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Biomass production and nutrient yields of four green manures and their effect on the yield of cucumber

(Hasil biojisim dan nutrien empat jenis baja hijau serta kesanya pada hasil timun)

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Abstrak

Empat jenis kekacang iaitu *Centrosema pubescence, Calopogonium mucunoides, Calopogonium caeruleum* dan *Pueraria javanica* telah dinilai sebagai baja hijau di tanah asid sulfat. Selepas 7 minggu disemai, pertumbuhan kanopi *C. pubescence, C. mucunoides dan P. javanica* melebihi 80% manakala untuk *C. caeruleum* pertumbuhan hanya 63%. Berat basah tuaian pada 12 minggu masing-masing sebanyak 39, 37, 31 dan 29 t/ha untuk *C. mucunoides, P. javanica, C. caeruleum* dan *C. pubescence*. Berat kering tuaian pula berjumlah 8.7, 6.4, 7.0 dan 6.1 t/ha. Kandungan N ialah 1.4–1.7% bagi akar, 1.8–2.5% bagi batang dan 4.0–4.5% bagi daun. Baja hijau ini juga mengandungi 0.2–0.3% P, 0.4–2.2% K, 0.2–1.0% Ca dan 0.1–0.5% Mg. Kandungan mikronutrien ialah 14–68 ppm Mn, 8–47 ppm Cu, 24–48 ppm Zn dan 11–46 ppm B. Hasil nutrien ialah 196–263 kg N/ha, 14–22 kg P/ha, 111–163 kg K/ha, 23–43 kg Ca/ha dan 11–23 kg Mg/ha. Membubuh baja hijau dengan baja tak organik meningkatkan hasil timun berbanding dengan penghasil daripada tanaman timun yang dibaja dengan tahi ayam pada kadar 4.4 t/ha dan baja tak organik. Walau bagaimanapun, apabila hanya baja hijau digunakan, hasil sebanyak 6.1 kg dan 5.3 kg diperoleh daripada tanaman pertama timun dan yang kedua daripada petak berukuran 3 m x 1.5 m. Tanaman yang diberi baja hijau dan NPK 12:12:17:2 (0.6 t/ha) mengeluarkan hasil yang lebih tinggi iaitu 15.1 kg dan 14.9 kg. Hasil meningkat secara ketara kepada 21.1 kg dan 18.9 kg apabila penggunaan NPK 12:12:17:2 ditingkatkan kepada 1.1 t/ha. Adalah dirumuskan bahawa baja hijau sahaja tidak mencukupi untuk penghasilan timun yang berterusan di tanah asid sulfat. Walau bagaimanapun, pemberian baja hijau dan baja tak organik berkesan dalam mengeluarkan hasil timun yang lebih tinggi daripada tanaman yang dibaja dengan tahi ayam dan baja tak organik.

Abstract

Four leguminous crops, i.e. *Centrosema pubescence, Calopogonium mucunoides, Calopogonium caeruleum* and *Pueraria javanica* were evaluated on acid sulphate soils as green manures. At 7 weeks from sowing, *C. pubescence, C. mucunoides* and *P. javanica* achieved a canopy coverage of over 80%, while the canopy coverage for *C. caeruleum* was 63%. Fresh biomass production when harvested

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at 12 weeks were 39, 37, 31 and 29 t/ha for *C. mucunoides, P. javanica, C. caeruleum* and *C. pubescens* respectively. The corresponding dry weights were 8.7, 6.4, 7.0 and 6.1 t/ha. Nitrogen contents were 1.4–1.7% in the roots, 1.8–2.5% in the stems and 4.0–4.5% in the leaves. The green manures also contained 0.2–0.3% P, 0.4–2.2% K, 0.2–1.0% Ca and 0.1–0.5% Mg. Micronutrient contents were 14–68 ppm Mn, 8–47 ppm Cu, 24–48 ppm Zn and 11–46 ppm B. Nutrient yields were 196–263 kg N/ha, 14–22 kg P/ha, 111–163 kg K/ha, 23–43 kg Ca/ha and 11–23 kg Mg/ha. Incorporation of the crops as green manures plus additional inorganic fertiliser application gave higher cucumber yields than those given by poultry manure at 4.4 t/ha plus inorganic fertiliser. Yields obtained with green manure alone were however only 6.1 kg and 5.3 kg/4.5 m^2 plot, for the first and second crop respectively compared with 15.1 kg and 14.9 kg when the green manures were supplemented with NPK 12:12:17:2 at 0.6 t/ha. Yields increased significantly to 21.1 kg and 18.9 kg when NPK 12:12:17:2 was increased to 1.1 t/ha. It is concluded that green manures alone are not sufficient to sustain yields of cucumber crop on acid sulphate soils. Incorporation of green manures plus inorganic fertiliser was however effective in producing higher cucumber yields than incorporation of poultry manure plus inorganic fertiliser.

Introduction

Green manure is fresh plant material which is incorporated into the soil and allowed to decompose to supply mainly nitrogen and other nutrients to a succeeding crop. The major advantages of green manure have been attributed to its high nitrogen content, low carbon-nitrogen ratio and easy decomposibility (Cosico 1990). Mann (1959) showed that ploughing in lupins or vetches increased the yields of the following crops. Ploughing in legumes was particularly effective in increasing yields of the following kale or cabbage (Cooke 1967). Several other workers, too, have demonstrated yield increases with incorporation of green manures (Berdnikov 1987; Suzuki et al. 1988; Mappaona et al. 1994; Ndoye et al. 1996; Ghuman et al. 1997).

Acid sulphate soils are highly acidic soils found along the coastal areas of Peninsular Malaysia (Zahari et al. 1990). These soils have minimal agricultural activity with poor yields of paddy, rubber and vegetables (Kanapathy 1976). Studies to ameliorate acid sulphate soils for vegetable cultivation showed the need for lime, chicken manure and irrigation for high vegetable yields (Vimala et al. 1992).

The beneficial effects of leguminous cover crops on rubber tree cultivation and soil fertility have been extensively studied in Malaysia (Watson 1961; Watson et al. 1964; Broughton 1977). However, there is little research done on the effectiveness of leguminous crops as green manures in improving soils and vegetable yields on the various soil types in Malaysia. Vimala et al. (1994) found that incorporation of several green manures together with inorganic fertilisers on tin-tailings did not give high yields of cucumber.

In this study, four leguminous crops were evaluated as green manures in terms of growth, biomass production and nutrient yields on acid sulphate soils. The effect of these green manures on the yield of two succeeding crops of cucumber is also presented.

Materials and methods

Green manures and field preparation

Four leguminous crops, i.e. *Centrosema pubescence, Calopogonium mucunoides, Calopogonium caeruleum* and *Pueraria*

javanica, were evaluated as green manures. Planting bed size used was 3 m x 1 m. Four such beds were allocated for each crop per replicate. The experiment was arranged in a Randomised Complete Block Design with three replicates. Inter-bed space was 0.5 m giving an effective plot size of 3 m x 1.5 m or 4.5 m^2. The soil pH before lime application was 3.9.

Lime and chicken manure both at 2 kg/plot or 4.4 t/ha were applied and incorporated into the soil 2 weeks and 3 days respectively before sowing. The seeds of the various crops were inoculated with the appropriate Rhizobia inoculant (obtained from the Rubber Research Institute Malaysia) and mixed with CIRP.

About 3–4 seeds were sown at 60 cm x 10 cm to give two rows of plants per bed. At 2 weeks after sowing, the plants were thinned to 2 plants/point to give 120 plants/bed or 266 667 plants/ha. NPK fertiliser (12:12:17:2) was applied at 100 g/plot or 222 kg/ha at 3 weeks after sowing. Canopy coverage was recorded by visual estimation at 4, 5, 6 and 7 weeks after sowing.

The properties of the acid sulphate soils used have been described by Vimala et al. (1992).

Collection of samples for nutrient analysis

Four plants were randomly collected for each crop prior to harvest. In the laboratory, the samples were separated into plant part components, i.e. root, stem and leaf. The roots were washed and the other plant parts were cleaned of adhering soil particles. Fresh weight of each component was obtained. Each plant part was then chopped up and dried at 70 °C to constant weight. The proportion of component plant part was determined for each crop for the subsequent calculation of biomass and nutrient yields of root, stem and leaf.

Harvesting

The crops were harvested at 3 months and fresh yield per plot for each green manure recorded. The harvests were then chopped up and incorporated back into the beds as green manures, and left to decompose for 4 weeks.

Nutrient analysis

Nitrogen was determined by the micro-Kjeldahl method. For the other elements, 1–2 g of sample was weighed into a silica basin and dry-ashed in a muffle furnace at 500 °C (for 4–5 h) until ashing was complete. The ash was dissolved in a mixture of nitric and hydrochloric acids and allowed to evaporate in a water-bath. The residue was then washed with warm distilled water into a 100 mL volumetric flask. The nutrients P, K, Ca, Mg, Mn, Cu, Zn and B were determined using the ICP emission spectrophotometer.

Sowing cucumber

Cucumber seeds were planted on the beds 4 weeks after incorporation of the green manures. Seeds of variety MTi2 were sown at 60 cm x 60 cm spacings to give 10 plants/bed. Inorganic fertiliser (NPK 12:12:17:2) was applied at 0, 25, 50 and 100%, i.e. at 0, 250, 500, 1 000 g/plot or 0, 0.6, 1.1 and 2.2 t/ha, in two split applications at 3 weeks and 5 weeks after sowing. A control plot without green manure was applied with poultry manure at 4.4 t/ha and fertiliser NPK (12:12:17:2) at 2.2 t/ha. A second cucumber crop was sown 4 weeks after harvest of the first cucumber crop. The soil pHs were determined at the end of the first and second cucumber crops.

Results and discussion

Canopy coverage

Most of the green manures established well, giving a mean canopy coverage of about 30% by 4 weeks. *Calopogonium caeruleum* gave the lowest canopy coverage of 27% compared with the other green manures. However, there was no significant difference in the canopy coverage at this age and at 3 weeks from sowing *(Table 1). Calopogonium caeruleum* showed the lowest canopy coverage on sand-tailings as well (Vimala et

Table 1. Canopy coverage of four green manures grown on acid sulphate soils

Green manure	Coverage (%) weeks from sowing					
	3	4	5	6	7	8
Centrosema pubescence	11.7a	35.0a	43.3a	73.3a	86.7a	91.7a
Calopogonium mucunoides	10.0a	30.0a	38.3ab	66.7a	83.3a	88.3a
Calopogonium caeruleum	8.3a	26.7a	31.7b	43.3b	63.3b	73.3b
Pueraria javanica	8.3a	28.3a	43.3a	63.3a	83.3a	88.3a
Mean	9.6	30.0	39.2	61.7	79.2	85.4
C.V. (%)	19.4	13.3	11.1	8.1	5.5	5.1
Significance	ns	ns	*	**	**	*

Mean values in the same column with different letters are significantly different
ns = not significant
*significant at 5% level
**significant at 1% level

Table 2. Yield of four green manures grown on acid sulphate soils

Green manure	Yield/plot (kg/4.5 m^2)		Yield/ha (t)	
	Fresh yield	Dry yield	Fresh yield	Dry yield
C. pubescens	12.85d	2.73b	28.56d	6.06b
C. mucunoides	17.75a	3.90a	39.44a	8.65a
C. caeruleum	13.88c	2.89b	30.84c	6.95b
P. javanica	16.85b	3.13b	37.44b	6.42b
Mean	15.33	3.16	34.07	7.02
C.V. (%)	0	7.43	0	7.43
Significance	**	**	**	**

**Significant at 5% level
Mean values in the same column with different letters are significantly different

al. 1994). Significant differences in canopy coverage were first evident at 5 weeks from sowing. From the sixth week onwards, *C. caeruleum* showed significantly slower growth than the other green manures. At the seventh week from sowing, *C. pubescence, C. mucunoides* and *P. javanica* achieved a canopy coverage of above 80%, while the canopy coverage for *C. caeruleum* was only 63%. The mean canopy coverage at 8 weeks was 85.4%, with *C. caeruleum* trailing behind at 73.3%. *Calopogonium caeruleum* has been reported to be shade tolerant and more vigorous than *C. mucunoides or C. pubescence* under rubber (Tan et al. 1976). The no-shade conditions in this study probably caused the less vigorous growth of *C. caeruleum.*

Biomass production

The highest fresh yield was obtained with *C. mucunoides* which gave a yield of 17.75 kg/plot (39.4 t/ha). The other green manures gave significantly lower yields, i.e, 16.85 kg (37.4 t/ha), 13.88 kg (30.8 t/ha) and 12.85 kg/plot (28.6 t/ha) for *P. javania, C. caeruleum* and *C. pubescens,* respectively *(Table 2).* In a similar experiment on tin-tailings, *C. mucunoides* also gave the highest yields amongst the four green manures tested (Vimala 1992).

The dry yields obtained ranged from 2.73 to 3.90 kg/plot or 6.1 to 8.7 t/ha

(Table 2). In India, dry biomass production of 5.3–6.3 and 6.2–8.2 t/ha for the green manures *Sesbania aculeata* and *Crotaria juncea* respectively were obtained (Hiremath and Patel 1996).

The fresh and dry yields obtained in this study were almost double the yields obtained in earlier studies on sand-tailings where the green manures were harvested at 2 months (Vimala 1992). The high yields obtained augurs well for further research into the feasibility and economics of green manure incorporation as a mean of improving acid sulphate soils. This is especially relevant for organic vegetable cultivation, which is gaining popularity in Malaysia.

Nutrient contents

The macronutrient and micronutrient contents of the green manures are presented in *Table 3.* The leaf had the highest nitrogen content ranging from 3.98% to 4.50%. Similar green manures grown on sand-tailings showed lower leaf N contents (Vimala et al. 1994). The N contents of the stem ranged from 1.77% to 2.45%. Root nitrogen contents ranged from 1.37% to 1.72%.

Phosphorus contents ranged from 0.22% to 0.27% in the leaf *(Table 3).* The P contents of the stem were similar to the leaf ranging from 0.22% to 0.27% while roots had lower P contents of 0.15–0.18%.

Potassium contents were higher in the leaf (1.35–1.98%) and stem (1.92–2.21%) compared with the root (0.35–0.82%) *(Table 3)*. Earlier studies on sand-tailings showed 0.93–2.01% K in the leaf, 1.15–2.29% in the stem and 0.79–1.28% in the root (Vimala et al. 1994). The different soil types and different inputs on sand-tailings and acid sulphate soil probably account for the differences in nutrient contents.

Calcium contents were highest in the leaf (0.52–1.00%) compared with other plant parts *(Table 3).* In studies elsewhere on unlimed acid sulphate soils, the Ca concentration of two legumes, *Cajanas cajan* and *Sesbania aculeata*, was 0.32%. Poolpipatana and Hue (1994) found that with liming, the shoot Ca% in *C. cajan* increased to 1.2% and in *S. aculeata* to 0.8%. These are comparable with the Ca contents obtained in this study where lime was used.

Magnesium contents were highest in the leaf for all the green manures (ranging

Table 3. Macronutrient and micronutrient contents of four green manures

Green manure	Macronutrient (%)					Micronutrient (ppm)			
	N	P	K	Ca	Mg	Mn	Cu	Zn	B
C. pubescence									
Leaf	3.98	0.26	1.92	0.55	0.29	51	41	39	20
Stem	2.18	0.22	1.92	0.30	0.12	24	47	42	16
Root	1.72	0.17	0.82	0.26	0.20	19	21	46	15
C. mucunoides									
Leaf	4.27	0.27	1.98	0.52	0.29	40	22	31	29
Stem	1.77	0.26	1.96	0.29	0.21	23	37	37	19
Root	1.63	0.15	0.48	0.51	0.46	63	10	35	13
C. caeruleum									
Leaf	4.50	0.24	1.35	1.00	0.34	52	22	35	13
Stem	2.45	0.27	1.94	0.24	0.14	14	19	28	21
Root	1.55	0.16	0.35	0.28	0.19	24	8	24	11
P. javanica									
Leaf	4.16	0.22	1.38	0.57	0.49	43	33	37	46
Stem	1.98	0.25	2.21	0.38	0.26	68	21	48	15
Root	1.37	0.18	0.72	0.48	0.28	25	15	35	12

from 0.29% to 0.49%) except for *C. mucunoides (Table 3).*

For micronutrient contents, the values for Mn, Cu, Zn and B were 14-68, 8–47, 24–48 and 11–46 ppm respectively.

Nutrient yields

The nutrient yields of the crops used as green manures are presented in *Table 4.*

Nitrogen yields ranged from 196 to 263 kg/ha and were generally highest in the leaf and lowest in the root. Studies elsewhere showed that in 3 months, which is the same age as the crops in this study, Mucuna pruriens accumulated 313 kg N/ha (Sanginga et al. 1996). Schroder et al. (1997) reported N yields of 22–125 kg/ha depending on crop and the rate of N applied. Nitrogen accumulations of 80–93, 34-67 and 92–121 kg/ha were reported for *Sesbania aculeata, S. rostrata* and *Crotalaria juncea* respectively (Hiremath and Patel 1996). *Crotalaria juncea, S. aculeata* and *Vigna unguiculata* accumulated 103, 84 and 67 kg N in 55 days of growth (Datt and Bhardwaj 1995).

Phosphorus yields ranged from 14 to 22 kg/ha. Sesbania rostrata yielded 15.3 kg P/ha (Moreno et al. 1995).

Potassium yields ranged from 111 to 163 kg|ha and were highest in the stem for all the crops except *C. mucunoides.* Studies elsewhere showed that *S. rostrata* yielded 133 kg K/ha (Moreno et al. 1995).

Calcium yields ranged from 23 to 43 kg/ha and were generally highest in the leaves. Magnesium yields ranged from 11 to 23 kg/ha.

The varying nutrient yields of green manure crops in this study and in studies elsewhere is attributed to differences in species, age and the management practices for their cultivation.

Cucumber yields

Incorporation of the leguminous crops as green manures gave higher yields of the first

Table 4. Nutrient yields of four green manures

Green manure	Nutrient yield (kg\ha)				
	N	P	K	Ca	Mg
C. pubescence					
leaf	77.2	5.0	37.3	10.7	5.6
stem	80.0	8.1	70.5	11.1	4.4
root	79.1	0.8	3.8	1.2	0.9
Total	236.3	13.9	111.6	23.0	10.9
C. mucunoides					
leaf	188.7	11.9	87.5	23.0	2.8
stem	66.2	9.7	73.3	10.9	7.9
root	8.3	0.8	2.5	2.6	2.4
Total	263.2	22.4	163.3	36.5	23.1
C. caeruleum					
leaf	141.8	7.6	42.5	31.5	10.7
stem	89.9	9.9	71.2	8.8	5.1
root	20.2	2.1	0.5	0.4	0.3
Total	251.9	19.6	114.2	40.7	16.1
P. javanica					
leaf	134.0	7.1	44.4	18.4	15.8
stem	57.4	7.3	64.1	11.0	3.2
root	4.4	0.6	2.3	13.4	0.9
Total	195.8	15.0	110.8	42.8	19.9

cucumber crop compared with yields from the poultry manure treatment *(Table 5)*. The second cucumber crop also showed higher yields with green manures, especially with *C. cearuleum*, where the cucumber yield was significantly higher than the poultry manure treatment. The reason for the superiority of *C. caeruleum* over the other green manures is not evident as it was neither the highest biomass yielder nor the highest nutrient yielder. It could perhaps be due to its faster rate of decomposition and nutrient release, compared with the other green manures. The significant effect of green manures on the second cucumber crop but not the first cucumber crop appeared to indicate a need for a time lapse after incorporation, for the microbial decomposition of the green manures and release of nutrients. Franzluebbers et al. (1994) found that N mineralised 10 weeks after incorporation of cowpea was only 27%. According to Schroder et al. (1997), at least 35% of above ground N in green manure crops was not used within 18 months after incorporation. Both these studies suggest a gradual nutrient release from the green manures.

Increasing rates of inorganic fertiliser gave significantly higher yields for both crops (15–24 kg for the first crop and 15–19 kg for the second crop), compared with green manure alone which gave only 6 kg and 5 kg for the first and second crop respectively *(Table 6)*. Green manure alone appeared to be insufficient to sustain yields of cucumber though the amounts of nutrients from the green manures were substantial, the N (196–263 kg/ha) alone being equivalent to about 2 t/ha of fertiliser NPK (12:12:17:2). This is attributed to the nutrients in the green manure not being available to the growing cucumber crop due probably to slow decomposition and mineralisation. Similar yield increases with additional mineral fertilisers compared with yields from green manure alone have been reported (Palled et al. 1997; Nelson and King 1996). With incorporation of green manures that supplied 107–123 kg N/ha, wheat yields averaged 65% of yields when fertiliser at 90 kg N/ha was applied (Nelson and King 1996).

Table 5. Yield of cucumber crop with incorporation of four green manure

Green manure	Yield (kg/4.5 m^2)	
	1st crop	2nd crop
C. pubescens	14.85a	14.02ab
C. mucunoides	17.28a	15.02ab
C. caeruleum	18.04a	15.76a
P. javanica	16.05a	13.80ab
Chicken manure	14.97a	12.52b
Mean	16.24	14.22
C.V. (%)	23.2	17.2
Significance	ns	**

Mean values in the same column with different letters are significantly different

Table 6. Yield of cucumber at various rates of NPK

Rate of NPK (t/ha)	Yield (kg/4.5 m^2)	
	1st crop	2nd crop
0	6.09c	5.33c
0.6	15.05b	14.94b
1.1	21.09a	18.89a
2.2	23.51a	18.89a
2.2 + CM	14.97b	12.52b

Mean values in the same column with different letters are significantly different
CM = chicken manure at 4.4 t/ha

Table 7. Soil pH at the end of first and second cucumber crops

Green manure	Soil pH	
	1st crop	2nd crop
C. pubescence	4.7	5.4
C. mucunoides	4.7	5.4
C. caeruleum	4.7	5.6
P. javanica	4.7	5.2
Chicken manure	4.9	5.1
Mean	4.7	5.3
C.V. (%)	8.5	9.9
Significance	ns	ns

ns = not significant

Soil pH

There was no significant difference in soil pH between the incorporation of chicken manure and green manures *(Table 7)*. The increase in soil pH from the initial value of 3.9 to 4.7 and 5.3 for the first and second cucumber crop respectively, is attributed to the lime and chicken manure (pH of 7.5) which were applied for the growth of green manures. Earlier studies on acid sulphate soils showed a pH increase from 3.8 to 5.0 with the application 12 t/ha lime and 10 t/ha chicken manure (Vimala et al. 1992).

Conclusion

All the crops used as green manures established well on acid sulphate soils. Incorporation of the leguminous crops as green manures and applying inorganic fertilisers gave higher yields than incorporation of poultry manure and inorganic fertiliser indicating the possibility of including green manures as soil ameliorating agents for acid sulphate soils. Green manure alone without additional inorganic fertiliser was not sufficient to sustain yields of cucumber. However, incorporation of green manures with inorganic fertiliser NPK 12:12:17:2 at 1.1 t/ha gave higher yields than poultry manure plus NPK 12:12:17:2 at 2.2 t/ha.

Studies on nitrogen fixation, rates of application, decomposition rate, nutrient release from green manures and the benefits of green manures in improving the chemical, physical and microbiological properties of various soils for food crop cultivation are suggested. These studies are relevant, especially in view of the limited range of effective organic fertilisers presently available. Suitable organic sources of nutrients are urgently needed to cater to the growing interest in organic vegetable cultivation in Malaysia, as well as to provide environment-friendly and sustainable sources of nutrients to the organic and the conventional vegetable growers. Green manures are one of the most sustainable nitrogen sources that need to be exploited .

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