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Weed Dynamics and Crop Yields in Cassava Based Inter-cropping under Coconut

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ABSTRACT. A two-year study was conducted at the Regional Agricultural Research Centre at Makandura, Gonawila (NWP) during 1987/88, to study the effect of cropping patterns involving cassava based systems and time of weeding on weed growth and crop yields.

Three cropping patterns, cassava + sweet potato and cassava + cowpea followed by weliala, and cassava alone were tested at three weeding times viz. 3, 6 and 3 + 6 weeks after establishment (WAE) in a factorial experiment. During 1988/89, a weed free treatment was added as a control. The effectiveness of the treatments was evaluated based on weed dry weight, crop yield, land equivalent ratio (LER) and gross income.

Inter-cropping cassava with either sweet potato or cowpea lowered the weed dry weight when compared to cassava alone during both 1987/88 and 1988/89. The time of weeding did not significantly alter the weed biomass.

During 1987/88, tuber yield of cassava was highest (18.9 mt/ha) in the cassava + sweet potato - weliala cropping pattern, and lowest as a sole crop (14.9 kg/ha). Weeding at 3 WAE gave a tuber yield of 16.0 mt/ha which was significantly increased to 20.6 mt/ha with an additional weeding at 6 WAE. The tuber yield of cassava was highest from the sole crop (16.6 mt/ha) during 1988/89, and was reduced by 7 and 18% when inter-cropped with sweet potato and cowpea, respectively. Weeding at both 3 and 6 WAE gave the best tuber yield (16 mt/ha), but no significant reduction occurred with weeding at either 3 or 6 WAE. Growing of weliala after harvesting of sweet potato and cowpea added tuber yield of 290-355 kg/ha during 1987/88 and 276-354 kg/ha during 1988/89.

Cassava grown alone gave a gross income of Rs. 59,684/ha during 1987/88. Inter-cropping of cassava with sweet potato or cowpea resulted in a significant increase in gross income of 37 and 21 percent, respectively, with LER 1.41 and 1.74, respectively. During 1988/89, Yala inter-cropping

with sweet potato gave a significant increase (17%) in gross income, whereas cowpea resulted in a 5% decrease. LERs were 1.73 and 1.33 in cassava + sweet potato and cassava + cowpea inter-crops, respectively. Weeding at both 3 and 6 WAE gave the highest gross income and LER during 1987/88 and 1988/89.

INTRODUCTION

Coconut (*Cocos nucifera* L.) is a major plantation crop grown in approximately 0.4 m ha in Sri Lanka, and second in extent only to rice (1.0 m ha) (Liyanage *et. al.*, 1985). Nearly 70% of the total extent of coconut cultivation is in the coconut triangle which is demarcated by Kurunegala, Puttalam, Gampaha and Colombo Districts (Liyanage *et. al.*, 1985), and a considerable extent of the coconut triangle falls agro-ecologically in the wet zone.

Coconut is planted at a wide spacing of 7.89 m x 7.89 m, and approximately 88% of the land area receiving 40-60% of the incident light is available at the ground level (Liyanage, 1974). This permits the adoption of polycultural systems in coconut lands. Light penetration at the ground level decreases with increasing age of coconut palms. Therefore, polycultural systems cannot be practiced during 5-30 years (Santhirasegram, 1967). At present, about 16,000-20,000 ha are under polycultural systems, and nearly 100,000 ha remain underutilized (Anon, 1981).

The coconut plantations of the low country wet zone of Sri Lanka are most suitable for understorey cropping with perennial, subsidiary food crops and pasture. The low country intermediate zone is suitable for grain legumes while the dry zone is suitable only for short term crops such as grain legumes and vegetables during the *Maha* season (Santhirasegram, 1967; Liyanage, 1974; Karunaratne *et. al.*, 1985; Gunetilaka, 1985; and Anon, 1981-86. The cultivation of *cowpea*, sweet potato, and cassava gave promising results in the low country intermediate zone (Coconut quarterly, 1960-1985; Half yearly reports, R.A.R.C. Makandura, 1981-86; IDRC/Sri Lanka Root and Tuber Crops Project Reports, 1985 and 1986). Cassava is a popular root crop among the coconut growers because of its easy cultivation. However, it is a low yielder owing to weeds, when grown under coconut. The ability of cassava to suppress the weeds is very poor until four months.

Weeds compete with coconut for both nutrients and soil moisture, and with other crops such as cassava for light, space, soil moisture and nutrients and cause serious problems in the intermediate zone where the annual rainfall is around 1900 mm (Pethiyagoda, 1980). In addition they interfere with nut collection, thus increasing the cost of harvesting (Donald, 1979).

Several methods are used for weed control in coconut lands: hand slashing or mowing, periodic burning, grazing, combination of chemical, mechanical and agricultural methods – smother cropping and inter – cropping with food or cash crops (Donald, 1979). Cultural methods such as understory cropping of food and cash crops in coconut lands provide several other benefits such as making optimum use of land, increasing the employment potential and the net return per unit land area (Liyanage, 1974).

The objective of this experiment was to identify a viable inter – cropping system involving cassava with either sweet potato or *cowpea* with appropriate weed management to increase crop yields and gross income, and minimize weed competition in the coconut based polycultural systems in the low country intermediate zone.

MATERIALS AND METHODS

This experiment was conducted at the Regional Agricultural Research Centre (RARC), Makandura, Sri Lanka, during 1987 – 89. The experimental site falls into low country intermediate zone (IL1) and is at an elevation of 30 m above mean sea level. The soil type was a mixture of regosols and latesols with alluvial deposits, and characteristically deep, moderate to fine textured, underlain by soft lathyritic sub soils, moderate to well drained (Panabokke *et. al.*, 1972).

The experiment was started on 14th November, 1987 for *Maha* 1987/88 and was repeated during May 1988 – March 1989.

A 50 – 60 year old mature coconut plantation was selected as the experimental site. Cassava (*Manihot esculenta* Crantz.), variety CARI – 555, sweet potato (*Ipoemea batata* L.), variety CARI – 242, and *cowpea* (*Vigna unguiculata* L.), variety MI – 35 were the experimental crops. Twelve treatments in factorial combination of three cropping patterns

(*viz.* cassava sole crop, cassava + sweet potato and cassava + *cowpea*), and four weeding times (hand weeded once at 3 weeks after establishment (WAE), 6 WAE, twice at both 3 & 6-WAE and unweeded) were tested. The *weliala* (*Colocasia esculenta*) was inter-planted between cassava plants as the second companion crop at the 27th week (after *cowpea* and sweet potato were harvested), to exploit the available resources and increase the productivity and gross income. *Weliala* was a companion crop for three months during which the same weeding treatments were practiced for the other cropping patterns. The treatments were arranged in a randomized complete block design with four replicates.

Cassava was established with cuttings in 1.20 m rows with an intra-row spacing of 0.90 m in both sole and inter-crops. In plots with cassava + *cowpea* inter-crops, *cowpea* was seeded in three rows in a center 0.60 m strip with inter and intra-row spacings of 0.30 m and 0.15 m, respectively. In cassava + sweet potato inter-crops, sweet potato vine cuttings were established in two rows within the middle 0.30 m strip with an intra-row spacing of 0.25 m. A control strip adjacent to each experimental plot was left to compare and assess the weed population and growth in order to avoid the variability of weeds in different plots caused by the natural distribution.

The plot size was 5.0 m x 3.6 m. Each crop was fertilized as per recommendation by the Department of Agriculture, but *weliala* received the same regime as sweet potato. *Cowpea* and sweet potato were harvested in 56 and 105 DAE, respectively, while cassava was maintained for 10 months until mid-September 1988.

The experiment was repeated in *Yala* commencing on 5th may, 1988 with the same cropping patterns. A weed-free treatment was added, hence 15 treatment combinations were tested in the second year.

The crops in both seasons were frequently examined, and management practices were properly adopted. Monocrotophos was sprayed on *cowpea* to prevent the bean fly (*Agromyza phaseoli*) and other insect pests. The crop was grown under rainfed conditions.

Fresh tuber yields of cassava, sweet potato, and *weliala* and the dry weight of *cowpea* seeds were recorded. The land equivalent ratio (LER) for each treatment was computed using the sole crop yield of cassava,

and past yield data for sweet potato and *cowpea*. Gross income was calculated using the unit prices of crop yields in the Makandura area. Weed samples were collected in a 30 cm x 30 cm quadrant at 3 week intervals. The weed dry weight was recorded after drying at 70 C for 4 – 5 days until a constant weight was reached.

RESULTS AND DISCUSSION

Weather

The rainfall was very low during the first year of the experiment. There was an initial drought period during 6 – 15 and 33 – 39 WAE (Figure 1). During the second year, there was a long drought period which appeared to affect the growth of all the crops.

Weed dry weight

The cropping pattern had no effect on weed dry weight from 9 to 15 WAE, during the first year (Figure 2). At 36 WAE of cassava (9 WAE of *weliala*), cassava sole crop had the highest WDW (918 kg/ha) which was significantly greater than that of cassava + sweet potato inter – crop (484 kg/ha). Weed dry weight of cassava + *cowpea* was non – significant from both cassava and cassava + sweet potato.

Time of weeding had significant effects on weed dry weight through out the growth of cassava (Figure 3). At 3 WAE, weed dry weight was significantly greater in unweeded (2,093 kg/ha) and weeded once only at 3 WAE (1,256 kg/ha) than in weeded once only at 6 weeks (66 kg/ha), and also in 3 and 6 weeks (64 kg/ha) at 9 WAE of crops. Similar response of weed dry weight was also found at 12 and 15 WAE.

There was a cropping pattern x weeding time interaction for weed dry weight at the 33rd week (Figure 4). The highest weed dry weight was from sole cropped cassava when unweeded (2,546 kg/ha), which was significantly greater than the weeded treatments. The weed dry matter in cassava decreased by 60% when weeded at 3 WAE. Weed dry weight in sole cropped cassava did not differ between weeded once at 3 WAE and twice at 3 + 6 WAE. Inter – cropping of cassava with *cowpea* or sweet potato suppressed weed dry matter significantly.

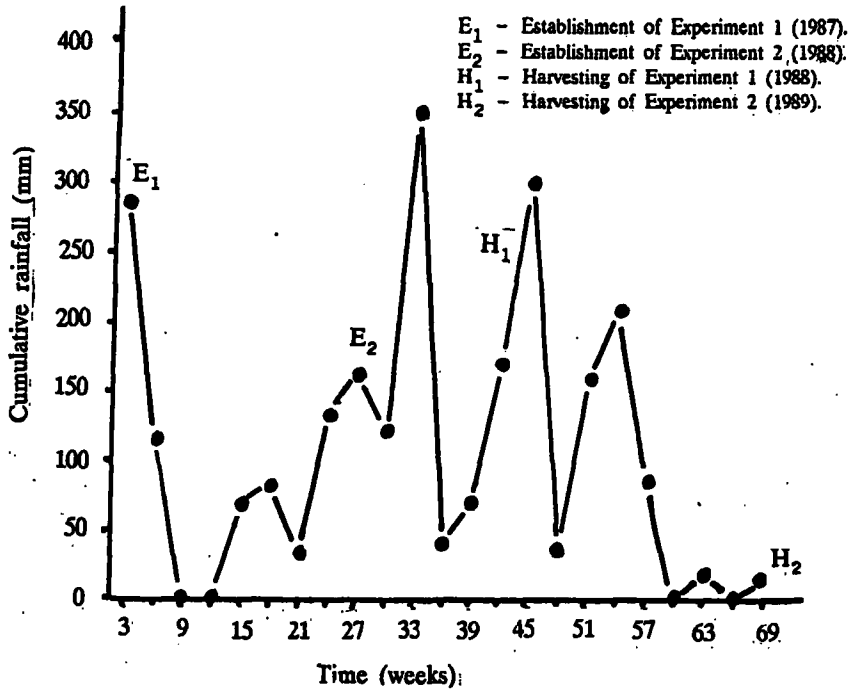

Figure 1. Three-week cumulative rainfall during 1987-89 at the Regional Agricultural Research Centre, Makandura, Gonawila (NWP).

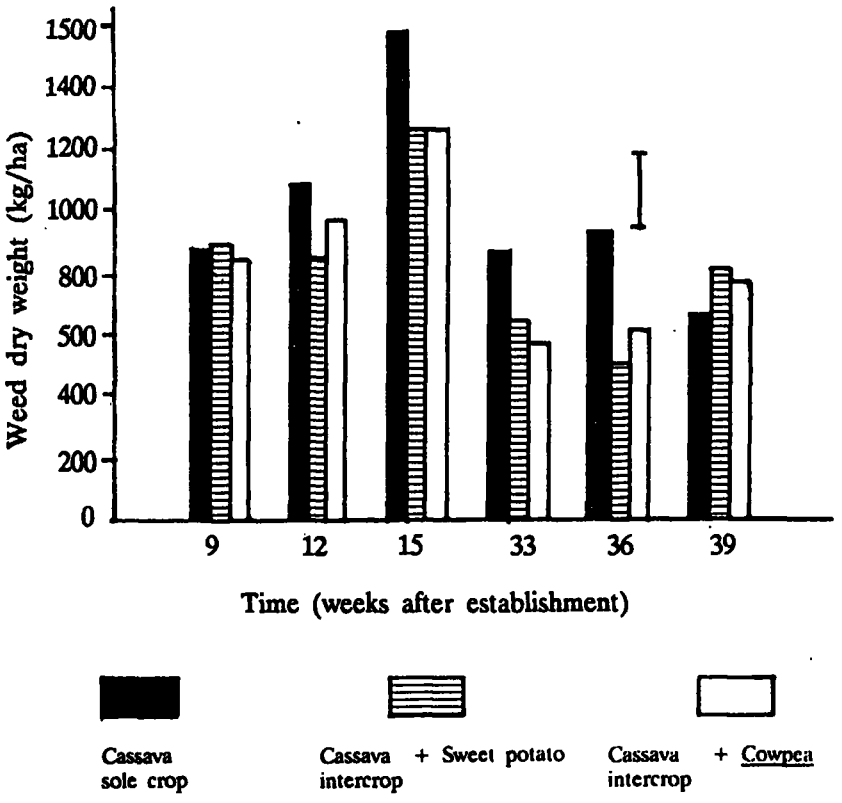

Figure 2. The effect of cropping pattern on weed dry weight during 1987/88.

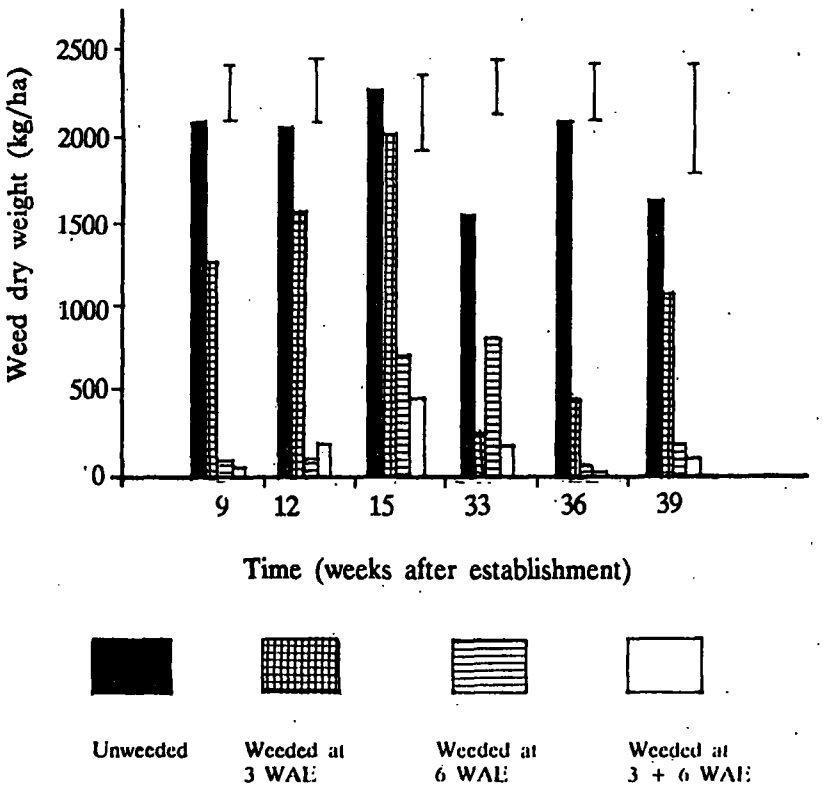

Figure 3. The effect of time of weeding on weed dry weight during 1987/88.

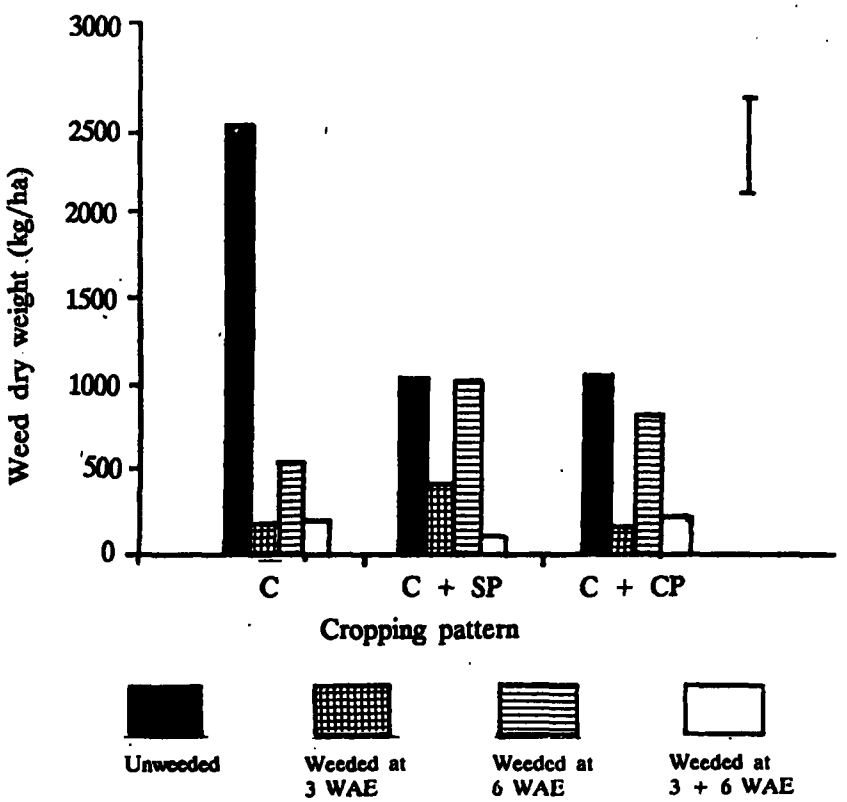

Figure 4. The interaction between cropping pattern and time of weeding on weed dry weight at 33 WAE of crops during 1987/88.

Weeding at 3 WAE significantly suppressed weeds in both Sweet potato and *cowpea* when associated with cassava. At 33 WAE with cassava, *weliala* was the companion crop, but the previous companion crop appeared to have some effects on weed dry weight: *cowpea* suppressed weeds better than sweet potato. This may be due to the high population effect of *cowpea* and the fact that sweet potato takes longer than *cowpea* to cover the ground thus allowing weeds to become established. *Cowpea* in contrast would offer greater competition due to its high population. These reasons may have attributed to lower weed dry weight in *cowpea* than sweet potato associated with cassava.

At 36 WAE, the weed dry weight was highest in unweeded sole cropped cassava, and decreased with increasing the intensity of weeding. A similar trend was found at 39 WAE (Figure 2).

In the second year, the cropping pattern had a significant effect on weed dry weight during 12 – 15 WAE of sweet potato, *cowpea* and *weliala* (36 – 39 WAE of cassava) (Figure 5). Similar to the 1987/88 study, weed dry weight was higher in cassava alone than inter – cropped cassava, but there was no significant difference between the two inter – crops. This can be attributed to the ability of inter – crops to compete with weeds. The main environmental factor affecting competition between crops and weeds is the sunlight (Donald, 1963; Stahler, 1948 and Mugabe *et. al.*, 1980). The reduction in light availability at ground level occurs when the leaf area index (LAI) increases (Watson, 1947). Therefore competition for light occurs not between species or plants, but between leaves (Donald, 1963; Stern and Donald, 1962), and shaded leaves may be unable to rise above its light compensation point leading to death (regardless of light relation of other leaves on the same plant) (Donald, 1961). Shading causes a significant reduction in weed growth (Pendleton and Seif, 1962). Sweet potato has been used for weed control due to its fast growth and smothering effect on weeds (Williams, 1978). Dense population through inter – cropping has also been successfully used to smother weeds, therefore, a good crop combination in inter – cropping could effectively control weeds (Evans and Sreedharan, 1962; Mugabe *et. al.*, 1980). The reduction in weed dry weight in inter – cropped cassava could be due to the ability of both *cowpea* and sweet potato to smother the weeds (Gupta, 1986) and also high light interception by cassava (Ashokan *et. al.*, 1983) and coconut (Liyanage, 1974).

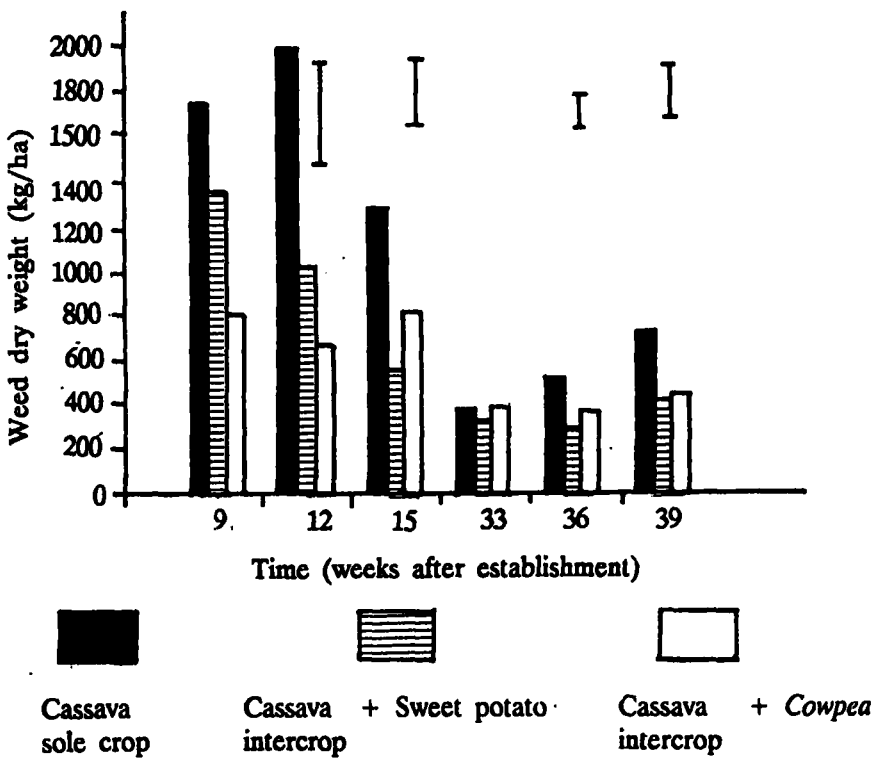

Figure 5. The effect of cropping pattern on weed dry weight during 1988/89.

The germination of weed seeds is also inhibited by the absence of light which is intercepted by the plant leaves. The red light promotes seed germination whereas far-red inhibits germination (Tailorson and Borthwick, 1968). Increased light penetration at the ground level by the removal of leaf layers (or other means) would induce weed seed germination and emergence. A competitive inter-crop could therefore reduce the number of seeds per weed, seed germination and seedling emergence. Towards the end of sole cropped and inter-cropped cassava, weed dry weights showed a decline which may be attributed to the shading effect by cassava. This effect was enhanced by coconut.

The time of weeding significantly decreased weed dry weight through out this experiment (Figure 6). Unweeded plots had the highest weed dry weight. At 9 WAE, unweeded plots had a significantly greater weed dry weight than weeded plots. The lowest weed dry matter was from weeding at 6 weeks. Even at 9 WAE, weed dry weight was significantly reduced during 1988/89 where weeding was done at 6 weeks. Weedings at 3 + 6 weeks gave the lowest weed dry weight from 12 WAE onwards.

Crop yield

Root yield of cassava

The cropping pattern had significant effect on tuber yield of cassava during 1987/88. The sole crop cassava yield was 14.92 mt/ha which significantly increased to 26.6% when inter-cropped with sweet potato, but no significant difference occurred between cassava sole crop and cassava + *cowpea* nor between cassava + sweet potato and cassava + *cowpea* (Table 1).

Unweeded treatments gave a tuber yield of 12.9 mt/ha (Table 1). Weeding once at 3 WAE only significantly increased tuber yield by 3.09 mt/ha, a 24% increase. There was no significant difference between weedings at 3 and 6 WAE. However the highest tuber yield of 20 mt/ha was obtained with weedings at both 3 and 6 WAE.

During 1988/89, the highest tuber yield was from cassava sole crop (Table 2), but it was not significantly different from cassava inter-

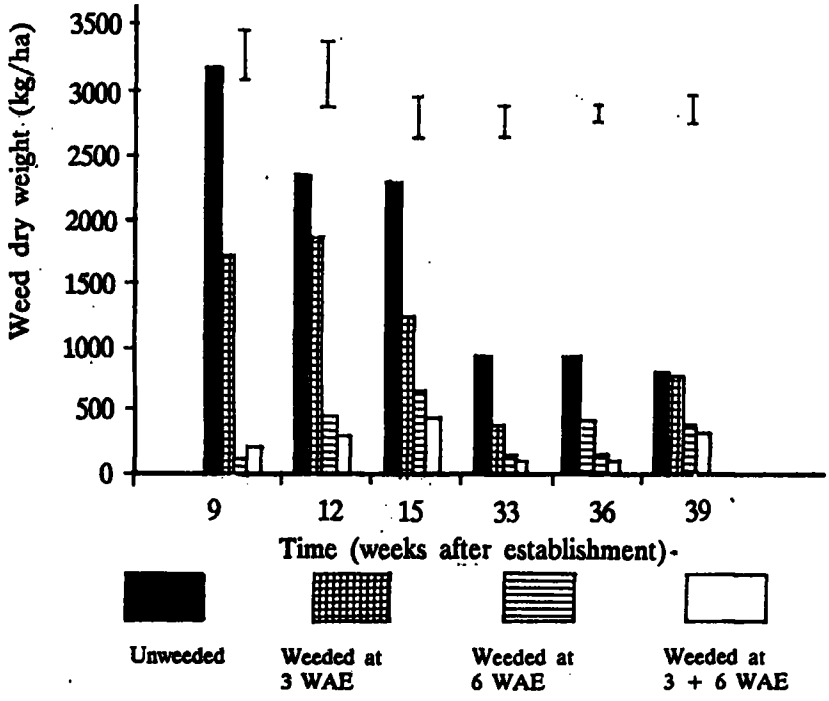

Figure 6. The effect of time of weeding on weed dry weight during 1987/88.

Table 1. Yields of cassava, sweet potato cowpea and weliala during 1987/88 at Regional Agriculture Research Station, Makandura.

Treatment	Cassava st/ha	Sweet potato kg/ha	Cowpee kg/ha	Weliala kg/ha
Cropping patterns +				
Cassava sole	14.92	-	-	-
Cassava + S. potato	18.89	245	-	290
Cassava + Cowpea	16.36	-	180	355
L.S.D.(0.05)	2.63	-	-	ns
Time of weeding				
Unweeded	12.90	99	130	276
3 WAE *	15.99	358	241	315
6 WAE	17.39	399	184	356
3 & 6 WAE	20.61	371	347	344
L.S.D.(0.05)	3.04	151.88	30.98	ns
CV%	21.9	32.53	9.11	41.70

*/ WAE - Weeks after establishment.
+/ S. potato - Sweet potato.

cropped with sweet potato. *Cowpea* with cassava caused a significant decrease in cassava tuber yield.

Cassava grown under weed free conditions gave the highest yield (16.6 mt/ha), while the unweeded yielded a 11.3% less. Cassava weeded once in 3 weeks and twice at 3 and 6 weeks yielded equal to the weed free treatment. The lowest cassava yield was from one weeding at 6 WAE. Initial competition may have caused this reduction in the tuber yield. Therefore, it is very important to adopt early weeding in order to minimize cassava - weed competition.

Tuber yield of sweet potato

Tuber yield of sweet potato was significantly affected by weeds: the unweeded treatment produced the lowest tuber yield of sweet potato (99 kg/ha) during 1987/88 (Table 1). There was no significant difference between weedings at 3, 6, or 3 + 6 WAE.

Table 2. Yields of cassava, sweet potato cowpea and weliala during 1988/89 at Regional Agriculture Research Station, Makandura.

Treatment	Cassava st/ha	Sweet potato kg/ha		Cowpea kg/ha	kg/ha	Weliala
Cropping patterns +						
Cassava sole	16.63	–		–		–
Cassava + S. potato	15.40	1268		–		368
Cassava + Cowpea	13.67	–		283		380
L.S.D.(0.05)	2.60	–		–		N.S.
Time of Weeding						
Unweeded	14.72	615		229		156
3 WAE *	16.21	840		372		391
6 WAE	12.82	1836		268		301
3 & 6 WAE	15.66	1147		270		347
Weed Free	16.60	1903		275		678
L.S.D.(0.05)	3.36			N.S		N.S
104						
CV%	22.90	60.80		25.00		22.90

*/ WAE – Weeks after establishment.
+/ S. potato – Sweet potato.

During 1988/89, the same trend was observed, however yields were considerably higher than in 1987/88 (Table 2). The highest yield of 1,903 kg/ha was from the weed free plot. Though not significant, tuber yields of sweet potato were higher in weeded treatments at 3 + 6 and 6 WAE and weed free plots.

Seed yield of *cowpea*

The time of weeding significantly effected seed yield of *cowpea* during 1987/88: unweeded plots had the lowest seed yield (130 kg/ha) whereas the mostly weeded (3 + 6 WAE) plots had the highest (347 kg/ha) indicating that *cowpea* needs early weeding (Table 1). Earlier weeding at 3 WAE gave a higher seed yield than late weeding (6 WAE). During 1988/89, there was no significant difference between weeding times, and the seed yield ranged from 268 – 372 kg/ha, a low yield when

compared with that in open lands. Low seed yields during 1987/88 may partly be attributed to the dry weather resulting in soil moisture stress, but in 1988/89 would be due to the overcast condition (Figure 1).

Yield of weliala

Cropping patterns and time of weeding did not significantly affect the yield of *weliala* during 1987/88 (Table 1). However, during 1988/89, weed management practices had a significant effect: weed free plots gave the highest *weliala* yield at 678 kg/ha. Unweeded plots yielded only 156 kg/ha, whereas with some degree of weeding, yields ranged from 300 – 391 kg/ha (Table 2).

Gross income

Total gross income calculated based on previous market prices was significantly affected by both cropping pattern and time of weeding during 1987/88 (Table 3). The highest gross income of Rs. 81,561 ha^{-1} was from cassava + sweet potato – *weliala* pattern, which was significantly greater than that of cassava + *cowpea* – *weliala* pattern (Rs. 72,413 ha^{-1}) or cassava sole crop (Rs. 59,684 ha^{-1}). The gross income of cassava + *cowpea* – *weliala* pattern was also significantly greater than cassava sole crop. The increases in the gross income were 36.7% and 17.6% by cassava + sweet potato – *weliala* and cassava + *cowpea* – *weliala* patterns, respectively, when compared with cassava sole crop. The addition of *weliala* after *cowpea* and sweet potato in two different inter – crops gave a significant contribution to per hectare gross income.

The time of weeding also had significant effects on gross income. Unweeded situations led to significantly very low gross income (Table 3). Weeded once either at 3 or 6 weeks increased gross income significantly. Weeding twice at 3 and 6 WAE gave significantly greater gross income than single weedings. Similar responses were observed in the 1988/89 study (Table 4). Although the highest gross income was from the weed – free treatments, there was no significant difference between weed – free and weeding twice at 3 and 6 WAE. This indicates that where crop yields as well as gross income were concerned initial weeding at both 3 and 6 WAE would be of economic benefit to the coconut

Table 3. Component and total gross income Rs/ha and land equivalent ratio (LER) of experimental treatments during 1987/88 at Regional Agriculture Research Station at Makandura.

Treatment	Cassava	Sweet potato or cowpea	Weliala	Total	LER
Cropping pattern +					
Cassava sole	59,684	–	–	59,684	1.00
Cassava + S.potato	75,587	3,070	2,904	81,561	1.41
Cassava + Cowpea	65,447	3,412	3,554	72,413	1.74
L.S.D.(0.05)	10,529	N.S	N.S	10,465	0.17
Time of weeding					
Unweeded	51,634	1,530	2,760	54,493	1.26
3 WAE *	63,965	3,412	3,554	72,413	1.57
6 WAE	69,581	3,374	3,565	74,207	1.44
3 & 6 WAE	82,444	4,459	3,437	87,708	2.02
L.S.D.(0.05)	12,158	897	N.S	12,084	0.19
CV%	21.90	26.60	41.70	20.40	11.99

+/ S. potato – Sweet potato.
*/ WAE – Weeks after establishment of crops.

growers although weed dry weight becomes insignificant at different time of weeding.

Land equivalent ratio

Land equivalent ratio (LER) is the land area needed under monoculture to produce equivalent crop yields in inter – cropping (Willey, 1979). Both cropping pattern and time of weeding affected LER (Table 3). During 1987/88, cassava + *cowpea* – *weliala* pattern gave the highest LER of 1.73, which was significantly greater than both cassava sole crop (1.00) and cassava + sweet potato – *weliala* pattern (1.41). Among the weed management treatments, significantly greater LER's were found with weeded treatments compared to unweeded, but the highest LER was from most intensive weeding (weeded twice at 3 and 6 WAE) (1.77).

Table 4. Component and total gross income (Rs/ha) and land equivalent ratio (LER) of experimental treatments during 1988/89 at Regional Agriculture Research Station at Makandura.

Treatment	Cassava	Sweet potato or cowpea	Weliala	Total	LER
Cropping Pattern +					
Cassava sole	66,159	–	–	66,159	1.00
Cassava + S. potato	61,618	12,683	3,684	77,985	1.73
Cassava + Cowpea	54,697	4,244	3,803	62,744	1.33
L.S.D.(0.05)	10,418	4,818	657	10,555	0.25
Time of Weeding					
Unweeded	58,884	5,919	1,559	63,869	1.42
3 WAE *	64,846	5,864	3,900	71,355	1.48
6 WAE	51,310	11,198	3,012	60,778	1.53
3 & 6 WAE	62,659	7,768	3,466	78,662	1.48
Weed Free	66,424	11,575	6,882	84,881	1.76
L.S.D.(0.05)	13,449	7,619	1,039	13,627	ns
CV%	22.90	74.20	22.90	20.53	23.44

+/ S. potato – Sweet potato.
*/ WAE – Weeks after establishment.

During 1988/89, cassava + sweet potato – *weliala* gave the highest LER (1.73), and cassava + *cowpea* – *weliala* gave significantly lower LER. However, it was significantly greater than the sole cropped cassava (Table 4). Unweeded treatments too had a higher overall LER value of 1.26 mainly due to inter-cropping. The highest LER of 1.62 in weed management was from weed-free treatment, but it was not significantly different from other weed management treatments.

CONCLUSION

The weed dry matter, crop yield and gross income in 1987/88 and 1988 of the cropping pattern consisting of cassava + sweet potato – *weliala* performed better than other cropping patterns tested. However, the land equivalent ratio (LER) indicated that cassava + *cowpea* –

weliala pattern to be superior to cassava + sweet potato – *weliala* pattern during 1987/88. The addition of *weliala* not only improved weed control but contributed significantly to final yield, gross income and LER in each cropping pattern.

Two weedings at 3 and 6 WAE always reduced weed dry matter and improved crop yields, gross income and LER over unweeded and single weedings at either 3 or 6 weeks after crop establishment in both years. However, it gave slightly lower but non-significant weed dry weight, crop yields, gross income and LER values compared with weed-free plots in the 1988/89 study.

Therefore, it appears that inter-cropping of cassava with sweet potato followed by *weliala* after sweet potato harvest and weeded twice at 3 and 6 WAE of each crop is the most suitable cropping and weed management combination for coconut lands in the Low-country Intermediate Zone.

REFERENCES

Anon. (1981-1986). Half Yearly Reports - Regional Agricultural Research Centre, Makandura. 1981-1986.

Anon. (1981). A study of inter-cropping in coconut lands. National Planning Division, Ministry of Finance and Planning Colombo. December 1981, pp. 8-10.

Akobundu, I.O. (1980). Weed control in cassava cultivation in the sub tropics. Tropical pest management, 26(4): 400-426.

Ashokan, P.K., Sudhakara, K. and Nair, R.V. (1981). Studies on weed problems of cassava-legume inter-cropping systems. Weed Abstract:1983, Vol. 32: 12.

Coconut Quarterly. (1960-85). Coconut Research Institute of Sri Lanka.

Donald, C.M. (1947). Competition among crop and pastures. Adv. in Agronomy, 15: 1-118. Academic Press.

Donald, C.M. (1961). Competition for light in crops and pastures. pp. 283 – 313. *In*: Mechanisms in Biological Competition. Soc. Exp. Biol. Symposia 15. Academic Press, N.Y. p. 365.

Donald, L.P. (1979). Managing pasture and cattle under coconut, Westview Tropical Agriculture Series, No. 2.

Evans, A.C. and Sreedharan, A. (1962). Studies of inter – cropping II. Castor beans with groundnuts or soybeans. East African Agricul – tural and Forestry Journal. 28: 7 – 8.

Gunatilaka, H.A.J. (1985). Weeds control in coconut lands. Coconut Bulletin, 1(2): 43 – 48.

Gupta, O.P. (1984). Scientific weed management – Revised Edition of Modern Weed Science. Today and Tomorrow's Printers and Publishers, New Delhi, India.

Half – yearly Progress Report. (1981 – 86). Regional Agricultural Research Centre, Department of Agriculture, Sri Lanka.

IDRC/Sri Lanka Tuber Crop Project. (1985 – 86).

Karunarathna, M.S., Gunasena, H.P.M., and Mantriratne, M.A.P. (1985). Growth and yield of *cowpea* (*Vigna unguiculata* (L) Walp.), Journal Nat. Agri. Soc. Ceylon. 15: 8 – 19.

Liyanage, M. De S. (1974). Some useful guidelines towards organized inter – cropping. Ceylon Cocon. Plrs. Rev. 7: 93 – 97.

Liyanage, M. De S., Tejwani, K.G. and Nair, P.K.R. (1985). Inter – cropping under coconut in Sri Lanka. March, 1985. ICRAF. *In*: Agro – forestry System Descriptions, Nair, P.K.R. (Ed).

Mugabe, N.R., Sinje, M.E. and Sibuga, K.P. (1980). A study of crop/weed competition in inter – cropping. *In*: Inter – cropping Proc. of the Second Symposium on Inter – cropping in Semi – arid Areas. Morogoro, Tanzania, 4 – 7 August 1980. Keswani, C.L. and Ndunguru, B.J. (Eds). pp. 95 – 101.

Pendleton, J.W. and Seif, R.D. (1962). Role of light in corn competition. Crop Sci. 2: 154 – 156.

Pethiyagoda, V. (1980). Hand book on coconut cultivation. pp. 11 – 68.

Prabbakar, M. and Nair, G.M. (1984). Inter – cropping in cassava. Indian Farming, 34(1): 9 – 10.

Santhirasegram, K. (1967). Inter – cropping for coconut with special reference to food production. Ceylon coconut Planters Review, 6: 43 – 53.

Stahler, L.M. (1948). Shade and soil moisture as factors in competition between selected crops and field bind weed (*Convolvulus arvensis*). J. Amer. Soc. Agronomy, 40: 490 – 502.

Stern, W.R. and Donald, C.M. (1962). Light relationships on grass – clover swards. Aust. J. of Agric. Sci. 13: 599 – 614.

Taylorson, R.B. and Borthwick, H.A. (1968). Foliar filtration of light: a mechanism of suppression of weed germination. Weed Sci. Soc. of Amer. Abstr., p. 92.

Watson, D.J. (1947). Competitive physiological studies on the growth of field crops I. Variation in net assimilation rate and leaf area between species and varieties and within and between years. Ann. Bot. 11: 41 – 76.