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SPECIES INTERFERENCE AND SOIL CHANGES IN CONTOUR HEDGEROWS PLANTED ON INCLINES IN ACIDIC SOILS IN SOUTHEAST ASIA

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Abstract: Contour hedgerow systems are widely viewed as an important element of conservation farming on the Oxisols and Ultisols that dominate the humid tropical uplands of Southeast Asia. However, little is known concerning the nature of hedgerow-crop interference planted on uplands on acidic soils This paper discusses recent results on above- and below-ground interactions on Oxisols and Ultisols. Row-wise sampling of upland rice biomass and grain yield showed a characteristic dome-shaped response pattern, often modelled satisfactorily by a quadratic response function. The suppression effect of hedgerow on crop was not overcome by the application of more nutrient as green leaf manure or inorganic fertilizer. Forage grasses interfered more with the alley crop than leguminous forages and shrubs. Guinea grass (Panicum maximum) and Vetiver (Vetiveria zizanoides) both suppressed rice yields near the hedgerow.

In the areas adjacent to the hedgerows, rice growth tended to be suppressed more than maize. The installation of root barriers between hedgerow and crop did not significantly prevent yield suppression near the hedgerow, even when frequent pruning minimized shading. Major soil properties changed as natural terraces developed behind the perennial contour vegetation and strongly affected crop performance in the upper alley. These soil spatial changes influenced crop performance more than direct interference (either below- or above-ground) between the perennial hedgerow and the annual crop.

1. Introduction

Interference between perennial hedgerows and annual crops is a dominant issue in the debate about the productivity and sustainability of hedgerow intercropping systems. During the past decade, research has begun to explore these interactions [Ong et al. 1991].

Competition occurs when the available supply of a resource is below the joint requirements of two organisms and as a result the performance of one or both is impaired. Resource sharing in agroforestry systems has been reviewed by Buck (1986). Competition is inevitable in alley cropping systems, but the dominant resource competed for varies in each situation. Accurate identification of this dominant resource will improve the prospects of alleviating the negative effects of competition.

The perennial plants tends to exert a competitive advantage vis-a-vis the annual crops both above- and below-ground. Above-ground interference is often due to a dominant stature. Below-ground, it may be due to a root system that is deeper, and very prolific, and fully developed prior to the establishment of the annual crop. In intercropping systems, competition sometimes increases the production of the system as a whole, or helps to stabilize output when the resource supply is erratic [Monteith et al. 1991]. However, where the perennial is over-dominant, the intercropping advantage may be lost.

Experience is accumulating with the use of contour hedgerow systems which are considered to be a useful element of conservation farming on the sloping, acidic soils that dominate the uplands of southeast Asia [Garrity et al. 1992]. Different hedgerow-crop combinations suit different ecosystems, farm resources, and market conditions. Depending on the species combination selected and management, contour hedgerow systems can reduce soil erosion and provide animal fodder, cash income, green manure for soil fertility improvement, and/or fuelwood.

Early work on alley cropping in southeast Asia [Guevara 1976, Vergara 1982, Alferez 1980, O'Sullivan 1985] did not give much consideration to species interference. This is probably because the majority of work done was on high-base status soils, hedgerows were pruned frequently, and yields were generally increased by alley cropping.

Strongly acidic Ultisols and Oxisols dominate the uplands of most countries in the region [Garrity 1984]. Recent studies on the acidic uplands of Indonesia [Evensen 1989] and the Philippines [Basri et al. 1990] treat species interference as a major issue. However, further research is urgently required on species selection and the management of inter-species competition.

This paper reviews work on species interaction on sloping acidic soils in the southern Philippines. Most of the work reported here was done in Claveria, northern Mindanao, Philippines where maize, upland rice, and cassava are cultivated with animal draft power on rolling to steep land. One or two crops are produced per annum. Annual rainfall is 1800-2000 mm. The soils are fine-textured Oxisols and acid Inceptisols with pH between 4.3 to 5.3. A companion paper (by Fujisaka) in this volume discusses how farmers adapted alternative hedgerow systems in the area.

2. Crop Spatial Variation Across the Alley

After two to three years of alley cropping with upland rice on a strongly acidic soil, the row-wise sampling of rice biomass and grain yield show a characteristic dome-shaped response pattern (figure 1), often modelled satisfactorily by a quadratic response function. The yields obtained in the center rows of the alley are usually greater than for a comparable area in a conventional open field system, however, yields from rows adjacent to the hedgerow are often much lower. The results of the studies by Fernandes (1990) on an Ultisol in the Peruvian Amazon, and by Evensen (1990) on central Sumatra Oxisol show a similar response of upland rice in alley cropping systems.

3. Interference Severity: Alternative hedgerow species

Most alley cropping research has been done with N-fixing leguminous trees. The local N-fixing legume found most suitable for acidic soil conditions in the southern Philippines was *Gliricidia sepium* [Mercado et al. 1989]. Another common local species with superior adaptation to soils with pH less than 4.5 is *Senna spectabilis*, a legume which neither nodulates nor fixes significant quantities of N [Ladha et al. 1992].

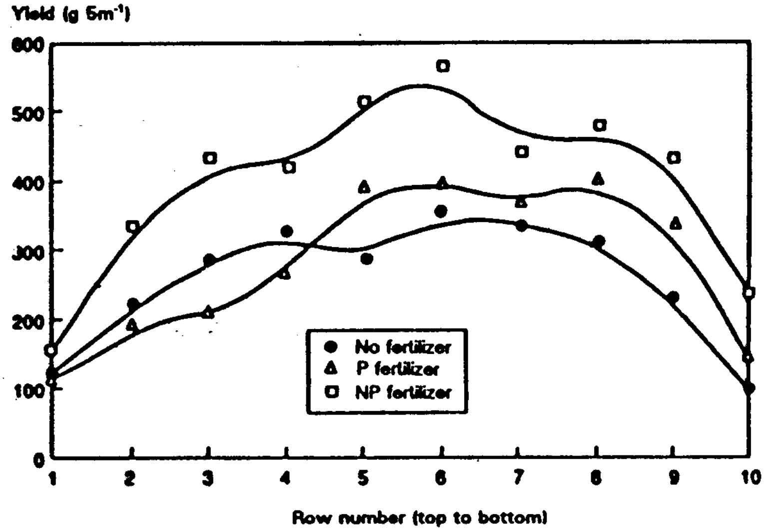

Figure 1. Grain yield of upland rice on a row-by-row basis, grown in alleys between hedges of *Senna spectabilis* which supplied green leaf manure for the crop. Fertilizer rates = 20 kg P/ha and 50 kg N/ha [*Source*: Basri et al. 1990]

The long-term above-ground biomass and nutrient content of these two species, and their effects on the performance of upland rice as an alley crop were compared. During the third and fourth year after establishment total biomass and N content of leaf and green stem prunings, remained highest in *Senna spectabilis* even without any contribution from rhizobial N fixation. In *Gliricidia*, 30-55% of the N yield of the prunings originated from atmospheric N fixation. The extent of yield reduction in rows near the hedgerow, and the distance from the hedgerow that is affected, greatly influence the overall system productivity. Application of inorganic fertilizer or greater quantities of hedgerow prunings, typically displaced the curve to a higher amplitude (figure 1) but did not flatten the shape of the response function. The shape of the response function did not change when all prunings were removed for fodder. This suggests that hedgerow competition with the crop is not overcome by nutrient application.

Fodder grasses such as Napier (*Pennesitum purpureum*) are a more popular hedgerow alternative among farmers at the Claveria research site and elsewhere [Fujisaka and Carrity 1991]. Their relative competitiveness vis-a-vis the tree legumes was therefore of interest. Napier was cut each month and used as a ruminant fodder in a cut-and-carry system. The above-ground biomass produced annually by Napier was 50-65% lower than that produced by the two tree species, but competition between the grass and the annual crop was accentuated by the removal of the cut grass from the field.

Results over three years (figure 2) indicate that yield depression on upland rice was lowest where *Gliricidia* hedgerows were adjacent to the rice, in comparison to *Senna* and Napier. *Senna* and Napier had a similar growth depressing effect on the adjacent upland rice rows. Rice yields in the center of the alley were similar for Napier and *Gliricidia*, but lower with *Senna*. Subsequently, species interference was compared (figure 3) using a range of prospective hedgerow species including a forage legume (*Stylosanthes guayanensis*), two grasses (*Vetiver* and Guinea grass), and a woody legume (*Flamengia congesta*).

Average grain yields were highest with the forage and woody legumes at all positions in the alley. The grasses, Guinea grass (*Panicum maximum*) and Vetiver (*Vetiveria zizanoides*), reduced rice yields most severely. This similarity in the relative competitiveness of Vetiver and Guinea grass is significant because of current interest in using Vetiver species for erosion control.

One prospective strategy for soil conservation, which minimizes hedgerow species interference with the annual crop, is the use of natural vegetative strips (NVS). These are narrow (0.5 m) strips of land left unplowed at intervals along the contour on which wild perennial grasses develop [Garrity et al. 1992]. The strips do not provide green manure, or substantial quantities of fodder, but have the advantage of ease of establishment, low maintenance labor requirements, and a presumed reduction in crop competition. Natural strips in trials using Claveria produced only 12-14% as much biomass as Napier grass, or a Napier and *Gliricidia* combination [P. Garrity and A. Mercado, unpubl. data]. The slower growth rates and low biomass accumulation of natural strips presumably reduce the hedgerow's demand for nutrients and water, and reduce or eliminate the shading of the adjoining crop.

Hedgerow intercropping improves yields in certain situations. Mercado et al. (1991) found that when *Gliricidia sepium* was interplanted with coffee arabica, it stimulated coffee growth and yield. *Gliricidia* prunings increased maize yields by 42% and upland rice by 132%.

4. Susceptibility of Different Crops to Hedgerow Interference

Crops differ in their response to hedgerow intercropping. Maize tends to respond more to the application of green leaf manure in the alleys than does upland rice (treatment M3 in figure 4). Maize also responds more to N and P fertilizer application (figure 4). Conversely, maize yields tend to be depressed to a greater

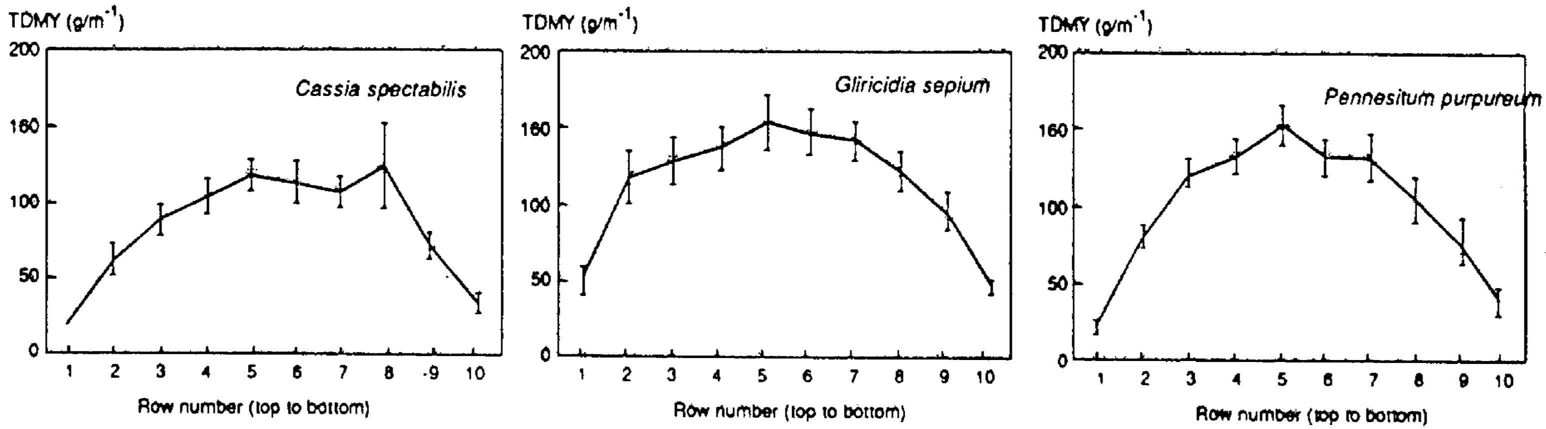

Figure 2. Total dry matter (TDMY) of upland rice row-wise across the alley with hedgerows on an N-fixing tree legume (*Gliricidia sepium*, non N-fixing legum (*Senna spectabilis*, and forage grass (*Pennesitum purpureum*) Values are averages for 3 years, with 4 replications per year. Claveria, Misamis Oriental, 1989-1991.

extent by the removal of prunings generated in situ for animal fodder (treatment M2 in figure 4).

Upland rice shows a lower fertilizer efficiency than maize in hedgerow intercropping, whether the nutrient is applied as green leaf manure or inorganic fertilizer. Its greater susceptibility to drought stress appears to be a contributory factor. Mid-season drought is common in Claveria and many Asian upland rice-growing areas. Drought depressed rice yields most severely when hedgerow prunings were abundant (figure 4). This was apparently due to increased evapotranspiration during the reproductive stage when the leaf area index of the whole system was high.

The pattern of yield response across the alley was parabolic for rice while maize yields frequently had a linear response with much less depression in the rows near the hedgerow than was the case with rice (figure 5). Plant height varied less across the alley for both crops. The differences in growth response to alley position between rice and maize may be attributed to the faster growth rate, taller stature, or the rooting pattern of maize.

5. Above and Below-ground Competition

The development and management of improved hedgerow intercropping systems requires a clear understanding of the components of species interference. Above-ground interactions in agroforestry systems were reviewed by Monteith et al. (1991). A taller-statured hedgerow tends to exert four types of microclimatic effects on an associated annual crop: changes in light interception, rainfall interception, saturation vapor pressure in the canopy, and crop temperature. The effect upon the crop may be negative or positive.

Shading effects tend to be particularly pronounced on short-statured crops such as upland rice grown in association with tree hedgerows. Above-ground competition is likely unless pruning is frequent. In our studies, pruning frequency was generally twice per cropping season, a frequency that farmers may be reasonably capable of applying.

In humid tropical environments, with severe soil nutrient deficiencies (particularly P) and high aluminum (Al) saturation of the exchange complex, competition for nutrients may dominate tree-crop interactions. High exchangeable Al tends to inhibit deep rooting by trees, promoting more intense root competition for P and other nutrients. The pruning inputs do not supply enough P and other nutrients to meet annual crop requirements [Szott et al. 1991, Basri et al. 1990]. Further, the P content of the prunings may have been captured by the trees predominantly from the crop root zone. The results of the studies by Fernandes (1990) and Evensen (1989) support this suggestion. Thus, concerns have been raised about the viability of hedgerow intercropping on very acidic soils [Szott et al. 1991, Garrity et al. 1992].

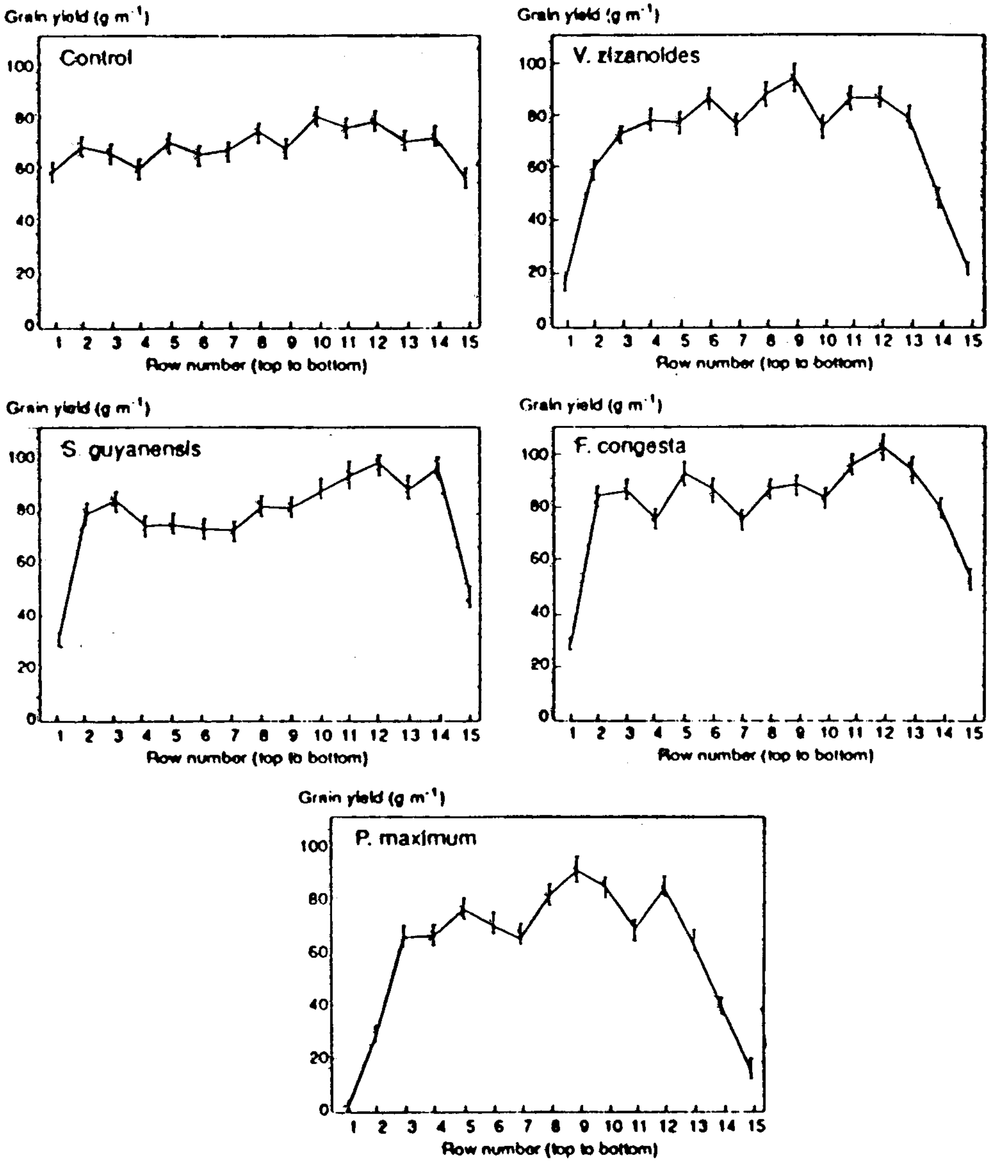

Figure 3. Upland rice yield across the alley between rows of two grasses (*Vetiveria zizanoides* and *Panicum maximum*), a forage legume (*Stylosanthes guyanensis*) and a woody legume (*Flamengia congesta*). Values are means of four replications in a randomized complete block design. Bars are standard errors. Claveria, Misamis Oriental, 1991

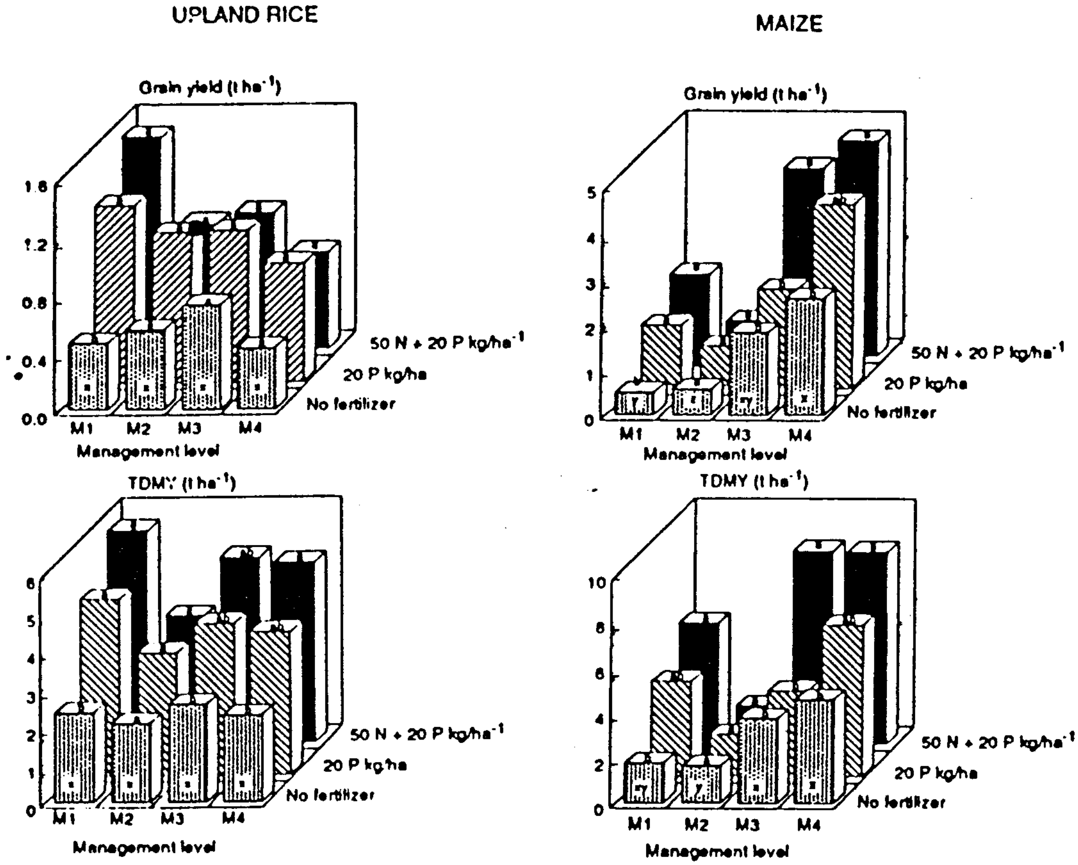

Figure 4. Grain yield and total dry matter yield (TDM) of upland rice and maize as affected by hedgerow management and fertility level. Claveria, Misamis Oriental, 1990. (M1 = Open field without hedgerows; M2 = Prunings removed; M3 = Prunings applied; M4 = Prunings applied at double M3)

Below-ground competition for nutrients, and in some seasons water, was expected under conditions in Claveria due to the shallow lateral root growth by the hedgerow perennials. Szott et al. (1991) observed intense root activity in the surface layers of the alleys on a low inherent fertility Ultisol in Peru. In Claveria, the biomass production of *Gliricidia* was found to be strongly and negatively correlated with the percentage Al saturation of the surface soils among sites (Mercado et al.

1989). Hedgerow tree root observations indicated that shallow lateral rooting was common, presumably due to the subsoil acidity and greater nutrient availability near the surface.

Below-ground and above-ground competition were compared by installing plastic barriers to a depth of 0.5 m between the hedgerow and the crop. An additional experimental treatment consisted of trenches 0.5 m deep without root barriers. A double-depth plowing treatment was included to test whether deep plowing with animal power was a practical alternative to reducing below-ground competition. The control treatment was conventionally-managed hedgerows.

In all treatments, hedgerows were pruned monthly to uniformly minimize shading. The experiments were conducted on farmers' fields in Claveria, at three separate sites on inclines of about 15 to 25%. Each site had a different hedgerow species: *Senna spectabilis*, *Gliricidia sepium*, or *Pennesitum purpureum*.

There were no significant differences in dry matter or grain yields among the barrier and non barrier treatments (figure 6). The elimination of root competition for below-ground resources did not improve the crop performance. Yields in the rice rows near the hedgerows were not affected by the root barriers or deep plowing.

However, there was a very distinct pattern of response across the alleys. Plant performance was generally much poorer in the entire upper half of the alleys in all treatments. The maximum yields were observed about three-quarters of the way across the alleys toward the lower side (figure 6).

In the following year, a 1.0 m depth root barrier treatment was added to further ensure that root competition was eliminated and a 'kill and remove' hedgerow trial was conducted to study the effect of eliminating the presence of the hedge entirely after the terrace risers formed. The results were similar to the first year.

Below-ground competition for water or nutrients between the crops and trees was not observed to be significant in this humid tropical environment. It was observed that root competition did not suppress crop growth near the hedgerows. Also, the major differences in responses occurring across the alleys could not be attributed to shading.

6. Effects of Natural Terrace Development

When contour hedgerow systems are installed on sloping land, an additional set of processes indirectly affect the perennial-annual interaction. These are associated with the development of terraces behind the vegetative barriers resulting from the displacement of soil from the upper alley to the lower.

Rapid terrace development occurs in the first years after establishment of the hedgerows [see Fujisaka, part 7; Garrity et al. 1992], partially because of water-induced soil erosion within the alley. The dominant cause is the downward movement of soil as successive animal-powered tillage operations are practiced on the contour. In Claveria, farmers plow 4-6 times per year to prepare the land for two successive annual crops. In addition, there is frequent harrowing and inter-row cultivation.

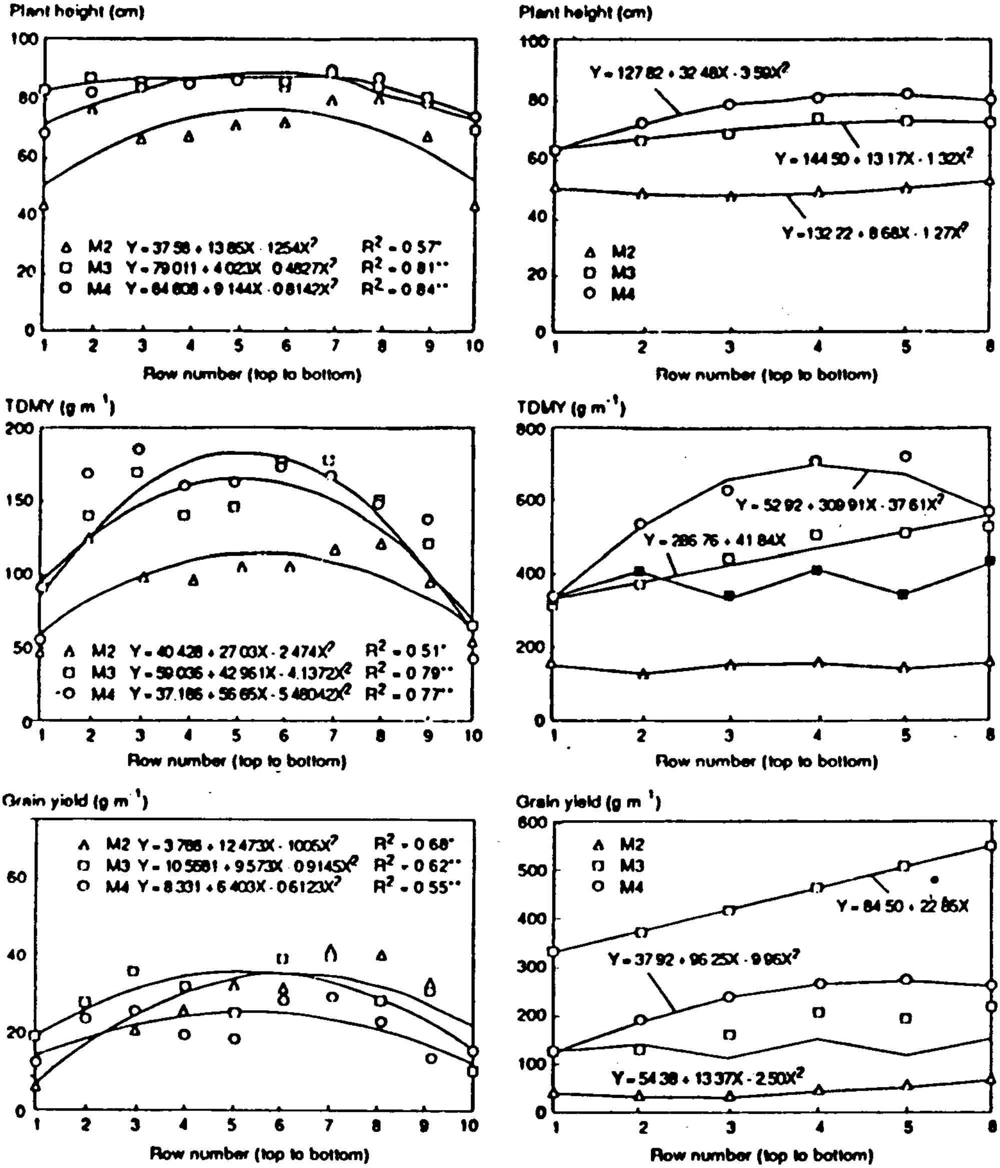

Figure 5. Comparison of response of upland rice and maize grown in an alley in a contour hedgerow system. Claveria, Misamis Oriental, 1990. (M1 = Open field without hedgerows; M2 = Prunings removed; M3 = Prunings applied; M4 = Prunings applied at double M3)

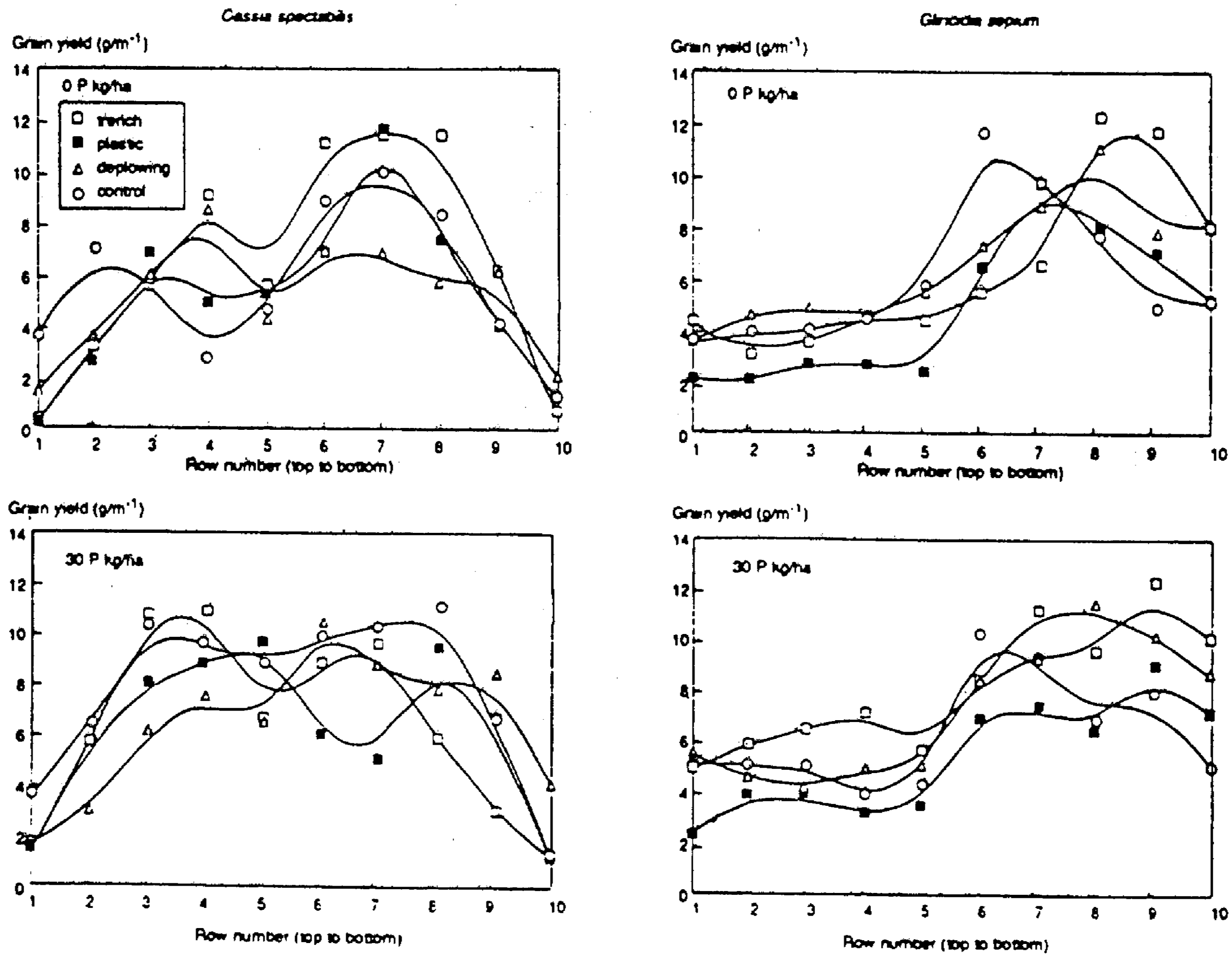

Figure 6. Yield response of upland rice across the alley with and without root barriers (plastic), trenching, or double-depth plowing (dd plowing), with hedgerows of two legume species and two phosphorus levels. Claveria, Misamis Oriental, 1990

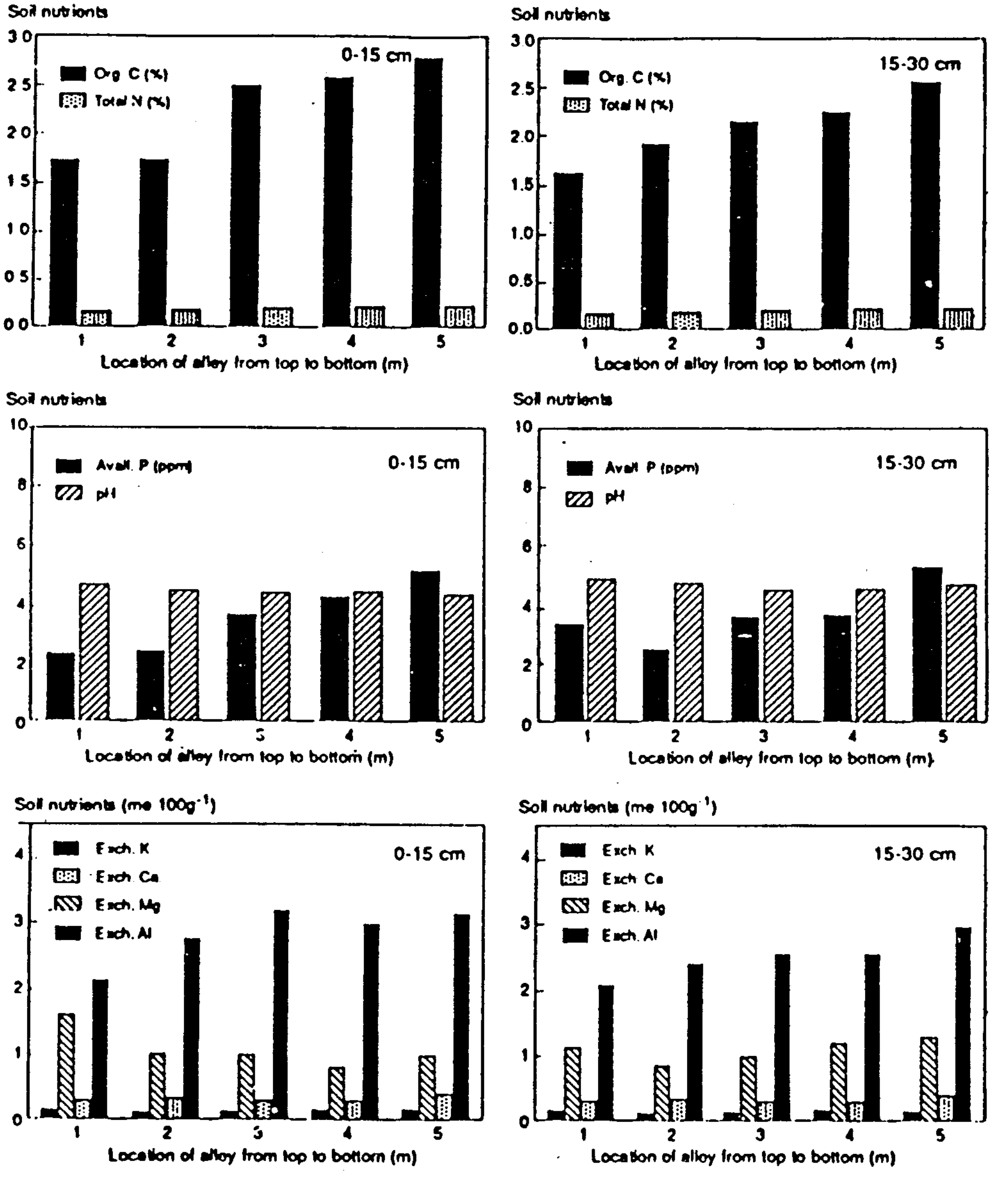

Figure 7. Soil chemical properties across the alley in a *Senna spectabilis* — upland rice contour hedgerow cropping system after four years of natural terrace development. Claveria, Misamis Oriental, 1990.

These processes result in scouring of the topsoil in the upper part of the alleys, and its deposition in the lower part of the alleys where it accumulates. Analysis of the soil properties in the *Senna spectabilis* root barrier experiment discussed in the previous section, indicated that dramatic changes occurred spatially across the alleys (figure 7). Soil organic carbon varied from 1.7% near the hedgerow in the upper alley, to 2.8% near the lower hedgerow. Available P was twice as high in the lower zone compared to the upper. Soil pH was unchanged from the upper alley to the lower, but exchangeable Al increased. Exchangeable Ca was higher in the upper alleyway. The patterns in the topsoil layer (0-15 cm) were similar in the subsoil (15-30 cm).

Soil quality in the upper alleys thus declined and was related to the pattern of crop response across the alleys as seen in figure 6. With the (near) elimination of above and below-ground interference in these trials through treatment design, it became evident that the scouring effects of soil displacement appear to have resulted in a zonation in crop response. The effects are particularly evident in the yield depression in the upper five rows in the *Gliricidia* experiment (figure 6). Yields from the top to the middle of the alley were only about 50-75% of those in the lower half of the alley.

The implications for the viability of contour hedgerow systems on sloping lands are clear: Hedgerows species interference may be less a deterrent to high alley crop productivity than altered soil quality resulting from soil redistribution, i.e., scouring and accumulation, which occurs in the alleys behind vegetative barriers. This issue needs more emphasis in future research. Ways to reduce the deterioration in soil quality in the upper part of the alleys must be identified.

7. Conclusions and Research Directions

Little is known about the nature of hedgerow/crop interference on acidic soils, on sloping terrains in the humid tropics, where the ecological factors influencing the balance of competition are unique and complex.

The serious yield depression generally observed in upland rice in the area adjacent to the hedgerow in alley cropping systems on strongly acidic soils is not overcome by the application of greater nutrient inputs, whether green leaf manure or inorganic fertilizer. Hedgerow species differ in the severity of interference with the annual crop in a contour hedgerow system. Forage grasses tend to be more competitive than N-fixing leguminous forages or trees.

Compatibility of annual crops to hedgerow systems may differ significantly. Maize tended to exhibit much less growth suppression than rice in the zone near to the hedgerows.

Root barriers between the hedgerow and the annual crop did not significantly overcome the yield suppression observed in the area adjacent to the hedgerow, even when frequent pruning minimized shading. Major changes in soil properties occur as natural terraces develop behind contour hedgerows and these affect crop performance in the upper alley more than below or above-ground competition between the perennial hedgerow and the annual crop.

It is now recognized that during terrace development on sloping land, major spatial soil property changes are overlaid on the hedgerow/crop interference phenomena. Differential management of the zones within the alleys is needed to overcome soil erosion in the upper alley. There is an urgent need for assessment of crop response to hedgerow/crop species interference and soil spatial changes.

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