AGRONOMIC AND GENETIC ATTRIBUTES OF VELVETBEAN (*MUCUNA* SP.): AN EXCELLENT LEGUME COVER CROP FOR USE IN SUSTAINABLE AGRICULTURE

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ABSTRACT

Conservation tillage is one of the most important changes that have taken place in the development of sustainable agriculture. Cover and green manure crops as a conservation practice can improve soil health. In the Southern USA, velvetbean (*Mucuna* sp.), a tropical legume cover crop, was once widely grown as a rotational crop in the early 1900's and offers tremendous potential for use in today's sustainable agriculture. Our objective was to evaluate 24 velvetbean accessions originating from different sources for fresh biomass (FB) and dry matter (DM) production, total N and C accumulation, and C: N ratio in two environments. Days to first flower were also recorded. The experimental design was a randomized complete block with four replications and treatments, considered as random, were accessions. Exotic lines had higher DM than the U.S. landraces. Within the U.S. landraces, DM ranged from 7.3 tons acre^{-1} (for the genotype 25.S5) to 8.0 tons acre^{-1} (for the genotype 24.S) averaging 7.6 tons acre^{-1}, while in the exotic lines DM ranged from 7.8 (for the genotype PI365415) to 9.2 tons acre^{-1} (for the genotype PI365411), averaging 8.5 tons acre^{-1}. Thus, the largest variability occurred in the exotic lines. N and C accumulations averaged 484.9 lbs acre^{-1} and 7037.8 lbs acre^{-1}, respectively, in the U.S. landraces, while in the exotic lines N and C accumulations averaged 517.6 lbs acre^{-1} and 7747.2 lbs acre^{-1}, respectively. For all accessions, the C:N ratio was less than 20 to allow early mineralization of N. These characteristics make velvetbean an excellent legume cover crop for use in a conservation tillage system. The range in relative maturity, as indicated by the days to first flowering shown among velvetbean accessions, may be potentially advantageous depending on the precise objective in specific farming systems.

KEYWORDS

Velvetbean, *Mucuna sp.*, dry matter, nitrogen, C:N ratio.

INTRODUCTION

Conservation tillage is one of the most important changes that have taken place in the development of sustainable agriculture. In the subtropical south, crop production is limited by a variety of economic factors and pest problems, which have resulted in high rates of pesticide use for some crops. Velvetbean (*Mucuna* sp.) has become one of the key groups of species promoted for use as a legume cover crop, weed control and green manure crop (Buckles, 1995). In the Southern USA, velvetbean was once widely grown as a rotational crop in the early 1900's and offers extensive potential for use in sustainable agriculture. Growing velvetbean as a cover crop is mainly the result of economic and environmental concerns, not just among chemical-conscious consumers, but among farmers too. A simple measure of success with a legume cover crop is the amount of nitrogen the producer does not have to purchase to produce cash-crop yields equal to those receiving a normal rate of fertilizer nitrogen. In general, dry matter yield, amount of nitrogen available for the next crop, availability of seed, and appropriate Rhizobium inoculant are among the factors to consider in the choice of a legume cover crop. Reports show that velvetbean is one of the most effective rotational crops for reducing nematode problems in cotton (*Gossypium hirsutum* L.), peanut (*Arachis hypogea*), and soybean (*Glycine max* L.).

Several factors affect biomass and dry matter production of crops. Velvetbean exhibits reasonable tolerance to a number of abiotic stress factors, including drought, low soil fertility, and high soil acidity, although it is sensitive to frost and produces poorly in cold, wet soils (Duke, 1981; Hairiah, 1992; Lobo *et al*., 1992). Velvetbean thrives best under warm, moist conditions, and in areas with plentiful rainfall. In such environments, velvetbean vines can grow up to 32.0 ft and the canopy may stand as high as 3.3 ft

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above the soil surface (Duke, 1981). However, specific growth characteristics depend on the genotype. Various studies have confirmed *Mucuna*'s high biomass and dry matter production and its ability to both fix and recycle large amounts of nitrogen. In the TROPSOILS program trials in Brazil, velvetbean produced up to 3.8 tons acre^{-1} of aboveground dry matter, containing 555.7 lbs of nitrogen (Lathwell, 1990; Lobo *et al.*, 1992). Triomphe (1996) reported an average dry matter biomass production of 5.2 tons acre^{-1}, containing 659 lbs acre^{-1} of N. Sanginga *et al.* (1996) measured an average nitrogen content of 279.5 lbs acre^{-1} in sole-cropped and 148.2 lbs acre^{-1} in intercropped conditions. Levels of aboveground biomass range from 2.2 to more than 5.4 tons of dry matter acre^{-1}; below ground, more than 893 lbs of dried roots acre^{-1} may be produced (Duggar, 1899; Ferris, 1917; Camas, 1991; Chávez, 1993). Buckles (1998) reported an average level of total above ground biomass falling within a relatively narrow range of 4.8 to 5.5 tons acre^{-1} on a dry matter basis. Dry matter accumulation may vary with growth stage and environment. Buckles (1998) reported that total dry matter increased from 4.5 tons acre^{-1} (early flowering) to 5.3 tons acre^{-1} a month later and to 6.2 tons acre-1 after another 3 to 4 weeks.

The velvetbean's N2 fixing and recycling abilities prevent significant nutrient losses to the environment and practically eliminate the need for costly and impractical use of external fertilizer without compromising yield levels (Buckles *et al.*, 1998). Thus, the crop acts alternatively as a major collector (when growing) or supplier (when decomposing) of nutrients, so its natural seasonal dynamics dictate the major features of the velvetbean system. In fact, because of the large dry matter accumulation and the amount of time it has to accomplish this task, velvetbean appears to be a prime candidate for removing any available N (Buckles *et al.*, 1998). The amounts of N fixed by *Mucuna* are variable, ranging from 0 to about 159.5 lbs acre^{-1} in a season (Carsky *et al.*, 1998). Sanginga *et al.*

Table 1 Accessions of velvetbean (*Mucuna* sp.) used for agronomic attributes. The full accession names are listed in this table. In the text these are abbreviated by replacing the code given by the authors.

Plant name	Code	Donor †	Origin
None	PI364362	USDA, ARS	Mozambique
Branco	PI365411	USDA, ARS	Mozambique
Oscola	PI365414	USDA, ARS	Mozambique
Verde Radio	PI365415	USDA, ARS	Mozambique
Mucuna pruriens var cochinchinensis	Cochinchinensis	CIEPCA	Singapore
Mucuna pruriens var rajada	Rajada	CIEPCA	Brazil
Mucuna pruriens var japeada	Jaspeada	CIEPCA	Brazil
Mucuna pruriens var preta	Preta	CIEPCA	Brazil
USA (AL)-black	22.B	AU	USA
USA (AL)-speckled	22.S	AU	USA
USA (AL)-white	22.W	AU	USA
Edgar farm (AL)-black	23.B	AU	USA
Edgar farm (AL)-speckled	23.S	AU	USA
Edgar farm (AL)-white	23.W	AU	USA
90 day runner-black	24.B	AU	USA
90 day runner-speckled	24.S	AU	USA
90 day runner-white	24.W	AU	USA
Belle Mina speckled-2	25.S2	AU	USA
Belle Mina speckled-3	25.S3	AU	USA
Belle Mina speckled-4	25.S4	AU	USA
Belle Mina speckled-5	25.S5	AU	USA
Belle Mina speckled-6	25.S6	AU	USA
Belle Mina light speckled	25.LS	AU	USA
Belle Mina light black	25.LB	AU	USA

† USDA, ARS: United States Department of Agriculture, Agriculture Research Service
CIEPCA: Centre d'Information et d'Echange sur les Plantes de Couverture en Afrique
AU: Auburn University

(1996) reported an amount of 200.0 lbs acre^{-1} of N fixed in three months after planting. The objective of this study was to evaluate velvetbean accessions for fresh biomass and dry matter production, total N and C accumulation, and C:N ratio. The evaluation of these traits will be useful for the integration of velvetbean as a legume cover crop in the development of sustainable southern agriculture.

MATERIALS AND METHODS

Culture

Twenty four velvetbean (*Mucuna* sp.) accessions were used as experimental materials. Sixteen of the accessions were U.S landraces and 8 were exotic lines from a tropical region (Table 1). Accessions differed for maturity, seedcoat color, pod color, pod pubescence, and leaf shape. These traits are among the main parameters observed in a process of genetic diversity estimate (Capo-chichi *et al.*, 2001). Seeds were planted on May 12, 2000 and May 16, 2001 at the Plant Breeding Unit (PBU), Tallassee, AL. The soil at PBU is a Cahaba fine sandy loam (fine-loamy, siliceous, thermic Typic Hapludults). The Latitude was 32°42'N. Plots were four rows wide with 2.5 ft between rows. All plots were 13.9 ft long. *Mucuna* sp. were sown 0.06 to 0.1 ft deep and 2 viable seeds per 1 ft of row, so that the seeding rate was approximately 36450 seeds acre^{-1}. No fertilizer was applied. Average air and soil temperatures and rainfall are shown in Fig. 1.

The number of days from planting to first flower was recorded. At that stage, plots were harvested for biomass. Fresh leaf and vine mixture was harvested and weighed on site. Samples were air dried over night. Sample dry matters were weighed to determine the total dry matter production. Subsamples were taken in bag. Contents of each bag were ground to pass a 1 mm sieve, and total C and N were determined by combustion method using LECON CHN-600 analyzer (Leco Corp., St. Joseph, MI).

The experimental design was a randomized complete block with four replications and treatments were accessions. Data were analyzed by analysis of variance using the general linear models procedure of SAS. Combined analysis of variance across environments was also computed. All factors were considered random. F-test was used to test all main effects and their interactions. Single-degree-of-freedom contrasts were used to test the difference among the means among all genotypes. Unless indicated otherwise, all tests were made at $P = 0.05$.

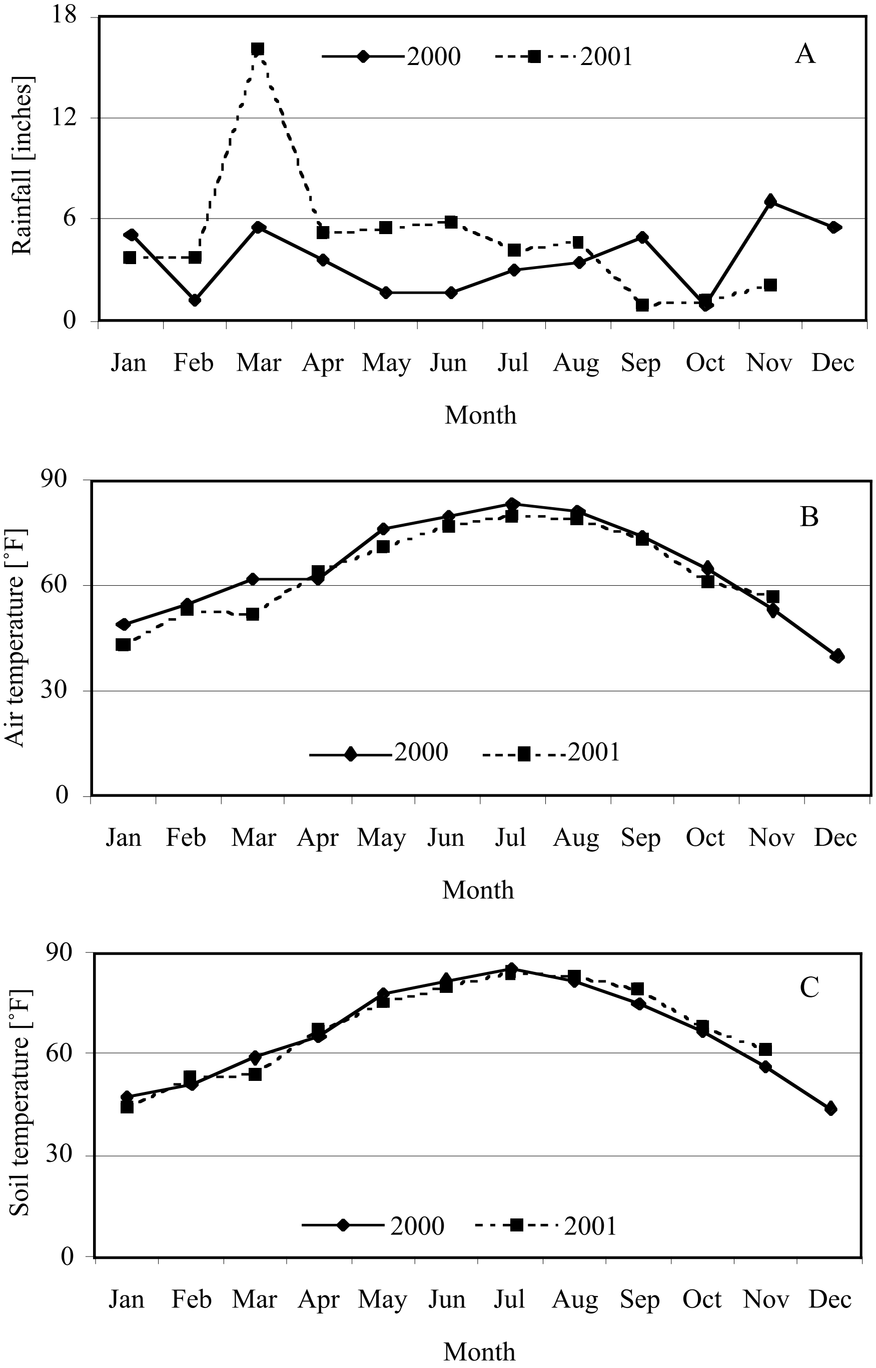

Fig.1 Rainfall (A), air (B) and soil (C) temperatures recorded at the Plant Breeding Unit, Tallassee, AL in 2000 and 2001

Table 2 Significance from the combined analysis of variance for fresh biomass, dry matter, nitrogen(N), carbon (C) and carbon to nitrogen ratio (C:N) of velvetbean grown in two environments.

Source	df	Fresh biomass	Dry matter	1st flower	N	C	C:N
Environment (E)	1	NS	*	***	-	-	-
Rep (R)	3	NS	NS	NS	NS	NS	NS
Error (a)	3	NS	NS	NS	-	-	-
Genotype (G)	23	***	***	***	***	***	***
US landrace vs Exotic	1	NS	***	***	***	*	NS
G x E	23	***	***	***	-	-	-
Error (b)	895†						

*,**,*** significant at $P = 0.05$, 0.01 and 0.001, respectively

†df = 464 for N, C and C:N

RESULTS AND DISCUSSION

In the combined analysis of variance, effects of genotype were highly significant for fresh biomass (FB) (Table 2). The genotype x environment interaction was significant for fresh biomass, indicating that genotype performance was dependent upon environment. Across environments, fresh biomass yields varied from 22.9 tons acre^{-1} for PI364362 to 17.2 tons acre^{-1} for Cochinchinensis (Table 3). Effects of the origin (the U.S. landraces vs. exotic lines) were not significant for fresh biomass (Table 2). The U.S. landraces and exotic lines averaged 19.4 and 19.6 tons acre^{-1}, respectively (Table 4). Effects of genotypes and environments were significant for dry matter (DM) (Table 2). This may be explained by the difference in rainfall observed between environments. When comparing the U.S. landraces and the exotic lines for DM, the exotic lines yielded slightly more than the U.S. landraces (8.5 and 7.6 tons acre^{-1}, respectively) (Table 4). This may be explained by the difference in time of harvesting, which was done at the first flowering. The U.S landraces flowered 91 days after planting (DAP) and the exotic lines flowered 120 DAP. A slight variability was observed within the U.S. landraces for DM. The average levels of total aboveground DM fell within a relatively narrow range of 7.3 tons acre^{-1} for the genotype 25.S5 to 8.0 tons acre^{-1} for the genotype 24.S (Table 4). Within the exotic lines, DM ranged from 7.8 tons acre^{-1} (for the genotype PI365415) to 9.2 tons acre^{-1} (for the genotype PI365411), averaging 8.5 tons acre^{-1} (Table 4). The largest variability for DM production occurred within the exotic lines and may be explained by their geographical origins. This may imply that the U.S landraces constitute a more homogenous population for DM compared to the exotic lines. Genotype x environment interaction was significant for DM, indicating that genotype

Table 3 Means of fresh biomass, dry matter, nitrogen and carbon of 24 velvetbean accessions grown in two environments.

Genotype	Origin	Fresh biomass	Dry matter	Nitrogen (N)	Carbon (C)	C:N ratio	1st flower
		----t acre^{-1}-----	----t acre^{-1}-----	---lb acre^{-1}--	----lb acre^{-1}-----		----days----
PI364362	Exotic line	22.9 a †	8.4 bc	490.5 bcd	7558.0 bcdef	15.6 bc	95.9 h
25.S2	Landrace	20.4 b	7.8 def	485.2 bcd	8002.1 ab	16.4 ab	89.6 i
24.S	Landrace	20.2 bc	8.0 cde	468.8 cd	7849.5 bc	16.8 a	90.1 i
PI365414	Exotic line	20.2 bcd	8.0 cd	504.1 bcd	7992.4 ab	16.4 ab	78.5 i
23.B	Landrace	20.2 bcd	7.7 def	500.5 bcd	7809.4 bcd	15.5 bc	87.9 i
23.S	Landrace	19.9 bcde	7.5 def	456.3 d	7347.8 bcdef	16.2 abc	90.0 i
24.B	Landrace	19.9 bcde	7.7 def	495.3 bcd	7727.4 bcde	15.6 bc	90.0 i
Rajada	Exotic line	19.9 bcde	8.9 ab	618.7 a	8727.7 a	14.2 de	102.9 g
22.W	Landrace	19.8 bcde	7.8 def	534.5 b	7524.2 bcdef	14.3 de	89.0 i
22.S	Landrace	19.6 bcdef	7.4 ef	484.5 bcd	6856.2 ef	14.2 de	86.9 i
23.W	Landrace	19.5 bcdef	7.5 def	495.5 bcd	7665.1 bcdef	15.4 bc	109.0 f
PI365411	Exotic line	19.5 bcdef	9.2 a	514.3 bcd	7919.1 ab	15.4 bc	117.1 e
25.S6	Landrace	19.4 cdef	7.6 def	497.9 bcd	7913.6 ab	15.9 abc	89.4 i
Preta	Exotic line	19.3 def	8.8 ab	500.8 bcd	6975.6 cdef	14.1 e	144.7 b
25.LB	Landrace	19.1 efg	7.4 def	476.4 bcd	6813.7 f	14.3 de	97.4 h
22.B	Landrace	19.0 efg	7.7 def	483.8 bcd	7503.9 bcdef	15.4 bc	89.5 i
24.W	Landrace	19.0 efg	7.4 def	454.6 d	7250.9 bcdef	15.9 abc	88.2 i
Jaspeada	Exotic line	18.9 fg	8.9 ab	502.0 bcd	7970.5 ab	15.9 abc	134.6 c
25.S4	Landrace	18.7 fg	7.6 def	483.6 bcd	7311.4 bcdef	15.1 dc	87.4 i
25.S3	Landrace	18.7 fg	7.4 ef	475.8 bcd	7262.8 bcdef	15.3 c	89.5 i
25.LS	Landrace	18.7 fg	7.5 def	473.9 bcd	7483.4 bcdef	15.9 abc	88.9 i
PI365415	Exotic line	18.7 fg	7.8 def	520.6 bc	7901.4 ab	15.1 dc	127.7 d
25.S5	Landrace	18.4 g	7.3 f	492.5 bcd	7547.6 bcdef	15.5 bc	90.0 i
Cochinchinensis	Exotic line	17.2 h	8.4 bc	490.2 bcd	6932.8 def	14.2 de	159.1 a

† Means followed by the same letter are not significantly different at 0.05 probability level with a Duncan's Multiple Range Test

Table 4. Ranges and means of FB, DM, N, C, C:N ratio of exotic lines and U.S. landraces grown in two environments

Accession	Range	Mean	Range	Mean
	Fresh biomass, tons acre^{-1}		**Dry matter, tons acre^{-1}**	
Exotic lines	17.2 - 22.9	19.6 a[†]	7.8 - 9.2	8.5 a
U.S. landraces	18.4 - 20.4	19.4 a	7.3 - 8.0	7.6 b
	Nitrogen (N), lbs acre^{-1}		**Carbon (C), lbs acre^{-1}**	
Exotic lines	490 - 619	509.9 a	6933 - 8728	7675.4 a
U.S. landraces	455 - 535	485.9 b	6813 - 8002	7497.6 a
	C : N ratio			
Exotic lines	14.1 - 16.4	15.2 a		
U.S. landraces	14.2 - 16.8	15.5 a		

[†] Means followed by the same letter are not significantly different at 0.05 probability level according to Least Significant Difference

performance was dependent upon environments. The two main phases of the velvetbean life cycle are the vegetative and the reproductive stages. Because DM accumulation does not stop at flowering (Buckles, 1998), it is possible that higher DM production could have been observed for the genotypes studied if plots had been sampled later. Buckles (1998) reported that DM increased from 4.5 tons acre^{-1} in early flowering to 5.4 tons acre^{-1} a month later and 6.2 tons acre^{-1} after another 3 to 4 weeks. The differences in DM production may be attributed to the growth characteristics of the genotype. Reports showed that seedling survival, which is an important component of DM yield, ranged from 15 to 95 % of the target seeding rate, depending on the environments (Chikoye and Ekeleme, 2001). Failure of Mucuna seedlings to emerge may be attributed to rotting or the inability of seed to imbibe water, and higher seedling survival may be related to the large seed size of some genotypes (Qi *et al*., 1999), which has been shown to improve germination percentages of *Mucuna* (Barbedo *et al*., 1988).

Effects of genotype and environment were highly significant for days from planting to first flower (Table 2). The genotype x environment interaction was significant for days to first flower, indicating that genotype performance depends upon environment. This agrees with early work by Aiming *et al*. (1999) who observed a significant response of *Mucuna* to photothermal and photoperiod. The photothermal regimes in which flowering did not occur within 200 days were generally the coolest and/or the warmest temperature combined with longer photoperiods (Aiming *et al*., 1999). Averaged across environments, the exotic lines were later flowering than the U.S. landraces (Table 3). Within the exotic lines, days from planting to first flowering varied from 159 for Cochinchinensis to 78 for PI365414, while in the U.S. landraces the genotype 23.W flowered in 109 days and genotype 22S flowered 86 days after planting.

Effects of genotype were highly significant for N, C, and C:N ratio (Table 2). Within the exotic lines, N accumulation ranged from 490.2 to 618.7 lbs acre^{-1}, averaging 509.9 lbs acre^{-1} (Table 4). In the U.S. landraces, N accumulation ranged from 454.6 to 534.5 lbs acre^{-1}, averaging 485.5 lbs acre^{-1} (Table 4). Reports showed that total N accumulation is greater at the beginning of flowering or during the flowering than other growth stages (Gataulina, 1992). Since N was determined at the beginning of flowering, the estimates may represent potential total N velvetbean should accumulate. The amount of N accumulated in velvetbean may have a great contribution in sustainable agriculture. Amado *et al.* (1999) showed that conservation tillage plus legume cover crop increased total N at soil surface.

Although N is the nutrient of interest in this study, the accumulation of other key nutrients in velvetbean biomass was significant. Carbon accumulation ranged from 3.4 tons acre^{-1} (for the genotype 25LB) to 4.4 tons acre^{-1} (for the genotype Rajada). Considerable variability was observed within the U.S. landraces and the exotic lines for total C. Within the U.S. landraces C accumulation ranged from 6813.0 to 8002.1 lbs acre^{-1}, averaging 7497.6 lbs acre^{-1}. In the exotic lines, C accumulation ranged from 6932.8 to 8727.7 lbs acre^{-1}, averaging 7675.4 lbs acre^{-1}. The C: N ratio ranged from 14.2 (for Cochinchinensis) to 16.4 (for the genotype 24.S). The C:N ratio has important implications for decomposition processes and nutrient availability. Fox *et al*. (1990) observed that N concentration in plant materials should be greater than 2% (or C: N ratio less than 20) before mineralization can occur. Nitrogen concentrations less than 2% or C: N > 25 lead generally to N immobilization (Fox *et al*., 1990; Myers *et al*., 1994). Thus, C: N ratios were low enough for the biomass of all genotypes used in the present study to allow early mineralization of N (Table 3). The velvetbean rotation may allow at least the conservation of the initial stocks of C and N despite continuous annual tillage or increase the level of C and N in any no-tillage cropping system. Gliessman *et al.* (1981) reported how the velvetbean system shows a working example of how to sustainably exploit the properties and dynamics of a natural ecosystem for the benefit of commercial crops.

CONCLUSIONS

In conclusion, the selected characteristics of the aboveground biomass in velvetbean such as dry matter yield, amount of nitrogen accumulated, and the C:N ratio evaluated in the present study make *Mucuna* a legume of excellent choice to use in rotation or inter-cropping systems. The range in relative maturity periods displayed among *Mucuna* accessions has potential advantages, depending on the precise objective in a specific farming system. If there is only a narrow window of opportunity for growing *Mucuna*, such as between the cropping of subsistence cereals, then an early-maturing genotype could guarantee the satisfactory completion of the crop's growth within the cropping cycle. However, if the objective was weed suppression for the longest possible period, such as under plantation crops or to maximize biological productivity for green manuring, an exceptionally late-flowering genotype might be preferable.

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