mentioned by Pingali et al. (1997) who studied the causes of yield decline in rice production (Kabir p 14). The yield data provided by farmers covered a six-year period and although there was no evidence that yield declined, these problems will have to be taken seriously if the present level of rice production is to be sustained or even improved.

Low fertiliser efficiency

The focus group discussion also revealed that during the wet seasons in the period 1992-1997, the most commonly used fertilisers were 'complete' (14-14-14) (30-68 % of the farmers), urea (46-0-0) (55-67 %) and ammonium phosphate (16-20-0) (11-16 %). The percentage of respondents using organic fertilisers gradually increased from 3 % in 1992 to 30 % in 1997. The amount of fertiliser most commonly applied in irrigated rice production was found to be about 90-30-30 kg/ha (N-P-K) in the wet season and 100-40-30 kg/ha in the dry season. This is slightly lower than the recommended amounts of 90-40-40 kg/ha and 120-40-40 kg/ha. Many farmers, however, could hardly afford to buy this amount of fertiliser.

According to Sri Adinigsh (1988) organic matter acts as a biological buffer ensuring that a balanced supply of nutrients are available to the plant roots. Soils that are poor in organic matter lose this buffering capacity and their fertiliser efficiency will decrease. The observed deficiencies in N and P may be caused by low rate of fertiliser application and the low amount of organic matter present in the soil leading to a low efficiency of N and P fertilisers.

Benefits of increasing organic matter

Follet (1981) showed there are many benefits to be derived from organic matter. It serves as the principal storehouse for anions such as nitrates, sulphates, borates, molybdates, and chlorides that are essential for plant growth. It increases the CEC of soils by a factor five to ten times that of clay. It acts as a buffer against rapid changes caused by acidity, alkalinity, salinity, pesticides and toxic heavy metals. Organic matter also supplies food for beneficial soil organisms like earthworms, symbiotic nitrogen-fixing bacteria, and mycorrhizae (beneficial fungi).

An increased and better use of organic 'waste' and green manures (animal manure, crop residues, household refuse and leguminous plants collected within and outside the farm) as organic fertiliser would greatly enhance nutrient availability, the biological functioning of the soil and the efficiency of chemical fertilisers. The soil would be softened and water retention improved. It would also make plants more resistant to pests and disease and prevent 'soil acidification'. In a follow up study (Peñaloza et al p 25) options for organic soil fertility management have been analysed in an effort to find alternatives to current soil fertility management practices.

More studies needed

Soil degradation in rice production is a complex problem and different processes play inter-related roles (Kabir p 14). The solution does not lie in simply increasing and improving the use of organic fertilisers. Monocultures, the indiscriminate use of agro-chemicals, mechanised soil management and continuous irrigation also contribute to soil degradation. Further studies and farmer experimentation should concentrate on finding combinations of practices that best fit farmers needs and the changing conditions under which they work. ■

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Rebuilding soil fertility

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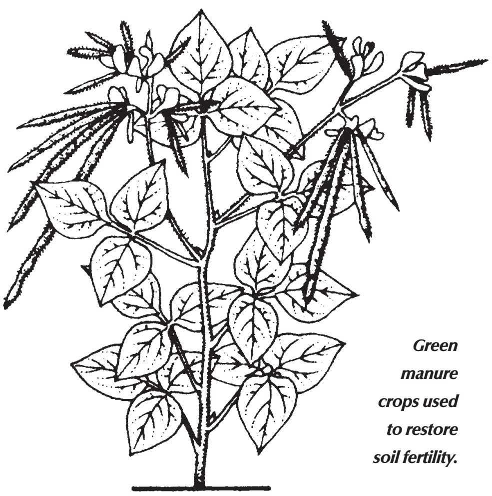
The authors' task force studied options for appropriate, alternative, soil fertility management techniques. Secondary data were collected and analysed from CLSU, the Philippine Rice Research Institute (PhilRice), the Bureau of Post-Harvest Research and Extension (BPRE) in Muñoz, Nueva Ecija, the University of the Philippines at Los Baños and the International Rice Research Institute (IRRI) in Laguna. Options identified included the use of green manure, farmyard manure (FYM), crop residue, municipal waste, and night soil. Combinations of organic and inorganic fertilisers were also considered.

Studies by Ladha, et al (1989) showed that Asian farmers prefer *Sesbania aculeata* as green manure. It grows vigorously, can withstand a wide range of adverse soil conditions including salinity, alkalinity and water logging and fixes nitrogen via root nodules. The plant can produce 15 to 22.5 t/ha biomass in six weeks giving nutrient yields of 82 kg nitrogen (N)/ha, 11-16 kg phosphates (P_2O_5)/ha and 23-34 kg potash (K_2O)/ha.

Researchers have also studied the green manure properties of Ipil-ipil (*Leucaena leucocephala* Lam.) leaves. Agustin (1978), found the best application level was 3,000 kg dried ipil-ipil leaves/ha. This produced 5775 kg rice/ha. Grain yield increased by about 15% (0.9 t/ha) as applied nitrogen increased from 60 kg/ha using ipil-ipil leaves to 120 kg/ha using either ipil-ipil leaves or ammonium sulfate (Lao-lao et al, 1978)]. Other green manure crops may be more suitable for specific local conditions (Misra and Hesse, 1983)

Long-term experimental evidence reviewed by Webster and Wilson (1966) suggests green manure crops can play an important role in fertility maintenance by acting as cover crops, raising the organic matter content of the soil, holding plant nutrients, and fixing nitrogen. Green manure crops can supply nutrients at the same level as inorganic fertilisers. Labour is the only significant cost, otherwise there are no transport costs and livestock husbandry is unnecessary.



Green manure crops used to restore soil fertility.

However, several difficulties affect their acceptability. Considerable human, animal and fossil energy is needed to plough in green manure. Providing water to further the growth and decomposition of the crop in the soil can be expensive particularly where water is a constraint. Land under green manure crops should also have a higher opportunity cost than fallow land and land requirements, particularly where population is dense and agriculture intensive as in Nueva Ecija can be a problem. Managing green manure crops requires specific knowledge and skill. KADAMA and KALIKASAN farmers have tried some green manure crops without satisfactory results.

Azolla

Azolla spp., a small aquatic fern that lives in symbiosis with the nitrogen fixing blue-green alga, *Anabaena azollae*, has proved to be a valuable green manure for wetland irrigated rice. It has a high nitrogen fixing ability, grows rapidly and can be grown before and during the rice crop (Ventura, et al., 1992). Farmers using azolla have ▶

stated that rice yields are comparable to those achieved with inorganic fertilisers and production costs are less. A study in Japan showed that incorporating azolla produced a 1-2 t/ha increase in paddy yield.

Azolla can be used in animal feed, cooking, and as food. It provides shelter for fish, suppresses weeds and is an income-generating crop (Pelegrina et al, 1992). Azolla is easily propagated but requires abundant standing water, relative humidity of 85-90%, pH of 4.5-6.5, salinity of between 90-150 mg/L and adequate phosphorus for its nutritional needs. It is labour intensive, grows fast and can clog irrigation canals and rice fields and can compete with the rice crop. Azolla doubles its weight in 3-5 days. From a start of 1t/ha, it can reach a fresh weight of 15-20 t/ha in about 20 days (Khan, 1983). KALIKASAN and KADAMA farmers used azolla in the past but found that growing conditions were so favourable that it was difficult to control.

Farmyard manure

Carabao, cattle, pig and chicken manures are potential sources of nutrients for soil fertility management. An application of farmyard manure (FYM) at the rate of 3.1 t/ha produced rice yields similar to those achieved when chemical fertiliser is applied at a rate of 18.7, 6.5 and 6 kg/ha of N, P and K, respectively (Songmuang, et al, 1989). However, usually farmers only have relatively small amounts of FYM available. This means that it can only be used to improve soil fertility in small areas of the farm and has little impact on overall rice production. Where livestock production is concentrated in pig or chicken bio-industrial units larger amounts of farmyard manure may be available for sale.

Results obtained by Manaog (1965) showed chicken manure gave the highest yield/ha on Macapagai BPI 121, a lowland rice variety. It proved better than horse, cow and carabao manure and ammonium sulfate (21%N). Padua (1979) showed that when different levels of chicken manure (0, 3, 6 and 9 t/ha) were applied to IR-42 rice 9t/ha gave the best results:1650 kg/ha more grain than the control plots.

KALIKASAN farmers started using chicken manure in 1992. After five years they harvested rice yields (5-6.25 t) comparable to or higher than those produced using inorganic fertilisers. Applications could be reduced from 60 bags/ha (3000 kg/ha) to 10 bags/ha without an immediate drop in yield, a great saving as chicken manure costs P40 a bag.

Crop residues

When the grain and straw from a five-ton paddy crop are removed, about 150 kg N, 20 kg P, 150 kg K and 20 kg S is taken from the soil. Almost all the K and about one third of the N, P and S are in the straw. Although lower in nutrients than azolla and chicken manure, crop residues, readily available on the farm, are cheap sources of nutrients. Long-term experiments show that when straw is incorporated rather than burnt or removed, higher rice yields are recorded. These benefits were confirmed in a study of three soils with pH values 4.7, 6.6 and 7.4 and no fertiliser. When straw was incorporation at a rate equivalent to 5t/ha, increases in grain and straw averaged over a seven-year period, were 31% and 71% respectively. However, incorporating straw into poorly drained soils over a long period depresses yields. In order to avoid this, Tanaka (1974) suggested that 6t/ha was the maximum amount of straw that could be incorporated without adverse effects.

Incorporating rice straw into the paddy field is a problem for farmers. They may not have the right machinery and in-situ decomposition of crop residues in anaerobic conditions can be too slow for those planting two to three crops a year. There is also the risk of nitrogen deficiency and depressed yields. Ordinary composting of crop residues is also very slow. However, the IBS rapid composting method introduced in 1986 (Cuevas 1993) speeds up the process with a compost fungus activator, *Trichoderma harzianum*, and procedures that facilitate the rapid decay of agricultural wastes.

Farmers need to mix a source of nitrogen and either animal or green manure, or urea with the straw for quick decomposition and good quality compost. If compost and inorganic fertilisers are combined, rice yields increase 10-15% and incomes rise by 10-20%. These results are better than those achieved using 100% inorganic fertilisers (Cuevas 1993).

Municipal waste and night soil

Municipal and industrial organic waste either as compost or sludge is plentiful in urban areas and is an important source of nutrients. Lardinois and Van der Klundert (1993) found little municipal waste recycling in low-income countries. Technology introduced from Europe for the large-scale processing of waste often does not work and transporting and making compost are often too expensive to compete effectively with chemical fertilisers. Small-scale recycling can provide a feasible alternative. The nutrient content of municipal organic waste varies considerably depending on type, treatment and how heavily it is polluted with plastics, heavy metals and other chemicals. Urgent investment is needed in urban waste recycling to facilitate the better utilisation of this important nutrient resource and to improve the environment and health of the urban population

Night soil, composted human excreta and urine are rich sources of nutrients. Although less important today, night soil is still widely used by many farmers particularly in China. Researchers at CLSU have used night soil fertiliser to produce squash and sunflower. Patricio and Urban (1981) reported that the highest seed yield per plot of sunflowers was obtained when 30t/ha of night soil was added in four applications. The computed net income from this treatment was P3,958.00/ha, an earning of P0.74 on each peso invested. However, whether night soil is acceptable as an organic fertiliser will depend on the cost of labour, health risks and culturally determined attitudes.

Organic-inorganic combinations

Intensive cropping, high yielding varieties and market production increases the demand for soil nutrients. The supply of organic fertilisers and green manures cannot meet this demand because recycling organic waste is only possible to a limited extent and green manures often compete with crop production. Using organic fertilisers alone may not be profitable enough. The best technical and financial option is often to use both organic and inorganic fertilisers. Many studies deal with this issue and countless combinations are possible. Results depend on the materials used and the costs involved.

Individual farmers report interesting experiences in this respect. In 1985, Ricardo Libo-on applied 6 bags of 16-20-0 and 3 bags of urea/ha to his 12ha rice field and harvested an average 7t/ha/season. When he used a mixture of 5t each of azolla, rice hull and sludge from the bio-gas digester and 3 bags of urea plus 2l of foliar fertiliser/ha, he harvested nearly 15t/ha (Pelegrina et al 1992).

AGTALON Cooperative, Pangasinan, produces a commercial organic fertiliser Ag-Bio which cost P135 for 50kg. Yields ranging from 5-6t/ha and returns of P2.90 on investment were achieved with a mixture of 10 bags of Ag-Bio and 1 bag of (14-14-14) inorganic fertiliser. However, pure Ag-Bio organic fertiliser used at a rate of 12 bags/ha yields 4.5-5t/ha giving an estimated return of P3.10 on investment.

Conclusions

Each individual option seems to have its own strengths and weaknesses. The most suitable option will depend largely on local conditions, market opportunities and farmers' preference. In subsistence agriculture and where farmers produce for the organic market, different options for pure organic fertilisers will be needed. Where farmers produce for the conventional market the best way to keep the soil fertile is to combine nutrient sources of different types: organic matter, green manures and commercial inorganic fertilisers (Pandey 1991).

■

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