

Full Length Research Paper

Effect of several weed control methods in tropical coconut plantation on weed abundance, coconut yield and economical value

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Accepted 15 December 2010

The influence of five different weed control methods on nut yield of coconut were evaluated to determine an economical and effective method of controlling weeds in coconut plantations in the low country, intermediate zone in Sri Lanka. Treatments imposed were cover cropping with *Pueraria phaseolodites*, planting *Gliricidia sepium*, tractor slashing, application of glyphosate (N-(phosphonomethyl)-glycine) at 1.44 kg ai ha⁻¹ and cattle grazing at two months interval. All the treatments were applied twice a year except for the cover cropping with *Pueraria* and cattle grazing treatments. Cattle grazing were applied at two monthly intervals. Based on the reduction of weed biomass, treatments cover cropping with *Pueraria phaseolodites* and application of glyphosate at 1.44 kg ai ha⁻¹ were significantly effective over other treatments. Coconut yield was increased significantly ($P < 0.05$) in glyphosate applied and cover cropping with *Pueraria*. Control of weeds with glyphosate (1.44kg ai ha⁻¹ and cover cropping with *Pueraria* resulted in 23% and 20% increase in nut yield over the uncontrolled weed plots respectively. Both methods were found to be the most effective and economical methods of controlling weeds in coconut plantations. Cover cropping with *P. phaseolodites* was effective in controlling weeds in the long term, but was not economical compared to the glyphosate application. Establishment of cover crop was helpful to conserve soil moisture when compared with other treatments.

Key words: cover crop, glyphosate, soil moisture and slashing

INTRODUCTION

Coconut palms in a plantation require a wide spacing between palms due to the broad canopy structure, which permits abundant sunlight to the understory. As a result, the unutilized space beneath the plantation becomes invaded by a wide range of perennial and annual weed species (Liyanage and Liyanage 1989). Such weeds compete with the coconuts for soil moisture and nutrients, affecting the growth and yield of the coconut crop and obstructing routine estate practices (Senarathne *et al.* 2003). Management of the weed growth is, therefore, essential to maintaining a coconut plantation. However, the cost of weed control is 20% of the total cost of production, which significantly reduces the profitability of coconut estates (Senarathne 2008). Therefore, there is an acute need to introduce effective and economically viable weed control strategies for coconut plantation in Sri Lanka.

In plantations, weed control is commonly managed by slashing (either by hand or tractor harrowing), inter-row cultivation of fast growing leguminous creepers or bushy type cover crops, grazing by ruminants and use of herbicides (generally glyphosate) (Liyanage and Liyanage, 1989). Four-wheel tractor mounted slashers and harrows are the main mechanical methods of weed control practiced in coconut plantations. Slashing removes the above ground weed biomass, resulting in a depletion of the food supply to the plant roots. Repeated slashing of above ground plant material creates a layer of mulch, which helps to conserve soil moisture. Removal of aerial parts also reduces the competitive ability of the weeds to an acceptable level (Pethiyagoda 1980). Weeds can also be out-competed by propagating fast growing cover crops. Suitable cover crops include *Pueraria phaseolodites*, *Centrosema pubescens* (creepers) and *Gliricidia sepium* (bushes). Cover crops and the residues they produce suppress weeds

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directly through a variety of physical and biological means (Sarrantonio and Gallandt, 2003; Teasdale 1996) while simultaneously improving soil health by adding nutrients and biomass, reducing erosion, and improving soil tilth (Griffn *et al.* 2000; Sarrantonio and Gallandt, 2003). Cover crops can also indirectly contribute to weed management by promoting beneficial weed seed predators (Carmona & Landis, 1999; Gallandt *et al.* 2005; Reader 1993). However, cover crops also have disadvantages, in that they require additional management and expense, may interfere with crop establishment, and may result in less predictable responses of (Teasdale 1996). Cover crops also compete for water, but can be killed to use as mulch (as so conserve water) (Unger and Vigil 1998). Therefore, the objective of this research was to evaluate the effect of different agronomic practices for weed management on the nut yield and weed population changes in coconut plantation.

MATERIALS AND METHODS

This experiment was carried out at the Pallama Seed Garden, Sub Research Station of the Coconut Research Institute, in the Low country Dry Zone of North Western province of Sri Lanka from August 2000 to May 2006. The area is characterized by bi-modal pattern of rain fall with an annual mean precipitation of 1200 mm. Approximately 65% of the annual rainfall is received from September to February (Maha season). There is a smaller peak of rainfall from March to May (Yala season), but the rainfall is erratic. Higher ambient air and soil temperatures (about 28°C – 32°C) and days with 6 to 8 hours of sunshine are more common especially during the dry periods from May to September.

The soil at the site is a predominantly well-drained Red Yellow Podzolic (RYP, USDA soil taxonomy - Typic Rhodudults, FAO/UNESCO soil taxonomy - Ferric Altitols) soil with soft or hard laterite (70-90%) (De Alwis & Panabokke 1972). Surface soil is brown, with a sandy loam texture. Structure development is moderate due to the presence of sand in the surface soil. Subsurface soil is dark brown to yellowish brown with prominent mottles. It is an acidic (pH 5.0-5.5) sandy loam or sandy clay loam. Base saturation of the subsurface soil is greater than 35%. Organic carbon content in the surface soil is generally less than 1% under natural conditions (Mapa *et al.* 2005). The trial was established within a 55 year old coconut plantation, where palms were regularly fertilized with 3kg per palm a year of adults palm mixture (800g Urea, 600g Rock Phosphate and 1600g Muriate of Potash) with 1kg of dolomite. Major weed species in this site were *Panicum maximum*, *Pennisetum polystachion*, *Imperata cylindrica*, *Panicum repens* *Cynodon dactylon*, *Chloris barbata*, *Chromoleana odorata*, *Mimosa pudica*, *Urena lobata*, *Croton hirtus*, *Allmania nodiflora*, *Mitracarpus villosus*, *Tephrosia purpurea*, *Vernonia cinerea*, *Tridax procumbens*, *Sida acuta*, *Scoparia dulcis*, *Stachytarpheta jamaicensis* and *Hyptis suaveolens*.

Environmental conditions from year 2004 to 2006.

Metrological data from January 2004 to December 2006 and a description of the soil type in the experimental site (at the Pallama Seed Garden in the low country dry zone of North Western Province of Sri Lanka) are presented in Table 1.

The average monthly rainfall was comparatively high in March, April, May, October and November months during the

experimental period in every year. In 2004 the highest average rainfall was obtained in May (319mm) and November (340 mm). The highest average rainfall occurring in March (130mm) and October (415mm) in 2005 and in March (142mm) and October (513mm) in 2006. The total rainfall during the experimental period was 1410.9mm, 1493.8 mm and 1577.9mm in years 2004, 2005 and 2006. The lowest rainfall was obtained in February and August during the experimental period in each year. The average morning relative humidity value (85%) was very high in January and November in 2004, February and November in 2005 and March and November in 2006.

The highest maximum sun shine hours were received in February and the value was lowest in November during the experimental period in each year. The maximum average day temperature was 34.2 °C in March and April in year 2004, in year 2005 and 2006 the highest day temperature was 33.6°C in March and 33.2 °C in September. The highest day temperature was in March and April during the experimental period due to the drought conditions.

Experimental management

The following treatments were used in a randomized complete block design with three replicates. Each plot had six effective coconut palms (coconut spacing of the square planting system is 8.2 m x 8.2 m). The treatments of the experiment were:

- T₁. Establishment of the cover crop *Puereria phasioloides*
- T₂. Establishment of *Gliricidia sepium*
- T₃. Tractor slashing (twice per year)
- T₄. Chemical weeding (application of glyphosate at 1.44 a.i. kg ha⁻¹)
- T₅. Cattle grazing (once in two months)
- T₆. Untreated control

In the chemically weeded plots, glyphosate was applied at 1.44 a.i. kg ha⁻¹, twice a year at six month intervals, at the latter part of the rainy season using a knapsack sprayer in the morning. There was no rain for five to six hours after applying glyphosate. The cover crop (*P. phasioloides*) was established to control weeds and the over grown conditions of cover crop was managed to overcome competition by twice a year. Cattle were allowed to graze the plots to control weeds at two monthly intervals. Tractor slashing was done at the latter part of the rain season at six monthly intervals. Two rows of *G. sepium* were planted between rows of coconut palms (spacing 2 m by 1 m) and plants were lopped at 6 monthly intervals. Loppings were mulched around the coconut palms.

Environmental data

Rainfall, sunshine hours, humidity and minimum and maximum temperatures were obtained from the weather station located 100 m from the experiment site, during the last three years of the trial (from 2004 to 2006).

Weed identification and biomass

The weed biomass was collected from four randomly placed, 1 m x 1 m quadrats per plot, and every two months from 2001 to May 2006. Weed samples were separated into species as monocotyledonous and dicotyledonous weeds, dried at 80°C for five days and weighed.

Soil moisture content

Soil samples from 30 cm soil depth were taken from four random points per plot, during the dry period to understand the treatment effect on the variation of soil moisture content during drying (February and August) and dried at 105°C. Samples were weighed and gravimetric soil moisture content was

Table 1. Average metrological data at the experimental site (Pallama Seed Garden) during the experimental period from January 2004 to December 2006

Year /Months	Rain fall	Mean RH % am	Mean RH% pm	Sunshine hours/day	Maximum (C ^o)	T ^o Minimum (C ^o)
2004						
January	0.00	82.50	60.50	7.7	32.7	22.2
February	25.80	73.80	53.30	7.9	33.9	21.2
March	11.50	71.00	59.40	6.8	34.2	23.1
April	56.80	75.90	62.40	6.7	34.2	24.1
May	319.20	81.90	76.30	4.4	31.9	25.0
June	93.10	79.70	73.50	5.9	30.9	25.3
July	84.90	82.50	75.30	6.5	30.2	24.5
August	11.40	75.90	68.80	7.8	31.7	24.8
September	128.00	79.60	71.80	6.3	31.2	24.2
October	229.10	79.00	74.50	5.2	31.3	23.9
November	340.30	84.80	77.30	4.3	31.1	23.6
December	110.90	81.70	74.90	5.7	30.7	22.2
2005						
January						
February	93.50	82.80	63.20	6.1	31.5	22.2
March	17.70	82.80	56.40	7.9	32.8	21.9
April	130.50	80.40	66.50	6.3	33.6	23.6
May	114.60	80.30	73.40	5.9	32.4	24.1
June	85.00	78.90	70.60	4.9	31.1	24.8
July	38.70	79.00	74.40	5.7	31.4	25.6
August	108.80	80.70	73.60	4.3	30.8	24.9
September	3.40	76.10	71.60	6.8	31.4	24.7
October	10.10	75.30	68.20	7.5	32.0	24.7
November	415.20	81.10	76.00	4.3	31.1	23.9
December	359.20	86.20	84.30	4.2	29.4	23.1
2006	117.10	87.00	80.00	5.3	29.7	22.4
January						
February	47.50	81.20	73.10	6.5	29.8	21.6
March	32.40	84.70	62.30	7.7	32.1	22.5
April	183.20	87.70	68.10	5.6	32.4	23.1
May	64.60	79.60	69.60	6.2	33.1	23.7
June	147.50	80.30	67.60	5.6	32.8	24.7
July	72.00	79.80	72.10	5.3	31.5	24.6
August	5.20	81.10	72.80	6.9	31.1	25.1
September	20.20	78.00	62.80	7.5	32.3	24.4
October	116.40	80.20	77.21	5.7	33.2	24.6
November	513.60	82.80	76.50	3.8	31.8	23.5
December	256.30	84.20	80.20	5.1	29.1	23.1
	118.90	87.50	79.60	5.8	29.4	22.1

estimated as follows.

Initial weight of the soil = Yg

Final dry weight of the soil = Xg

Soil moisture content per 100g of soil = $((Y - X) / Y) \times 100$

Coconut Yield

Total nut yield was assessed every two months and used to calculate the total nut production per palm per year.

Data analysis

Data analysis of the above experiment was conducted using an Analysis of Variance (ANOVA) with the (SAS version 8.2; SAS Institute, 1998) and the significance of the differences between means was tested using Least Significant Differences (LSD) at P=0.05 (SAS Institute 1998).

RESULTS AND DISCUSSION

Effect of different agronomic practices in controlling weeds on total weed biomass

Lowest weed biomass was recorded following glyphosate application and using the cover crop *Pueraria* (Figures 1, 2 and 3). When glyphosate was applied, the weed biomass was reduced and weed seeds in the soil seed bank initiated germination with the onset of rainy season.

Most of the new emerging weeds were annual dicotyledonous species (*Allmania nodiflora*, *Mitracarpus villosus*, *Tephrosia purpurea*, *Vernonia cinerea*) and the emergence of monocotyledonous

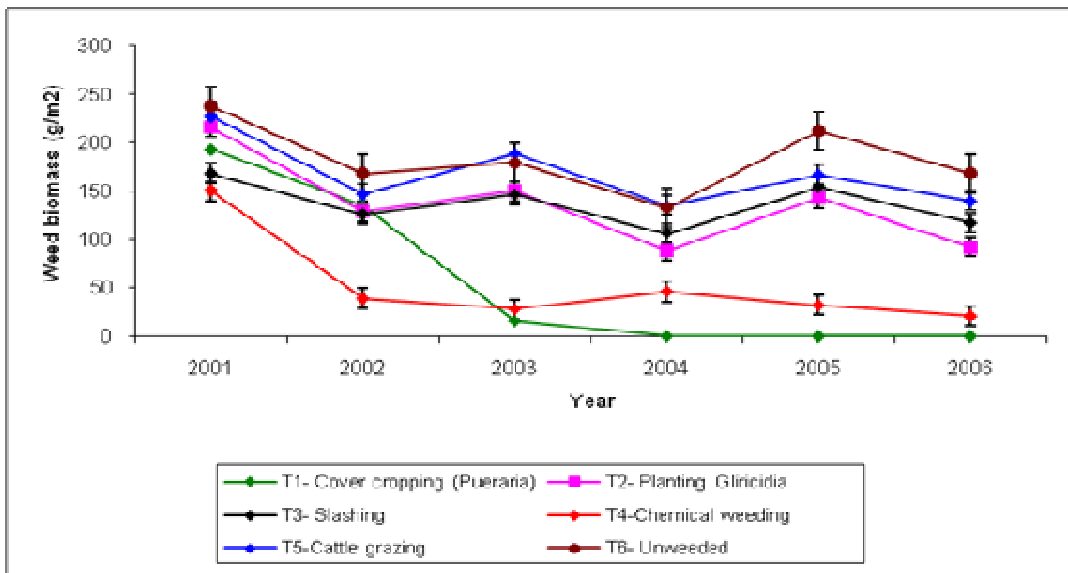


Figure 1. Effect of different agronomic practices on total weed biomass (g/m^2) between 2001 and 2006. (Vertical bars indicates the standard error of the means)

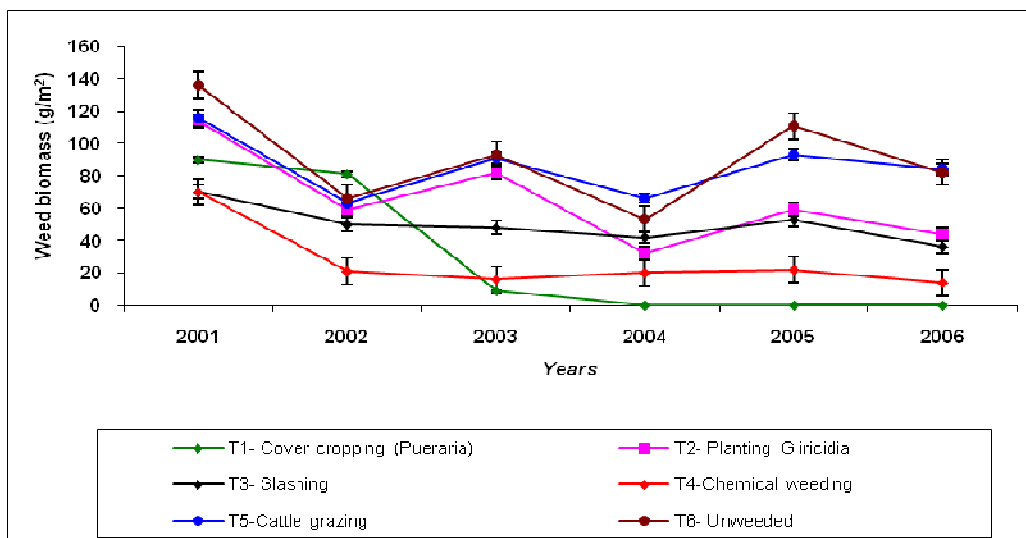


Figure 2. Effect of different agronomic practices on dicotyledonous weed biomass (g/m^2) between 2001 and 2006. (Vertical bars indicates \pm SE of the means)

(*Panicum maximum*, *Pennisetum polystachion*, *Imperata cylindrica*) weed species was comparatively low (Figure 3). Initially *Pueraria phaseoloides* took several months to establish a good cover. The weed biomass was very high at the initial stages in cover cropped plots which declined gradually later. *P. phaseoloides* became self seeded, and formed a good ground cover after few months after sowing, thereby suppressing weed populations by 90% (Figure 1). However, management was essential to avoid possible competition between coconut palms and *P. phaseoloides*.

Initially, the slashing treatment suppressed weed growth approximately for about two months period, but thereafter faster re-growth was observed in monocotyledonous weed species than in dicotyledonous weeds (Figure 3). Generally slashing damaged the aerial parts of the weeds but caused no damage to the root system or under ground plant biomass (such as stolen and rhizomes of the monocotyledonous weed species). Thus during the favorable weather conditions, about 70% of weed species re-sprouted, including the monocotyledonous weeds *Imperata cylindrica*, *Panicum maximum* and

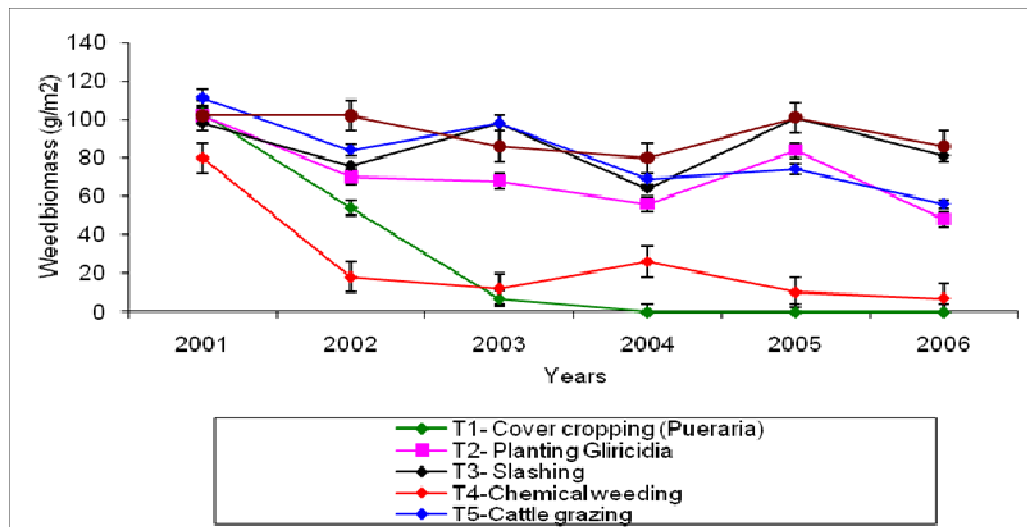


Figure 3. Effect of different agronomic practices on monocotyledonous weed biomass (g/m^2) between 2001 and 2006. (Vertical bars indicates \pm SE of the means)

Table 2. Effect of different agronomic practices in controlling weeds on nut yield (Nuts $\text{palm}^{-1}\text{year}^{-1}$) of coconut in Pallama Seed Garden, Sri Lanka

Treatments	Years						Cumulative average yield
	2001	2002	2003	2004	2005	2006	
T ₁ . Cover cropping	88	38	87	101	94	91	83 (20)
T ₂ . Planting <i>G. sepium</i>	77	38	74	84	59	79	69 (06)
T ₃ . Tractor slashing	78	27	81	87	75	76	71 (08)
T ₄ . Chemical weeding	81	44	97	102	99	93	86 (23)
T ₅ . Cattle grazing	83	36	75	81	66	75	69 (06)
T ₆ . Un-weeded (control)	72	26	68	82	62	70	63
Significance	ns	ns	*	*	*	*	
LSD (P=0.05)	-	-	15	13	17	14	

Values in parentheses are the percentage increase of nut yield over the control

Significantly different at P=0.05

Ns: non significant

Cynodon dactylon and the dicotyledonous weeds *Lantana camara* and *Chromolena odorata*. Olaoye (1977) found that slashing of *Chromolena odorata* caused rapid regeneration. However, repeated slashing and burning resulted in effective control of the weeds. Planting *Gliricidia* between coconut rows and cattle grazing were less effective methods to control weeds in coconut plantations (Figure 1). This was due to the less shading effect to control the growth of weed (REF) and due to the selective feeding habit of cattle and therefore there is a domination of other weed species hence the effectiveness of both of these method to control weed is very low (REF).

Effect of different agronomic practices in controlling weeds on coconut yield

Chemical weeding and cover cropping (*Pueraria*) practices significantly increased ($P < 0.05$) nut yield

from the third year of the trial onwards, compared to the other treatments. Cumulative yield over six years showed 20% and 23% yield increase in cover crop and glyphosate plots compared to un-weeded plots (Table 2). This likely resulted from reduced competition for soil nutrients and soil moisture due to lower weed density. Creeping legumes like *Pueraria* have the additional potential of fixing nitrogen and so improving soil fertility. Control of weeds with slashing, cattle grazing and planting *Gliricidia* did not produce any significant yield increase in coconut.

This might be a result of the presence of competition by weeds for nutrients and water. It is interesting to note that there was no significant difference between the slashing, cattle grazing and planting *Gliricidia sepium* (Table 2). This indicates that competition was more for soil moisture rather than soil nutrients and is further supported by the fact that in areas with inadequate and poor distribution of rainfall, control of weeds with slashing and cattle grazing did not produce any yield in coconut.

Table 3. Soil moisture content (%) at 1.0 ft (depth) as affected by different agronomic practices in controlling weeds at Pallama Seed Garden in Sri Lanka

Treatment	Sampling time			
	2004 February	2004 August	2005 February	2005 August
T ₁ - Cover crop (<i>Pueraria</i>)	10.38	8.32	6.31	9.76
T ₂ - Planting <i>G. sepium</i>	7.20	5.12	4.81	5.26
T ₃ - Tractor slashing	4.21	4.37	4.37	4.38
T ₄ - Chemical weeding	7.88	6.89	8.20	6.98
T ₅ - Cattle grazing	5.22	4.50	4.50	4.12
T ₆ - Un-weeded (control)	5.71	4.34	4.25	3.56
Significance	*	*	*	*
LSD (P=0.05)	3.02	3.80	3.88	3.18

Table 4. Cost and benefit (B/C) analysis of different agronomic practices in controlling weeds

Treatments	Weeding cost (SL Rs/ha annum)	Average annual incremental yield (SL per ha ⁻¹)	Incremental benefits (SL Rs), (SL 20/nut)	Non discounted B/C ratio
T ₁ . Cover crop <i>Pueraria</i>	9500	3200	64000	6.73
T ₂ . Planting <i>Gliricidia</i>	11300	960	19200	1.70
T ₃ . Tractor slashing	10000	1280	25600	2.60
T ₄ . Chemical weeding	9800	3680	73600	7.51
T ₅ . Cattle grazing	1200	960	19200	1.60

Average price of commercial product of glyphosate SL Rs 850/L

Average labour wage SL Rs 400/day

US 1\$= Sri Lanken (SL) Rs. 110

However, cover cropping with *P. phaseoloides* was the most effective long term method for weed control, as indicated by the lowest weed biomass in the experiment. Although cover crops control weeds, they are also expected to compete for soil nutrients and water. In this situation, soil water might be the most critical factor. To overcome this situation cover crops should be managed. If unmanage situation of the cover, it produce the desired out come of weed control but failed to show benefits in coconut yield improvement.

Effect of different agronomic practices in controlling weeds on soil moisture

Since the different agronomic practices in controlling weeds are directly affect on conserving moisture content during the drought period, soil moisture content was estimated under different treatments. Soil moisture content at the depth of 30 cm in different treatments varies from 3.56 – 10.38% which the lowest was very low at this depth. However, since the adult coconut palm has the large well distributed deep root system it could observe that during drought coconut palms has ability to uptake water from the deeper layer (Jayasekera and Jayasekera. 1993).

Soil moisture content was significantly high in cover cropping and glyphosate applied treatments plots compared with other weeding treatments at every sampling time (Table 3). Cover crops produce large amount of biomass and finally make a good litter on the soil surface. It helps to conserve soil moisture and to increase the soil fertility. This emphasized the effectiveness of treatments on the improving soil moisture content during drying. Since the treatment effect could be observed drying, the soil moisture data were collected during that time. The increased nutrient recycling by using leguminous cover crops may also improve fertilizer use efficiency as shown in comparison to natural grass cover for an oil palm plantation (Broughton 1976).

Cost/benefit analysis of different agronomic practices in controlling weeds

The cost of different weed control practices are outlined in Table 4. Benefits were calculated as the average incremental yield per year over the unweeded control. The highest nut yield was achieved with application of glyphosate and establishment of cover crop (*Pueraria*). The highest return to investment (B/C ratio of 7.51 and 6.73) were

given by the application of glyphosate and cover crop establishment methods. Therefore, the most cost effective methods of controlling weeds in the present study were application of glyphosate at the rate of 1.44 kg ai ha⁻¹ and cover cropping with *Pueraria*.

The other methods like slashing, cattle grazing and planting gliricidia were not highly economically viable as indicated by the B/C ratios of 2.60, 1.60 and 1.70 respectively.

CONCLUSION

The conclusion from the present study is that the application of glyphosate and cover cropping with *Pueraria* produced the best cost-effective treatment for the control of weeds in coconut plantations. Possibly using an integrated approach of glyphosate followed by establishment of leguminous creeping cover crops would be the most effective method to control grass weed species such as *Imperata cylindrica*, *Panicum maximum* and *Pennisetum polystachion*. When compared with the other treatments, cover cropping with *Pueraria* conserve more water and maintain high soil moisture level in the soil.

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