

Rice Straw Management

By A. Dobermann and T.H. Fairhurst

Straw is the only organic material available in significant quantities to most rice farmers. About 40 percent of the nitrogen (N), 30 to 35 percent of the phosphorus (P), 80 to 85 percent of the potassium (K), and 40 to 50 percent of the sulfur (S) taken up by rice remains in vegetative plant parts at crop maturity.

Straw is either removed from the field, burned *in situ*, piled or spread in the field, incorporated in the soil, or used as mulch for the following crop. Each of these measures has a different effect on overall nutrient balance and long-term soil fertility. Where S-free mineral fertilizers are used, straw may be an important source of S; thus, straw burning should not be practiced. In contrast, burning effectively transforms straw into a mineral K nutrient source, and only a relatively small amount of K is lost in the process. The effect of straw removal on long-term soil fertility is much greater for K than for P (Table 1). Spreading and incorporation of straw, however, are labour-intensive tasks, and farmers consider burning to be more expedient. Straw is also an important source of micronutrients such as zinc (Zn) and the most important influence on the cumulative silicon (Si) balance in rice.

Straw Removal

Removal of straw from the field is widespread in India, Bangladesh, and Nepal, which explains the depletion of soil K and Si reserves at many sites. Straw can be used as fuel for cooking, ruminant fodder, and stable bedding or as a raw material in industrial processes (e.g., papermaking). In the process, some or all of the nutrients contained in straw may be lost to the rice field, particularly where animal manure is used in other parts of the farming system where the response to straw application is greater than for rice.

Straw Incorporation

Incorporation of the remaining stubble and straw into the soil returns most of the nutrients and helps to conserve soil nutrient reserves in the long-term. Short-term effects on grain yield are often small (compared with straw removal or

Table 1. Nutrient content of rice straw and amounts removed with 1 tonne of straw residue.					
	N	P ₂ O ₅	K ₂ O	S	Si
Content in straw, % dry matter	0.5-0.8	0.16-0.27	1.4-2.0	0.05-0.10	4-7
Removal with 1 tonne straw, kg/ha	5-8	1.6-2.7	14-20	0.5-1.0	40-70

burning) but long-term benefits are significant. Where mineral fertilizers are used and straw is incorporated, reserves of soil N, P, K, and Si are maintained and may even be increased. Incorporation of straw and stubble into wet soil (during plowing) results in temporary immobilization of N and a significant increase in methane (CH₄) emission from rice paddy, a practice that contributes to greenhouse gases. Incorporation of large amounts of fresh straw is either labour-intensive or requires suitable machinery for land preparation and may result in the build-up of disease problems. Transplanting should be carried out two to three weeks after straw incorporation.

Recent research results from experimental farms indicate that early, dry shallow tillage at 5 to 10 cm depths (to incorporate crop residues and enhance soil aeration during fallow periods) has beneficial effects on soil fertility in intensive rice-rice systems. Shallow tillage of dry soil should be carried out up to two to three weeks after harvest in cropping systems where the dry-moist fallow period between two crops is at least 30 days. Beneficial effects include:

- A more complete carbon (C) turnover is achieved by aerobic decomposition of crop residues (about 50 percent of the C within 30 to 40 days), thereby minimizing negative effects (e.g., phytotoxicity) of the products of anaerobic decomposition on early rice growth.
- Improved soil aeration...i.e., reoxidation of iron (Fe²⁺) and other reduced substances that accumulate during the flooding period.
- Increased N mineralization and soil P release to the succeeding crop, up to the panicle initiation stage.
- Reduced weed growth during the fallow period.
- Reduced irrigation water requirement during land preparation (i.e., less soil cracking and bypass flow water losses in heavy clay soils).
- Easier wetland preparation (i.e., there is often no need for a second plowing operation).
- Smaller CH₄ emissions compared with straw incorporation during land preparation for the crop.

Burning

Burning causes almost complete N loss, P losses of about 25 percent, K losses of 20 percent, and S losses of 5 to 60 percent. The amount of nutrients lost depends on the method used to burn the straw. In areas where harvesting has been mechanized (e.g., Thailand, China, and northern India), all the straw remains in the field and is rapidly burned *in situ*; therefore, losses of S, P, and K are small.

In Indonesia and the Philippines, straw is heaped into piles at threshing sites and burned after harvest. The ash is usually not spread on the

field, and this results in large losses of minerals...K, Si, calcium (Ca), magnesium (Mg)...leached from the ash piles, although nutrients contained in the relatively long stubble (30 to 40 cm) remain in the field. Moreover, such a practice results in a significant transfer of nutrients from the periphery of the field to the center, or even from surrounding fields to the center field where, after threshing, the residues are burned. Over time, this practice results in the accumulation of nutrients (K, Si, Ca, Mg) in some parts of the field and nutrient depletion in other parts.

Burning causes atmospheric pollution and results in nutrient loss, but it is a cost-effective method of straw disposal and also helps reduce pest and disease populations that may occur due to reinfection from inoculum in the straw biomass.

Conclusions

An assessment of farmer straw management practices is an important part of developing fertilizer recommendations. The major impact of straw removal is on the soil K balance. Complete straw removal over several cropping seasons without replenishing soil K with mineral fertilizer is likely to lead to increased incidence of K deficiency.

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Further reading

- Ponnamperuma, F.N. 1984. Straw as a source of nutrients for wetland rice. Organic matter and rice. Manila (Philippines): International Rice Research Institute. p. 117–136.
- Qi-Xiao W. 1984. Utilization of organic materials in rice production in China. Organic matter and rice. Manila (Philippines): International Rice Research Institute. p. 45–56.
- Singh, Y., B. Singh, M.S. Maskina, and O.P. Meelu. 1988. Effect of organic manures, crop residues, and green manure (*Sesbania aculeata*) on nitrogen and phosphorus transformations in a sandy loam soil at field capacity and under waterlogged conditions. *Biol. Fert. Soils* 6:183–187.
- Ventura, W.B., and J.K. Ladha. 1997. *Sesbania* phosphorus requirements when used as biofertilizer for long-term rice cultivation. *Soil Sci. Soc. Am. J.* 61:1240–1244.
- Verma, T.S., and R.M. Bhagat. 1992. Impact of rice straw management practices on yield, nitrogen uptake, and soil properties in a wheat-rice rotation in northern India. *Fert. Res.* 33:97–106.
- Witt, C., K.G. Cassman, J.C.G. Ottow, U. Biker. 1998. Soil microbial biomass and nitrogen supply in an irrigated lowland rice soil as affected by crop rotation and residue management. *Biol. Fert. Soils* 28:71–80.

Rice Fact File

Origin—Domesticated in Africa (*Oryza glaberrima*) and Asia (*Oryza sativa*). Several centres of origin have been proposed for *O. sativa*, including India and northern Thailand. Evidence points to the Yangzi Valley in southern China as one site of origin for domesticated rice.

Botany—Rice is a grass (*Gramineae*) and belongs to the genus *Oryza* (meaning oriental). *Oryza sativa* is grown in a wide range of environments from the equatorial tropics to sub tropical mid-latitudes, from lowland paddy fields to high altitude terraces, and from swamps to upland rice fields.

Cultivars—Since the introduction of modern varieties in the 1960s, most paddy rice farmers cultivate short straw, nitrogen (N)-responsive varieties with multiple pest resistance. Local varieties are more common in upland, rainfed, and deep-water rice environments. Improved germplasm for some of these environments is now available.

Harvest part—In upland rice fields, the ripe panicle is removed with a special knife concealed in the palm of the harvester's hand, and straw is left standing. In paddy rice fields, rice is harvested with a sickle or mechanical harvester, and the panicle together with a portion of the stem is removed. The amount of stem removed depends on the threshing method used and farmer requirement for straw as livestock bedding, fuel or mulch.

Life cycle—The growing season of some traditional varieties is about 260 days, but is between 90 to 110 days for most modern varieties. Shortening the growing season is a key factor in increasing cropping intensity (crops/ha/yr). Crop maturation is extended under conditions where phosphorus (P) or other nutrients are deficient.

Maximum yield—At present, the genetic yield barrier for inbred varieties in irrigated rice systems is about 10 t/ha. Under best management practices in favourable environments, farmers are able to achieve yields of greater than 8 t/ha. To meet future food demand, short duration varieties with a yield potential of 15 t/ha will be required. Some researchers argue that the rice plant's radiation conversion factor of 2.6 to 2.9 g/MJ (megajoule) may not be sufficient to reach such yields. The possibility of incorporating C₄ plant physiological characteristics into rice to increase yield potential is presently under consideration.

Nutrient removal—Nutrient balance is strongly affected by straw management. Straw contains more than 85 percent of the potassium (K) contained in the above-ground biomass. Thus, much greater amounts of K must be applied to maintain the soil supply where straw is removed from the field. Removal of N and P is mostly associated with grain harvest.

	Nutrient removal, kg nutrient/tonne				
	N	P ₂ O ₅	K ₂ O	Mg	Ca
Rice grain	10.5	4.6	3.0	1.5	0.5
Rice straw	7.0	2.3	17.5	2.0	3.5
Rice grain + straw	17.5	6.9	20.5	3.5	4.0

Micronutrient requirements—Rice often requires zinc (Zn) in alkaline soils and soils containing very large concentrations of organic matter. Copper (Cu) is usually required to prevent male sterility in rice grown on peat soils.

Fertilizer nutrient recovery efficiency—In irrigated lowland rice fields with good crop management and grain yields of 5 to 7 t/ha, typical fertilizer recovery efficiencies are 30 to 60 percent for N, 10 to 35 percent for P, and 15 to 65 percent for K. Recovery efficiency for N and K is strongly influenced by splitting and timing of fertilizer applications.

Planting density and canopy management—Optimal planting density depends on the crop establishment method and variety (tillering capacity). In transplanted rice, a plant spacing of 0.2 x 0.2 m gives 250,000 hills/ha. In direct seeded paddy rice, rates range from 60 to 80 kg seed/ha. In upland rice, seed is dibbled into evenly spaced planting points, and seed rates are lower, ranging from 30 to 35 kg/ha. Excessive early canopy development (seeding/transplanting to early tillering) may result in a very leafy canopy that is more susceptible to pest and disease infestation. Proper splitting and timing of N fertilizer applications are required to produce an optimal canopy without incurring pest and disease damage.

Climatic requirements—In paddy rice, maximum yields are obtained in the dry season, when cloud cover is less and photosynthetic active radiation (PAR) is greater than during the wet season. In irrigated rice, rainfall is not important, provided the irrigation water supply is reliable and sufficient in quantity. In rainfed and upland rice, rainfall is a major yield determinant, particularly in coarse textured soils with poor water retention.

Soil requirements—In upland and rainfed rice, soil structure and fertility are major yield determinants because the amount of mineral fertilizer used is often small. In irrigated rice, soil structure is deliberately destroyed during land preparation. The effect of flooding generally improves nutrient availability and reduces the effects of very alkaline or acid soil conditions on plant growth that occurs under aerobic conditions. In high yielding environments where modern varieties are used, the difference between the soil's indigenous nutrient supply and crop nutrient demand must be provided in the form of mineral fertilizer. **BCI**