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Effects of Some Agronomic Practices on Dry Matter Partitioning of *Boerhavia diffusa* L.

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ABSTRACT. *Although traditional knowledge on the medicinal properties of Boerhavia diffusa L. of the family Nyctaginaceae is known, production potential, assimilate partitioning to economic yields and agronomic requirements for commercial cultivation are poorly understood. Consequently, the objective of this study was to identify agronomic practices that could partition more assimilate to economic components to obtain optimum yield from cultivation. A factorial experiment was carried out at the University of Peradeniya Experimental Station, Dodangolla, Sri Lanka from July 2006 to August 2008. Treatments include two types of planting materials, five types of fertilizers and five harvesting methods. The results revealed that the seedlings performed better than cuttings in all studied parameters. Among types of fertilizers, the recommendation for Ipomoea batatas (L.) Lam. (Sweet potato) was the best for production of below ground dry matter in seedling plants. The optimum rate of below ground dry matter was attained at 8 months after planting (MAP) in seedlings. Organic or inorganic fertilizer recommendation for Trianthema portulacastrum L. (Sarana) was the most suitable for harvesting of above ground dry matter of seedling plants. The study also showed that B. diffusa could be managed by repeated harvesting of above ground dry matter as a leafy vegetable at two month intervals up to six months followed by harvesting the entire plant at eight MAP for medicinal as well as a leafy vegetable. Implications of research findings are discussed.*

INTRODUCTION

Plants have been the most important source of medicine since the beginning of human civilization. In Sri Lanka, about 200 species of medicinal plants are commonly used in traditional medicine and of these 50 are heavily used for ayurvedic preparations (Gunasena *et al*., 2003). *Boerhavia diffusa* L. of the family Nyctaginaceae is one of the important perennial medicinal plants, commonly known as "*Pitasudupala"* or "*Sarana*" which has been found to posses diuretic action and anti-inflammatory, anti-fibrinolytic, anti-convulsant and hepato protective activities (Jayaweera, 1982; Paris and Amarnath, 2004). It is a common weed in Sri Lanka in sandy areas especially near the coast (Abeywardena and Hettiarachi, 2001). The economic yield of *B. diffusa* is in the form of dried tuber for medical preparations and fresh leaves as a vegetable. Although Sri Lanka has a suitable climate for cultivation of medicinal plants at a commercial level, the requirement for Ayurvedic medical preparations is largely met by imports from India. In 2000, the annual demand of dried tuber of *B. diffusa* for medicinal preparation was 21,742 kg. In the same year, 14,603 kg of dried

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tubers was sold in the market outlets. Over 180 kg was imported from India spending U$ 200 (Ayurveda Department, 2001; Abeywardena and Hettiarrachi, 2001).

The dried tuber and fresh leaves are the consumable products of photoassimilates in *B. diffusa*. Improvement of partitioning photoassimilates between economic yield components and the remaining portions of the plant have generally been responsible for improved yields over the last century (Zamaski and Schafler, 1996). Plants with desired dry matter partitioning characteristics and quality can be produced by identifying suitable growing conditions and selection of appropriate planting materials (Fitter and Stickland, 1991; Karlson and Henis, 1991). Plants respond to environmental conditions by modification in morphology to utilize available resources more efficiently for growth. As plant morphology changes, dry matter accumulation and partitioning are also expected to be influenced by the environment during growth. Although traditional knowledge on medicinal properties of *B. diffusa* is known, production potential, assimilate partitioning to economic yield components and agronomic requirements for commercial cultivation is poorly understood in Sri Lanka or else where. Therefore, the objectives of this study were to identify suitable: (i) planting material, (ii) fertilizers, and (iii) the method of harvesting to obtain maximum tuber and leaf yield from *B. diffusa*.

MATERIALS AND METHODS

Experimental design and treatments

The study was conducted at the University of Peradeniya Experiment Station, Dodangolla, Sri Lanka ($7^0$17.725 N, $8^0$42.359 E, 465 m amsl) from July 2006 to August 2008. The site is located in IM_{3a} agroecological region and has immature brown loam soil (NRMC, 2003). Mean annual rainfall of the area is greater than 1,400 mm and mean ambient temperature ranges from 25-32 ^{0}C. The experimental design was 2 x 5 x 5 factorial in Randomized Complete Block Design (RCBD) with 3 replications. Two types of planting material (seedlings and cuttings), four types of fertilizers with a control and five methods of harvesting were used as treatments (Table 1). The plot size was 3 x 2 m. Each plot carried 20 plants and the spacing between plants were 45 x 45 cm. Plants in the center of the experimental plot were used for data collection.

Table 1. Treatment combinations used in the experiment.

Treat. No.	Type of planting material	Type of Fertilizers	Time and methods of harvesting 1st	2nd	3rd	4th	5th
T1	Seedling	F1	W	LW	LLW	LLLW	LLLLW
T2	Cutting	F1	W	LW	LLW	LLLW	LLLLW
T3	Seedling	F2	W	LW	LLW	LLLW	LLLLW
T4	Cutting	F2	W	LW	LLW	LLLW	LLLLW
T5	Seedling	F3	W	LW	LLW	LLLW	LLLLW
T6	Cutting	F3	W	LW	LLW	LLLW	LLLLW
T7	Seedling	F4	W	LW	LLW	LLLW	LLLLW
T8	Cutting	F4	W	LW	LLW	LLLW	LLLLW
T9	Seedling	F5	W	LW	LLW	LLLW	LLLLW
T10	Cutting	F5	W	LW	LLW	LLLW	LLLLW

Note: See the text for details of five methods of harvesting (1-5) and five types of fertilizers (F1-F5).

Selection of fertilizers was based on Department of Agriculture recommendations for *Trianthema portulacastrum* L. (Sarana) which is harvested as a leafy vegetable and *Ipomoea batatas* (L.) Lam. (Sweet potato) which is harvested as a root crop (DOA, 1998). The following fertilizers were used in the experiment: compost at the rate of 25 t/ha recommended to "Sarana" (F1); basal application of urea : T.S.P: M.O.P at the rate of 60:120:120 kg/ha at 15 DAP followed by application of urea : M.O.P at the rate of 60: 60 kg/ha as top dressing 45 DAP recommended to "Sweet potato"(F2); application of urea: T.S.P: M.O.P at the rate of 100:150:100 kg/ha at the time of planting recommended to "Sarana" (F3); half of the F2 and F3 (F4); control (without fertilizer) (F5). Since *B. diffusa* is used as a leafy vegetable and a root crop, the following harvesting combinations were used to identify optimum harvesting time: (i) harvesting of entire plant at 2 months after planting (MAP)-W; (ii) harvesting of leaf biomass at 2 MAP followed by harvesting of entire plant at 4 MAP-LW ; (iii) harvesting of leaf biomass at 2 and 4 MAP followed by harvesting of entire plant at 6 MAP-LLW; (iv) harvesting of leaf biomass at 2, 4 and 6 MAP followed by harvesting of entire plant at 8 MAP-LLLW; and (v) harvesting of leaf biomass at 2, 4, 6 and 8 MAP followed by harvesting of entire plant at 10 MAP-LLLLW.

Data collection and statistical analysis

The morphological characteristics such as leaf number, leaf area, number of branches, length of branches and chlorophyll content using a SPAD meter were recorded from the plants in the center of the plot. Leaves, stems, inflorescences and tubers were separated from uprooted plants and dried in an oven at 70 ^{0}C to a constant weight. Total dry matter, below ground dry matter, leaf dry matter were measured and rate of below ground dry matter accumulation per square meter per month, total harvest index (THI) and below ground harvest index (BHI) were calculated as follows:

$$\text{Total Harvest Index (THI)} = \frac{\text{Below ground dry weight of tubers + Leaf dry weight}}{\text{Total plant dry weight}}$$

$$\text{Below ground Harvest Index (BHI)} = \frac{\text{Below ground dry weight of tubers}}{\text{Total plant dry weight}}$$

Data were analyzed using SAS version 8 and means were separated by Duncan Multiple Range Test (DMRT) (SAS, 1999).

RESULTS AND DISCUSSION

Tuber dry weight

The interaction among types of planting material, fertilizers and methods of harvesting was significant ($p<0.05$). Application of fertilizer to cutting and seedling plants of *B. diffusa* significantly increased below ground dry matter yield ($p<0.05$) (Fig. 1; Plate 1). Plants grown from seedling performed better than those from cuttings (Fig. 1; Plate 1). Below ground dry matter accumulation exhibited continuous increase from 2 to 10 MAP Tuber yield of seedlings grown under inorganic fertilizers recommended to "Sweet potato" (F2) was almost double than that of cuttings grown under the same fertilizer recommendation. Organic fertilizer recommendation for "Sarana" (F1) was the second best although there was a yield reduction by 29% compared with F2 in seedlings.

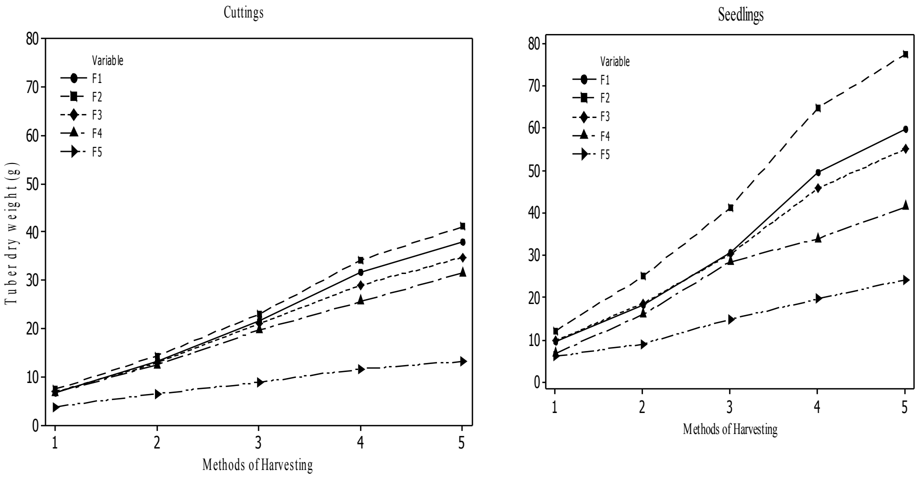

Figure 1. Below ground dry matter production (tuber yield) under different planting material, fertilizers and five methods of harvesting.

Note: See text for details of five methods of harvesting (1-5) and five types of fertilizers (F1-F5).

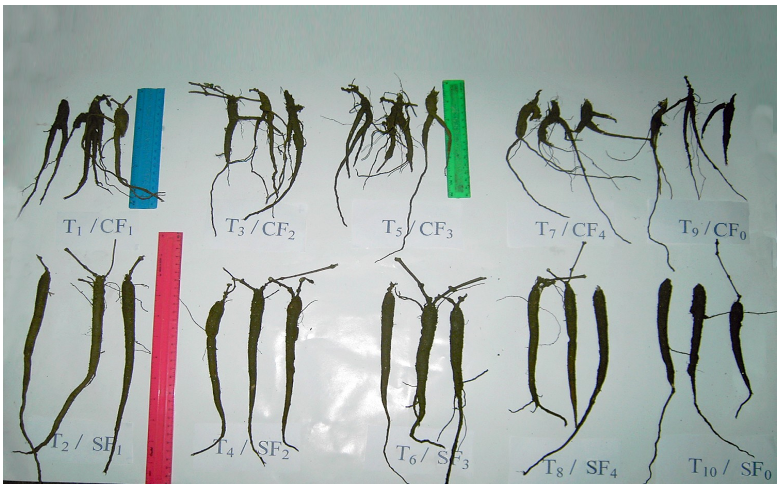

Plate 1. A comparison of tuber quality of cuttings and seedlings at 10 months after planting.

Note: The first and second rows represent cuttings (C) and seedlings (S), respectively. F1-F5 represent five fertilizers and T1–T10 represent different treatments (see text for details).

Leaf dry weight

Leaf dry matter productions under different methods of harvesting and different fertilizers are shown in Fig. 2. The leaf dry weights obtained at the time of whole plant harvesting showed significant variation ($p<0.05$) and had significant interactions between types of planting material, fertilizers and methods of harvesting ($p<0.05$) (Fig. 2). The leaf dry matter produced by seedlings was different from that of dry matter accumulation by tubers. Harvested leaf dry matter continuously increased from 2 to 10 MAP. In seedlings, leaf dry matter harvested at 2 MAP was higher than that of 4 MAP and it continued to increase from 4 to 10 MAP.

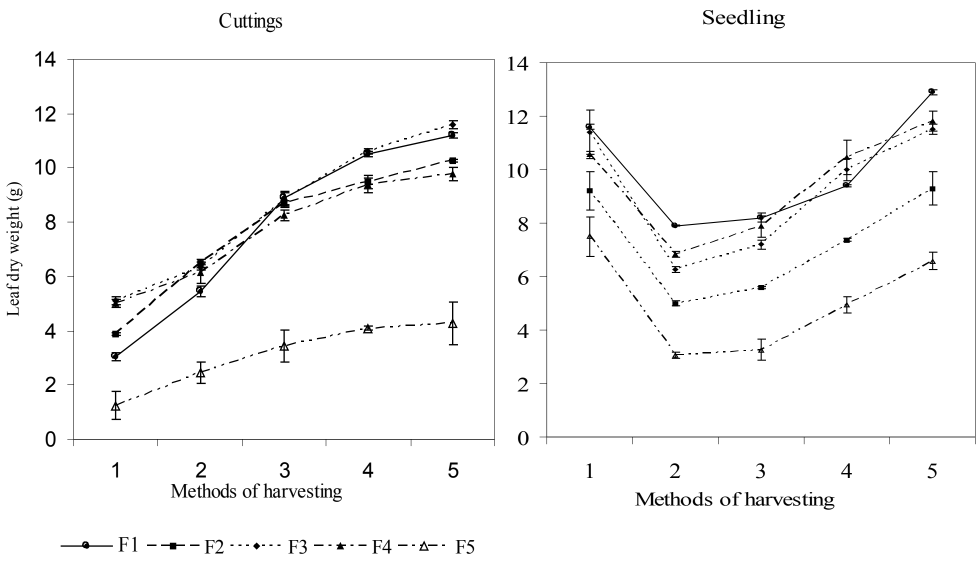

Figure 2. Leaf dry matter production under different planting materials, fertilizers and methods of harvesting

Note: See text for details of five methods of harvesting (1-5) and five types of fertilizers (F1-F5).

Net below ground dry matter accumulation rate

Average rate of below ground dry matter accumulation per square meter per month was higher for seedlings than cuttings in all treatments ($p<0.05$). There was a significant interaction among types of planting material, fertilizers and methods of harvesting ($p<0.05$) (Fig. 3). The rate of dry matter accumulation reduced from 2 to 4 MAP in each treatment for both cuttings and seedlings except for fertilizer (F4) 1/2 "Sarana" + 1/2 of "Sweet potato" recommendation for seedlings. The rate of dry matter accumulation for cuttings under organic fertilizer recommendation for "Sarana" (F1), inorganic fertilizer recommendation for "Sweet potato" (F2) and inorganic fertilizer recommendation for "Sarana" (F3) showed continuous increase from 4 to 8 MAP. The highest below ground dry matter accumulation rate was achieved at 8 MAP and reduced at 10 MAP.

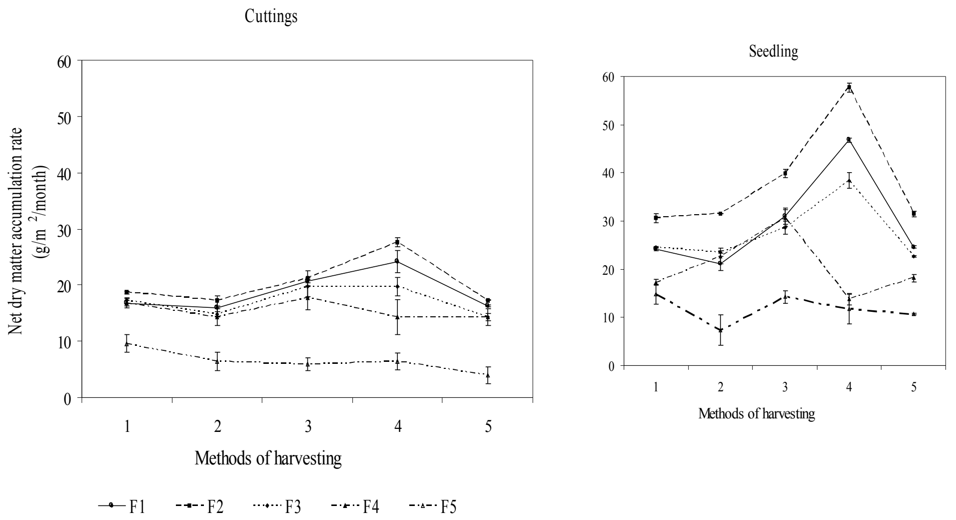

Figure 3. Net below ground dry matter accumulation rates under as affected by planting material, fertilizers and methods of harvesting.

Note: See text for details of five methods of harvesting (1-5) and five types of fertilizers (F1-F5).

The rate of below ground dry matter accumulation of seedlings continuously increased from 2 to 8 MAP and then reduced to 10 MAP in all fertilizer levels except 1/2 "Sarana" + 1/2 "Sweet potato" in F4. Maximum rate of below ground dry matter accumulation achieved with the fertilizers recommended to "Sweet potato" was 23% higher than that with organic fertilizer recommendation for "Sarana". Under the fertilizer recommendation 1/2 "Sarana" + 1/2 "Sweet potato", (F4) maximum below ground dry matter accumulation was achieved at 6 MAP.

Net above ground dry matter accumulation rate

Average net above ground dry matter accumulation rates per square meter per month are shown in Fig. 4. There was significant interaction among types of planting material, fertilizers and methods of harvesting ($p<0.05$) (Fig. 4). Plants from cuttings showed continuous increase of above ground dry matter accumulation rates and reached the highest at 4 MAP under the inorganic fertilizer recommended for "Sarana" (F3). Organic fertilizer recommendation for "Sarana" (F1) gave a lower above ground dry matter accumulation rate among other tested inorganic fertilizers and reached second highest value at 10 MAP. In seedling plants, rates were higher at 2 MAP and reduced at 4 MAP and then showed a continuing trend up to 10 MAP in all tested fertilizers. The highest rate was achieved at 2 MAP under the organic fertilizer recommendation to "Sarana" and rapidly reduced to 4 MAP and showed continuous increase to reach the 2nd highest value at 10 MAP.

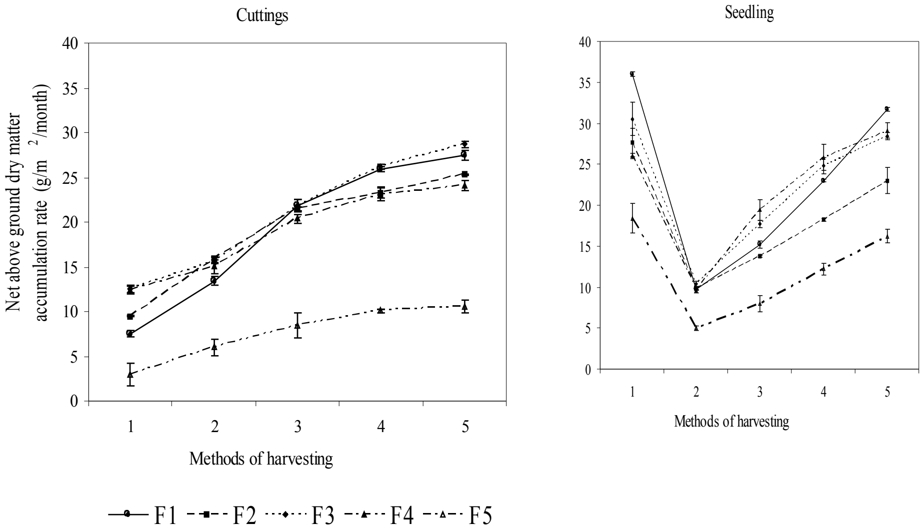

Figure 4. Net above ground dry matter accumulation rates as affected by under different planting material, fertilizers and methods of harvesting.

Note: See text for details of five methods of harvesting (1-5) and five types of fertilizers (F1-F5).

Total dry matter, total and below ground harvest index

Total plant dry matter (TDM), total harvest index (THI) and below ground harvest index (BHI) were significantly affected by type of planting material, fertilizers and methods of harvesting ($p<0.05$) (Table 2). As suggested by Donald and Hamblin (1976) total dry matter production is a result of growth rate and duration of crops. The growth rate of *B. diffusa* was influenced by the application of fertilizer and increased production. Further, Pathiratna *et al.* (2004) reported that the use of organic and inorganic fertilizer was important for obtaining higher dry matter yield in the medicinal herb *Aerva lanata* (L.)

Dry matter production increased from 2 to 10 MAP in each fertilizer level. The highest total dry matter harvested with the fertilizer level recommended to "Sweet potato" at 10 MAP with four times repeated harvesting of leaves at two months intervals. Harvest index is the proportion of the total dry matter which forms the economic yield and is the measure of the efficiency of conversion of photosyntheates (Baker and Gebegehou, 1982).

The highest THI value was obtained in the organic fertilizer recommended for *T. portulacastrum* (Sarana) and inorganic fertilizer recommended to "Sweet potato". The highest BHI value was obtained in 10 MAP in the inorganic fertilizer level recommended to "Sweet potato" (Table 2). The second highest value was obtained 10 MAP with the organic fertilizer recommended to *T. portulacastrum* (Sarana). Based on net below ground dry matter accumulation and harvest index values, it can be concluded that the best time for harvesting would be around 8 MAP. This is because the highest net assimilation rate was achieved in all treatments at 8 MAP.

Table 2. Total dry matter (TDM), total harvest index (THI) and below ground harvest index (BHI) of *Boerhavia diffusa*.

Treatments		TDM		THI		BHI	
Fert.	**Mtd.**	**C**	**S**	**C**	**S**	**C**	**S**
F1	1	15.1	30.0	0.65	0.81	0.45	0.32
	2	28.4	31.2	0.67	0.71	0.47	0.58
	3	46.1	50.5	0.67	0.73	0.47	0.61
	4	60.3	77.7	0.70	0.76	0.52	0.64
	5	67.8	73.7	0.73	0.78	0.56	0.64
F2	1	22.0	31.0	0.52	0.76	0.34	0.39
	2	38.0	40.6	0.54	0.72	0.38	0.62
	3	55.5	62.9	0.52	0.75	0.41	0.66
	4	70.9	93.0	0.61	0.77	0.48	0.69
	5	77.0	110.6	0.67	0.78	0.53	0.70
F3	1	24.4	36.7	0.49	0.61	0.29	0.27
	2	34.7	45.0	0.56	0.51	0.38	0.41
	3	51.3	68.2	0.58	0.55	0.41	0.44
	4	65.3	92.0	0.61	0.61	0.44	0.50
	5	73.8	102.2	0.63	0.65	0.42	0.54
F4	1	24.0	26.9	0.49	0.64	0.29	0.26
	2	33.6	39.0	0.56	0.51	0.38	0.41
	3	48.0	61.7	0.58	0.59	0.41	0.46
	4	57.7	71.3	0.61	0.62	0.44	0.47
	5	63.6	77.8	0.65	0.68	0.49	0.53
F5	1	10.9	20.6	0.46	0.66	0.35	0.30
	2	18.2	22.1	0.49	0.51	0.36	0.41
	3	26.3	34.7	0.47	0.52	0.34	0.43
	4	30.4	44.0	0.52	0.56	0.38	0.45
	5	32.6	41.6	0.54	0.62	0.41	0.49
Type x Fert. x Mtd		*		*		*	
CV		4.48		2.78		3.59	

Note: * Indicates significant difference at $p<0.05$; CV= coefficient of variation; Mtd= method of harvesting; 1-5 represent five methods of harvesting; Fert= types of fertilizers and F1 to F5 represent fertilizer treatments; C and S represent cuttings and seedlings, respectively.

CONCLUSIONS

Type of planting material, fertilizers, method and time of harvesting interactively affected the tuber and leaf dry matter yield of *B. diffusa*. Seedlings were identified as the best planting material for production of both leaf and tuber than cuttings. The fertilizer recommendation for "Sweet potato" was the best for tuber production. The organic fertilizer recommendation for "Sarana" produced higher leaf dry matter but gave a tuber yield 29.7%

lower than the fertilizer recommendation for "sweet potato" at 10 MAP. The optimum rate of below ground dry matter accumulation per square meter per month was attained with the fertilizer recommendation of "Sweet potato" in seedlings. Maintaining the plant with repeated harvesting of leaf at two month intervals up to six months and whole plant harvested at 8 MAP was identified as the best method to obtain both tuber and leaf yield from *B. diffusa* than the separate fertilizer recommendation solely for higher leaf dry matter production. In addition to improvement of dry matter production, further research on quality of tuber in terms of medicinal constitutes is important to recommend these practices for commercial level cultivation of this valuable medicinal plant.

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