation of crops, human and animal lives, soil erosion etc.

Agriculture sector is the major user (78% water use) of water. It contributes 17% of the National GDP and sustains livelihood of about two thirds of population. India has total water resources of 400 M ha-m which is almost 4.2% of worlds' fresh water resources with 16% of world's population, 15% of world's livestock and 2.4% of world's geographical area.

Indian agriculture has 66.7% rainfed areas, contributing 42% of total food production whereas 33.3% irrigated areas have 58% share in food production. According to planning commission, investment in agriculture generates three times more employment as compared to equivalent investment in industrial sector.

GENESIS OF WATER USE IN COMMAND AREA

One of the major problems in command areas is the lack of adequate communication between farmers and the Government agencies. The irrigation department control the main system upto outlet levels and deliver the water at these points to the farmers. It is clear that the irrigation department can not bring equity in water use or provide equitable water supply to all farmers. The irrigation department at the best can plan and implement equitable supply to various sub components of the project whereas further equity within that unit can only be achieved by farmers themselves. Assured and timely supply of irrigation water is the key factors to bring confidence in farmers enabling to go for higher inputs and higher level of crop productivity. It is more important for enabling farmers to switch over to the high risk, high value crops on canal irrigation.

The amount of water (litres) required to produce 1 kg of food as dry matter varies with place, soil, climate, methods of irrigation etc. The International Research Centre for Renewable Energy, Germany worked out the water requirement to produce 1 kg of wheat, rice and soybean as 1500, 3000 and 4800 litres respectively, while that to produce 1 kg of melon, and tomato is 400 and 290 litres of water respectively. Similarly to produce 1 kg of meat 6600 litres and that of 1 kg of chicken 4780 liters of water is required.

CHHATTISGARH SCENARIO

Canal irrigation is an age old and major source of irrigation in Chhattisgarh. It forms 61.4% (gross) and 66.2% (net) of the gross and net irrigated area of the state respectively. It's coverage is 9.43 lakh ha (gross) and 8.87 lakh ha (net), out of the total irrigated area of 15.37 lakh ha (gross) and 13.39 lakh has (net). The district Raipur has highest irrigated area of 2.41 lakh ha, and the district Narayapur has no area under canal irrigation. Inspite of being a major source of irrigation, the irrigation efficiency in most canal command areas is very low, often 30% or less (Tanwar, 1998; Pandey and Reddy, 1988). Similarly crop productivity level in the canal irrigated areas of state is quite low as compared to its achievable potential. Even 54.9% area under irrigation is also dependent upon the rainfall intensity and distribution in the catchment area, which determines the runoff for irrigation projects. The uncertainty of availability of water at the time of sowing forces farmers to go in for *broadcast biasi* system in irrigated areas. The irrigation system is designed to avert famine rather than productive system. There is one outlet for 40 ha (100 acres). The water flows from field to field resulting in to deep submergence in the head reach and moisture stress in the tail-end areas. This also results in growing of tall late duration photo-sensitive rice varieties (145 days).

PARTICIPATORY IRRIGATION MANAGEMENT

Participatory approaches are bottom – up, people centred and demand–driven compared with the top-down government centred and supply - driven development of the past. Analysing location-specific problems through Participatory Irrigation Management and working out appropriate remedies by harmonizing indigenous technical knowledge with exogenously developed innovations under diverse micro situations are the major consideration of the PIM.

On the concept of peoples management of developmental infrastructures that requires local solution to local problems affecting them, the National Water Policy of Government of India 1987 and the National Water Policy – 2002 as well as Chhattisgarh state Water Policy stressed on farmers participation in irrigation management. In the state of Chhattisgarh after rehabilitation, the irrigation system has been rapidly shifting over to farmer's organizations under Water User's Association (WUA) umbrella in each project. The philosophy of participatory irrigation management has been put into practice under turned over minor irrigation projects in Chhattisgarh. The modus operandi of *Pani Panchayat* or WUA is through financial and institutional reforms. The community under defined unit of area of the system will have the control over supply and influence the demand for water through participatory crop planning.

CWC Aided Participatory Action Research

Farmer's Participatory Action Research Programme was funded by Central Water Commission, Ministry of Water Resources, Government of India, New Delhi and is being implemented in different parts of the country. The programme involves demonstrations of technologies developed by the institutes which will increase agricultural productivity and profitability per unit of water used. The nature and activities include soil and water management practices, crops and varieties, crop diversification, integrated and sustainable farming and use of pressurized irrigation methods and improved implements for conserving soil and water. The study includes not only demonstration of technologies but also the training and awareness campaign to the farmers, besides impact analysis in terms of physical and financial gains of this programme. The funding agency appointed Central Ground Water Board, North Central Chhattisgarh Region Raipur as monitoring agency to review the work being carried out under this scheme from time to time.

OBJECTIVES AND INTERVENTIONS

The major objectives of the research conducted on farmer's field here was to find out ways and means to augment the water resource scenario of a flow based minor irrigation project which suffers badly from inadequate irrigation water availability at critical crop growth stages. The possibility of increasing the capacity of the main reservoir is very remote. Therefore, the concept of secondary storage reservoir in the command of each outlet at farm level is hypothesized. The major objective was to demonstrate the following interventions/ technologies to the farmers:

1. Conjunctive use of surface and ground water through SFRs and shallow dug wells has an assurance for availability of water to crops at critical growth stages.
2. Irrigation scheduling as per the ET requirement of crops and at critical crop growth stages in order to develop seasonal plan/schedule.
3. Demo trial on full submergence, partial submergence and intermittent submergence at critical crop growth stages of rice crop.
4. Provision of drainage system in rice fields.

BACKGROUND INFORMATION

The study was undertaken in 4 villages – two each in districts of Dhamtari and Durg.

Location of the Study Area

All the 4 study villages are situated at about 15-18 km from Dhamtari town. The villages Arkar and Palari of district Durg are situated near the boundary of Dhamtari district at about 12 km distance from each other. The location of study area is: 20°42' N latitude and 81°33' E longitude with altitude 300.2 m above mean sea level. The study area represents Chhattisgarh plains agro-climatic zone of the state as per NARP classification.

Mahanadi Command Area

The study area comes under Pt. Ravishankar Shukla Reservoir (Gangrel dam) command area under Mahanadi basin. The canal irrigation was started in the year 1966-67, basically it was designed to provide protective irrigation to rice crop during *Kharif* season. The supply of water to the second crop depends on the storage in reservoir. Only recently few years back the supply of water to second crop in *Rabi* season was regularized. This is basically a mono-cropped area with rice as the main crop. The irrigation is limited to 28% area in the state however the districts of Dhamtari (59%) and Durg (41.5%) have higher irrigation percentage.

Agro-climate and Meteorological Data

Historical meteorological data of study site regarding estimation of rice ET were collected for the period 1971-2009, documented, analyzed and investigated SMW - wise regarding various weather parameters used for calculation of ET requirement of rice.

Rainfall: The normal rainfall of the project area is 1169.9 mm distributed over 64 rainy days. The average monsoon rainfall is 1073.2 mm which is 91.7 per cent of the annual rainfall. This is distributed over 58 days, which is about 92 per cent of the annual number of rainy days. Most of the precipitation is due to south-west monsoon during the month of June to October. The monsoon normally enters in the study area around 10th June and withdraws by 15th September.

Temperature: The daily mean temperature ranges from 15.4 °C to 40 °C. May is the hottest month when maximum temperature reaches to 46.0 °C. The overall climate of area is sub-humid. The day time temperatures during peak summer season are usually very high in the entire area varying from 36 °C to 46 °C in the second fort night of May. The average minimum temperature reaches around 15° C during winter season, by mid November.

Humidity and Sun Shine Hours: The RH is very low in summer (34–43%) and reaches up to 94% during monsoon season. It remains high through out the rainy season – varying between 80-96%. The daily mean RH varies from 20% in April to maximum of 96% in July and August. In winter months it varied between 72-98%. The sunshine hours during monsoon months are very less (3-4 hours per day). In the months of July and August the sun shine hours are some times almost zero for 8-10 days.

Wind: The winds are moderate and blow with average speed of 2-8 km h^{-1}. In general, wind blows from East to West and SE to NW during June to November but it blows from West to East and NW to SE during December to May. Hot winds are experienced only after mid of April to first week of June.

Land Use Pattern and Agricultural Characteristics

Total geographical area of district Dhamtari is 4,08,190 ha. Forests occupy 2,12,554 ha which is 52.1% of the geographical area. On contrary to this, the district Durg has only 8.6% of the geographical area under forest. Total cropped area in district Dhamtari forms 51.7% of the geographical area whereas in the district Durg it is relatively high (89%). Mono-cropped area as a percent of total cropped area in the district Dhamtari is relatively low (27.1%), as compared to double cropped (rabi) area (36.5%). On the other hand the mono cropped area in the district Durg is comparatively high (41.6%) as compared to double cropped area in rabi (29.2%). It is reflected in higher rice productivity under both rainfed and irrigated conditions in Dhamtari district (10.4 q ha^{-1} and 20.4 q ha^{-1}) as compared to Durg district (6.7 q ha^{-1} and 11.4 q ha^{-1}).

Number and Area of Operational Holdings

The socio – economic profile analysis have indicated that majority of the farmers (63.64%) are mainly engaged in cultivation with marginal holdings (< 1.0 ha) with only 25.26% area coverage in Dhamtari district. Whereas, 56.1% of the farmers have marginal land holdings with 16.8% of the cultivated area in Durg district. The average size of land holding in Dhamtari district is quite lower (1.11 ha) and that of Durg district was higher (1.56 ha) as compared to the states average land holding size (1.45 ha).

Irrigation and Water Use Pattern

About 20.8% of the gross cropped area of two project districts is irrigated by different water sources. There are 306 canals with 1893 km length which provide irrigation water to the 205393 ha area of crops. Canal irrigation forms 48.4 per cent gross irrigation in above districts. There are about 47327 tube wells in these districts, out of which 46339 are under private ownership. These tube wells irrigate 187741 ha area that forms 44.3 per cent gross irrigation. There are total 4947 numbers of dug wells in the project districts, which irrigate 2987 ha area constituting less than 1 percent of gross irrigation. There are 66 reservoirs in the project districts that fed water to canals for distribution in the command areas. There are 559 ponds that irrigate 3562 ha area, constituting less than 1 percent of gross irrigation. Other sources of irrigation cover 24309 ha area that forms 5.73 percent of gross irrigation.

Presently flood irrigation is practiced in both the seasons (*kharif and rabi*), through canal supply. The canal supply is available at the early crop growth period (i.e. during *biasi* operation- the local method of sowing cum interculture of rice) for one month. The second canal supply is available at the late crop growth stages. This is again for about one month period. It is evident from the present water use pattern that canal water supply is not available as per the critical crop growth stages.

Crops and Crop Productivity

Rice is the main crop of the project area, grown in 619 thousand hectares comprising 62.8 per cent of gross cropped area during the year 2008-09. The overall average productivity of rice in the project districts is 1.12 t ha^{-1}, which is lower than the state's average (1.19 t ha^{-1}). Similarly the average productivity of rice in the project districts under both rainfed (0.72 t ha^{-1}) and irrigated conditions (1.43 t ha^{-1}) is lower than the state's average (rainfed: 0.98 t ha^{-1}, irrigated: 1.64 t ha^{-1}). The rice productivity of Dhamtari district is quite higher (rainfed: 1.04 t ha^{-1}, irrigated: 2.00 t ha^{-1}), as compared to Durg district (rainfed: 0.67 t ha^{-1}, irrigated: 1.14 t ha^{-1}). Lathyrus is the second most important crop of the area grown in 1,41,454 ha with average productivity of 1.03 t ha^{-1}. Pigeon pea is the third important crop of project area which is grown in about 4.90 thousand ha with average productivity of 0.66 t ha^{-1}. Urad is the fourth important crop grown in 4904 ha with average productivity of 0.27 t ha^{-1}.

Soil Characteristics

The soils of the study area at Dhamtari and Durg represent black soil. The information about the physical and chemical properties of soils of the study collected from various research area reports of IGKV, Raipur and NBSS & LUP Nagpur. The soil physical characteristics included mechanical analysis, soil texture, bulk density, water retention, organic carbon, CEC, pH and EC. The typifying pedon in the study area is (0-19 cm) yellowish red, clay, dark reddish brown, moderate medium, subangluar blocky, slightly hard friable, slightly sticky and slightly plastic, many fine root, pH 6.4 and clear boundary.

Live Stock Resources

It was interesting to note that majority of the farmers were having on an average less than 1 bullock in the project area as compared to the state average of 1.7 bullock per landholder. Similar pattern was observed for cows, he-buffalos and she-buffalos. Domination of poor live stock holding shows farmer's preference for crop planning.

Socio-economic Profile and Constraints

Poor participation of farmers in the social organization and simultaneously average exposure to different communication sources are unhealthy signs. Present study revealed that 56% of respondents were having favourable attitude towards the usefulness of canal irrigation in cultivation. But an alarming 44% of the farmers showed unfavourable attitude towards it.

TECHNOLOGICAL INTERVENTIONS

Attempts were made to alleviate or to reduce the intensity of some of the farm level constraints of a canal command area of Mahanadi basin. Some technical interventions/technologies were laid out and executed in farmer's field for enhancing crop production. Brief accounts of these technologies/ interventions and their impact on crop production are given in the following pages.

Participants and Technologies/interventions Demonstrated

A total number of 30 demonstrations were laid out and implemented in farmer's fields, in which 56 farmers directly participated in conduction of demonstration of technologies/interventions in their own fields; besides, 108 farmers associated with them directly are indirectly to avail similar benefits in their fields.

Technologies/Interventions Demonstrated Conjunctive Use of Surface and Ground Water

The concept of construction of SFR (SFR) as a secondary storage system in the command of each outlet at farm level was hypothesized. These reservoirs were able to harvest the rainwater during monsoon as well as capture excess irrigation water supplied from canal at the time of irrigation. The harvested water in these SFR was primarily utilized for providing supplemental irrigation to rice crop at all the critical crop growth stages when the canal supply was either unavailable or inadequate to full fill the water requirements of crops or mismatched with the crop growth stages. The augmented water resource can be utilized in more effective and productive manner through multiple use management for example fish rearing and duck rearing in stored farm pond water. This assured water source was further augmented with the construction of shallow dug wells in the vicinity of SFR. It facilitated the conjunctive use of surface and ground water to raise second short duration vegetables in dry season, after meeting the requirement of *kharif* crops.

With this concept to have assured supply of water to rice, under this technology, a total 8 number of SFR of about 1500 m^3 capacity were constructed which were spread out in 4 project villages as mentioned earlier. These reservoirs were used to fill water by canal supply whenever available and through direct rains and runoff. The peripheral bunds were used to grow crops like pigeon pea, drumstick, cowpea, tomato, chili, radish and other vegetables.

Design of Farm Ponds

From an economic view point, SFR should be located where the largest storage volume can be obtained with the least amount of earth work. Large water spread areas with shallow storage depth should be avoided to restrict evaporation losses, land wastage and weed growth. Excavating type SFR can be constructed in varying topo sequence. This is a common situation prevailing in farmer's cultivable fields. It is generally constructed at the lowest area of field where higher water storage capacity is achieved per unit volume of earth work. However in canal command area the SFR was constructed near the point where canal supply is available.

The design of the SFR (i.e. finding a suitable combination of water spread area and depth of storage at a permissible side slope and for a given storage volume) was accomplished by analyzing past 36 years of daily rainfall data and estimating runoff by soil conservation service USDA curve number technique. Daily rainfall data were also analyzed to know its probability of occurrence during the period June to October. Krimgold equation was found to be appropriate for designing SFR capacity and size. This relationship uses different water balance and hydrological parameters of a field for arriving at the suitable size of SFR. The relationship between the various hydrological parameters is given as follows:

$$\frac{RA}{a} + P - \left(E + \frac{U}{a} + S \right) = d + \frac{W}{a}$$

Where A is the size of farmer's field or part thereof (2 ha)

R is the total runoff from the field (Jun-Oct.) at 80% probability - 0.45 ha-m

P is the rainfall during (Jun.-Oct.) at 50% probability - 1.109 m

U is the amount of irrigation (Jun.-Oct.) - 0.3 ha m per ha

S is the seepage during June to October (1.022 m)

E is the evaporation from pond water surface (Jun.-Oct.) - 0.529 m

D is the average depth of water is the pond (Jun.-Oct.) - 2.1 m

W is the amount of outflow (nil) a is the water spread area at the surface (ha) on solving we get a = 0.30 ha

On an average, by using this technology, the yield of main product of rice was enhanced (49.6 to 62.3 q ha^{-1}), registered a growth of 12.7%. Similarly yield of rice by product increased (81.8 to 102.8 q ha^{-1}) with increase of 21%. The peripheral bund of SFR was also found useful to grow pulses and vegetables, which provided them extra remuneration. Drum stick and other vegetables grown on bunds are fetching better remunerations around Rs. 9,000/- in a year additionally. Some farmers have started fish rearing and fish seed production inside SFR that provide three times more profit than that of rice. Thus the land lost due to SFR is better compensated though these remunerative activities.

Irrigation Scheduling as per Crop ET

Knowledge of consumptive use is necessary in planning and operating water resources. ET data are essential for estimating water requirements for irrigation. Actual measurements of ET, under each of the various physical and climatic conditions, are not possible but reliable methods (Penman-Montieth) are available for estimating ET of crops based on past historical meteorological data. ET requirement of various duration rice varieties are essential to know how much and when to irrigate. The lysimeter data are available at IGKV, Raipur and the same were used to determine the ET requirement of different duration rice varieties. On an average 24.1 mm water is required at establishment stage of rice, followed by 190.9 mm at vegetative stage, 186.3 mm at reproductive phase, and 97.0 mm at maturity stage, with a total of 498.3 mm covering all growth stages.

Length of Dry Spell, ET and Water Supply Requirement

The length of dry spell in different probability of exceedance, its number of days, crop growth stage, ET (mm), canal supply availability and irrigation requirement at project site was analysed and it was observed that the length/ number of days of dry spell increased with lower probability of exceedance. During flowering stage which coincides with 37 and 38 SMW the length of dry spell/ number of continuous dry days are 6, 8, 9, 11 at 75 and 80, 50 and 60, 40 and 25 per cent of probability of exceedance. During this period 55 mm water is required to meet out the crop ET requirement, which can be fulfilled with the available rains of 88.7 mm. However, late duration rice varieties particularly those grown at the tail end require one-irrigation of 50 mm to meet out various water losses. In absence of supplemental irrigation, drastic reduction in rice yield destabilized the productivity in the command area. Similarly during reproductive stage (37 and 40 SMW) taken together, including flowering stage, the length of dry spell/ number of continuous dry days was 9, 10, 12, 13, 15 and 18 days at 80, 75, 60, 50, 40 and 25 per cent probability of exceedance respectively. During this period 111.6 mm water is required to meet out the crop ET demand, the rainfall received during this period is higher (132.1 mm) than ET, hence theoretically the ET demand is fulfilled. However, to meet out various water losses such as percolation and seepage and conveyance losses etc. particularly to the late duration rice grown at the tail end requires one-irrigation (50 mm), to realize full potential of the crop. The canal supply availability, at this stage is either inadequate or absent due to shortage of water in reservoirs. It was observed that the monsoon withdraws in the second fortnight of September and therefore it is urgent to provide supplemental irrigation to rice at this stage, particularly at the tail end with late duration photo sensitive varieties, to realize full production potential of the crop. In absence of supplemental irrigation, drastic reduction in rice yield destabilized the productivity in the command area.

Presently flood irrigation is practiced in both the seasons (*kharif and rabi*), through canal supply. The canal supply is available at the early crop growth period (i.e. during *biasi* operation- the local method of sowing cum interculture of rice) for one month. The second canal supply is available at the late crop growth stages. This is again for about one month period. It is evident from the present water use pattern that canal water supply is not available as per the critical crop growth stages. In view these situations of water scarcity, it was decided to make three levels of assured water in selected farmer's field. Full submergence, partial submergence and intermittent submergence at critical crop growth stages of rice crop were maintained in farmer's field. Full submergence was made with 5+2 cm through out the growth period of rice crop. The partial submergence was made with water level just above the saturation to 3 cm. The water level in intermittent submergence is maintained 5+2 cm at all the critical stages of crop growth, besides maintaining shallow water level at other stages with a provision of draining the rice fields from time to time viz. 45 and 75 days after transplanting.

Yield of Main and by Product: The intermittent submergence resulted in rice yields ranged from 51.2 to 58.3 q ha^{-1} with yield advance ranged from 8.7 to 9.0 q ha^{-1} over the conventional method. The conventional method resulted in rice yields ranged from 42.2 to 49.6 q ha^{-1}. Similarly the yield advantage of by product of rice ranged from 14.3 to 15.0 q ha^{-1} over the conventional method.

Deep submergence (5 + 2 cm) resulted in 2.4% to 9.8% higher yields over the intermittent submergence in farmer's field. The relative yield benefit over conventional method was found to be 7.0 - 8.5 q ha^{-1} and to that of intermittent submergence was 1.4 - 5.0 q ha^{-1}. By intermittent drying and watering the field every third day, the crop yields were of the same order as by maintaining continuously a 7.5 cm depth of water in the field.

In partial submergence the water was kept from field capacity/saturation to 3 cm standing in rice fields. This practice, though good for aeration of plant roots, but scarcity of water to some extent was felt at some critical crop growth stages. Therefore it resulted in lowest yield of main and by product of rice in farmer's field. The relative yield disadvantage over intermittent submergence ranged from 1.6 to 4.7 q ha^{-1} that was 3.1% to 8.1% of intermittent submergence. On covering the partial submergence to deep submergence, it was found the relative yield disadvantage further aggravated in the ranged 6.1 to 6.6 q ha^{-1} that forms 1.2 to 11.7 per cent of the yields under deep submergence. Partial submergence when compared with equivalent conventional practices, it was found that it resulted in yield advantage: 5.1 - 5.8 q ha^{-1} that forms 11.5-12.1% of yields under conventional practices.

Water Use: Intermittent submergence required water ranged from 7100 to 7800 m^3 ha^{-1}, with saving of water ranged from 1100 to 1500 m^3 ha^{-1}, over that spent in equivalent conventional practices. Similarly deep submergences saved water ranged from 1100 to 1400 m^3 ha^{-1} over that used in equivalent conventional practice. In a like manner the partial submergence saved water in the range of 1200 to 1400 m^3 ha^{-1} over the conventional equivalent practices. If the comparison is made among various treatments, it can be found that intermittent submergence required lowest amount of water; it ranged from 7100 to 7800 m^3 ha^{-1}. The highest amount of water was required in deep submergence: ranged from 8100 to 9300 m^3 ha^{-1}, while that used in the intermittent submergence various from 7700 to 8800 m^3 ha^{-1}. The relative saving of water ranged from 1000 to 1500 m^3 ha^{-1} in intermittent submergence over deep submergence and from 600 to 1000 m^3 ha^{-1} in partial submergence. It forms 12.3% to 16.1% saving is water in intermittent submergence as compared to deep submergence. In a similar manner, the saving in water in intermittent submergence forms 7.8% to 11.4% as compared to partial submergence.

Water Use Efficiency: The water use efficiency was found highest in case of intermittent submergence ranged from 0.72 to 0.75 kg ha/m^3. It was lowest in case of partial submergence wherein it ranged from 0.60 kg/ha/m^3 to 0.64 kg/ha/m^3. Deep submergence showed medium level of water use efficiency. Based on these facts it can be concluded that intermittent submergence is beneficial to rice in command areas where intermittent water supply from canal is available. The only question is regarding its timing. The timing of canal supply and critical crop growth stages of rice usually do not match. This is the fact based on which we should think of transient storage in SFR to avoid this mismatch and recycle the stored water in SFR to the rice crop in canal command area.

Provision of Drainage System in Rice Fields

In study area, field to field irrigation is practiced; in such situation submergence of land for continuous long periods prevail. Under submerged condition in the absence of oxygen toxic substances such as sulphides are developed. The root system also gets restricted supply of oxygen. In order to remove such toxic substances and accelerate oxygen supply, it is beneficial to provide surface drainage, once or twice during the growth period. The drainage period lasted from 6 to 8 days, depending upon the field situation, outlet conditions etc. Accordingly, under this technology, two times drainage of rice fields through surface drains and field to field at some places was exercised. During the period of 40th to 50th day after transplanting fields were drained completely. The second drainage was provided about 7 days before harvesting. This facilitated the use of mechanical equipment in harvesting and to make ready the rice fields for subsequent post-monsoon second crop. The response of drainage in the project area was quite encouraging.

While in conventional method without drainage the yield of main product rice varied from 46.0 to 52.6 q ha^{-1}. By using this technology the yield increased to a satisfactory level. It ranged from 50.9 to 58.3 q ha^{-1} in different farmer's field with a relative yield advantage of 4.9 to 5.7 q ha^{-1}. Similarly in case of by product of rice, the yield advantage was 2.8 to 9.4 q ha^{-1} in various fields. This extra benefit in monetary units ranged from Rs. 5200 to Rs. 5300 per ha. In general the cost of investment could be recouped in one year only. In a study conducted at Tamilnadu to determine effects of internal drainage (percolation rate) on growth and yield formation in rice, in interaction with nitrogen (N) management, similar results were obtained. The grain yield response to drainage was increased by 10% to 25% at various level of drainage (Ramasamy *et. al.*, 1997).

Drainage Design

To mitigate the water-logging problem, a surface drainage system was designed and commissioned. The Hydrologic Soil Cover Complex Method was used for estimation of runoff volume to be disposed through the surface drainage system. According to this method, the runoff is given by:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S} \qquad \text{.........(1)}$$

Q = runoff, P = rainfall, I_a = Initial abstraction, S = Max. potential abstraction

The soil properties of project area such as soil type, infiltration rate, hydrologic soil group etc were analyzed. I_a was estimated as 24.1 mm and S as 80.2 mm. The design rainfall P was adopted as the 5 year 24 hour rain which was worked out as 180 mm on analysis of 36 years daily rainfall data. Accordingly, Q of equation (1) was found as 103 mm. This was converted into discharge by considering 16 hours as the excess water removal time. Thus, from the 2 ha rice field, the design discharge is 0.036 m^3/sec. Using this as the drainage coefficient and adopting Manning's equation for the hydraulic design (with n = 0.04, side slope 1:1, bottom width 0.25 m), the channel flow depth was determined as 0.35 m including a 5 cm free board. All these drains through collector and main drain, led to the inlet of the SFR.

RECOMMENDATIONS

1. Water use planning should be done on micro-watershed basis with government support and people's participation in blocks and districts on the pattern of land use planning for optimal and sustainable water resource development. Teams of leading scientists and experts of water management should be formed to explore and develop technology packages for better integrated water resource utilization in the region.

2. For promoting conjunctive use of surface and groundwater construction of SFR and shallow dug well in individual farmer's field need to be subsidized to the extent of 50% of the total cost and the money be transferred to the bank account of farmers to avoid regularities in such money transactions. Such water harvesting structures in Indonesia and Phillippines are individually owned, managed and operated by farmers where similar land holding pattern as that of our country exists.

3. Policy makers of water resources development in our country should realize that expenditure on water resource development to individual farmers in an investment for future food security, because these small water resource/ water harvesting structures contribute to a great extent the recharge of ground water, alleviate submergence and drought in order to promote sustainable agriculture and crop diversification.

4. In most of the canal command areas, the efficiency of water use is about 30% or less. At least it should be improved to the extent of 50% by adopting transient storages system and using pressurized irrigation system such as drip, sprinkler and surge irrigation.

5. For effective crop diversification and increase in cropping intensity low water requirement and high value crops are need to be promoted. More flexibility of irrigation system to meet water demands, in terms of time, amount and locational accessibility should be ensured. Appropriate marketing and processing facilitates hold the key to success of the diversified agriculture and the measures should be taken by the government to meet this need.

6. The farmer's irrigation cooperative movement should be encouraged. The operation and maintenance of irrigation minors and sub minors must be entrusted to the farmer's cooperatives. Concession in water rates can be given to these cooperation for the services rendered by them. Suitable drainages should be made in irrigation Act to revitalize the system.

7. Rice fish farming accommodates crop diversification and reduces the investment risks in SFR based rice cultivation. The system also generates year round employment in the farm and ensures high productivity and profitability besides assuring conservation of ecosystem.

8. Suitable legislative action should be taken to provide legal status to WUAs. The managerial aspect of personnel of irrigation department should be highlighted and they should be suitable trained. The responsibility of WUAs can begin from minor downwards leaving the department to pay greater attention to management of head works and main/branch canals.

9. The district, block and Panchayat levels water management committee should be entrusted to bear the responsibility to take decisions on: 1. timing of canal closure for annual repair and maintenance, 2. design of suitable cropping pattern for each block within the irrigation command, 3. delineating the waterlogged and high water table areas for rice and fish farming, 4. control of stray cattle menace specially during dry season, 5. avoiding mismatch between timing of water delivery and crop needs in canal command areas, 6. laying out field channels and drains and making suitable provisions for their maintenance at Gram Panchayat Level.

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