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Farmer-to-Farmer Program

FENCA

Improving Fertilization & Irrigation for Rice Production
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Santa Cruz – Bolivia

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Preface

In assisting agriculture producers, be they rice producers or producers working with other crops and animals enterprises, I usually find it best to assume, that even though the rural educations standards may be low and many producers may not have had the best opportunities for obtaining higher levels of education, they are still highly intelligent individuals that are capable of rationalizing the optimal production program suitable to their individual needs within the overall economic conditions of their country or region. The rice farmers in Bolivia and members of FENCA definitely fit that profile and appear to be dynamic in their approach to rice production keeping up with advances well away from Bolivia. When Mr. Emilio Chileno mentions such things as Roundup Ready rice seeds including Monsanto's variety complete with "Terminator" gene and golden rice, he is as knowledgeable on modern rice technology as I am. Similar most suggestions I made to producers were things they were aware of, interested in, but did not have the financial or other resources to implement. This then makes it a real challenge for an outsider to offer as much as he would like. However, I will do the best I can. Perhaps I may only reinforce what many of you are already considering.

Also, one is biased by the specific conditions at the time of any short visit. In this case the visit occurred in March 2008. This is the end of the rainy season when rains should be tapering off. However, it coincided with a major late season surge in the rains, and thus many rice fields were excessively flooded with the mature rice head touching the water and farmers forced to harvest the rice with combines operating in fairly deep water, much to the determent of the soils and the pneumatic tires were seriously slipping making pairs of deep ruts in the fields every 4 meters that would have to be clean up before the next planting of soybeans sometime in July. It is understood that this is a somewhat unusual occurrence, but most likely not totally outside the normal. Having mature rice head in the water normally allows some of the hull and bran to discolor the grain and giving it a yellowish color that severely downgrades the quality and price farmers can expect at the market. I fear that this is one of the occupational hazards of rice cultivation in this part of Bolivia. Two weeks later the same fields were drained of water and late planted plants undergoing moisture stress. Also, at the time of the visit most of the early planted rice, which most likely was the best and highest yielding, had been harvested with ratoon panicles developing.

Finally, the smallholder FENCA rice famers as well as the other rice farmers around Yapacani are generally larger than I normally have assisted in Asia and Africa, where the total farm size is normally less than 5 ha. However, it is comparable to the rice farmers of Italy where the average rice farms are 60 ha. I also noted that the mechanization being used is very much comparable to that of Italy. This I fully appreciate.

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List of Acronyms

CGIAR	Consultative Group for International Agriculture Research
CIAT	Centro Investigacion Agricola Tropical, Research Center for Tropical Agriculture
CIAT-I	Centro Internacional Agricola Tropical, International Center for Tropical Agriculture in Cali, Columbia
DAP	Diammonium Phosphate, a common fertilizer mix (Spanish Acronym FDA)
FAO	Food & Agriculture Organization of the United Nations based in Rome
FENCA	Federacion Nacional de Cooperativas Arroceras – National Federation of Rice Cooperatives
IDRC	International Development Research Center - Canada
IFAD	International Fund for Agriculture Development
IRRI	International Rice Research Institute, Philippines
JICA	Japan International Cooperation Agency

Executive Summary

The consultancy was to evaluate prospects for enhancing rice production in the Santa Cruz area of Bolivia with particular interest in the Yapacani area some 120 km north west of Santa Cruz city. The consultancy took place from 8 March to 5 April 2008.

The consultancy highlighted the need for improved water management and land development in terms of controlling the excess water entering the field as well as leveling the land to retain water at the same level across the fields. The consultancy also looked at the irrigation potential but this would be difficult to develop as, in most incidences, the fields are a couple kilometers from the nearest surface water source and would require some coordination between farmers on government undertaking.

In addition, some major concerns were expressed about red rice, the most noxious weed in rice worldwide. There are no simple answers to the problem but it might be worth looking at some wet puddling type cultivation or use of herbicide ready seeds in conjunction with the appropriate herbicides.

Other concerns were rice fertilization and the use of some liquid fertilizers that were most likely not effective and represent some form of scam. However, the concerns about urea are most likely unfounded as it is the most common and effective source of nitrogen fertilizer for rice worldwide. Other nutrients of concern are Phosphorus, but more for the soybean or other crops following rice than rice, and Zinc.

The use of certified seed was examined and represents concern but not a major one as the logistics for supply and verifying certified seed most likely exceeds the capacity of the agency responsible. They need to give priority to hybrid crops like maize, sorghum, and sunflowers, and crops with viability problems such as soybeans. For rice it is possible to have seed that is 3 or 4 generations removed from certified seed, with only minor loss in quality unless it become visible contaminated with red rice.

The variety development program seems to being doing well with access to international germ plasma via IRRI and CIAT-I as well as more regional sources such as Brazil. However, given the importance of growing rice after soybeans with a fast and possible delayed turnaround it might be wise to concentrate on early maturing varieties that will still do well when planting is delayed.

The mechanization may need to look at techniques that are less destructive to the land when forced to work in flooded fields. An example would be the Italian rice program.

Introduction

The consultancy was arranged at the request of FENCA (Federacion Nacional de Cooperativas Arroceras – National Federation of Rice Cooperatives) to evaluate the prospects for improving rice production in the Yapacani area of Santa Cruz, Bolivia. The consultancy was for 4 weeks from 8 March to 5 April 2008. This corresponded to the end of the rainy season and the end of the rice growing season. For this year, it also corresponded with a major surge in the rains resulting in some major flooding including road closures. This included major flooding of rice fields just as farmers were preparing to harvest their crops. The result was farmers were forced to harvest in flooded muddy fields to prevent major yield and quality loss. It also resulted in severe damage to the fields.

Rice in Santa Cruz is primarily grown as rainfed rice, often in low lying areas subject to flooding to depth of 1.2 m from 1 to 5 times per season. However, while the accessible rainfall data is limited with substantial missing elements, the annual average rainfall in Santa Cruz is only somewhat more than 1300 mm. This is reasonable but not really an excessive amount for rice. The rainfall is divided between the rainy season from October to March, consistent with the southern hemisphere tropical rains, with lesser rains during the remainder of the year (Table 1). The annual variation in the monthly rains is from 30 to 50% during the rainy season which, while most people intuitively think is high, is very typical or even less than other wet-dry tropics.

Also, rice is generally not the only crop or farm enterprise undertaken by the producers. The larger farmers cultivating 50 or more hectares of rice are typically producing rice in conjunction with soybean. In this case, soybeans are planted in July and harvested in October into November, just before rice is planted. When the soybean harvest is delayed such as an early heavy surge of rain as occurred this season, the rice planting becomes delayed and extremely rushed. The result this year was a noticeable 8 week spread in rice establishment, as noted by many early and probably the best yielding fields, already harvested while other fields were just at the heading stage and needed another 6 weeks to reach maturity. This also resulted in some incomplete land preparation for rice that could be aggravating the red rice infestation. However, the soybeans are normally the more profitable of the crops when the lower production costs relative to returns are factored in. This has to be fully appreciated by all concerned.

Smaller farmers who grow only 5 to 10 ha of rice are also involved in other farm enterprises including citrus and cattle. The total land they manage can be as high as 50 hectares. The ultimate consideration here it to appreciate that farmers in Santa Cruz, like farmers all over the world, are not interested in the maximum yield they can received from one field or one farm enterprise, but maximize the total returns to all farm enterprise, willingly sacrificing yield in one field or enterprise to enhance the returns to another. Most of these decisions are based on good sound economic assessments of what is in the best interest of individual farmers. However, the expectation should be for average rice yields of 4.0 t/ha or more. This appears higher than what

was visible during the field visits, although the early crop that was already harvested could be substantially higher.

Table 1. Monthly Variation in Annual Precipitation for Santa Cruz, Bolivia (mm)

Year/ Month	Jan.	Feb.	Mar	April	May	Jun	July	Aug	Sept	Oct.	Nov.	Dec.
1987	162	108	287	176	68	154	210	48	18	146	169	340
1988	162	95	151	111	47			9	33	96	78	222
1989	193	169	148	129								
1990												
1991												
1992												
1993												
1994												
1995			12					35				
1996					44			45				189
1997				45				16	52		132	
1998	161	258					8				260	
1999				40						34	31	154
2000										223		
2001		115	103			68	33	39	119	235		
2002	147	333	87	95		88	63		89	48	127	144
2003	223	157	133	76	71		19	15		127		209
2004			90									141
2005						58				63		179
2006				227	123			76		97		
Count	6	7	8	8	5	4	5	8	5	9	6	8
Sum	1048	1235	1011	899	353	368	333	283	311	1069	797	1578
	174.6	176.4	126.3	112.3	70.6	92.0	66.6	35.3	62.2	118.7	132.8	197.2
Ave.	7	3	8	8	0	0	0	8	0	8	3	5
Std.					36.5	15.2	23.8	23.1	38.3			
Dev	30.63	90.80	48.19	63.56	5	8	1	7	5	76.20	85.62	31.91
CV	0.18	0.51	0.38	0.57	0.52	0.17	0.36	0.65	0.62	0.64	0.64	0.16
	Ave. Total Annual Rainfall					**1365**						

Also, farmers in Santa Cruz appear highly knowledgeable about their production practices and technology available from outside sources. They appear to be continually rationalizing through their practices and attempting to improve them as needed.

With this brief introduction the following are some of the issues that concerned the consultant. These include:

1. Water management
    a. Water control
    b. Land leveling
2. Irrigation Potential
3. Red Rice Control
4. Certified seed and Varietal Improvement
5. Fertilization
6. Mechanization

Water and Land Issues

One of the major concerns developed from the field visits was the issue of water control within the rice fields and its impact on overall yields, uniformity of yields, mechanization and other aspects of rice production management. There are really 2 issues involved. These are first, controlling the non-rain water entering the fields, and when necessary the water leaving the individual fields. Second is the levelness of the fields.

Ideal Water Management

Ideally in paddy (flooded) rice production, it is desired to have a uniform 10 cm of ponded water on the soil. This is primarily for weed control and effectively eliminates any non-aquatic weeds. However, rice, including most modern varieties developed under idea research conditions, has become so adapted to the ponded conditions that it suffers very quickly when the water fully recedes from the field. The actual terminology for this is accumulated stress days. A stress day is defined as the number of days in excess of 3 that the field is not ponded. The stress days can be accumulated over the growing season with the 3 day allowance being renewed each time the field is flooded. The number of stress days can be closely correlated with yield loss. While this is a good researcher tool, it is not something producers can do other then be aware of.

While under irrigated conditions, it is fairly easy to maintain close to the 10 cm of ponded water. Under rainfed conditions, it becomes difficult and not really desirable as one never fully knows when the next surge of rains will come and any field drained to meet the 10 cm ideal will be re-ponded. Thus, with rainfed rice management the desire is to retain as much water as the rice plant will tolerate depending on its height and stage of development. The actual water loss from a rice field is estimated to be between 1.5 and 2 cm/day, divided equally between upward loss to evapotranspiration from the rice plant and ponded water and downward loss from percolation into the soil. Thus, if the rice is well established approaching flowering and 60 cm tall or more and the field well sealed from lateral flows with 40 cm of water, the water should last 20 days or more to bridge until the next rains. That represents nearly 3 weeks and should last through most lulls in the seasonal rains.

Water Control

Controlling the excess water entering the fields in many cases may be difficult or impossible without some extensive levee work on the river banks or flood control dams in the upper catchment. This would require a national undertaking that could only be done as part of an overall large scale multi-purpose water development project. This is because much of the rice is grown in low lying areas near rivers and subject to flooding to a depth of 1.0 to 1.2 m from 1 to 5 times during the season when heavy surges in rainfall combine with runoff from the upper watershed. These floods are normally of short duration rarely lasting more than 3 or 4 days. In most cases, a well established rice crop can withstand these floods with little or no damage. The key is well established meaning at least at the tillering stage. Many rice varieties have an elongation potential and can extend up to 10 cm a day to keep up with flooding. The important feature is to have the upper leaves of the rice plants above the water within 48 or 72 hours (2 to 3 days) after submergence by flood waters.

From the producers' management perspective, it is desirable to have a well constructed set of bunds surrounding each field complete with permanent adjustable water control structures as needed. The suggestion would be for such bunds to be approximately 70 cm high with the water control structures controlling the water at depths up to 50 cm. This should allow most of the water, even during flooding, to go through the control structures instead of overtopping and potentially eroding and breeching the bunds. The control structures should be made of concrete with a slot that will allow various flash boards to be inserted to control the water level as at least one farmer was attempting (Fig. 1). They could also be prefabricated as is done in the Japanese colony (Fig. 2).



Fig. 1. Water control structure installed by farmer near Yapacani



Fig. 2. Pre fabricated water control structure used in Japanese Colony

Such control structures should be able to equilibrate the water within the fields within 24 hours, including fully draining the water prior to combine harvesting.

There remains a concern for equipment access. This has to be done through limited and well identified access points as now appears the case. However, it might be possible to see how such access points can be reinforced so they are less damaging to the bunds and easily repaired once the equipment has completed the tasks. One possibility would be, when the road borrow pit is between the road and field, placing approximately 15 cm diameter culvert in the borrow pit and constructing a road across the borrow pit to the top of the bund, and a solid ramp leading from the bund into the field. Here is where a visit to the Po Valley outside Milan, Italy and see how the Italian manage their rice fields might be useful. This might be arranged through the European Union. Sorry but developing such water control structures will be costly, and most likely done incrementally over several years as funding become available. However, the returns to better water control in terms of higher potential yields would normally allow for cost recovery within a couple years.

Land Leveling

The second concern would be for precision leveling the fields. While precision leveling is usually related to surface irrigation systems, it can be equally important in rainfed rice fields where the desire is to maintain uniform water level across the fields. At present fields may have as much as 50 cm of difference between different sections as compared to the official engineering standard of ± 2 cm. The big concern here in Bolivia, as opposed to Asia and Africa where farm size is smaller and less mechanized, is making the fields large enough for convenient mechanization including combine harvesting. Thus the field sizes have to be 8 to10 ha or more.

Smaller fields would substantially reduce the equipment efficiency as too much time would be wasted in turning around and backing into corners. Even at 8 to 10 ha, the fields would be only half the 40 acre (16 ha) rice fields in California, one of the major rice producing areas in the US. Precision leveling field this size can be a major undertaking requiring moving earth several hundred meters.

However, the advantages of precision leveling would be:

- More uniform and higher yield, removing the yield losses from both the high areas and low areas.
- Better water control, particularly the more complete removal of water prior to harvest allowing the fields to be dry faster for the combines.
- Reduction in the mechanization destruction of fields currently taking place with the tractors and combines using pneumatic tires, that then requires considerable effort to remove the massive ruts prior to planting the soybean crop in July. With level fields there is a better chance for shallower mud and thus better traction as well as reduced splashing of mud into the bearing, resulting in less frequent replacement and thus reduced maintenance cost to the equipment.

The actual leveling will again be a costly and time consuming process that could be incrementally done over several years. Some initial leveling can be done mostly from memory of high and low places and use a simple scraper to move soil from high to low. One estimate of this was $15/hr. However, this will eventually have to give way to laser leveling to reach the intended ± 2 cm. Such equipment is available for hire but expensive. One Japanese farmer in the Japanese colony mentioned it cost him $1000/ha to laser level an 8 ha field. That sounds exceptionally high. Smaller fields would cost less per hectare. However, he claimed he got his money back through increased yield in only 3 years. Sound better than anticipated, but if true would be a reasonable return on the money invested. We were able to visit one laser leveled field done with JICA assistance (Fig. 3). It looked real nice and they claimed the yield doubled after leveling. That is possible.

It is possible to level rice fields using the ponded water to indicate the high and low spots. However, this could only be done at the beginning of the season after there are sufficient rains to pond the fields. This is also when there is some severe competition to convert soybean fields to rice fields, and really not sufficient time to extend the conversion time with detailed land leveling. The bottom line is that individual farmers need to evaluate the basic economic for their specific fields.

Land development including precision leveling in the US and most likely in Europe was done with government assistance in some type of cost sharing activity. I doubt that the government of Bolivia has the resources to provide such financial assistance. Thus it might be good to see if you can obtain some donor assistance for cost sharing of the leveling effort. However, this might be

easier said than done in as most donors are heavily committed to the mechanism by which they offer assistance and are not very receptive to ideas originating with the beneficiaries. You might want to contact JICA, who has already done some land leveling activities in the area. Others to contact would be European Union, FAO, or IFAD. The later is the International Fund for Agriculture Development it is headquartered in Rome not far from FAO's headquarters. You might also contact IDRC (International Development Research Center). It is a Canadian government organization that does small time pilot projects. One of the justifications for seeking assistance would be to bring Bolivian farmers on par with US and European farmers in terms of land development assistance.



Fig. 3. Laser leveled field with uniform water and uniform yields

Irrigation Potential

When producing rice, the discussion frequently turns to irrigation and the potential for irrigation to assure field remain ponded and the optimal potential yields are obtained. This was also the case with this visit. The discussion took several aspects which will be reviewed.

General Consideration

For good surface irrigation of rice, it takes considerable volume of water. When involved in the initial construction of a 3000 ha rice based irrigation scheme in Tanzania the design consideration was to provide the equivalent of 2.5 l/s/ha continuous flow to the fields. This was actually a 30% excessive amount so a more realistic rate would be 2 l/s/ha so that a cubic meter per second of water would irrigate 500 ha. The flow would then be rotated among the different fields. The 2.5 l/s/ha was estimated to account for evapotranspiration, infiltration and conveyance losses. This is still a lot of water and for a 3000 ha scheme we were diverting up to 9 m^3. If 2 l/s/ha is required for good rice irrigation, the first question is how much water is available and when is it available. In this regard the hydraulic information is not clear. The

impression given during the visit was that each rain surge's hydrograph was of short duration and a few days after each surge of rain the streams would return to their base flow. In this case, when the rain surge's water dissipates from the fields, there would be only limited stream flow to replace it.

Normally, during the rainy season the streams will continue to run relatively full during the entire rainy season with some additional water during the surges in rainfall. Thus during the rainy season there is more than adequate flow to divert water for irrigation. This could be easily done with low lift pumps such as that being used by the Japanese (Fig. 4). It has a discharge of about 40 l/s and which is sufficient to intermittently irrigate their research plots. These simple single cylinder diesel pumps are very common for small scale irrigation in many developing countries, most noticeable Egypt. India is the most common source for such pumps. Thus, before making any commitment to developing irrigation projects it will be necessary to get some better hydraulic data on stream flow including any downstream demands for water that need to be considered before diverting any.



Fig. 4. Typical low lift irrigation pump used in the Japanese colony

One concern in developing individual irrigations system is that many fields are at least 2 km from the surface water source. Thus, it would be necessary to construct some canal work either individual or jointly or depend on the government to develop and build.

Comments on Irrigation Ideas

Some of the ideas for irrigation that were put forth during the field visits include:

Public Sector Scheme North of Yapacani: There was mention of a medium size public sector scheme on the unpaved road some 30 to 40 km north of Yapacani. It would irrigate some 2 or 3 thousand hectares. The concern was the intended land allocation per family. The impression

was that it would be low, ranging from 12 to 2 ha/family. Within the context of Bolivia, where most farmers are managing 30 to 60 ha of mechanized farming, this small a family allocation is most likely not economically viable as a full time livelihood. Thus, if implemented at best there will be some informal reallocating and consolidation of land to make economic viable units with some families renting their allocation to other farmers, and leaving for other economic prospects. The alternative would be to manage irrigated land within the scheme plus rainfed land outside the scheme. In this case, the rainfed land would have to receive the highest priority. If not the opportunity would be lost since the irrigation system would provide operational flexibility for delayed operations. The delay could be up to 6 or 8 weeks after the rains begin and irrigation system becomes operational for the season.

Private Scheme West of Yapacani: There was also discussion of a private scheme west and south of Yapacani to serve several families in blocks of 50 ha. each with water pumped from the stream for a total development of some 2000 ha. While the allocation size is reasonable the available stream flow most likely is not. At the time of visit, the flow was no more than a couple cubic meters and at most would irrigate 1000 ha. There is a need for more quantitative stream hydraulic data prior to proceeding.

Use of Retention Tanks: Based on the efforts and example of the Japanese, the idea that retention tanks could be build to retain sufficient water for irrigation during lulls in the rains was mentioned. This need to be carefully considered as the area needed for the retention tank could be considerable more than can be justified. Most likely to hold sufficient water for supplemental irrigation of rice the retention tanks would occupy nearly 20% of the rice lands. This would be a tank of approximately 3 m depth. During the visit to the Japanese colony the retention tank observed in the background (Fig. 5) was no longer being used for irrigation and filled with water weeds, etc. It beneficial use was limited to informal fish production.



Fig. 5. Retention pond originally intended for irrigation storage now mostly abandoned in the Japanese Colony.

Sprinkler Irrigation: Another suggestion considered for irrigating rice was the use of sprinkler irrigation such as large scale Center Pivots that can irrigate a square of 50 ha. While this is well appreciated for the potential water saving, attempts to use center pivots with rice have not been highly successful. While I have not looked at this in the past 14 years, when I did, it had been tried in both Brazil and Texas. The results were similar with a general yield loss of 25%. Technically I would consider it possible but you would need to start with varieties specifically adapted for upland conditions and the more extensive root system these varieties tend to have. The major source of upland rice varieties is University of the Philippines in Los Banos. It is the university associated with IRRI and could be contacted through IRRI. I would recommend this as something CIAT could look at. You would also have to be aware of more intense fungi infestations as many of the fungus infecting rice rely on high humidity in the canopy as would occur with the daily passing of a center pivot, particularly for areas irrigated daily just after dusk that would remain moist the longest. However, since there is contact with the Brazil rice program, it might be worth checking with them on any more up-to-date information on sprinkler irrigation of rice.

Japanese Experience

During the visit, the Japanese colony was mentioned as source of technology that was appropriate for the rest of the area. For the most part this was true. However, somewhere the Japanese obtained the resources to undertake some of the capital investments that maybe restricting the rest of the producers. This includes the Japanese experience in irrigation. For example as mentioned in another section the Japanese did invest in laser leveling their fields. They also invested in irrigation wells. These are major 40 cm diameter wells to a depth of from 60 to 200 m. They are well developed wells with yields approximating 55 l/s that can provide supplemental water to some 30 or 40 ha. These are expensive high pressure systems require up to 300 psi just to get the water to the surface. The wells are used mostly for supplemental irrigation during the rainy seasons when rains and surface water is inadequate. They are also used for early rice planting prior to the beginning of the rainy season.

Large Scale Water Projects

If the rain surge hydrographs are as indicated above and of short duration with flooding during the surge followed by limited flow during the lulls, it would be desirable for the government of Bolivia to look at the prospects for a large scale water development project that would include multi-purpose dams for flood control, irrigation and hydroelectric. However, that is way beyond the capacity of this consultant to do more than suggest.

Red Rice

Red Rice is the most noxious weed in rice worldwide. That is because it is actually a true rice variety that is difficult to distinguish from other rice plants until the panicle emerges and distinctive head with awns and red color appear. Red Rice is not harmful and in parts of Asia,

such as Viet Nam and Thailand where it is cultivated in small quantities as a specialty rice with a very pleasant favor, and perhaps more nutritious than regular rice. However, as a contaminant in white rice, it distracts from the appearance and severely downgrades the quality and what the producer receives for his crop. In the Yapacani market, red rice contaminated rice is priced at least 1 Bs below regular rice representing a 16% discount. Producers with severe red rice contaminated fields tend to harvest this rice for personal consumption rather than selling it.

Red rice tends to shatters easily so that it becomes volunteer rice in subsequent years. It is possible that the soybean production prior to rice and the quick conversion from soybean to rice with minimum to no tillage could exasperate the problem as the red rice seeds could be lying dormant during the soybean crop and be ready to germinate with the rice crop. For these reasons, it is very difficult to control and I have no magic answers. On returning to Fort Collins, I consulted with colleague who has extensive experience in weed control on rice. He had no magic answers but did provide a couple extensive proceeding on red rice conferences which I am happy to forward, but for the most part will require translation to Spanish.

Red rice also tends to be taller than regular modern low statured rice varieties with awns on the individual grains so that it can be easily identified in the field and rouged out (Fig. 6 & 7). However, this is a time consuming process that has to be done fairly quickly once the head appears and prior to when the seeds become viable and start to shatter. Thus, rouging the red rice is only practical for seed production areas as is currently being done.

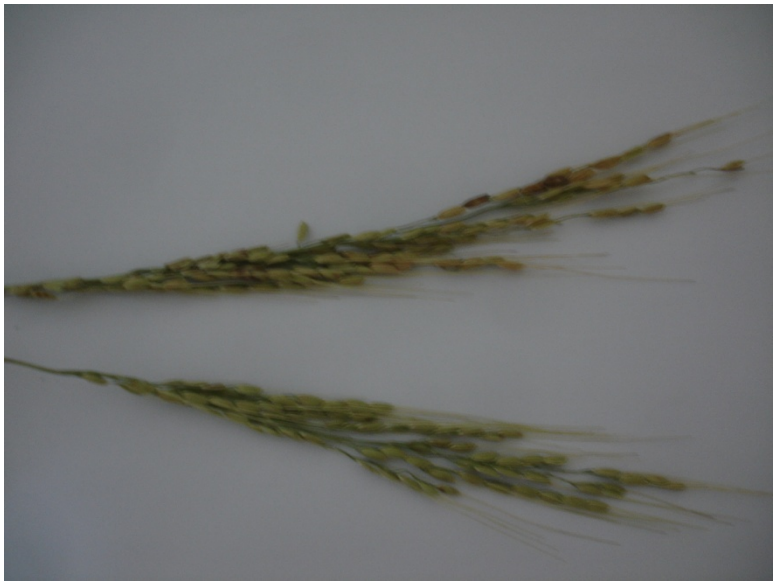


Fig 6. Red Rice heads showing awns extending from individual seeds.

As for control in commercial fields, I can only speculated and appreciate the over 2,000,000 listing for red rice control on the internet. What I am noticing is that the problem appears less in the major rice producing areas of Asia and one of the Japanese growers mentioned he reverted to transplanting rice to control the sever red rice infested fields. Synthesizing all this, it might be



Fig. 7. Red Rice plants extending above the canopy of regular rice.

possible to partly control red rice with a wet land preparation also known as “puddling”. This would involve attaching rotovators to large tractors and enter the fields once they are flooded to do basic land preparation (Fig. 8). The idea is to force all the red rice volunteer seeds, quietly sitting on or near the soil surface, well below the soil surface into what will quickly become the



Fig. 8 Rototiller attachment to large tractor that could be used for wet puddling type land preparation in rice fields and help control red rice.

anaerobic reduced zone when flooded. Like any rice seed in the reduced zone it will suffocate without oxygen and can only tolerate reduced conditions once the leaves are above the soil. After wet land preparation rice seeds can only be broadcast with cyclone applicators so they remain on the soil surface to germinate. I can only suggest this, but some of the internet references were referring to this technique. An additional benefit for this puddling wet cultivation would be to seal the soils and reduce the percolation rate so they retain water longer during lulls in the rains.

One problem with this is that if farmers are late in harvesting their soybean crop and trying to quickly plant the rice, as happened this year, it will delay the planting even more. However, if you can get some reasonable control on the red rice it might be worth it for the most heavily infested fields. Meanwhile the question is "is the red rice more a problem in the higher or lower part of the field?" If the higher part of the fields then the above would suggestion would be promising. Improved red rice control could be another benefit from leveling the fields.

Another possibility would be using Round-up and Round-up ready seeds or other herbicide in conjunction with their resistant seeds. This will be expensive and best used sparingly for the worst infested fields. However, the red rice should not be tolerant to the Round-up which would allow the Round-up to bring the red rice under control. However, this should not be done for more than a couple years as the red rice could mutate and become tolerant to the round-up.

Certified Seed Requirements

There is a major concern for Certified Seed and desire for farmers to obtain certified seed each season as well as the substantial logistical undertaking needed to meet this desire including the extra costs incurred by the farmers. While I can appreciate the desire for certified seed each season, and recognize that its use can be heavily promoted by seed companies as well as research and extension programs, it may not really be practical. Since rice is a self-pollinated crop, retaining seed does not result in any genetic degradation of the variety. Thus the only concern is contamination particularly with volunteer red rice, which unlike most other contaminations, such as chaff, unfiled grains, stones, mud, and weed seeds, cannot be easily removed with normal seed cleaning equipment.

In most rice producing areas, farmers do not use certified seed every year, but only when necessary to shift to newer varieties. This is similar to the wheat farmers in Colorado which only plant 25 to 30% of the acreage to certified wheat seed. The rest of the time both rice and wheat farmers retain seed from previous crops or purchase seed from informal local sources within their communities. It is also often difficult to show a yield difference between Certified Seed and retained seed as shown in the comparison of project distributed seed with farmers distributed seed in Tanzania (Table 2).

Table 2. Yield Comparison of Project and Farmers' Seed for 3 Varieties					
Subarimati		**Zambia**		**IR 54**	
Source	**Yield (t/ha)**	**Source**	**Yield (t/ha)**	**Source**	**Yield (t/ha)**
Project	1.72	Project	0.61	Project	1.44
Farmer 1	2.24	Farmer 4	1.11	Farmer 7	0.97
Farmer 2	2.01	Farmer 5	1.01	Farmer 8	1.68
Farmer 3	1.56	Farmer 6	0.42	Farmer 9	2.28
Ave.	1.89	Ave.	0.79	Ave.	1.59
Std. Dev	0.57	Std. Dev	0.57	Std. Dev	0.80

Source: Madibiria Agronomy Report 2000, MSADP, Tanzania

Thus, while I can see a need to maintain a flow of certified seed into the area, I don't see the need to expect the farmers to plant all their land to certified seed each season. I would expect that you could retain seed for 2 or 3 and possible 4 generation before the 3% out crossing and red rice contamination become too much. Since rice as nearly a 50 to 1 multiplication ratio, in which a kg of seed can produce 50 kg of additional seed, it is possible for farmers to plant 1 ha to certified seed, and use that seed for the balance of their fields the following year as well as sell some to their neighbors. Or it would be possible for a few farmers to use Certified Seed and then distribute their production of sub-certified or commercial seed to other producers. This is something FENCA might wish to coordinate. It also might be something being informally done among producer, particularly the smaller producers that use more manual practices to avoid contamination between fields. There is a small seed processing facility in the area owned by the City of Yacapanci. It is working but struggling with equipment in need of some major maintenance (Fig. 9). I would recommend trying to keep track of the generation away from certified seed to make certain the seed does not get more than 3 or 4 generations away.



Fig. 9. Seed processing equipment at small facility outside Yapacani.

There really may be little alternative to the limited use of seed certification as the organization responsible for certification has to deal with maize, sunflower and sorghum which are all hybrids and thus absolutely require fresh seed each year. They also deal with soybeans which can have severe storage viability and germination problems. The limited resources available to the seed certification program force them to rightfully concentrate on these 4 crops and leave rice and other crops a justifiable second priority.

Variety Development and Improvement

The development and introduction of new varieties is the responsibility of the Centro de Investigación Agrícola Tropical (CIAT). While not a major visit of the consultancy CIAT appears to be doing a good job of acquiring germ plasma from international sources including the Centro Internacional Agrícola Tropical (CIAT-I) in Cali, Colombia with its long standing link to the International Rice Research Institute (IRRI) in the Philippines and IRRI's germ plasma distribution system. Both CIAT-I and IRRI are part of the 16 international centers that constitute the Consultative Group for International Agriculture Research (CGIAR) system. CIAT is also acquiring genetic material from regional sources such as Brazil.

It was not certain the extent CIAT is involved in taking external germ plasma and using it in breeding programs prior to formal release under a local name, or simply screening the breeding lines they receive and releasing the most promising again under a local name. In working with the CGIAR system the genetic material they make available is freely available for either activity without encountering any intellectual property rights difficulties, as would occur with companies like Monsanto. It is noticed that all the rice varieties in the field appeared to be the modern short statured, erect leaf morphology indicative of those developed and distributed through the IRRI genetic distribution system. However, they also contain local names and thus not recognizable for this consultant.

While CIAT's rice variety improvement and foundation seed production program is genuine effort, like research program everywhere, rice or other crops, the CIAT center are endowed with the ideal facilities for evaluating rice varieties including full water control for both irrigation and drainage. This makes it difficult for the CIAT scientists to fully appreciate the deviation from these ideal conditions faced by most of the rice producers visited. These producers are struggling with vary degrees of unlevel fields and uncontrolled water resulting in flooding over the tops of any retaining bunds and/or drought stress conditions when paddy water recedes, as well as delayed planting associated with harvesting the previous soybean crop and rapid conversion to rice. The best that can be recommended to the CIAT program is to take a closer look at early maturity to see if some 90 to 100 day varieties are available for planting after soybeans, and some measure of drought stress to cover periods when the fields have dried. IRRI genetic indexing usually includes some indication of both these prospects. The potential yield loss associated with early vs. medium maturing varieties could easily be more than compensated for

by the yield loss associated with delayed planting and maturing under moisture stress at the beginning of the dry season.

Fertilization

Another concern was for the proper fertilization of rice. At the time the input supply stores in Yapacani were promoting liquid fertilizer for aerial application at a rate of only 2 lit/ha and there was some major concern that Urea would have an adverse affect on the soils. Both cases may represent mostly disinformation.

Caution

Several farmers were using, and many of the input suppliers in Yapacani were promoting liquid fertilizer with a recommended application rate of only 2 lit/ha (Fig 10). This is not really practical as for optimal rice production it is usually necessary to apply fairly large quantities of chemical fertilizers. This could reach 100 kg/ha of added fertilizers with Nitrogen being the most needed nutrient. This amount of fertilizer is vastly greater than what can be obtained from some of the "liquid" fertilizers being marketed to farmers in Yapacani and most likely other areas with a recommendation for applying as foliar sprays at only 2 l/ha.



Fig. 10. Liquid fertilizers being promoted in Yapacani that are most like a fraud.

These liquid fertilizers contain a little N, so when applied they turn the crop a nice green that gives the appearance of a favorable response, but it will soon disappears. They also contain some micronutrients such as Iron, Manganese, and Boron. None of these are usually a problem with rice. Thus basically these fertilizers are a scam. I am sorry to say but at least one is claims to have come from the US. Such scams also occur in the US. The recommendation here is to avoid what seem like too good a thing.

Urea

Urea was mention as a potential fertilizer source of major concern fearing it would adversely harm the soils. This is most likely disinformation. Urea is the most highly concentrated and common source of nitrogen fertilizer for rice worldwide. It is frequently applied continuously for many years, if not decades, with little to no adverse effects. Urea does produce a slightly acidic reaction but it would take decades for that to become a problem, and even then easily corrected with simple liming treatment. This would be mostly needed for the crop following rice more than the rice crop as flooding tends to reduce acidity, at least while water is ponded. On occasion Urea will become contaminated with a compound call biurette. This is usually a result of poor quality in the manufacture of the urea or poor storage. If the concentration of biurette is high enough, it can be toxic to crops including rice, but this is extremely rare. For the most part, urea can be safely used on rice and its use encouraged, but be careful that it is not heavily caked like cement, which would be an indication of some biurette being formed in storage.

Basic Rice Fertility

Fertility in rice fields is very much tied up with the chemistry of submerged soils and the oxidation reduction taking place with anaerobic conditions. This is all briefly described in a separate document and I do not want to get into a complex discussion of flooded soil chemistry. I will simply highlight some of the major concerns (Appendix).

Nitrogen: The critical concern is for nitrogen, for which the flooded soil environment is usually not beneficial. For this reason, as much as 50% of the chemical N applied is lost. It is also highly desired that only ammonium based N be used. This would be from Urea or DAP, which appear to be the major sources of N available in the area. It could also be some of the 15-15-15 or 20-20-20 mixed fertilizer as most of their N comes from ammonium. It is also best if the nitrogen can be incorporated in the soil so that it quickly become reduced and remains in the reduced layer of the soil. That is OK for the initial fertilizer application, if the land can be quickly tilled immediately to incorporate the fertilizer and then flooded. It is more difficult for any mid-season top-dressings. In addition, the intermittent flooding that most fields appear to undergo during the growing season is also detrimental for N fertility and aids in the loss of N. As for the amount of N to apply, with research plots under ideal conditions, the recommendations can be as high as150 kg/ha N. However, considering the less than ideal water management conditions observed in the field visits and reduced yield potential the recommendations should most likely be lowered to around 50 kg/ha N. Also, the final rate should be determined by the individual farmers based on their experience with applying fertilizer.

Phosphors: This is a nutrient that becomes substantially more available under submerged soil conditions and tends to be mined by the rice crop. Thus, rarely will extra phosphors be required for rice. However, if you are growing a dry season crop like soybeans after rice, there could be a high need for Phosphors on the soybeans to compensate for what the rice mined from the soil.

Zinc: Another important nutrient to be careful of is Zinc. It becomes less available under flooded conditions and can become a major problem particularly in depressed areas that remain submerged for lengthy periods. It is noticed by the red bronzing discoloration along the leaves. This can usually be quickly corrected by draining the field or foliar application of zinc sulfate.

Acidity: Is normally not a concern in flooded rice as under submerged conditions the pH will tend to neutral from either the acidic or basic side. However, this will be short lived and the soil will revert to the normal pH when no longer flooded.

Mechanization

With the large farm and field size of the rice producers in Bolivia relative to other rice producing areas of Asia and Africa, mechanization is essential for any chance to manage these holding sizes. The mechanization thus tend to be large scale mechanization based on 4-wheel tractors and combines, with a full complement of implements for drilling seed, cyclone spreading of fertilizer and seeds, spraying chemicals, combine harvesting and bulk handling of paddy to the mills. Missing are the crop duster planes for aerial application of seeds, fertilizer and crop protection chemicals as commonly done in the US, where the farm size is substantially larger. As it is the farm size and mechanization is similar to that of Italy, which is probably the most appropriate.

Much of this mechanization is by contract. Virtually all the combine harvesting is by contract as few farmers can afford to own or are justified in owning combines. Also, much of the more conventional 90 hp tractors are contracted. This can be a mixed good as contractors can be under pressure from other clients to get an individual job done as quickly as possible so they can move on to the next job. In this case, it can make for some limited quality workmanship as noted in the amount of rice left in the fields after harvest.

The concern with mechanization is that 4-wheel drive tractors were not really designed for working in wet fields. Mechanically the mud gets splashed into the wheel bearing resulting in excessive wear and more frequent replacements. One operator mentioned he had to replace the bearing every year instead of every 3 or 4 years when working outside the rice fields. The cost of these annual overhauls can be upward of US$ 2,000 (Bs 18,000) and represent perhaps as much as an extra Bs 5 per hour of operation. Perhaps it was the timing of this visit, but the use of pneumatic tires in the rice fields tends to make a major mess of the field requiring extensive reworking prior to the next crop such as soybean being planted (Fig.11). This is most noticeable after combining that requires 2 tracks every 4 meters (Fig. 12). Fortunately, there appears some delay as soybeans are normally not planted until July providing some 3 months to do the land repairs.



Fig. 11 Tractor with pneumatic tires working in rice field.



Fig. 12. Soil destruction from combine working flooded field

An alternative might be to look at some steel wheels for tractors (Fig. 13). They are commonly used in Italy but are at least available at the Japanese colony. They tend to have a smaller foot print the field, displacing less soil and perhaps splashing less mud into the bearings. They do have a problem in they cannot be used on the roads and have to be transported to and from the fields in small trailers which ties up another tractor. Someone needs to work out the economics of this with the tractor contractors for the extra cost vs. benefits in reduced damage etc.



Fig. 13. Steel wheeled tractor that can reduce the destruction working in flooded fields.

All of the above is intended for large farmers. There are also farmers in the area who are producing only 5 ha of rice among their total mix of farm enterprises. Many of these farmers are in the sub-certified, commercial seed business and resort to manual operations for harvesting and threshing (Fig. 14). They might be interested in several smaller size thresher and even small combines. For example, the beating of rice as shown below could be easily mechanized with a mobile thresher (Fig. 15), or even a small combine that can operate in small fields (Fig. 16). The small thresher is actually an IRRI design for which the blue prints are readily available on request at no charge for local manufacture. The small combine was originally developed by the Japanese and should be available through JICA. Another consideration for the small producers would be using power tillers equipped with cage wheels and rotovators for wet land cultivation. This is now a common practice throughout Asia. It could be useful for small seed producers and could positively impact the red rice problem. Such power tillers are manufactured by the Japanese, Koreans, and Chinese and available in Bolivia, but not generally used for rice.



Fig. 14. Manually threshing rice for seed production



Fig. 15. Small portable thresher often used by small farmers.



Fig 16. Small combine used for harvesting smallholder farms in Thailand.

Recommendations

As noted at the beginning, most of the rice producers are doing as good a job as they can within the limitations on what they have to work. They are basically keeping up to date with advancing technology sorting out what is appropriate and not. This keeps the whole system dynamic at maximum efficiency. What limitations there are represent more a lack of resources, particularly financial resources to make the necessary capital investments. That said the basic recommendations are:

- Try to improve the water management of the rice fields with formal control structures, and land leveling. Included in this would be developing less destructive access for equipment.

- Evaluate the possibility of irrigation
- See if it is possible to use a wet “puddling” land preparation for enhanced control of heavily invested red rice fields.
- Consider using Round-Up and Round-Up ready seeds.
- Recognize that certified seed each year is not practical, but keep track of the number of generations away from certified seed the commercial seed is. This should not exceed 3 or at most 4 generations.
- CIAT might be encouraged to look at some earlier maturing and more draught tolerant varieties to assist with the late established fields following soybean and deal with the limited water retention in parts of the field.
- Be careful with the liquid fertilizer being promoted for low levels of application, they are more likely a fraud then a *boni fide* fertilizer source.
- Use Urea when possible it should not adversely affect the yield or fields.
- Look at some equipment options that will be less destructive to the fields including steel wheels.

Follow-Up

For follow-up on this consultancy you might:

- Reaffirm your connections to JICA, they already are involved in the area and could be good source for some to the small scale equipment that smaller rice producers might appreciate as well as other aspects of their overall development assistance effort.
- Seek development assistance for co-payment of land development costs.
- European Union as a means to become familiar with the European rice production programs as they appear more on the scale of the Bolivian rice producers. The specific interest would be Italy, but Spain and Portugal are also major rice producers and most likely have similar farm sizes to Bolivia. This would include any government assistance or subsidizes they received with the initial capital investment in land development.
- Also, VOCA for potential additional consultants.

Appendix

Daily Schedule

ACDI/VOCA Assignment 497008-A

Improving Fertilizer & Irrigation Technology for Rice Production Yapacani, Santa Cruz, Bolivia

Daily Activities

8 Mar	Departed home in Fort Collins at 08:45 for Denver Airport
9 Mar.	Arrived in Santa Cruz without luggage 08:45 checked into hotel, meet with Ms. Daisy Chavez de Cespedes and daughter as interpreter. Had general briefing and with provided additional written briefing material on the visit.
10 Mar.	Reclaimed luggage and meet with Mr. Gonzalo Vasquez, President of FENCA, the host organization.
11 Mar.	Morning met with Edilberto Osinaga Rosado, Gerente General Camara Agropecuaria del Oriente, an overall coordinating and political empowering support service for all agriculture in region including rice. Afternoon joined by Candelaria Pizavori as ACDI/VOCA translator and proceeded to met with Juan Carlos Arandia Antelo, Presidente and Jorge Rosales King, Director Comite de Semillas Santa Cruz, Oficina Regional de Semillas, the overall seed certification office. Continued to meet with Luis Alberto Hurtado Vaca, Generete Tecnico for detailed discussion of seed program. Final meeting was with Cesar Samur R. of CIAT (Centro Investigacion Agricola Tropical) the regional agriculture research program. Was later joined by Hugo Serrate Rea, Director Ejecutivo CIAT
12 Mar.	Afternoon traveled to Yapacani and had late afternoon meeting at CIAT to coordinate program. Checked into the dormitory at CIAT training center.
13 Mar	Morning visit to some rice fields in area. Fields varied from harvest, to panicle initiation representing 8 week spread in activity. All activities were mechanized similar to Italy. Afternoon visited agriculture input shops to see what was available. Some liquid fertilizer appears available that is most likely a con-job.

Also, Urea, mixed fertilizers and DAP (FDA) were available along with plenty of insecticide and herbicide, including Roundup.

14 Mar. Attended CIAT field day at their main experiment station in Saavedra and returned to Santa Cruz for weekend

15 – 16 Mar. Remained in Santa Cruz for weekend

17 Mar. Joined by Wilfredo Justiniano as translator and returned to Yapacani after late start, arriving too late for field visits and could only coordinate for remaining week. Review report of previous VOCA volunteer back in 1993.

18 Mar. Met with several persons in the morning to coordinate program for the week, then proceeded to visit a seed processing facility that was owned by the City of Yapacania but leased to a cooperative. We also tried to visit a rice mill that the government had taken over and now was giving to a producers group. However, it was closed.

19 Mar. Had difficulty organizing transport to field so remained in town but did have good interview with a couple technicians on rice production including personal experience. Also made courtesy visit with the Mayor of Yapacania, Mr. Jorge Bilbao Hidalgo.

20 Mar. Had early departure for field visit some 2 hours away (70 km) to visited farm at confluence of 2 streams and thus subject to considerable uncontrolled flooding and hazards imposed by such including a real messy harvest that disturbed about 50% of land and would require considerable effort prior to planting soybeans.

Afternoon return to Santa Cruz as next day was Good Friday and a holiday.

21 – 23 Mar. Remained in Santa Cruz for Easter Weekend with one day side trip to Samaipata, the carved rock outcrop from Inca civilization.

24 Mar. Returned to Yapacania and organized program for week to include 2 days of field visits in Yapacania on Tuesday and Wednesday, one day visit to Japanese settlement and return to Santa Cruz and one long day visiting FECNA members the other side of Santa Cruz on Friday.

25 Mar. Field visit to several larger farmers North of Yapacani perhaps as much as 60 km.

26 Mar. Field visit to several smaller farmers 40 km west of Yapacani, community of Cascabel.

27 Mar. Visited the Japanese colony near San Juan and proceeded back to Santa Cruz.

28 Mar.	Remained in Santa Cruz working on report and presentation.
29 Mar	Continued work on report and presentation in Santa Cruz
30 Mar	Continued work on report and presentation in Santa Cruz
31 Mar	Continued work on report and presentation in Santa Cruz
1 Apr.	Continued work in report and presentation while most was being translated to Spanish
2 Apr.	Collected Translation, photocopied draft, travelled to Yapacani and delivered evening seminar workshop
3 Apr.	Had additional field trip prior to returning to Santa Cruz
4 Apr.	Wrap-up in Santa Cruz
5 Apr.	Returned to Fort Collins on delayed flight resulting in overnight in Dallas
6 Apr.	Arrived safely at home

Excerpt From
Developing Smallhodler Agriculture: A Global Perspective
Chapter 9

PADDY SOILS

Another situation when basic soil chemistry becomes skewed is the submerged conditions of paddy cultivation. Under these conditions the soil microbes rapidly consume all the oxygen and soils become chemically reduced. The initial reduction will take place in about 24 hours after ponding and proceeds as long as the soil remains ponded with successive reduction of the progressive harder materials to reduce. The extent of reduction is dependent on the duration of the ponding, amount of organic matter, and the temperature. As a biochemical process, it is a slow reaction taking days or weeks to reach equilibrium. The reduced conditions change the availability of various nutrients, particularly, Nitrogen, Phosphorus and Zinc.

The oxidation-reduction process results in three layers forming in the soil; the ponded water, the very thin oxidized layer, and the reduced layer. The oxidized layer can be as a thin as two or three millimeters and is normally reddish in color. As such it is sometime confused with fresh sediment coming in with the water. The reduced layer is always gray. The color again reflects the pigmentation of iron minerals in the soil in which the oxidized forms of iron are red or yellow, while the reduced forms are gray.

Nitrogen Efficiency

The oxidized and reduced layer heavily interact with nitrogen fertilizer as under oxidized conditions ammonium fertilizer will nitrify to the nitrate form, which will then leach into the reduced layer. In the reduced layer nitrate nitrogen will be denitrified and lost as NO_2 or N_2 gas. This makes the paddy environment very inefficient for nitrogen fertilizer and necessitates the use of ammonium fertilizers like urea or ammonium sulfate, and avoiding the use of nitrate fertilizers such as calcium nitrate and even ammonium nitrate.

Typical recovery of fertilizer Nitrogen in rice is approximately 50% of the applied Nitrogen. It is also desirably for the Nitrogen fertilizer to be placed into the reduced layer, if at all possible. For basal applications this is reasonably possible by applying the fertilizer just prior to the last land preparation tillage activity, which is normally puddling, and allowing the tillage operation to incorporate the fertilizer. However, this can be difficult for top dressing applications normally planned for panicle initiation, with near full canopy through which broadcast granular fertilizer must filter through the canopy to reach the ponded water and then sink to the oxidized soil surface. It will then have to dissolve and diffuse into the reduced layer to become available to the roots. All this must take place before it can be nitrified before it can be nitrified to minimize the 50% recovery loss.

Phosphorus Availability

Phosphorus availability actually improves in the paddy environment as it is normally retained in association with iron, which becomes reduced and more soluble under paddy conditions. Phosphate fertilizer is thus rarely required. However, if the paddy land is converted to upland crops, phosphorus needs to be applied sufficiently to replace all that was mined while under paddy.

Zinc Availability

The reduced condition also adversely affects the availability of Zinc. Under reduced conditions the oxide forms of Zinc are reduced to the less soluble sulfide form, making Zinc the second most important nutrient management concern after Nitrogen. The problem becomes more severe in calcareous soils or other soils with a pH of above seven, where the normal oxidized forms of Zinc become less available. There are numerous

ways to increase the Zinc, including dipping seedling in a Zinc oxide (ZnO) slurry, direct soil applications with Zinc sulfate ($ZnSO_4$) and foliar sprays. It can also be made more available by simply draining the soil, and allowing it to reoxidize for a couple days in the middle of the season. Since oxidation is an inorganic reaction, it will take place quite rapidly, hours rather than days. Thus, in areas where the common water management practice is for a brief mid-season draining of the soil, making Zinc more available is most likely the reason.

The other nutrients are less affected by the reduced conditions of the paddy environment and can be expected to follow normal soil chemical and soil fertility conditions regarding availability and soil management needs.