Chapter 4

Nutrient Competition Between Hedgerows and Crops in a Contour Hedgerow Intercropping System

Tang Ya

INTRODUCTION

Sloping agricultural land technology (SALT), or contour hedgerow intercropping agroforestry technology (CHIAT) as it is often called, has been promoted in the HKH region since the early 1990s. However, during the course of testing, demonstration, and extension, a number of concerns have appeared. A particular concern voiced by farmers is that of competition between the hedgerows and crops for nutrients; this is a major consideration for farmers when deciding whether to adopt the technology.

Nutrient competition

Plants require light, nutrients, water, and soil for their growth and survival. The incorporation of woody perennial plants as hedgerows into a cropping system on sloping land introduces the possibility of competition between the hedgerow plants and crops in the alleys for light, nutrients, and water. Competition between hedgerow plants and companion crops is probably the most frequent reason given as to why crops have not yielded more under hedgerow intercropping than when grown alone (Lal 1989; Singh et al. 1989; Fernandes et al. 1990).

The competition between hedgerows and crops can be both above and below ground. Competition for light is the most prominent above-ground factor. This can be reduced by timely pruning, as confirmed by some authors. For example, Leihner et al. (1996) showed that there was no decisive shading effect on crops when hedges were pruned 2-3 times a year. The below-ground competition includes competition for nutrients and competition for soil moisture. The competition between a hedgerow and crops for nutrients might be very severe as both the hedgerow and the crop species have a tendency to concentrate their roots in the fertile surface soil. Kang (1993) cites a number of studies conducted in various parts of the tropics with different hedgerow species that showed significant reductions in performance and yield when crops were grown in the first few rows adjacent to the hedgerows (*Inga edulis*, Fernandes et al. 1990; *Senna spectabilis,* Basri et al. 1990; *Calliandra calothyrsus* and *Paraserianthes falcataria*, Evensen and Yost 1990).

Research, testing, and demonstration of contour hedgerow intercropping in the HKH region started in 1991 but there have been few studies on hedgerow-crop competition, although there have been reports of a considerable increase in soil nitrogen and organic matter in a system established on very poor soil in Ningnan, China (Sun Hui et al. 1999). The results from ICIMOD's project on Appropriate Technologies for Soil Conserving Farming Systems (ATSCFS) in six of ICIMOD's member countries also indicated the positive effects of contour hedgerows of nitrogen-fixing plants on soil fertility. Furthermore, there is increasing evidence that alley cropping has the potential to improve soil conditions, particularly nutrient availability (Lal 1989; Yamoah et al. 1986) and soil physical structure. Although competition for nutrients was identified as one of the highest priorities for research (Anderson et al. 1993), it has not yet been thoroughly investigated (Gregory 1996). The following describes the results of an experiment carried out between 1998 and 2001 at ICIMOD's Godavari Trial and Demonstration Site in the mid hills of Nepal to investigate the competition between hedgerow plants and crops for soil nutrients in a SALT system.

MATERIALS AND METHODS

Study site

The experiment was carried out at ICIMOD's Godavari Trial and Demonstration Site. The site characteristics are summarised briefly in Chapter 1.

The experiment was carried out along a single established hedgerow alley. The hedgerows of *Alnus nepalensis* had been established in 1993 with seedlings. In 1998, when the experiment commenced, the alley between the two hedgerows had already become a level terrace; the riser at the upper side was about 70 cm high. Vegetables or maize had been planted along the alley for about four years prior to the study.

Experimental design

The experiment consisted of two treatments with three replicates. Treatment 1 was with cultivation of crops and Treatment 2 without crops (control). The basic layout is shown in Figure 4.1**.** The two treatments were arranged alternately along one alley with about 1m gap between treatments as a buffer area. The alley was around 5m wide; experimental plots 5m long and 3m wide were laid out close to the terrace hedgerow, i.e., there was a gap of 1.5m or more between the study plot and the terrace riser at the upper side.

The crops in Treatment 1 were planted according to normal farmer's practice in the area. Radish was planted in October and harvested in March/April of the following year, maize was planted in March/April and harvested in late September or early October of the same year. The first crop was radish planted in 1998, the last crop was radish planted in 2000. Four rows of crops were planted in each plot (Figure 4.1). Local varieties of both maize and radish were used. A locally purchased concentrated organic fertiliser 'kisan mal' (see Chapter 2) was applied to the treatment plots with crops at a rate of 16 t/ha for each planting season; its nutrient composition is 3% N, 5% P_2O_5, and 2% K_20.

Crop yield was measured row by row. The weight of corn seeds and total biomass were measured for maize; the fresh weight of the radish root was measured for radish.

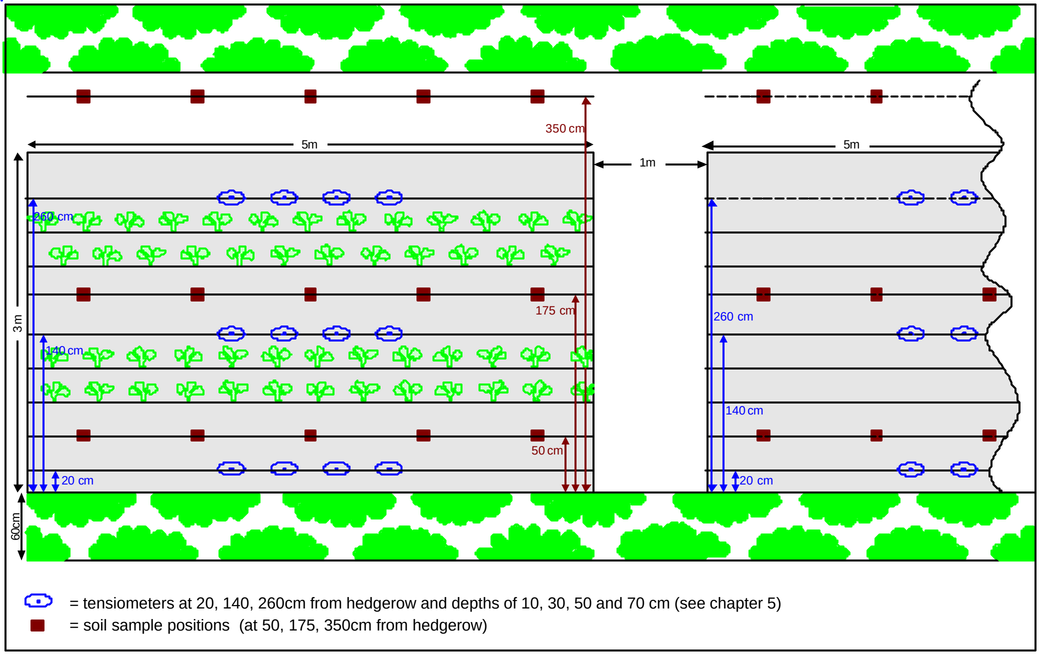

Figure 4.1: Experimental layout

The fresh biomass produced each year by the two rows of the double hedgerow bounding the alley was also measured.

Soil samples were collected in 1999, 2000, and 2001 from a depth of 0-30 cm at distances of 50, 175, and 350 cm from the hedgerow of the alley. The samples were collected in March or April after radish was harvested and just before the maize was sown. Soil samples were collected at five points within each experimental plot at each distance and were mixed to obtain one compound sample for each distance for each treatment. A representative 1 kg sample was taken from the compound sample. The soil samples were analysed at the Nanjing Institute of Soil Science, Chinese Academy of Sciences.

The experiment was repeated three times in consecutive years from 1998 to 2001. The first crops were planted in 1998 and the first soil samples taken in 1999 before the second maize crop was planted.

Results

Soil fertility

Soil acidity (pH value)

The values for soil active acid (pH_{H_2O}) for each of the three distances from the hedgerow in the two treatments in each of the three years are shown in Figure 4.2; those for soil potential acid (pH_{HCl})] are shown in Figure 4.3.

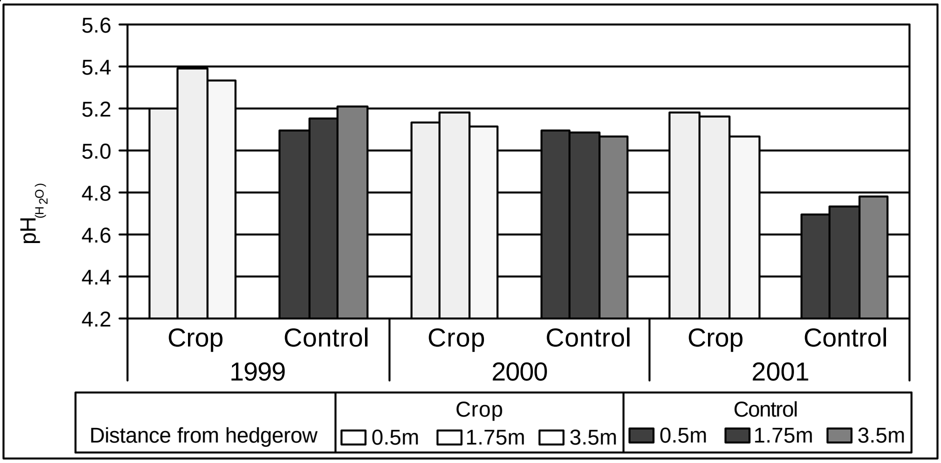

Figure 4.2: Soil active acid

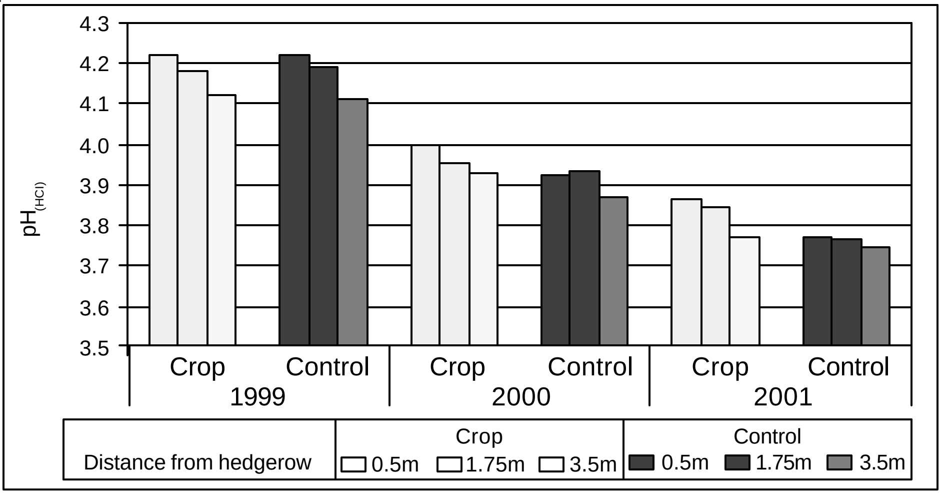

Figure 4.3: Soil potential acid

Soil acidity rarely decreases unless lime or similar materials are applied. Over the three years, there was a slight decrease in soil pH (increase in acidity) which was more marked in the control plots. In all years, the pH values in the plots with crops were slightly higher than in the control plots; the difference was greatest in 2001. This may have resulted from the use of organic fertiliser in the crop plots, but the change in pH value of the control was not significant compared to the crop treatment. In the crop plots, the pH value closest to the hedgerows remained fairly constant, whereas those further from the hedgerows decreased in the first year. In the control plots, the pH values at all distances from the hedgerows decreased.

Figure 4.3 shows clearly that the potential acidity decreased for both treatments in each year. Regardless of whether crops were planted, the soil closer to the hedgerows had a higher potential acidity, indicating that the hedgerows have an impact on this soil characteristic.

Organic matter

The soil content of organic matter for each of the three distances from the hedgerow in the two treatments in each of the three years is shown in Figure 4.4.

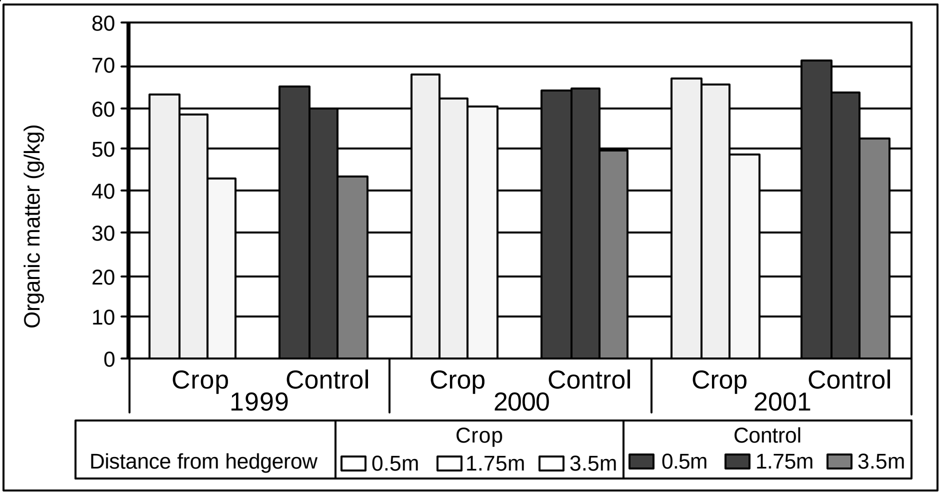

Figure 4.4: Soil organic matter

The soil organic matter content was generally higher close to the hedgerows in all the plots, with or without crops. The difference in the values of soil organic matter at 0.5m or 1.75m from the hedgerows and at 3.5m from the hedgerows was significant in 1999 and 2001 in the crop plots and in 1999 and 2000 in the control plots. There was no significant difference in soil organic matter content at 0.5m and 1.75m from the hedgerow. The soil organic matter content at 0.5 m from the hedgerow increased slightly over the years in both the crop and control plots. The values of soil organic matter were similar in the plots with crops and the control plots.

The results indicate that the hedgerows of nitrogen-fixing plants helped increase soil organic matter, confirming the results reported by Sun Hui et al. (1999). There are two likely reasons: one is the addition of hedgerow clippings and litter into the soil; the other is the decay of roots cut off during ploughing each year. The experimental site was already level, so it is unlikely that organic matter moved from the terrace and accumulated at the base of the hedgerows. Studies on hedgerow systems in the tropics have not identified similar increases in soil organic matter, possibly because organic matter decomposes much faster in the tropics so that there is less residual matter.

Clearly there was no negative competition between hedgerows and crops for soil organic matter rather the opposite; the hedgerows actually increased soil organic matter.

Total nitrogen

The soil nitrogen content for each of the three distances from the hedgerow in the two treatments in each of the three years is shown in Figure 4.5.

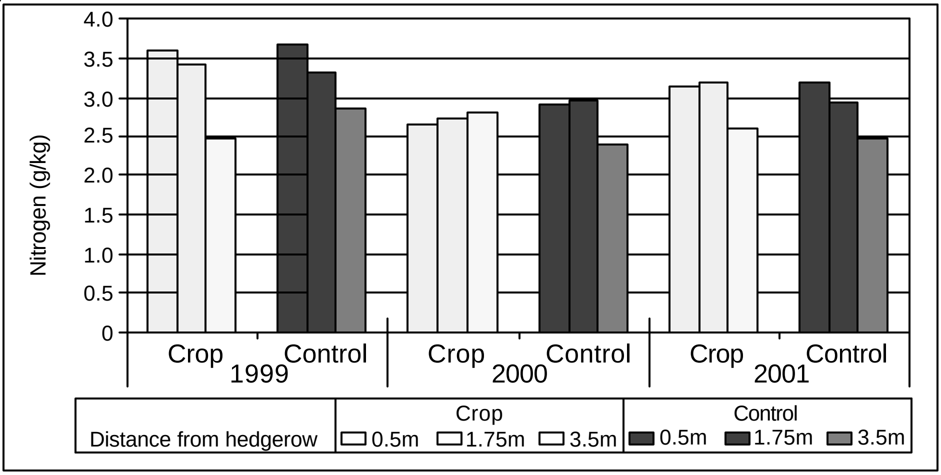

Figure 4.5: Soil nitrogen

The total nitrogen values fluctuated somewhat, mostly decreasing in the first year and remaining constant or slightly increasing in the next. With the exception of the crop plot in 2000, the nitrogen content at 0.5m and 1.75m from the hedgerows was higher than at 3.5m from the hedgerows. The difference was significant in both crop and control plots in 1999 and 2001, in control plots the difference between soils at 0.5m and 1.75m was also significant. There was no significant difference between crop and control plots.

The results indicate that the hedgerows had a positive effect on soil nitrogen. This contrasts with the results obtained in the soil erosion plots, where hedgerows did not show any positive effect on soil nitrogen maintenance compared to traditional farming practice (Chapter 3). The difference may have resulted from the fact that this study was carried out on almost level terrace with well-established hedgerows, whereas the soil erosion plots were established on quite steep sloping land and the hedgerows were just developing.

Available phosphorous

The soil available phosphorous for each of the three distances from the hedgerow in the two treatments in each of the three years is shown in Figure 4.6. The content of total phosphorous is often high in acidic soils, but as a result of the low pH, the available portion is usually very low. The soil available phosphorous varied considerably among years, but in all cases the value was lowest furthest from the hedgerow and, except for the crop plots in 2001, highest close to the hedgerow. The results suggest strongly that hedgerows can improve the availability of soil phosphorous. This could be related to the use of hedgerow clippings, the activity of hedgerow roots, or the segregation by hedgerows of chemicals that improve the availability of soil phosphorous.

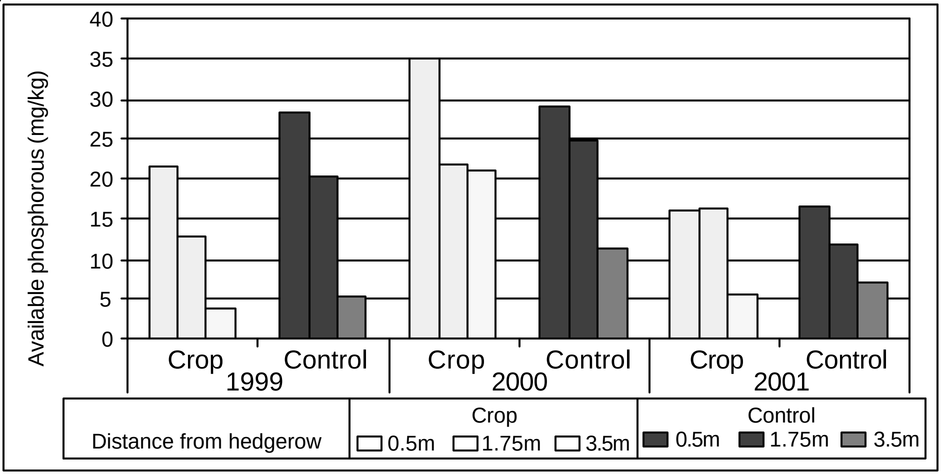

Figure 4.6: Soil available phosphorous

Available potassium

The soil available potassium for each of the three distances from the hedgerow in the two treatments in each of the three years is shown in Figure 4.7. The available potassium decreased every year under both treatments at all positions except for the farthest point from the hedgerow in the crop plots in 2001, a similar pattern to that observed in the soil erosion plots (Chapter 3). The lowest value for available potassium was observed at a distance of 1.75m from the hedgerows in all plots and years, there was no clear pattern for the highest value, however, which was found both closest and furthest from the hedgerow depending on the treatment and year.

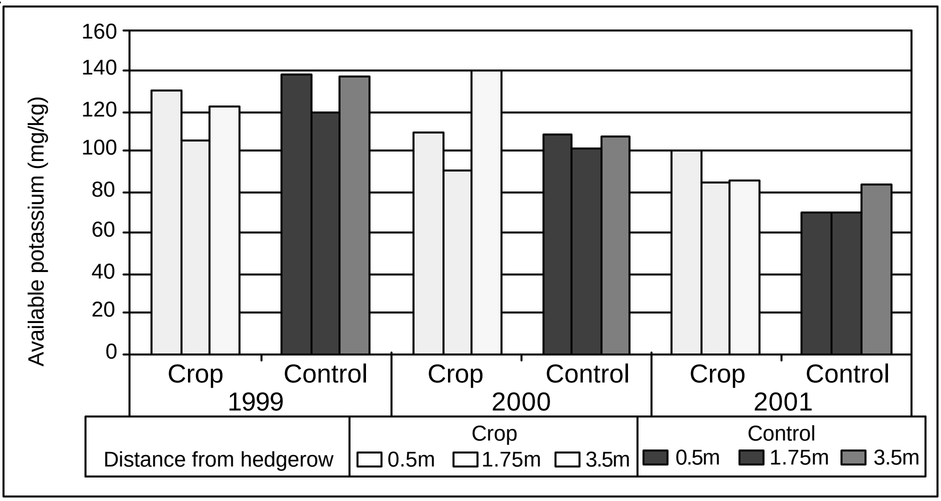

Figure 4.7: Soil available potassium

Crop yield

The average yields of maize and radish in 1999 and 2000 in the three replicate plots is shown row by row in Table 4.1. (The hedgerow alley lay at some distance from the forested area of the site and was at the centre of a series of hedgerow terraces; the crops were not particularly affected by wild animals.)

Table 4.1: Yield of maize and radish (kg/ha)

		Maize		Radish
	Crop row	Biomass	Grain	
1999	1 (Closest to hedgerow)	2,809	409	8,069
	2	3,064	395	6,414
	3	4,124	639	5,979
	4	3,807	906	6,393
2000	1 (Closest to hedgerow)	3,103	598	9,331
	2	2,920	644	8,228
	3	5,030	1,039	7,428
	4	3,301	795	7,834

The results for radish showed a clear pattern with the highest yield from the row closest to the hedgerow, a decrease in yield in the next two rows and a slight increase in yield in row 4 which lay furthest from the bottom hedgerow, but closer to the riser of the upper hedgerow. The higher radish yield correlated with the higher nutrient level closer to the hedgerow.

The results for maize were less clear. There was no direct correlation between biomass production and grain production for the maize – more biomass was not necessarily associated with more grain – which further complicated the interpretation of the results. Even so, for both biomass and grain, there was a higher yield in rows 3 and 4, furthest from the hedgerow, than in rows 1 and 2, closest to the hedgerow, with a tendency to lower yields in row 4, closer to the next hedgerow riser, than in row 3. This is the opposite of the results obtained with radish, although statistical analysis indicated that the differences were not significant (Chapter 5).

Other authors have reported significant affects of hedgerows on crop yield: with much lower grain and biomass production closer to hedgerows. For example, Salazar et al. (1993) reported that crop yields in the rows closest to the hedgerows were reduced by up to 60% compared to more distant rows, and there are many similar reports (Lawson and Kang 1990; Fernandes et al. 1990; Basri et al. 1990, Evensen and Yost 1990). The results for maize in the present study are similar to those in these earlier reports, but those for radish are the direct opposite.

Fresh biomass of hedgerow clippings

The annual fresh pruned biomass from the upper row of the double hedgerow and the lower row of the double hedgerow is given in Table 4.2.

The quantity of biomass produced by the hedgerows is likely to be the most important factor contributing to fertility changes in a hedgerow intercropping system. As discussed in Chapter 3, the production of fresh biomass (5.3t/ha) was much lower than the 8-14 t/ha reported for other species in the HKH region (Sun Hui et al. 2001). Selection of other fast growing hedgerow species is needed.

Table 4.2: Fresh biomass of hedgerows of *Alnus nepalensis* (t/ha)

	1998	1999	2000	2001	Average
Upper hedgerow	2.6	2.8	3.0	3.2	2.9
Lower hedgerow	2.3	2.1	2.5	2.8	2.4

Discussion

One of the significant advantages of contour hedgerow intercropping is the improvement of soil fertility that is gained through the continuous addition of hedgerow clippings to the soil. Nitrogen-fixing plants are used for the hedgerows as they can fix nitrogen from the atmosphere in the form that plants can use. Most of the perennial woody nitrogen-fixing plant species that have been used to establish hedgerows are fast growing. However, fast growth also implies a need for nutrients from the soil. Fear of above ground and below ground competition between hedgerows and crops for light, soil nutrients, and soil moisture – and a resultant reduction in crop yield – was one of the major reasons given for farmers not adopting the technology (Böhringer and Leihner 1997). Farmers in Ningnan in Sichuan Province, China, also considered that the hedgerows grow so fast that they must use up most of the nutrients in the alley, and were sure that crops in the alley would not grow well. Competition for nutrients has been regarded as a cause of reduced crop yield in many tropical areas. But there have been reports of both positive (Leihner et al. 1996) and negative effects (Singh et al. 1989) of hedgerows on crop production.

The results of this study indicate that there was no competition between hedgerows and crops for most soil nutrients in an established hedgerow system. On the contrary, the hedgerows contributed to improving soil fertility: the highest content of many nutrient elements was found closest to the hedgerow, especially organic matter, nitrogen, available phosphorous, and a number of exchangeable cations. If there was competition, the lowest content should have been found closest to hedgerows.

However, the crop yield did not correspond directly with the nutrient status of the soil at different distances from the hedgerows. The fresh yield of radish was higher closer to the hedgerows, as expected, but the yield of maize was not. The difference may be because radish is sensitive to phosphorous, and thus the yield was best where the phosphorous values were highest. Maize may be more sensitive to other factors like light (shading) and moisture that have a more significant effect than the effect of the better pool of nutrients close to the hedgerows.

The nutrient contribution from the hedgerow clippings was not significant. We did not analyse the nutrient composition of the *Alnus nepalensis* used in this study, but the N content of the leaves can be estimated from analyses of this and similar species in other parts of the region (Deng Ting-xiu; Liu Guo-fan 1987; Sharma et al. 1994). These analyses indicate that young leaves have a nitrogen content of 2.6 to 3% (dry matter). An average of 45.5 kg/year of fresh hedgerow clippings, or around

11.5 kg dry matter (estimated using a moisture content of 75%), were added to the experimental plots, indicating an addition of around 0.30 kg of nitrogen for the whole experimental alley of (42.3 x 5m or 187 m^2), equivalent to 16-19 kg/ha per year.

Conclusions

The results of the study suggest that there is no competition between hedgerows and crops for underground soil nutrients. The soil content of most nutrients was higher closer to the hedgerows suggesting that the *Alnus nepalensis* hedgerows actually improved the soil nutrient status. The reduced maize yield closer to the hedgerows, though insignificant statistically, might be the result of shading. The soil nutrient status in the same alley needs to be studied again (preferably after 5 and 10 years) to properly elucidate the effects.

References

Anderson, L.S.; Muetzelfeldt, R.I.; Sinclair, F.L. (1993) 'An Integrated Research Strategy for Modelling and Experimentation in Agroforestry.' In *Commonw. For. Rev*. 72: 166-174

Basri, I.H.; Mercado, A.; Garrity, D.P. (1990) 'Upland Rice Cultivation Using Leguminous Tree Hedgerows on Strongly Acid Soils.' In *Experimental Agriculture,* 26: 1-10 (cited in Kang 1993)

Böhringer, A.; Leihner, D. E. (1997) 'A Comparison of Alley Cropping and Block Planting Systems in Bubhumid Benin.' In *Agroforestry Systems,* 35:117-130

Deng Ting-xiu; Liu Guo-fan (1987) 'A Preliminary Study on Alder and Cypress Mixed Forest. 'In *Acta Phytoecologica et Geobotanica Sinica*, 11(1): 59-66

Evensen, C.L.; Yost, R.S. (1990) 'The Growth and Lime Replacement Value of Three Woody Green Manures Produced by Alley Cropping in West Sumatra.' In: Moore, E. (ed) *Agroforestry Landuse Systems*, pp 109-112. Waimanalo (Hawaii): Nitrogen Fixing Tree Association (NFTA)

Fernandes, E.C.M.; Davey, C.B.; Sanchez, N.C. (1990) 'Alley Cropping on an Ultisol: Mulch Fertiliser and Hedgerow Root Pruning Effects.' In *Agronomy Abstracts* (1990): 56

Gregory, P.J. (1996) 'Approaches to Modelling the Uptake of Water and Nutrients in an Agroforestry System.' In *Agroforestry Systems,* 34: 51-65

Kang, B.T. (1993) 'Alley Cropping: Past Achievements and Future Directions.' In *Agroforestry Systems*, 23: 141-155

Lawson, T.L.; Kang, B.T. (1990) 'Yield of Maize and Cowpea in an Alley Cropping System in Relation to Available Light.' In *Journal of Agricultural and Forest Meteorology*, 52: 347-357

Lal, R. (1989) 'Agroforestry Systems and Soil Surface Management of a Tropical Alfisol. 2. Water Runoff, Soil Erosion and Nutrient Loss.' In *Agroforestry Systems*, 8: 97-111

Leihner, D.E.; Ernst-Schaeben, R.; Akonde, T.P.; Steinmüller, N. (1996) 'Alley Cropping on an Ultisol in Subhumid Benin. Part 2: Changes in Crop Physiology and Tree Crop Competition.' In *Agroforestry Systems*, 34:13-25

Salazar, A.; Szott, L.T.; Palm, C.A. (1993) Crop-tree Interactions in Alley Cropping Systems on Alluvial Soils of the Upper Amazon Basin. In *Agroforestry Systems*, 22: 67-82

Sharma, R.; Sharma, E.; Purohit, A.N. (1994) 'Dry Matter Production and Nutrient Cycling in Agroforestry Systems of Cardamom Grown under Alnus and Natural Forest.' In *Agroforestry Systems*, 27: 293-306

Singh, R.P.; Ong, C.K; Saharan, N. (1989) 'Above and Below Ground Interactions in Alley-cropping in Semi-arid India.' In Agroforestry Systems, 9: 259-274

Sun Hui; Tang Ya; Chen Keming; He Yonghua (1999) 'Effect of Contour Hedgerow System of Nitrogen Fixing Trees on Soil Fertility Improvement of Degraded Sloping Agricultural Lands.' In *Chinese Journal of Applied and Environmental Biology*, 5(5): 473-477

Tang Ya //Check refs to books in this series//

Yamoah, C.F.; Agboola, A.A.; Wilson, G.F. (1986). 'Nutrient Competition and Maize Performance in Alley Cropping Systems.' In *Agroforestry Systems*, 4: 247-254

Part of a terrace formed by nitrogen-fixing hedgerows showing the terrace riser at the back, which affects the moisture gradient in the terrace – as discussed in the next chapter.