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About 12% (40m ha) of total geographical area (329 M ha) in our country is susceptible to flood. Out of this 40m ha flood prone area, on an average about 7.5 M ha is affected by flood every year amounting to average net loss of 8.2 million tonnes of food grain production annually. The pattern of occurrence of flood normally coincides with excess monsoon though it varies significantly among different flood prone areas, even with in the same basin from year to year.

**Crop Management in Flooded and Flood Prone Areas**

**Rice**

Rice basically a water loving crop is dominant in *kharif* season in 90% of the flood affected agricultural lands. Rice field generates a bunded eco-system itself and provides an ideal storage ground for excess water prevailing during S-W monsoon. But at times extent and intensity of flood exceeds the tolerance threshold of these areas inflicting damage and reduction of productivity. The excess water stress leads to problems like inadequate crop stand, suppressed growth or tillering, excess iron toxicity, deficiency of Zn, dominance of pests (stem borer and gall midge) and diseases (bacterial blight, sheath blight etc), low fertilizer utilization etc (Mohapatra et al., 1998). As rice is the major crop which experiences flood, the contingency measures to combat menace of flood also maximally exist in this crop.

Performance of rainfed low land rice depends on initial crop stand and seedling vigour, time and pattern of increase in water level after seedling emergence, elongation ability and submergence tolerance capacity of varieties.

In coastal West Bengal prone to occasional flooding, crop also suffers from salinity of soil and ground water and lack of irrigation and drainage facilities. In a field of 0.2 – 4 ha size in about one fifth area, construction of a 2.5 m deep tank facilitates storage of rain and flood water. The level of the rest 4/5th of the field is elevated by 50 cm through excavation of soil to avoid flood water damage. Moreover this well drained elevated area is available for second and third crop after wet season rice, with guaranteed water supply from adjoining storage tank. The tank embankments are utilized for vegetable and tree or horticultural crops.

Another method followed in flood prone area, is construction of alternate parallel raised and sunken beds in the field. The height of raised beds is determined depending on expected level of rise of floodwater. While submergence tolerance tall long duration wet land rice varieties are cultivated in sunken beds, the raised beds are utilized for vegetable/horticultural or perennial crops.
Direct seeding in relatively dry soil by May end is another successful strategy for rice cultivation in flood prone rainfed low land condition. Depending on varieties, transplanting method wastes crucial 15-20 days period before rise of floodwater. Moreover transplanting in excess water subjects plants to two fold stress, transplanting as well as excess water stress, leading to poor crop stand. But in direct seeding by the time floodwater starts accumulating in field, seedlings in the field is well settled to take on floodwater stress, avoiding crop failure. The sowing of seeds at deeper depth (6 cm) yields better due to better germination by a following rain (> 15mm). The faster adaptation of established seedling with rising water increases survival chances of the crop yielding as much two times than transplanted crop. Similarly in flood prone coastal Orissa, positive weekly rains after mid May is 70% and monsoon is active from mid June. In this situation delayed sowing after mid June is risky and more likely to be damaged by flood. Thus in most of the flood prone low land areas (in Eastern India in general) crop sowing should be over by latest 10-15th June (or 7th June) to combat excess water situation at later part of the season. Thus direct seeded early planting should be given preference over transplanting in the flood prone low land areas for reasonably assured productivity. The sowing time should be June 1st week so that seedlings are one month old before the crop experiences submergence.

Unpredictable arrival of flood water often makes precision agriculture difficult. Out break of floods at the time of planting keeps field inundated for more than a month. Similarly late onset of monsoon often delays transplanting of rice. Under such condition bunch planting of aged seedling of longer duration (150-180 days) rice varieties is adopted (in Erasama area in Orissa). In coastal area with saline soil mature seedlings (50-55 days old) are transplanted to the field, where salt level is diluted due to excess water resulting in better crop establishment. Another practice of using mature seedling for transplanting is followed in North Bihar, known for its vulnerability to flood. Know as “Kharuhan” practice, seedlings are first raised in nursery bed as usual. After one month seedlings are further transplanted to another nursery and grown at a much closer spacing (of 5x5 cm) for another 30-40 days. These plants are subsequently used for transplanting in the field after recession of flood water in September. These ‘double’ transplanted seedlings have thicker culms, better seedling vigour and can tolerate flood water better. More importantly they are less susceptible to insect-pests (case worm and hispa ) and tungro virus, prevalent in late transplanted rice in flooded areas.
In Assam, flood extends for much longer duration from May to October and damages both summer (March-June) and winter (July to November) rice crop. Even deep water 'bao' rice is also affected by severe flood in September. To avoid risk of total crop failure a mixed cropping of early rice varieties ('ahu') with late maturing deep water ('bao') rice is adopted in flood prone areas. This takes care of either early flood (May-June, damaging only 'ahu' rice) or late flood situation (September-October, affecting 'bao' rice only) resulting in significantly higher yield than sole crop of either 'ahu' or 'bao' rice. A similar practice of mixing early maturing rice with long duration deep water rice to avoid risk of total crop failure is also popularly followed in Thailand and Bangladesh.

In low lying waterlogged areas such mixed cropping of autumn and winter rice is also popular in Tamil Nadu (known as 'Udu' rice) and Kerala (known as 'Koottumundakan' rice), eliminating cost of land preparation for transplanting of winter crop. In 'koottumundakan' system, a short duration autumn variety (e.g. 'Towan') is broadcasted with a photo sensitive long duration winter variety (e.g. 'Munon') in 3:1 ratio during April-May amidst optimum soil moisture. The winter variety gets a topping where the autumn variety is harvested during September and stubbles are left for decomposition in the field. The winter variety grow with normal good tillering, spreading over the field and matures in January.

Due to its low productivity (< 1 t/ha) cultivation of deep water rice alone is not always profitable. Therefore it is mixed sown with various non-rice crops like 'jowar', pulses and oil seeds in parts of eastern India. In flooded and flood prone areas in Bihar and Eastern UP the land is tillable only in February. To increase productivity in such areas mixed cropping or inter cropping of short duration green gram, sesame, black gram, jute, maize, forage sorghum etc with deep water rice is adopted. Both the crops are sown in March-April and the inter crop is harvested before advent of flooding in June. In green gram, only pods are harvested allowing the plants to decompose in the field, adding nutrient for rice plants. Rice in combination with sesame reduces pest population due to biological interference for pest growth.

Integration of aquaculture with rice farming augments farm output and income and also benefits rice by improving its growth environment. Many fish species like catfish, snakehead, Anabas sp. and Trichogaster sp. are adapted to swamp condition of rice field. This system is economically beneficial, besides reducing stem borer infestation and fish works as predator of several pests of rice.
In shallow lowlands, 500-700 kg fish or prawn per ha with 5-6 t/ha of rice is obtained by farmers under such mixed farming systems. In deepwater situations where water remains in the field for longer periods, the yield of fish/prawn may go up to 2000 kg/ha, although the yields of rice are lower under such conditions. Cultivation of vegetables and horticultural crops like banana, papaya on bunds (raised around the field with the soil excavated from the trenches) further adds to productivity.

The coastal saline lands, which grow ‘kharif’ rice or remain barren as unproductive wetlands provide ample scope for development of a rice-fish/prawn production system. Rice-fish system in coastal saline areas with salt tolerant rice varieties and fresh water fish/prawn during kharif and sole cropping of salt-water fish/prawn are grown in sequence during rabi. These wetlands can produce 400-600 kg/ha fish in three months in rabi and another 500-600 kg/ha of fish during an integrated rice fish/prawn culture in the monsoon season. Rice fish integrated farming has proved to be a viable technology that is suited to the low lying rice fields lying below the mean sea level in Kuttanad region of Kerala. Raising of marketable fish and prawn in rainfed lowlands including coastal saline areas (brackish water bodies) along with rice has been accomplished successfully in West Bengal, Orissa and Coastal Andhra Pradesh.

The lowland soils of flooded and flood prone areas are mostly alluvial, light to heavy in texture and developed from the deposition of silt and organic matter for several years. They are generally rich in fertility compared to irrigated or upland soils. But lowland soils may of late suffer from soil salinity, acid sulphate conditions, excess iron toxicity or deficiencies of P, Zn and S. Salinity is increasing in Gandak and Koshi command areas of north Bihar due to the rising water table, due to which the toxicity of excess B and Mo is on rise. In saline soils, the plants are vulnerable to early drought and early termination of the rainy season. They are also subjected to daily tidal movement. In peat soils, although rice growth is luxuriant because of high organic matter but the yields are usually low due to Cu deficiency.

Thus fertilizer management is one of the important problems encountered in waterlogged rice fields because of the difficulty in its application and nutrient losses. Healthy and vigorous rice plants are able to tolerate flooding due to greater accumulation of dry matter, carbohydrates and nutrients for utilization during anaerobic submerged condition. Therefore, proper fertilizer application of the crop is important for attaining a high initial crop stand and vigour before onset of flood. With early seeding and moderate doses of N fertilizer (at 40kg N/ha) the crop
establishes well and imparts vigour, which help the seedlings withstand the ravages of floods. Mortality of seedlings after flood has been found to be 45-60% in the plots receiving no nitrogen due to weaker and thinner seedlings but it reduced to 5-15% in plots receiving 40 kg N/ha at sowing. The response to nitrogen under flood prone lowlands is weak due to greater nutrient losses, low productivity and high native soil fertility. Therefore, application of 40-60 kg N/ha is adequate for rice under rainfed lowland and flood prone conditions. The recovery of plants subjected to simulated flash flood was better with top dressing of N fertilizer after the submergence stress. Some of the partially damaged tillers regained growth and produced more dry matter, leading to increased number and weight of panicles. Top dressing of 20 kg N/ha after recession of floodwater increased the grain yield under submerged condition by 0.6 t/ha.

Application of P helps rice crop to withstand flooding stress better, during the early vegetative stage. In flood prone areas, acid sulphate soils have many adverse effects such as low pH and toxicity of Al, Fe and H₂S etc. Phosphorus is essential for the survival of rice plants and promotes root growth, strong stems, preventing lodging. The P also promotes plant elongation and its survival in rapidly rising floodwater. Rock phosphate is a better source of P than triple super phosphate because the rapidly available P in triple super phosphate tends to get fixed while rock phosphate releases P gradually from its non-available factors.

Rice plants fertilized with both N and P tolerated flooding and produced significantly higher grain yields than the unfertilized or those fertilized with N or P alone. A moderate application rate of 20-40 kg P₂O₅/ha combined with 40-60kg N/ha is recommended at sowing time to improve the population density, growth and yield of rice under submergence. In calcareous lowland soils of north Bihar which are deficient in Zn, an application of ZnSO₄ @ 25kg/ha mixed with compost is essential and is sufficient for 3-4 crops grown in succession. Foliar spray of 1% FeSO₄ is beneficial for stouter seedling growth.

During planting the rice seeds and NPK fertilizers are drilled in the same furrow. Seed and fertilizer remain in a relatively drier environment until rains are received within a week of sowing which induce seed germination.

Drilling sulphur coated urea behind plough at sowing has been found to be promising in prolonging N availability to rice plants under excess water conditions. In transplanted rice, the grain yield was highest with urea supergranule placement at 30 days after transplanting followed by sulphur coated urea broadcast. In the
calcareous lowland soils of Bihar, sulphur coated urea, urea super granules and neem cake coated urea have shown promise. However, in view of the high cost of sulphur and non availability of urea super granules and difficulty in applying it in standing water, prilled urea drilled behind plough in direct sown rice and broadcast incorporation in transplanted rice are recommended for improving nitrogen use efficiency in excess water conditions.

Incidence of wild rice is a major problem in flooded, flood prone rice cropping systems. The wild rice, resemble rice plants and does not bear panicle thus compete with rice plant sharing space and nutrients. The effective measures for controlling wild rice in flood prone areas include: (i) ploughing after crop harvest to kill wild rice plants from the previous season and to bring up seeds within the ploughed layer, (ii) allowing wild rice to germinate after rain, (iii) a shallow second tillage with dry surface soil to kill wild rice seedlings and sowing of rice immediately after tillage in rows and (iv) by killing emerging wild rice by hoeing between rows.

Considerable area of marshy or swampy land in India (about 6 m ha) remains without cultivation of any crop. Such area forms a significant part of 40 m ha flood prone area in India. Few aquatic, semiaquatic crops which finds a natural place in such situation remained neglected for cultivation despite their economic potential. A medium harvested crop of swamp taro (Colocasia esculenta schott) can fetch up to Rs. 43,000 per hectare. A good crop of water chestnut can give a net profit up to Rs.15,000 to Rs. 20,000 per ha.

**Water chestnut**

Water chestnut (Trapa bispinosa) or `singhara` or `paniphal` is very commonly grown in shallow (0.5-1 m) to deep water bodies throughout India and in maximum intensity in Eastern India. Even though cultivated mainly in roadside ponds or side of railway tracks ditches, the unique extension ability of the stem, floating leaf rosette and anchorage to bottom of water body make this crop suitable for flood prone areas (Roy Chowdhury et al., 2003). It is more suitable in areas where flood water rises slowly with less water current. The weak stem of the plant makes it unsuitable for areas prone to tidal waves or high water current.

The crop is planted in early June before onset of monsoon at a spacing of 1.5 m from plant to plant. About 0.5 - 0.8 m water depth is suitable for planting by adjusting its vine length so that crown leaf rosette remain afloat. About 3-4 seedling are tied in a knot and the knot is pressed against soft mud bottom of the water body
using feet at a spacing of 1.5 m X 1.5 m. At the time of planting compost @ 8-10 t/ha is applied in the pond. The inorganic fertilizer is applied @ 87 kg urea 250 kg SSP: 100 kg MOP per hectare (NPK 40:60:40) while N and K is given in three equal doses in 1st, 2nd and 4th month after planting. The total P is given at the time of planting. Sometimes one third N and K with full P is applied as basal dosage. Within three months entire surface of the water is covered extensively with the crop.

**Intercultural operation**

The crop is kept weed free by weeding at regular interval. With increase of foliage, there is appearance of singhara beetle (*Galerucella barmanica*) which is controlled by foliar spray of sevin @ 1.5 kg/ha with teepol 0.05% v/v as surfactant. Foliar spray of 0.01% v/v Miraculan (Tricontanol 0.05%) increase the flowering frequency as well as fruit size and total production.

**Harvest**

Harvesting starts from September and continues upto December-January depending upon the time of planting and the growth of the crop. The fruits are normally harvested at an interval of 3-12 days. At the time of harvest selective harvesting is done depending on the size and firmness of the fruits and softness of peel, the two main features for market acceptability. Initial peaking yields less fruit and reaches its maximum at third or fourth peaking finally declining at last stages of harvest. An average crop yields upto 7-10 t/ha while depending on crop growth it may be upto 15-20 t/ha. The fruit is quite balanced as per its nutritional content given below.

<table>
<thead>
<tr>
<th></th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Minerals (g)</th>
<th>Fibre (g)</th>
<th>Carbohydrate (g)</th>
<th>Ca (mg)</th>
<th>P (mg)</th>
<th>Fe (mg)</th>
<th>Carotene (µg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh fruit</td>
<td>4.7</td>
<td>0.3</td>
<td>1.1</td>
<td>0.6</td>
<td>23.3</td>
<td>20</td>
<td>150</td>
<td>0.8</td>
<td>12</td>
</tr>
<tr>
<td>Dry fruit</td>
<td>13.4</td>
<td>0.8</td>
<td>3.1</td>
<td>-</td>
<td>68.9</td>
<td>70</td>
<td>440</td>
<td>2.4</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note: per 100 g kernel; source: Gopalan et al 1987.*

With average yield of 7.0 t/ha the net profit from the crop is about Rs. 18,000 per hectare. The fruits are either consumed fresh or sun dried to make flour for use in various rituals and fasting.
A portion of the crop is left without peaking of fruits for seeds for next season crop. After the crop decomposes in January-February, new seedling germinate from this portion of the crop and are transferred to nursery pond with 20-30 cm deep water. Otherwise big fresh mature fruit is harvested and cured as seed material. 100 kg fresh fruit gives approx 30 kg cured seed which are kept in earthen pitcher in cool, humid place and away from light to retain its viability. Seeds are then placed in 20-25 cm nursery pond to develop seedling directly. These seedlings are used in early June as planting material or further multiplied to develop lateral suckers. These suckers are again used as planting material.

**Swamp taro**

Extensively popular in Assam, West Bengal, and parts of Bihar, this crop is locally known as ‘Pani kachu’ in Assam, ‘Kachulati’ or ‘Latì’ in West Bengal and ‘arbi’ in Bihar. The entire plant starting from leaves, petioles and stolons or runners is popularly consumed as green vegetable. The major nutrient composition of 100 g edible part of swamp taro follows.

<table>
<thead>
<tr>
<th></th>
<th>Protein (g)</th>
<th>Fat (g)</th>
<th>Minerals (g)</th>
<th>Iron (mg)</th>
<th>Carotene (μg)</th>
<th>Ca (mg)</th>
<th>P (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Petiole/runner</td>
<td>0.3</td>
<td>0.3</td>
<td>1.2</td>
<td>0.6</td>
<td>104</td>
<td>60</td>
<td>20</td>
</tr>
<tr>
<td>Leaves*</td>
<td>3.9</td>
<td>1.5</td>
<td>2.2</td>
<td>10.0</td>
<td>10278</td>
<td>227</td>
<td>82</td>
</tr>
</tbody>
</table>

*Source: Gopalan et al 1987. C. antiquorum*

It is a 7-9 month crop. Sprouting runner with roots or root stock with defoliated petiole is used as planting material. In January before planting of the crop, the field is prepared by weeding and compost is applied @ 8 t/ha. Crop is planted at a spacing of 60 x 45 cm (32,000 seedlings/ha). In marshy land spacing can be 60 X 75 cm (i.e. 22222 seedlings/ha) with N:P:K 50:60:60 kg/ha (Roy Chowdhury et al., 2004). A well-developed seedling is preferred for early seedling establishment and quicker sprouting of runner. At the time of planting about 2 cm standing water on the field is necessary for better seedling establishment. To minimize the rotting of seedlings they are dipped in Ridomil solution (0.5 g/liter) overnight before planting. The fertilizer N:P:K is applied @ 52:60:63 per ha i.e. 113 kg urea, 375 kg SSP and 105 kg MOP per
ha in three doses. The full doses of phosphate, one third urea and potash are applied at the time of planting of seedling. The rest N and K is applied after 2\textsuperscript{nd} and 3\textsuperscript{rd} month in equal doses. If at the time of planting water is more than 0.5 cm, then entire N:P:K can be applied in three equal doses at 2\textsuperscript{nd}, 5\textsuperscript{th} and 7/8\textsuperscript{th} month after planting. Application of zinc sulphate at 3\textsuperscript{rd} month after planting @20kg/ha improves the size of runner and petiole.

**Intercultural operation:**

Water level upto one feet can be allowed in the field. Prolonged water stagnation (more than three weeks) reduces runner quality and yield. Upto 4 months field should be weeded at periodic interval. The older yellow leaves are removed at regular interval to promote runner formation. During extreme dry period in May-June if there is wilting of leaves due to water stress one irrigation can be given to reduce plant mortality and yellow leaves are removed from the plant. However, with onset of monsoon, growth of crop is restored. Soil application of Ridomil (0.15/W/V), at the time of planting control stem rot effectively.

**Harvest**

The runner starts appearing from 4\textsuperscript{th} month after planting. Runners are not allowed to grow beyond 70-80 cm to 1m depending on cultivars. Otherwise new plantlets appear on tip of the runner reducing its market value. Runners are harvested periodically at 15 days interval. In total with 6-8 peaking about 10-15 t/ha runner is harvested. The net profit from a crop of 8 month is about Rs. 40,000 per hectare.

**Makhana (Euryale ferox)**

It is a bottom rooted floating plant with large spinous leaves. This aquatic cash crop is exclusively grown in parts of North Bihar covering upto 70% of permanent wet lands in North Bihar. Out of annual 500 metric ton of makhana produced Bihar accounts for 90% of it. Rest 10% comes from Manipur. All the seven districts of Bihar growing this crop i.e. Darbhanga, Madhubarni, Muzaffarpur, Purnia, Samastipur, Barauni and Saharsa are chronically flood prone, pointing out feasibility of the crop in flood prone areas.

Cured seed of Makhana is planted at the bottom of water bodies during Feb-March from where plants emerge. By August – September, the surface water is fully covered by the crop. Harvestable part is seed, which normally matures inside fruit below water during October – November. By December crop decompose and mature.
seeds are sieved out from bottom of the pond. They are graded according to size and dried in sunlight. Graded dry seeds are roasted for particular duration before cracking with a wooden spatula for popping of makhana. According to size of seed price of makhana varies from Rs. 80-200 in retail market. After planting occasionally urea, potash and phosphate is applied depending on growth of the plant. The yield of total seed is 1.2-1.5 t/ha with a net profit of Rs. 10,000-13,000/ha for 400-500 kg edible makhana.

References


