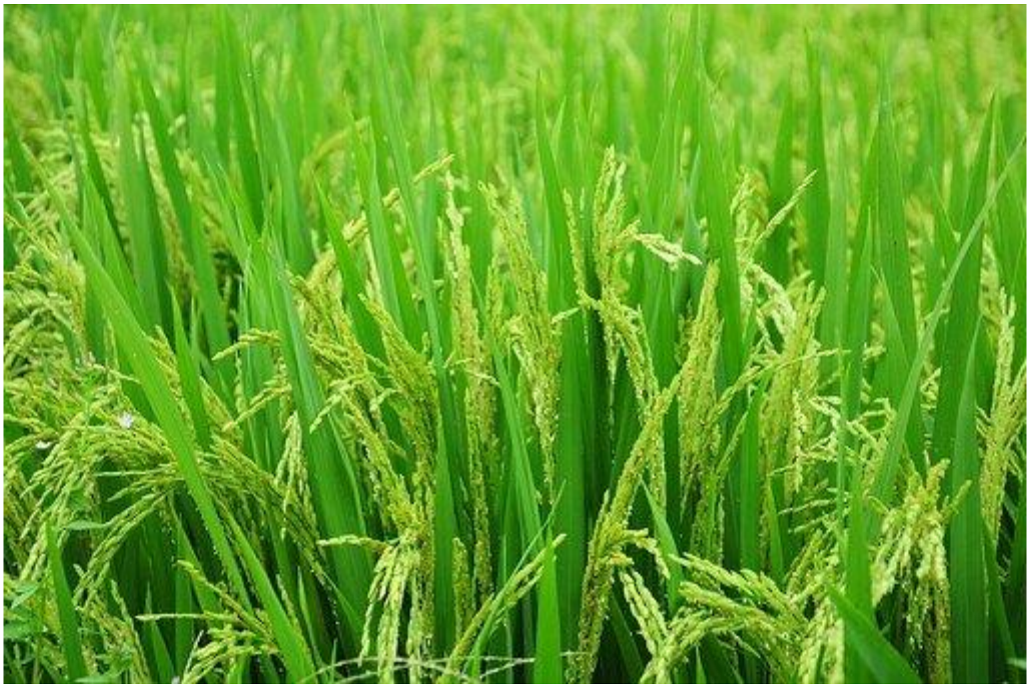
RICE FARMING



1. Introduction to Rice:

Rice is synonym with food throughout Asia e.g. Toyota means bountiful rice field and Honda means the main rice field. In India and in some other countries, rice is associated with tradition and customs and is often thrown on newlywed couples as it is supposed to bring good luck and health.

It is also a rich source of a number of vitamins and minerals like Vitamin D, fiber, niacin, thiamin, iron, etc. Because rice is free of gluten, it makes an excellent for people who are advised to stay off gluten rich diet. It also keeps the bowel healthy, as it contains resistant starch that helps in the growth of beneficial bacteria, when it reaches the bowel in an undigested form.

It is a good source of foreign exchange earnings. Global rice bran oil production varies from 1-1.4 million tonnes of which India accounts for 0.7-0.9 m tones. Rice bran oil is used for cooking after refinement. It is also used in making soap. Rice hulls can be used in manufacture of insulation materials, cement, card board and as litter in poultry keeping. Rice straw is good cattle feed and litter during winter season, as well as it is also used in preparing hats, mats and ropes.

2. Climate Required for Rice Cultivation:

Rice cultivation in India extended from 8° to 35°N latitude with a tropical and subtropical climate. Rice is indigenous to the humid area of tropics, sub-tropics and temperate regions. It has a wide physiological adaptability and is grown successfully from below the sea level to 2000 meters above the sea level. It is being cultivated from Kashmir, Kulu valley of Punjab, semi-arid of Rajasthan to wettest area of Assam.

Among the various weather elements, rainfall is the most single important factor, which determines the extent, growth and production of rice crop, because rainfall during active phase of the initiation of panicle primordial is significantly beneficial.

The distribution of rainfall in different regions of the country is greatly influenced by the physical features of the terrain, the situation of the mountains and plateau. Rice may be grown under an annual rainfall ranging from 1,000 to 1,500 mm or even more.

Temperature is another climatic elements which has a favourable and in some cases unfavourable influence on the development, growth and yield of rice. Rice being a warm- season, short-day species, requires a fairly high temperature, ranging from 20° to 40°C. High temperature, high humidity and high rainfall have a considerable effect on growth and development of rice plant.

At higher mean temperatures (25-32°C), early flowering is induced by reducing the growth duration; whereas the mean low temperature (<15°C) forces the crop to remain dormant with no flowering.

Therefore, a day temperature of 25°to 33°C and night temperature of 15° to 20°C is considered optimum for the development and growth of rice. In fact, low temperature affects the rate of tillering.

The period of tillering is prolonged due to low temperature, but it gives more tillers and more number of panicles than the higher temperature. Low temperature depresses the internodal elongation and thereby induces the partial emergence of panicles.

This phenomenon further affects the rate of photosynthesis and induces partial sterility. However, low temperature during the period of ripening, prolongs the ripening period and enables the plant to maintain green leaves. Such condition contributes to the accumulation of carbohydrates in the grains.

Sunlight is very essential for the growth and development of rice plants. In fact, sunlight is the source of energy for plant life. The response to solar radiation is a varietal character. The yield of rice is influenced by the solar radiation particularly during the last 35-45 days of its ripening period. Bright sunshine with low temperature during ripening period of the crop helps in the development of carbohydrates in the grains.

The effect of solar radiation is more profound where water, temperature and nitrogenous nutrients are not limiting factors. The low productivity in the case of upland rice is a problem in the tropics due to inadequate availability of solar radiation and low rate of photosynthesis as upland rice is mainly grown during rainy season.

Depending on the temperature requirement, rice crop is grown during kharif season in north-western plains zone, but in south and north-eastern parts of the country, it is grown in all the 3 seasons, as these areas do not have very cold weather during winter. Rice crop needs a hot and humid climate. It is best suitable to regions which have high humidity, prolonged sunshine and an assured supply of water.

It is essentially a short day C_3 plant. A combination of temperatures, photo-period, however, determine the growth and productivity. Heavy wind causes severe lodging or shattering depending upon the crop growth stage. Bright day associated with gentle winds are the best condition, because carbon-di-oxide (CO_2) supply and utilization are regulated to the maximum.

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3. Soil Required for Rice Cultivation:

Rice is grown on almost all types of soils ranging from clay loam of alluvium nature, red-laterite loamy hill, sub-mountains and foot hill soil to the black cotton soils found in different parts of the country. It grows best on loam to clay loam soils that turn into soft mud when puddle and develop cracks on drying.

Thus, soils having good water holding capacity with good amount of clay and organic matter are ideal for puddled rice cultivation. Rice, being a semi-aquatic crop, grows best under submerged conditions. A major part of rice crop in India is grown under low land conditions. Rice plant is able to tolerate a wide range of soil reaction, but it does have preference for acidic soils: It grows well in soils having a pH range between 5.5 and 6.5. The soils with extreme acidity (<4.5 pH) are not suitable. It can also be grown on alkaline soils after treating them with gypsum or pyrite.

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4. Growing Seasons of Rice:

It is well known fact that rice seasons vary in different parts of India depending on rainfall, temperature, soil types, water availability and other climatic conditions. In eastern and southern regions of the country, the mean temperature remained favourable for rice cultivation throughout the year. Whereas, in northern and western parts of the country, where rainfall is high and winter temperature is fairly low, only one crop of rice is grown during the month from May to November.

In eastern and southern regions of the country, the mean temperature is found favourable for rice cultivation throughout the year. Hence, two or three crops of rice are grown in a year in eastern and southern states. In northern and western parts of the country, where rainfall is high and winter temperature is fairly low, only one crop of rice is grown during the month from May to November.

There are three seasons for growing rice in India viz.- autumn, winter and summer. These three seasons are named according to the season of harvest of the crop. Autumn rice is known as pre-kharif rice. The sowing of pre- kharif rice is taken up during May to August. However, the time of sowing slightly differs from state to state according to weather condition and rainfall pattern. It is harvested in September-October.

Autumn rice crop is known as ‘ Aus’ in West Bengal, ‘Ahu’ in Assam, ‘ Beali’ in Orissa, ‘ Bhadai’ in Bihar, ‘ Virippu’ in Kerala and ‘ Kuruvai/kar/Sornavari’ in Tamil Nadu. About 7% crop is grown in this

season. The varieties grown during this season are mostly varieties of short duration ranging from 90 to 110 days.
The main rice growing season in the country is the Kharif. It is known as winter rice as per the harvesting time. The sowing time of winter (kharif) rice is June-July and it is harvested in November-December. Winter rice is known as 'Aman' in West Bengal, 'Sali' in Assam,' Sarrad' in Orissa,' Agahani' in Bihar and Uttar Pradesh,' Sarava' in Andhra Pradesh, 'Mundakan' in Kerala and 'Samba/Thaladi' in Tamil Nadu.
About 84% of the country's rice crop is grown in this season and generally, medium to long duration varieties are grown in this season. Summer rice is called as Rabi rice. It is known as 'Boro' in Assam and West Bengal, 'Dalua' in Orissa, ' Dalwa' in Andhra.

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5. Plant Types (Idiotype) of Rice:
Yield is a function of total dry matter and harvest index (HI). Therefore, yield can be increased either by enhancing the total dry matter (biomass) or the HI or both. The HI of modern high yielding varieties is around 0.45-0.50. It may be possible to raise it to around 0.6.
Following varietal characteristics may need improvement (through plant breeding) for increasing the HI and biomass production:
1. For increased harvest index: Increased sink size through large spikelet number per panicle and greater partition of assimilates in to spikelet formation. Increased spikelet filling through manipulation of canopy senescence, higher proportion of high density grains, maintenance of healthy root system and increased lodging resistance.
2. Increased biomass production: Establishment of desirable canopy structure through rapid leaf area development and rapid nutrient uptake. Reduced carbon consumption.
Ideal Plant Types for Irrigated Ecosystem:
i. About 100-130 days growth duration with photoperiod insensitivity.
ii. Low tillering (3-4 tillers when direct seeded and not more than 15 when transplanted.

iii. About 90-100 cm tall and very sturdy stems.
iv. Dark green, thick and erect leaves and vigorous root system.
v. No unproductive tillers, 200-250 grains/panicle with harvest index of 0.5 to 0.6.
vi. Multiple pest and disease resistance.
vii. Acceptable grain quality.

Ideal Plant Type for Rainfed Lowland:

i. Growth duration of 90-110 days and early seedling vigour.
ii. Plant height 90-100 cm (semi-dwarf stature).
iii. Dark green and erect leaves.
iv. About 8-10 productive tillers with 200 grains/panicle.
v. Drought tolerance and resistance to lodging, pests and diseases.
vi. Harvest index of 0.4 and acceptable grain quality.

Rice Eco-System:

Rice is grown under varying eco-systems on a variety of soils under varying climatic and hydrological conditions ranging from waterlogged and poorly drained to well drained situations. Rice is also grown under rain fed as well as irrigated conditions.

1. Irrigated Rice:

Rice is grown under irrigated conditions in the states of Punjab, Haryana, Uttar Pradesh, Jammu & Kashmir, Andhra Pradesh, Tamil Nadu, Sikkim, Karnataka, Himachal Pradesh and Gujarat.

2. Rainfed Rice:

The rainfed eco-system may be broadly classified into two categories:

a. Upland:

Upland rice areas lies in eastern zone comprising of Assam, Bihar, C.G., M.P., Orissa, Eastern U.P., West Bengal and North-Eastern Hill region. In the rain fed upland rice, there is no standing water in the field after few hours of cessation of rain. The total areas under upland rain fed rice in the country is about 6.00 million ha., which accounts 13.5 per cent of the total area under rice crop in the country. The productivity of upland rice is very poor.

b. Low Land:

Rainfed lowland rice areas include all the areas where water stagnates up to a depth of 100 cm or more excluding manageable irrigated lowlands. The rice crop in this situation occasionally faces moisture stress in the early or terminal stages of growth but mostly excess water stress (waterlogging) at any stage. Low land rice area is mostly located in the eastern region comprising of Assam, West Bengal, Bihar, Orissa, Chhattisgarh, Eastern M.P. and Eastern Uttar Pradesh.

Low land rice area is about 14.4 million ha., which accounts 32.4 per cent of the total area under rice crop in the country. The average productivity of rice in low land areas ranges from 1.0 to 1.2 tonnes per ha. Important constraints limiting the productivity of rainfed lowland rice includes inadequate crop stand due to early drought, suppressed tillering and mortality of plants due to deeper submergence, low use of manure and fertilizers, iron toxicity in acid soils, premature lodging of tall varieties, delayed planting and incidence of weeds, pests and diseases.

The low land rice may be further classified into three categories depending upon the standing depth of water in the field as discussed below:

(i) Shallow Water:

The standing depth of water in the field is generally below 50 cm. The shallow rice area is located in the eastern states viz. Assam, Bihar, Chhattisgarh, M.P., Orissa, U.P. and W.B.

(ii) Semi-Deep Water:

The standing depth of water in the field varies between 50-100 cm. These areas are lying in the eastern states viz. Assam, Bihar, Madhya Pradesh, Orissa, Uttar Pradesh and West Bengal.

(iii) Deep Water:

The standing depth of water is more than 100 cm in the field. Such deep water rice areas are mostly situated in the eastern states, viz.- Assam, Bihar, Madhya Pradesh, Orissa, Uttar Pradesh and West Bengal. These areas are subjected to flood occurrence and duration of flooding varies from year to year.

(iv) Coastal Saline:

The coastal area is always subjected with salinity problem and these areas are situated in West Bengal, Orissa, Andhra Pradesh, Tamil Nadu and Kerala. The total area under coastal saline rice in the country is estimated about 1 million hectares which accounts for 2.3%

each of total area under rice in the country. The yield in coastal saline soil is very poor. Average yield in costal saline area is about 1 tonnes per ha. The coastal Saline soils are often affected with deficiency of ferrous and zinc which causes chlorosis and reduced tillering.

(v) Cold/Hill:

Such rice areas lies in the hill regions comprising of Jammu and Kashmir, Uttaranchal and North-Eastern hill states. The total area under rice in cold/hill region is estimated about 1 million ha which accounts for 2.3% of total area under rice in the country. The productivity in cold/hill areas is very poor. The average yield is about 1.1 tonnes per ha as against the average National yield of 1.9 tonnes/hectare.

The major problems of these areas are cold injuries, blast, drought spell and very short span of cropping seasons. Because of the rolling topography in these areas bench terracing is being followed which limits the use of fertilizers and improved agronomical practices. In these areas the crop is sometimes affected due to low temperature in the early stage and sometimes at the flowering times which leads to sterility problems.

Looking to the risky nature of the rainfed lowland production system, the technology should aim at risk avoidance and produce stable yields. Maintenance of optimum crop stand, efficient fertilizer management and proper plant protection are important for realizing higher yields. Moreover, diversification and integration of different cropping system is essential for improving the prosperity of the farmers. Mostly tall indica varieties of rice are grown by the farmers of these areas which are susceptible to moisture stress, pests and diseases. Therefore, selection and adoption of varieties that have a broader spectrum of tolerance to stress and yield potential are desirable.

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6. Manure and Fertilizers Required for Rice Cultivation:

Organic manures and chemical fertilizers are both important for rice cultivation. Application of bulky organic manures is desirable particularly under upland conditions, to maintain the soil in good physical condition and to increase the water holding capacity of the

soil for maximum utilization of rain water. About 10-15 tonnes of well-rotted farm yard manure or compost per hectare should be applied 4-6 weeks before sowing.
Irrigated rice responds well to fertilizer application if applied judiciously and with proper cultural management. Responses to fertilizer are usually higher in dry season as compared to wet season due to higher solar radiation and lack of rains and better possibility of irrigation management. Fertilizer management in transplanted rice is different from that of direct seeded rice, because continuous submergence of the field in the former creates different conditions. Application of chemical fertilizers depends basically upon the fertility status of the field, previous crop grown and amount of organic matter added. Soil testing is the simplest and easiest scientific method to know the quantity of nitrogen, phosphorous and potassium fertilizers that are needed to get optimum rice yield in a field.
Due to variation in soil fertility, rainfall and climatic conditions, a common dose of fertilizer cannot be recommended for all regions. However, in general a level of 30 to 40 kg of nitrogen per hectare in kharif and 60 to 80 kg of nitrogen per hectare in rabi appears to be the optimum dose for the tall indicas and double that level for the high yielding varieties on soils of average fertility in the southern and eastern regions.
In the northern region, where sunshine is available for longer hours, higher dose of nitrogen is beneficial in the kharif season. High yielding varieties of rice do better than tall varieties at all levels of fertilizer applications and management conditions, and the margin of increase in the grain yield rises up proportionately with increase in the application of fertilizer. Tall varieties lodge beyond 50- 60 kg of N application per hectare whereas dwarf varieties grow well even at 200 kg N/ha.
For the realization of full yield potentiality, these dwarf HYV require 100-120-150 kg N, 40- 45 kg of phosphorus and 40 kg of potash/ha. Hybrid varieties needs higher doses of N (180- 200 kg N/ha) because of their greater yield potential. As a thumb rule 20 kg N/tonne of rough rice may be applied.

A basal dose of 50-60 kg N, 60 kg P_2O_5 60 kg K_2O/ha at sowing followed by top dressing of 25 kg N/ha each at tillering stage (30 days after sowing) in between panicle-initiation and boot leaf stage (45 days after sowing) should be applied for increasing N use efficiency and yield of rice.

Zinc Deficiency:

Zinc deficiency is generally observed in those soils which have a pH of 7 or above. In zinc-deficient soils 20-25 kg of zinc sulphate ($ZnSO_4$) per hectare should be applied at the time of puddling the field or spray 1-2 kg of zinc sulphate dissolved in 150-200 liters of water. One kg of calcium hydroxide {$Ca(OH)_2$} may be added in zinc solution to prevent leaf scorching and for the better adhesion of droplets on leaves.

Method of Fertilizer Application:

Increasing efficiency of applied N fertilizers, a costly and yet the most rewarding single input is of major concerns. In the lighter soils with higher percolation, rainfed areas, and fields with poor water control, N should be applied in several split doses so as to minimize losses and maximize uptake by the plants.

With the present system of incorporation, even in heavy soils, split application is a decisively more efficient management of added fertilizers. In moderately rich soils, no nitrogen fertilizer need to be applied before planting, and even where applied, there is no need to apply more than 1/4th to 1/3rd of the total N recommended.

One heavy dose (2/3rd to ½) at mid-tillering, i.e.,20-25 days after planting, when plant uptake is good, followed by the remaining at the panicle-initiation stage results in more than 30% increase in N-efficiency even in heavy soils. The practice of top-dressing of N fertilizers in standing water leads to great loss to added N, particularly in heavy soils with high pH and low vertical percolation.

In order to fix the added N on the colloidal complex of the soil and to make it available to the plants, fertilizer should be applied on drained rice fields and re-flooded 24-48 hours later. The duration of drainage should not be so extended as to dry and/or crack the soil.

Fertilizer Schedules:

i. In order to obtain better results, full dose of phosphorus and potash should be applied as basal dressing at the time of transplanting.

ii. In light soils 1/3rd to ½ the dose of total N should be given after 25-30 days after transplanting. At this stage, plants are fully established and the N applied in the field is readily absorbed by the roots. This reduces the loss of N by percolation especially in light sandy soils.
iii. The remaining 1/3rd of the N should be top-dressed at the time of flowering and milk stage in equal amounts. In case of poor tillering in the light soils, number of top dressings should be increased. Extra N should be provided in those pockets where plants are yellowish-green.
iv. On the other hand, in heavy soils, there is no need of giving basal application of N at the time of planting. First dose that is ½ of the total quantity of N should be applied 25-30 days after planting, second and third dose, viz., 1/4th each should be given at flowering and milking stage.
v. In case of extra early varieties 1/3rd of the total N and full dose of phosphorus and potash should be given as basal at the time of transplanting and the remaining N should be applied at the time of maximum tillering and flowering stage.
The di-ammonium phosphate (DAP) is an excellent fertilizer for dressing in rice fields. Nitrogen should be applied in reduced zone and subsequently incorporated at the time of puddling or manually placed to avoid conversion of ammonia to NO_3 and subsequent loss by leaching. Sulphur-coated urea has been found better than normal urea for rice fields, where flooding is delayed or intermittent.
In acid soils, rock phosphate in finely powdered form can be used as phosphorus source with advantage. Potassium is the major limiting nutrient in crop production. The deficiency of K in light textured soils is one of the major causes to reduce vigor and disease resistance in plant, strength in straw and stalks of plants and ultimately reduced the yield of the crop.
Fertilizer use efficiency of K is low because of its fixation in soil and losses through leaching etc. Split application of K may increase its efficiency in light textured soils of high rainfall areas. The combined application of K with FYM may also help in increasing productivity of crops.
In rice, hardly 30-40% of applied N is used by the rice crop, and the remaining N is lost through leaching and denitrification.

Nitrogen should be applied in ammonical form. Ammonium sulphate should be applied as basal and urea in top-dressings. In light sandy and sandy loam soils, urea is never applied as basal dose. Calcium ammonium nitrate (CAN) can also be used for top-dressing. In high pH soils such as alkaline and saline soils, only ammonium sulphate should be used. In the absence of ammonium sulphate, can may be used but urea is never applied.

Chemistry of Fertilizer Use in Rice Field:

A series of physical, chemical and biological reactions take place in transplanted rice fields due to presence of excess water in the field. In the root zone anaerobic environment is formed from aerobic condition due to depletion of oxygen in the soil profile, which is responsible for gaseous loss of nitrogen fertilizer due to the process of de-nitrification. This anaerobic environment also affects the availability of phosphorus and micro-nutrients especially iron and manganese.

The soil in the transplanted rice fields after puddling develops two zones in water logged conditions. The upper layer of soils (1 to 10 mm thick) generally receives Oxygen periodically from fresh supplies of irrigation water and turns in to brown colour called "Oxidized zone" and reacts like an un-flooded upland soil. The remaining lower portion of puddle soil without oxygen is called "reduced zone".

When ammonical nitrogen fertilizer is applied in such soils, it gets oxidized to nitrate (NO_3) form in the oxidized zone (upper surface layer of the soil). Afterwards nitrate nitrogen is leached down to the reduced zone and further gets denitrified to gaseous nitrogen. This gaseous nitrogen is lost.

If ammonical nitrogen is incorporated in to the reduced zone of the soil, where it is held, the loss can be prevented. Fertilizers containing nitrogen in the nitrate form are more susceptible to loss of nitrogen through leaching and de- nitrification process. Therefore, ammonical form of nitrogen is found more beneficial for rice crop.

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7. Efficient Use of N Fertilizers for Rice Cultivation:

For minimizing the losses of N and increasing its use efficiency, following methods may be used:

(i) Use of Mud Ball:
Prepare small balls of moist soil and put urea or any other fertilizer in the center of ball. Close the opening and allow it to dry a little. Use these small balls in the rice fields where it is not possible to drain out water from the field at the time of fertilizer application in the standing crop.

(ii) Use of Pre-incubated Urea:
Mix urea with moist soil @ 1 kg urea with about 5 kg soil. Allow this mixture to stand in shade for 36-48 hours before applying in the field.

(iii) Use of Neemseed Cake:
Finely ground neemseed cake is mixed with urea @ 15-20%. mahua or karanj cakes may also be used in a similar way. These oil cakes delay nitrate formation from urea and thus the possibility of nitrate losses through denitrification or leaching is reduced.

Experiment carried out at CRRI, Cuttack revealed that when chemical fertilizers are applied with organic manures, the efficiency of applied fertilizers increases significantly. Conjunctive use of N at 75 kg N/ha in the form of organics (green manures, FYM or azolla) and inorganic in the proportion of 50:50 proved to be better from the point of soil health and sustainable productivity on a long term basis.

a. Green Manuring:
In-situ incorporation of green manure crops (Sesbania aculeate or S.rostrata) ads N which is available quickly to the rice crop. The green manure crop can be grown in the field and incorporated 45-60 days after sowing. Transplanting of rice can be done immediately after incorporating the green manure crop.

b. Azolla:
Azolla (water fern) fixes atmospheric N due to the presence of symbiotic blue green algae Anabaena azollae in its leaves and is important biofertilizer for rice. Results of field experiments conducted at CRRI and other places revealed that consistent yield increase in rice were observed due to green manuring with azolla coupled with fertilizer N. Apply 15 kg blue green algae(BGA) or azolla @ 15 kg/ha 7 days after transplanting.

Incorporation of a layer of azolla or blue green algae adds about 25-30 kg N/ha. It was also reported that by algal supplementation, one third of the recommended N fertilizer can be saved without sacrificing the yield of rice.

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8. Water Management for Rice Cultivation:

Rice is the largest consumer of water as about 5000 liters of water are required to produce one kg of rice grain (IRRI 1994-95). The high water requirement of rice is mainly due to percolation losses. Soils with percolation losses up to 5 mm/day are ideal for rice cultivation, whereas soils with percolation loss of >10 mm/day are not suitable for puddle rice culture.

The water requirement of rice varies from 1190 to 2,650 ha-mm depending upon growing season, soil type, crop duration and management practices etc. Transplanted rice, in general, requires about 40-60, 200-300 and 800-1000 mm of water, respectively for nursery raising, puddling and crop growth in the main field from transplanting to physiological maturity.

The water requirement is high during initial seedling period covering about 10 days. Tillering to flowering is the most critical stage of irrigation. Ensure enough water from panicle- initiation to flowering stage. Application of small quantities of water at short intervals to keep the soil saturated is more effective and economical than flooding at long intervals.

Flooding may not be necessary if the soil is saturated with water and biofertilizer have not been used. However, flooding suppresses the weed growth. It increased the availability of many nutrients, particularly phosphorus, potassium, calcium, iron and silica.

The peak water demand of rice is between maximum tillering and grain filling; tiller initiation, primordial initiation and flowering are most important. Number of tillers and panicles/hill and percentage of filled grains/panicle are sensitive characters. Lack of adequate moisture at these stages reduces the yield drastically up to the extent of 50 per cent.

Experiments conducted at several places in India on low land rice reveal that the practice of keeping the soil under shallow depth of submergence (2-5 cm) throughout the crop growth period is conducive to higher yields. On the other hand, for good yields of rice, it is not necessary to follow continuous submergence, especially in the kharif season when the humidity is high and evaporative demands are low. This is also applicable for shallow water-table conditions.

Under such situations, the practice of intermittent submergence, i.e. submergence during the critical stages of initial tillering and flowering and maintenance of saturation or field capacity during the rest of the growth period gave yields comparable to those obtained under continuous shallow submergence. Moreover, the practice of intermittent submergence saves about 30- 40 % water and thus improves WUE as compared to the continuous submergence.

Allow only a thin film of standing water in the field for about a week after transplanting. Thereafter follow cyclic submergence of water to a depth of 5 + 2 cm one day after disappearance of pounded water till panicle initiation (PI) stage. Maintain about 5-7 cm standing water in the field from PI to dough stage. Certain stages of growth like early flowering has been found to be more susceptible to waterlogged conditions than the other stages of growth.

The drainage should be synchronized with the period just following tillering and flowering. In case of sandy soils drainage period is about 3 days while in the case of heavy soil it is about 5-7 days. The field should finally drained at least 1 week earlier to harvest in light soils and 2-3 weeks in heavy soils to facilitate uniform maturity, easy harvesting and timely sowing of successive rabi crops.

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9. Weed Management for Rice Cultivation:

Weeds compete with young rice plants for space, light, nutrients and water. Infestation of weeds in rice fields may reduce the grain yield by 50-90 % in upland, 30-35% in drilled irrigated and 15-20% in transplanted crop. Thus, timely control of weeds is very important.

The important weed flora of rice fields are:

1. Weed Flora of Upland Rice:

Grasses:

Echinochloa colonum, E.crusgalli, Elicine indica, Dactyloctenium aegyptium, Digitaria sanguinalis, Paspalum distichum, Cynodon dactylon.

Broad-Leaf Weeds:

Amaranthus spinosus, Ageratum conyzoides, Commelina benghalensis, Eclipta Alba, Digitaria marginata and Trianthema portulastrum.

Sedges:

Cyprus rotundus, Fimbristylis miliacea.

2. Weed Flora of Transplanted Rice:

Grasses:

E.crusgalli, E.colonum, Digitaria sanguinalis, Paspalum disticum.

Broad-Leaved Weeds:

Eclipta Alba, Caesulia axillaries, Ludwigia parviflora, Manochoria vaginalis.

Sedges:

C.rotundus, C.iria, C.difformis, Filmbristylis dichotoma, Scripus sp.

The critical period of weed competition lies between 15-45 days of sowing. Two or three manual weeding may be required during this period i.e., first 3 weeks after transplanting in transplanted crop and 2 weeks after sowing in direct-seeded crop, and the second 40-45 days after transplanting/sowing. Generally, weeds are removed either by hand pulling or khurpi.

In line sown wetland crop, the weeds can be removed by Japanese paddy weeder, but it requires well maintained line-to-line distance and some standing water in the field. Wheel finger weeder or paddy weeder should be used as the cost of mechanical weeding is much less than the conventional weeding practices. Continuous pounding for at least 3-4 weeks also helps a lot in reducing and controlling nearly all weeds of transplanted paddy.

It is difficult to remove weeds in rice nurseries and direct-sown broadcast puddle rice by hand/khurpi/paddy weeder due to close spacing of seedlings. Moreover, manual weeding is a costly and labour-intensive operation. Therefore chemical method of weed control should be adopted. A number of herbicides have been found effective in controlling annual weeds of grassy and broad-leaf nature.

i. Annual grasses and sedges in rice nursery can be controlled with the application of 1.5 kg/ha of butachlor/thiobencarb 7 days after sowing of pre germinated rice seeds after mixing in sand. These herbicides can also be applied on a moist soil 3-7 days before puddling and sowing of pre germinated rice seed. Alternatively application of Sofit 30.5 EC (Pretilachlor + safner) at 0.38 kg/ha as sand mix, 3 days after sowing or broadcasting of pre germinated rice seed can be done for effective weed control in rice nursery.
ii. Thiobencarb 50 EC(Saturn) @ 1.5 kg/ha mixed with 60 kg of dry sand and broadcast uniformly in 4-5 cm of standing water within 2-3 days after transplanting. Should be sprayed after 4-6 days of sprouted seedlings. Delayed application causes poor weed control and early application may cause toxicity to seedlings.
iii. Pretilachlor:
The pre-emergence application of this herbicide at 0.75-1.0 kg/ha gives excellent control of grasses.
iv. Butachlor 50 EC (Mechete G):
This is widely used herbicide used to control annual and broad-leaved weeds in rice. This is a pre-emergence herbicide applied @ 1.5 kg/ha in 400-600 liters of water. Drain out water before its application.
v. Fluchloralin (Basalin):
This herbicide should be sprayed or broadcast in standing water (3-5 cm) after the final puddling and planking or 1-3 days after transplanting rice. It is used @ 1 kg/ha in 400-600 liters of water or 25-30 kg granules/ha as broadcast.
vi. Anilophos 30 EC (Arozin):
Its pre-emergence application gives complete control of broad-leaved weeds and grasses at 0.4 – 0.5 kg/ha. It is more effective when applied in combination with 2, 4-D.
vii. For the control of some broadleaf weeds and sedges, sulfonylurea herbicides particularly metsulfuron is very effective. Metsulfuron (Algrip royal 20 WP) is applied through spray application as post emergence (20-25 DAT) at 15 g/ha after draining the water from the field.
viii. Chlorimuron ethyl is a new brand of herbicides applied in very small amounts. As a pre as well as post-emergence application, it gives

excellent control of broad-leaved and satisfactory control of grassy weeds.

Aerobic Rice:

About 92% of the world's rice is produced and consumed in Asia, where 90% of the fresh water is used for irrigated agriculture and of which >50% is used in rice cultivation. Food security of this continent depends heavily on rice production from conventional transplanted system, which is under threat as decreasing freshwater availability may lead to water scarcity in 15 million ha of Asia's irrigated rice by 2025.

The percent availability of water in most of the basins in India, rice-growing regions in particular, also is predicted to decline below water scarcity line by 2025. Hence, it is imperative to develop alternate rice production systems, which will save water, while maintaining the productivity.

Growing rice under aerobic conditions as in case of other cereal crops will reduce the water requirement by at least 30 percent. In India, upland rice is grown traditionally in aerobic soils under rainfed conditions with minimal inputs and thus produces very low yields. Cultivation of high-yielding lowland rice varieties under aerobic upland conditions has shown significant amount of water savings but accompanied by severe yield penalty. Consistent efforts made by researchers in various parts of the world in the past one decade led to the development/identification of high yielding rice genotypes suitable for 'aerobic rice system' with high water productivity without compromising much on grain yield.

In this direction, the IRRI, Philippines, has released the first tropical aerobic rice variety 'Apo' which yielded 5.7 t/ha with total water savings to the extent of 40-50 %. Water Technology Centre, IARI, New Delhi has identified some of the rice varieties/hybrids (Pusa rice hybrid-10, Pusa-834, Apo-l, Proagro 6111) with grain yield of 4-5 t/ha under aerobic conditions. Recently, UAS, GKVK, Bangalore has released an aerobic rice variety 'MAS946 1' which yields 5.5 tons of grain and 6.0 tons of straw/ha under aerobic conditions with water saving to the tune of 40-50%.

Similarly, TNAU, Coimbatore has identified PMK 3 and ASD 16 with the grain yield 3,684 and 3,138 kg/ha respectively. The water input (effective rainfall and irrigation) was only 520 to 650 mm, and thus aerobic rice saved >50% water and water productivity was 60% higher than that of transplanted rice. In all cultivation of aerobic rice saves about 40-50% water. Hence, cultivation of one ha of aerobic rice saves >600 mm water, which is sufficient to cultivate other crops in an addition one ha of land, thus doubling the irrigated area.

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10. Cropping Systems of Rice:

The cropping pattern in different Agro-climatic zones has been adopted by the farmers after long experience based on suitability of soil, profitability, availability of market and industrial infrastructure and quantum of water available. Techniques such as relay cropping, inter cropping, mixed cropping, minimum tillage, weed control and use of fertilizers and pesticides have helped not only in reducing the cost of cultivation but also in sustaining high level of production over a period of time. Scientific cropping patterns can actually result in increased soil productivity by improving the physical, chemical and micro-biological properties of soils and increasing the fertility status.

Some of the rice based cropping patterns being followed in the country are discussed below:

i. Rice-Rice-Rice:

This crop rotation is most suitable for areas having high rainfall and assured irrigation facilities in summer months, particularly, in soils which have high water holding capacity and low rate of infiltration. In some canal irrigated areas of Tamil Nadu, a cropping pattern of 300% intensity is followed. In such areas three crops of rice are grown in a year.

ii. Rice-Rice-Cereals (Other than Rice):

This cropping pattern is being followed in the areas where the water is not adequate for taking rice crop in summer. The alternate cereal crops to rice being grown are Ragi, Maize and Jowar.

iii. Rice-Rice-Pulses:

In the areas where, there is water scarcity to take up cereal crops other than rice in summer, the short duration pulse crops are being raised.

iv. Rice-Groundnut:

This cropping pattern is being followed by the farmers of Andhra Pradesh, Tamil Nadu and Kerala. After harvesting of rice crop, groundnut is grown in summer.

v. Rice-Wheat:

This crop rotation has become dominant cropping pattern in the Northern parts of the country.

vi. Rice-Wheat-Pulses:

In this sequence of cropping pattern, after harvesting of wheat green gram and cowpea as fodder are grown in the alluvial soil belt of Northern states. Besides, cowpea is grown in red and yellow soils of Orissa and black gram is grown in the black soils.

vii. Rice-Toria-Wheat:

This crop sequence is commonly followed in Northern parts of the country.

Among the above mentioned cropping patterns followed in the country, Rice-wheat cropping pattern is the largest one. The Rice-wheat cropping pattern is being practiced in the Indo-Gangetic plains of India since long time.

viii. Rice-Fish Farming System:

The field with sufficient water retaining capacity for a long period and free from heavy flooding is suitable for rice-fish farming system. This system is being followed by the small and marginal poor farmers in rain fed lowland rice areas. These farmers are not able to invest much in agricultural development. They raise a modest crop of traditional low yielding rice varieties.

In order to improve the economic condition of these farmers, the Central Rice Research Institute, Cuttack has developed the production technology for rice and fish farming system. Steps have already been taken to popularize rice-fish farming system in low land areas to increase the production and productivity of crops and thereby improving the economic conditions of the resource poor farmers of these areas.

11. Harvesting of Rice:

Rice varieties usually take 100-150 days to mature. Harvest the crop as soon as it matures. If harvesting is delayed, grain may be lost due to damage by rats, birds, insects, shattering and lodging. Timely harvesting ensures good grain quality, consumer acceptance, since the grain is less likely to break when milled. The proper stage for harvesting is when about 80% of the panicles become grey in colour (straw colour) and the grains in lower portion of panicles are in hard dough stage.

The right stage for harvesting is when panicles turn into golden yellow and the grains contain about 20 percent moisture. Harvesting of the crop when it is not fully matured might result in loss of yield with poor quality grains. Delayed harvesting (until the crop dry to 14-16% moisture) may cause shedding of grains resulting in considerable loss in grain yield and increased percentage of broken rice during hulling. Grain may also be lost due to damage by rats, birds, insects, shattering and lodging.

If the crop remains in the field and dries to less than 18% moisture, the cyclic moisture content due to day-night humidity differences will cause fine cracks called sun cracks or stress cracks that will reduce head rice yield and increase broken kernels at milling. Thus, timely harvesting ensures better yield, good quality of grains, consumer acceptance and less breakage when milled.

Harvesting between 27 and 39 days after flowering at high moisture content (18-23%) results maximum head rice recovery. The plant should be cut close to the ground by improved sickles (serrated edge) and left in the field for a few days to dry. Later on, these should be collected in bundles and stalked for threshing. For hard soil and non-lodged crop of rice, power tiller or tractor operated vertical conveyor reaper (VCR) may be used.

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12. Threshing, Winnowing and Milling of Rice:

Threshing of rice on small farms is still a serious problem. The most common and popular methods of threshing are churning by bullocks or tractor treading or by beating the small bundles of harvested crop on hard platform. Now a days pedal operated paddy threshers or power driven stationary threshers are commonly used. Cleaning of paddy is a major problem as it depends on velocity of wind.

Hand operated mechanical winnower should be used for winnowing purpose. Big farmers use Combine harvesters (harvesting, threshing and winnowing is done simultaneously) owned by individuals who provide custom hieing services to the farmers. International Rice Research Institute (IRRI), Philippines has developed a drum shaped power driven thresher, which is able to do threshing as well as winnowing.

Milling:

About 85% of the rough rice produced in the country is converted in to rice. A fraction of rough rice (10%) is used for making rice products (puffed and flaked rice) and about 5% of the rice production is used as seed for the next crop. Rice is mostly consumed as cooked whole grains.

Milling (converting rough rice, paddy in to milled or brown rice) of rice is done by various systems suitable for small-scale industry to very large units. These include huller, sheller, huller cum shelter mill and modern rice mill. Total capacity of rice mills in India is 300 Mt/year on 300 working days.

The most commonly used machine is a rice huller, which combines de-husking and polishing in one operation, but the whole rice(head) recovery is below 65% and rice breakage is very high (30-40%). In medium rice mills de-husking is done in rubber shellers, while brown rice is polished through polishers. In these mills rice breakage is considerably reduced. The recovery of rice from modern rice mills is 66-70 per cent.

Modern technology is now further perfected to obtain maximum out turn of milled rice reducing the breakage to the minimum. For further improving the milling and nutritive value of rice, it is parboiled before milling. This process involves soaking in water, steaming and drying.

Byproducts of Milling:

Paddy when milled usually yields, apart from white rice, 21-24% husk, 3-7% small brokens and 0.2-2% germs. Two major byproducts are husk and bran. One-fifth of un-husked rice by weight consists of husk. It contains about 20% ash, 90% of which is silica. The heat value of husk is 3000 K cal/Ag. Husk is used as fuel in rice milling industry. Rice bran is the most valuable byproduct of rice milling industry. It contains 12-15% protein, 14-25% oil and is a rich source of vitamin B-complex. Bran is generally used as animal feed and is a source of oil extraction. The by-products of milling industry are marketed separately and fetch good returns to the miller.

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13. Varieties of Rice:

Although there are more than 4000 varieties of rice that are growing every year, the most common varieties of rice that are seen in the market can be described as follows:

(i) Brown Rice:

It is a variety of rice in which only the hull is removed. Due to the bran layers that are left on the grain, it has a natural tan color. The texture of the brown rice is slightly chewy with a nut like flavor, which is due to the bran present inside the grain. Brown rice takes about 30-45 minutes to cook and is considered to be a very good for health because of its nutritional value, as it contains less of starch as compared to white rice.

(ii) White Rice:

White rice is defined as that form of rice whose husk, bran and germ have been removed completely during the milling process. Because the white rice undergoes this process, it is also known as 'polished rice'. The entire husk, bran and germ get removed so that the rice does not get spoiled. In this manner, its storage capacity is increased to a great extent. It has a delicate flavor and contains lots of nutrients like thiamin, riboflavin, niacin, and iron.

(iii) Parboiled Rice:

Parboiled rice is yet another variety of rice which is cooked in a steam pressure before it is milled. The steam pressure process helps in pushing the vitamins and minerals present in the outer coats to shift to the central part of the kernel. The entire process of cooking takes about 20 minutes, and after cooking, the rice becomes firm in texture and also the grains of the parboiled rice do not cling to each other after it has been cooked