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

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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 Parabia (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.
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. & 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 (N 120) 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)
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 3 Effect of tree-crop combinations and nitrogen levels on plant height, leaf area and leaf area index (LAI) of Withania somnifera

<table>
<thead>
<tr>
<th>Tree-crop combinations</th>
<th>Plant height (cm)</th>
<th>Leaf area (cm²/Leaf)</th>
<th>LAI</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N₄₀</td>
<td>N₈₀</td>
<td>N₁₂₀</td>
</tr>
<tr>
<td>T₁ (P+G+S+W. somnifera)</td>
<td>30.17</td>
<td>38.02</td>
<td>46.42</td>
</tr>
<tr>
<td>T₂ (P+M+S+ W. somnifera)</td>
<td>26.64</td>
<td>40.46</td>
<td>43.26</td>
</tr>
<tr>
<td>T₃ (P+S+ W. somnifera)</td>
<td>28.34</td>
<td>38.90</td>
<td>44.33</td>
</tr>
<tr>
<td>T₄ (G+S+ W. somnifera)</td>
<td>29.36</td>
<td>38.02</td>
<td>42.75</td>
</tr>
<tr>
<td>T₅ (M+S+ W. somnifera)</td>
<td>29.09</td>
<td>36.77</td>
<td>45.54</td>
</tr>
<tr>
<td>T₆ (W. somnifera)</td>
<td>29.61</td>
<td>38.35</td>
<td>44.35</td>
</tr>
<tr>
<td>Mean</td>
<td>28.87</td>
<td>38.42</td>
<td>44.55</td>
</tr>
</tbody>
</table>

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

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

<table>
<thead>
<tr>
<th>Tree-crop combinations</th>
<th>Aboveground Biomass (q/ha)</th>
<th>Belowground Biomass (q/ha)</th>
<th>Total Biomass (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N₄₀</td>
<td>N₈₀</td>
<td>N₁₂₀</td>
</tr>
<tr>
<td>T₁ (P+G+S+W. somnifera)</td>
<td>2.49</td>
<td>3.71</td>
<td>5.48</td>
</tr>
<tr>
<td>T₂ (P+M+S+ W. somnifera)</td>
<td>2.36</td>
<td>3.62</td>
<td>5.46</td>
</tr>
<tr>
<td>T₃ (P+S+ W. somnifera)</td>
<td>2.53</td>
<td>3.65</td>
<td>5.53</td>
</tr>
<tr>
<td>T₄ (G+S+ W. somnifera)</td>
<td>2.30</td>
<td>3.47</td>
<td>5.27</td>
</tr>
<tr>
<td>T₅ (M+S+ W. somnifera)</td>
<td>2.54</td>
<td>2.89</td>
<td>4.26</td>
</tr>
<tr>
<td>T₆ (W. somnifera)</td>
<td>2.46</td>
<td>3.73</td>
<td>5.37</td>
</tr>
<tr>
<td>Mean</td>
<td>2.45</td>
<td>3.51</td>
<td>5.23</td>
</tr>
</tbody>
</table>

CD (P = 0.05)
T NS NS NS NS
N 0.35 0.21 0.49 NS
T × N NS NS NS NS

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 and N doses was non-significant.

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 fodder 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