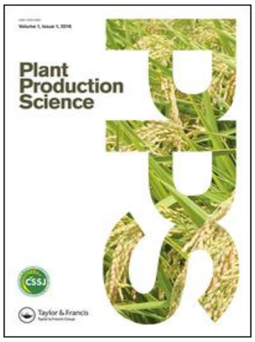

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Growth and Nutrient Accumulation of Winged Bean and Velvet Bean as Cover Crops in a Subtropical Region

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Abstract: We examined biomass dry matter and nutrient uptake of live plant parts, leaf area index, and litter of winged bean (*Psophocarpus tetragonolobus*) and velvet bean (*Mucuna pruriens*) 12, 18, 24 and 30 weeks after sowing (WAS). The two plants had similar leaf and stem+petiole biomasses. At 30 WAS winged bean had a significantly lower pod yield than velvet bean. Between 18 and 30 WAS, winged bean produced less litter than velvet bean due to differences in growth stages. The total mulch of live parts and litter of winged bean and velvet bean completely covered the ground by 18 and 12 WAS, respectively. Compared to velvet bean, the leaf and stem+petiole of winged bean had a significantly higher N concentration; significantly higher N uptake at 24 and 30 WAS; significantly lower C/N ratio; and significantly higher P, K and Mg concentrations. In winged bean, P uptake was significantly higher in the leaf at 30 WAS and in the stem+petiole at all harvesting times. The total biomass of the leaf, stem+petiole and litter of winged bean was 317−561 g DM m^{-2}, and their N content was 12.3−17.7 g m^{-2}. The total biomass of live parts and litter of winged bean might be sufficient to suppress weeds and increase soil N. Winged bean is an appropriate legume cover crop and green manure due to its longer growing period and superior ground-covering ability and high N input.

Key words: Biomass, Cover crop, Nutrient uptake, Subtropical region, Velvet bean, Winged bean.

Soils left bare for long periods are susceptible to wind and water erosion, water evaporation, and weed infestation. The practice of planting bare soil with legume cover crops can be applied broadly to conserve topsoil and save nutrients that might leach out of the soil in the absence of plants (Kaizzi et al., 2004; Anthofer and Kroschel, 2005; Bodner et al., 2007).

Velvet bean (*Mucuna pruriens*) is a well-known and promising legume cover crop in tropical and subtropical regions (Anthofer and Kroschel, 2005; Nagumo et al., 2006). As a cover crop, velvet bean reduces erosion (Puustinen et al., 2007), fixes N (Hauser and Nolte, 2002), suppresses weeds (Baijkya et al., 2005), and conserves soil water (Salako and Tian, 2003). After harvesting and subsequently applying to either no-tillage or tillage systems, velvet bean residue serves as a green manure that conserves soil fertility by enhancing C and N stores (Barthès et al., 2004; Kaizzi et al., 2004).

In tropical regions, winged bean (*Psophocarpus tetragonolobus*) is a crop with vigorous production of new foliage, high protein content, and tolerance of soil acidity and salinity (Weil and Khalil, 1986). Moreover, winged bean can be used for human nutrition as the seeds, leaves, flowers, pods, and fleshy roots are edible (Weil and Belmont, 1991). Using the ground-cover evaluation method (Sasaki et al., 1994), we previously found that winged bean achieved a soil cover of 60% at 12 weeks after sowing (WAS) and almost 100% from 16 to 36 WAS; the total biomass of the leaf and stem+petiole of winged bean at 36 WAS reached 700 g DM m^{-2} (Anugroho et al., 2007).

The leaf and stem+petiole of winged bean and velvet bean mainly serve as ground cover, but the pod is used as food and medicine in regions of southern Asia (Weil and Belmont, 1991; Dhanasekaran et al., 2008; Vadivel and Pugalenthi, 2009). The pods can also be used as green manure when they are allowed to decompose in the field. However, using pods as green manure results in many seeds germinating the following spring and interfering with the subsequent cash crop. Plant litter is a major source of soil organic matter in natural and many plantation crop ecosystems. Some nutrients remain in the litter of winged bean and velvet bean and are released gradually as green

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Abbreviations: WAS, weeks after sowing.

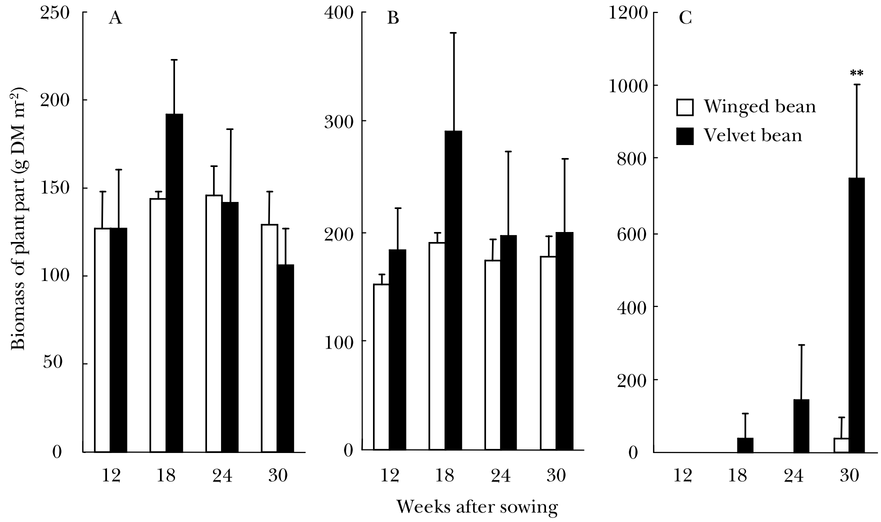

Fig. 1. Biomass dry matter in (A) leaves, (B) stems and petioles, and (C) pods of winged bean and velvet bean. Vertical bars represent the standard error of the mean (n=3). ** indicates significant difference at P<0.01 by Student's *t*-test.

manure during the growing period.

Little research has been conducted to determine the quality of winged bean and velvet bean as cover crops and green manure in subtropical regions. The objectives of the present study were to determine: (i) the biomass and nutrient uptake of the leaf and stem+petiole parts, the leaf area index (LAI), and the nutrient contents of winged bean and velvet bean litters in a subtropical region; (ii) the best times for plant slashing and mulching for use as a cover crop and green manure; and (iii) the yields and nutritional composition of winged bean and velvet bean pods as foods.

Materials and Methods

1. Experimental site and soil chemical properties

The study was conducted at the Subtropical Field Science Center, University of the Ryukyus, Okinawa, Japan (26°N, 127°E). The soil type was dark red, and pH and electrical conductivity of the initial soil were 7.8 and 9.4 mS m^{-1}, respectively. Total C, total N, total phosphate, available phosphate, and phosphate absorption coefficient was 19.8, 2.2, 6.5, 0.1, and 10.6 g kg^{-1}, respectively. The exchangeable K, Ca, and Mg were 27.8, 153.0 and 10.7 $mmol_c$ kg^{-1}, respectively.

2. Plant materials and experimental design

Five seeds each of winged bean (*Psophocarpus tetragonolobus* (L.) D.C. cv. Urizun) and velvet bean (*Mucuna pruriens* (L.) D.C. var. *utilis* cv. Hashou) were sown manually on 1 May 2007, with 0.5 m interrow and intrarow spacing between hills. The plants were thinned to two plants per hill at 4 WAS. Both cropped plots were 10 m×8 m in size, and no fertilizer was added. Crops were harvested from 0.5 m×0.5 m quadrats in a completely randomized block design with three replications on 24 July (12 WAS), 4 September (16 WAS), 16 October (24 WAS), and 29 November (30 WAS). Litter in the form of senesced and fallen leaves and stems+petioles was also collected at each harvesting time.

3. Measurement of plant materials

After scanning all the leaves from each plant, the LAI was determined by counting pixels of the scanned images using Adobe Photoshop 7.0 (San Jose, CA, USA). Leaves, stems plus petioles, and pods of plants were separately dried at 70°C for 72 hr, weighed, and ground to a powder. Total C and N concentrations were determined by a CHN Coder (JM10; G-Science Laboratory Company, Tokyo, Japan). Total P concentration was determined by calorimetric methods after dry combustion at 450°C for 1 hr and dissolving in 1:30 (v/v) diluted nitric acid solution (Hafner et al., 1993). Concentrations of K, Ca, and Mg were determined using an atomic absorption spectrophotometer (Solaar 969, Japan Thermo Corp., Tokyo, Japan) after Kjeldahl digestion.

4. Statistical analysis

Statistical differences in biomass, leaf area index (LAI), nutrient concentrations, and nutrient uptake between winged bean and velvet bean were determined with Student's *t*-test using Microsoft Excel (Redmond, WA, USA).

Results

1. Leaf and stem+petiole biomass and leaf area index

There was no significant difference in the biomass of leaf or stem+petiole between winged bean and velvet bean at each harvesting date, although the biomass of both leaf and stem+petiole of winged bean at 18 WAS were lower than those of velvet bean (Fig. 1A, B). The leaf biomass tended to increase in winged bean and velvet bean at 18 WAS, remained constant in winged bean and decreased in velvet bean at 24 WAS, and decreased in both plants at 30 WAS (Fig. 1A). The stem+petiole biomass of winged bean and velvet bean tended to increase at 18 WAS and then decreased at 24 WAS (Fig. 1B). The total biomass of leaf and stem+petiole parts was in the range of 277−332 g m^{-2} in winged bean and 303−483 g m^{-2} in velvet bean.

Winged bean had a significantly higher LAI than velvet bean at 24 and 30 WAS (Fig. 2A). The LAI of both plants increased significantly at 18 WAS and then decreased at 24 and 30 WAS. There was a positive correlation between the LAI and leaf biomass in both winged bean and velvet bean (Fig. 2B).

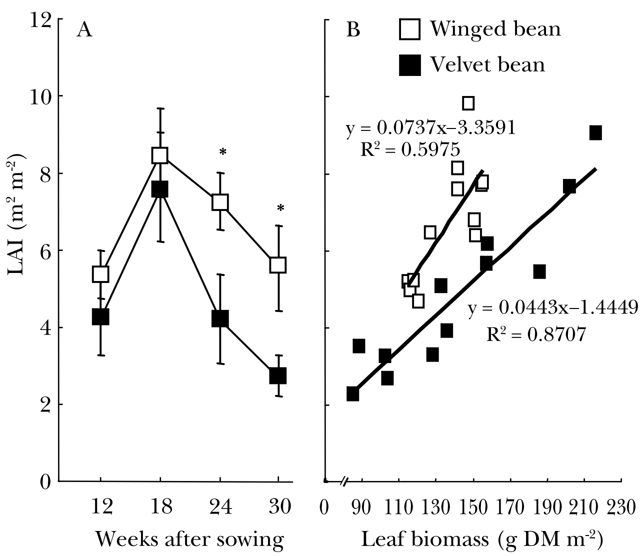

Fig. 2. (A) Leaf area index (LAI) of winged bean and velvet bean; and (B) LAI correlation with leaf biomass. Vertical bars represent the standard error of the mean (n=3). * indicates significant difference at P<0.05 by Student's *t*-test.

2. Nutrient uptake by leaf and stem+petiole parts of plants

Table 1 shows the concentrations and uptake of C and N, as well as the C/N ratios in winged bean and velvet bean. The C concentration in the petiole at 12 and 18 WAS was significantly lower in winged bean than in velvet bean. Similarly, the C concentration in the stem+petiole of winged bean was significantly lower at 12, 18 and 24 WAS. Compared to velvet bean, the fixed C of the leaf part of winged bean was significantly lower at 18 WAS, and the fixed C of the stem+petiole part of winged bean was lower at all harvesting dates but not significantly. In contrast, the N concentrations of the leaf and stem+petiole parts of winged bean were significantly higher than those of velvet bean at all harvesting dates. N uptake in winged bean leaves at 24 and 30 WAS was significantly higher than that in velvet bean. Similarly, N uptake by the stem+petiole of winged bean was significantly higher at 12, 24, and 30 WAS. Total fixed C of the leaf and stem+petiole parts was in the range of 119−142 g m^{-2} for winged bean and 136−216 g m^{-2} for velvet bean across all harvesting dates, whereas total N uptake by the leaf and stem+petiole parts was in the range of 10.9−14.6 g m^{-2} in winged bean and 5.1−11.4 g m^{-2} in velvet bean. Furthermore, C/N ratios of winged bean were in the range of 7.3−8.7 (leaf) and 13.4−19.3 (stem+petiole), both of which were significantly lower than those of velvet bean, which were in the range of 12.0−15.0 (leaf) and 32.2−46.5 (stem+petiole).

Table 2 shows the P, K, Ca, and Mg concentrations and uptake in winged bean and velvet bean. The P, K, and Mg concentrations in the leaves and stem+petiole were significantly higher in winged bean than in velvet bean. As compared with velvet bean, leaves of winged bean had significantly higher P uptake at 30 WAS, and stem+petiole significantly higher P uptake at all harvesting dates. Total P uptake by the leaf and stem+petiole was in the range of 0.8−1.3 g m^{-2} in winged bean and 0.5−0.9 g m^{-2} in velvet

Table 1. C and N concentrations, C/N ratio, fixed C, and N uptake in winged bean (WB) and velvet bean (VB).

Plant Part	Time (WAS)	C (g kg^{-1})		N (g kg^{-1})		C/N ratio		Fixed C (g m^{-2})		N uptake (g m^{-2})	
		WB	VB	WB	VB	WB	VB	WB	VB	WB	VB
Leaf	12	443.53	464.31*	54.72	38.80†	8.25	12.01†	57.50	58.65	7.00	4.90
	18	443.60	467.92†	60.96	38.89‡	7.28	12.03‡	63.83	89.87*	8.78	7.48
	24	468.18	467.50	58.66	33.75‡	7.98	13.86‡	68.22	66.19	8.55	4.81*
	30	461.91	452.96*	53.02	30.25‡	8.73	14.99‡	59.98	47.91	6.89	3.19†
Stem+petiole	12	411.88	427.73‡	27.26	12.97†	15.22	33.39†	61.74	77.81	4.07	2.37*
	18	415.18	435.43‡	31.08	13.53‡	13.38	32.21‡	78.07	126.57	5.84	3.93
	24	431.59	438.72†	25.09	11.06‡	17.23	40.37†	74.30	85.88	4.33	2.10*
	30	439.41	444.57	22.99	9.62†	19.33	46.48‡	77.50	87.71	4.03	1.87†
Pod	18		441.28		35.73		12.58		18.19		1.25
	24		444.95		29.71		15.12		64.34		4.03
	30	421.93	442.43‡	54.81	23.77†	7.82	19.11†	16.42	329.65†	2.01	18.47*

*, †, and ‡ indicate significant differences at P<0.05, P<0.01, and P<0.001, respectively, by Student's *t*-test (n=3).

Table 2. Concentration and uptake of P, K, Ca, and Mg in winged bean (WB) and velvet bean (VB).

	Time (WAS)	P		K		Ca		Mg	
		WB	VB	WB	VB	WB	VB	WB	VB
Concentration (g kg^{-1})									
Leaf	12	3.45	2.81*	5.04	3.97‡	8.57	7.67	2.53	2.16*
	18	3.65	2.34†	6.02	4.49†	8.68	11.37	2.36	1.64†
	24	3.69	2.47†	4.75	3.41*	9.99	13.11*	2.61	1.39‡
	30	2.84	2.06†	3.20	2.69†	16.96	16.28	3.14	0.98‡
Stem+petiole	12	4.78	2.06‡	9.38	7.89*	5.33	6.18	1.65	1.07†
	18	4.11	1.51‡	9.87	7.76	4.19	6.58‡	1.28	0.83†
	24	4.41	1.95‡	9.91	4.93‡	5.30	9.22‡	1.76	0.84†
	30	2.59	1.23†	6.67	3.46†	6.74	6.77	1.66	0.67‡
Pod	18		2.04		6.64		5.36		1.59
	24		2.50		4.63		7.75		1.63
	30	5.15	1.78†	8.59	5.16*	7.49	4.24*	2.78	1.44†
Uptake (g m^{-2})									
Leaf	12	0.44	0.35	0.64	0.50	1.10	0.97	0.32	0.27
	18	0.53	0.45	0.87	0.87	1.25	2.29	0.34	0.31
	24	0.54	0.36	0.68	0.49*	1.47	1.88	0.38	0.20†
	30	0.37	0.22*	0.42	0.29	2.18	1.6 a	0.41	0.10†
Stem+petiole	12	0.72	0.38†	1.40	1.44	0.80	1.11	0.25	0.19
	18	0.77	0.44*	1.85	2.30	0.79	1.91*	0.24	0.24
	24	0.76	0.38*	1.69	0.96‡	0.91	1.81	0.30	0.17*
	30	0.45	0.24†	1.17	0.71	1.19	1.41*	0.29	0.13*
Pod	18		0.08		0.08		0.19		0.06
	24		0.32		0.68		1.08		0.22
	30	0.19	1.38*	0.31	3.87*	1.89	3.07*	0.10	1.07†

*, †, and ‡ indicate significant differences at $P<0.05$, $P<0.01$, and $P<0.001$, respectively, by Student's *t*-test (n=3).

bean. K concentration in the leaf and stem+petiole was significantly higher at 24 WAS in winged bean than in velvet bean. Total K uptake by the leaf and stem+petiole was in the range of 1.6−2.7 g m^{-2} in winged bean and 1.0−3.17 g m^{-2} in velvet bean. The Mg uptake in both leaf and stem+petiole parts tended to be higher in winged bean than in velvet bean, and the values were significantly higher at 24 and 30 WAS. The total Mg uptake by the leaf and stem+petiole was in the range of 0.6−0.7 in winged bean and 0.2−0.6 g m^{-2} in velvet bean.

3. Pod yields and nutritional value

The pods of winged bean appeared at 30 WAS, whereas the pods of velvet bean appeared from 18 to 30 WAS. At 30 WAS, the pods of winged bean were still immature, whereas those of velvet bean were almost fully mature. The pod yield was 11% of the aboveground biomass for winged bean and in the range of 8−71% for velvet bean (Fig. 1C). At 30 WAS, the N concentration was significantly higher and the C concentration was significantly lower in the pods of winged bean than in those of velvet bean (Table 1). Moreover, winged bean had significantly lower fixed C and N uptake of the pods than velvet bean (Table 1). The P, K, Ca, and Mg concentrations in the pods were significantly higher in winged bean than in velvet bean (Table 2), whereas the P, K, Ca and Mg uptake by the pods was significantly lower in winged bean than in velvet bean.

4. Litter biomass and nutrient contained in litter

The amounts of litter and nutrients contained in the litter (total nutrient per unit area) of winged bean and velvet bean during the growing period from 12 to 30 WAS are shown in Table 3. The amount of litter of winged bean and velvet bean tended to increase over time and was in the range of 40−255 and 39−446 g m^{-2}, respectively. The amounts of N, P, K, Ca, and Mg contained in the litter of the two plants were not significantly different, except that velvet bean litter contained significantly more Ca than winged bean litter at 12 and 30 WAS.

Discussion

In the present study, the total biomass of the leaves and stem+petiole of winged bean grown in a subtropical region reached a maximum level of 332 g DM m^{-2} and tended to be lower than the values reported for both velvet bean and winged bean (Anugroho et al., 2007). The total biomass of the leaves and stem+petiole of winged bean obtained in the present and previous studies was about

Table 3. The litter biomass and nutrient contained in litter of winged bean (WB) and velvet bean (VB).

Time (WAS)	Litter ($g\ m^{-2}$)		N ($g\ m^{-2}$)		P ($g\ m^{-2}$)		K ($g\ m^{-2}$)		Ca ($g\ m^{-2}$)		Mg ($g\ m^{-2}$)	
	WB	VB	WB	VB	WB	VB	WB	VB	WB	VB	WB	VB
12	40.39	38.97	1.22	1.03	0.10	0.07	0.16	0.15	0.12	0.30*	0.18	0.14
18	115.20	186.40	3.12	3.04	0.31	0.24	0.33	0.24	0.80	1.67	0.34	0.45
24	116.00	207.20	3.14	2.92	0.37	0.33	0.69	0.89	0.85	1.19	0.32	0.37
30	255.30	446.10[‡]	6.70	8.01	0.56	0.56	0.48	1.77	0.24	3.87[†]	0.69	0.76

* and ‡ indicate significant differences at $P<0.05$ and $P<0.001$, respectively, by Student's *t*-test ($n=3$).

0.3−0.7 times lower than that reported for winged bean growing in tropical regions (Weil and Belmont, 1991). The total biomass of the leaves and stem+petiole of velvet bean reached a maximum level of 483 g DM m^{-2}, whereas a range of 437−922 g DM m^{-2} was reported for velvet bean in tropical regions (Hauser and Nolte, 2002; Kaizzi et al., 2004; Anthofer and Kroschel, 2005; Chikagwa-Malunga et al., 2009). Furthermore, the ratios of leaf/stem+petiole biomass of winged bean and velvet bean during the growing periods were 0.7−0.9 and 0.5−0.7, respectively, indicating that the proportion of leaf biomass was higher in winged bean than in velvet bean.

Velvet bean effectively prevented soil erosion when cultivated during the fallow period in a subtropical region, where it almost completely covered the soil by 10 WAS (Nagumo et al., 2006). In comparison with velvet bean, winged bean covered the ground later and its cover lasted longer in the growing period, from 16 to 36 WAS (Anugroho et al., 2007). In the present study, field-grown plants shed their lower leaves, stems, and petioles and formed a litter mulch layer on the ground, presumably due to shading by the upper plant parts, total ground cover by live and litter mulch of 60% for winged bean and 100% for velvet bean were reported previously (Nagumo et al., 2006; Anugroho et al., 2007). Such shedding intensified greatly over the growing period. In addition, the litter of winged bean and velvet bean doubled from 24 to 30 WAS, and the litter of winged bean was about 0.5 times greater than that of velvet bean at 30 WAS. Litter has been recommended to be left on the ground to reduce erosion by water and wind (Steiner et al., 2000). The total biomass of the leaf, stem+petiole, and litter was in the range of 317−561 g DM m^{-2} for winged bean and 347−749 g DM m^{-2} for velvet bean, and this biomass provides ground cover to prevent soil erosion and suppress weeds. Previous studies showed that velvet bean with a ground cover of 100% reduced the soil loss in no-tillage cultivation to 3% (Nagumo et al., 2006) and suppressed weed biomass to 90% of the corresponding values occurring under conventional tillage (Eilitta et al., 2003).

In the present study, the highest LAI values of winged bean and velvet bean occurred at 18 WAS, similar to the finding reported in a tropical region (Hauser and Nolte, 2002). Although LAI is closely related to the number of leaves and leaf biomass, LAI does not represent the ground cover of plants. LAI gradually decreased after 18 WAS, whereas the ground cover during the growing period from 16 to 36 WAS was almost 100% in our previous study (Anugroho et al., 2007). This discrepancy may be due to the fact that stem+petiole biomass was often higher than leaf biomass during the growing period.

Generally, winged bean and velvet bean flower after they completely cover the ground. Winged bean first flowered between 25 and 30 WAS, whereas in previous studies in tropical regions, the first flowering of winged bean was between 10 and 22 WAS (Chow and Price, 1989; Motior et al., 1998). The late flowering stage of winged bean in our study may have been related to the delay in achieving the day/night temperatures of 24.5/20.1°C that favors flowering, which occurred in November (Japan Meteorological Agency, 2008). This is similar to the findings reported previously (Wong and Schwabe, 1979; Ruegg, 1981; Schiavinato and Valio, 1996).

Total N uptake by the leaf and stem+petiole of winged bean and velvet bean reached similar maximum levels of 14.6 and 11.4 g m^{-2} at 18 WAS. The N uptake by leaves of winged bean and velvet bean was 60% and 66%, respectively, of total N uptake. Studies performed on the total N uptake of these cover crops in tropical regions gave values of 28 to 31.2 g m^{-2} for winged bean (Weil and Belmont, 1991) and 17 g m^{-2} for velvet bean (Kaizzi et al., 2004). In the present study, the total N uptake was 3.7−4.4% and 2.2−2.4% of total biomass for winged bean and velvet bean, respectively. In a tropical region, Weil and Belmont (1991) reported that total N uptake was 2.7−3.1% of total biomass. Moreover, the use of winged bean as green manure supplied 7 g N m^{-2} and increased maize yields by 52−91% in a tropical region, as compared with no addition of winged bean (Weil and Samaranayake, 1991). The high N content of winged bean might be related to its high N-fixing activity measured by the acetylene reduction assay method, reaching a peak of 70 μmol C_2H_4 $plant^{-1}$ hr^{-1} at the onset of the flowering stage (Motior et al., 1998). The total N accumulation in winged bean and velvet bean was in the range of 12.3−17.7 and 8.3−14.4 g m^{-2}, respectively. The high N accumulation in leaf, stem+petiole, and litter from the flowering to immature pod stage would make good green manure after incorporated into the soil. Mature pods incorporated into soil might germinate and become weeds competing with the subsequent cash crop. Therefore, winged bean and velvet bean must be slashed and applied as dead mulch to the soil surface and as a green manure no later than 2 weeks after the first flowering, in the period of 18−30 WAS for winged bean and 18 WAS for velvet bean.

P, K, and Mg concentrations were higher in winged bean than in velvet bean from 12 to 30 WAS. In contrast, the Ca concentration was lower in winged bean than in velvet bean. Such nutrient differences might be related to the stage of maturity (flowering and pod formation). In contrast to Ca uptake, P and Mg uptake of leaves and stems+petioles tended to be higher in winged bean than in velvet bean. K uptake of leaves and stems+petioles was higher in winged bean than in velvet bean in the period of 24−30 WAS, which might have been related to the fact that winged bean was in its flowering stage. Nutrient concentrations of velvet bean were higher during the flowering stage than during the full pod stage (Chikagwa-Malunga et al., 2009).

Nutrient accumulation in the litter of winged bean was similar to that of velvet bean, and both plant's litter has potential as a green manure. The quality of the litter depends on its physical properties and chemical composition, particularly the concentrations of N, P, C, lignin, and polyphenols (Myers et al., 1994). Litter decomposition and N release in soil were strongly correlated with the ratios of (lignin + polyphenol)/N, lignin/N, polyphenol/N, and C/N of the residues (Ibewiro et al., 2000). In this study, only the C/N ratio was measured to describe the litter quality of winged bean and velvet bean; the C/N ratios for leaves, stems+petioles, and pods of winged bean were significantly lower than those of velvet bean. According to the C/N ratio of plant litter reported by Praveen-Kumar et al. (2003), the litter of winged bean grown in a subtropical region was categorized as highly decomposable (<18), whereas the litter of velvet bean was moderately decomposable (18−27) to highly decomposable. Similarly, rapid decomposition of the litter of velvet bean in tropical regions has been well documented; 60% and 54% of the litter and litter N residues, respectively, were lost within 28 d (Ibewiro et al., 2000). Aqueous extracts of velvet bean have been shown to inhibit the germination of seeds of several crops, such as tomato, cabbage, and corn (Gleissman, 1983; Caamal-Maldonado et al., 2001). The allelochemical activity of velvet bean has been attributed to L-DOPA, which is exuded from leaves and roots. Velvet bean contributes 200−300 kg ha^{-1} of L-DOPA to the soil each year (Fujii et al., 1991; Fujii, 2003; Nishihara et al., 2005). However, the allelochemical compounds of winged bean remain unknown. When used as green manure, the nutrients and allelochemicals released from the litter of both plants must be synchronized with subsequent crop demand and toxicity for effective nutrient conservation and crop productivity.

The mature pod yield production of winged bean was 190 g m^{-2} in February (Anugroho et al., 2007), whereas that of velvet bean in the present study was 744 g m^{-2} in November. Beside the benefits as a cover crop and green manure, a wider variety of foods can be processed from the mature seeds of winged bean than from velvet bean seeds. Tempeh and sauce can be produced from the mature seeds of winged bean, whereas the mature seeds of velvet bean can be used to produce tempeh (Asian Productivity Organization, 2003).

Legume cover crops influence soil and water quality, weed emergence, and crop yields (Kaizzi et al., 2004; Anthofer and Kroschel, 2005). Because legume cover crops take up and temporarily store nutrients from the soil, nutrient loss through erosion and leaching after harvesting the main crop is reduced by planting a cover crop. Moreover, during the growing period, the edible parts of winged bean can be harvested as food. The longer growing period and superior ground-covering ability of winged bean as compared with velvet bean indicate that winged bean is useful as a cover crop to suppress weeds and prevent soil erosion. Although inferior in total biomass production, winged bean may produce better green manure than velvet bean due to efficient nutrient uptake. The residues of fresh leaves, petioles, stems, and litter of winged bean left in the field should increase soil organic matter and reduce the N fertilizer requirement for crops requiring high N levels. The effect of winged bean incorporated into the soil as green manure on the growth and yield of subsequent crops in subtropical regions requires further study. Winged bean litter should be collected periodically for a long-term to evaluate the plant's nutrient dynamics and influence on soil fertility and crop yield.

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