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High-yielding provenances of bhimal (*Grewia optiva*) for fodder and fuelwood production in north-western Himalayas

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ABSTRACT

Provenance evaluation of bhimal (*Grewia optia* J R Drumm. ex Burret) was initiated in 1995 with respect to growth and productivity parameters for assessing genetic variations and identifying the most productive provenances which could be recommended in prevailing agroforestry systems. The materials comprised seven provenances of *G. optiva* collected from different locations of the northern states of Uttarakhand and Himachal Pradesh and planted in complete randomized block design with three replications. The data were recorded for growth and productivity parameters for 10 years. Significant variations were recorded for growth and productivity parameters. The highest fresh fodder productivity recorded in I C Malas 3.57 tonnes/ha, statistically at par with I C Bhaintan 3.49±0.04 tonnes/ha) was 1.21 times more than the least productive provenance I C Nauni. However, in respect of dry weight of debarked fuelwood and dry weight of bark fibre, I C Bhaintan produced 0.71 and 0.37 tonnes/ha biomass, which was 1.80 and 2.0 times higher than the least productive provenance (I C Tachla). The ranking of provenances based on the cumulative score of growth and productivity parameters indicated that I C Malas was the most productive provenance, followed by I C Bhaintan. These elite provenances (I C Bhaintan, I C Malas and I C Chamba) were multiplied in 2006 in a polyhouse and planted under different agroforestry systems on the farmers' fields at different elevations in the lower and middle Himalayas of Uttarakhand, as part of multi-location testing.

Key words: Fodder productivity, Elite provenances, Genetic variation, *Grewia optiva*, Growth parameters

Bhimal (*Grewia optiva* Drummond J R ex Burret) is a medium sized multipurpose tree (MPT) species growing in sub-tropical climates of north-western Himalayas and belongs to the family Tiliaceae. It is the most important fodder species of the lower and middle Himalayas, generally raised on terrace risers for its nutritious fodder (Semwal *et al.* 2002). It is fairly well distributed in the Western Himalayas up to middle elevations (500–2 500 masl) in India, Pakistan and Nepal. Hilly farmers of the north-western states of India (Jammu and Kashmir, Himachal Pradesh and Uttrakhand) and Central Nepal are dependent on its lopped fodder to a great extent (Verma and Mishra 2000). Other MPTs like *Celtis australis, Quercus* sp., *Bauhinia variegata, Dalbergia sissoo, Toona ciliata* and *Bombax ceiba* etc. are also retained on field bunds/risers by the farmers as an common age-old practice (Singh *et al.* 2006). However, the scarcity of fodder and fuelwood is widespread and on the rise due to rising human and animal population affecting seriously living conditions of rural people (Singh 1987).

The subsistence of livestock on *G. optiva*-based lopped tree fodder is quite crucial as it provides nutritious fodder during the lean season in winter (December to February) when no other fodder is available (Singh 1982). Its bark is used for extracting fibre, which is used for making paper, ropes, bags, wallets and other fancy items. The mucilage of bark fibres is used as indigenous hair shampoo by native women. Wood is tough and elastic and is used for making oar shafts and tool handles. The debarked branches and twigs are used as fuelwood and torch by villagers during the rainy season when common fuelwood sources get wet due to all round high moisture and find it difficult to cook their food on earthen hearths. They are largely dependent on this fuelwood as it easily catches fire and is a traditional substitute of LPG (liquid petroleum gas). It is drought and frost hardy species and comes up well even on the degraded sites like bouldery riverbed lands in silvipastoral system (Singh *et al.* 1982).

Till date no emphasis has been given to the use of high

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quality seed source for forestry plantations and characterizing the productivity of provenances obtained from different geographical areas. Generally, the seeds are collected from crooked trees, which are easy to climb or swept from the forest floor. Most of the genecological studies comprising provenance trials have been conducted in temperate forest regions of Europe and North Africa with fewer published studies of tropical or boreal species (Aitken 2004, Durga and Mollet 1977). Therefore, the present investigations were undertaken with a view to identify the most suitable and productive provenances of *G. optiva* with desirable specific traits (fodder, fuelwood and bast fibre) for agroforestry systems being practised in the north-western Himalayas. The paper describes the results of growth an productivity parameters recorded in a collection of *G. optiva* provenances for 10 years.

MATERIALS AND METHODS

The study was conducted from 1995 to 2004 at the Central Soil and Water Conservation Research and Training Institute (CSWCRTI) Research Farm, Selakui, Dehradun, Uttarakhand (India) situated 16 km North West of district Dehradun on Dehradun-Chakrata Highway in Doon valley at latitude/longitude of 30°19'N/78°02'E and at an altitude of 683 m asl. Soils are derived from heavy textured and very deep alluvium with yellowish brown to dark yellowish brown in colour. The soil of the experimental field belonged to Dhoolkot series; it was fine silty mixed hypothermic udic Haplustalf, slightly acidic (*p*H 6.4) with permanent wilting point (PWP) 10.8, field capacity (FC) 25.9, organic carbon (%) 0.62, total N (%) 0.062; available P_2O_5 (kg/ha) 29.00 and available K_2O (kg/ha) 201 (Table 1).

Table 1 Characteristics of soil at the study site at Selakui, Dehradun

Soil characteristics	Soil depth (cm)		
	0–15	15–30	>30
*p*H	6.8	6.3	6.1
Organic carbon (%)	0.868	0.519	0.490
Total N (%)	0.094	0.065	0.043
Available P_2O_5 (kg/ha)	55.14	25.97	5.81
Available K_2O (kg/ha)	225.45	145.15	232.85
Zn	2.42	2.18	1.24
Mn	39.2	26.2	20.7
B	0.54	0.43	0.27
Cu	3.30	2.26	1.51
Mo	0.085	0.065	0.027
Fe	16.07	11.17	7.98
Cl	809.5	727.5	748.8
Dispersion ratio	20.08	12.03	13.35

Soil contains medium to high quantities of all macro and micronutrients under study except boron which is low

Meteorological parameters of the site averaged during the study period (1995–2004) are presented in Table 1 along with 48 years average (1956–2004). It is observed that 80% of the rainfall is received during July–September with the onset of north-western monsoon on 29 June. The number of rainy days during the period of study was 76 in rainy season. There are wide variations in mean maximum and mean minimum temperature. During winter mean maximum temperature ranged from 18.4°C to 26.4°C while in peak summer, mean maximum temperature is as high as 36.9°C and 34.7°C associated with acute moisture stress in May and June, respectively. The perusal of Table 2 also indicated that there

Table 2 Average climatological parameters at Dehradun (S C Farm, Selakui) during 1995–2004 and 1956–2004 (in brackets)

Month	Rainfall (mm)	No. of rainy days	Mean temperature (ºC)		Wind velocity (km/hr)	Relative humidity (%)		Evaporation (mm/day)	Bright sunshine hours (hr/day)
			Max	Min		719 (hr)	1 419 (hr)		
January	48.40 (53.2)	4 (5)	19.3 (18.4)	4.5 (4.3)	0.8 (1.2)	95 (97)	51 (46)	1.1 (1.2)	6.0 (6.3)
February	56.7 (54.6)	4 (4)	22.0 (22.1)	6.4 (6.1)	1.0 (1.4)	94 (95)	47 (45)	1.7 (1.9)	7.1 (7.3)
March	42.5 (61.0)	3 (3)	27.4 (28.0)	9.7 (9.5)	1.4 (1.9)	92 (90)	39 (37)	3.1 (3.4)	8.0 (8.2)
April	28.2 (24.7)	2 (3)	33.7 (34.2)	13.9 (13.3)	1.8 (1.9)	78 (66)	27 (23)	5.3 (5.4)	9.2 (9.1)
May	46.6 (49.1)	3 (4)	36.9 (36.9)	18.8 (18.1)	1.9 (2.2)	69 (67)	30 (29)	7.0 (7.4)	9.5 (9.4)
June	180.1 (188.4)	10 (10)	34.7 (34.7)	22.4 (21.8)	1.5 (1.9)	81 (80)	53 (51)	5.0 (5.3)	7.3 (7.3)
July	486.1 (453.1)	16 (16)	31.5 (34.9)	24.4 (23.6)	0.7 (1.7)	94 (93)	76 (75)	2.9 (3.0)	4.8 (5.0)
August	414.4 (430.8)	19 (18)	31.0 (30.90	23.8 (24.0))	0.6 (1.0)	96 (95)	79 (77)	2.5 (2.6)	4.2 (4.8)
September	173.3 (182.8)	8 (9)	31.0 (30.7)	21.9 (21.2)	0.6 (0.8)	95 (95)	69 (69)	2.8 (2.9)	6.6 (7.0)
October	43.4 (35.3)	2 (2)	30.3 (30.5)	15.0 (13.9)	0.4 (0.6)	94 (95)	53 (51)	2.5 (2.6)	8.4 (8.8)
November	3.8 (6.1)	4 (1)	26.6 (26.4)	8.6 (7.8)	0.4 (0.6)	95 (95)	46 (45)	1.6 (1.7)	7.7 (8.0)
December	13.8 (18.3)	1 (2)	22.5 (22.1)	5.4 (4.5)	0.5 (0.9)	95 (96)	48 (47)	1.1 (1.2)	6.5 (6.9)
Average	1537.3 (1557.4)		28.9 (29.1)	14.6 (14.0)	0.96 (1.30)	89 (88)	51 (49)	3.0 (3.2)	7.1 (7.3)

was 0.6°C rise in the average minimum temperature during the study period. The decade 1995–2004 also witnessed fall in total rainfall to the extent of 20.1 in comparison to last 48 years average, which could be attributed to general trend of climate change being experienced throughout the world (Barnett *et al.* 2005).

Provenance field studies comprising seven indigenous collections (ICs) of *G. optiva* were initiated in 1995. The provenances were collected from different geographical areas of north-western Himalayas with contrasting physical and edaphic features mentioned in Table 3. Nine-month-old seedlings of seven provenances were raised in randomized complete block design with three replications. Each plot comprised 15 plants of each provenance at a spacing of 3 m × 3 m.

The data were recorded on growth parameters, viz collar diameter, plant height, diameter at breast height, crown length, crown width, number of branches and bole diameter on 10 plants at the time of planting in 1995 to 2004 at yearly intervals in November-December. Diameter of stem was measured with a measuring tape 1 cm above the stem/root junction. Plant height was measured from ground level to the highest point on tree with a graduated meter scale. Crown length was measured with the metered scale from the point where the first crown branch originated to the highest point of sapling/tree while crown width was recorded as the largest distance between two branches at opposite ends. Number of branches was counted above the ground level by direct counting.

Productivity traits, viz lopped fodder (fresh and dry), dry weight of debarked fuelwood and dry weight of bark fibre were determined in 2001 when first lopping treatment was imposed till 2004. Leaf litter production was monitored using polyethylene litter traps (50 cm × 50 cm) at the base of each tree and collected at monthly intervals, stored in paper bags and oven dried at 60°C for 24 hr before weighing. Leaf litter production was averaged over 12 months.

In 2001 (five years after initial plantation in 1995), five trees per experimental unit were marked and lopped for estimation of lopped fresh fodder weight (lopped fodder included leaves and the edible twigs consumed by the cattle), dry fodder weight, dry weight of bark fibre and dry weight of debarked fuelwood. Leaf and wood samples of each provenance were dried in an oven at 65°C for 72 hr for biomass weight determination and weighed on top pan balance.

The data was subjected to the analysis of variance using SPAR 1 package. The overall evaluation of provenances was calculated as sum of ranks obtained by each provenance for each attribute (growth and productivity parameters) divided by the sum of ranks obtained by all provenances tested.

RESULTS AND DISCUSSION

Genetically superior planting stock is necessary along with standardized silvicultural practices for increasing productivity of agroforestry plantations (Zobel and Talbert 1984). Results indicated substantial genetic variation among provenances in respect of growth parameters and productivity traits studied during 1995–2004.

Growth parameters plant height, collar diameter/diameter at breast height, crown length, crown width, number of branches

Significant differences were observed among provenances for plant height (PH), collar diameter/diameter at breast height (CD/DBH), crown length (CL), crown width (CW) and number of branches/plant (NB) ($P< 0.05$) in 2004 after ten years of planting (Table 4). The initial *P*H, CD, DBH,

Table 3 Physical and edaphic features of locations from where provenances were collected

Provenance	Elevation (masl)	Soil type/series
I C Bhaintan	1 225	Moderately gravelly, non-calcareous, medium textured, deep to very deep. Well-drained with moderate permeability, *p*H 7.7 in all soil horizons
I C Chamba	1 500	Silty clay to silty clay loam in texture. Soil depth upto 2 m with soil *p*H 5.5 to 5.6
I C Malas	1 450	Slightly to moderately gravelly, non-calcareous, medium-textured and very deep soils derived from shale and colluvium of varying depths. Well-drained with moderate permeability, *p*H decreasing with profile depth 6.7 – 6.3
I C Katkor	1 550	Moderate to very gravelly, stony, non-calcareous, medium-textured, moderate deep soils derived from slate, fine sand stone, quartzite conglomerate and their colluvium of varying depths, soil occurs on steep slopes at higher altitudes. Well-drained soil with moderate permeability with *p*H 5.0 to 5.4
I C Nauni	1 250	Sandy loam, moderately deep to deep with coarse medium texture admixtured with gravels and pebbles. Parent material comprising ferro-magnesium shales and dolomitic limestones with soil *p*H ranging from 6.5 to 7.2
I C Naur	1 350	Slight to moderate gravelly. Moderate deep, stony quartzite conglomeration
I C Tachla	1 300	Rocky with sand stone, quartzite, hard shale and occurs on steep slope

CL and CW averaged over all provenances were 2.72 m, 3.98 cm, 1.51 cm, 2.3 m and 2.34 m, respectively after one year of planting, which increased to 5.67 m, 13.13 cm, 4.60 cm, 4.08 m and 2.93 m, respectively after 10 years. Maximum plant height was recorded in I C Tachla (6.22 m), followed by I C Malas (5.86 m) and I C Nauni (5.65 m). Similar trend was recorded for DBH. The current annual increment (CAI) and mean annual increments (MAI) were worked out for each provenance in response of collar diameter and plant height, which showed narrow range of variability with respect to these parameters (Figs 1, 2). The ratio of crown width: bole diameter (which is a desirable attribute of an ideal agroforestry ideotype) was minimum for I C Bhaintan (58.0), followed by I C Malas (59.0) and I C Chamba (62.0). The range of number of branches was 22–33 in 1995 with an average of 27 and after ten years, the range varied from 18–26 with an average of 18 branches. I C Malas had the highest number of branches (26), followed by I C Tachla (24) and I C Bhaintain (21) in the final year (2004). Theses results are in consistence with the earlier studies on *G. optiva* (Sehgal *et al.* 2003), *Calliandra calothyrus* (Dugma and Mollet 1997).

Further, in an ideal agroforestry plant ideotype, branches should be uniformly distributed as much as possible with minimum spreading habit so as to cause minimum possible shading to the intercrop since small and marginal farmers can hardly afford to loose grains primarily meant for their own subsistence. Crown width was the narrowest with respect to I C Bhaintan (2.75 m) and I C Chamba (2.78 m), while I C Tachla (3.19 m) on the other extreme had the maximum spreading habit making it unsuitable for agroforestry systems in view of its pronounced shading effect for field crops.

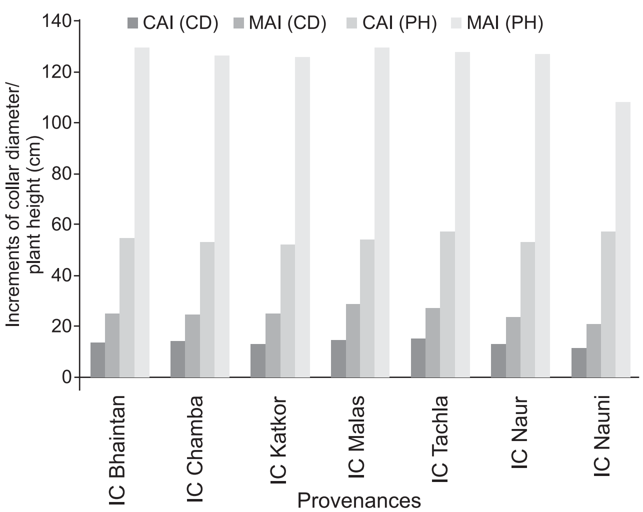

Fig 1 Current annual and mean annual increments of collar diameter and plant height in different provenances of *Grewia optiva* 1995–2004

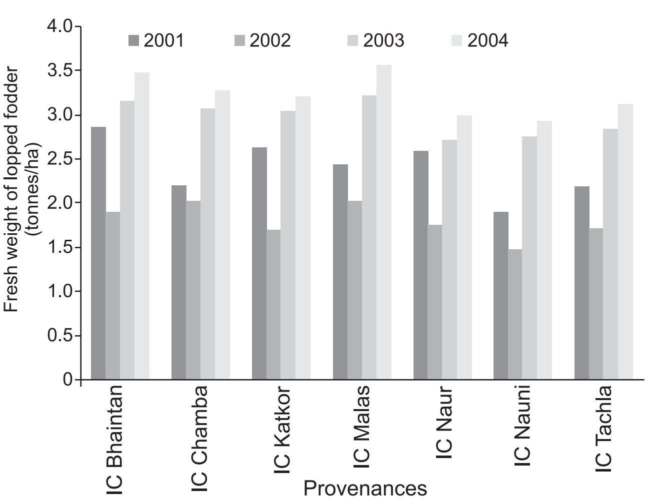

Fig 2 Fresh weight of lopped fodder in *Grewia optiva* during 2001–04

Productivity parameters: Fresh weight of lopped fodder, dry weight of lopped fodder, debarked fuel wood and bark fibre, litter fall

The species is primarily grown for its nutritious leaf fodder and wide variations in leaves plus edible twigs (1.49– 3.57 tonnes/ha) were detected for this parameter (Fig 2). The fresh fodder weight of I C Malas (3.57 tonnes/ha) was 1.21 times higher than the least productive provenance I C Nauni. Semwal *et al.* 2002 reported tree fodder productivity of 1.58 tonnes/ha (3 m × 3 m spacing) after six years. Dry fodder yield ranged between 0.75 and 1.4 tonnes/ha as trial average for 2001–04, respectively (Table 5) in comparison to the highest value of 0.80 tonne/ha reported by Vishwanatham *et al.* (1999). Such differences could be primarily attributed to the site conditions and physico-chemical properties of soil where these trials have been conducted as well as different germ plasm materials. Earlier studies have been conducted on gravelly flood plains and the marginal lands of Doon valley (Singh *et al.* 2008), while the present studies have evaluated the maximum genetic potential of the provenances under good fertility conditions. This allowed the immediate selection of superior provenances and individuals within a provenance. Similarly, the dry weight of debarked fuelwood was the highest in I C Bhaintan at 0.71±0.087 tonnes/ha (Table 5) which was 1.81 times higher than the lowest productive provenance I C Tachla at 0.39 tonnes/ha. I C Bhaintan proved to be the best provenance for fibre extraction at 0.37 tonnes/ha, which was two times higher than I C Tachla. The range of litter fall was 6.82 to 5.29 tonnes/ha for I C Malas and I C Nauni, respectively. I C Malas was closely followed by I C Bhaintan at 6.32 tonnes/ha (Table 4).

Phenological traits

The *G. optiva* provenances came to flowering after five years in 2000. The range of variation for fruit production

Table 4 Initial (1996) and final (2004) growth parameters and phenological traits of different *Grewia optiva* provenances

Provenances	Plant height (m)		Diameter at breast height (cm)		Crown length (m)		Crown width (m)		Branches plant		Crown width:bole diamter		1000 fruit weight (g)		Fruit production (g/tree)		Litter fall (tonnes/ha)	
	I_o	F_o	I_o	F_o	I_o	F_o	I_o	F_o	I_o	F_o	I_o	F_o	I_o	F_o	I_o	F_o	I_{97}	F_o
I C Bhaintan	2.62	5.63	1.46	4.74	2.27	4.11	2.22	2.75	32	21	1.53	58.0		104.4		682	6.83	6.32
I C Chamba	2.98	5.48	1.31	4.50	2.28	3.98	2.54	2.78	22	20	1.94	62.0		105.6		628	5.25	5.85
I C Katkor	3.03	5.33	1.49	4.30	2.31	3.81	2.35	2.99	24	21	1.56	70.7		100.1		622	5.00	5.77
I C Malas	2.86	5.86	1.61	4.87	2.65	4.30	2.56	2.86	31	26	1.59	59.0		101.7		658	6.13	6.82
I C Nauni	2.27	5.65	1.40	4.28	2.16	3.85	2.12	2.94	22	18	1.51	68.0		107.8		527	4.84	5.48
I C Naur	2.72	5.51	1.81	4.55	2.44	4.22	2.11	2.95	23	20	1.17	65.0		109.2		570	5.10	5.29
I C Tachla	2.59	6.22	1.53	4.99	2.36	4.30	2.46	3.19	33	24	1.61	66.0		106.8		5.38	6.00	6.27
X	2.72	5.67	1.51	4.60	2.35	4.08	2.34	2.93	27	21	1.56	64.0		105.0		603	5.59	5.97
S E (m)±	0.1	0.2	0.2	0.1	0.1	0.2	0.1	0.1	1.7	0.9	0.2	1.0		1.4		10.2	0.24	0.23
CD (*P* = 0.05)	0.4	0.6	0.5	0.5	0.4	0.5	0.4	0.2	5.3	2.7	0.6	3.0		4.4		31.4	0.73	0.71
CV	7.8	6.3	15.8	6.7	8.7	7.3	9.7	4.9	11.2	5.3	23.3			2.3		2.9	3.4	2.8

I, Initial; F, final

Table 5 Dry weight of lopped fodder (tonnes/ha), wood biomass and fibre yield (tonnes/ha) of different *Grewia optiva* provenances (2001–04)

Provenances	Dry weight of lopped fodder				Dry weight of debarked fuelwood				Dry weight of bark fibre			
	2001	2002	2003	2004	2001	2002	2003	2004	2001	2002	2003	2004
I C Bhaintan	1.35	0.80	1.35	1.54	1.18	0.90	0.66	0.71	0.41	0.48	0.38	0.37
I C Chamba	1.00	0.88	1.32	1.46	1.22	1.02	0.55	0.56	0.37	0.41	0.31	0.28
I C Katkor	0.99	0.71	1.28	1.36	1.01	0.92	0.50	0.56	0.33	0.37	0.27	0.24
I C Malas	0.95	0.83	1.35	1.54	1.57	1.02	0.54	0.58	0.56	0.34	0.30	0.29
I C Naur	1.00	0.72	1.10	1.25	1.04	0.86	0.57	0.46	0.36	0.40	0.26	0.23
I C Nauni	0.81	0.59	1.15	1.28	0.78	0.76	0.45	0.46	0.26	0.29	0.24	0.20
I C Tachla	0.88	0.71	1.19	1.38	0.94	0.86	0.40	0.39	0.32	0.32	0.22	0.19
X	1.00	0.75	1.25	1.40	1.11	0.91	0.52	0.53	0.37	0.37	0.28	0.26
S E (m)±	0.02	0.04	0.02	0.02	0.02	0.07	0.02	0.09	0.03	0.03	0.01	0.04
CD (0.05)	0.05	0.12	0.06	0.06	0.05	0.20	0.08	0.27	0.09	0.10	0.04	0.12
CV	3.09	9.33	2.92	2.83	2.66	12.62	8.44	2.84	2.58	15.80	8.40	2.72

Table 6 Correlation coefficients for different productivity parameters of *Grewia optiva* over the years

	2001–02	2001–03	2001–04	2002–03	2002–04	2003–04
Fresh weight of lopped fodder	0.15	0.47	0.50	0.51	0.65*	0.96**
Dry weight of lopped fodder	0.48	0.52	0.55	0.74**	0.77**	0.94**
Dry weight of bark fibre	0.30	0.55	0.62*	0.85**	0.83**	0.99**
Dry weight of barked fuelwood	0.78**	0.56	0.54	0.68*	0.67*	0.98**

was recorded from 527 to 682 in 2004 with an average of 603 fruits. Highest 1000 fruit weight was recorded in I C Naur and I C Nauni.

Correlation coefficients determined for different productivity parameters between years starting from 2001 (Table 6) indicated that fodder productivity in first year of lopping was poorly correlated with fodder productivity in subsequent years (2002, 2003 and 2004). However, fodder productivity levels of second year of lopping were strongly correlated with third and fourth year (*P* = 0.01). The correlation coefficients were quite stronger for third and fourth year (>0.90**) which indicated that the predictable comparative expression of genetic potential was noticeable after second year of lopping than first year. Lopping yield of first year was not a true reflection of genetic potential of a provenance as it is clubbed with genotype × year interaction effects accumulated over five years.

The overall ranking of *G. optiva* provenances was worked out on the basis of eight growth/phenological traits and five productivity parameters as overall rank sum index (ORSI) value. This index gives a single cumulative value with which provenances could be discriminated and the best provenances identified. ORSI index was the highest in case of I C Malas (0.21), followed by I C Bhaintan (0.20), thereby indicating that these are the best available provenances is respect of fodder productivity, fibre and fuelwood production. They also embody suitable ideotypes and are recommended to be adapted in agroforestry systems. The next best provenance was I C Chamba with a cumulative score of 0.14. Further, the provenances I C Bhaintan and I C Malas have higher fecundity (more number of fruits), which makes them easy to propagate through seedling.

Based on 10-year studies (1995–2004), ample genetic variation was observed among provenances for growth and productivity parameters. Three best provenances, viz I C Malas, I C Bhaintan and I C Chamba have been narrowed down, which adequately meet agroforestry requirements. These provenances can be used as the basic stocks for developing quality planting materials in clonal orchards. Progeny trials can be initiated by selecting superior 'plus' type trees within each of these provenances and intra provenance variation exploited.

In continuation of the present study, 1 200 saplings of these three best provenances were developed in a polyhouse during 2005–06 and one-year-old saplings were subjected to multi-location testing at four sites in the north-western Himalayas at diverse elevation in valley and hilly areas ranging from 515 m to 1 750 m asl. on farmers' fields under different agroforestry systems. Significant provenance × location interactions have been detected in 2008 and 2009 and it will be possible to develop location-specific technologies in respect of this agroforestry tree species.

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