



Growth and yield performance of ashwagandha (*Withania somnifera*) under agroforestry

N S THAKUR¹, K S VERMA² and R C RANA³

Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh 173 230

Received: 17 October 2012; Revised accepted: 30 April 2014

ABSTRACT

Investigations on effect of tree-crop combinations and nitrogen levels on growth, yield and withanolides content and yield of *Withania somnifera* L. Dunal were carried out during 2005-2006 and 2006-2007, in mid hills of Himachal Pradesh (India). *W. somnifera* was grown in association with *Prunus persica* (fruit), *Grewia optiva*, *Morus alba* (fodder) and *Setaria sphacelata* (grass). The distinctive tree-crop combinations (agroforestry systems) formed were Peach + *Grewia* + *Setaria* + *W. somnifera*, Peach + *Morus* + *Setaria* + *W. somnifera*, Peach + *Setaria* + *W. somnifera*, *Grewia* + *Setaria* + *W. somnifera*, *Morus* + *Setaria* + *W. somnifera* and *W. somnifera* as sole crop. Three nitrogen doses, viz. 40, 80 and 120 kg/ha were applied to *W. somnifera*. The plant height and leaf area of ashwagandha plants was not affected by tree-crop combinations. The nitrogen dose of 120 kg/ha resulted in maximum height (44.55 cm) and leaf area (17.76 cm²/leaf). Leaf area index was maximum (0.97) for plants grown in association with Peach+*Grewia*+*Setaria*. Belowground, aboveground and total biomass yield was not affected significantly by various tree-crop combinations. It ranged from 3.23 to 3.91, 2.30 to 2.63 and 5.53 to 6.46 q/ha, respectively. The N dose 120 kg/ha gave significantly higher below, aboveground and total biomass yield to the tune of 5.23, 3.37 and 8.60 q/ha, respectively. Withanolide content in roots varied from 0.73 to 0.79 per cent but was not affected due to different tree-crop combinations and nitrogen doses.

Key words: Agroforestry, *Grewia*, Nitrogen, Peach, *Withania*

Withania somnifera L. Dunal (Family Solanaceae), vernacularly known as Ashwagandha or Indian Ginseng, is one of the important component of geriatric tonics mentioned in Indian system of medicine. Plant is a source of various withanolides (Kumar *et al.* 2004), which are the most important bioactive constituents of roots. Roots, seeds and leaves of ashwagandha are used in Ayurveda and Unani system of medicine for various ailments, as general tonic, in herbal tea, and syrups (Vaidyaratnam 1994, Charak Samhita 1997). Ashwagandha has been included in the prioritized list of 32 medicinal plants (Herbs in India, NABARD publication). It grows in dry tropical parts of the country. In Madhya Pradesh alone, it is cultivated in more than 5000 hectares. The estimated production of ashwagandha roots in India is more than 1500 tonnes and annual requirement is about 7000 tonnes. National Medicinal Plants Board of India (New Delhi) estimated annual demand of ashwagandha roots in 2001-2002 to 7028.7 tonnes, which was expected to go up to 9127.5 tonnes by 2004-2005 at an annual growth rate of 9.1 per cent, which might have increased manifolds till now at projected growth rate. Singh

and Parabha (2003) have estimated 229 tonnes consumption of Ashwagandha roots by 63 per cent pharmacies in Gujarat state alone, which is met from naturally growing plants. Thus, to narrow the widening gap between demand and supply the need of the hour is to increase commercial cultivation. For the large scale farming, one has to find out whether monoculture is the right way to cultivate all medicinal plants or one has to promote polyculture model for better production of medicinal plants. Since many medicinal plant species prefer to grow under forest cover, agroforestry offers a convenient strategy for their cultivation as well as conservation (Rao *et al.* 2004). The present investigations were carried out to study the effect of agroforestry and varying levels of nitrogen on growth, biomass, root yield and withanolides content in *W. somnifera*.

MATERIALS AND METHODS

The investigations were carried out at experimental farm of Dr Y S Parmar University of Horticulture and Forestry, Nauni Solan, Himachal Pradesh, located within 30°51' N latitude and 76°11' E longitude at an elevation of 1250 m above mean sea level. The climate is transitional between subtropical to sub-temperate with maximum temperature rising up to 37.8°C during summer. The mean annual temperature is 19.8°C. The annual rain fall ranges between 800-1300 mm.

¹e mail: drnsthakur74@gmail.com, ²Professor and Head, Department of Environmental Sciences, ASPEE College of Horticulture and Forestry, Navsari Agricultural University, Navsari, Gujarat 396 450, ³Professor and Head, Department of Forest Products

Table 1 Details of area occupancy and magnitude of different components (per hectare) of various tree-crop combinations

Tree-crop combinations		Spacing		No. of trees/ha	Land area under trees/grasses (m ²)	Land area for intercropping MAPs (m ²)
T ₁	(Peach + Grewia + Setaria + <i>W. somnifera</i>)	Peach	5 × 10 m	200	2 000	8 000
		Grewia	1 × 10 m (3 trees in between 2 trees of peach)	600		
		Setaria	Planted in blocks (400 m ²) on strip for trees			
T ₂	(Peach + Morus + Setaria + <i>W. somnifera</i>)	Peach	5 × 10 m	200	2 000	8 000
		Morus	1 × 10 m (3 trees in between two trees of peach)	600		
		Setaria	Planted in blocks (400 m ²) on strip for trees			
T ₃	(Peach + Setaria + <i>W. somnifera</i>)	Peach	5 × 10 m	200	2 000	8 000
		Setaria	Planted in blocks (1200 m ²) on strip for trees			
T ₄	(Grewia + Staria + <i>W. somnifera</i>)	Grewia	1 × 10 m	1000	2 000	8 000
		Setaria	Planted in blocks (1000 m ²) on strip for trees			
T ₅	(Morus + Setaria + <i>W. somnifera</i>)	Morus	1 × 10 m	1000	2 000	8 000
		Setaria	Planted in blocks (1000 m ²) on strip for trees			
T ₆	(<i>W. somnifera</i> sole)					8 000

The surface soil was high in organic carbon (1.01%), medium in nitrogen (457.70 kg/ha), high in available phosphorus (31.50 kg/ha) and available potassium (354.20 kg/ha). It has pH of about 7. The agroforestry systems were established in 2002 by planting *Prunus persica* (L.) (fruit), *Morus alba* (Perr.) Loudon and *Grewia optiva* Drumm. (fodder) and *Setaria sphacelata* (Schumach.) Stapf & C.E.Hubb. ex M.B.Moss (grass), planted in row planting geometry in East to West direction during 1992, 2001 and 2002, respectively. The *W. somnifera* was cultivated at 30×30 cm spacing (transplanted in July) between the tree and grass component. Treatment consisted of six tree-crop combination (Table 1) and three nitrogen doses: 40 (N₄₀), 80 (N₈₀) and 120 (N₁₂₀) kg/ha. Details of area occupancy and magnitude of different components under different tree-crop combinations have been given in Table 1. The experiment was laid out in randomized block design with each treatment replicated thrice. Necessary cultural practices were carried out to raise the intercrop and maintain the fruit and fodder components of agroforestry systems. The data was collected from three plots of 1×1 m² for all the treatments and replications. The leaf area of fully extended leaf of ashwagandha was measured using pre-calibrated portable

leaf area meter (CI-203, INC. USA), leaf area index (LAI) was measured with the help of pre-calibrated, pre-programmed LAI-2000 plant canopy analyzer (LICOR-USA). Ashwagandha yield (above and below ground) was recorded at full bloom stage. Fresh weight was recorded immediately after harvesting. Dry biomass yield (leaves, stems and roots) of ashwagandha was obtained after drying it in shade to a constant weight. Total withanolides in roots of *W. somnifera* were estimated using colorimetric method (Mishra 1994). The tree height, diameter, basal area and crown area were measured using Ravimultimeter and measuring tape.

The data generated were analyzed statistically using the technique of analysis of variance for factorial randomized design in accordance with the procedure outlined by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Different tree-crop combinations had no significant effect on plant height of *W. somnifera* (Table 3). But it was influenced significantly by varying levels of N. Application of N dose of 120 kg/ha produced the tallest plants (44.55 cm) whereas, 40 kg N/ha produced the shortest (44.55 cm)

Table 2 Growth attributes of fruit and fodder tree under *Withania somnifera* based tree-crop combinations

Tree-crop combinations	Peach			<i>Grewia optiva</i>			<i>Morus alba</i>		
	Average height (m)	Average diameter* (cm)	Average crown area (m ²)	Average height (m)	Average DBH (cm)	Average crown area (m ²)	Average height (m)	Average DBH (cm)	Average crown area (m ²)
T ₁ (P+G+S+ <i>W. somnifera</i>)	3.68	12.00	7.13	3.76	4.65	2.87			
T ₂ (P+M+S+ <i>W. somnifera</i>)	4.08	15.96	13.55				4.69	6.17	5.84
T ₃ (P+S+ <i>W. somnifera</i>)	3.76	17.38	13.89						
T ₄ (G+S+ <i>W. somnifera</i>)				3.32	4.90	3.41			
T ₅ (M+S+ <i>W. somnifera</i>)							5.08	6.90	7.48
T ₆ (<i>W. somnifera</i>)									

* 5cm above the graft union, N= Nitrogen, P = Peach, G = *Grewia optiva*, M = *Morus alba*, S = *Setaria sphacelata*

Table 3 Effect of tree-crop combinations and nitrogen levels on plant height, leaf area and leaf area index (LAI) of *Withania somnifera*

Tree-crop combinations	Plant height (cm)				Leaf area (cm ² /Leaf)				LAI			
	N ₄₀	N ₈₀	N ₁₂₀	Mean	N ₄₀	N ₈₀	N ₁₂₀	Mean	N ₄₀	N ₈₀	N ₁₂₀	Mean
T ₁ (P+G+S+W. <i>somnifera</i>)	30.17	38.02	46.42	38.21	13.91	16.66	17.68	16.08	0.89	0.97	1.04	0.97
T ₂ (P+M+S+ W. <i>somnifera</i>)	26.64	40.46	43.26	36.79	13.74	16.29	18.14	16.02	0.84	0.93	0.92	0.93
T ₃ (P+S+ W. <i>somnifera</i>)	28.34	38.90	44.33	37.19	14.01	16.13	17.50	15.88	0.86	0.90	0.99	0.92
T ₄ (G+S+ W. <i>somnifera</i>)	29.36	38.02	42.75	36.71	13.58	15.75	17.66	15.66	0.88	0.94	1.02	0.95
T ₅ (M+S+ W. <i>somnifera</i>)	29.09	36.77	45.54	37.13	14.19	15.98	17.30	15.82	0.88	0.97	1.02	0.96
T ₆ (W. <i>somnifera</i>)	29.61	38.35	44.35	37.65	13.13	15.32	18.26	15.57	0.87	0.93	1.01	0.93
Mean	28.87	38.42	44.55		13.76	16.02	17.76		0.87	0.93	1.01	
CD (P = 0.05)												
T			NS				NS					0.03
N			1.32				0.28					0.02
T × N			NS				0.68					NS

N= Nitrogen, P = Peach, G = *Grewia optiva*, M = *Morus alba*, S = *Setaria sphacelata*

plants. The interaction between tree-crop combinations and N levels was statistically non-significant.

Leaf area experienced a non-significant effect due to tree-crop combinations (Table 3). Application of different N levels significantly influenced the leaf area. The highest N dose (120 kg/ha) produced plants with maximum leaf area (17.76 cm²/leaf) whereas, lowest dose of 40 kg N/ha produced plant with minimum leaf area (13.76 cm²/leaf). The interaction effect between tree-crop combinations and N levels on leaf area was significant.

Leaf area index (LAI) experienced a significant effect due to various tree-crop combinations (Table 3). It was highest (0.97) in tree-crop association Peach + *Grewia* + *Setaria*. N @ 120 kg/ha gave significantly maximum LAI (1.01) over N 40 kg (0.87) and N 80 kg/ha (0.93). Interaction effect due to various tree-crop combinations × N doses had no significant effect on LAI.

The growth parameters namely plant height, leaf area and leaf area index (LAI) were studied and had no significant effect on their growth except LAI, which had enhancing effect due to various tree crop combinations. On the other

hand various N levels increased the plant height. An application of 120 kg N/ha produced the tallest plants. Kaushal *et al.* (2002) while studying the response of N and P on growth of *W. somnifera* reported that the application of 15 kg N + 60 kg P₂O₅/ha produced the tallest plants. Application of rock phosphate along with dolomite recorded maximum plant height under acidic soils at Yercaud, Tamil Nadu (Muthumanickam *et al.* 2003). A progressive increase in leaf area was observed with increase in N levels. The application of 120 kg N/ha exhibited maximum leaf area. Kaushal *et al.* (2001) also reported increasing effect of N doses on leaf area of *W. somnifera*. Maximum leaf area was achieved in plants grown as sole crop supplied with 120 kg N/ha. It is inferred that plants grown with Peach + *Morus* + *Setaria* also exhibited almost equal leaf area as obtained for open grown crop. The findings are in line with Karikalan *et al.* (2002), Jha and Gupta (1991) and Dutt (2004).

The leaf area index (LAI) was higher for plants grown in association with Peach + *Grewia* + *Setaria*. An increasing effect of N doses was observed with maximum LAI at N level of 120 kg/ha nevertheless the LAI achieved in present

Table 4 Effect of tree-crop combinations and nitrogen levels on biomass yield of *Withania somnifera*

Tree-crop combinations	Biomass (q/ha)											
	Aboveground				Belowground				Total			
	N ₄₀	N ₈₀	N ₁₂₀	Mean	N ₄₀	N ₈₀	N ₁₂₀	Mean	N ₄₀	N ₈₀	N ₁₂₀	Mean
T ₁ (P+G+S+W. <i>somnifera</i>)	2.49	3.71	5.48	3.89	1.33	2.66	3.64	2.54	3.82	6.37	9.12	6.44
T ₂ (P+M+S+ W. <i>somnifera</i>)	2.36	3.62	5.46	3.81	1.48	2.78	3.63	2.63	3.84	6.40	9.09	6.44
T ₃ (P+S+ W. <i>somnifera</i>)	2.53	3.65	5.53	3.91	1.47	2.74	3.47	2.56	3.99	6.39	8.99	6.46
T ₄ (G+S+ W. <i>somnifera</i>)	2.30	3.47	5.27	3.68	1.61	2.60	3.32	2.51	3.91	6.07	8.60	6.20
T ₅ (M+S+ W. <i>somnifera</i>)	2.54	2.89	4.26	3.23	1.59	2.47	2.85	2.30	4.13	5.36	7.11	5.53
T ₆ (W. <i>somnifera</i>)	2.46	3.73	5.37	3.85	1.69	2.78	3.31	2.59	4.16	6.50	8.68	6.45
Mean	2.45	3.51	5.23		1.53	2.67	3.37		3.98	6.18	8.60	
CD (P = 0.05)												
T				NS				NS				NS
N				0.35				0.21				0.49
T × N				NS				NS				NS

N = Nitrogen, P = Peach, G = *Grewia optiva*, M = *Morus alba*, S = *Setaria sphacelata*

Table 5 Yield attributes of peach, Grewia, Morus and Setaria under Withania somnifera based tree-crop combinations (per hectare)

Tree-crop combinations	Peach			<i>Grewia optiva</i>		<i>Morus alba</i>			Setaria
	Fuelwood	Fruit	Fuelwood	Fodder yield		Fuelwood	Fodder yield		Grass
	yield	yield	yield	(q/ha)		yield	(q/ha)		yield
	(q/ha)	(q/ha)	(q/ha)	Fresh	Dry	(q/ha)	Fresh	Dry	(q/ha)
			weight	weight		weight	weight		
T ₁ (P+G+S+W. <i>somnifera</i>)	6.74	30.90	5.33	4.55	2.19				10.57
T ₂ (P+M+S+ W. <i>somnifera</i>)	10.20	31.54				7.52	18.56	6.74	11.97
T ₃ (P+S+ W. <i>somnifera</i>)	12.24	32.80							27.80
T ₄ (G+S+ W. <i>somnifera</i>)			11.10	7.40	3.70				23.55
T ₅ (M+S+ W. <i>somnifera</i>)						14.75	36.90	13.40	23.20
T ₆ (W. <i>somnifera</i>)									

N= Nitrogen, P = Peach, G = *Grewia optiva*, M = *Morus alba*, S = *Setaria sphacelata*

study was less than that obtained by Nigam *et al.* (1991) for improved varieties namely WS 20 without fertilizer application at Mandsour, Madhya Pradesh.

Different tree-crop combinations did not bear any significant effect on aboveground biomass yield (Table 4). Nitrogen doses had a significant effect on above ground biomass yield. Nitrogen dose of 120 kg/ha produced maximum above ground biomass yield (5.23 q/ha) and N level 40 kg/ha produced minimum (2.45 q/ha). The interaction effect between different tree-crop combinations and N doses was non-significant.

Various tree-crop combinations did not affect below ground biomass significantly (Table 4). The increasing levels of N increased the below ground biomass significantly. The highest N dose (120 kg N/ha) yielded maximum root biomass (3.37 q/ha) and lowest dose (40 kg N/ha) produced minimum root biomass. The interaction effect between tree-crop combination × N doses bore non-significant influence on root yield of *W. somnifera*.

Total biomass yield was not influenced significantly due to different tree-crop combinations (Table 4). But the N application of 120 kg/ha gave significantly higher total biomass yield (8.60 q/ha) whereas, N dose of 40 kg/ha produced minimum total biomass yield (3.98 q/ha). The interaction effect between tree-crop combination and N level was non-significant. The yield attributes namely above-below ground and total biomass was not influenced significantly due to various tree-crop combinations. However, the effect of different N levels exhibited an increasing trend on all the yield attributes. Above findings are however in contrast to the reports of Nigam (1984) and Nigam and Kandalkar (1986) wherein, they found that increasing levels of fertilizers had no effect on dry root yield on account of either the genotype or inadequate levels of fertilizers tried. Increasing and positive effect of fertilizers on biomass yield have been reported by many workers (Kaushal *et al.* 2002, Maheshwari *et al.* 2000, Muthumanickam and Balakrishnamurthy 1999). Furthermore, increased dose of N resulted in the higher aerial biomass which eventually increased the root yield in the present investigation. Thus, it can be inferred that growth attributes of *W. somnifera*, viz. plant height, leaf area and

leaf area index and above, -belowground biomass can be boosted with application of N with maximum respective values at 120 kg/ha, which however did not show optimum level. Nitrogen being responsible for stimulating vegetative growth in plants, above findings are in accordance with its role in plants. A significant increase in plant height at higher level of N application may also have occurred owing to medium status of soil nitrogen.

The withanolides content in roots ranged between 0.72-0.79% and was not influenced due to tree-crop combinations. The per cent withanolides estimated in the present investigation fall well within the range recorded by Muthumanickam and Balakrishnamurthy (1999), Patel *et al.* (2003), Ganzera *et al.* (2003), Kumar *et al.* (2001) and Ozguven and Sener (1992).

The yield attribute of fruit, fodder trees and setaria are given in Table 5. Tree-crop association Peach + Setaria yielded maximum (12.24 q/ha) fuel wood and fruit yield in Peach (32.80 q/ha) followed tree-crop association Peach + Morus + Setaria + *W. somnifera* and Peach + Grewia + Setaria + *W. somnifera*. In *Grewia optiva*, tree-crop combinations Grewia + Setaria gave maximum (11.10 q/ha) average dry fuel wood and fodder (7.40 q/ha fresh; 3.70 q/ha dry) yield followed by Peach + Grewia + Setaria + *W. somnifera*. Tree-crop association Morus + Setaria provided maximum (14.75 q/ha) fuel wood and fodder yield (36.90 fresh; 13.40 q/ha dry) followed by tree-crop combination Peach + Morus + Setaria + *W. somnifera*. The yield of Setaria grass was highest (27.80 q/ha) for tree-crop combination Peach + Setaria (Table 5).

CONCLUSIONS

The results of present findings showed that the variations in fodder, fuel wood, fruit yield and grass production under different tree-crop combinations was due to the difference in the magnitude of each component in respective combinations. The findings indicate that various tree-crop associations did not bore any significant effect on growth attributes, viz. plant height and leaf area whereas, maximum LAI was obtained for tree-crop combination Peach + Grewia + Setaria + *W. somnifera*. The growth and yield parameters achieved significantly higher values with

highest dose of N, i.e. 120 kg/ha. A positive and progressive increase in growth and biomass yield was recorded with the increase in N doses from 40 to 80 and 120 kg N/ha. Furthermore, the withanolides content in roots (%) did not vary significantly due to various agroforestry systems, nitrogen levels and their interaction effect. From the present investigations it can be concluded that *Withania somnifera* can be integrated under various tree-crop combinations without any effect on its growth, biomass yield and active constituent. All the tree-crop combinations were found equally suitable for integration of ashwagandha. Thus, medicinal plant based agroforestry systems besides catering the industrial demand for ashwagandha roots, leaves and seeds; can also address the diverse needs like, availability of quality fodder round the year for cattle, fruit, fuel wood, drugs for personal health care and socio-economic growth.

REFERENCES

- Charak Samhita. 1997. Chikitsa Sthana. Chowkhamaba Publishers, New Delhi 38 (English Edition).
- Dutt V. 2004. 'Screening of medicinal and aromatic plants for popular (*Populus deltoides* Marsh) based agroforestry system under sub-Himalayan conditions'. Ph D thesis, Dr Y S Parmar University of Horticulture and Forestry, Nauni, Solan, Himachal Pradesh.
- Ganzer M, Chaudhary M and Khan I A. 2003. Quantitative HPLC analysis of withanolides in *Withania somnifera*. *Fitoterapia* **74**: 68–76.
- Gomez K A and Gomez A A. 1984. *Statistical Procedures for Agricultural Research*. John Willey and Sons, New York., pp 89–107.
- Jha K K and Gupta C. 1991. Intercropping of medicinal plants with poplar and their phenology. *Indian Forester* **117**: 535–44.
- Karikalan T V, Yassin M M, Duvya M P and Gopi D. 2002. Effect of intercropping and nitrogen management on growth and yield of medicinal plants under Kapok. *Indian Journal of Agroforestry* **4**: 88–93.
- Kaushal S K, Kumar S and Upadhyay R G 2002. Response of nitrogen and phosphorus on growth, development and seed yield of ashwagandha (*Withania somnifera*) under mid hill conditions of Himachal Pradesh. *Research on Crops* **3**(2): 376–9.
- Khan I A and Khanum A. 2000. *Role of Biotechnology in Medicinal and Aromatic Plants*. Ukaaz Publications, Hyderabad.
- Kumar A, Ali M and Mir S R. 2004. A new withanolides from the roots of *Withania somnifera*. *Indian Journal of Chemistry* **43**(B): 2 001–3.
- Kumar A, Kaul B L and Verma H K. 2001. Phenological observations on root yield and chemical composition in different morphotypes of *Withania somnifera*. *Journal of Medicinal and Aromatic Plants Sciences* **23**: 21–3.
- Lacuna-Richman C. 2002. The socio-economic significance of subsistence non-wood forest products in Leyte, Philippines. *Environmental Conservation* **29**: 253–62.
- Lozoya X. 1994. *Ethnobotany and the Search of New Drugs*. John Wiley and Sons, England.
- Maheshwari S K, Sharma R K and Gandrade S K. 2000. Response of ashwagandha (*Withania somnifera*) to organic manures and fertilizers in shallow black soil under rainfed conditions. *Indian Journal of Agroforestry* **45**(1): 214–6.
- Kaushal M S K and Kaistha B P. 2001. Response of ashwagandha (*Withania somnifera*) to nitrogen fertilization under mid hill conditions of Himachal Pradesh. *Himachal Journal of Agricultural Research* **27**(1/2): 77–80.
- Mishra S N. 1994. Colorimetric method for estimation of total withanolides. 10th All India Workshop Report on Medicinal and Aromatic Plants held at Trichur, pp 379–81.
- Muthumanickam D, Murugesan and Sumaiyah. 2003. Effect of different phosphorus sources and soil amendments on yield and quality of aswagandha (*Withania somnifera* Dunal) under acidic soils. *Journal of Spices and Aromatic Crops* **11**(2): 118–21.
- Muthumanickam D and Balakrishnamurthy G. 1999. Studies on nutritional requirement for aswagandha (*Withania somnifera* Dunal) in Shevroy hills of Tamil Nadu, India. *Journal of Spices and Aromatic Crops* **8**(2): 179–83.
- Nigam K B and Kandalkar V S. 1986. Stability of performance in *Withania somnifera*. Paper presented at the symposium on Agriculture Development in Malwa and Nimar region of Madhya Pradesh, held during 19–20 November 1986 at Indore, pp 192–3.
- Nigam K B, Patidar H, Kandalkar V S and Pathan M A. 1991. Performance of WS 20, a new variety of ashwagandha (*Withania somnifera* Dunal). *Indian Journal of Agricultural Sciences* **61**(8): 581–2.
- Nigam K B. 1984. Ashwagandha cultivation. *Indian Horticulture* **28**(4): 39–41.
- Ozguven M and Sener B. 1992. Drug yield and withanolide contents of *Withania somnifera* L. Dunal cultivated in Turkey. *Acta Horticulturae* **306**: 219–28.
- Patel K V, Patel D H, Patel S A and Sriram S. 2003. Effect of seed rate and crop duration on root yield and quality of ashwagandha (*Withania somnifera*). *Journal of Medicinal and Aromatic Plant Sciences* **25**: 54–7.
- Rao M R, Palada M C and Becker B N. 2004. Medicinal and aromatic plants in agro-forestry systems. *Agroforestry Systems* **61**:107–22.
- Singh A P and Minoo Prabia. 2003. Status of medicinal plants consumption by the pharmaceutical industries in Gujarat state. *Indian Forester* **129** (2):198–212.