An irrigated rice based cropping system for tropical Australia

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Summary. The development of a rice based cropping system for tropical Australia, in which rice, soybean, and maize are double cropped in rotation, is discussed. It is argued that such a system, based on rice production under saturated soil culture on permanent beds, improves productivity and has considerable advantages over the traditional rice/fallow system. Advantages identified include water, nitrogen, and phosphorus economies, energy savings, greater timeliness of field operations and reductions in soil compaction.

Introduction

Under irrigation, tropical Australia has potential for year round crop production. In the Burdekin River Irrigation Area (BRIA) (20?03'S, 147?17'E) of north Queensland irrigated cropping has historically centred on a sugar cane monoculture and, to a lesser extent, an annual rice (summer or winter)/fallow rotation, horticulture and other field crops. As part of the downstream development of the Burdekin Falls Dam (completed 1987), 50,000 ha will be developed for irrigation over the next 15 years. This expansion will double the current area under irrigation.

It was expected that sugar industry expansion would occupy most of the new land developed. However, in the mid 1980s world sugar markets were depressed and this coupled with regulations limiting sugar expansion onto new land made it necessary to consider alternatives. Experience elsewhere in tropical Australia, particularly in the Ord Irrigation Area, suggested that the production of field crops other than those of high value (e.g., cotton), would not be profitable on a one-crop-a-year basis. Consequently, we decided to evaluate a double crop rice-based cropping system in which rice was rotated with field crops such as soybean (summer/wet season) and maize (winter/dry season). In this paper we discuss the rationale behind, and our approach to, developing this system. The outcomes of a range of experiments conducted at Millaroo Research Station on a heavy cracking clay soil (4) are discussed briefly in relation to the establishment of a viable rice-based cropping system for the Australian tropics.

Components of the system

For each crop it was considered necessary to identify and examine in isolation, those cultural and management components likely to inhibit the development of a viable and practical rotation. We considered the following areas:

- Incompatible irrigation practices *viz* paddy (flood) and furrow irrigated upland crops.
- Impact of cultural changes on timeliness of operations.
- Effects of crop and irrigation practice on soil chemistry and nutrient availability.

In initiating research in these areas, we were also aware that water and nitrogen (N) fertiliser account for 40% and 25%, respectively of the variable cost of growing a rice crop.

Incompatible irrigation practices

Field crops such as maize and soybean cannot survive under the flooded soil conditions used for rice production. Hence, to improve compatibility between rice and field crops, rice would need to be grown under a different system. Experiments were established to study different strategies for irrigating rice. Treatments included the traditional practice of flooding at the three leaf stage (PF-3L), intermittent irrigation (II), with rice grown as a field crop and irrigated weekly, and saturated soil culture (SSC) with rice grown on raised beds with water maintained in the furrows between beds. SSC was initially developed for soybean (2).

Briefly, rice yields were similar ($P>0.05$) under PF-3L (8.2 t/ha) and SSC (7.4 t/ha) but lower ($P<0.05$) under II (5.1 t/ha). More importantly SSC used 32% less water than PF-3L and efficiency of water use for grain production was improved by 30% (1). The lower water use with SSC was because evaporation from the saturated soil surface was less than from a free water surface throughout crop growth.

Impact of cultural changes on timeliness of operations

Separate studies, using permanent beds and controlled traffic lanes with soybean and maize indicated the following advantages over conventional cultural practices: (i) improvements in timeliness of operations; (ii) significant energy savings; (iii) less soil compaction; and (iv) reduced weed problems (3). The beds were stable after establishment and required only a furrow cleaning operation between crops.

In the above irrigation experiment, beds under SSC were not observed to degrade, suggesting there was no obvious limitation preventing the combination of SSC, permanent beds and traffic lanes. Since rice, maize, and soybean have a four- to five-month growth period in the BRIA, the time between crops with double cropping is short. A combination of SSC, permanent beds and controlled traffic lanes has the advantages of fewer cultural operations and an increase in the time between crops.

Nitrogen

With the high cost of N in traditional rice production, the inclusion of a legume as a source of N was considered an important nutritional factor in the development of this rotation. The availability of organic N to flooded rice was assessed after fallow, soybean, and maize. Since residual N following these cropping options was insufficient for maximum rice yield, fertiliser N was required. In the absence of fertiliser N, rice yields increased 4 t/ha following soybean ($P<0.05$), 3.4 t/ha following maize, and 1.9 t/ha after fallow, suggesting the importance of crop residue as a potential N source (5). The results further suggest that there is little value in terms of nitrogen economy from a fallow period between rice crops.

In addition, N supply from residues varied during rice growth. Prior soybean provided a relatively constant source of N during the rice crop, whereas prior fallow provided N mostly during early growth and prior maize mostly during grain filling. Therefore prior soybean (and to a lesser extent prior maize) has potential to lessen N fertiliser requirements for rice providing a steady source of organic N from its residues. Implications for the timing of applications of fertiliser N to rice have been discussed elsewhere (6).

Phosphorus

Phosphorus (P) requirements for field crops increase after flooded rice (7). A series of field and glasshouse studies were carried out in conjunction with the irrigation study described above, to determine the magnitude and direction of changes in P requirements for field crops after rice. These P requirements increased ($P<0.05$) with the number of days under flood, with the traditional PF-3L method of irrigation increasing requirements by 60% relative to unflooded soil. Similar increases in P requirement were not found following rice grown under II and SSC. This result suggests that, with rice grown under SSC, increases in P requirement for field crops will be small relative to those following flooded rice.

Also, we are considering four additional, and highly interactive, factors likely to have implications for P availability to field crops after rice. These factors are: (i) soil oxidation/ reduction (redox) during flood and subsequent draining phases; (ii) vesicular-arbuscular mycorrhizza (VAM) fungi; (iii) as interaction between P and zinc with the possibility of a P induced zinc deficiency; and (iv) the effect of P stress on plant development.

Practical considerations

Collectively, these complementary studies suggest that the development of a rice based cropping system, in which rice and field crops are double cropped in rotation, is feasible and may provide additional synergistic and logistic benefits over those found in the traditional rice/ fallow system. We believe the accrued benefits of such a rice based system will be higher than for the traditional system. The key to integrating the different research components would seem to rest with the development of SSC technology for rice production. If SSC is accepted by rice farmers, efficiencies through reduced water use will be realised. Further, adoption of controlled traffic and permanent bed concepts will improve the timeliness of farm operations, facilitate the change from one crop to the other, and greatly improve the reliability of achieving two crops a year. Considerable reductions in energy use and soil compaction will ensue. The probability of unproductive fallow periods will lessen. There are obvious benefits in improved N and P economies by incorporating a grain legume such as soybean, and using SSC to minimise P requirements for field crops following rice.

The program now focuses on the development of a preferred rice based cropping system where dry (winter) season rice will be grown, using SSC, on permanent raised beds with controlled traffic lanes, in rotation with wet (summer) season soybean. This preferred system will be evaluated on a semi-commercial basis to identify other management constraints (e.g., weeds, upland rice genotypes, and fertiliser N placement within SSC beds).

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