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The Potential of Alleycropping as a Labor Efficient Management Option to Control Weeds: A Hypothetical Case

Alleycropping als Möglichkeit zur Verringerung des Arbeitsbedarfes für die Unkrautbekämpfung

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1 Introduction

Over the past decade, alleycropping has emerged as a potential cropping especially suited to alleviate some constraints of low-input farmers in resource poor countries (BÖHRINGER and CALDWELL, 1989). Alleycropping is defined here as the growing of parallel spaced rows of trees or bushes in the field, managed as hedgerows to enhance crop production. Experimental results have demonstrated the potential and role of alleycropping in improving the productivity and sustainability of existing cropping systems, using locally available resources (ARNOLD, 1983; ATTAH-KRAH and FRANCIS, 1987; BUDELMAN, 1985 & 1988; NGAMBEKI, 1985; SUMBERG, 1986; SUMBERG and ATTAH-KRAH, 1988; TORRES, 1983; YAMOAH ET AL., 1986).

Alleycropping can be implemented under varying environmental conditions, but its wide adoption by smallscale farmers seems to be questionable, unless the economic viavility and profitability of the system could be proved (ARNOLD, 1983; ATTAH-KRAH and FRANCIS, 1987).

In many countries of Africa and South America labor (besides capital) is of critical importance within the economy of the farming system and the factor land is often less important (BÖHRINGER and CALDWELL, 1989; RUTHENBERG, 1980). In situations where the supply of labor is short and limited, the returns to labor are an important criteria for farmers in

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accepting new cropping systems. This even more so, where hired labor is unreliable or not available.

It has been hypothesized that alleycropping might increase labor demands by 50% or more compared to traditional cropping systems (NGAMBEKI, 1985). This would be unacceptable in current cropping systems where the available labor is already fully absorbed during the cropping period. Contrary to some speculations (HOEKSTRA, 1983), the operations of lopping and mulching in alleycropping take place during the cropping period when labor is not available. It has been suggested that the higher costs for labor in alleycropping could be offset by the expected higher crop yields, as result of better nutrient availability (NGAMBEKI, 1985; SUMBERG and ATTAH-KRAH, 1988; TORRES, 1983). This benefit may only be speculative as it has not yet been demonstrated economically. The economic risk involved with alleyfarming, lies solely with the farmers who consequently find alleycropping unattractive (ATTAH-KRAH and FRANCIS, 1987).

A large part of the seasonal labor within most traditional cropping systems worldwide, is taken up by handweeding operations (BUDELMAN, 1988; RUTHENBERG, 1980; WEIL, 1981; YAMOAH ET AL., 1986). The mulch produced in alleycropping could play a significant role in suppressing weeds depending on the management practice, timing and quality of the cut material. This could help to improve the labor economy in alleycropping.

It is hypothesized that the reduced labor input for weeding may compensate for the additional labor requirements for tree management. Alleycropping may compare favorably to the labor demands in traditional cropping systems and could be more compatible an acceptable to farmers.

This paper will only investigate the potential of alleycropping in reducing the labor demand for weeding. The labor demands for the management of the trees to produce mulch and the total productivity of an alleycropping system are neglected. A full economic evaluation of alleycropping will not be attempted and should be subject of further studies.

2 Objectives

The objective of this paper are fourfold:

a Determine the amount of weeds and the labor demand for weeding in a common traditional maize cropping system as standard for comparison.

b Determine the capabilities of different mulch sources to suppress weeds.

c Describe factors influencing the extent of weed suppression by mulches.

d Convert the weed suppression capability of mulches to the amount of saved labor and compare the standard system to a hypothetical alleycropping system.

3 Methodology

3.1 The standard maize cropping system

Maize is one of the major staple foods in the world and therefore most alleycropping research trials have used it as the crop component under study (NGAMBEKI, 1985; RUTHENBERG, 1980; SUMBERG and ATTAH-KRAH, 1988; TORRES, 1983).

A "typical" maize cropping system in East Africa was used as the standard system. WEIL (1981), reported weed competition in maize under varying populations and fertilizer input levels at a location in Malawi (1100 m NN) with soils described as Oxic Rhodustalfs [OM = 4.3%; C.E.C. (NaOAc) = 14.7 meq/100 g; pH(H_2O) = 5.4; sandy clay texture (40% clay)] and a mean annual rainfall of 1046 mm. An open pollinated cultivar (U.C.A.) was grown with 24 kg/ha N and 4.4 kg/ha P as fertilizer applications. WEIL (1981), included 18 spacing treatments in his studies resulting in plant populations of 20,000, 40,000 and 80,000 plants/ha. A maize spacing of 0.99 m x 0.50 m (20,000 plants/ha) yielded 1.05 t/ha grain and 6.25 t/ha weed dry matter (WEIL, 1981).

It is worthwhile to note here, that low maize populations of 20,000 plants/ha are most common in Africa and any relevant evaluation of an alleycropping system should address similar populations (SUMBERG and ATTAH-KRAH, 1988).

The critical time for weeding of maize occurs within 40 to 50 days after planting (WEIL, 1981). No significant increases in terms of yield with weedings after maize-tasseling have been reported, making two hand-weedings per maize growing cycle a recommended and economical practice (Eastern Province Agricultural Development Project/Zambia, 1987, unpublished; WEIL, 1981).

Labor demands for a maize system with inputs of pesticides and fertilizers in Malawi were calculated by RUTHENBERG (1980) to be 342 man-hours for weeding out of a total of 1402 man-hours. An amount of 300 man-hours seems to be a realistic estimate for two hand-weedings per hectare in a lower input system and shall be used for the subsequent calculations.

3.2 The alleycropping system

Most alleycropping research has been conducted on *Leucaena leucocephala* (ATTAH-KRAH and FRANCIS, 1987; BUDELMAN, 1985 & 1988; HOEKSTRA, 1983; NGAMBEKI, 1985; SUMBERG and ATTAH-KRAH, 1988; TORRES, 1983). *Gliricidia sepium* und *Flemingia macrophylla*, two other potential alleycropping species, have been studied to some extent and will also be included in the following evaluation (BUDELMAN, 1988; YAMOAH ET AL., 1986).

It is assumed that the tree-hedges were cut once, at the time of maize planting. More than one cutting during the 40 to 50 day period after maize planting may be necessary, mainly to reduce interspecies competition for light (KANG ET AL., 1981), but this is not considered. It has also been shown that application of nitrogen later than 50 to 60 days after planting of maize will not increase grain yields significantly (Eastern Province Agricultural Development Project/Zambia, 1987; unpublished).

A hedgerow-population of approximately 13,500 plants/ha is assumed for all species. Tree hedges could be planted in the center between two maize rows. A maize to tree hedge ratio of 3 to 1 is suggested, resulting in an alley width of 3 m (SUMBERG and ATTAH-KRAH, 1988). Other assumptions for this arrangement are: all three species were spaced at 0.25 m within the hedge, resulting in approximately 13,500 plants/ha, and the effect of tree hedges in the filed on weed growth are not considererd. It is further assumed that weed dry matter is directly proportionally related to the amount of mulch applied and, also, to be resulting labor demand for weeding.

Table 1 reviews reported leaf dry matter yields for the three tree species. Results vary considerably depending on plant populations and locations. For 13,500 plants/ha realistic yields for *Leucaena* seem to be 3.62 t/ha, corresponding to an alley width of 3 m (SUMBERG and ATTAH-KRAH, 1988). For *Gliricidia* the closest approimation seems to be 3.4 t/ha (SUMBERG, 1986). Data for *Flemingia* were scarce, so that 2.9 t/ha is the only dry matter yield estimate available (BUDELMAN, 1985).

Table 1: Leaf-mulch dry matter yields as affected by plant populations and alley width for three tree species, *L. leucocephala*, *G. sepium* and *F. macrophylla*.

Source	Species[a]	Plants (ha^{-1})	Alley Width (m)	Leaf Dry Matter (t/ha)
BUDELMAN, 1985[b]	L	10,000	?	3.4
BUDELMAN, 1985	G	10,000	?	2.0
BUDELMAN, 1985	F	10,000	?	2.9
BREWBAKER, 1972[c]	L	111,111	0.9	10.6
HOEKSTRA, 1983	L	?	2.0	22.7
SUMBERG, 1988	L	?	2.2	54.8
SUMBERG, 1988	L	?	3.0	3.6
SUMBERG, 1988	L	?	3.7	52.9
SUMBERG, 1988	L	?	4.5	2.4
SUMBERG, 1986	G	62,500	4.0	4.5
SUMBERG, 1986	G	15,250	4.0	3.4
SUMBERG, 1986	G	10,000	4.0	3.6
SUMBERG, 1986	G	5,000	4.0	3.8

a L = *Leucaena leucocephala*; G = *Gliricidia sepium*; F = *Flemingia macrophylla*

b Mean of 4 harvests

c After TORRES, 1983

The effectiveness of the three different mulch sources in terms of weed suppression, should be evaluated over the critical period of 40 to 50 days after planting the maize crop

(BUDELMAN, 1988; WEIL, 1981). The effective life span of a mulch was defined as the length of time during which a mulch layer yields significantly less weed dry matter as compared to a control bare soil plot (BUDELMAN, 1988).

The three species under discussion were studied by BUDELMAN (1988) at a site near Abidjan, Ivory Coast, with soils described as a well draining sandy soil [(clay < 15%; pH 4.7; C.E.C. 3-5 meq/100g soil; strongly desaturated, typically < 15%)] and a mean annual rainfall of 2000 mm (BUDELMAN, 1988). Five tons of dry leaf mulch from each species was applied per hectare and weed dry matter yields were compared to a bare soil treatment over a period of 40 days.

4 Results

The effect of the three leaf mulches at applications of 5 t/ha on the dry matter yield of weeds is summarized in Table 2. Calculations are based on results obtained be BUDELMAN (1988). The results show that *Leucaena* promoted weed growth by 10.9% compared to the bare soil check. *Flemingia* was able to control weeds almost entirely, reducing weed dry matter by 94.6% compared to the check. The same was true for *Gliricidia* with a decrease in weed dry matter of 72.3%.

Table 2: The potential of leaf mulches from *Leucaena leucocephala*, *Gliricida sepium*, and *Flemingia macrophylla* in suppression of weeds at applications of three rates at 40 days after maize planting and the resulting labor demands for hand-weeding

Treatment	Weed Dry Matter (t/ha)	Weed Dry Matter Difference[a] (%)	Weed Dry Matter in Alleycropping[b] (t/ha)	Labor Demand for Hand-Weeding (man-hours)
Maize control	6.25[c]	+ 29.4	–	300[d]
Bare soil	1.84[e]	0	–	
Leucaena				
5.0 t/ha mulch	2.04[e]	+ 10.9	6.93	333
3.6 t/ha mulch[f]	2.82	+ 53.3	10.26	460
1.8 t/ha mulch	3.35	+ 82.1	11.38	546
Gliricidia				
5.0 t/ha mulch	0.50[e]	- 72.8	1.73	82
3.4 t/ha mulch[g]	0.66	- 64.1	2.24	108
1.7 t/ha mulch	0.83	- 54.9	2.82	135
Flemingia				
5.0 t/ha mulch	0.10[e]	- 94.6	0.34	16
2.9 t/ha mulch[h]	0.14	- 92.3	0,48	23
1.45 t/ha mulch	0.17	- 90.8	0.58	28

a compared to bare soil plot without mulch b Based on 6.25 t/ha weed dry matter in maize control
c for 20,000 maize plants/ha, spaced 99 cm x 50 cm and grain yield 1.05 t/ha (WEIL, 1981)
d after RUTHENBERG, 1980 e ex BUDELMAN, 1988 f ex SUMBERG, 1988
g ex SUMBERG, 1986 h ex BUDELMAN, 1985

The yield of 5 t/ha appears to be quite high compared to other results (Table 1) an might be considerable smaller under on-farm alleycropping conditions. Using the proposed per hectare leaf dry matter yields for each species, it can be calculated that *Leucaena* will yield 28% less than the assumed 5 t/ha (3.6 t/ha), *Gliricidia* 32% less (3.4 t/ha) and *Flemingia* 42% less (2.9 t/ha). The resulting weed yields in an alleycropping system for the three species, adjusted to their per hectare leaf mulch yields, are given in Table 2. *Leucaena* increased weed dry matter by 53.5%. The decrease in weed dry matter for *Gliricidia* and *Flemingia* was 64.1% and 92.3%, respectively. Consequently, the difference in labor for weeding in an alleycropping system was caculated to be 460 man-hours for *Leucaena*, 108 man-hours for *Gliricidia* and 23 man-hours for *Flemingia* (Table 2).

The yield potentials of the species in leaf mulch were reduced once again to simulate very low productivity levels, anticipating 1.8 t/ha for *Leucaena*, 1.7 t/ha for *Gliricidia*, and 1.45 t/ha for *Flemingia*. The latter two species would decrease weed dry matter by 54.9% and 90.8%, respectively. The low yield potential for *Leucaena* would increase weeds by 82.1% (Table 2).

5 Discussion and Conclusions

The drastic increase in weed dry matter with applications of *Leucaena* leaf-mulch is hard to explain, especially in view of the opposite effect of the leaf mulches from the other two tree species. BUDELMAN (1988), concluded from this study that leaf dry matter and area to weight rations were not necessarily related to the extent of weed suppression. The inportance of the mulch morphology was emphasized in explaining the effectiveness of the different mulches to control weeds: 1) the actual volume of the mulch layer in the field (including air); 2) the behavior of the leaves during drying (*Leucaena* leaves were curling); 3) the lignin content of the leaves which was directly related to the decomposition factor K (PALM, 1988); 4) the sensitivity of the leaves to wind erosion and 5) the extent of the disturbance of the mulch layer in the field by cattle and man (BUDELMAN, 1988). The curling of *Leucaena* leaves at drying may not explain a 40% increase in weed dry matter alone. The nitrogen mineralization rates of *Leucaena* leaves are fast, so that the applied nitrogen from the leaf mulch becomes quickly available to the system, although only for a shorter period of time (PALM, 1988). It can be assumed that this nitrogen is equally available to weeds and to the maize crop. This could result in a more aggressive growth of the weeds and may be part of an explanation for their higher dry matter yields. Overall, the effect of *Leucaena*-mulch as a potential weed control agent, was non-existent (BUDELMAN, 1988; TORRES, 1983).

The leaf mulch of *Gliricidia* had the potential to control half of the weed dry matter, compared to a bare soil plot. Due to the fast decomposition rate of its leaf-mulch, it seemed to be questionable whether the mulch of this species will be equally effective in weed suppression, after 40 days from its time of application (PALM, 1988).

On the other hand, the leaves of *Flemingia* decomposed extremely slowly which explained their excellent ability to control weeds, even beyond the 40 day time period after application (PALM, 1988). In fact, BUDELMAN (1988), showed that *Flemingia* mulch controlled weeds effectively up to 9.5 weeks after application, with non-significant differences between mulch-rates of 3, 6 and 9 t/ha. This classifies *Flemingia* leaf mulch as a highly effective weed control agent.

The ability of leaf-mulches to control weeds has to be linked with their ability to provide nutrients for the crop. It had been suggested, that a 30% increase in maize grain yields was the bottom line for a successful adoption of the new system "alleycropping" by farmers (HOEKSTRA, 1983; SUMBERG and ATTAH-KRAH, 1988; TORRES, 1983). It is unclear, if this increase in maize yield could be achieved by all three tree species equally with the three per hectare leaf-mulch yields used in the calculations.

The labor savings for weeding, resulting from applications of leaf mulches of *Gliricidia* and *Flemingia*, have to be weighed against the additional labor requirements arising from the management of the tree-hedges. It is unknown, how much labor is needed for tree-planting, tree-weeding, pruning and mulch application in an alleycropping system and to what extend this would vary among species? It had been shown, that directly seeded trees which required little care for establishment occupied less labor than others (BÖHRINGER and CALDWELL, 1989). If all these favorable characteristics could be met by the tree species, the only unknown labor requrements remaining, would be the ones for cutting the hedges and applying the material to the surface.

This may also answer the question of the best application method of the mulch. In farming systems where labor is a main constraint, mulch has to be applied to the soil surface, to fully utilize the benefits of weed suppression from the cut material and save labor for the management of the hedges. The incorporation of the mulch into the soil might increase mineralized nitrogen rates and thus enhance benefits to the crop in the alley (PALM, 1988). But, the value of the mulch as a weed suppressor would be lost and may be even changed into that of a weed promotor, by spreading rhizomes of noxious weeds and creating an ideal radiation environment for their growth.

The presented alleycropping system was a hypothetical case, based on data obtained under different environmental conditions. The soils, rainfall, altitude, temperature etc. were variable for the weed dry matter yields in the standard maize system, the leaf mulch production figures for the tree species and the weed suppression capabilities of the mulches. This discrepancy becomes obvious in the weed dry matter yields of the maize-control plot (WEIL, 1981). and the bare soil plot (BUDELMAN, 1988). It is difficult to explain why weed dry matter should incease more than threefold in a maize crop field compared to a fallow plot? BUDELMAN (1988) may have eradicated weeds in his experiment more effectively, decreasing weed pressure to unusually low leafes?

Plant population differed considerably among the listed sources for leaf mulch yields (Table 1). Mulch dry matter yields *Gliricidia sepium* differed substantially at varying plant populations (SUMBERG, 1986). Therefore, the used figures should not have been related directly to each other. But, the obtained results may serve as a valid estimate for a real alleycropping situation. They underlined the impotance of tree species selection in respect to their capabilities to control weeds in the system, an aspect, often neglected in favor of the issue of the nutrient supply from leaf mulches.

Interactions between weeds, hedgerows and the crop were completely ignored and should influence the results. It can be expected that the treee hedges in the field decrease the growth and abundance of weed even more (BÖHRINGER and CALDWELL, 1989). The amount of labor needed for weeding would be reduced further, making the presented calculation a conservative one.

A solution to the possible antagonism between weed suppression and nitrogen production from mulches could be the planting of a mixture of different tree species in the hedges, complementing each others mulch characteristics. A hedge of *Gliricidia* or *Leucaena* mixed with *Flemingia* may provide mulch with readily available amounts of nitrogen for the crop and, at the same time, suppress weeds effectively.

6 Summary

In many farming systems of the tropics, the factor labor represents a constraint during the cropping period. Alleycropping, as a system innovation, may put additional labor strains on the farming family and may, therefore, not be acceptable. On the other hand, it was hypothesized that the application of leaf mulches to the soil surface could help to suppress weeds effectively and reduce the labor demands for weeding substatially. The objective of this paper was to quantify the amount of labor reduced by the application of different leaf mulches. Figures from the available literature were used and transposed to a hypothetical alleycropping system. A traditional maize cropping system, with plant populations of 20,000 plants/ha, yielded 1.05 t/ha grain and 6.25 t/ha weeds (WEIL, 1981) and required 300 man-hours for two handweedings (after RUTHENBERG, 1980). Realistic yields of leaf mulches at 13,500 trees/ha were estimated to be 3.6 t/ha for *Leucaena* (SUMBERG and ATTAH-KRAH, 1988), 3.4 t/ha for *Gliricidia* (SUMBERG, 1986) and 2.9 t/ha *Flemingia* (BUDELMAN, 1985). Related to the amount of weed dry matter in a bare soil check, the application of leaf mulch at these rates resulted in an increase of weed dry matter of 53.3% for *Leucaena* and a decrease of 64.1% and 92.3% for *Gliricidia* and *Flemingia*, respectively. This change, expressed in man-hours for weeding, was quantified to be 460 man-hours for *Leucaena*, 108 man-hours for *Gliricidia* and only 23 man-hours for *Flemingia*. The importance of the quality of the different mulches was discussed. In farming systems with limited supply of labor,the effectivity of leaf mulches to suppress weeds was found to be crucial in selecting tree species for alleycropping.

Zusammenfassung

In vielen landwirtschaftlichen Betrieben der Tropen ist der Faktor Arbeit während der Zeit des Feldfruchtanbaus nur begrenzt verfügbar. Alleycropping könnte den Arbeitsbedarf sogar noch steigern und wird wohl auch deshalb bisher nur wenig von den bäuerlichen Familien als Betriebsinnovation akzeptiert. Es wurde die Hypothese aufgestellt, daß die richtige Verwen-

dung von Blattmulch den Wuchs von Unkräutern einschränkt und so den Arbeitsbedarf für die Unkrautbekämpfung erheblich verringern könnte. Die vorliegende Arbeit erörtert den Einfluß verschiedener Mulcharten auf den Arbeitsbedarf für das Unkrautjäten. Veröffentlichte Bestimmungswerte wurden eingesetzt und für ein angenommenes Alleycroppingsystem zur Berechnung verwendet. Die Produktivität eines traditionellen Maisanbausystems mit einer Bestandesdichte von 20.000 Pflanzen pro Hektar war 1,05 t/ha Kornertrag und 6,25 t/ha Unkrauttrockenmasse (WEIL, 1981), bei einem gleichzeitigen Arbeitsbedarf von 300 Stunden für zweimal Unkrautjäten von Hand (nach RUTHENBERG, 1980). Eine Bestandesdichte von 13.500 Bäumen pro Hektar erzielte 3,6 t/ha Blattmulche (trocken) für die Species *Leucaena* (SUMBERG und ATTAH-KRAH, 1988), 3,4 t/ha für *Gliricidia* (SUMBERG, 1986) und 2,9 t/ha für *Flemingia* (BUDELMAN, 1985). Der Einfluß der Blattmulche auf die Verunkrautung wurde mit der ermittelten Unkrauttrockenmasse in einer vegetationsfreien Kontrollparzelle verglichen. *Leucaena* steigerte die Verunkrautung um 53,3%, *Gliricidia* und *Flemingia* verringerten die Unkrautmasse jeweils um 64,1% und 92,3%. Diese Differenzen wurden in Arbeitsstunden für die Unkrautbekämpfung umgewandelt und ergaben 460 Arbeitsstunden für *Leucaena*, 108 für *Gliricida* und nur 23 für *Flemingia*. Hierbei wurde die Bedeutung der verschiedenen Mulchqualitäten erörtert. Bei der Auswahl von geeigneten Bäumen im Alleycropping wurde empfohlen, den unterschiedlichen Qualitäten der Blattmulche bezüglich der Unkrautbekämpfung mehr Aufmerksamkeit zu schenken. Dies ganz besonders in landwirtschaftlichen Betrieben, wo der Faktor Arbeit nur begrenzt verfügbar ist.

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