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Germination capacity of seeds of leguminous plants under water deficit conditions: implication for restoration of degraded lands in Kumaun Himalaya

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Abstract: Investigations were carried out to study the effect of water deficit on the germination capacity of some leguminous plants of Kumaun Himalayan region of India. Healthy seeds of *Acacia nilotica*, *Astragalus leucocephalus*, *Cassia mimosoides*, *Crotalaria prostrata, Desmodium elegans*, *D. laxiflorum*, *Indogofera heterantha*, *I. hirsuta*, *Lespedeza gerar-diana*, *Medicago denticulata*, *Mimosa himalayana*, *Smithia ciliata*, *Trifolium repens*, *Trigonella corniculata* and *Vicia rigidula* were collected and kept under five water deficit levels (0 to -20 bars). The seed germination was reduced with increasing water deficit except *C. mimosoides* in which low moisture stress (-5 bar) increased seed germination. *A. nilotica, A. leucocephalus, L. gerardiana M. himalayana S. ciliata* and *T. corniculata* were able to germinate even at the highest water deficit level with low germination percentage. Thus, these species can be used for direct seeding on degraded sites with low moisture content.

Key words: Germination capacity, legumes, response breadth, water deficit.

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Introduction

Soil water supply is an important environmental factor controlling seed germination and seedling establishment (Kramer & Kozlowski 1980). If the water potential is reduced, seed germination will be delayed or prevented depending on the extent of its reduction (Hegarty 1977). A large number of studies have been carried out on the effects of water stress on the germination of forest species (Baskin & Baskin 2001; Lopez *et al*. 2000; Zobel *et al.* 1995). The young Himalayan Mountains are geologically unstable and vulnerable to landslides and landslips (Valdiya 1980). As a result, primary and secondary bare areas are created frequently and need immediate restoration to arrest environmental degradation. The environment of bare site is characterized by wide fluctuations in moisture conditions. In such situation, the seeds of species which have an ability to germinate under fluctuating moisture conditions can germinate and survive (Quinlivan 1968).

Seed germination and early seedling growth are considered the most critical phases for the establishment of any species (Bargali & Singh 2007; Pratap & Sharma 2010; Vibhuti *et al*. 2015). Soil water potential modulates seed germination and species differ in the minimum water potential at which germination can occur (Daws *et al*. 2007). Thus, it is often emphasized that the tolerance of seeds to various stress during germination should be determined. This information will be helpful in understanding the adaptive strategies of seeds for

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germination (Uniyal & Nautiyal 1998).

Nitrogen fixing leguminous plants are an important source of nitrogen input to the ecosystem through the process of biological nitrogen fixation, therefore, can be an effective tool to hasten the recovery of degraded lands (Choudhary *et al.* 2014; Ramchandran *et al.* 2014). Keeping this in view, we select leguminous plants and regarding the fact that the most sensitive life stage of a plant is germination that seriously affects plant stability and establishment, we study seed germination in response to water deficit to identify suitable nitrogen-fixing plants, native to the locality; those can thrive well during the process of stabilization and restoration of degraded sites.

Materials and methods

Seed source

Leguminous plants which form nodules with nitrogen fixing bacteria were selected for the germination test. Life habit, habitat and distributional range of selected species are given in Table 1. Fresh ripen pods of all selected species were collected from the healthy plants in the year 2006 - 2007 in different seasons which vary from species to species from forests around Nainital, brought to the laboratory in polyethylene bags and sun dried. Seeds were excised from their pods, stored and subjected to water stress treatments.

Seed germination test

A technique for studying the effect of water stress on germination is to simulate stress condition using artificial solutions to provide variable water potential levels. In this study, various levels of external water stress (-5, -10, -15 and -20 bars) were produced by mannitol solution, according to the formula given by Helmerick & Pfeifer (1954); Rao & Singh (1989):

$$\text{Water stress} = \frac{1}{-25} X \frac{\text{Molality}}{\Psi\text{P}}$$

where, ΨP is the osmotic potential of the mannitol solution (water deficit). In addition one control (0 bar) water stress level was also maintained.

Experimental design

Germination tests were performed in 11 cm diameter glass Petri dishes on two layers of filter paper saturated with mannitol solutions (distilled water for control). Only seeds that sank to the bottom when immersed in water were used in these experiments. Five 20-seed replicates for each species and for each experimental condition were used (15 species × 5 water stress level × 5 replicate = 375). Experiments were carried out in a temperature controlled seed germinator. Germination counts were performed daily for 30 days and the seeds were considered germinated if the radical exceeded 3 mm in length. Cumulative germination percentage (%) was evaluated daily and final value was obtained after 30 days. At the end of each experiment, ungerminated seeds were classed either as sound viable or dead. Seeds that collapse when pinched gently with forceps and have a yellow or brown embryo were considered dead while seeds that do not collapse when pinched and have a firm, white embryo were considered sound viable.

Mean daily germination (MDG) was calculated by dividing cumulative germination percentage by the number of days in the test.

Germination capacity, GC, was calculated following Paul (1972) as:

$$\text{GC (\%)} = \frac{\text{Total germinated seeds} + \text{ total ungerminated sound seeds}}{\text{Total seeds tested}} \text{x } 100$$

Niche breadth for each species was calculated using Levins's (1968) equation (see Bargali & Singh 1996) to determine the performance of species on a moisture deficit gradient (Bisht 1990).

$$\text{B} = \frac{1}{(\sum_{i=1}^{s} \text{Pi2 })\text{S}}$$

where, B is niche breadth; Pi is the proportional response of species P in the ith water stress level and S is the number of water stress level. The measure ranges from 0 to 1 with 1 being a perfectly even distribution of response.

Statistical analysis

The results were analysed using analysis of variance. The data were analysed for original data in case of mean daily germination and transformed value in case of percent germination. Least significance difference (LSD) multiple comparison test to separate significant differences among species and water deficit level was done following Bhatt & Ram (2007).

Results and discussion

Analysis of variance showed highly significant differences among species, water deficit levels, and their interaction (Table 2). In most of the species, the mean seed germination was reduced with

Table 1. Habit, elevation range and distribution of selected species in Kumaun Himalaya.

Species	Species Habit	Distribution Range	Habitat
Acacia nilotica (Linn.) Del	Small tree	Upto 1400	In valleys
Astragalus leucocephalus Garh. Ex Benth	Herb	1600 - 2500	Shady and dry places
Cassia mimosoides Linn.	Prostrate herb	Upto 1600	In grassy open localities, roadside and way side
Crotalaria prostrata Roth	Diffuse hairy shrubs	Upto 2000	Forest margins, roadsides and grassy localities
Desmodium elegans DC	Shrub	1500 - 2000	In oak forests and scrub jungles
D. laxiflorum DC	Erect shrub	Upto 1800	Common in forest edges, ravines and grassy slopes
Indigofera heterantha Wall ex Brandis	Shrub	Upto 3000	Throughout the hills along way sides and vacant plots in oak forest
I. hirsuta Linn.	Annual sub erect herb	Upto 2000	Grassy localities, roadsides
Lespedeza gerardiana Garh.ex Baker	Undershrub	1500 - 2000	Open grassy localities
Medicago denticulata Willd.	Annual procumbent herb	1500 - 2000	Common in gardens, agricultural fields and way sides
Mimosa himalayana Gamble	Small tree or straggling shrub	Upto 1600	Along the water courses and scrub jungles
Smithia ciliata Royal	Diffused herb	800 - 1900	In marshy and sandy localities
Trifolium repens Linn	Perennial herb	1400 - 3200	In waste places, waysides and fields
Trigonella corniculata Linn.	Herb	Upto 3600	Field boulders, Roadside field margin, waste place
Vicia rigidula Royal	Herb	2000 - 2800	Forest edges, scrub jungles and roadsides

Table 2. Analysis of variance for seed germination parameters of fifteen species at five water deficit levels.

Parameters	Species (S)		Water deficit level (W)		S X W	
	d.f.	F Value	d.f.	F Value	d.f.	F Value
Percent seed germination	14	156.37***	4	1383.26***	56	17.61***
Mean daily germination	14	1.469*	4	29.932**	56	2.783*
Error	296		296		296	

P* < 0.05; ** *P* < 0.01; * *P* < 0.001.

increasing water deficit (Table 3). The only exceptions was *C. mimosoides* in which low water stress (-5 bar) increased seed germination to some extent. Most of the species examined in present study could not germinate at highest water deficit level (-20 bar) and germination was checked toward the higher side of water deficit gradient (Table 3). Falleri *et al.* (2004) reported that direct effects due to slower decomposition of endosperm or slower transition of decomposed materials to seedlings is one of the factor reducing the percentage of germination in the water stress condition. However, some species viz. *A. nilotica, A. leucocephalus, L. gerardiana, M. himalayana, S. ciliate* and

Table 3. Effect of water deficit on cumulative seed germination (%) of leguminous plants of Kumaun Himalaya. (Mean ± 1SE).

Species	Cumulative seed germination (%)				
	0 bar	-5 bar	-10 bar	-15 bar	-20 bar
Acacia nilotica	68 ± 4.06[a]	66 ± 3.32[a]	45 ± 3.53[b]	29 ± 2.91[c]	15 ± 1.58[d]
Astragalus leucocephalus	86 ± 2.91[b]	59 ± 4.00[a]	39 ± 1.87 [c]	18 ± 2.55[d]	9 ± 1.87[ad]
Cassia mimosoides	80 ± 5.24[b]	90 ± 3.53[c]	50 ± 2.24[d]	30 ± 2.74[a]	-
Crotalaria prostrata	40 ± 3.53[c]	40 ± 2.74[cd]	40 ± 4.18[cd]	-	-
Desmodium elegans	47 ± 2.55[c]	42 ± 5.15[cd]	30 ± 3.53[ac]	18 ± 2.55[bd]	-
D. laxiflorum	58 ± 2.55[c]	52 ± 1.22[cd]	39 ± 1.87[ac]	16 ± 2.91[bd]	-
Indigofera heterantha	24 ± 1.87[d]	16 ± 1.00[b]	10 ± 1.58[e]	06 ± 1.00[f]	-
I. hirsuta	31 ± 1.87[d]	20 ± 2.24[b]	21 ± 1.87[bf]	17 ± 1.22[bd]	-
Lespedeza gerardiana	100± 0.0[e]	85± 3.86[ac]	54± 2.44[d]	38± 1.87[a]	13± 1.37[b]
Medicago denticulata	51 ± 4.30[c]	35 ± 2.23[ec]	13 ±2.00[ae]	-	-
Mimosa himalayana	90 ± 2.74[e]	80 ± 3.53[ac]	57 ± 3.39[d]	36 ± 1.87[ba]	18 ± 2.0[cd]
Smithia ciliate	58 ± 2.55[c]	61 ± 2.91[cd]	52 ± 3.74[d]	21 ± 1.87[bd]	8 ± 1.22[ad]
Trifolium repens	75± 5.00[b]	46 ± 1.87[cd]	24 ± 1.87[bf]	10 ± 1.58[af]	-
Trigonella corniculata	100 ± 0.0[e]	71 ± 2.91[ed]	42 ± 2.55[bd]	10 ± 0.0[af]	5 ± 0.0[ad]
Vicia rigidula	48 ± 3.39[c]	36 ± 2.91[ec]	27 ± 2.55[bf]	9 ± 1.87[af]	-

- Indicates failure of seed germination

Values in a row and column for seed germination suffixed with different letters are significantly different from each other at $P < 0.05$.

T. corniculata were able to germinate even at the highest water stress level, though the germination percent was reduced.

In some species germination was decreased up to 5 % (*T. corniculata*), while in others (*M. himalyana*) seed continues to germinate up to 18 % at the highest water stress level. The mean daily germination (MDG) was markedly influenced by water stress (Table 4). Most of the species were susceptible to high water deficit and their germination rates were lowest towards high water deficit. In addition to germinated seeds, some more seeds showed capacity to germinate as they remain sound and viable till the end of experiment but could not germinate (Appendix Table 1). This indicates that germination capacity (determined on the basis of ungerminated sound seeds) of all the species was higher than their germination percentage (Table 5). Water deficit inhibited the germination in most of the species as suggested by Ahmadloo *et al.* (2011).

Seed germination behavior plays a key role in the persistence and dynamics of plant species as the evolution of the germination restrictions of plant species is a consequence of their responses to environmental conditions (Smith *et al.* 1997). Considering the present study, the influence of water deficit on seed germination of the investigated species showed that regardless of the species, increase in water deficit resulted in reduced percent germination as well as rate of germination. However, *C. mimosoides* showed higher germination at low (-5 bar) water stress indicating that this species can withstand low water deficit as compared to other species. Furthermore, differences under water stress also showed that species are characterized by a significantly different tolerance to drought. Bargali & Bargali (1999), Silva *et al.* (2001), Valio & Scarpa (2001), Socolowski & Takaki (2004) also reported difference in water deficit tolerance for different species. Most reported species failed to germinate at very high water stress level (-20 bar), although a few species such as *A. nilotica, A. leucocephalus, L. gerardiana, M. himalayana, S. ciliata* and *T. corniculata* were able to germinate. Germination failure under higher water deficit may be considered as secondary or induced dormancy, because water deficit prevent water absorption and seed require low water potential in germination medium to start germination process (Almansouri

Table 4. Effect of water deficit on mean daily germination (on the basis of cumulative germination percentage) of leguminous plants of Kumaun Himalaya. (Mean ± 1SE).

Species	Mean daily germination				
	0 bar	-5 bar	-10 bar	-15 bar	-20 bar
Acacia nilotica	2.27 ± 0.13^{a}	2.20 ± 0.11^{a}	1.50 ± 0.12^{b}	0.97 ± 0.09^{c}	0.50 ± 0.05^{d}
Astragalus leucocephalus	2.86 ± 0.09^{a}	1.97 ± 0.13^{ba}	1.30 ± 0.06^{b}	0.60 ± 0.08^{d}	0.30 ± 0.06^{c}
Cassia mimosoides	2.67 ± 0.17^{a}	3.00 ± 0.12^{ac}	1.67 ± 0.07^{b}	0.99 ± 0.08^{c}	-
Crotalaria prostrata	1.33 ± 0.12^{b}	1.33 ± 0.09^{b}	1.33 ± 0.59^{b}	-	-
Desmodium elegans	1.57 ± 0.08^{b}	1.40 ± 0.17^{b}	1.00 ± 0.12^{c}	0.60 ± 0.08^{d}	-
D. laxiflorum	1.93 ± 0.08^{b}	1.73 ± 0.04^{b}	1.30 ± 0.01^{cd}	0.54 ± 0.10^{d}	-
Indigofera heterantha	0.8 ± 0.06^{c}	0.53 ± 0.03^{db}	0.33 ± 0.05^{a}	0.20 ± 0.03^{b}	-
I. hirsuta	1.03 ± 0.06^{c}	0.67 ± 0.07^{db}	0.70 ± 0.06^{a}	0.57 ± 0.04^{b}	-
Lespedeza gerardiana	3.33 ± 0.0^{a}	2.83 ± 0.97^{bc}	1.80 ± 0.13^{e}	1.27 ± 0.08^{cd}	0.43 ± 0.05^{b}
Medicago denticulata	1.70 ± 0.14^{b}	1.17 ± 0.07^{c}	0.43 ± 0.07^{a}	-	-
Mimosa himalayana	2.99 ± 0.09^{a}	2.67 ± 0.11^{bc}	1.89 ± 0.11^{e}	1.20 ± 0.06^{cd}	0.60 ± 0.06^{d}
Smithia ciliata	1.93 ± 0.08^{b}	2.03 ± 0.97^{b}	1.73 ± 0.12^{e}	0.70 ± 0.06^{a}	0.37 ± 0.08^{c}
Trifolium repens	2.50 ± 0.16^{b}	1.53 ± 0.06^{c}	0.80 ± 0.06^{d}	0.33 ± 0.05^{e}	-
Trigonella corniculata	3.33 ± 0.0^{a}	2.37 ± 0.09^{b}	1.40 ± 0.08^{c}	0.33 ± 0.0^{e}	0.17 ± 0.0^{e}
Vicia rigidula	1.60 ± 0.11^{b}	1.20 ± 0.09^{c}	0.90 ± 0.08^{d}	0.30 ± 0.06^{e}	-

- Indicates failure of seed germination.

Values in a row and column for mean daily germination suffixed with different letters are significantly different from each other at $P < 0.05$.

et al. 2011). However, according to Khan (1994) water stress is a factor which inhibits germination but it is not a dormancy induction factor.

The fact that water deficit, which is frequently encountered in the region (except rainy season), is a limiting factor for the seed germination of a majority of species is also indicated by the relatively narrower response breadth (Fig. 1). These results suggest that moisture is a main factor controlling germination under field condition as it is the initiatory factor of germination and is directly or indirectly involved in all the steps of the subsequent metabolism. Species like *A. nilotica* and *M. himalayana* showed broad response breadth as compared to other species. Species that germinate readily over a relatively wide range of moisture stress should be easier to establish in the fields than those with specific moisture requirements (Kozlowaski 1970, 1971; Osmond *et al.* 1980).

The climate of Central Himalaya is characterized by the monsoon pattern of rainfall, with about three fourth of the annual rainfall occurring during mid June to mid September (rainy season). The seed fall of most of the species examined in the present study is not synchronized with rainy season; therefore, the seeds may often be subjected to prolonged dry spell in the field. The greater ability of seeds of *A. nilotica, A. leucocephalus, L. gerardiana, M. himalayana, S. ciliata* and *T. corniculata* than rest of the species to germinate under high moisture stress should give an advantage particularly in gaps where water stress may often be very severe (up to -30 bars) during periods outside the rainy season (Bargali *et al.* 2003).

Seeds play a vital role in natural and artificial regeneration. In natural exposed conditions where drought is a major limiting obstacle to the regeneration, seeds which can tolerate high water stress have better chance to germinate. In this study, the response of germination to water deficit differed among the species. This interspecific variation could be useful in selection of species for reclamation of degraded sites. Leguminous plants like *A. nilotica, A. leucocephalus, L. gerardiana, M. himalayana, S. ciliata* and *T. corniculata* showed ability to germinate under very high water deficit level. Thus, these species can be used for direct seeding on degraded sites with low moisture content. Seeds of species vulnerable to the marked reduction in seed germination under high water

Table 5. Effect of water deficit on germination capacity (%) of leguminous plants of Kumaun Himalaya. (Mean ± 1SE).

Species	Germination capacity (%)				
	0 bar	-5 bar	-10 bar	-15 bar	-20 bar
Acacia nilotica	81 ± 1.87	74 ± 2.45	55 ± 4.47	39 ± 2.91	21 ± 1.87
Astragalus leucocephalus	89 ± 1.87	64 ± 4.00	44 ± 1.87	27 ± 1.22	19 ± 2.91
Cassia mimosoides	96 ± 1.87	97 ± 2.0	76 ± 1.87	41 ± 3.32	9± 0.07
Crotalaria prostrata	54 ± 5.78	55 ± 3.53	42 ± 3.53	16 ± 1.28	7 ± 0.76
Desmodium elegans	67 ± 2.54	55 ± 5.24	41 ± 2.91	26 ± 2.91	11 ± 0.89
D. laxiflorum	66 ± 1.87	62 ±1.22	49 ± 1.87	24 ± 1.87	12 ± 0.79
Indigofera heterantha	60 ± 2.14	54 ± 1.87	44 ± 1.87	18 ± 1.87	5 ± 0.0
I. hirsuta	48 ± 3.00	34 ± 1.87	33 ± 2.00	20 ± 1.58	8 ± 0.07
Lespedeza gerardiana	100 ± 0.0	90 ± 2.55	62 ± 1.45	51 ± 0.86	20 ± 0.06
Medicago denticulata	71 ± 4.30	50 ± 3.53	27 ± 1.32	16 ± 1.28	8 ± 0.0
Mimosa himalayana	100 ± 0.0	91 ± 2.91	71 ± 3.32	47 ± 1.22	29 ± 1.87
Smithia ciliata	70 ± 2.24	73 ± 2.55	61 ± 2.91	28 ± 1.87	15 ± 1.58
Trifolium repens	79 ± 4.85	57 ± 1.22	34 ± 1.88	15 ± 1.58	5 ±0.08
Trigonella corniculata	100 ± 0.0	83 ± 2.55	58 ± 2.13	12 ± 1.22	9 ± 1.87
Vicia rigidula	57 ± 3.74	46 ±1.87	37 ±2.55	19 ± 1.87	16 ±1.87

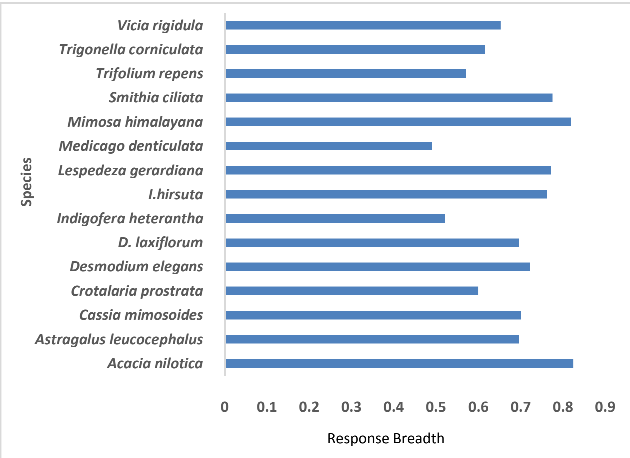

Fig. 1. Levins's B (Response Breadth) for different leguminous species on water deficit gradient.

stress cannot germinate when exposed to dry conditions. Such species like *C. prostrata* and *M. denticulata* can be used for establishment on degraded sites only during rainy season. The seeds of leguminous plants generally have hard seed coats that are impermeable to water. It is one of the forms of dormancy and caused by both genetic and environmental factors (Baskin & Baskin 2001). Presence of such character ensures greater survival value and biological advantage in adapting the growth cycles of the plants to the seasonal and fortuitous variations in the environmental conditions (Vickers & Palmer 2000). Suitable conditions for seed germination and seedling growth are the most important factors that affect the natural regeneration of forests. This study was carried out on N_2-fixing leguminous plants because of their importance in degraded lands as N_2-fixing legumes have the potential to facilitate surrounding vegetation by increasing soil N levels. A preliminary study on seed germination behaviour of plant species could be helpful in understanding suitable condition in terms of water deficit for seed germination and provide a basis for selection of species for successful seeding trials in afforestation programmes on degraded lands varying in soil moisture content.

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Appendix Table 1. Number of germinated (G), ungerminated (UG) sound (S) and dead (D) seeds of leguminous species on water deficit gradient.

Species	Control			-5 Bar			-10 Bar			-15 Bar			-20 Bar		
	G	UG		G	UG		G	UG		G	UG		G	UG	
		S	D		S	D		S	D		S	D		S	D
Acacia nilotica	13.6 ±0.81	2.6 ±0.24	3.8 ±0.86	13.2 ±0.86	1.6 ±0.60	5.2 ±0.73	9.0 ±0.11	2.0 ±0.0	9.0 ±0.11	5.8 ±0.98	2.0 ±0.11	12.2 ±1.11	3.0 ±0.32	1.2 ±0.37	15.8 ±0.98
Astragalus leucocephalus	17.2 ±0.98	0.6 ±0.24	2.2 ±0.98	11.8 ±0.80	1.0 ±0.0	7.2 ±0.80	7.8 ±0.37	1.0 ±0.32	11.2 ±0.98	3.6 ±0.91	1.8 ±0.73	14.6 ±1.03	1.8 ±0.37	2.0 ±0.71	16.2 ±0.48
Cassia mimosoides	16.0 ±1.05	3.2 ±0.73	0.8 ±0.37	18.0 ±0.71	1.4 ±0.4	0.6 ±0.4	10.0 ±0.45	5.2 ±0.37	4.8 ±0.37	6.0 ±0.95	2.2 ±0.48	11.8 ±0.86	Nil	1.8 ±0.37	18.2 ±0.37
Crotalaria prostrata	8.0 ±0.71	2.8 ±0.78	9.2 ±1.16	8.0 ±0.95	3.0 ±0.32	9.0 ±0.71	8.0 ±0.84	0.4 ±0.24	11.6 ±0.68	Nil	3.2 ±0.2	16.8 ±0.3	Nil	1.4 ±0.24	18.6 ±0.24
Desmodium elegans	9.4 ±0.91	4.0 ±0.84	6.6 ±0.91	8.4 ±1.03	2.8 ±0.37	8.8 ±1.11	6.0 ±0.11	2.2 ±0.2	11.8 ±0.98	3.6 ±0.31	1.6 ±0.91	14.8 ±0.80	Nil	2.2 ±0.48	17.8 ±0.48
D. laxiflorum	11.6 ±0.91	1.6 ±0.91	6.8 ±0.73	10.4 ±0.24	2.0 ±0.32	7.6 ±0.31	7.8 ±0.37	2.0 ±0.0	10.2 ±0.37	3.2 ±0.98	1.6 ±0.40	15.2 ±0.98	Nil	2.4 ±0.24	17.6 ±0.24
Indigofera heterantha	4.8 ±0.37	7.2 ±0.98	8.0 ±0.84	3.2 ±0.20	7.6 ±0.91	9.2 ±0.48	2.0 ±0.32	6.8 ±0.37	11.2 ±0.38	1.2 ±0.20	2.4 ±0.24	16.4 ±0.24	Nil	1.0 ±0.45	19.0 ±0.45
I. hirsuta	6.2 ±0.37	3.4 ±0.40	10.4 ±0.31	4.0 ±0.45	2.8 ±0.73	13.2 ±0.37	4.2 ±0.37	2.4 ±0.24	13.4 ±0.40	3.4 ±0.24	0.6 ±0.24	16.0 ±0.32	Nil	1.6 ±0.31	18.4 ±0.31
Lespedeza gerardiana	20.0 ±0.0	Nil	Nil	17.0 ±0.71	1.0 ±0.0	2.0 ±0.71	10.8 ±0.48	1.6 ±0.81	7.6 ±0.31	7.6 ±0.24	2.6 ±0.67	9.8 ±0.86	2.6 ±0.24	1.4 ±0.91	16.0 ±0.95
Medicago denticulata	10.0 ±0.86	4.2 ±0.37	5.8 ±0.86	7.0 ±0.44	3.0 ±0.32	10.0 ±0.71	2.6 ±0.40	2.8 ±0.37	14.6 ±0.4	Nil	3.2 ±0.98	16.8 ±0.98	Nil	1.6 ±0.4	18.4 ±0.4
Mimosa himalayana	18.0 ±0.95	2.0 ±0.94	Nil	16.0 ±0.70	2.0 ±0.0	1.8 ±0.98	11.4 ±0.68	2.8 ±0.20	5.8 ±0.86	7.2 ±0.97	2.2 ±0.20	10.6 ±0.24	3.6 ±0.40	2.2 ±0.20	14.2 ±0.37
Smithia ciliata	11.6 ±0.31	2.4 ±0.81	6.0 ±0.45	12.2 ±0.38	2.4 ±0.31	5.4 ±0.31	10.4 ±0.75	2.0 ±0.45	8.6 ±1.03	4.2 ±0.37	1.4 ±0.31	14.4 ±0.31	1.6 ±0.24	1.2 ±0.48	17.0 ±0.32
Trifolium repens	15.0 ±1.0	0.8 ±0.37	4.2 ±0.86	9.2 ±0.37	2.2 ±0.73	8.6 ±1.02	4.8 ±0.37	2.0 ±0.0	13.2 ±0.37	2.0 ±0.32	3.4 ±0.31	14.6 ±0.68	Nil	3.8 ±0.37	16.2 ±0.37
Trigonella corniculata	20.0 ±0.0	Nil	Nil	14.2 ±0.98	2.4 ±0.91	3.4 ±0.91	8.4 ±0.91	3.2 ±0.80	8.4 ±0.40	2.0 ±0.0	0.4 ±0.24	17.6 ±0.24	1.0 ±0.0	0.8 ±0.37	18.2 ±0.37
Vicia rigidula	9.6 ±0.68	1.8 ±0.19	8.6 ±0.15	7.9 ±0.11	2.0 ±0.45	10.8 ±0.37	5.4 ±0.31	2.0 ±0.0	12.6 ±0.91	1.8 ±0.37	2.0 ±0.32	16.2 ±0.37	Nil	3.2 ±0.37	16.8 ±0.37