Table 17.1. Comparison of N concentration in young, fully expanded leaves (outer canopy) and old leaves approaching senescence (inner canopy) and the N concentration in litter collected below the same trees, in a *Eucalyptus grandis* plantation in southern Queensland (R.J.K. Myers, D.M Cameron and S.J. Rance, unpublished manuscript).

Age of trees (months)	Canopy part	Fertilized %N	Unfertilized %N
6		2.54	1.92
		1.93	1.36
		1.16	
7.5		2.55	1.92
		1.75	1.50
		0.66	
21		1.94	1.96
		1.44	1.73
		0.58	

To date, most interest in the synchrony idea has focused on manipulating the immobilization–remineralization cycle. Myers *et al.* (1994) concluded that quality factors influenced the rate of decomposition of litter, and the quantity of nutrients such as N that were immobilized. It was less clear that the nutrients were then remineralized sufficiently rapidly to supply plant needs. It was also considered that the published information found did not adequately test some of the synchrony hypotheses. According to hypothesis S2, the low quality litter immobilizes the nutrient, but later the nutrient is mineralized and eventually the available nutrient accumulation equals that of the soil without litter. However, there would be no advantage nor disadvantage to the synchrony of supply and demand unless some of the nutrient would otherwise have been lost or become converted to an unavailable form. There is anecdotal evidence for such situations in the real world, but we lack solid scientific evidence. Particularly lacking is evidence for rapid enough remineralization of nutrients. Most observations are that remineralization of nutrients occurs relatively slowly and that only a fraction of the immobilized nutrient is remineralized during one crop cycle. There seems to be a difference between the relatively slow rate of remineralization of immobilized N and the relatively rapid release of N from high quality materials such as green manures. The absence of solid supporting evidence for substantial enough remineralization is partly due to the absence so far of experiments specifically designed to test the hypothesis. In particular, many past studies have not run for long enough to truly evaluate the rate of remineralization.

Another mechanism contributing to synchrony is that whereby chemical constituents of litter slow or delay the release of nutrients. Constituents with such properties have included the lignins and polyphenols. In some cases the rate of mineralization from a material was dependent on the lignin-to-N ratio (Becker *et al.*, 1994; Becker and Ladha, Chapter 18, this volume), or the polyphenol-to-N ratio (Palm and Sanchez, 1991; Oglesby and Fownes, 1992), or the (lignin + polyphenol)-to-N ratio (Fox *et al.*, 1990; Handayanto *et al.*, 1994). We believe that a large part of the differences between these various results stems from the different ranges of materials used by the different researchers (see Palm and Rowland, Chapter 28; Handayanto *et al.*, Chapter 14, this volume). Thus when one group used materials with a wide range of lignin and N but a narrow range of polyphenol concentration, lignin-to-N was the best predictor. When another group used

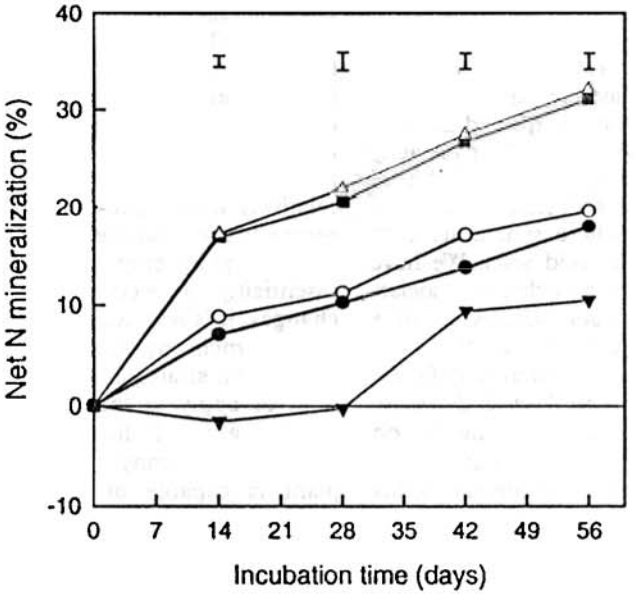


Fig. 17.3. Percentage net N mineralization of N from legume tree prunings (redrawn from Handyanto *et al.*, 1994). ●, *Calliandra calothyrus*; ▼, *Peltophorum dasyrachis*; ■, *Leucaena leucocephala*; Δ, *Gliricidia Sepium*; O, *Gliricidia and Peltophorum.*

materials with a range of polyphenol and N concentration, but a narrower range of lignin, then polyphenol-to-N was the best predictor. There is still a need for a comprehensive study in which a wide range of all three components is included. There is also a need for some longer term studies. The way that short-term studies are difficult to interpret is shown well in several studies, of which that of Handayanto *et al.* (1994) provides an example (Fig. 17.3). One interpretation of this figure is that between 14–56 days, all materials behaved similarly – the slopes are reasonably close together. Then if we believe the idea of lignin and polyphenols inhibiting mineralization, there are delays of a few days to about 4 weeks in the onset of mineralization. However, it would be very interesting to know what happens after 56 days – do the curves continue parallel to each other, or do they converge? This is important because in this example, a loss event occurring at either 14 or 28 days would provide no advantage due to synchrony for the materials with the delayed start to mineralization. Only longer-term studies can answer this question. Handayanto *et al.* (1994) emphasized the role of leaching of water-soluble polyphenolics out of litters, but their data show that a certain, perhaps cell-wall bound, fraction of the polyphenolics resists leaching and remains active.

Research into the importance of polyphenols has suffered from analytical uncertainties. Questions have been raised regarding the most suitable solvent for extraction, the standard used, and the tissue-to-solvent ratio. Constantinides and Fownes (1994) have recommended a tissue-to-solvent ratio of 1.0–2.0 mg ml^{-1}, the use of aqueous methanol rather than water as solvent, and the use of the Folin–Ciocalteu reagent rather than the Folin–Denis reagent (see Palm and Rowland, Chapter 28, this volume). They also observed that air drying gave higher concentrations than oven drying. The group of materials referred to as polyphenols is diverse, and may well be differentially soluble in the solvents used. The usual standards represent only one type of polyphenol, and one can envisage errors if

materials are high in a different type. Further, there is considerable variation in the protein-binding capacity of different polyphenols. Handayanto *et al.* (1994; Chapter 14, this volume) explored the idea that an assay of protein-binding capacity might have predictive value for the N mineralization of different materials.

Another niche where synchrony may be achievable may be acid soils. We have already mentioned the asynchrony associated with the shallow root systems of some crops growing in strongly acidic soils. Strongly acid soils are frequently deficient in nutrients such as N, P and S whose availability depends at least partly on organic cycling. For such nutrients, synchrony may be promoted by organic inputs whereby decomposition products could complex Al and thereby increase soil microbial activity, which in turn may increase the supply of these nutrients. Decomposition products high in low molecular weight aliphatic and aromatic acids are active in complexing Al. However, these compounds are likely to have only transient existence in soil solutions, and fulvic and humic acids are more probably detoxifiers of Al in acid soils (Edwards *et al.*, 1994).

Placement of fertilizers has long been recognized as a means of promoting synchrony. However, placement of residues may also have a role. This could apply to placement of residues relative to that of the fertilizers provided that it was established that there was an improvement in nutrient use efficiency. In the case of P synchrony, it might be necessary to make maximum use of the residues to block adsorption, in which case it may not work unless there is localized placement. In the case of residues containing polyphenols, it may be desirable to place the residues in such a way that leaching of the polyphenols is minimized, for example along ridges. This is another area for research.

Aspects of Synchrony Related to Phosphorus

Synchrony with respect to P refers to the promotion of processes whereby P is maintained in the soil solution for longer. In agricultural production systems which become P deficient sooner or later, despite large stocks of total soil P, P is out of synchrony. The asynchrony is expressed as deficiency, and is even more evident when fertilizer is applied. Fertilizers in which P is relatively soluble produce highly asynchronous situations where the P is highly available early in crop growth, but due to essentially irreversible soil chemical changes, it is less available later in growth. This asynchrony can be reduced by P application strategies such as split application, or applying the P in bands (locally swamping the P fixation sites), and the need for synchrony can be reduced if the plant is capable of taking up P more rapidly than its need for current growth (luxury uptake). There are several other possibilities for improving synchrony of P.

The rate of the P fixation processes can be reduced by some organic materials which react with potential phosphate sites in the soil. Hue *et al.* (1994) observed that P sorption by an Ultisol was reduced by the addition of a yard-waste compost (Fig. 17.4). Rebafka *et al.* (1994) found that fertilizer P utilization was increased from 6% to 14% by adding crop residues, and to 25% after repeated crop residue applications. This was attributed to increased root length density, increased mobility of P and influx of P per unit root length, and perhaps to reduction in the rate of reaction of P with fixation sites. Wang *et al.* (1995) found that adding humic acids to soil with P fertilizer significantly increased the amount of water-soluble P, strongly retarded the formation of occluded P and increased P uptake and yield of wheat by 25%. Singh *et al.* (1991), reviewing research on green manures, concluded that green manure increased the availability of P in waterlogged soils by a range of mechanisms including that of reduction of P sorption capacity.

A second soil biological mechanism that might improve synchrony with respect to P is that of immobilization–remineralization. In this case microorganisms attacking an organic input with a suitably high C-to-P ratio would require an exter-

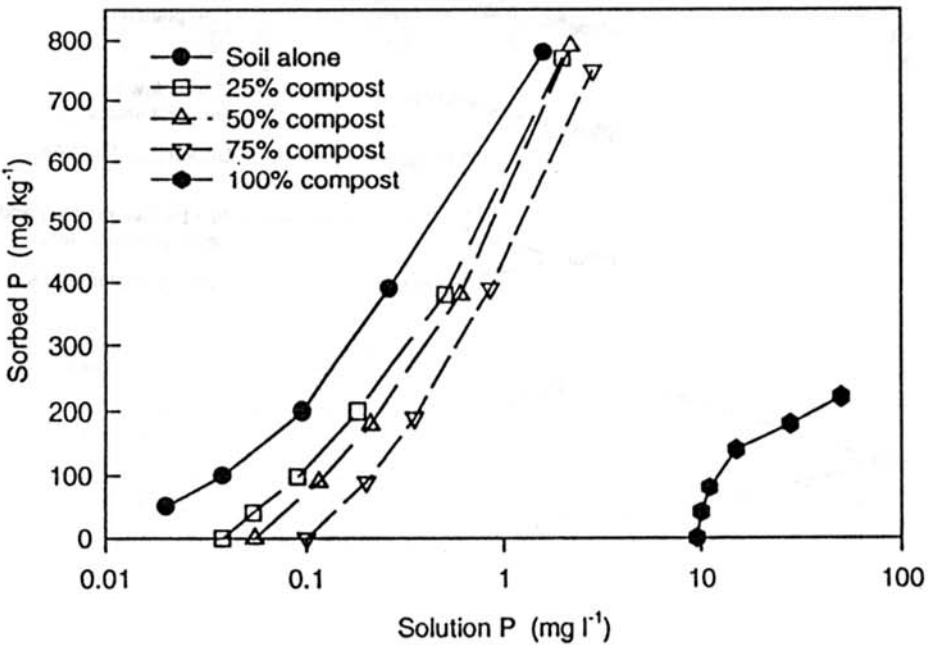


Fig. 17.4. Phosphate sorption isotherms of an Ultisol, a yardwaste compost, and soil/compost mixtures (Hue *et al.*, 1994).

nal source of P, and would therefore remove P from the soil solution, and reduce the opportunity for soil solution P to react with adsorption sites. Hue *et al.* (1994), though not specifically addressing this question, found that immobilized P in a compost had the capacity to mineralize P and maintain the soil solution P of an Ultisol at higher levels than in the unamended soil.

A third mechanism would be that whereby organic anions may reduce soil solution Al by complexation, and as a consequence Al toxicity is decreased and N mineralization is increased, and P demand is increased due to increased plant vigour. Whereas such ideas have logic, it is not so easy to devise experiments that test them exclusively, nor is it easy to interpret the results of past work as related to this sequence of events to the exclusion of other explanations.

The existence of several P-synchrony mechanisms is easy to establish, but it is not easy to ascribe relative importance. In practice, it is more important to identify the management options. Apart from the 'motherhood' options of maintaining soil organic matter and retaining residues, there are some specific questions:

- Can placement of organic inputs together with P fertilizer, as for example in a band or a 'pocket', enhance P-synchrony?
- Can immobilization and remineralization of P improve synchrony, and if so is it necessary, to immobilize before growing the crop, as for example would occur with composting?
- What are the quality factors of organic materials that contribute to the complexing of potential P adsorption sites or which optimize the immobilization–remineralization processes?

Can Synchrony be Farmer-friendly?

Technologies that follow the synchrony concept need to be farmer acceptable or

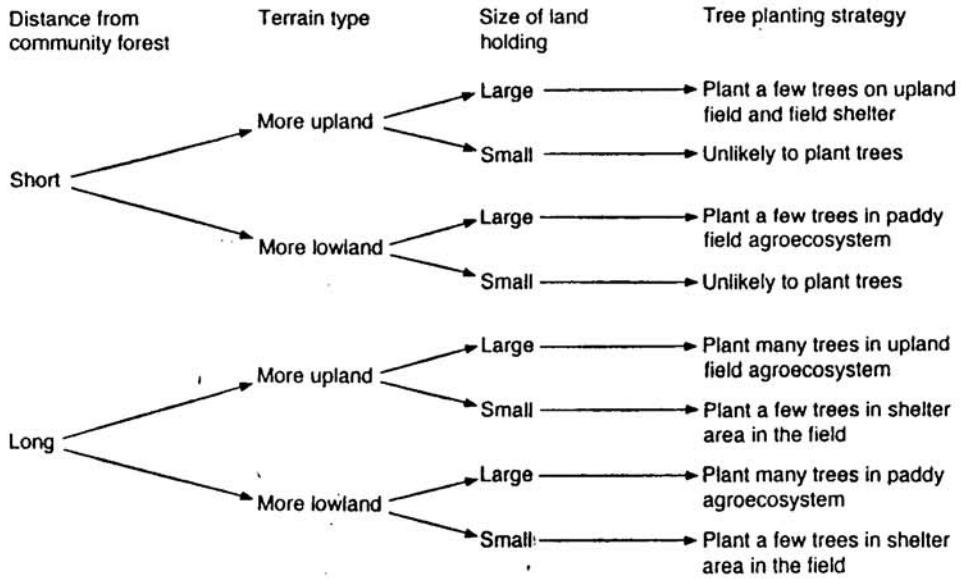


Fig. 17.5. Decision tree for northeast Thailand farmers' strategy to integrate trees into their farms (after Vityakon *et al.*, 1994).

they will remain merely textbook phenomena. Many factors influence farmers in their decisions (Fujisaka, 1992) and researchers need to understand them in order to see which technologies can be adapted and adopted by farmers.

It is a basic TSBF hypothesis that mature natural systems have a tight nutrient cycling as uptake demand normally exceeds the available supply and that they thus are in synchrony.

Many traditional farming systems, particularly those practising polyculture with a considerable tree component, may mimic natural systems and show synchrony of uptake and supply. This explains the research interest in trying to understand complex traditional systems such as the Indonesian home garden system (Michon and Mary, 1994) as well as the slash and burn system of farming (Kleinman *et al.*, 1995). However, increasing pressure on land, plus other factors, has led many farmers to intensify their farming and frequently this has resulted in adoption of higher input monocropping, lacking synchrony, as alternative to the low input traditional systems. Increasing nutrient supply may or may not increase the 'economic efficiency' of the farm, but it often reduces the 'uptake efficiency'. Achieving a high uptake efficiency without incurring plant nutrient stress is not impossible, but it requires additional efforts. Even in the most technically advanced horticultural production systems, a wide range of nutrient use efficiencies can be found (van Noordwijk, 1990).

The likelihood of soil improvement technologies being adopted and adapted by farmers depends on a number of factors. These factors pertain to physical, biological, economic, social and cultural aspects of the farmer's livelihood. Soils, water sources, terrain, climate and infrastructure are among the physical factors. Biological factors include the plants (annual crops, tree crops and cropping systems) and animals (livestock). Among the economic factors are amount of land holding, labour, marketing, on-farm and off-farm income, availability of credit, access to information, and education and experience of farmers. Cultural factors include the

farmers' beliefs and traditions. A combination of these factors influence the farmers' decision whether to adopt and adapt a technology. In northeast Thailand, rice cultivation is the rural people's way of life, and constitutes their food security. Rice cultivation therefore strongly influences decisions regarding other farming operations and off-farm activities. Any new technology should not therefore interfere, for labour or for time, with rice growing if it is to be adopted by the farmers. It is helpful to understand the process of farmer decision making in deciding whether to adopt an introduced technology. The decision tree given in Fig. 17.5 illustrates the process in selecting the best strategy for integrating trees into farms. Distance from the community forest, which reflects accessibility, is the key indicator. The major factors influencing farmers' decision making then are biological (forest availability), physical (terrain type) and socioeconomic (size of land holding).

Some existing technologies of soil improvement, whether or not they are traditional, can be developed further. Technologies that are built from existing ones stand a better chance of adoption by farmers than those that are totally new and unknown. In northeast Thailand, soil improvement by use of compost made in the livestock pen has been practised for decades, whereas new compost-making techniques promoted by government extension agents have not been adopted. The farmers' technique is simpler, less tedious, and less expensive (Wongsamun *et al.*, 1989). Also in northeast Thailand, the effects of trees on soil fertility and growth of associated rice have been studied (Sae-Lee *et al.*, 1992). Traditionally trees and agricultural crops, such as rice and cassava, grow in association. Socioeconomic studies (Vityakon *et al.*, 1994) have identified farmers' criteria for adopting trees into the farming system. Such studies bring about better understanding of factors controlling the existence of a farming practice, and can improve the chances of adoption of new technologies.

The transfer of technologies from an area where they work well to another area depends on whether the environment is suitable for the technology, as well as the constraints of farmers. This can be seen in some areas of northeast Thailand where farmers practise mixed cultivation of rainfed paddy rice and mungbean. The seeds of both are broadcast onto untilled soil at the beginning of the rains. A layer of rice straw is then added to maintain soil moisture and prevent weed growth. The paddies are flooded when the rice is about 10 cm tall. This kills the mungbean which then acts as a green manure for the rice. This practice will work only where there is adequate rice straw for the mulch, and where rains come in sufficient quantity and at the right time to kill the mungbean (Vichiensanth *et al.*, 1992).

Provided that the technology is economically sound, it should be adopted by at least some farmers. Those who adopt it will do so to different degrees; some will adopt it wholeheartedly and others not at all. Success will be greater if the farmers are categorized according to some appropriate criteria, and the technology can then be modified to suit the different categories.

Adoption of soil improvement technologies frequently depends on farmers' economic status. Well-to-do farmers are often more willing to try new things, and are less concerned about risk than poorer farmers. Often this is related to size of land holding and this also indicates potential availability of resources. Extension often follows this approach, initially aiming at adoption by well-to-do farmers followed by diffusion to the poorer farmers. Synchrony may not be exciting to farmers by itself, but it may be acceptable if promoted together with some other beneficial technology. Currently, integrated packages of agroforestry, cropping systems, soil erosion control, and soil fertility maintenance are being promoted. The synchrony concept could readily be built into such packages. However, the risk exists that in adapting the package to their needs, farmers may remove the components giving synchrony.

Potentially there are many reasons why synchrony may not be adopted. Let us examine some scenarios: