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SURVIVAL OF *NARDOSTACHYS JATAMANSI* DC. - AN ENDANGERED MEDICINAL HERB AT THREE DIFFERENT ALTITUDES

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SUMMARY

Propagation of *Nardostachys jatamansi* through vegetative propagation as well as seedlings (60, 90 and 180 days old) transplantation methods was carried out for three consecutive growth seasons and survival percentage of transplanted plants was analyzed at three different altitudes, *i.e.* natural habitat (3600 m), middle altitude (2200 m) and lower altitude, (1800 m). Plant survival percentage varied with altitude and treatments and was minimum in 60 days old seedlings and maximum in vegetatively propagated plants under various treatments. Seedlings (90 and 180 days old) and vegetatively propagated plants showed better ability to survive as compared to 60 days old seedlings under similar treatments. No seedling mortality was recorded during third growth season at 2200 m and 3600 m, whereas total plant mortality was observed at 1800 m in all the treatments. Transplantation during the month of May in raised beds with farm yard manure (FYM) treatment at 3600 m and plain beds with FYM treatment at 2200 m are suitable for better survival of the species.

Key words: **Cultivation, *Nardostachys jatamansi*, plant survival.**

INTRODUCTION

Nardostachys jatamansi DC. is a small herbaceous perennial, dwarf hairy, rhizomatous herb of family Valerianaceae, commonly known as Jatamansi, Indian Nard, Balchhar or Spikenard. The plant is mostly found growing in steep, moist, rocky, undisturbed grassy slopes or on coarse sandy loam soil. The species is well known for its medicinal and aromatic properties (Anonymous 1966, Kirtikar and Basu 1989, Prakash 1999, Chauhan and Nautiyal 2005). Due to over-exploitation of rhizomes for its medicinal value, habitat degradation and other biotic interferences in its distribution ranges, *N. jatamansi* has become endangered in Northwest Himalaya (Nayar and Shastri 1988, Airi *et al*. 2000, Nautiyal *et al.* 2003). Due to high level of threat, CITES has notified *N. jatamansi* in its schedule for care. Market survey reveals that demand of many high altitude MAP species including *N. jatamansi* is increasing regularly (Ahuja 2003, Chauhan 2004). Cultivation is the only option to fulfill increasing demand of market, improve the socio-economic status of the local people as well as help in conservation of species in its natural habitat. Hence urgent need was felt for increased cultivation of species (Nautiyal 2000, Nautiyal *et al.* 2002, Dhar 2002, Nautiyal *et al.* 2003, Nautiyal and Nautiyal 2004, Chauhan and Nautiyal 2005).

Cultivation of any species in any region depends on survival of transplanted plants. Low seedling survival even after good seed germination potential is one important factor for random distribution of *N. jatamansi* in its natural habitat (Chauhan and Nautiyal 2005). Seed grading, sowing date, seedling vigour, water regime,

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seedling age etc. have important influence on plant survival. It is well known that alpine plant species are habitat specific and flourish well only within a narrow range of environment. Sexual reproduction is considered less important than vegetative propagation for arctic and alpine species (Bliss 1971), whereas seedling establishment in these habitats is episodic (Billings and Mooney 1968). Survival was generally lowest for the youngest individuals in a plant population in these habitats (Cook 1979, Streng *et al* 1989). In view of above literature, plant survival was observed by vegetative propagation as well as seedling transplantation methods at three different altitudes, *i.e.* natural habitat Tungnath (TN), middle altitude Pothiwasa (PW) and comparatively lower altitude Tala in different treatments with a view to develop the package for its conservation and cultivation.

MATERIALS AND METHODS

Experiments were conducted at Tungnath (3600 m asl, between 30°14' N Lat. and 79°13' E Long.), Pothiwasa (2200 masl, between 30°28' N Lat. and 79°16' E Long.) and Tala (1800 masl, between 30°31' N Lat. and 79°07' E Long.) in Rudraprayag district of Garhwal Himalaya, Uttaranchal, India. Three replicates were used for all the treatments. Experimental beds of 1x1 m area were prepared by digging or ploughing the land three times. These beds were raised up to 10 cm from land surface to remove excess water. To observe impact of land condition on plant survival, ridges/bunds were made, *i.e.* vertical ridge (ridges along the slope) and horizontal ridges (ridges across the slope) prior to plantation. Plain beds prepared inside the polyhouse to protect plants from adverse environmental conditions were termed as polyhouse beds. Manure (FYM) was prepared with a mixture of decomposed cow dung, sheep dung and decomposed plant leaves (leaf litter) in equal volume, *i.e.* 1:1:1 and spread into experimental beds at the start of each growing season. No manure was added in control beds (CB), whereas, two kg manure/bed/year in manure bed-1 (MB-1), vertical ridge (VR), horizontal ridge (HR) and polyhouse beds (PB), and four kg/bed/year in manure bed-2 (MB-2) was mixed well in soil.

Planting in experimental beds was carried out by two different means, *i.e.* through vegetative propagation and seedlings transplantation with 20×30 cm planting distance. For vegetative propagation, rhizomes of *N. jatamansi* were collected from natural population at Tungnath (3600 m asl) and separated in such a way that each rhizome got at least an apical bud and transplanted in control (CB), manure beds-1 (MB-1), vertical ridges (VR), horizontal ridges (HR) and polyhouse beds (PB). Seedlings were grown under polyhouse at Tala for experimental purposes. Seedlings (60, 90 and 180 days old) were taken for transplantation at three different altitudes and treatments in experimental beds. Equal size planting material was taken and each treatment contained three replicates of 25 plants each.

Seedlings (60 and 180 days old) were transplanted during the month of May in CB, MB-1 and MB-2 treatments. Ninety days old seedlings were transplanted during two different seasons, *i.e.* early planting season in May and late planting season during July. During the month of May, season was dry and plantation needed regular irrigation whereas, during July, heavy rain was dominating in these nurseries and irrigation was not needed. These seedlings were transplanted in CB, MB-1, MB-2, VR, HR and PB at different altitudes. Data on plant survival percentage was analyzed statistically by (analysis of variance) (Snedecor and Cochran 1968). Cultural practices, i.e. weeding and irrigation etc. were performed whenever felt necessary. Each treatment was examined for plant survival during the month of September till maturation of plants.

RESULTS

Plant mortality started few days after transplantation in nurseries and continued during first, second and third year in most of the treatments due to which plant survival percentage decreased in all the nurseries. However, the rate of plant mortality was different among treatments, altitudes and age of plants. Plant survival percentage did not decrease during third year in Pothiwasa (PW) and Tungnath (TN), whereas in Tala nursery, all the plants died by the end of second year.

In plants propagated by vegetative means (Table 1) survival was highest in TN and lowest in Tala in all the treatments. In TN, plant survival was minimum (93.33%) in control beds (CB) and maximum (98.66%) in manure

Table 1. Survival percentage of plants at different altitudes using vegetative propagation.

Treatments	Nursery	I season	II season	III season
CB	Tungnath	93.33 ±6.11	90.0 ±5.77	90.0 ±5.77
	Pothiwasa	85.33 ±6.11	81.76 ±7.63	81.76 ±7.63
	Tala	78.66 ±9.23	55.0 ±8.66	0.0
MB-1	Tungnath	98.66 ±2.30	93.93 ±2.88	93.93 ±2.88
	Pothiwasa	92.0 ±6.92	89.83 ±7.63	89.83 ±7.63
	Tala	81.33 ±6.11	68.33 ±2.88	0.0
VR	Tungnath	96.0 ±4.0	95.83 ±7.21	95.83 ±7.21
	Pothiwasa	76.0 ±8.0	69.66 ±5.77	69.66 ±5.77
	Tala	62.62 ±12.2	33.33 ±5.77	0.0
HR	Tungnath	97.33 ±2.30	96.96 ±5.77	96.96 ±5.77
	Pothiwasa	86.66 ±4.61	80.0 ±5.0	80.0 ±5.0
	Tala	72.0 ±8.0	33.33 ±7.63	0.0
PB	Tungnath	96.66 ±5.77	96.96 ±6.11	96.96 ±6.11
	Pothiwasa	93.33 ±5.77	93.33 ±3.11	93.33 ±3.11
	Tala	56.66 ±5.77	0.0	0.0

CB: control bed; MB-1: manure bed-1; VR: vertical ridge; HR: horizontal ridge; PB: Polyhouse bed.

bed 1 (MB-1) during first year's growth whereas during second year's growth survival was between 90.00-96.96% among different treatments. In plants transplanted at PW, survival was minimum (76%) in vertical ridges (VR) and maximum (93.33%) in polyhouse beds (PB) during first year's growth whereas during second year's growth survival percentage was minimum (69.66%) in VR and between 80.0-93.33% in other treatments. In plants transplanted at Tala, survival was minimum (56.66%) in PB and between 62.62-81.33% in other treatments during first growth season. All the plants died in PB, whereas survival percentage was between 33.33-68.33% in other treatments during second growth season. No plant sprouted during third year and it was considered as total mortality in Tala. Variation in survival percentage suggested significant increase (LSD value 7.70, P=0.05) only in PB of PW.

In seedlings transplanted at 60 days age (Table 2) in CB treatment at different altitudes survival percentage during first year was minimum (45.33%) in Tala and maximum (64%) in PW. During second year similar trend was observed and it was recorded minimum (33.33%) in Tala and maximum (58.66%) in PW. In MB-1 treatment survival percentage was recorded minimum (54.66%) in Tala and maximum (72%) in TN during first growth season, whereas during second year's growth it was minimum (45.33%) in Tala and maximum (70.66%) in TN. In MB-2 treatment survival percentage was minimum (54.66%) in Tala and maximum (78.66%) in TN during first growth season, whereas during second year's growth it was minimum (42.62%) in Tala and maximum (72.0%) in TN. No seedling mortality was recorded during third growth season in PW and TN, whereas survival percentage became zero at Tala in all the treatments. Variation was found significant among applied treatments.

In seedlings transplanted at 180 days (Table 3) in CB treatment at different altitudes, survival percentage during

Table 2. Survival percentage of 60 days old seedlings at different altitudes.

Treatments	Nursery	I season	II season	III season
CB	Tungnath	61.33±10.06	56.0 ±6.92	56.0 ±6.92
	Pothiwasa	64.0± 10.58	58.66 ±6.11	58.66 ±6.11
	Tala	45.33±10.06	33.33 ±6.11	0.0
MB-1	Tungnath	72.0 ±12.0	70.66 ±12.2	70.66 ±12.2
	Pothiwasa	68.0± 10.58	64.0 ±9.92	64.0 ±9.92
	Tala	54.66 ±8.32	45.33 ±4.61	0.0
MB-2	Tungnath	78.66±9.23	72.0±10.58	72.0±10.58
	Pothiwasa	68.0±10.58	60.0±12.0	60.0±12.0
	Tala	54.66±8.32	42.62±2.30	0.0

CB: control bed; MB-1: manure bed-1; MB-2: manure bed-2.

Table 3. Survival percentage of 180 days old seedlings at different altitudes.

Treatments	Nursery	I season	II season	III season
CB	Tungnath	85.33±12.22	84.0 ±6.92	84.0 ±6.92
	Pothiwasa	77.33 ±6.11	74.66 ±8.32	74.66 ±8.32
	Tala	73.33±12.85	64.0 ±6.92	0.0
MB-1	Tungnath	92.0 ±4.0	92.0 ±4.0	92.0 ±4.0
	Pothiwasa	81.33 ±6.11	78.66 ±6.11	78.66 ±6.11
	Tala	76.0± 14.42	68.0 ±4.0	0.0
MB-2	Tungnath	93.33±2.30	93.33±2.30	93.33±2.30
	Pothiwasa	78.66±4.61	77.33±4.61	77.33±4.61
	Tala	73.33±12.85	68.0±2.88	0.0

CB: control bed; MB-1: manure bed-1; MB-2: manure bed-2.

first year was minimum (73.33%) in Tala and maximum (85.33%) in TN and minimum (64%) in Tala and maximum (84%) in TN during second growth season. In MB-1 treatment survival percentage was minimum (76%) in Tala and maximum (92%) in TN during first growth season and minimum (68%) in Tala and maximum (92%) in TN during second growth season. In MB-2 treatment survival percentage was minimum (73.33%) in Tala and maximum (93.33%) in TN during first growth season and minimum (68.0%) in Tala and maximum (93.33%) in TN during second growth season. No seedling mortality was recorded during third growth season in PW and TN and survival was recorded similar to second growth season, whereas survival percentage became zero in Tala in all the treatments. Survival percentage showed significant increase in MB1 and MB2 in TN and MB1 in PW only.

Seedlings (90 days old) transplanted during the month of May at different altitudes (Table 4) showed that in CB treatment, plant survival percentage was minimum (72%) in Tala and maximum (77.33%) in PW during first

Table 4. Survival percentage of 90 days old seedlings transplanted in May at different altitudes.

Treatments	Nursery	I season	II season	III season
CB	Tungnath	73.33±12.85	69.33 ±2.30	69.33 ±2.30
	Pothiwasa	77.33 ±8.32	72.0 ±10.58	72.0 ±10.58
	Tala	72.0 ±8.0	61.33 ±2.30	0.0
MB-1	Tungnath	85.33 ±9.23	82.66 ±12.85	82.66 ±12.85
	Pothiwasa	81.33 ±8.32	77.33 ±2.30	77.33 ±2.30
	Tala	74.66 ±8.32	66.66 ±6.06	0.0
MB-2	Tungnath	89.33 ±8.32	89.33 ±8.32	89.33 ±8.32
	Pothiwasa	78.66±10.06	77.33 ±6.11	77.33 ±6.11
	Tala	73.33±12.85	68.0±12.0	0.0
VR	Tungnath	77.33 ±8.32	72.0 ±8.0	72.0 ±8.0
	Pothiwasa	68.0 ±12.0	60.0 ±8.0	60.0 ±8.0
	Tala	0.0	0.0	0.0
HR	Tungnath	78.66 ±4.61	74.66 ±8.32	74.66 ±8.32
	Pothiwasa	73.33±12.85	70.0 ±5.29	70.0 ±5.29
	Tala	0.0	0.0	0.0
PB	Tungnath	93.33±11.54	93.33 ±11.54	93.33 ±11.54
	Pothiwasa	76.66±15.27	73.33 ±15.27	73.33 ±15.27
	Tala	46.66 ±15.27	33.33 ±5.77	0.0

growth season, whereas, it was minimum (61.33%) in Tala and maximum (72%) in PW during second growth season. In MB-1 treatment, survival was minimum (74.66%) in Tala and maximum (85.33%) in TN during first growth season and minimum (66.66%) in Tala and maximum (82.66%) in TN during second growth season. In MB-2 treatment survival was minimum (73.33%) in Tala and maximum (89.33%) in TN during first growth season and minimum (68.00%) in Tala and maximum (89.33%) in TN during second growth season. In both the ridges (VR as well as HR) total mortality was recorded in Tala, whereas survival percentage was higher in TN as compared to PW during all the growth seasons. In PB treatments survival was minimum (46.66%) in Tala and maximum (93.33%) in TN during first growth season and minimum (33.33%) in Tala and maximum (93.33%) in TN during second growth season. Survival percent became zero in Tala in all the treatments, whereas it was similar to previous year in PW and TN during third growth season. Survival percentage showed significant increase in MB1 of TN, PW, Tala, MB2 of TN, PW, HR of TN and PB of TN.

Seedlings (90 days old) transplanted during the month of July at different altitudes (Table 5) showed that in CB treatment, plant survival percentage was minimum (56.66%) in TN and maximum (68.00%) in Tala during first growth season whereas minimum (45.33%) in TN and maximum (61.33%) in PW during second growth season. In MB-1 treatment survival was minimum (61.33%) in TN and maximum (81.33%) in Tala during first growth season and minimum (56%) in TN and maximum (68%) in PW during second growth season. In MB-2 treatment survival was minimum (64%) in TN

Table 5. Survival percentage of 90 days old seedlings transplanted in July at different altitudes.

Treatments	Nursery	I season	II season	III season
CB	Tungnath	56.66±11.19	45.33 ±10.06	45.33 ±10.06
	Pothiwasa	66.66±16.65	61.33 ±8.32	61.33 ±8.32
	Tala	68.0 ±12.0	50.66 ±10.06	0.0
MB-1	Tungnath	61.33±10.06	56.0 ±10.58	56.0 ±10.58
	Pothiwasa	70.66±12.22	68.0 ±10.58	68.0 ±10.58
	Tala	81.33 ±6.11	61.33 ±8.32	0.0
MB-2	Tungnath	64.0±10.58	58.66±6.11	58.66±6.11
	Pothiwasa	70.0±5.29	68.0±12.0	68.0±12.0
	Tala	81.33 ±6.11	68.33±2.88	0.0

and maximum (81.33%) in Tala during first growth season and minimum (58.66%) in TN and maximum (68.33%) in Tala during second growth season. No seedling mortality was recorded during third growth season in PW and TN, whereas total mortality was shown in Tala in all the treatments during third growth season. Survival percentage showed significant increase in MB1 of PW, Tala and MB2 of Tala.

DISCUSSION

Based on the age of plant at the time of transplantation, maximum plant mortality was noted in smaller seedlings (60 days old) as compared to larger (90 and 180 days old) seedlings and vegetatively propagated plants. Survival, however, was almost similar in 90 and 180 days old seedlings. Larger size plants showed better ability to survive, as they were more competitive and showed better ability to tolerate stress conditions. It clearly indicates that younger will be seedlings higher will be mortality. Thus, seedlings of >90 days should be transplanted for better survival at 2200 and 3600 masl. This study supports earlier study (Cook 1979, Streng *et al.* 1989, Maruta 1983, Douglas 1995) that smaller size of seedlings was responsible for higher seedling mortality.

Higher plant survival in ridge condition at Tungnath as compared to plain beds becomes possible due to proper drainage of excess water during heavy rain and roots escaped from water logging in such beds, as this region is well known for high rainfall. Total seedling mortality in ridge condition at Tala and decrease in plant survival at Pothiwasa may be due to porous nature of soil, which washed away with heavy rainwater, dries early and affects growth and development of plant as compared to plain beds. Higher plant survival in Tala in July transplanted seedlings was due to frequent rain leading to sufficient moisture availability during this month. This indicates that one important factor among others for higher plant mortality at lower altitude in *N. jatamansi* is low moisture level in soil. Bonde (1968), Bell and Bliss (1980) also found drought as a key mortality factor. It can be concluded that raised beds at higher altitude and plain beds at middle altitudes are suitable for cultivation of this species. Nautiyal *et al.* (2001) also supported levelled ground for cultivation of *Picrorhiza kurrooa* at lower altitude. Some variation in survival at different altitudes can also be due to variation in microclimate of nursery environment and nursery practices, etc. Even small micro environmental difference can affect seedling establishment in arctic and alpine (Manjkhola and Dhar 2002).

Increase in plant survival at all the three altitudes with increased manure may possibly be due to addition of FYM which increases moisture-retaining capacity of soil and protected plants from drought. Significantly higher plant survival at Tungnath in higher manure (MB-2) treatments is due to the availability of sufficient mineral nutrients required for growth. This study supports the earlier study of Chapin (1980), Chauhan and Bhatt (2000) that the alpine soil is poor in nutrient levels.

Reduction in plant mortality during the second growth season as compared to first growth season was due to increase in size of seedlings and acclimatization. Further, during the third year's growth, seedlings attained larger size and no mortality was seen in Tungnath and Pothiwasa. Effect of most of the applied treatments were significant and therefore, total mortality of plants at Tala may be due to desiccation and low biomass accumulation during first and second growth seasons. Plant mortality may be due to problem of acclimatization, higher moisture requirement, insufficient carbohydrate accumulation (Kullman 1986) and higher respiration rate, at lower altitude and soil frost activities at higher altitude (Bliss 1985). Photorespiratory activity may be increased at lower altitude, resulting decrease in carbohydrate reserve. Depletion of carbohydrate reserve by high respiratory rate at warmer temperature has often been suggested as a limiting factor for warmer regions (Moony and Johnson 1965). The ability of plants to acclimatize along an altitudinal gradient depends upon many morpho-physiological and biochemical adaptability of the plants (Rajsekaran *et al.* 1998). Good seedling survival, growth performance and economic yield at middle altitude indicated that growers in mid hill region (2200 masl) can cultivate this species in the vicinity of the villages. Cultivation of such species will fulfill increasing market demand, improve economic status of rural grower and also help in conservation of this species.

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REFERENCES

Ahuja, P.S. (2003). Medicinal Plants in India: Report and Directory. Institute of Economic and Market Research, New Delhi.

Airi, S., Rawal, R.S., Dhar, U. and Purohit, A.N. (2000). Assessment of availability and habitat preference of Jatamansi - A critically endangered medicinal plant of west Himalaya. *Curr. Sci.* **79**: 1467-1470.

Anonymous (1966). The Wealth of India-Raw Material. Vol. 7. Publication and Information, Directorate, CSIR New Delhi.

Bell, K.L. and Bliss, L.C. (1980). Plant reproduction in a high arctic environment. *Arct. Alp. Res.* **12:** 1-10.

Billings, W.D. and Mooney, H.A. (1968). The ecology of Arctic and alpine plants. *Biol. Rev*. **43:** 481-529.

Bliss, L.C. (1971). Arctic and alpine plant life cycles. *Annu. Rev. Ecology Syst.* **2:** 405-438.

Bliss, L.C. (1985). Alpine. In: B. F. Chabot and H. A. Mooney (eds.), Physiological Ecology of the Northern American Plant Communities, pp. 41-65. Chapman Hall.

Bonde, E.K. (1968). Survival of seedling of an alpine clover (*Trifolium nanum* Torr.). *Ecology* **49:** 1193-1195.

Chapin, F.S. (1980). The mineral nutrition of wild plants: A review. *Ecol. Syst*. **11:** 233-260.

Chauhan, R.S. (2004). Ecophysiology, agro-technology and trade of an endangered medicinal herb *Nardostachys jatamansi* DC. D. Phil. Thesis, HNB Garhwal University, Srinagar Garhwal.

Chauhan, R.S. and Nautiyal, M.C. (2005). Commercial viability of cultivation of an endangered medicinal herb *Nardostachys jatamansi* at three different agroclimatic zones. *Curr. Sci.* **89:** 1481-1488.

Chauhan, V.S. and Bhatt, J.C. (2000). Agriculture in Uttarakhand: From subsistence towards self-sufficiency. In: M.C. Sati and S.P. Sati (eds.), Uttarakhand Statehood: Dimensions of Development, pp. 168-180. Indus Pub. Co., New Delhi.

Cook, R.E. (1979). Patterns of juvenile mortality and recruitment in plants. In: O.T. Solbrig, S. Jain, G.B. Johnson, and P.H. Raven (eds.), Topics in Plant Population Biology. pp. 207-231. Columbia University Press New York.

Dhar, U. (2002). Conservation implication of plant endemism in high altitude Himalaya. *Curr. Sci.* **82**: 141-148.

Douglas, D.A. (1995). Seed germination, seedling demography, and growth of *Salix setchellina* on glacial river gravel bars in Alaska. *Can. J. Bot*. **73:** 673-679.

Kirtikar, K.R. and Basu, B.D. (1989). Indian Medicinal Plants, 2: 1307-1309, Lalit Mohan Basu, Allahabad.

Kullman, L. (1986). Demography of *Betula pubescans* sps. *tortuosa* sown in contrasting habitats close to the birch tree- limit in central Sweden. *Vegetatio* **65:** 13-20.

Manjkhola, S. and Dhar, U. (2002). Conservation and utilization of *Arnebia benthamii* (Wall.ex G. Don) Jonston–A high value Himalayan medicinal plant. *Curr. Sci.* **83:** 484-488.

Maruta, E. (1983). Growth and survival of current-year seedlings of *Polygonum cuspidatum* at the upper distribution limit on Mt. Fuji. *Oecologia* **60:** 316-320.

Mooney, H.A. and Johnson, A.W. (1965). Comparative physiological ecology of an arctic and alpine populations of *Thalictrun alpinum* L. *Ecology* **46:** 721-727.

Nautiyal, B.P., Prakash, V., Chauhan, R.S., Purohit, H. and Nautiyal, M.C. (2001). Assessment of germinability, productivity and cost benefit analysis of *Picrorhiza kurrooa* cultivated at lower altitude. *Curr. Sci.* **81**: 579-585.

Nautiyal, B.P., Chauhan, R.S., Prakash, V., Purohit, H. and Nautiyal, M.C. (2003). Population studies for the evaluation of germplasm and threat status of the alpine medicinal herb *Nardostachys jatamansi*. *Plant Genetic Resource News Lett.* **136:** 34-39.

Nautiyal, M.C. (2000). Medicinal plants: A resource for Uttarakhand. In*:* M.C. Sati and S.P. Sati (eds.), Uttarakhand Statehood: Dimensions of Development, pp. 302-312. Indus Pub. Co., New Delhi.

Nautiyal, M.C. and Nautiyal, B.P. (2004). Agrotechniques for high altitude Medicinal and Aromatic plants. Bishan Singh Mahendra Pal Singh, Dehradun.

Nautiyal, M.C., Prakash, V. and Nautiyal, B.P. (2002). Cultivation technique of some high altitude medicinal herbs. *Ann. For.* **10:** 62-67.

Nayar, M.P. and. Sastry, A.R.K. (1988). Red Data Book of Indian Plants. Vol. II. Botanical Survey of India, Calcutta.

Prakash, V. (1999). Indian Valerianaceae. Scientific Publishers, Jodhpur.

Rajasekaran, C., Kuniyal, C.P., Prasad, P. and Bhadula, S.K. (1998). Growth and ammonium assimilation in *Selinum veginatum* Clarke and *Glycine max* L., seedlings grown at different altitudes of Garhwal Himalaya, India. *Physiol. Mol. Biol. Plants* **4:** 33-37.

Snedecor, G.W. and Cochran, W.G. (1968). Statistical Methods (VI Edn.) Oxford and IBH Publishing Co., New Delhi.

Streng, D.R., Glizenstein, J.S. and Harcombe, P.A. (1989). Woody seedling dynamics in an east Texas floodplain forest. *Ecolo. Monograph* **59:** 177-204.