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132

Rice-based Cropping Systems - ICRISAT's Experience

A. Ramakrishna, M.M. Anders, and D.J. Flower

Resource Management Program, ICRISAT

Introduction

Rice is the most important staple food crop in Asia, where about 90% of the world's rice production is located. Rice covers 81 m ha in South and Southeast Asia, where approximately 30% of the cropped land is irrigated and double-cropped throughout the year. With the increase in population and a continuous decline in the average farm size (0.5-2.0 ha), there is a growing need to put the existing land base to better use. The prevailing practice of monocropping rice and then leaving the fields fallow after the harvest, could prove disastrous because of its inability to meet the increasing demand for rice and grain legumes.

Grain legumes are a major source of protein and can enrich the rice land. Further, with the rising cost of nitrogenous fertilizer, their importance in sustainable rice farming systems will increase. Grain legumes are important in RBCS.

Cropping-systems research at ICRISAT is focused on developing economically and ecologically sound and sustainable cropping systems for the rainfed areas in the SAT, which include agroecological zones where upland rice is grown.

Legumes with Upland Rice

Upland rice is the primary subsistence crop of very poor farmers in the tropics. Upland ecosystems present a difficult challenge to sustainability. Productivity of upland rice has remained low (about 0.6 t ha^{-1}) largely because of climatic stresses, of which rainfall is the most variable and least predictable. Recently-developed early-maturing upland rice cultivars (75-100 days) with fertilizer responsiveness have increased the prospects for crop diversification in upland areas. Crop diversification through intercropping can assist in stabilizing productivity in such systems. The most important criterion for intercropping upland rice is to maintain the rice yield while obtaining additional yield from grain legumes.

At ICRISAT, research was initiated on the grain legume-upland rice intercropping system with the focus on improved resource use and higher productivity by improving N availability to rice and associated crops, reducing late drought stress on rice, and increasing protein availability and cash income to farm families.

Intercropping consists of growing two crops on the same land at the same time. It can stabilize the yield from season to season, which is an important criteria in subsistence or near-subsistence agriculture. Another advantage of intercropping can be increased productivity of complementary component crops. Well-designed intercropping combines component crops that use available resources better than would single crops. While one crop is harvested early, the second continues to grow after the first is harvested, making full use of the residual resources, primarily moisture. The overall advantage of such a system is the complementary use of resources by component crops.

Given the long growing period in upland rice systems, there is a choice of two types of intercropping: temporal and spatial.

Temporal intercropping. Rice/pigeonpea intercropping is an example of the temporal system in which rice grows fast and pigeonpea slowly. Following the rice harvest at about 100 days, the pigeonpea continues to grow for an additional 50 to 80 days making the best use of the residual moisture and light. In studies conducted at ICRISAT using an upland rice/pigeonpea intercrop, rice gave 85-90% of the sole crop yield with pigeonpea producing 70-80% of the sole crop yield. This resulted in a land equivalent ratio (LER) between 1.54 and 1.74. In this study, intercropping was 54-74% more productive than monocropping.

Spatial intercropping. The spatial system of intercropping involves growing two crops which have similar maturity but dissimilar canopy height in the same area. Rice/cowpea and rice/extra-short-duration pigeonpea systems are examples of this system. Mixtures of short-duration and short-statured determinate legumes were found to be more appropriate for intercropping with upland rice. Intercropping increased the total intercepted radiation due to the faster canopy cover i.e., spatial complementarity. An intercropping advantage was achieved with a small reduction in rice yield and a substantial increase from the legume.

Intercropping experiments. A series of agronomic experiments were initiated at ICRISAT with the objective of identifying pigeonpea cultivars with growth habits compatible with upland rice and testing these genotypes for their sensitivity to intercropping competition (e.g., crop ratios). Productivity of each intercrop component and its respective sole crop was determined in terms of Crop Performance Ratio (CPR). Extra-short-duration pigeonpea recorded the largest partial CPR for grain (2.89) followed by early (2.39) and medium (1.21) pigeonpea genotypes. Spreading genotypes had a larger partial CPR than semi-compact types. However, the CPR of intercropped rice was less (0.65-0.69) with spreading pigeonpeas and greater than 1 with compact types. Pigeonpea canopy appeared to be more important than differences in phenology. A wide range of light transmission coefficients (K)(0.45 to 0.78) were recorded in pigeonpea. Another factor which appears to determine competitive ability is the relative height of intercropped pigeonpea and upland rice. Rice appears to be very sensitive to low light and shading during its reproductive phase.

Legumes Following Irrigated Rice

Partially irrigated areas i.e., lands irrigated only during the rainy season contribute 70% of Asia's total rice production. In these areas the fields are usually kept fallow following the rice harvest. In the areas growing a second crop under residual moisture after rice, the crop could add to the farmers' income.

Cropping-systems research at ICRISAT has concentrated on increasing cropping intensity in rainfed rice areas and rice fallows by using early-maturing, photoperiod-insensitive, drought-tolerant, and high-yielding legume genotypes. Experiments have been conducted to identify better techniques in crop establishment that will result in an improved plant stand and reduce the time between crops.

The main rainy-season cereal crop in Vertisol areas is rice followed by a grain legume. Two varieties of rice (120-day and 100-day genotype) were used as the main rice crop. Postrainy-season crops of pigeonpea, chickpea, groundnut, and sorghum were raised on residual moisture at ICRISAT Center, Patancheru, Andhra Pradesh, India and with irrigation at the Directorate of Rice Research, Rajendranagar, Andhra Pradesh, India. In these experiments, efforts were made to optimise production in the first and second crops and maximize efficiency of water and fertilizer use.

At Rajendranagar, 2.5 t ha^{-1} of groundnut or sorghum were harvested with irrigation whereas at ICRISAT Center the groundnut yield was very poor under residual moisture conditions (about 0.4 t ha^{-1}). Sorghum and pigeonpea yielded about 1.0-1.2 t ha^{-1}. Our experience indicates that groundnut yields were lower after rice and that acceptable yields were possible only when irrigation was available. The two primary factors for reduced yields, particularly for ICRISAT Center, were the absence of a fine seedbed and drought stress for the legumes. However, sorghum and pigeonpea were able to withstand both stresses and gave reasonably good yields. On the other hand, at Rajendranagar where irrigation was applied to all legume crops so that seedbed preparation could be better, legume yields were acceptable.

Delayed seedbed preparation and sowing of upland crops after the rice crop cause serious reduction in yield. By selecting early-maturing rice cultivars and by reducing the turnaround time, good plant stands of groundnut, pigeonpea, chickpea, and sorghum could be obtained. This system has reduced the need for irrigation water and fertilizers, and is more restorative of soil fertility. It is also more remunerative as the price of grain legumes is about 2-3 times that of rice. These studies indicate that through better soil management and use of improved varieties of grain legumes the farmer should be able to diversify RBCS.

Problems Affecting the Efficiency of RBCS

Growing legumes after rice offers more challenges than any other cropping system. After the rice harvest the soil becomes hard and compact resulting in poor drainage. The ability of a seed to germinate and establish when the top soil is drying is a major constraint on residual soil moisture. Change from the submerged soil condition to upland condition

brings significant changes in soil reaction and nutrient availability, particularly of phosphate, iron, manganese, and zinc. Hence fertilizer application is essential for obtaining good yields of upland crops.

Factors to be Considered when Developing a Suitable Technology for RBCS

Varietal development. Varietal requirements of grain legumes in RBCS are early maturity, multiple disease and insect resistance, and drought tolerance.

Tillage. Zero or reduced tillage provides yield comparable to conventional tillage. Zero-tillage soils usually have high surface soil moisture at sowing time and soil exposure to evaporation is minimized.

Plant establishment. Deep sowing is an obvious way to reduce the affect of early moisture deficiency but seedling emergence and its subsequent vigour is dependent on seed size and genotype. One 'come-up' irrigation can make a significant difference in yield since the profile may be fully charged while the surface soil is dry.

Seed quality and seed rate. Under limited-moisture conditions, low plant density may be beneficial but under adequate-moisture conditions, optimum or slightly higher density improves yields. Poor seed viability and low seed rates lead to a low population density and poor yields.

Inoculation and fertilizer application. Use of proper *Rhizobium* inoculation following lowland rice often improves the yield of grain legumes. The addition of 30-50 kg P_2O_5 ha^{-1} has also been shown to increase yields. Band placement of fertilizer is generally more efficient particularly when only a small amount is being applied. Deep placement of nutrients is beneficial especially when the surface layers become dry.

Conclusion

Researchers have developed photoperiod-insensitive, high-yielding, and short-duration legume varieties which can fit in rice-based systems as a sequential, intercrop, or alley crop. Careful selection of species, genotype, and efficient management will lead to the most beneficial system. Crops requiring little water and fertilizer should be introduced to minimize inputs and improve efficiency. Crop diversification is desirable for the economy of the system along with a rational utilization of resources to maintain soil health.

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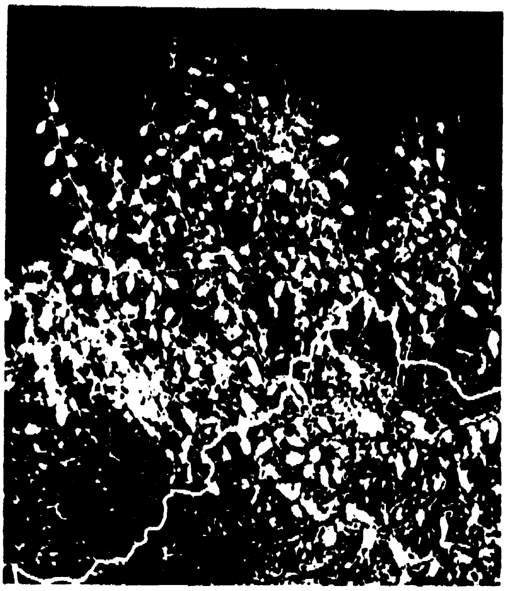

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