Chapter 7
The Rice–Wheat Cropping System

Abstract The rice–wheat rotation is the principal cropping system in south Asian countries that occupies about 13.5 million hectares in the Indo-Gangetic Plains (IGP), of which 10 million hectares are in India, 2.2 million hectares in Pakistan, 0.8 million hectares in Bangladesh and 0.5 million hectares in Nepal. This system covers about 33% of the total rice area and 42% of the total wheat area in the four countries as stated above, and account for one quarter to one third of the total rice and wheat production. This cropping system is dominant in most Indian states, such as Punjab, Haryana, Bihar, Uttar Pradesh and Madhya Pradesh, and contributes to 75% of the national food grain production. This cropping system is also very prevalent in Himachal Pradesh and Jammu & Kashmir, especially the Jammu region. There was a time when the yield of paddy was the highest, i.e. more than 4.2 t ha^{-1} in the valley of Kashmir among the north-western Himalayan states, but now it has reduced considerably. Thus, the rice–wheat cropping system is the cornerstone of India's food self-sufficiency. The environmental requirements for the growth and development of both rice and wheat crops are contrastingly different. Rice grows best under stagnant water conditions, while wheat requires a well-pulverized soil with a proper balance of moisture, air and thermal regime. Therefore, a dominating feature of the rice–wheat cropping system is the annual conversion of soil from aerobic to anaerobic and then back to aerobic conditions.

Keywords Rice–wheat cropping system • south Asian countries • Indo-Gangetic Plains self-sufficiency • food grain production

The rice–wheat is the most dominant double-cropping system in Asian subtropical countries such as China, India, Nepal, Bangladesh and Pakistan, where it is practised on about 24 million hectares. Rice is cultivated in 111 countries of the world compared to wheat, which is grown in 92 countries. On an average, the world yields of 1 ha of rice could sustain 5.7 persons per year compared to 4.1 persons per year for wheat. Globally, rice ranks second to wheat in terms of area harvested, but first in terms of calories per hectare (18% of total kilocalories per person per day). China and India produce more than half of the world's rice, and the rice cultivation

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generates the highest employment for the rural Asian population. These two most important crops are rich sources of starch and fair to good sources of proteins, certain minerals and vitamin B.

7.1 Distribution of the Rice–Wheat Cropping System and Contribution to Food Security in South Asian Countries

In south Asian countries, the rice–wheat cropping system is prevalent in about 13.5 million hectares in the Indo-Gangetic Plains (IGP), of which 10 million hectares lies in India, 2.2 million hectares in Pakistan, 0.8 million hectares in Bangladesh and 0.5 million hectares in Nepal, and about 10.5 million hectares in China. This system covers about 33% of the total rice area and 42% of the total wheat area in the four countries, namely India, Pakistan, Bangladesh and Nepal, and accounts for one quarter to one third of the total rice and wheat production (Ladha et al., 2000). It provides food, income and employment to millions of people. The annual system productivity in IGP is low (3–5 Mg ha^{-1}) compared to the climatic crop yield potential of the region, i.e. 12.0–19.3 Mg ha^{-1} (Ladha et al., 2003; Pathak et al., 2003). The rice–wheat system is pivotal to food security not only of the country, but also of the Indian subcontinent as a whole. The tenfold increase in rice–wheat sequence in India, Nepal, Bangladesh and Pakistan during the last 30 years is an ample proof of it (IRRI, 1992). Further, rice has been grown as a food crop for more than 6,000 years in Asia. Today, more than 90% of global rice supplies are produced and consumed in Asia (Blake, 1992), contributing 30–75% of dietary calories for populations in Asian countries (Dobermann and Cassman, 1996). About half of the irrigated wheat production in South Asia comes from rice–wheat rotation (Pillai, 1994).

In India, the rice–wheat is the most extensive and traditional cropping system which has become the mainstay of cereal production in the country. It occupies an area of 9.77 million hectares (Table 7.1) (Yadav, 1996), dominates agricultural systems in India, mostly in Punjab, Bihar, Haryana, Uttar Pradesh and Madhya Pradesh (Table 7.2) (Kanwar and Sekhon, 1998), and contributes to the tune of

Table 7.1 Area under major cereal-based cropping systems (Adapted from Yadav [1996])

Cropping system	Area (million hectares)
Rice–wheat	9.77
Rice–rice	2.12
Maize–wheat	1.29
Pearl millet–wheat	1.03
Pearl millet–sorghum	1.35
Sorghum–sorghum	0.74
Rice–wheat–gram	1.03

Table 7.2 Dominant cereal-based cropping systems in major food grain producer and fertilizer consumer states (Adapted from Kanwar and Sekhon [1998])

Cropping system	States
Rice–wheat	Punjab, Haryana, Uttar Pradesh and Madhya Pradesh
Rice–rice	Andhra Pradesh and Tamil Nadu
Rice–cotton	Andhra Pradesh and Tamil Nadu
Rice–sugarcane	Andhra Pradesh, Tamil Nadu and Maharashtra
Maize/millet–wheat	Haryana and Uttar Pradesh

Table 7.3 Area and production of rice and wheat in India over the years (Adapted from Anonymous [2005–06])

	Area (million hectares)		Production (million tonnes)	
Year	Rice	Wheat	Rice	Wheat
1950/51	30.81	9.75	20.58	6.46
1955/56	31.52	12.37	27.56	8.76
1960/61	34.13	12.93	34.57	10.99
1965/66	35.47	12.57	30.59	10.44
1970/71	37.76	19.14	42.23	23.83
1975/76	39.48	20.45	48.47	28.85
1980/81	40.15	22.28	53.63	36.31
1985/86	41.14	23.00	63.83	47.05
1990/91	42.69	24.17	74.29	55.14
1991/92	42.67	23.26	74.68	55.69
1992/93	41.78	24.59	72.87	57.21
1993/94	42.54	25.15	80.30	59.84
1994/95	42.81	25.70	81.81	65.77
1995/96	42.84	25.01	76.98	62.10
1996/97	43.50	25.96	81.74	69.35
1997/98	43.48	26.70	82.54	66.35
1998/99	44.80	27.52	86.08	71.29
1999/2000	45.16	27.49	89.68	76.37
2000/01	44.71	25.73	84.98	69.68
2001/02	44.90	26.35	93.34	72.77
2002/03	41.76	25.20	71.82	65.76
2003/04	42.59	26.60	88.53	72.16
2004/05	41.91	26.38	83.13	68.64
2005/06	–	–	91.04	69.48

75% of the national food grain production (Yadav and Subba Rao, 2001). Besides, it also occupies a sizeable area in the adjoining parts of Rajasthan, Himachal Pradesh and the Jammu region (Jammu & Kashmir). This cropping system has helped tremendously in the socio-economic development of the rural population in India. On an all-India basis, the total area under rice and wheat cultivation is 41.91 and 26.38 million hectares, with the production of 91.04 and 69.48 million tonnes (Table 7.3) (Anonymous, 2005–06), respectively. Thus, the rice–wheat cropping system is of considerable significance to India's food self-sufficiency and self-esteem.

7.2 Characteristics of the Rice–Wheat Cropping System

The rice–wheat cropping system in the Indian subcontinent is quite new and started only in the late 1960s with the introduction of dwarf wheat from CIMMYT, Mexico, which required a lower temperature (mean below 23°C) for good germination than that required for traditional tall Indian wheat. On the other hand, rice is cultivated in diverse growing conditions such as wet tropical, humid to subtropical and temperate climate with elevation below sea level to 2,000 m. The environmental requirements for the growth and development of both rice and wheat crops are quite different. Rice grows best under soft, puddled and water-saturated soil conditions, while wheat requires a well-pulverized soil having fine tilth with a proper balance of moisture, air and thermal regime. Thus, a dominating feature of the rice–wheat cropping system is the annual conversion of soil from aerobic to anaerobic and then back to aerobic conditions (Mahajan, 2006).

Rice in most parts of south and south-east Asia is traditionally cultivated in well-puddled soils. Puddling (wet tillage) is an intensive system, which brings about significant changes, especially in physical properties of soil, including structural, hydraulic and mechanical properties. Sometimes puddling induces pan formation in rice-growing soils besides reducing percolation (Greenland and De Datta, 1985). However, in rice soils of the north-west Himalayas, no pan formation was observed; instead massive structures were seen in lower horizons (Gupta and Tripathi, 1993; Mahajan, 2001; Mahajan et al., 2007c). Such changes, although favourable for rice, are not suitable for the following upland wheat crop (Sharma and De Datta, 1986; Sharma et. al., 2003). Consequently, the growth and the yield of wheat crop are poor in post-rice soils, probably constrained due to factors such as large turnaround time (Fujisaka et al., 1994), poor soil tilth of seedbed (Chenkual and Acharya, 1990), subsoil compaction (Bhushan and Sharma, 1997), poor drainage (Regmi et al., 2002), restricted aeration (Bhushan and Sharma, 1999), nutrient stress (Hobbs, 1994) and high mechanical impedance to roots (Bhagat and Verma, 1991). Apart from alteration of chemical and physical changes in flooded rice soil as mentioned above, its microbial activities are also changed (Gupta et al., 1992; Mahajan and Bhagat, 2006). Generally, ammonifying bacteria predominated over nitrite or nitrate formers. There was invariable presence of *Clostridium* and *Beijerinckia*. The atmospheric nitrogen fixed in these soils was mainly through *Clostridium* spp. Table 7.4 summarizes the relative advantages and disadvantages of puddling in the rice–wheat cropping system (Sharma et al., 2003).

The water requirement for rice cultivation is very high, and puddling reduces the permeability besides controlling weeds. It consumes around 5,000 l of water under irrigated conditions for each kilogram of grain produced (IRRI, 1995). On the other hand, a good crop of wheat requires about 1,000–1,200 l of water to produce 1 kg of wheat. Flooding of rice fields also causes several chemical changes in the soil, which regulates transformations and availability of nutrients (Ponnamperuma, 1972 and 1985). The flooded lowland soil is characterized by larger amounts of exchangeable K and Na compared to the upland soil, particularly in the cultivated layer. Submerged soils differ from others in the control of acidity and alkalinity because the partial pressure of CO_2 in floodwater buffers carbonate content and lower pH. The change

Table 7.4 Summary of advantages and disadvantages of puddling in rice–wheat cropping system (Adapted from Sharma et al. [2003])

Rice

Advantages

- Levelling land for proper water control.
- Making soil soft for ease of transplanting.
- Enhanced water and nutrient use efficiency; reduction in water permeability leads to decrease in total water requirement and leaching losses of nutrients.
- Enhanced plant availability of soil nutrients; reduced conditions in puddled soils increase solubility of various macronutrients and micronutrients.
- Weed control.
- Takes advantage of monsoon in land preparation.

Disadvantages

- Labour-, capital-, and energy-intensive process.
- Leaching losses of residual soil NO_3-N during puddling.

Wheat

Advantages

- Moderate subsoil compaction due to puddling in highly permeable coarse-textured soils may improve nutrient and water use efficiency as well as wheat yield.

Disadvantages

- Destruction of soil structure, leading to higher bulk density, higher soil penetration resistance and more surface cracking.
- Higher draft power requirement.
- Clod formation and difficulties in obtaining seedbed with fine tilth.
- Longer turnaround time, leading to delayed sowing.
- Development of subsurface hardpans, having high bulk density, low porosity, high soil penetration resistance, and low water permeability, which lead to problems of water logging, poor soil aeration and restricted root growth.
- Reduced subsoil conditions decrease the availability of soil nutrients to wheat.

of pH alters chemical equilibria and consequently the availability of different plant nutrients. However, most of the changes are reversible on drainage, which suggests important implications for nutrient management in rice–wheat systems.

7.3 Package of Practices and Methodologies for the Rice–Wheat Cropping System

The package of practices and methodologies pertaining to improve fertilizer use efficiency has been published for the rice–wheat cropping system as well as for other major cropping systems (Acharya et al., 2003). Some additional information is given below:

- Use of 40–50% of the recommended doses of NPK through chemical fertilizers and the rest (50–60%) through green manuring and FYM gave the yield of rice crop almost equivalent to that which was obtained through the use of 100% NPK recommended doses.

- Application of 20–25 kg of $ZnSO_4$ was found to increase the yield of both the rice and wheat crops under the soil conditions of Jammu & Kashmir and Himachal Pradesh.
- Application of 40 kg $ZnSO_4$ ha^{-1} was found to eliminate Zn deficiency in rice-growing sodic soils when treated with gypsum, FYM, pyrites and rice husk.
- Under saline soil conditions of Uttar Pradesh, application of one third of total N at the time of sowing and one third as top dressing indicated maximum yield of wheat.
- Application of *Azolla* along with 30 kg N ha^{-1} produced rice yield equivalent to use of 60 kg N ha^{-1}, thereby showing a net gain of 30 kg of N ha^{-1} in the soil conditions of eastern Indian states.
- Application of sulphur to an extent of 20–40 kg ha^{-1} in the form of gypsum has increased yield of rice in the eastern hill regions and in the north-west Himalayas.

7.4 Nutritional Value of Rice and Wheat

Cereals such as rice, wheat, maize and barley form the staple food of the population of the Indian subcontinent and differ widely in their content of various nutrients. They are rich sources of starch and fair to good sources of proteins, certain minerals and vitamin B. About 70–80% of our food requirement comes from cereals (Yadav et al., 1999). Rice alone accounts for 40% of the protein in Asian diet. In India, rice provides 25% of the protein requirement, besides being the principal source of vitamins (thiamine and riboflavin) and minerals (Fe and Ca). The protein content of husked rice varies from 6% to 8% with good vitamin B and P content, poor source of Ca and fair source of Fe. The quality of rice depends on milling. Among cereal proteins, rice protein is biologically the richest by virtue of its true digestibility (88%), high lysine content (4%) and relatively better net utilization.

The wholewheat flour contains germ and bran. It contains more proteins than other cereals, which varies between 11% and 15%. It is a good source of thiamine, nicotinic acid and vitamin B. It also contains a fair source of Ca and Fe and is a good source of P. Besides, their significance in nutrition principally concerns in providing the characteristic substance 'gluten' which is very essential for bakers. In bakeries, gluten provides the structural framework for the familiar spongy, cellular texture of bread and other baked products. Therefore, other cereals lacking gluten are not good for bread-making.

Impact Points to Remember

- The rice–wheat rotation is the principal cropping system in south Asian countries that occupies about 13.5 million hectares in the IGP, of which 10 million hectares are in India, 2.2 million hectares in Pakistan, 0.8 million hectares in Bangladesh and 0.5 million hectares in Nepal.

- Rice is cultivated in 111 countries of the world compared to wheat, which is grown in 92 countries.
- China and India produce more than half of the world's rice, and rice cultivation generates highest employment for the rural Asian population.
- This cropping system is dominant in India, mostly in Punjab, Haryana, Uttar Pradesh and Madhya Pradesh, and contributes 75% of the national food grain production.
- The total area under rice and wheat in India is 42.50 and 26.58 million hectares with the production of 85.31 and 72.00 million tonnes respectively.
- The environmental requirements for the growth and development of both rice and wheat crops are quite different. Rice grows best under stagnant water conditions, while wheat requires a well-pulverized soil with a proper balance of moisture, air and thermal regime.
- The dominating feature of the rice–wheat cropping system is the annual conversion of soil from aerobic to anaerobic and then back to aerobic conditions.
- Rice in most parts of south and south-east Asia is traditionally cultivated in well-puddled soils.
- Wheat growth and yield are poor in post-rice soils, probably constrained due to factors such as large turnaround time, poor soil tilth of seedbed, subsoil compaction, poor drainage, restricted aeration, nutrient stress and high mechanical impedance to roots.
- The water requirement of rice is very high compared to that of wheat. Rice consumes around 5,000 l of water under irrigated conditions for each kilogram of grain produced, while a good crop of wheat requires about 1,000–1,200 l of water to produce 1 kg.
- These two crops are rich sources of starch and fair to good source of proteins, certain minerals and vitamin B.
- Among cereal proteins, rice protein is biologically the richest by virtue of its true digestibility (88%), high lysine content (4%) and relatively better net utilization.

Study Questions

1. Define the following:
   (a) Puddling
   (b) pH
   (c) Protein
   (d) Milling
   (e) Minerals
   (f) Vitamins
   (g) Starch
   (h) Milled rice
2. Explain briefly the distribution of the rice–wheat cropping system in India and its contribution to food security.

3. Justify the statement ‘Environment requirements for growth and development of rice and wheat are contrastingly different’.
4. Why are wheat growth and yield poor in post-rice soils?
5. What are the advantages and disadvantages of puddling in rice–wheat cropping system?
6. Write a short note on the nutritional value of rice and wheat.
7. Differentiate the following:
   (a) Water-logging and submergence
   (b) Acidity and alkalinity
   (c) Lowland crops and upland crops
8. How much water is required to produce 1 kg of rice and wheat grains under irrigated conditions?
9. Explain the package of practices and methodologies for rice–wheat cropping system.

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