Experiences with Greenleaf desmodium *(Desmodium intortum)* seed production in Bhutan

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Abstract

Desmodium intortum is a promising fodder legume for subtropical areas in the Himalayan region and has shown outstanding performance across a range of conditions in Bhutan. However, its promotion has been limited by the lack of seed. In an effort to develop technologies for local seed production, effects of location, altitude, spacing, irrigation, closing date and physical support on flowering and seed production were evaluated at locations between 26°–28° N. Silverleaf desmodium *(D. uncinatum)* was added in some of the studies to expand the scope of the investigations. In 1997, average yields at 3 locations were 0–23.0 g/m^2 for Greenleaf desmodium and 0.6–78 g/m^2 for Silverleaf desmodium. Across the elevation range of 640–1590 m, location and elevation had no consistent effect on flowering date and seed production of Greenleaf desmodium. Irrigation treatments applied over 2 years had no effect at a location with an annual rainfall of 1100 mm. Greenleaf desmodium seed yield was not affected when row spacing was increased from 50 cm to 100 cm and yield was only marginally reduced (16%, $P<0.08$) when the spacing was increased further to 150 cm. Cutting in May and June reduced seed yield. Providing support with bamboo sticks increased pod formation and seed yield consistently over 3 years. The results established that Greenleaf desmodium seed production is feasible in the Himalayan foothills and allowed for the release of recommendations for commercial seed production.

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Introduction

Greenleaf desmodium *(Desmodium intortum)* has been widely used as a fodder legume in east Africa, Australia and South America (Bryan 1969; Skerman *et al.* 1988). Although the species was introduced to the Himalayan region several decades ago, it was not adopted by the farmers at a significant level. Seed production and seed availability were major constraints to its wider adoption.

Limited information is available on seed production methods and environmental factors influencing seed yield. Greenleaf desmodium is daylength sensitive (Bryan 1969; Ison and Hopkinson 1985; de Andrade 1999). The traditional areas where Greenleaf desmodium was and is used are generally situated close to the equator, 20° N to 20° S (Skerman *et al.* 1988). Responding to short days, Greenleaf desmodium flowers in June–July in Madagascar at 18° S at an elevation of 600 m (corresponds to flowering in December–January in the northern hemisphere). In Queensland, Australia, the plant starts flowering at the end of May and flowers throughout June (English 1988). High temperatures inhibit flowering (de Andrade 1999). Seed yields reported were in the range of 80–300 kg/ha (Bryan 1969; English 1988; Skerman *et al.* 1988). Frost during the flowering or ripening period will cause seed losses and can completely ruin seed crops (Bryan 1969; English 1988). Harvesting, even with modern harvesters, was considered to be a problem due to large amounts of vegetative material and sticky seed pods (English 1988). Under the climatic conditions prevailing in the Himalayas, drought stress coinciding with the onset of flowering could be another limitation to seed production.

Greenleaf desmodium was first introduced to Bhutan in the late 1970s. Based on its excellent performance across a range of conditions, it was recommended for the subtropical areas of Bhutan (Roder *et al.* 2001). However, it could not be widely used because seed was unavailable on the international market and could not be produced in Bhutan. Because of its outstanding performance across a wide range of environments in Bhutan, priority was given to developing methods for seed production within the country. Therefore, several studies were carried out from 1996–2000 with the objective of evaluating the effect of location, cutting management, support, planting density and irrigation on flowering and seed production. In order to expand the scope of the investigations, Silverleaf desmodium *(Desmodium uncinatum)* was included in some of the on-station studies.

Materials and methods

The studies were carried out across a wide range of conditions with inputs by the RNR-RC (Renewable Natural Resources Research Centre) Jakar, the RNR-RC Khangma and their respective substation or outreach centres. All locations are between latitudes 26°–28° N (Table 1).

Effect of location, cutting management and support in existing stands (on-farm studies)

Greenleaf desmodium stands established in 1995 were selected at 6 locations in the Zhemgang district, representing a range of elevations and micro-climates. In 1996, 3 management treatments (no cutting, May cutting and June cutting) were applied to single plots of 100 m^2 at each site. Cutting management plots were split into subplots and 2 treatments (no support and support by staking with bamboo sticks to a height of 1m) were imposed. Observations on flowering (10–15 % of the flower buds open), pod formation and seed yield were taken from 0.25 m^2 quadrats placed randomly in each subplot (4 quadrats per subplot). Data were analysed taking locations as replicates.

Effect of irrigation, spacing, support and desmodium species (on-station studies)

The effects of location, irrigation, spacing and support were evaluated in on-station studies. In 1996, studies were established at 3 locations (Lingmethang, Khotakpa and Bhur; Table 1) using Greenleaf and Silverleaf desmodium. Following poor results in the first year, the study was discontinued at Khotakpa and Bhur. A modified design using Greenleaf desmodium only but with the addition of irrigation treatments and wider row spacing was used for a second study at Lingmethang. Hand weeding was carried out when necessary. Before seeding, P (in the form of single superphosphate) was applied at the rate of 21 kg/ha P.

Observations were taken on flowering date (10–15% of the flower buds open), harvesting date and seed yield. Seed was harvested from whole plots.

Study (a) Bhur, Lingmethang and Khotakpa (1996–97). A split-plot design with 6 replicates and a subplot size of 20 m^2 was used. The main plot treatments consisted of: inter-row spacing 50 cm; inter-row spacing 100 cm; and inter-row

Table 1. Effect of location and soil conditions on Greenleaf desmodium seed production (1996–97).

Parameter	Locations					
Location	Bhur	Lingmethang	Khotakpa	Birthay	Dhakphai	Wangdugang
Elevation (m)	200	640	850	800	1490	1590
Latitude (north)	26° 55′	27° 15′	27° 4′	27° 8′	27° 12′	27° 14′
Soil pH[1]	5.3	5.7	na[2]	6.1	5.8	5.8
Available P[3] (mg/kg)	35	3.0	na	225.4	10.5	5.9
Soil texture	Sand	Sandy clay loam	Sandy loam	Sandy loam	Loam	Sandy loam
Water-holding capacity[4]	very low	high	low	medium	high	medium
Annual rainfall (mm)	5000	1100	2000[5]	2000[5]	2000[5]	1500[5]
Flowering date	—	24.11	21.11	18.11	22.11	19.11
Harvesting date	—	29.1	26.1	16.1	18.1	19.1
Seed production (g/m^2)	0	23	1.4	1.1	7.0	3.2

[1]1:1 soil:water ratio.
[2]Information not available.
[3]Bray II extraction.
[4]Estimated by authors based on soil depth and soil texture.
[5]Based on rainfall isolines; unpublished, Ministry of Agriculture, Thimphu, Bhutan.

spacing 100 cm with support provided by a bamboo structure to a height of 100 cm. The subplot treatments were: Greenleaf desmodium; and Silverleaf desmodium. Seeding rate for Greenleaf desmodium was 0.33 g/m^2 for the 50 cm row spacing and 0.16 g/m^2 for the 100 cm row spacing. Because of the larger seed size, the rate was doubled for Silverleaf desmodium. Seeding dates were June 5, June 19 and June 21 for Bhur, Lingmethang and Khotakpa, respectively.

Study (b) Lingmethang (1997–99). The treatments consisted of a factorial arrangement of irrigation (no irrigation; and irrigation on November 4, 1997, March 18, 1998 and April 10, 1998) × inter-row spacing (100 cm; and 150 cm) × support (no support; and support with a bamboo structure to a height of 100 cm). The seeding rate was 0.16 g/m^2 for the 100 cm row spacing and 0.11 g/m^2 for the 150 cm row spacing. Plots were sown on June 20, 1997. The study had 3 replicates.

Results

Effect of location on Greenleaf desmodium (on-farm and on-station studies)

Flowering of Greenleaf desmodium started almost simultaneously at all sites around November 20 (Table 1). Similarly, at all locations, seeds were ready for harvest in the second part of January. Latitude, elevation, soil pH, annual rainfall and available P had no consistent effect on seed yield. Seed yields ranged from 0–23 g/m^2. Yield variations at the on-farm sites were influenced by farmers' previous management, grass component, cutting treatments and insect damage. Highest seed yields were obtained at sites with soils having comparatively better water-holding capacity.

Effect of altitude, cutting management and support in existing stands (on-farm studies)

Across the range from 800–1580 m, elevation had no consistent effect on the number of flowers, pod formation and seed production. The late cutting treatments resulted in lower flower and pod densities and reduced seed yield (Table 2). Compared with no cutting, seed yield was reduced by 30% if cut in May and by 70% if cut in June. High variation, however, precluded statistical significance of the cutting treatments. Support increased flower density by 79% and pod formation by 60% but had no significant effect on seed yield (Table 2). Average seed yields ranged from 0–7 g/m^2. At some sites (Tama and Zurphey), no seed could be harvested due to insect damage after flowering. All stands used in this study were initially established for fodder production and thus consisted of desmodium-grass mixtures (mostly *Melinis minutiflora*). Through the manipulation of plant density, the exclusion of competition effects from grasses and weeds and the control of insect pests, better seed yields should occur.

Table 2. Effect of location and management on flowering, pod formation and seed production of Greenleaf desmodium (1996–97).

Parameter	Flowering (no/m^2)	Pods formed (no/m^2)	Seed yield (g/m^2)
Location/elevation			
Wangdugang 1590 m	64	44	3.2
Dhakphai 1490 m	44	34	7.0
Birthay 800 m	29	13	1.1
Tama 1560 m	16	1	—
Tama 1580 m	21	7	—
Zurphey 1150 m	64	—	—
Cutting time			
No cutting	43	25	5.6
May cutting	44	23	3.9
June cutting	31	12	1.7
Support			
Control	28	15	3.6
Support[1]	50	24	3.9
Anova summary			
Cutting time	NS	NS	NS
Support	<0.01	<0.01	NS
CV (%)	22.6	39.0	41.3

[1]Support was provided by staking with bamboo sticks to a height of 1 m.

Effect of species, location, spacing, support and irrigation (on-station studies)

In 1996–97, both desmodium species performed poorly at the lowest elevation, Bhur (Table 3) and no seed of Greenleaf desmodium was produced at this location. Average yields at Bhur, Khotakpa and Lingmethang were 0, 1.4 and 23.0 g/m^2 for Greenleaf desmodium and 0.6, 22 and 78 g/m^2 for Silverleaf desmodium, respectively. Support consistently increased Greenleaf desmodium seed yields in the Lingmethang studies (Tables 3 & 4). The average increases were 72, 39 and 30% for 1996–97, 1997–98 and 1998–99, respectively.

Increasing row spacing from 50 cm to 100 cm had no significant effect on seed yield (Table 3). Similarly, the increase of row spacing from 100 cm to 150 cm reduced seed yield only marginally. The reductions were 5 and 16% for 1997 (not significant) and 1998 ($P < 0.08$), respectively (Table 4).

Table 3. Effect of row spacing and support on seed production of Greenleaf and Silverleaf desmodium at Lingmethang, Khotakpa and Bhur (1996–97).

Treatment	Lingmethang		Khotakpa		Bhur
	Green-leaf	Silver-leaf	Green-leaf	Silver-leaf	Silver-leaf
	Yield (g/m^2)				
Row spacing 50 cm	20	81	1.6	24	0.6
Row spacing 100 cm	18	78	1.5	21	0.7
Row spacing 100 cm + support	31	76	1.0	20	0.6
LSD ($P < 0.05$)	9.7	NS	NS	NS	NS
CV (%)	18.6	21.7	88.3	33.4	40.0

Table 4. Effect of irrigation, row spacing and support on Greenleaf desmodium seed production at Lingmethang.

Treatment	1997–98	1998–99
	Seed yield (g/m^2)	
Irrigation		
Control	21	58
Irrigated	22	71
Row Spacing		
100 cm	22	70
150 cm	21	59
Support		
Control	18	56
Support[1]	25	73
Anova		
Irrigation	NS	NS
Row spacing	NS	0.08
Support	0.03	0.02
Irrigation × Support	NS	0.04

[1]Support was provided by staking with bamboo sticks to a height of 1 m.

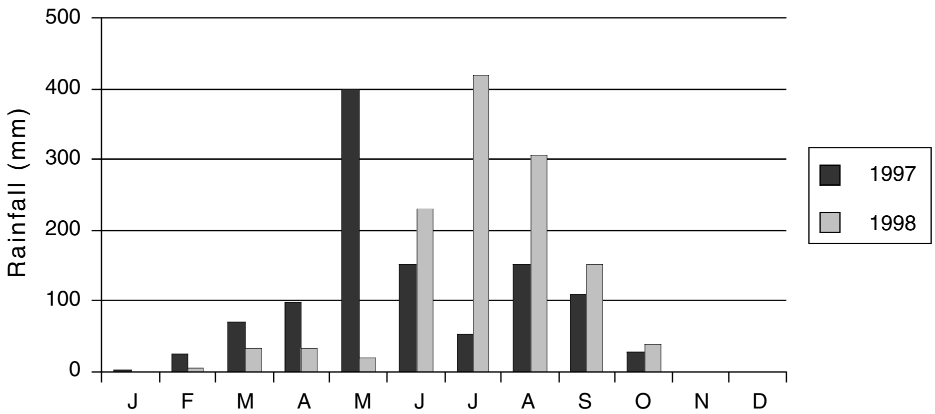

Figure 1. Monthly rainfall in Lingmethang during 1997 and 1998.

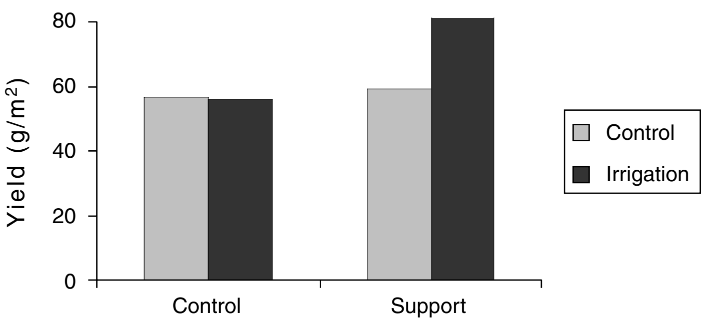

Figure 2. Effect of irrigation and support on Greenleaf desmodium seed yield at Lingmethang in 1998–99.

In spite of the relatively low rainfall during the period September–April, irrigation had no effect on seed yield in 1997–98 but resulted in significant interaction effects for irrigation × support treatments in 1998–99 (Table 4, Figure 2). The higher seed yield for the irrigation × support treatment in 1998–99, if due to irrigation, would be due to effects of the irrigation applied in March and/or April.

Discussion

The time of flowering for Greenleaf desmodium was similar at all locations and elevations except for the absence of flowers at the lowest location, Bhur. The study does, however, not allow us to make any conclusions on the suitability of this location as the poor performance may have been influenced by soil conditions. The soils at Bhur are extremely poor; moreover, the experiment was planted in a paddy field with relatively poor drainage. High temperatures may have further accentuated the problem and prevented the plants from setting flowers (Ison 1985; Ison and Hopkinson 1985).

The synchrony in flowering of Greenleaf desmodium across locations and elevations is inconsistent with observations made by Ison (1985), who recorded a delay of flowering with increasing altitude. A synchronised inception of flower formation should be expected as the species is photosensitive and responds to short day length (Ison and Hopkinson 1985; Skerman *et al.* 1988), but temperature differences will affect the duration of the interval between flower initiation and emergence of the flower. It is, however, possible, that temperature differences between our sites were less pronounced than differences at the sites used by Ison (1985).

Greenleaf desmodium seed yields of 3.2 and 7.0 g/m^2 as observed at on-farm sites are very good considering that this was an average yield across cutting date treatments. Average yield for Greenleaf desmodium in the on-station studies at Lingmethang was 23.0, 21.5 and 64.5 g/m^2 for 1996, 1997 and 1998, respectively. Rainfall quantity and distribution were similar to the long-term average except for the comparatively higher rainfall quantities during July, August and September in 1998. This may have resulted in higher average seed yields for the same year. In our studies, irrigation was applied in November, March and April only, without conclusive results from a 2-year study. It would be interesting to further explore the effect of additional irrigation treatments in October and December.

Silverleaf desmodium produces higher seed yields than Greenleaf desmodium and is less sensitive to unfavourable conditions. The higher seed yield is partly due to a larger seed size. Skerman *et al.* (1988) reported seed yields of 8–10 g/m^2 for Greenleaf desmodium and 22–33 g/m^2 for Silverleaf desmodium. Although it may be easier to produce Silverleaf desmodium seed, this species can not be used as a substitute for Greenleaf desmodium due to the lower dry matter yield potential at low elevation. At elevations above 1500 m, however, Silverleaf desmodium has good potential for the Bhutanese conditions.

Greenleaf desmodium seed yields in the on-farm studies did not correspond with the flower and pod densities observed. This was largely due to insect damage but could also be the effect of soil moisture interactions affecting seed formation after flowering and pod formation. Except for Bhur, Greenleaf desmodium seed could be produced at all locations, elevations and years included in the study. The most critical factors appeared to be rainfall distribution and soil conditions, especially water-holding capacity. These experiences collected from a wide range of different locations indicate that good seed yields of Greenleaf desmodium can be expected across a range of subtropical environments under Himalayan conditions. This will make it possible to recommend the species for wider use.

The objective of the initial studies was to explore whether Greenleaf desmodium could produce seed under the given conditions or not. The consistent results and the simple experimental methods used made it possible to formulate recommendations for commercial seed production. It is practical and feasible for individual farmers to have small seed plots to produce their own seed. Alternatively, yields obtained would justify some farmers setting up as specialised seed producers to supply seed commercially. If there is a demand in the world market, seed surplus could be exported.

For commercial seed production, attention will need to be given to site characteristics, especially soil conditions. Only deep soils with good water-holding capacity should be used. Seed producers can make use of the results from these studies for management interventions such as row spacing, cutting date and providing support. The results demonstrated that wide row spacing was possible with little or no loss in seed yield. Increasing row spacing to 150 cm will make it possible to use the power tiller for weed control. Power tillers are widely used by Bhutanese farmers. Seed production is possible from stands established for forage production but no grazing should be allowed during the summer. Providing support to increase seed yield could be a technique suitable for small seed producers, especially farmers producing seed for their own consumption.

Economic considerations, especially labour cost and extent of mechanisation, will be the key factors influencing the use of these techniques. In our studies, seed was collected manually by removing the mature inflorescence. If seed is to be produced on a larger scale, this method will have to be compared with cutting and threshing the entire plant biomass.

Further investigations are required to: a) minimise cost of weed control (including use of herbicides); b) optimise harvesting methods; and c) quantify moisture constraints and irrigation effects. Practical experiences from Australia (English 1988) for pest and weed management, as well as mechanised harvesting and threshing, may be partly applicable in Bhutan.

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