Agronomy – Kharif Crops

Rice

Dr. B. Gangaiah
Senior Scientist
Division of Agronomy
Indian Agricultural Research Institute
New Delhi – 110 012

RICE

Botanical name: *Oryza sativa* L.

Chromosome number: 2n = 24

Rice is primarily a high-energy food. It is staple food of about $^{2}/_{3}$ population of world. It contains less protein than wheat and in milled rice it is usually 6-7%. The biological value of its protein is high. The fat content of rice is low (2.0-2.5%) and much of fat is lost during milling. Rice grain contains as much B group vitamins as wheat. Rice contains a low content of calcium.

The by-products of rice milling are used for various purposes. Rice bran is used as cattle and poultry feed, and oil extraction. Rice bran (pericarp, seed coat, nucellus, and aleurone layer) accounts for about 8% of paddy weight. It contains 15-20% oil (15% is recoverable). Of the total oil in grain, about 75% is present in bran itself. Global rice bran oil production varies from 1-1.4 million tonnes of which India accounts for 0.7-0.9 m tones. Rice hulls can be utilized in manufacturing insulation materials, cement, card board and as litter in poultry keeping. Rice straw can be used as cattle feed as well as litter during winter season.

Geographic distribution

Rice is the second most important food crop of the world, cultivated in 118 countries on about 153.8 million ha with a production of about 618.5 million tonnes (paddy). About 90% of all rice grown in the world is produced and consumed in the Asian region. The average productivity of rice is the highest in Egypt i.e. 9.4 t/ha as against world's average of 4.04 t/ha (Table 1).

Table 1. Rice, acreage, production and productivity in major countries

Continent/Country	**Area (m ha)**	**Production (m t)**	**Yield (t/ha)**
Asia	**136.56**	**532.98**	3.90
China	29.30	185.50	6.33
India	43.00	129.00	3.00
Indonesia	11.80	54.00	4.58
Bangladesh	11.00	40.10	3.64
Thailand	10.20	27.00	2.65
Vietnam	7.34	36.30	4.95
Myanmar	6.27	24.50	3.91
Philippines	4.12	14.80	3.60
Pakistan	2.40	6.90	2.88
*Brazil**	3.73	13.28	3.62
*Japan**	1.70	10.91	6.42
*USA**	1.35	10.47	7.78
*Egypt**	0.65	6.35	9.84

Production values are for brown (unhusked) rice

Source: FAO Quarterly Bulletin of Statistics, 2005, Vol. 12(3/3):18-19 and * FAO Production Year Book, 2004.

In India, rice is the most important and extensively grown food crop, occupying about 43 million ha of land. It is grown in almost all the states, with Uttar Pradesh, West Bengal and Punjab leading in area, production and productivity, respectively (Table 2).

Table 2. Area, production and productivity of rice in various states of India (2004-05)

State	Area (m ha)	Production (m t)	Productivity (kg/ha)
Andhra Pradesh	3.086	9.601	3111
Assam	2.376	3.470	1460
Bihar	3.122	2.472	792
Chattisgarh	3.746	4.383	1170
Gujarat	0.685	1.238	1806
Haryana	1.028	3.023	2941
Himachal Pradesh	0.081	0.122	1506
Jammu & Kashmir	0.250	0.492	1969
Jharkhand	1.285	1.677	1305
Karnataka	1.308	3.547	2712
Kerala	0.289	0.667	2301
Madhya Pradesh	1.622	1.169	720
Maharashtra	1.519	2.164	1425
Orissa	4.472	6.466	1446
Punjab	2.647	10.437	3943
Rajasthan	0.101	0.150	1485
Tamil Nadu	1.872	5.062	2703
Uttarakhand	0.306	0.572	1869
Uttar Pradesh	5.339	9.555	1790
West Bengal	5.783	14.883	2574
India	41.906	83.131	1984

Source: Fertilizer Assosciation of India, 2006

Origin and History

Of the 24 species of genus *Oryza,* only two viz. *Oryza sativa* and *Oryza glaberrima* are cultivated. *Oryza sativa* is raised in all rice producing areas, but *Oryza glaberrima* is raised in tropical West Africa only. *O. sativa* has wild perennial, *O. rufipogen* and annual *O. nivoroo* relatives. Similarly *O. glaberrima* has wild perennial, *O. longistominata* and annual *O. barthii* relatives. Rice was the first cultivated crop in Asia. This has been proved by the Sanskrit and other literatures. Carbonized paddy grains were found in the excavations at Hastinapur (Uttar Pradesh) at a site dated between 1000-750 BC .Vavilov (1926) suggested the India and Burma (now Myanmar) as the center of origin of cultivated rice. According to Chang (1985), the broad belt from the foothills of Himalayas and the Gangetic belt up to the southern China and northern Vietnam could be the homeland of *O. sativa*. According to Porteres (1956), the inner delta area of river Niger in Africa is the primary center of origin of *O. glaberrima*.

Genetic Classification

Rice (*Oryza sativa*) varieties are commonly grouped into following 3 sub-species.

indica: Rice grown in India belongs to this sub-species. They are awnless or possess short and smooth awns. They are characterized by having leaves slightly pubescent and pale-green in colour. The caryopsis is thin, elongated, narrow and slightly flattened.

japonica: The varieties developed in Japan belong to this sub-species. They have mostly oval or round grains. They may be awned or awnless, leaves are narrow and dark green in colour.

javanica: These varieties are characterized by a stiff straw, long panicle with awned grains, sparse tillering habit, long duration and low sensitivity to differences in day light. These are found mainly in Indonesia.

The differences in these 3 sub-species are given in Table 3.

Table 3. The main characteristics of *Oryza sativa* ecotypes

Characteristics	Sub-species		
	indica	Japonica	javanica
Tillering	Profuse	Moderate	Low
Height	Tall	Short	Tall
Lodging	Easily	Not easily	Not easily
Photoperiod	Sensitive	Non-sensitive	Non-sensitive
Low temperature	Sensitive	Tolerant	Tolerant
Grain shattering	Easily	Not easily	Not easily
Grain shape	Long	Short	Large
Grain texture	Non-sticky	Sticky	Intermediate

Characteristics	Sub-species		
	indica	Japonica	javanica
Foliage	Light green	Dark green	Light green
Lemma and palea pubscence	Sparse, short	Dense, long	Long
Drought	Tolerant	Sensitive	Variable
Grain shattering	Easy	Low	Low
Grain amylose (%)	23-31	20-25	10-24

Source: Takahashi, 1984

Climate Requirement

Rice cultivation in India extends from 8^{o} to 35^{o}N latitude and from sea level to as high as 3,000 m elevation. Rice accomodates itself under an annual rainfall ranging from 1,000 to 1,500 mm or even more. High temperature, high humidity and high rainfall has considerable effect on growth and development of rice plant. At higher mean temperatures (25-32^{o}C), early flowering is induced by reducing the growth duration; whereas the mean low temperature (<15^{o}C) forces the crop to remain dormant with no flowering. Therefore, a day temperature of 25^{o} to 33^{o}C and night temperature of 15^{o} to 20^{o}C is preferable.

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.

Soil Requirement

Rice is grown on clay loam of alluvium nature, red-laterite loamy hill, submoutain and foot hill soil and black cotton soil of different parts of the country. 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 grows well in soils having pH between 5.5 and 6.5. The soils with extreme acidity (<4.5 pH) are not suitable. It can be grown on alkali soil also after treating them with gypsum or pyrite.

Varieties

The dwarf high yielding varieties have higher yield potential than the traditional tall varieties. Under low fertility too, the high yielding dwarf varieties yield comparatively more than the traditional tall varieties. Today in India, there are quite a good number of varieties suitable for different agro-climatic regions. Selection of varieties depends to a great extent on the agro-climatic conditions, the cropping system followed, grain quality and several other factors. In India, rice hybrids have been developed which gave 2-3 times more production

than the improved varieties. The hybrids, basmati, high yielding varieties for irrigated conditions, varieties suitable for rainfed lands, boro season and low land situations are given below.

Oryza sativa

Rice Hybrids recommended for different states

State	**Hybrid**
Andhra Pradesh	APHR 1, APHR 2, DRRH 1, PBH 71, HRI 120
Bihar, Gujarat, Madhya Pradesh & Chattisgarh	PHB 71, DRRH 1, PA 6201
Haryana	PHB 71, DRRH 1, PA 6201, Pusa RH 10, Pusa Sugandh-3
Karnataka	KRH1, KRH 2, HRI 120, Mugad Sugandha
Maharashtra	Sahyadri, PHB 71, PA 6201, HRI 120
Orissa	KRH 2, DRRH 1, PHB 71, HRI 120
Punjab	Pusa RH 10, RH 204, Pusa Sugandh-3
Tamil Nadu	CORH 1, CORH 2, ADTRH 1, PHB 71, DRRH 1, DRH 2, HRI 120
Uttaranchal	Pant Sankardhan 1, PHB 71, HRI 120, Pant Sugandh Dhan 15
Uttar Pradesh	Pusa RH 10, Narendra Sankardhan 2 , PHB 71, PA 6201, HRI 120, UPRH 27
West Bengal	CNRH 3, PA 6201, KRH 2, PHB 71
*Basmati rice varieties recommended for cultivation in different states****Zone/State***	**Selected varieties (hybrids)**
For Northern India (Haryana, Punjab, Uttar Pradesh)	N 10 B, Basmati 370, Pusa Basmati 1, Hansraj T 3, T 9, N 12, Taraori Basmati (Karnal local), Pusa Sugandh 2, Pusa Sugandh 3, Pusa Sugandh 4, Pusa Sugandh 5, PRH 10, Pant Dhan 15, Kalanamak
Jammu & Kashmir	Ranbir Basmati, Muskh Budgi, Basmati 370
Andhra Pradesh	Sumati, Kaki Rekhalu (HR 59), Sukhdas (HR 47)
Bihar & Jharkhand	Basmati 370, Badshahbhog, Mohanbhog, Ram Tulsi
Assam	Prasadbhog, Malbhog, Badshahbhog
Rajasthan	Mahasugandha, Kala Badal, Kamod, Nawabi Kolam
Uttarakhand	Pant Dhan 15, Hansraj
Himachal Pradesh	Desi Basmati 23
Gujarat	Kamod 118, Pankhari 203, Zeerasal

State	**Hybrid**
Karnataka	Jeerakasala, Gandhkasala, Sindigi local
Madhya Pradesh	Gopalbhog, Kali Kamod, Chattri
Maharashtra	Ambemoha 102, Ambemoha 147, Ambemoha 159, Krishnasal
West Bengal	Badshah Pasand, Govindabhog, Kataribhog, Sitabhog
Tamil Nadu	Jeeraga Samba

Rice varieties recommended for various states of India under irrigated conditions	
State	***Improved varieties***
Bihar & Jharkhand	*Pusa 33, Pusa 2-21, Pusa 169, Mehsuri, Saket 4, IR-8, IR-20, IR-24, BR 368, Jaya, Padma, Deepa, Sita, Bala, Kaveri, Ratna, Sabarmati, Janki, Rajendra Dhan 101, R. Dhan 202, Birsamati, Arvindha Amrit*
Madhya Pradesh & Chattisgarh	*Prabhat, IR 8, IR 24, Jawahar 75, Mehsuri, Bala, Kaveri, Ratna, Jaya, Pragati, Jagrati, Kranti, Garima, Anupama, Akashi, Madhuri, Vani, Mahamaya*
Rajasthan	*Jaya, Ratna, Pusa 33, Ajay, Sabarmati, Chambal PR 106, BK 29, BK 130, Vani*
Haryana	*Pusa 33, Pusa 169, Ajay, Jaya, Bala, Ratna, Jhona 349, IR 8, PR 106, Kasturi*
Punjab	*Jaya, Bala, Ajai, PR 105, PR 108, PR 109, IR 8, Palman 579, Mutant 95, Ratna, Sabarmati, Aravinda Amrit*
Uttar Pradesh	***Early duration varieties*** ***For plains:****Saket 4, Govind, Prasad, Manhar, Pusa 169, Pusa 33, Pusa 2-21, Ratna, Narendra 2* **For Bundelkhand and Jhansi :**PNR 381, Saket 4, Prasad, Manhar, Pusa 169, Ratna **For Hilly areas:**Ratna, VLK 35 **Medium duration varieties** **For plains:**Pant Dhan 4, Pant Dhan 10, Pant Dhan 11, IR 24, IR 36, Sarju 52, Jaya, NDR 80, Pant Dhan 12 **For Bundelkhand and Jhansi:** Pant Dhan 4, Jaya *For Hilly areas:* ***VL 8, VL Dhan 16, VLK Dhan 39, P Dhan 6*** *Long duration varieties* **For plains:** Mehsuri, Cross 116, T 100 **For Hilly areas:**VL Dhan 221, VL 206
Jammu & Kashmir	*SKAU 23, SKAU 27, Chena, Jhalum, Kohsaar*

State	Hybrid
Himachal Pradesh	*Himalaya 2216, RP 2421*
Gujarat	*Gau R 1, Gau R 10, Gau R 100, Dandi*
Karnataka	*Prakash, Madhu, Vikram, Suma, Kusuma, Vani, Akash, Sharavati, Maha Maya, BR 2655-9-3-1, Pant Dhan 12, Sakuntala, Gautam*
Kerala	*Anupurna, Aswathi, Bharti, Jyoti, Rohini, Triveni, Sabari, Kunju, Priya, Varsha, Kunju Varna, Gauri, Sweta*
Maharashtra	*Ratnagiri 24, Karjat 184, Karjat 2, Ratnagiri 3, PKV Makarand*
Orissa	*Rajeshwari, Hema, Sakti, Kumar, Bala, IR 20, Prakash, Vikram, Vani, Anjali*
Tamil Nadu	*Kari Kalan, Karuna, Bhawani, Vaghair, Bharti, Caveri, Krishna, Kanchi, PMK 2 and ADT 42, ADT (R) 45.*
Andhra Pradesh	*Hamsa, Tella-Hamsa, Vashista, Mahsuri, Kasturi, Kakatiya, Prakash, Vikrant, Bhadra Kali, Jagtiala Mahsuri, Jagitiala Sannalu, Santhi, Apurva, Mahamaya, Nandyal Sannalu, Varalu, Bapatla Sannalu*
West Bengal and Assam	*IR 20, Jayanthi*
Pondicherry	*Aravinder, Ratnagiri 3*

Promising rice varieties for rainfed/water scare areas in different states

State	Varieties
Andhra Pradesh	Tulasi*, Aditya, Prasanna, Rudramma, Krishna Hamsa, MTU 9993, Ravi, Varalu, Bapatla Sannalu, Vagad Dhan, MTU 17, Mettasanna, Tellavadlu
Assam	Dumai, ARC 5929, Annada, Rasi*, Tulasi*, Anjali
Bihar & Jharkhand	Tulasi*, Aditya*, Rasi*, PNR 381*, Vandana, Birsadhan 101, BR 17, BR 16, Fine gora, Birsadhan 102, Birsadhan 103, Birsadhan 104, Birsadhan 105, Birsadhan 6, Birsadhan 7, Birsadhan 201, Birsadhan 202 Birsadhan 221, Heera*, Kanchan, Kalinga III, Vaidehi
Goa	Goa 1 (Annada), Rasi*, Krishna Hamsa, Tulasi*
Gujarat	GR 2, GR 3, GR 5, GR 6, Rasi*, Prasanna, Tulasi*, GR 8, Sathi 34-36, Early Kolam 161-172
Karnataka	Amrut, Mukti, IET 7564, Tulasi*, Ravi, Krishna Hamsa, Avinash,

State	**Varieties**
	Holomaldgiga, Mugad 161
Kerala	Suvarna Modan, Onam, Harsha, PTB 10, PTB 28, PTB 29, PTB 30, Annapurna
Madhya Pradesh & Chattisgarh	Tulasi*, Aditya*, Heera*, Purva, JR 75, Rathe, Annada, Jawahar Rice 3-45, Safed dhan-3, Laloo 14
Maharashtra	Tulasi*, Aditya*, Heera*, Annada, Tuljapur 4, Ratnagiri 73-1-41, Rasi*, Ratnagiri 73-1, Kranti, Jalgaon 5, Nagpur 22, Ambemohar 159, Karjat 3
Meghalaya	Rasi*, Heera*, Ngoba, Krishna Hamsa, Tulasi*, Lam Pnah-1, Bha Lum 1, Bha Lum 2, Shah Sarang 1
Orissa	Heera*, Kalinga III, Annada, Parijat, Pathara, Kalyani II, Sattari, Neela, Rudra, Vanaprabha, Khandagiri, Nilgiri, Ghanteswari, Sneha, Badami, B 76, Kalakeri, BAM 12
Tamil Nadu	IR 64*, IR 50*, TKM-9, Co 41, PMK 1, ASD 18, ADT 36, ADT 37, PKU 2, Tulasi*, Krishna Hamsa, Aditya, ADT (R) 45, PMK(R)3
Tripura	Tulasi*, Heera*, Rasi*, Annada
Uttar Pradesh	Narendradhan 97, Narendradhan 18, Narendradhan 80, Narendradhan 118, Saket 14, Tulasi*, Aditya*, Jawahar Rice 3-45, Sudha**,** Bala, Kaveri, Pusa 2-21, Narmada, Saket 4, N-22, ND 2, Narendradhan 1, Govind, Jhona 349
Uttarakhand	NDR 84, NDR 118, VL Dhan 263, VL Dhan 221, VL Dhan 206, Shankar Dhan-1
West Bengal	Rasi*, Khitish, Kiran, Bhupen, Khanika, Dular
Himachal Pradesh	Shankar Dhan 1, Lalna Kanda 41
Punjab	Lalnakanda
Jammu & Kashmir	Ch 988, Ch 1039
For coastal and salt affected soils of West Bengal, Orissa, Kerala, Andhra Pradesh	Sumati, CSR 23
For Tamil Nadu, Maharashtra	TRT(R)2 Panvel-3

*Central Release

Rice varieties grown in Boro season in different states

State	Traditional varieties	Modern varieties
Meghalaya	Risi, Pisum, CH 1039, CH 988	IR 36, Vijaya
West Bengal	CB-1, CB-2, Latisail, Patnai-23, Kalma 222, Jhingasail, Raghusail	IR 36, Khitish, IET 2233, Ratna, IET 826, IET 4786, IET 1414
Assam	Boro 1, Tepi Boro, Madhab-Boro, Jagliboro, Gabriboro	Mehsuri, Krishna, Mala, Jaymati, Jaya, Vijeta, Chandrama
Bihar	Traditional tall cultivars	Pusa 2-21, Pusa 33, Saket 4, Jaya, Sita, Sujata, Mehsuri, Gautam
Eastern Uttar Pradesh		NDR 7, Barani Deep, Gautam, Prabhat, Richhariya, Suraj, Dhan luxmi, Joymati, Boro Dhan, Borochina, Chinese Boro, Boro Safeda, NDR 359, ARC 4377, Kala Boro (Malhar), Surya, Bans Bareilly, Saket-4, Sarjoo-49, Sarjoo-52
Kerala		Dhanu
Tripura		Swati

Promising HYVs suitable for rainfed lowlands

State	DEPTH OF WATER				Very deep & floating(>100cm)
	Shallow (0-30 cm)	**Intermediate**	**Semi-deep (30-60 cm)**	**Deep (50-100 cm)**	**For eastern India: *(Transplanted in June)*** **Maguribao, KDML 105, JM 50, Barjahingia, Panidhan, Tulasi, Sabita, Manoharasali, Bash-Avarodhi** ***(Direct seeding in August*)** **Kaling III, Neela, Luit**
Bihar	Radha, Sugandha, Jayashree, Rajashree, Rajendra Mahsuri-1		Jitendra, Sudha, Janaki		
West Bengal	Neeraja, Jogen	Mandira, Biraj, Suresh	Bhudeb, Matangini, Nalini, Sabita, Amulya, Dinesh	Jaladhi 1, Jaladhi 2, Purrendu	
Orissa	Savitri, Aditya Ramakrishna, Mahalaxmi, Moti, Padmini, Samalai,	CR 1014, Dharitri	Kalashree, Panidhan, Utkalprabha, Gayatri, Tulasi, Seema	Rambha, Purrendu	
Assam	Bhogali, Rongilee, Kushal, Moniram, Piolee, Ranjit				
Uttar Pradesh	Mehsuri, Pankaj, T 26, T 100, Cross 116		Jalpriya, Jitendra	Purrendu, Jalmanga, Jalnidhi	
Madhya Pradesh	Madhuri, Rashmi				
Maharashtra	SKL 8, Dhanarasi				
Andhra Pradesh	Tholakari, Godavari				

Types of Rice Cultivation

In India, rice is cultivated mainly on two types of soil, uplands and lowlands

A. Upland rice cultivation

(a) Drilling

(b) Broadcast

B. Lowland rice cultivation

1. Cultivation in puddled soil

(i) Transplanting method

(a) Nursery or traditional method

(b) Dapog method

(c) System of rice intensification (SRI)

(ii) Direct seeding method

(a) Sowing in line

(b) Broadcast

2. Cultivation of rice in unpuddled lands by sowing seeds in dry soils

(i) By drilling

(ii) Broadcast

Upland rice cultivation

The upland rice cultivation is mostly adopted in areas which receive an annual rainfall of 800-1000 mm and irrigation facilities are not available. In this system of cultivation, farmer has to depend upon rain water. Due to failure of monsoon, the farmer has to bear a heavy loss. A vast tract of paddy in Uttar Pradesh, Bihar, Orissa, parts of Tamil Nadu and Andhra Pradesh is under rainfed upland situation.

Field Preparation

After harvesting the *rabi* crops in April-May, the field should be ploughed with soil turning plough. The field should be prepared and bunds should be made around the field just after the first shower of monsoon. This will check loss of rain water by run-off.

Growing Seasons

It is well known fact that rice seasons vary in different parts of India depending on rainfall, temperature and other local climatic conditions. In general, there are three growing seasons of rice in India. These are *aus* or autumn rice, *aman* or winter rice or *boro* or spring/summer rice.

Different rice crop sesaons and their vernacular names are given below.

Rice cropping season in different states of India

State	Local name of season	Period
Andhra Pradesh	*Sarwa, Abi*	May-June to October-November
	Dalwa	November-December to April-May
	Tabi	December-January to April-May
Assam	*Ahu*	April-May to August-September
	Sali	June-July to November-December
	Boro	November-December to April
Bihar, Eastern UP	Kharif	June-July to November December
	Rabi	March-June
J&K	*Kharif*	March-April to September-December
Karnataka	*Haine*	June to November-December
Kerala	*Viruuppa*	April-September
	Mundakan	September-October to January-February
	Poonja	December-January to April
Orissa	*Beali*	May-June to September-October
	Sarad	June-July to November-December
	Dalva	December-January to April-May
Tamil Nadu	*Swarnavasi*	May-September
	Kar, Kuruvai	June to September
	Samba	July to January-February
	Thaladi	October to February-March
	Pisharax, Karthigai	October-March
	Navarai, Manavari	January-May
West Bengal	*Aus*	April-May to August-September
	Assam	June-May to November-December

State	Local name of season	Period
	Boro	December-January to April-May
Gujarat, Haryana, HP, MP, Punjab, Rajasthan and Western UP	Kharif	June-July to October-Novewmber

Sowing

Under upland rice cultivation, no definite recommendation for time of sowing could be made because of unavailability of irrigation water and uncertainty of monsoon. However, the crop must be sown soon after monsoon sets in and 15-20 cm deep soil layer becomes completely wet. The ideal time in north India is between end of June and first week of July. If the sowing is delayed, crop is adversely affected because of soil and atmospheric drought due to aberrant weather conditions during the grain filling stage. This results in shriveling grains of poor quality.

In some rice growing areas, dry seeding a little before onset of monsoon is practiced. The seed remains in the soil, which germinates with the onset of rains.

Table Time of sowing/transplanting

Crop	Season	Transplanting/ sowing time	Harvesting time
Early	*Aus*-Autumn	May-June	September-October
Rainy season	*Aman*-Winter	June-July	November-December
Summer season	*Boro*-Spring	November-December	March-April

Seed rate and Spacing

Under upland conditions, drilling or line sowing is always better than broadcast because line sowing facilitates the cultural operations and enables to identify the weeds even at the early stage for weeding purpose. Usually sprouted seed should be sown in rows 30 cm apart at a depth not more than 5 cm. The moisture stress condition may result in poor germiantion, therefore, about 25% higher seed rate than the recommended rate (100-120 kg/ha) should be used.

Drill the seeds with seed drill or behind the plough with the help of funnel in rows after applying fertilizer. The row to row distance should be 20 cm. About 60 kg seed/ha is recommended.

For obtaining an uniform plant population and higher crop yields, it is advisable to thin out the excess plants or resowing in gaps in the rows after about 2-3 weeks of sowing.

B. Wet or Lowland Rice Cultivation

This system of rice cultivation is practiced in areas having an assured and adequate supply of water. In this system, sprouted seeds may be directly sown in puddled field or the crop may

be transplanted with seedlings raised in a nursery. It is also called as medium land rice for those areas, which receive an annual rainfall of 1,000-1,500 mm.

Method of Raising Seedlings

There are 3 methods of raising seedlings. Detailed description is given below.

Wet nursery*:* Wet nurseries are preferred under irrigated condition. The soil is puddled by 2-3 runs of puddlers or 3-4 ploughings with country plough. After 2 days of puddling, divide the nursery area into narrow beds of 1.25 m width and of convenient length. Prepare the drainage channel 30 cm wide in between the beds. Apply 225 g urea and 500 g single superphosphate per 10 m^2 area. Uniformly broadcast about 2-3 handfuls of desired seed on a square meter of seed bed. Keep the seed beds saturated with water up to 50 cm as the seedling grow. Adopt suitable control measures for insect-pests and diseases. Drain the excess water in periods of heavy rainfall. An application of 50 g urea/m^2 may be applied as top dressing in case of N deficiency symptoms. Seedlings would be ready for transplanting within 20-25 days after sowing.

Dry nursery: This method is adopted in areas, where water is not sufficient to grow seedlings in wet nurseries. Plough the field till the soil is thoroughly pulverized. Prepare beds of the same size as in wet nurseries, but 15 cm high with channels (30 cm wide) between them. Sow the seeds in rows 10 cm apart in dry or moist condition of the soil. The seeds should be covered immediately with a layer of soil. Use the same seed rate and fertilizer as in wet nurseries. Allow the water to run in channels first and then raise the level of water slowly to saturate the soil. Keep the seed bed saturated with water, but do not flood water in beds. Follow all the operations as described for wet nurseries.

Dapod method: This method of raising nursery has been introduced in India from the Philippines. It has been adopted by some farmers in Andhra Pradesh for raising seedlings. It saves almost half of the time in raising seedling. The main advantage of this method is that less area is required to raise seedlings i.e., 25-30 m^2 area is enough to grow seedlings for transplanting one ha. The seedlings grow at faster rate in this method. The method of raising seedlings is described below.

In this method, beds of about 1.5 m width are prepared on an even but slightly raised (4-5 cm) surface in an open field or on even a cement floor. About 1 m^2 of seed bed is required for every 3 kg of seed. Cover the soil surface of the seed bed uniformly with banana leaves (protruding midribs removed) or plastic sheets. Carefully lay strips of banana bracts into the soil to keep bracts upright and firm. The sprouted seeds are broadcast uniformly @ 1.5 kg/m^2 area or 50 times of the test weight/m^2 of the variety used. The beds are kept moist constantly and pressed slightly 2-3 times a day with a smooth wooden plant for the first 3 days, so that root remain in constant touch with water. When the seedlings attain 2 cm height, a constant film of water should be maintained. In about 12 days roots are well developed and are entangled with another. The nursery can be cut into strips and rolled like a mat and then transferred to the planting site easily. Seedlings of 1 m^2 area can be transplanted in 200 m^2 area.

Advantages

The seedlings raised by this method are established immediately. The crop comes to flower 4 days earlier than the normal transplanted crop. At the event of drought or failure of irrigation system when transplanting of over-aged seedlings can not be done, this system offers a good scope to get another lot of fresh seedling within 12 days.

Dapod nursery method does not require seed-bed preparastion, fertilizer or other chemicals use for raising the seedlings. The labour cost in seedling uprooting is saved as the whole mat of seedlings over polythene is lifted, rooted and straight way transferred to transplanting site.

Disadvantages

Seed rate is exceptionally high (2.5 times more than other methods). Seedlings being very small can not be transplanted in presence of even slight water in the field, which sometimes becomes unavoidable. Three to four seedlings are to be transplanted/hill instead of 2.

System of Rice Intensification (SRI)

Fr. Henry de Laulaine developed this system in Medagascar in association with Association Tefy Saina (ATS) an NGO, and many small famrers from different countries. In SRI, young seedlings (8-10 days old) are transplanted at optimal spacing and the crop is aerobically grown during vegetative phase. The economy in water has led to its wider adoptation by farmers.

Evidences have shown that SRI gave higher yields than transplant crop in South India only. The SRI also proved better in clay loams than sandy loam, clay or silty loam soils. The increase in yield with SRI has been attributed to more panicles/m^2 and greater panicle weight. It economizes up to 50% of water for rice cultivation.

Field Prepation

The field should be ploughed once followed by harrowing and planking soon after first rain. Summer deep ploughing is also beneficial as it exposes the eggs of harmful insect-pests and rhizomes of weeds. All the weeds and stubbles of the previous crop should be removed from the field. The field should be flooded or saturated with water for 15 days before planting. This helps in decomposition of chaff and straw of previous crop. Before puddling, an earthen bund of about 30 cm high should be made around the field. Puddling is very important operation in transplanted rice. It helps to kill the weeds and buries them in puddled layer. It helps to create beneficial physical, biological and chemical conditions for plant growth of rice. Puddle the field by 3-4 runs of puddler in standing water. Apply uniformly ½ of N and total quantities of P, K and Zn on drained surface at the time of last puddling and incorporate in the top 10-15 cm deep soil.

Transplanting

The most ideal seedling for transplanting should have 4 leaves. They may have 3 leaves, but under no circumstances, the seedling should have more than 5 leaves. Usually 2-3 healthy seedlings of 20-30 days per hill should be planted at 20 cm x 15 cm apart during *kharif*, and 30-35 days at 15 cm x 15 cm during *rabi* season. However, the general recommendation is to use 21-25 days old seedlings. It is advisable to plant seedlings in mud at shallow depth (2-3 cm). Planting in double rows in sunrise and sunset direction helps in better transmission of sunlight, better movement of carbondioxide (CO_2) in the rice field. Early planting in beginning of July for *kharif* crop gives higher yield.

In case of older seedlings of more than 25 days age are to be planted, the number of seedling/hill should be increased (3-4/hill), besides use of higher dose of N should be used at the time of sowing and reduced spacing. This would help in maintaining required plant population, as older seedlings usually produce less tillers/plant.

Transplanting enables the cultivator to have optimum plant population at desired spacing in the field. It also provides scope for land preparation, that aids in keeping down the weeds. Since the nurseries occupy a small area of the field, the control of insect-pest and diseases and irrigation and manuring of young crop is easier and cheaper than direct sown crop.

Broadcast Sprouted Seeds in Puddled Soils

This method is adopted in areas, where there is a shortage of manpower for transplanting. In this method the field is prepared and puddle in the same way as in case of tra nsplanted rice. About 100 kg seed/ha is required. Seeds are soaked in water for germination before broadcast. Seeds with radicle length of 1-2 mm are uniformly broadcast by hand.

Manure and Fertilizers

In upland rice, organic manures (FYM or compost) @ 10-15 tonnes/ha should be incorporated 4-6 weeks before sowing.

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. Presence of excess water in rice fields modifies physical, chemical and biological reactions in the soil. The root zone is converted form aerobic to anaerobic environment due to depletion of oxygen in the profile. The flooded or waterlogged puddled soil develops 2 zones. The upper zone (1-10 mm soil profile) receives oxygen periodically from fresh supplies of irrigation water, and is called 'oxidized zone' and behaves like an unflooded upland soil. The remaining lower soil profile of puddled portion of puddled soil without oxygen is called 'reduced zone'.

Ammonical N fertilizers applied in such soil system get oxidized in the soil. Use of nitrate fertilizer should, therefore, be avoided in rice. DAP is an excellent fertilizer for dressing in rice fields. 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.

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.

In rice, hardly 30-40% of applied N is used by the rice crop, and the remaining N is lost through leaching and denitrification. For minimizing the losses of N, various methods have been suggested as described below:

Use of mudball: 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.

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.

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.

In zinc deficient soils, 20-25 kg of zinc sulphate/ha should be applied at the time of last puddling.

Water Management

Rice requires 5000 litres of water to produce a kg of grain. 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 pudled rice culture.

The water requirement of rice varies from 2,500 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 raising in 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.

Water should be allowed to stand in the field at a depth of 2-3 cm till the transplanted seedlings are established. Thereafter, about 5 cm of water may be maintained up to the dough stage of the crop. The water should be drained out from the field at maximum tillering stage for a week to remove toxic substances. The field is drained finally at least 1 week earlier to harveste in light soils and 2-3 weeks in heavy soils for uniform and smooth field operations for the next crop.

Cropping Systems

In north India, a number of crop rotations involving paddy are feasible in irrigated areas. After the harvest of paddy, crops like *berseem, toria,* potato etc. can be grown in intensive crop rotation. In rainfed areas, where the soils are well drained and have good moisture retention capacity, legume crops like gram, lentil could be raised successfully after the harvest of paddy with residual fertility and moisture. Some of the important rice-based crop rotations are given below.

Irrigated areas

Paddy-*toria* or gram	Paddy-wheat or barley
Paddy-potato-blackgram	Paddy-potato-greengram
Paddy-potato-cowpea or soybean	Paddy-wheat-greengram
Paddy-pea (for pods)-greengram	

Rainfed areas

Paddy-pea Paddy-gram Paddy-lentil

Weed Control

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. The important weed flora of transplanted rice include:

Cyperus difformis L., Fimbristylis litoralia, Typha sp., Cyperus iria L., Monocharia spp., Potamogeton sp., Celosia argentia, Setaria glauca, Panicum sp., Dactyloctaneum aegypticum (L.) Beauv. , Scirpus spp., Charazeylanica, Echinochloa colonum, Cynodon dactylon, Echinochloa crusgalli (L.) Beauv., Nymphaea stellata, Hydrilla verticillata, Eclipta alba, Salvenia sp.

The critical period of weed competition lies between 15-45 days of sowing. Two or three manual weedings 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.

It is difficult to remove weeds in rice nurseries and direct-sown broadcast puddled rice by hand/*khurpi*/paddy weeder due to close spacing of seedlings. Moreover, manual weeding is a costly and labour-intensive operation. It is, therefore, necessary to find out possibilities of using herbicides for controlling weeds in rice nurseries and fields

Pendimethalin or Thiobencarb @ 1.5 kg/ha should be sprayed after 4-6 days of sprouted seedlings. Delayed application causes poor weed control and early application may cause toxicity to seedlings. Anilofos @ 0.25 kg/ha and oxadiazon @ 1.0 kg/ha should be applied 3-7 days before sowing.

Propanil: This should be used 6-8 days after transplanting when weeds are in 1-3 leaf stage. Spray @ 3 kg/ha in 400-600 litres of water. It would be advisable to remove water before spraying the herbicide. The field is flooded again within 24-48 hr and kept submerged till crop covers the land.

Butachlor: This weedicide is effective against annual and broad-leaved weeds in rice. This is a pre-emergence herbicide applied either through spray or granules immediately after planting the crop. Granules of butachlor should be applied @ 50 kg/ha in standing water (4-5 cm), and never in dry soils. It is sprayed @ 2 kg/ha in 400-600 litres of water. Drain out water before the application of herbicide.

Nitrofen: It is used as pre-emergence to control annual weeds for about four weeks. This should be applied with 2-3 days after transplanting rice. Adequate soil moisture is necessary to activate its herbicidal property. Broadcast 20-25 kg granules/ha or spray @2.0 kg/ha in 400-600 litres of water.

Fluchloralin: 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 litres of water or 50-60 kg granules/ha as broadcast.

Harvesting

Rice varieties take 100-150 days to mature. The proper stage for harvesting is when about 80% spikelets in 80% panicles show ripening. Timely harvesting ensures quality and consumer acceptance. The plant should be cut close to the ground and left in the field for a few days to dry. Later on, these should be collected in bundles and stalked for threshing.

Threshing and Storage

Threshing of rice on small farms is still a serious problem. The most common and popular methods of threshing are churning by bullocks with bare human feet (in hills) or lifting the bundles and striking them on the raised wooden platform. On big farms, pedal threshers or power driven stationary threshers are used. International Rice Research Institute, Philippines has developed a drum shaped power driven thresher, which is able to do threshing as well as winnowing.

The produce should be properly dried in the sun before storage. The grains should be stored in bins or kept in a heap inside the room. The optimum moisture content for storage of rice grains is 12%.

Yield

A well managed crop of mid-late duration (135-150 days) varieties like IR 8. IR 20, Jaya, etc. and hybrids yield about 6.0-7.0 tonnes grain/ha, whereas short duration cultivars yield about 4.5-5.5 tonnes grain/ha. The milling percentage is 60-65%.

Additional Reading Material

http://www.hort.purdue.edu/newcrop/duke_energy/Oryza_sativa.html

http://www.knowledgebank.irri.org/Rice/Ricedefault.htm

Source: **oak.cats.ohiou.edu/.../Philippine_Plants.html**

Source: **www.botanik.uni-karlsruhe.de/garten/fotos-knoch/**

Source: **www.ubcbotanicalgarden.org/**