

WORKING MATERIAL

Integrated Soil, Water and Nutrient Management for Sustainable Rice-Wheat Cropping Systems in Asia

*Report of the Second Research Co-ordination Meeting of
the Joint FAO/IAEA Co-ordinated Research Project,
Nanjing, People's Republic of China on
8 – 12 September 2003,*

**Reproduced by the IAEA
Vienna, Austria, 2003**

NOTE

The material in this document has been agreed by the participants and has not been edited by the IAEA. The views expressed remain the responsibility of the participants and do not necessarily reflect those of the government(s) of the designating Member State(s). In particular, neither the IAEA nor any other organization or body sponsoring this meeting can be held responsible for any material reproduced in the document.

**JOINT FAO/IAEA DIVISION
OF NUCLEAR TECHNIQUES IN FOOD AND AGRICULTURE**

**INTERNATIONAL ATOMIC ENERGY AGENCY
FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS**

WORKING MATERIAL

**Integrated Soil, Water and Nutrient
Management for Sustainable Rice-Wheat
Cropping Systems in Asia**

*Report of the Second Research Co-ordination Meeting of
the Joint FAO/IAEA Co-ordinated Research Project,
Nanjing, People's Republic of China on
8 – 12 September 2003*

IAEA-311-D1-RC-858.2

**Working Material Produced by the IAEA
Vienna, Austria
2003**

EDITORIAL NOTE

In preparing this publication for press, staff of the IAEA have made up the pages from the original manuscripts as submitted by the authors. The views expressed do not necessarily reflect those of the governments of the nominating Member States or of the nominating organizations.

Throughout the text names of Member States are retained as they were when the text was compiled.

The use of particular designations of countries or territories does not imply any judgment by the publisher, the IAEA, as to the legal status of such countries or territories, of their authorities and institutions or of the delimitation of their boundaries.

The mention of names of specific companies or products (whether or not indicated as registered) does not imply any intention to infringe proprietary rights, nor should it be construed as an endorsement or recommendation on the part of the IAEA.

The authors are responsible for having obtained the necessary permission for the IAEA to reproduce, translate or use materials from sources already protected by copyrights.

TABLE OF CONTENTS

1.	Summary	1
2.	Programme	2
3.	Abstracts of presentations	5
4.	Conclusions and Recommendations	18
5.	List of participants	20
	Annex	23

1. Summary

The 2nd RCM was held at the Nanjing Agricultural University (NAU) with Prof. Qirong Shen as the local organizer. All participants in the CRP, including seven research contract holders from Bangladesh (1), India (2), Nepal (1), Pakistan (1) and PR China (2), a technical contract holder (Australia), a representative of a technical contract holder (IRRI, Philippines), and two agreement holders (CSIRO, Australia; CIMMYT-India) attended the RCM. The Meeting was officially opened by Prof. Dr. Guanghong Zhou, Vice-president, NAU.

A total of four Technical Sessions were scheduled during the first two days of the RCM, during which three invited speakers and each contract/agreement holder gave a 45-minute presentation on their research endeavours. Chairpersons gave an oral summation of the proceedings of each Technical Session at the end of the second day.

An excursion to Yancheng, Jiangsu Province, to see the field experimental plots of Prof. Qirong Shen, was scheduled on the third day of the RCM.

On the fourth day, the Scientific Secretary made a presentation on CRP management issues, and outlined the requirements for the mid-term review of the CRP. The participants then proceeded to discuss issues in plenary and to formulate the conclusions and recommendations of the 2nd RCM. In addition, the Scientific Secretary, in collaboration with the participants, drafted the CRP Progress Report, for the mid-term review. All activities were completed on the final day according to the planned schedule.

The participants agreed to recommend that the 3rd RCM be convened in Dhaka, Bangladesh, Feb./March 2005, to be held back-to-back with the 12th Meeting of the Regional Technical Co-ordination Committee of the Rice-Wheat Consortium of the Indo-Gangetic Plain.

P.M. CHALK
Scientific Secretary

2. Programme

Monday, 8 September

09:00 – 09:25	Official Opening Prof. Dr. Guanghong Zhou, Vice President, NAU
09:25 – 09:45	Welcome, objectives of the Meeting and review of the CRP P.M. Chalk Local arrangements, Prof. Q. Shen
Session I	Chairperson: Prof. Qirong Shen (NAU, China)
09:45 – 10:30	Dr. Yong Li (UM, Australia) “GIS based decision support model for optimal water and nitrogen fertiliser use for sustainable agricultural production and environmental quality”
10:30 – 11:00	Coffee Break
11:00 – 11:45	Prof. Linzhang Yang (NISS, CAS, China) “Non-point pollution of N and rural environment in Tai Lake region”
11:45 – 12:30	Prof. Fusuo Zhang (CAU, China) “Nutrient management in rice -wheat rotation system”
12:30 – 14:00	Lunch Break
Session II	Chairperson: Dr. Raj Gupta (CIMMYT-India)
14:00 – 14:45	Dr. Jiarong Pan (CAAS, China) “Effect of water, fertilization and straw management on N recovery and water use efficiency for rice-wheat rotation in Southwest China”
14:45 – 15:30	Prof. Qirong Shen (NAU, China) “Cropping system N and water management: aerobic barley in rotation with aerobic and waterlogged rice”
15:30 – 16:00	Coffee Break
16:00 – 16:45	Dr. Graeme Blair (UNE, Australia) “Interactions between silicon and phosphorus in flooded and non-flooded soils determined by ³⁰ Si and ³² P”

16:45 – 17:30 Dr. Liz Humphreys (CSIRO, Australia)
“Productivity, water use efficiency and hydrology of wheat on beds and flats in Punjab, India”

18.00 Reception at International Exchange Centre, NAU

Tuesday, 9 September

Session III Chairperson: Dr. Liz Humphreys (CSIRO, Australia)

09:00 – 09:45 Dr. Raj Gupta (CIMMYT-India)
“Managing crop residues and nutrients in permanent no-till and furrow irrigated-bed planted rice-wheat systems of South Asia - Some experiences”

09:45 – 10:30 Dr. Yadvinder Singh (PAU, India)
“Rice and wheat yields response to fertilizer N and straw management under a permanent bed planting system in Punjab, India”

10:30 – 11:00 Coffee Break

11:00 – 11:45 Dr. Manbir Sachdev (IARI, India)
“¹⁵N stem injection technique for evaluation of below ground biomass and root derived N of wheat under conventional flat-bed and raised-bed planting systems”

11:45 – 12:30 Ms. Crisanta Bueno (IRRI, Philippines)
“Rice-wheat productivity as affected by management practices”

12:30 – 14:00 Lunch Break

Session IV Chairperson: Dr. Graeme Blair (UNE, Australia)

14:00 – 14:45 Dr. Fayyaz Hussain (NARC, Pakistan)
“Nutrient management for rice and wheat in the rice-wheat area of Punjab, Pakistan”

14:45 – 15:30 Dr. Ram Munankarmy (NARC, Nepal)
“Fate of applied nitrogen with tillage and crop establishment methods under rice-wheat cropping system in Nepal”

15:30 – 16:00 Coffee Break

16.00 – 16.45 Dr. Md. Akhter Khan (BRRI, Bangladesh)
“Productivity evaluation of rice-wheat cropping systems under new crop establishment technique”

16:45 – 17:30 Summaries of presentations in Technical Sessions 1 – IV by Chairpersons and General Discussion

Wednesday, 10 September

07.30 Field excursion to Yancheng (350 km from Nanjing) to see the experiments of Nanjing Agricultural University (Prof. Shen).

Thursday, 11 September

Session V **Chairperson: P. Chalk (IAEA, Austria)**

09:00 – 10:30 Formation of Working Groups, appointment of Chairpersons and commencement of deliberations

10:30 – 11:00 Coffee

11:00 – 12:30 Working Groups

12:30 – 14:00 Lunch Break

Session VI Chairperson: P. Chalk (IAEA, Austria)

14:00 – 15:30 Working Groups

15.30 – 16.00 Coffee Break

16:00 – 17:30 Presentation of Reports of Working Groups by Chairpersons

Friday, 12 September

Session VII **Chairperson: Dr. Graeme Blair (UNE, Australia)**

09:00 – 10:30 Formulation of Conclusions and Recommendations of the 2nd RCM

10:30 – 11:00 Coffee Break

11:00 – 12:00 Summary and Closing of the 2nd RCM. Venue for 3rd RCM.

12:00 – 13:00 Lunch Break

13.00 – 17.30 Visit to farm of Nanjing Agricultural University and/or Institute of Soil Science, Chinese Academy of Science (CAS), Nanjing

3. Abstracts of Presentations

EFFECT OF WATER, FERTILIZATION AND STRAW MANAGEMENT ON N RECOVERY AND WATER USE EFFICIENCY FOR RICE-WHEAT ROTATION AT SOUTHWEST CHINA

Jiarong Pan
Institute for Application of Atomic Energy
Chinese Academy of Agricultural Sciences
P.O. Box 5109, Beijing
China

Abstract

At Southwest China, rice-wheat rotation system is predominant and intensified. But the nitrogen uptake from fertilizer is as low as 25%, while as high as 35~50% was lost due to the improper application of nitrogen fertilizers. In addition, water shortage and straw burning at this area become serious problems, to optimise yield and minimize external inputs in intensive rice-wheat rotation system, a 4-year field trial with ¹⁵N micro-plot experiment was conducted to investigate the effect of water, fertilization and straw management on recovery of fertilizer nitrogen and water use efficiency for rice-wheat rotation. The field trial was conducted at tropical Wenjiang county, near Chengdu city, the Capital City of Sichuan Provinces, at the middle of South West China. 6 treatments were used as follows: (1) FNL, flooded rice at 180 kg N/ha, low density; (2) ANL, aerobic cultivation of rice at 180 kg N/ha, monitoring irrigation, low density; (3) ASL, aerobic cultivation of rice at 180 kg N/ha, monitoring irrigation, low density, straw mulching; (4) AML, aerobic cultivation of rice at 180 kg N/ha, monitoring irrigation, low density, plastic covering; (5) ASH, aerobic cultivation of rice at 180 kg N/ha, monitoring irrigation, high density, straw mulching and (6) OASH, aerobic cultivation of rice, monitoring irrigation, high density, straw mulching, monitoring fertilization. The results were as follows:

1. During rice season, soil water content was very high in the top 0-10cm layer and declined sharply from topsoil to lower layers. While in 40-50cm layer, soil water content was a little higher than that of upper layers, maybe due to upward movement of groundwater.
2. Soil water content for conventional flooded rice (FNL) maintained very high through the whole vegetation period of rice, higher than those of aerobic cultivation treatment (ANL). For aerobic cultivation with plastic covering (AML), soil water content was higher at top 10cm soil but lower in the other layers, probably due to prevention of water from evaporation and blocked the upward movement of ground water. While under aerobic cultivation, straw mulching (ASL, ASH, OASH) would protect water from loss to some extent.
3. When more irrigation was done at previous season, soil water content at top 10 cm soil was rather high.
4. Aerobic cultivation of rice could decrease the growth of rice, but the decrement could be remedied to some extent by straw mulching or plastic covering. The experience-based optimisation for aerobic cultivation with straw mulching did not take much positive effect.
5. The nitrogen uptake by crops with relation to fertilizer, water and straw management was similar to that of dry matter.

6. With the change of flooded cultivation (FNL) to aerobic cultivation (ANL), fertilizer nitrogen recovery did not change very much, but soil residual part of applied nitrogen decreased sharply, leading to great nitrogen loss. Under aerobic condition with straw mulching (ASL), the nitrogen uptake by rice crop decreased, if increase in the density of rice plants, nitrogen uptake and soil residual parts increase and loss decrease. Under aerobic cultivation with plastic covering, fertilizer nitrogen uptake by rice was as high as 34.6% of applied.
7. Among treatments, water use efficiency of aerobic cultivation with plastic covering (AML) was the highest. Although flooded treatment (FNL) was given more irrigation by 50mm water than that of aerobic cultivation (ASL, ASH), but water use efficiency was higher. Under aerobic cultivation, frequent irrigation did not increase yield, but decrease water use efficiency.

FATE OF APPLIED NITROGEN WITH TILLAGE AND CROP ESTABLISHMENT METHODS UNDER RICE-WHEAT CROPPING SYSTEM IN NEPAL

Ram Munamkarmy¹, RK Shretha¹, G Shah², JK Ladha³, SL Maskey¹, S Chapaga¹

¹Soil Science Division, Khumaltar, Lalitpur, Nepal

²Agricultural Implement Research Centre, Ranighat, Nepal

³IRRI, Los Baños, Philippines

Abstract

Conventionally, rice is transplanted manually on puddled field. Amount of inorganic manure applied to rice crop is very little as compared to neighbouring country but application coincides with rains that occur during monsoon period, & that might result into higher losses of applied nitrogen. In this experiment, ¹⁵N – labelled urea (5 atom %) was applied to rice and wheat crop separately. Rice was transplanted or direct seeded in puddled and unpuddled flat land and unpuddled raised beds. Subsequently, wheat was sown with conventional tillage practice (by machine) in puddled flat field (T1) and with zero till drill machine without bed maker attachment in unpuddled flat field (T3) and in beds with ridge attachment (T2 & T4). It revealed that the conventional transplanting of rice in puddled soil produced the highest rice grain yield but the highest rice straw yield was recorded with direct seeding of rice in unpuddled flat land. Wheat grain and straw yields subsequently grown after rice, were not significantly different due to differences in treatments.

Nitrate nitrogen were found to be confined to top layers, 0-15cm depth and the level decreased at the later part of the crop growth. Disappearance of nitrate nitrogen from soil profile seems to be faster both in rice and wheat systems. Recovery of applied N in plant parts found to be unaffected with the treatment differences. On an average, 46.7% of the applied nitrogen was recovered in plant parts, 10.45 in soil profile, most of which were recovered at 0-15cm depth (87.6% of total soil N) at harvest. The nitrogen unaccounted for was found to be 42.8%.

RICE AND WHEAT YIELDS RESPONSE TO FERTILIZER N AND STRAW MANAGEMENT UNDER A PERMANENT BED PLANTING SYSTEM IN PUNJAB, INDIA

Yadvinder Singh
Punjab Agricultural University
Ludhiana
India

Abstract

Field experiment was conducted on a sandy loam soil at Punjab Agricultural University, Ludhiana, India to study the effects of different methods of crop establishments and N application on crop yields, N uptake, and N and water use efficiency in rice-wheat cropping system during 2002-03. Main plot treatments were direct seeded rice followed by wheat on permanent beds with and without straw mulch (wheat straw in rice and rice straw in wheat), transplanted rice followed by wheat on permanent beds with and without straw mulch, puddled transplanted rice followed by conventional tilled wheat, and direct seeded rice on flat followed by conventional tilled wheat. Subplot treatments were four rates of N (0, 80, 120 and 160 kg ha⁻¹) applied to both rice and wheat. In 120 kg N ha⁻¹ treatment microplots were established, which received 15-N labelled urea during rice and wheat season. Puddled transplanted rice produced the highest grain yield followed by rice transplanted on beds with inter-row placement of wheat straw. Grain yield of rice on flat beds was significantly reduced under direct seeding on flat as compared to that when transplanted in puddled soil. Straw mulching significantly reduced the grain yield of direct seeded rice on beds at all levels of applied N. Grain yield response to applied N was observed up to 160 kg N ha⁻¹ under all the crop establishment treatments, except in case of direct seeded rice on flat where significant response was observed up to 120 kg N ha⁻¹. Dry matter accumulation and N uptake of wheat at 94 days after planting did not differ significantly among different crop establishment treatments when no N was applied. Application of 120 kg N ha⁻¹ significantly increased the dry matter accumulation over no N control. Dry matter of wheat was significantly higher on conventionally tilled plots than on permanent beds in the presence of N fertilizer. Soil temperature at 5-cm depth recorded at 8 am was 1-2^o C higher under rice straw mulch applied on beds than under no mulch. Soil temperature at 3 pm was 1-4^o C lower on straw mulch than on no mulch plots. Grain yield of wheat in no N control treatment was adversely affected by the application of straw mulch, but it had no significant effect on grain yield when 120 and 160 kg N ha⁻¹ was applied to wheat. Grain yield and N uptake were increased significantly in conventionally tilled plots as compared to that obtained on permanent beds in the presence of fertilizer N. Response to N was observed up to 120 kg N ha⁻¹ in conventionally tilled wheat and up to 160 kg N ha⁻¹ under permanent beds. Wheat grain yield was 29.8% higher at 120 kg N ha⁻¹ and 15.6% higher at 160 kg N ha⁻¹ on conventionally tilled plots than planted on permanent beds. Rice straw mulch significantly reduced the N uptake as compared to no mulch at low rates of applied N. The efficiency of N use was lower when rice straw mulch was applied as compared to no mulch.

CROPPING SYSTEM N AND WATER MANAGEMENT: AEROBIC BARLEY IN ROTATION WITH AEROBIC AND WATERLOGGED RICE

Qirong Shen and Yangchun Xu
College of Resources and Environmental Sciences
Nanjing Agricultural University
Nanjing 210095
China

Abstract

Novel rice cultivation in aerobic soil condition is becoming more popular in rice-growing area in China because of its unique advantages, i.e., water and labour saving, small reduction of rice grain. The new rice cultivation system challenges soil scientists in water and nutrient management since the traditional rotation system of “waterlogged (paddy rice)—aerobic (wheat, barley or rapeseed)” is now changed into “aerobic (rice cultivated in aerobic soil) —aerobic (wheat, barley or rapeseed)”. There is almost nothing known about nutrient and water use by the plants in the new rotation system. A field experiment was done from 16 May 2002 to 24 May 2003 (a whole period of rice—barley rotation system) to study the effect of different rice cultivating ways on the nutrient and water management in the system. The main results were as follows. Total mineral nitrogen and nitrate content in aerobic soil were higher than those in waterlogged soil and it was greatly affected by nitrogen fertilizer application. There was no significant residual effect of the proceeding rice cultivation in paddy and in aerobic soil on the content of soil ammonium and nitrate during barley growing period. The growing period of rice was delayed when it was cultivated in aerobic soil with mulching. Nitrogen uptake accumulation of rice was increased with the rice growing stage up to heading and decreased after that. Rice cultivated in waterlogged soil produced the highest grain yield, which was not significantly higher than that of the rice cultivated in aerobic soil with straw mulching. The maximum barley grain yield occurred in the treatment of proceeding plot of rice cultivated in aerobic soil with straw mulching and this might result from the residual effect of mulching straw in the rice season. Water use efficiency of rice cultivated in waterlogged soil was 3 times low than that of rice cultivated in aerobic soil with mulching. Average nitrogen recovery rates from ^{15}N balance at the rate of 180 kg N ha^{-1} were 30%, 31% and 27% in the treatment of rice cultivated in waterlogged soil, and in aerobic soil mulched with plastic film and with straw, respectively. Our preliminary results suggested that barley-rice cultivated in aerobic soil with straw mulching was a best cropping system.

PRODUCTIVITY, WATER USE EFFICIENCY AND HYDROLOGY OF WHEAT ON BEDS AND FLATS IN PUNJAB, INDIA

E. Humphreys¹, P.R. Gajri², S.S. Dhillon², Yadvinder-Singh², S. Thaman², A. Prashar², A. Nayyar² and J. Timsina¹

¹CSIRO Land and Water, PMB 3, Griffith NSW 2680, Australia.

²Punjab Agricultural University, Ludhiana 141 004, Punjab, India

Abstract

Rice-wheat rotations are major contributors to both rice and wheat production in South Asia. However, their sustainability is at risk due to associated problems including groundwater depletion, waterlogging and salinity, deteriorating soil physical conditions, declining soil organic matter content, groundwater and air pollution. Over the past decade it has been shown that wheat can be grown successfully on beds in rice-wheat systems, with many advantages including substantial irrigation water savings and higher yields. However the nature of the water savings has not been quantified, and guidelines for irrigation management for wheat on beds, based on understanding of the system, have not been developed. This report presents the results of field experiments to evaluate irrigation scheduling options for wheat on beds in comparison with the recommended practice for conventionally tilled wheat in Punjab, India.

Replicated, small plot experiments were established on three soil types (sandy loam, loam, reclaimed sodic loam) in November 2002. Irrigation treatments were commenced following an initial common irrigation 2-4 weeks after sowing. Irrigation of beds was scheduled when cumulative pan evaporation minus rain (CPE-R) reached 40, 60 or 80 mm (B40, B60, B80) and when CPE-R=80 mm (recommended practice) or 120 mm on flats (F80, F120). Irrigation treatment application rates were 40 mm on beds and 80 mm on flats.

Mid-season conditions were unusually foggy and cold, and the crops virtually stopped growing during the month prior to anthesis, resulting in lower than normal yields. Grain yields ranged from 3.5 to 3.6 t/ha on the reclaimed sodic loam, and 4.1 to 4.9 t/ha on the other two soils. Lodging prior to heading on the reclaimed sodic loam probably contributed to the lower yields. Rainfall at all sites was much higher than average, and there were no differences in yield between irrigation treatments and layouts, with one exception. On the sandy loam yields on the flats were generally significantly higher than on the beds. This was due to failure of the crop on beds to produce sufficient tillers to compensate for the wider row spacing between the beds. It is not clear why this occurred on the sandy loam, but not on the other two soil types. The poorer yield of beds on the sandy loam is inconsistent with most other studies comparing wheat on beds and flats.

There was a substantial amount of residual soil water in all treatments at all sites at the time of harvest, more so on the two loam soils, largely due to the heavy rain (108-118 mm) prior to anthesis. It is questionable whether the irrigations in March, based on CPE-R, were necessary given that the soil profile was replenished in mid-February, and suggesting that irrigation practice could be more efficient if knowledge of the soil water content were considered in addition to CPE in making irrigation scheduling decisions.

The pattern of crop water extraction was quite different between the bed and flat treatments. The degree of drying at each site was relatively uniform to depth in the flat treatments. In contrast, drying was much greater in the surface layers of the beds, more so on the loam soils, where there was less drying at depth. The crops extracted water to at least 180 cm in all treatments on the sandy loam, and in the flat treatments on the two loam soils, however extraction was confined to the upper 100 and 180 cm in the bed treatments on the two loams. In the bed treatments, soil water depletion from under the beds was greater than from the furrows in the upper layers, and averaged 58-67% of the total soil water depletion over the 0-180 cm profile, consistent with determinations of root length density. Soil water potential gradients indicated drainage fluxes from 120-140 cm throughout the cropping period in F80 and B40 at all sites, and were similar in both treatments, except for the latter part of the season in F80 on the sandy loam, when upward fluxes occurred.

The efficiency of applied water (irrigation plus rain) in producing grain ranged from 1.1 to 1.6 g grain/kg water on the sandy loam and loam soils, and from 1 to 1.2 g/kg on the reclaimed sodic soil. Applied water productivity decreased with increasing irrigation application. There was no effect of layout or soil type on efficiency of use of available water (crop water use/total available water) nor on grain and biomass total water productivity.

MANAGING CROP RESIDUES AND NUTRIENTS IN PERMANENT NO-TILL AND FURROW IRRIGATED BED PLANTED RICE-WHEAT SYSTEMS OF SOUTH ASIA: SOME EXPERIENCES

Raj Gupta¹ and J.K. Ladha²

¹RWC – CIMMYT India, NASC Complex, Pusa, New Delhi 110012, India

²IRRI, Los Baños, Philippines

Abstract

Irrigated rice-wheat systems occupy 13.5m ha in the Indo-Gangetic Plain of South Asia and are a vital source of food for the populous region. Its importance, and threats to sustainability of the RW systems led to setting up of the Rice-Wheat Consortium (RWC) in 1989, with the objectives of sharing knowledge on rice-wheat systems across the vast region, prioritising research on constraints in rice-wheat, and attracting extra funds to well targeted research on priority problems. RWC works in the region with its partners on Resource Conserving Technologies (RCTs), a host of technologies comprising of zero-tillage, bed planting, Leaf Colour Charts for N management etc. These technologies conserve on and off farm inputs thus increasing the farm profits. Local estimates indicate that the area has expanded from almost 2000ha in 1997-98 to about 500,000 hectares in 2002-03. This is truly an agronomic revolution, catalysed by early research by consortium partners, and now driven by several factors including the costs savings achieved, the advantage of zero tillage in control of *Phalaris minor*.

Another revolution, namely planting on the raised beds and irrigating the furrows is promoting aerobic rice and crop diversification in monsoonal climates. Bed planting system is promoting diversification of RW systems with high value crops such as vegetables and pulses. Aerobic rice on raised beds made in unpuddled soils is proving as a major water-wise

rice technology. The advantages include water saving, easier weed and nitrogen management, less waterlogging, less crop lodging, improved grain quality and some times better yield.

Currently, generally beds are remade between crops, involving considerable tillage, with loss of some of the advantages evident in the above described zero tillage system for wheat planted on the flat. Efforts are going on to meet challenge of making the beds more permanent and drills with minimal disturbance for both wheat and rice and other crops year after year on the same beds. Farmers in the sub-continent are still experimenting with the systems and are realizing the potential of transplanting rice and direct dry seeding of rice and other crops in No-Till and furrow irrigated bed planting systems. Use of Sofit and Pendimethylene together with a broad leave herbicide proved helpful in management of weeds in direct seeded / transplanted rice in unpuddled soils.

Although wheat straw does have fodder value and some is still removed after combine harvest, much of the wheat straw and even more of the rice straw is burnt in the field in order to facilitate planting the next crop. The resultant pollution and CO₂ release is substantial, as is the loss of nutrients and potential soil organic matter. Indeed loss of soil organic matter is one of the recognized treats to rice-wheat sustainability. The major challenge in the rice-wheat systems with regards to the No-till and Raised bed Planting systems is seeding crops in presence of loose stubbles.

Use of organics (crop residues) is generally seen as a key issue for soil health and sustainability in intensive rice – based systems, both in terms of maintaining the amount and quality of soil organic matter (SOM) and in terms of supplying important micronutrients (Bronson et al., 1997; Nambiar, 1997; Reichardt et al., 2000; Yadav et al., 2000; Timsina and Connor, 2001). Although general concepts of long-term SOM dynamics are similar in different cropping systems, but the significance of SOM for specific soil properties or crop productivity varies considerably in different types of rice soils and cropping systems (Dobermann and Witt, 2000; Olk et al., 2000) Powlson and Olk, 2000). In a recent analysis of 25 long-term experiments in progress primarily in South Asia, Dawe, et al. (2003) concluded that application of either manure or straw alone did not improve grain yield trends in rice-rice and rice-wheat cropping systems (i.e. organic materials used as the primary nutrient source), but use of manure or straws in these cropping systems may be profitable, provided organics are used to complement a recommended dose of inorganic NPK. In our understanding, most farmers use organics in conjunction with externally added fertilizer nutrient inputs. Of recent, however some farmers have taken to organic agriculture in intensively irrigated tracts. Whether it will be possible for these farmers to sustain current high levels of productivity (8-10tons/ha/yr) with only organics is not clearly understood and known.

This presentation will discuss some of the nutrient and crop residues management practices in relation to resource conserving technologies that improve input use efficiency and crop productivity. The machinery issues are also discussed for management of crop residues and planting of the crops in permanent No-till and furrow irrigated raised bed systems.

Selected References

- Bhandari, A.L., Ladha, J.K., Pathak, H., Padre, A.T., Dawe, D., Gupta, R.K., 2002. Yield and soil nutrient changes in a long-term rice-wheat rotation in India. *Soil Sci. Soc. Am. J.* 66, 162-170.
- Bronson, K.F., Cassman, K.G., Wassman, R., Olk, D.C., van Noordwijk, M., Garrity, D.P., 1997. Soil carbon dynamics in different cropping systems in principal ecoregions of Asia. In: Lal, R. et al. (Eds.) *Management of Carbon Sequestration in Soil*. CRC Press, Boca Raton, Florida, pp. 35-57.
- Dawe, D., A. Dobermann, J.K. Ladha, R.L. Yadav, Lin Bao, R.K. Gupta, P. Lal, G. Panauallah, O. Sariam, Y. Singh, A. Swarup, Q.-X. Zhen. 2003. Do Organic Amendments Improve Yield Trends and Profitability in Intensive Rice Systems? *Field Crops Res.* (in press).
- Dobermann, A., Witt, C., 2000. The potential impact of crop intensification on carbon and nitrogen cycling in intensive rice systems. In: Kirk, G.J.D., Olk, D.C. (Eds.), *Carbon and Nitrogen Dynamics in Flooded Soils*. International Rice Research Institute, Makati City, Philippines, pp. 1-25.
- Gill, H.S., Meelu, O.P., 1982. Studies on the substitution of inorganic fertilizers with organic manure and their effect on soil fertility in rice-wheat rotation. *Fert. Res.* 3, 303-314.
- Ladha, J.K., Dawe, D., Ventura, T.S., Singh, U., Ventura, W., Watanabe, I., 2000a. Long-term effects of urea and green manure on rice yields and nitrogen balance. *Soil Sci. Soc. Am. J.* 64, 1993-2001.
- Powelson, D.S., Olk, D.C., 2000. Long-term soil organic matter dynamics. In: Kirk, G.J.D., Olk, D.C. (Eds.), *Carbon and Nitrogen Dynamics in Flooded Soils*. International Rice Research Institute, Makati City, Philippines, pp. 49-63.
- Timsina, J., Connor, D.J., 2001. Productivity and management of rice-wheat cropping systems: issues and challenges. *Field Crops Res.* 69, 93-132.
- Yadav, R.L., Dwivedi, B.S., Prasad, K., Tomar, O.K., Shurpali, N.J., Pandey, P.S., 2000. Yield trends and changes in soil organic-C and available NPK in a long-term rice-wheat system under integrated use of manures and fertilisers. *Field Crops Res.* 68, 219-246.

PRODUCTIVITY EVALUATION OF RICE-WHEAT CROPPING SYSTEM UNDER NEW CROP ESTABLISHMENT TECHNIQUE

Akhter Hossain Khan¹, Murshedul Alam² & J.K. Ladha²
Bangladesh Rice Research Institute, Gazipur-1701, Bangladesh
²IRRI, Los Baños, Philippines

Abstract

The Rice-Wheat cropping systems occupy about 13.5 million hectares in Indo-Gangetic Plains. It is a dominant cropping system in Bangladesh. Covering about 6% of the cropland, 85% of the wheat is grown in sequence with transplanted Aman (T. Aman) rice, which is grown from July to December. In many recent reports stagnation or in some cases declining in the productivity of rice-wheat system has been reported. Though population growth rate has been assumed to be declined, the population will continue to increase. So, the productivity of Rice-Wheat system will be essential to increase at sustainable manner to feed the ever-increasing population.

In the rice-wheat system, the soil tillth and water requirement of the two crops are contrasting. Puddling of soil for the previous rice crop has also been claimed as one of the important constraints to improving wheat yield for the system. Raised bed planting - a new emerging tillage and crop establishment technique, which do not create problems of puddled soils for the subsequent wheat crop has been evaluating by NARS under the umbrella of RWC of Indo-Gangetic Plains. The use efficiency of fertilizer N and applied water in the rice-wheat system are of critical importance in determining the fertilizer N (using ¹⁵N) and water management in improving the system productivity for the new crop establishment technique. The present study has been developed to evaluate the productivity of the rice-wheat system under conventional and new crop establishment technique in terms of yields, and resource use and efficiency. Linking with the work of RWC, this study is being conducted since 2001-2002 in farmer's fields. There are five different treatments for each rice and wheat crops. Four replications in RCB design were followed. There are 20 plots and there is a micro-plot in each main plot. Micro-plots are constructed by putting a metal frame into the soil. Labelled N (¹⁵N) was applied in micro-plots using the recommended rate to determine N use efficiency. BRRIdhan39 and Kanchan were used in the study.

Grain yields of rice and wheat were affected by different crop establishment techniques. Grain yields produced by transplanting on the puddled flat bed at 20 x 20 cm row spacing (T₁), transplanting on unpuddled raised (permanent) bed at 20 x 30 x 20 cm paired row spacing (T₃) and direct dry seeding on raised (permanent) bed at 20 x 30 x 20 cm paired row spacing (T₄) were comparable. Wheat seeds sown on well-pulverized flat bed (T₁: conventional practice) at 20 cm apart line, sown on raised (permanent) bed at 20 x 30 x 20 cm paired row spacing (T₃) and sown on raised (permanent) bed 20 x 30 x 20 cm paired row (T₄) showed similar trend of rice in grain yield. Significantly lowest grain yield for both crops were obtained from zero tilled plots. Irrigation water savings were, on an average, 23 and 26% more for raised bed planting over the conventional planting practices in Aman and wheat crops, respectively. Water productivity was also higher in both seasons. Results on nutrient uptake will be reported after the completion of plant and soil analysis.

RICE-WHEAT PRODUCTIVITY AS AFFECTED BY MANAGEMENT PRACTICES

J.K. Ladha and C.S. Bueno
International Rice Research Institute
Los Baños
Philippines

Abstract

The rice-wheat (RW) rotation is one of the world's largest agricultural production systems, occupying 17 million ha of cultivated land in the Indo-Gangetic Plains and in China. It accounts for about one-third of the area of both rice and wheat grown in South Asia and its production provides staple grain for more than one billion people (world population exceeds 6 billion). Adoption of green revolution technologies led to impressive increases in rice and wheat production during 1965 to 1985 when the major focus was to maximize outputs. However the future sustainability of an agricultural system strongly depends on maximizing input use efficiency and reducing the cost of cultivation. Technological options for producing more rice and wheat with efficient use of resources (water, labour, fertilizer, and agrochemical inputs) are emerging, but they have yet to be integrated into a systems approach and thoroughly evaluated on farm. Our goal is to integrate resource saving technologies for rice within rice-wheat systems employing resource saving management for wheat. The technologies being considered for integration into the rice-wheat system include land levelling for water savings, production of non-puddled rice for water and labour savings, alternative residue management for environmental protection and nutrient savings, and balanced nutrient management for fertilizer savings. This work involves an interdisciplinary team of IRRI scientists with NARES, RWC, CIMMYT, and other IARCs and organizations.

During last two years, the following activities were carried out in Bangladesh, India, Nepal and Pakistan.

Major research topics include:

- Analysis of yield trends and changes in nutrient dynamics and balances.
- Development of soil test/biochemical indices to estimate soil nutrient supply and to monitor soil organic matter quality.
- Evaluation of integrated nutrient management strategies for yield maximization.
- Development, evaluation and dissemination of field specific nutrient management strategies for improving productivity and farm profitability.
- Development and evaluation of aerobic or non-puddled rice production system with laser-aided land levelling within rice-wheat systems employing minimal tillage for wheat.
- Development of strategies for rapid decomposition and management of straw left on surface after combined harvest for planting of wheat with zero tillage.
- Increase the capacity of NARS scientists in rice research in rice-wheat system through training and interdisciplinary research.

This paper will review the recent results on a few selected topics.

¹⁵N STEM INJECTION TECHNIQUE FOR EVALUATION OF BELOW GROUND BIOMASS AND ROOT DERIVED N OF WHEAT UNDER CONVENTIONAL FLAT BED AND RAISED BED PLANTING SYSTEMS

M.S. Sachdev
Nuclear Research Laboratory
Indian Agricultural Research Institute
New Delhi – 110 012
INDIA

Abstract

The amount of fertilizer nitrogen uptake by wheat grown in conventional flat beds and on raised beds was estimated. Also the amount of residual fertilizer N in soil after the wheat harvest was determined in the two planting geometries. Further, an attempt was also made to estimate the amount of below-ground biomass (BGB) and the amount of N requirement for the same under the two planting geometries in field conditions using the ¹⁵N stem injection technique. The identical investigations were carried out in two climatic situations, one at the Seibersdorf laboratory of the IAEA, where the wheat crop was grown in freshly prepared field plots during April – July, 2002, and the other at the research farm of the Indian Agricultural Research Institute in conventional flat beds and raised beds made in the previous season with rice crop and planted with wheat with zero tillage operation except minor reshaping of the raised beds during 2002-03 winter season.

In clayey soil of the Seibersdorf site the grain as well as the total dry matter yield in raised bed planted wheat was lower than the conventional flat bed planting. However, at IARI site in clay-loam soil it was similar in both the planting conditions. The fertilizer N recovery in the above ground biomass (grain and straw) at Seibersdorf was 60.7% and 58.5%, respectively, in raised bed and flat bed planting conditions. While at IARI site the corresponding values were 55% and 53.2%, respectively. Under flat bed planting conditions 40 per cent of the applied fertilizer N could be found in the residual form in the soil to a depth of 45 cm. Under raised bed conditions the distribution of residual fertilizer N in beds and furrows was skewed. In the raised bed soil (0-15cm) there was appreciable amount but below the bed it was much less compared to that in furrows on either side. The data of residual fertilizer N under raised bed conditions at two sites showed similar trend but differed in amount.

Nearly 92 to 95 % of the stem-injected ¹⁵N could be traced in soil-plant system. Most of the injected ¹⁵N could be traced in the injected tiller of the wheat plant. The recoverable roots of the injected plant contained less than 1 per cent of the injected ¹⁵N and nearly 27.5 to 35 % was found in the soil sampled below the injected plant to a depth of 45 cm, with maximum amount being present in upper 10 cm soil. The below-ground biomass (BGB) estimate based on the ¹⁵N determined in the sampled soil and in recoverable roots was 4.87 and 4.44 t ha⁻¹ under raised and flat bed conditions, respectively, at IARI site and the estimates for the same at Seibersdorf site are 5.00 and 5.63 t ha⁻¹. The nitrogen requirement of the BGB ranged from 30.4 to 40.5 kg ha⁻¹. Thus the data show the potentiality of estimating the BGB, mainly roots and root-derived nitrogen under field conditions using the ¹⁵N stem injection technique. The technique can be further refined by sampling the soil in more number of layers with lesser soil thickness and under raised bed planting conditions sampling the soil in the furrow region also, as considerable proportion of the residual fertilizer N was traced in the soil in furrows.

INTERACTIONS BETWEEN SILICON AND PHOSPHORUS IN FLOODED AND NON-FLOODED SOILS DETERMINED BY ^{30}Si and ^{32}P

Graeme Blair
Agronomy and Soil Science
University of New England,
Armidale NSW 2350
Australia

Abstract

The research objectives are:

1. To determine the impact of additions of silicon on phosphorus dynamics in soil, and
2. To determine the impact of soil water status on the dynamics of P and Si in a rice/wheat system.

A preliminary experiment has been conducted where ^{32}P was used to study the effect of Si addition on P dynamics in a non-flooded soil growing wheat. Application of an activated olivine resulted in a marked growth response in rice and in significant modification of P uptake, fertiliser P recovery by the plant and P sorption by the soil. It is hypothesised that the silicate ion competes with the phosphate ion for sorption and that this increases P utilisation efficiency.

A series of glasshouse trials have been conducted to identify a soil suitable for the main experiment where ^{30}Si and ^{32}P will be used. The soils investigated have been collected largely from North Queensland, Australia where responses to Si application have been reported. Using rice as a test crop a P and Si responsive soil has been identified in one unfertilised soil and a bulk sample of this is being collected.

Laboratory work has progressed to develop a digestion procedure to enable determination of $^{28}\text{Si}/^{30}\text{Si}$ ratios in an ICP-MS. It is essential to have a digest that does not contain NO (mass 30) as this would interfere with the measurement of ^{30}Si . A microwave digestion procedure has been developed using $\text{H}_2\text{SO}_4/\text{H}_2\text{O}_2/\text{HF}$ and plant and soil digests.

A procedure has been evaluated to produce monosalicylic acid from SiO_2 by fusion with Na_2CO_3 in a platinum crucible. This has proved to be successful and a second procedure, which has been used in ^{30}Si experiments in Japan, is being evaluated.

¹⁵N STEM INJECTION TECHNIQUE FOR EVALUATION OF BELOW GROUND BIOMASS AND ROOT DERIVED N OF WHEAT UNDER CONVENTIONAL FLAT BED AND RAISED BED PLANTING SYSTEMS

Fayyaz Hussain
Land Resources Research Program
NARC, PO NIH-45500
Islamabad
Pakistan

Abstract

The prevalent cropping systems in Pakistan are cotton-wheat, rice-wheat, and maize-wheat. Rice-wheat system is the most important cereal system in Pakistan. It is practiced on 1.5 million ha in Punjab and 0.3 million ha in Sindh. Despite prime position of rice and wheat, productivity of the system is poor, with average rice yield of 2.0 t ha⁻¹ and that of wheat less than 2.2 t ha⁻¹. Wheat is aerobic crop and is sown in rotation with anaerobic rice crop that is commonly sown by using traditional methods of flat sowing and flood irrigation, which entails a significant consumption of water and accompanying water losses. Soil puddling is generally considered beneficial for rice, but it destroys soil aggregates and creates hardpan that can restrict the rooting depth of both rice and wheat. Furthermore, the poor soil structure produced due to puddling creates interference in establishment of wheat timely and often leads to poor crop stands and growth. To overcome the problems new alternative techniques have been introduced for rice and wheat. Direct seeding on unpuddled soil and raised beds has been proposed as alternative rice establishment methods for rice and zero tillage and bed sowing for wheat. There is a need to compare the new tillage and crop establishment techniques in the rice-wheat area with conventional methods.

Therefore, by keeping in view the objective to improve the productivity and sustainability of rice-wheat cropping system through increased efficiency of water and nutrient use, a field experiment were conducted on rice and wheat in the alluvial plain at an altitude of 214 m above mean sea level. The climate of the region is semi-arid. The average rainfall during the growing season of rice was 34.3 mm. The mean maximum and minimum temperatures during rice were 34.4 °C and 24.5 °C, respectively. The experiments were laid out by following the randomised complete block design with five treatments and four replications. One micro-plot was established in each main plot. The micro plot size in flat bed was 0.8 m x 1.0 m = 0.8 m² and in raised bed 0.67 m x 1.2 m = .804 m². Nitrogen was applied as urea (120 kg N ha⁻¹) in three equal split doses (Basal, MT stage and PI stage). Phosphorus as SSP (60 kg P₂O₅ ha⁻¹) and K as SOP (60 kg K₂O ha⁻¹) were applied as basal.

Rice transplanted on raised beds produced the highest paddy (4388 kg ha⁻¹) and straw (6194 kg ha⁻¹) followed the rice transplanted on puddled flat bed treatment (20x20 cm apart). The lowest paddy (3337 kg ha⁻¹) and straw (5036 kg ha⁻¹) yield was recorded in treatment where direct seeding was done on flat beds. Percent nitrogen derived from fertilizer (%Nddf) differed significantly in different crop establishment treatments. Highest %Nddf was in the puddled rice transplanted on flat beds followed by the rice transplanted on raised beds while the N yield showed the reverse trend. Different cultural practices resulted different fertilizer N yield. The highest total fertilizer N yield (41.53 kg ha⁻¹) was recorded in puddled flat bed followed by the treatment where rice was transplanted on the raised beds. But the difference

was non significant. The lowest total fertilizer N yield (27.89 kg ha^{-1}) was in the direct seeding treatment. Recovery efficiency ranged from 23.24% to 34.61% and showed the similar trend like fertilizer N yield. The water saving was significantly high in raised bed transplanting than all other crop establishment treatments. Our preliminary results of rice crop suggested that rice transplanted on raised beds is the best crop establishment technique than all other treatments used in this study. The results of wheat crop will be reported after the completion of ^{15}N analysis.

4. Conclusions and Recommendations

The progress towards achieving the project objectives since the beginning of the CRP (1 October 2001) was thoroughly reviewed. All contractors are following the experimental protocols established at the 1st RCM (04 – 08 March 2002). Based on the progress reports received and the oral presentations made, it was concluded that the project participants have achieved satisfactory progress, and no deviations from the previously agreed work plans were foreseen.

Conclusions:

The participants concluded that:

- Yields of wheat and rice on furrow-irrigated raised beds (FIRB) or aerobic cultivation (AC) of rice in China are variable in comparison with conventional agronomic practices (flats) for wheat and rice
- Irrigation water, seed, fuel and labour are saved on-farm under FIRB and AC, but the consequences on a regional scale with respect to water are unclear
- Mulching for rice and wheat gives variable responses across sites in comparison with non-mulched treatments and the reasons are poorly understood
- Current nitrogen fertilizer practices (forms, rates, timing, placement) used in FIRB/AC and flats result in poor use efficiency and potential adverse environmental effects including nitrate pollution of ground and surface waters and atmospheric pollution (ammonia, nitrous oxide), especially when overused
- Imbalanced use of nutrients, especially N, P and K, and increasingly S and Zn, is widespread in R-W systems. Tools are currently being developed to identify and correct the imbalances.
- Direct seeding of rice and zero-till of wheat on flats and FIRB are expanding in the IGP, but FIRB is yet to be introduced in China. Weed control is a problem with direct-seeded rice under current economic conditions and with existing technologies, and is being studied in other projects.
- FIRBs are viable layouts in many situations in the short-term but studies on their long-term performance and resilience are beyond the scope of the CRP.
- Root-derived N and below-ground biomass of wheat under FIRB and flats, as determined by N-15 foliar labelling, did not differ at two sites with contrasting soil texture, but the technique requires further validation and refinement using supplementary isotope labelling techniques. Such techniques need to be evaluated with rice.

- Crop diversification in R-W systems is desirable, but is not a specific research objective of the CRP. Permanent FIRB offer opportunities for crop diversification/intercropping.
- Soil sampling techniques to accurately estimate N and water balance under FIRB/AC and flats need to accommodate layout heterogeneity.
- Economic and risk analysis and modelling which take account of spatial and temporal variation will aid in the identification, evaluation and adoption of the most appropriate resource conserving technologies for different situations across the R-W areas.
- Silicic acid can increase fertiliser P efficiency on some soils which has the potential to reduce fertilizer P requirements and P losses to the environment.

Recommendations:

- Treatments, tailored to local conditions, as specified in the report of the first RCM, to be continued.
- Renegotiate the way the data is being centrally collected and synthesised in terms of public access and publication with the view of protecting ownership
- Contractors to respond in a timely manner to requests for annual reports, requests for contract renewals and supply of equipment, labelled fertilizers and analytical services.
- Participants are encouraged to publish the results of their research with due acknowledgements, and to make all participants and the project officer aware of the publications.
- 3rd RCM in Feb/March 2005 in Bangladesh to coincide with the 12th Meeting of the Regional Technical Co-ordination Committee (RTCC) of the Rice-Wheat Consortium (RWC) of the Indo-Gangetic Plain (IGP).
- The CRP to continue beyond R3 (Sept 30, 2005) with funding for at least an additional 6 months (R4) and a 4th RCM in March 2006. Australia to be considered as the venue for the 4th RCM.

5. List of participants

Research Contracts:

Dr. Md. Akhter Hossain Khan **BGD-11757** (in lieu of Dr. Md. Murshedul Alam)

Rice Farming Systems Division
Bangladesh Rice Research Institute
Gazipur - 1701

Bangladesh

Tel.: +88 02 9350122
+88 02 8825341 (IRRI Dhaka Office)
e-mail: petrrab@dhaka.net

Dr. Qirong Shen **CPR-11758**

College of Resources and Environmental Sciences
Nanjing Agricultural University
Nanjing 210095, Jiangsu Province

P.R. China

Tel.: +86 (25) 4395212
Fax: +86 (25) 4432420
e-mail: qrshen2003@yahoo.com.cn

Dr. Jiarong Pan **CPR-11759**

Institute for Application of Atomic Energy
Chinese Academy of Agricultural Sciences
Department of Agro-Ecological Environment
P.O. Box 5109
Beijing 100094

P.R. China

Tel.: +86 (10) 62815875
Fax: +86 (1) 62896314
e-mail: panjr@263.net

Dr. M.S. Sachdev **IND-11761**

Nuclear Research Laboratory
Indian Agricultural Research Institute
New Delhi – 110 012

India

Tel/Fax: +91 11 25733063 (Residence);
Tel/Fax: +91 11 25842902 (Office)
Fax: +91 11 25842454 / 25847705 / 258466420
Mobile: +91 9811379500
e-mail: mssachdev@excite.com; mssachdev@iari.res.in

Dr. Yadvinder Singh **IND-11762**

Department of Soils
Punjab Agricultural University
Ludhiana, Punjab 141 004

India

Tel: +91 (161) 401961
Fax: +91 (161) 400945
e-mail: yadvinder16@rediffmail.com

Dr. R. C. Munankarmy **NEP-11763**

Nepal Agricultural Research Council
Soil Science Division
P.O. Box 5459
Kathmandu

Nepal

Tel.: +977 (1) 47 30 42 or 49 97 30
Fax: +977 (1) 521197
e-mail: ram@neparequest.cjb.net

Dr. Fayyaz Hussain **PAK-11764**

Land Resources Research Program
National Agricultural Research Centre
PO NIH, Park Road
Islamabad 45500

Pakistan

Tel.: +92 (51) 9255218 (res. 22 41 716)
Fax: +92 (51) 9255034
e-mail: fayyazbhatti2001@yahoo.co.uk or drfayyaz@isb.comsats.net.pk

Technical Contracts:

Dr. Graeme Blair **AUL-12446**

University of New England
Department of Agronomy and Soil Science
Armidale, NSW 2351

Australia

Tel. +61 267 73 2687
Fax: +61 267 73 3465
e-mail: gblair@metz.une.edu.au

Ms. Crisanta S. Bueno **PHI-12497** (in lieu of Dr. J.K. Ladha)
Crop, Soil & Water Sciences Division
International Rice Research Institute (IRRI)
DAPO Box 7777, Metro Manila
Philippines
Tel.: +63 (2) 845 0563; 845 0569
Fax: +63 (2) 845 0606; 891 1292
e-mail: C.Bueno@cgiar.org

Research Agreements:

Dr. Elizabeth Humphreys **AUL-11756**
CSIRO Land and Water
Griffith Laboratory
Research Station Road
Private Bag 3
Griffith, NSW 2680
Australia
Tel.: +61 (2) 69601528
Fax: +61 (2) 69601600
e-mail: liz.humphreys@grf.clw.csiro.au

Dr. Raj Gupta **IND-11760**
Rice-Wheat Consortium for Indo-Gangetic Plains, CIMMYT India Office
CG Block, Ground Floor
National Agriculture Science Centre
DPS Marg, Pusa Campus
New Delhi 110 012
India
Tel.: +91 (11) 25842940 or 25847432
Fax: +91 (11) 25842938
e-mail: r.gupta@cgiar.org

Scientific Secretary:

Phillip M. Chalk
Head, Soil and Water Management & Crop Nutrition Section
Joint FAO/IAEA Division of Nuclear Techniques and Agriculture
Wagramer Strasse 5
P.O. Box 100
A-1400 Vienna
Austria
Fax: (+43 1) 26007
Tel.: (+43 1) 2600 ext. 21648
Email: P.M.Chalk@iaea.org
Internet: <http://www.iaea.org>

Co-ordinated Research Project Progress Report

Part A.

1. Title of Co-ordinated Research Project:

Integrated Soil, Water and Nutrient Management for Sustainable Rice-Wheat Cropping Systems in Asia (D1.50.07)

2. Specific Research Objective:

The overall objective of this CRP is to improve the productivity and sustainability of rice-wheat cropping systems through increased efficiency of water and nutrient use.

The specific objective of this CRP is to modify existing water and nutrient management systems, and improve soil management in both traditional and emerging (raised beds, non-puddled soil, direct seeding) tillage systems, for sustainable intensification of cereal production.

3. Continued Relevance to Agency Project and Target Countries:

This CRP addresses the important issue of optimum use of natural resources and external inputs in crop production in intensive rice-wheat systems in Asia, and as such is directly relevant to the Projects E1.01 “Development of integrated plant nutrient and water management practices for increasing soil fertility and crop yields”. The rice-wheat cropping system in Asia covers some 12.5 Mha in the countries of the Indo-Gangetic Plain (IGP), which includes Bangladesh, India, Nepal and Pakistan and, and 13.5 Mha in China, and is absolutely essential for the food security of over 2 billion inhabitants of these countries. Overexploitation of the natural resource base and the overuse of external inputs (fertilizers, irrigation water, pesticides) threaten the long-term sustainability, productivity and profitability of this cropping system.

The CRP addresses major issues of sustainable development that were identified in international fora such as UNCED (Rio, 1992) and the WSSD (Johannesburg, 2002) that require urgent action. The Agency is well positioned to continue to make a contribution to this effort through collaboration with existing international and bilateral research networks (The Rice-Wheat Consortium of the IGP, ACIAR-PAU Project, etc.). It adds value to on-going research efforts through the strategic use of nuclear and related techniques to gain unique information and thus a better understanding of nutrient and water dynamics in the R-W system. The Agency has a comparative advantage in the international arena through the operation of its research contracts programme, procurement of equipment and supplies, and its laboratories at Seibersdorf, which can provide isotope analytical services, external quality assurance and training to CRP participants.

4. Outputs:

Expected	Present status
1. Improved understanding of nutrient and water dynamics and balances with emerging tillage practices in rice-wheat systems	Experiments to date have shown that modified management systems have resulted in variable responses and experiments to understand such variation are underway
2. Recommendations for improved soil, water and nutrient management in rice-wheat systems formulated.	Aerobic rice cultivation system (including intercropping) with straw mulch has been shown to be very successful in China and is recommended for adoption in high rainfall areas and those with polluted surface waters and in soybean and peanut cropping areas FIRB offers the prospect to improve WUE
3. Means to extrapolate experimental findings across the rice-wheat system developed.	Technical contract awarded to J.K. Ladha (IRRI) to simulate water and nitrogen interactions in the rice-wheat cropping system using DSSAT models.
4. NARS capacity to conduct integrated soil, water and nutrient management studies with the aid of nuclear techniques enhanced	Through the activities of the CRP, participants have gained experience on the use of isotope techniques such as i) the soil moisture neutron probe to monitor soil water status ii) ¹⁵ N labelled fertilizers to estimate crop recovery and losses iii) ¹⁵ N foliar labelling to estimate below ground biomass and root-derived N
5. Research findings communicated to the wider community.	Results of foliar labelling work summarized in IAEA Soils Newsletter and reports of first and second RCM are available on the NAFA website

5. Activities

Expected	Present Status
1. Organise the first RCM and training workshop to establish protocols for experiments to be conducted by the participants within the framework of the CRP.	The first RCM and training workshop was held in Vienna and Seibersdorf from 4 – 8 March 2002. All participants presented reports of on-going work in the rice-wheat systems of the IGP and China. Experimental protocols were established and the experimental guidelines were provided to all the participants in the report of the RCM.
2. Initiation of experiments according to the guidelines provided. The Agency to provide ¹⁵ N-labelled fertilisers to the contract holders and assistance in analysis of soil and plant samples for ¹⁵ N. The Agency to order soil moisture neutron probes (SMNP) and accessories for India (1), Bangladesh (1), Pakistan (1) and Nepal (1). The Agency to provide training on the SMNP and other soil water measuring devices	Field experiments have been established according to the experimental guidelines provided. Labelled fertiliser (¹⁵ N) was supplied to all contract holders in 2002 and 2003 and the soil and plant samples sent by the contract holders were analysed at the Soil Science Unit, Seibersdorf. SMNPs and accessories were ordered for each of the 4 IGP countries. Training was provided to participants/technicians from India and Pakistan during July 2003.
3. Organise the second RCM to review the progress of the project. All participants to provide progress reports. All participants to present and discuss their experimental results.	The second RCM was held in Nanjing, PR China, 8 – 12 Sept 2003. All contract and agreement holders submitted reports highlighting their major achievements and participated in the RCM. Results were evaluated in line with CRP objectives.

6. Overall Assessment of Progress Towards Achieving Objective:

Two of the contract holders (Mr. M. Alam, Bangladesh and Mr. R. Shrestha, Nepal) left the project in its early stages of implementation. They were replaced immediately by Mr. A. Khan and Mr. R. Munankarmy from their respective research institutes. One agreement holder (Mr. J.K. Ladha, IRRI) became a technical contract holder, taking on the responsibility for the modelling component of the CRP. Another technical contract was awarded to Mr. G. Blair (Australia) for an innovative proposal to study interactions between P and Si using the radioactive isotope ³²P and the stable isotope ³⁰Si, respectively. The CGIAR, CIMMYT-India (Mr. R. Gupta) and IRRI-Philippines (Mr. J.K. Ladha) continued to provide close technical and managerial support to contract holders in the IGP (Pakistan, India, Nepal, Bangladesh) through the operations of the Rice-Wheat Consortium (RWC). Also the bilateral ACIAR-India project continued to support collaborative efforts between CSIRO (Ms. E. Humphreys) and PAU (Mr. Y. Singh).

Field experiments have been conducted over two years (Oct. 2001- Sept. 2003) at multi-locations in five countries according to protocols established at the first RCM. Key factors affecting the performance of rice and wheat in this diverse range of environments under a range of cultural practices have been identified. Key processes in resource use efficiency by

rice and wheat (water and nitrogen fertilizer dynamics, root distribution) have been quantified through the use of nuclear and related techniques. This information has been incorporated into planned experiments to study the impact of innovative management practices on productivity and sustainability. Experiments have commenced and analytical procedures developed to study the interactions between P and Si under flooded and aerobic conditions using isotopic tracers.

7. Adjustments to Proposed Work Plan Until Next RCM:

No major deviations from the agreed experimental protocols established at the first RCM are contemplated.

An updated logical framework of the project is attached.

8. Expenditure to Date (\$):

Contracts:	98, 000
Meetings:	23, 531 (1 st RCM); 18, 150 (2 nd RCM)
Labelled fertilizer:	45, 067
Total:	184, 748 =====

9. Proposed Future Expenditures (\$)

Contracts:	57, 000 (R2); 57, 000 (R3); 26, 000 (R4, 6 months)
Meetings:	20, 000 (3 nd RCM); 25, 000 (4 th RCM)
Labelled fertilizer:	45, 000
Total:	230, 000 =====

Logical Framework for Co-ordinated Research Project on “Integrated Soil, Water and Nutrient Management for Sustainable Rice-Wheat Cropping Systems in Asia” (D1.50.07)

9. Logical Framework

Narrative Summary	Verifiable Indicators	Means of Verification	Important Assumptions
<p>Overall objective</p> <p>To improve the productivity and sustainability of rice wheat cropping systems through increased efficiency of water and nutrient use</p>	<p>N/A</p>	<p>N/A</p>	<p>N/A</p>
<p>Specific objective</p> <p>To modify existing water and nutrient management systems, and improve soil management in both traditional and emerging (raised beds, non-puddled soil, direct seeding) tillage systems, for sustainable intensification of cereal production</p>	<p>Improved soil, water and nutrient management practices in rice - wheat systems identified</p>	<p>Crop yield data. Data on water and nutrient use efficiencies</p>	<p>Support from national authorities and the rice-wheat consortium is provided to participants</p> <p>Close co-ordination provided between contract and agreement holders and the Agency</p> <p>Appropriate technical and managerial support provided by the Project Officer</p> <p>Adequate funding available</p>

Narrative Summary	Verifiable Indicators	Means of Verification	Important Assumptions
<p>Outputs</p> <p>1. Recommendations for improved soil, water and nutrient management in rice-wheat systems</p>	<p>Contract holders test: The effect of traditional and innovative tillage systems on water and nutrient dynamics The impact of residue management and cropping systems on water and nutrient flows Strategies for management of external inputs of macro (N, P, K & S) and micro - nutrients Modelling approaches are evaluated.</p>	<p>Annual reports</p>	<p>Appropriate experimental design. Effective research teams. Sufficient human, institutional and financial resources. Favourable climatic conditions.</p>
<p>2. Means to extrapolate experimental finding across the system</p>	<p>Modelling approaches are evaluated.</p>	<p>Models used to extend results beyond the experimental areas</p>	<p>Modelling expertise available</p>
<p>3. NARS capacity to conduct integrated soil, water and nutrient management studies with the aid of nuclear techniques enhanced</p>	<p>Contract holders are trained and use nuclear-based techniques in their research.</p>	<p>Successful completion of training workshop at first RCM. Annual progress reports. Publications. New project initiatives formulated.</p>	<p>Contract holders receive sufficient training. Equipment and analytical facilities available in institution. Scientists in CRP remain active in research and obtain competitive research grants.</p>
<p>4. Research findings communicated to the wider community</p>	<p>Research results disseminated through publication of TECDOC, guidelines, scientific papers, and conference and workshop presentations.</p>	<p>Citations in abstracting journals. Demand for publications. Website visits.</p>	<p>Contract holders write manuscripts; project officer co-ordinates publications.</p>

Narrative Summary Activities	Verifiable Indicators	Means of Verification	Important Assumptions
<p>1. Consultants' Meeting formulates CRP</p> <p>2. Project Officer, Consultants and RWC identify key institutions and personnel to participate in CRP</p> <p>3. Research network formed through research contracts and agreements</p> <p>4. 1st research co-ordination meeting finalizes workplan and experimental protocols and contract holders trained</p> <p>5. Research specified in work plan conducted according to timeframe</p> <p>6. 2nd research co-ordination meeting reviews progress, plans research and drafts CRP review document.</p> <p>7. 3rd research co-ordination meeting reviews progress and plans research</p> <p>8. 4th research co-ordination meeting reviews CRP activities, formulates conclusions and recommendations.</p> <p>9. Publications and CRP evaluation</p>	<p>CM held 23-25 August 2000, project document prepared and submitted to PCC NA</p> <p>Project Officer gathers information and contacts prospective clients</p> <p>Research proposals and agreements received and evaluated by July 2001, and submitted to PCC for approval by August 2001.</p> <p>1st RCM and training workshop held 4-8 March 2002. Workplans and experimental protocols were developed and agreed.</p> <p>Annual progress reports submitted on time</p> <p>2nd RCM held 8-12 Sept. 2003. Annual progress reports submitted. CRP review document drafted and submitted to PCC.</p> <p>By April 2005 RCM held. Annual progress reports submitted on time</p> <p>By Oct 2006 final RCM held. Final reports and manuscripts submitted on time</p> <p>By Oct 2007 all manuscripts received, edited and peer-reviewed where necessary. CRP evaluation completed by project officer</p>	<p>Report of Consultants' Meeting and Project Document. PCC NA 27 Approves CRP2001-02-16</p> <p>Research contract proposals and agreements submitted</p> <p>PCC NA 31 approved 7 contracts and 4 agreements 2001/08/30. Project commenced 2001-10-01. CRP documents on file.</p> <p>Report of RCM</p> <p>Individual annual reports on file</p> <p>Report of RCM, annual progress reports, CRP review document and PCC memo on file.</p> <p>Report of RCM</p> <p>Final reports and manuscripts, report of final RCM, evaluation of CRP document on file</p> <p>TECDOC and special journal issue published. CRP evaluation doc. on file in NACA.</p>	<p>Consultants available and actively participated. PCC NA approves CRP</p> <p>Appropriate institutions and scientists notified of CRP</p> <p>Scientists and funding available. PCC gives approval for initial contracts and agreements.</p> <p>Scientists and funding available</p> <p>Scientists and funding adequate to conduct research</p> <p>Scientists submit reports and participate in RCM. PCC approves CRP extension.</p> <p>Scientists submit reports and participate in RCM</p> <p>Scientists submit reports and participate in RCM.</p> <p>Manuscripts of sufficient quality received. Funds available for editing and publication.</p>

PART B

Summary of the Second Research Co-ordination Meeting of the Co-ordinated Research Project on “Integrated Soil, Water and Nutrient Management for Sustainable Rice-Wheat Cropping Systems in Asia” (Project E1.02, Task 3)

Dates: 8 – 12 September 2003

Location: Nanjing, China

Scientific Secretary: Phillip Chalk

1. LIST OF PARTICIPANTS

Name	Institute	Contract/Agreement No.	Title of Project
HUMPHREYS, Elizabeth	CSIRO Land and Water Griffith Laboratory Research Station Road Private Bag 3 Griffith, NSW 2680 Australia	AUL-11756	Permanent raised beds for sustainable irrigated cropping system in the rice-wheat areas of Australia
KHAN, Md. Akhter Hossain	Rice Farming Systems Division Bangladesh Rice Research Institute Gazipur – 1701 Bangladesh	BGD-11757	Integrated soil, water and nutrient management for sustainable rice-wheat cropping systems in Bangladesh
SHEN, Qirong	College of Resources and Environmental Sciences Nanjing Agricultural University Nanjing 210095, Jiangsu Province P.R. China	CPR-11758	Integrated water and nitrogen management for rice cultivated in upland soil compared to rice in traditional waterlogged soil
PAN, Jiarong	Institute for Application of Atomic Energy Chinese Academy of Agricultural Sciences Department of Agro- Ecological Environment P.O. Box 5109 Beijing 100094 P.R. China	CPR-11759	The use of nuclear and related techniques to enhance the efficient use of nitrogen fertilizers for sustainable rice-wheat rotation systems
GUPTA, Raj	Rice-Wheat Consortium for Indo-Gangetic Plains, CIMMYT India Office CG Block, Ground Floor National Agriculture Science Centre DPS Marg, Pusa Campus New Delhi 110 012 India	IND-11760	Study on sustaining the rice-wheat systems in Asia

Name	Institute	Contract/Agreement No.	Title of Project
SACHDEV, Manbir Singh	Nuclear Research Laboratory Indian Agricultural Research Institute New Delhi – 110 012 India	IND-11761	Isotope aided investigations for developing integrated soil, water and nutrient management for sustained production in the rice-wheat system
SINGH, Yadvinder	Department of Soils Punjab Agricultural University Ludhiana, Punjab 141 004 India	IND-11762	Integrated soil, water and nutrient management for sustainable rice-wheat cropping systems in Punjab, India
MUNANKARMY, Ram	NEPAL AGRICULTURAL RESEARCH COUNCIL Soil Science Division P.O. Box 5459 Kathmandu Nepal	NEP-11763	Integrated soil, water and nutrient management for sustainable rice-wheat cropping systems in Nepal
HUSSAIN, Fayyaz	Land Resources Research Program National Agricultural Research Centre PO NIH, Park Road Islamabad 45500 Pakistan	PAK-11764	Integrated soil, water and nutrient management for sustainable rice-wheat cropping systems in Pakistan
BLAIR, Graeme	University of New England Department of Agronomy and Soil Science Armidale, NSW 2351 Australia	AUL-12446	Interactions between silicon and phosphorus in flooded and non-flooded soils determined by ³⁰ Si and ³² P
LADHA, Jagdish BUENO, Crisanta (alternate)	Crop, Soil & Water Sciences Division International Rice Research Institute (IRRI) DAPO Box 7777, Metro Manila Philippines	PHI-12497	Simulating water and nitrogen interactions in the rice-wheat cropping system

2. Summary of Work Done/Results Achieved:

Participant	Report Received Yes/No	Satisfactory Yes/No	Continued Participation Yes/No
E. Humphreys (A)	Yes	Yes	Yes
M. Khan (R)	Yes	Yes	Yes
Q. Shen (R)	Yes	Yes	Yes
J. Pan (R)	Yes	Yes	Yes
R. Gupta (A)	Yes	Yes	Yes
M. Sachdev (R)	Yes	Yes	Yes
Y. Singh (R)	Yes	Yes	Yes
R. Munankarmy (R)	Yes	Yes	Yes
F. Hussain (R)	Yes	Yes	Yes
G. Blair (T)	Ann. Report due by 2004-03-14	Yes (interim report)	Yes
J. Ladha (T)	Ann. Report due by 2004-04-14	Yes (interim report)	Yes

A = agreement; T = technical contract; R = research contract

3. Main Scientific/Technical Conclusions from Meeting:

- Yields of wheat and rice on furrow-irrigated raised beds (FIRB) or aerobic cultivation (AC) of rice in China are variable in comparison with conventional agronomic practices (flats) for wheat and rice.
- Irrigation water, seed, fuel and labour are saved on-farm under FIRB and AC, but the consequences on a regional scale with respect to water are unclear
- Mulching for rice and wheat gives variable responses across sites in comparison with non-mulched treatments and the reasons are poorly understood.
- Current nitrogen fertilizer practices (forms, rates, timing, placement) used in FIRB/AC and flats result in poor use efficiency and potential adverse environmental effects including nitrate pollution of ground and surface waters and atmospheric pollution (ammonia, nitrous oxide), especially when overused
- Imbalanced use of nutrients, especially N, P and K, and increasingly S and Zn, is widespread in R-W systems. Tools are currently being developed to identify and correct the imbalances.
- Direct seeding of rice and zero-till of wheat on flats and FIRB are expanding in the IGP, but FIRB is yet to be introduced in China. Weed control is a problem with direct-seeded rice under current economic conditions and with existing technologies, and is being studied in other projects.
- FIRBs are viable layouts in many situations in the short-term but studies on their long-term performance and resilience are beyond the scope of the CRP.
- Root-derived N and below-ground biomass of wheat under FIRB and flats, as determined by N-15 foliar labelling, did not differ at two sites with contrasting soil texture, but the technique requires further validation and refinement using supplementary isotope labelling techniques. Such techniques need to be evaluated with rice.
- Crop diversification in R-W systems is desirable, but is not a specific research objective of the CRP. Permanent FIRB offer opportunities for crop diversification/intercropping.
- Soil sampling techniques to accurately estimate N and water balance under FIRB/AC and flats need to accommodate layout heterogeneity.

- Economic and risk analysis and modelling which take account of spatial and temporal variation will aid in the identification, evaluation and adoption of the most appropriate resource conserving technologies for different situations across the R-W areas.
- Silicic acid can increase fertiliser P efficiency on some soils, which has the potential to reduce fertilizer P requirements and P losses to the environment.

4. Recommendations:

(a) To Participants

1. Workplans

- Treatments, tailored to local conditions, as specified in the report of the first RCM, to be continued.

2. Modelling of data

- Renegotiate the way the data is being centrally collected and synthesised in terms of public access and publication with the view of protecting ownership

3. Contractual obligations/reporting

- Contractors to respond in a timely manner to requests for annual reports, requests for contract renewals and supply of equipment, labelled fertilizers and analytical services.

4. Publications

- Participants are encouraged to publish the results of their research with due acknowledgements, and to make all participants and the project officer aware of the publications.

(b) To Agency

- 3rd RCM in Feb/March 2005 in Bangladesh to co-inside with 12th RTCC of RWC
- The CRP to continue beyond R3 (Sept 30, 2005) with funding for at least an additional 6 months (R4) and a 4th RCM in March 2006. Australia to be considered as the venue for the 4th RCM.