

Productivity, quality and economics of rainfed ashwagandha (*Withania somnifera*) as influenced by spacing and fertilizer levels

V.S. KUBSAD¹, Y.B. PALLED AND C.P. MANSUR

Department of Agronomy, University of Agricultural Sciences, Dharwad, Karnataka 580 005

Received: December 2008

ABSTRACT

A field experiment was conducted at Annigeri (Karnataka) during *rabi* 2004-05 and 2005-06 to study the effect of 4 spacings (15 cm × 5 cm, 15 cm × 10 cm, 30 cm × 10 cm and 45 cm × 10 cm) and 4 N-P fertilizer levels (control, 12-10.6, 18-15.9 and 24-21.2 kg/ha) on performance of *ashwagandha* (*Withania somnifera* Dunal). The results indicated that dry root yield, nutrient uptake and total withanolide content were significantly higher at a spacing of 15 cm × 10 cm when compared with other spacings. At 15 cm × 10 cm spacing, the increase in dry root yield was 10.2, 54.9 and 107.4% over 15 cm × 5 cm, 30 cm × 10 cm and 45 cm × 10 cm respectively. Significant increase in dry root yield, nutrient uptake and total withanolide content was noticed with increase in fertilizer levels from control to 24-21.2 kg N-P/ha. Application of 24-21.2 and 18-15.9 kg N-P/ha, being comparable recorded significantly higher dry root yield, N and P uptake and total withanolide content than control and 12-10.6 kg N-P/ha. At 24-21.2 kg N-P/ha, the increase in dry root yield, N, P uptake and total withanolide content was 22.1, 51.5, 43.6 and 13.5% over control respectively. Further, there was remarkable improvement in root length, root diameter and dry root weight of *ashwagandha* which resulted in increase in dry root yield. Maximum dry root yield (1.55 t/ha), net returns (Rs 50,141/ha) and total withanolide content (0.62%) accrued when the crop was sown at 15 cm × 10 cm spacing along with fertilizer doze of 24-21.2 kg N-P/ha. Consequently, a spacing of 15 cm × 10 cm spacing along with fertilizer application of 24-21.2 kg N-P/ha was found optimum for *ashwagandha* in vertisols of Northern dry zone of Karnataka.

Key words : Economics, Fertilizer, Nutrient uptake, Roots, Spacing, Vertisols, *Withania somnifera*, Yield

Ashwagandha (*Withania somnifera* Dunal) is one of the important medicinal plants and used in the traditional Indian medicine since ancient times. The roots of *ashwagandha* are the economic part of the plant and are used in the preparation of Ayurvedic and Unani medicines. In US market, *ashwagandha* has recently acquired considerable significance on account of its large demand due to its reported male sex stimulating properties (Joshi *et al.*, 1981). The medicinal properties are mainly ascribed to total withanolides content (0.4-1.2%) that are present in roots of *ashwagandha* (Gupta *et al.*, 1996). It is cultivated over an area of 10,780 ha with a production of 8,429 tonnes (t) in India. While the annual demand increased from 7,028 t (2001-02) to 9,127 t (2004-05) necessitating the increase in its cultivation for higher production (Tripathi *et al.*, 1996). In rainfed areas, the productivity of traditional crops is at stake due to vagaries of weather and mono cropping. Cultivation of medicinal crops either in sequence / intercropping or as sole crops may help in sustaining the productivity and profitability of the farmers.

Ashwagandha being drought hardy plant, there exists good scope for its extensive cultivation in India under rainfed situation. The spacing and fertilizer are the important factors for maximization of yield and quality in any crop. A diversified response of *ashwagandha* to spacings (Maheshwari *et al.*, 2000) and fertilizer levels (Ajay *et al.*, 2005) were reported by different workers. In Karnataka, recently *ashwagandha* is being cultivated in medium to deep black soils of rainfed areas by conventional methods and the farmers are harvesting about 0.5 to 0.6 t/ha of dry root yield. The area is spreading every year due to its higher market price (about Rs.60,000/t) and the dry root yield could be increased with adoption of suitable production technologies. Considering the medicinal value of the crop, its increasing demand and meager scientific information on the cultivation of *ashwagandha*, the present investigation was undertaken to optimize the spacing and fertilizer level for Northern dry zone of Karnataka.

MATERIALS AND METHODS

A field experiment was conducted during *rabi* 2004-05 and 2005-06 at Agricultural Research Station, Annigeri

¹Corresponding author : (E mail: vskubsad@rediffmail.com)

(Karnataka) under rainfed conditions. The soil of the experimental site was vertisols with pH 8.1, low in available N (231.6 kg/ha), medium in available P (22.7 kg/ha) and high in K (468.1 kg/ha). The experiment was laid out in factorial randomized block design with 3 replications. There were 16 treatment combinations comprised of 4 spacings (15 cm × 5 cm, 15 cm × 10 cm, 30 cm × 10 cm and 45 cm × 10 cm) and 4 fertilizer levels (0, 12-10.6, 18-15.9 and 24-21.2 kg N-P/ha). The gross and net plot sizes were 5.4 m × 4.0 m and 2.7 m × 3.5 m respectively. The FYM @ 2 t/ha was applied and mixed well in soil 15 days prior to sowing. The seeds of *ashwagandha* 'Jawahar Asgandh 20' were treated with Bavistin @ 2 g/kg seeds against damping off (*Pythium aphanidermatum* Fitz) disease. The seed rate of 10.0, 5.0, 2.5 and 1.5 kg/ha were used at 15 cm × 5 cm, 15 cm × 10 cm, 30 cm × 10 cm and 45 cm × 10 cm spacing respectively. The crop was sown on 15 September during both years at different spacings and fertilized as per the treatment at sowing. The crop was thinned at 30 DAS to retain one seedling per hill. The total rains received during cropping period were 352.8 mm and 515.4 mm in 2004 and 2005 respectively. A heavy rainfall of 107.6 mm in 1 day was received during November 2005 which was a run off and did not affect the crop. However, the higher rainfall received during 2005-06 reflected in higher yield components and dry root yield compared to 2004-05. The crop was sprayed with monocrotophos @ 1 ml/l against aphids. The crop was harvested on 15 March (180 DAS) during both years. At harvest, 5 plants were randomly selected in each treatment for recording growth and yield parameters. These samples were oven dried at 70°C temperature, powdered and analysed for N and P concentrations following standard procedures and the total uptake was calculated. The total withanolide content (%) in roots were estimated by modified spectrophotometer method (Mishra, 1994). The plants from each net plot were uprooted and the roots and shoots were separated and sun dried for a week. The root yield was recorded and expressed in kg/ha. For working out the economics, prevailed market prices for *ashwagandha* seeds (Rs 50/kg), dry roots (Rs 40,000/t), urea (Rs 10.50/kg N), DAP (Rs 36.52/kg P) and cost of labour (Rs 40/day) were considered. The data were statistically analysed and the results of individual years and pooled analysis were presented.

RESULTS AND DISCUSSION

Dry root yield and yield attributes

The outcome of the investigation revealed that the dry root yield was higher at a closer spacing of 15 cm × 10 cm than 15 cm × 5 cm, 30 cm × 10 cm and 45 cm × 10

cm (Table 1). The magnitude of increase in dry root yield was up to the tune of 10.4, 56.8 and 105.9% as well as 9.9, 54.8 and 108.7% over 15 cm × 5 cm, 30 cm × 10 cm and 45 cm × 10 cm spacings in 2004-05 and 2005-06 respectively. The yield increment at closer spacing is attributed to improvement in root length and higher plant population per unit area compared to wider spacings. Saudan Singh *et al.* (2003) also reported 53.8 % higher root yield of *ashwagandha* at higher plant density when compared with lower plant density. Significantly the lowest dry root yield was recorded at wider spacing of 45 cm × 10 cm. The dry root yield was reduced by 0.71 and 0.75 t/ha in 45 cm × 10 cm over 15 cm × 10 cm during first and second year respectively (Table 1). While the performance of root diameter, fresh root weight and dry root weight per plant was superior under wider spacings which was mainly due to better resource availability and reduced interplant competition in the community.

There was linear and significant increase in dry root yield with increase in fertilizer levels from control to 24-21.2 kg N-P/ha. The increase in root yield was 23.9, 14.0, 0.9 and 20.4, 19.3, 1.7% higher over control, 12-10.6 and 18-15.9 kg N-P/ha during 2004-05 and 2005-06 respectively. Puttanna *et al.* (2005) also recommended 50-60-60 kg N-P-K/ha along with 10 t FYM/ha for the maximum root yield of *ashwagandha*. The higher dry root yield was mainly due to higher values of yield attributes like root length, root diameter and dry root weight compared to other fertilizer levels. The better performance of yield and yield attributes can be related to better growth of the plant brought about by adequate supply of nutrients when compared with lower fertilizer levels. However, the yield attributes and dry root yield were at par with 18-15.9 kg N-P/ha. In the absence of the fertilizer, the root yield and yield parameters were significantly reduced.

The crop responded to higher fertilizer levels with closer spacing of 15 cm × 10 cm when compared with others. The fertilizer level of 24-21.2 kg N-P/ha with a spacing of 15 cm × 10 cm resulted in the maximum dry root yield which was statistically at par with 18-15.9 kg N-P/ha with the same spacing (Table 3). The maximum root yield was mainly attributed to more number of plants/ha and more availability of N and P to the plants through fertilizers. Compared with no fertilizer treatment, the fertilizer level of 24-21.2 kg N-P/ha with spacings of 15 cm × 5 cm, 15 cm × 10 cm, 30 cm × 10 cm and 45 cm × 10 cm increased the dry root yield by 17.7, 19.6, 21.9 and 8.7% respectively. The fertilizer levels of 12-10.6, 18-15.9 and 24-21.2 kg N-P/ha with 15 cm × 10 cm spacing increased dry root yield by 8.0, 18.8 and 19.6% respectively over control plots.

Nutrient uptake

Maximum uptake of N and P by the crop was noticed at a spacing of 15 cm × 10 cm which was significantly higher than other spacings (Table 1). The highest dry root yield could be obtained when the crop removed maximum N and P at the spacing of 15 cm × 10 cm. The higher uptake of N and P can be related to higher dry root yield and higher total dry matter. The uptake of N and P increased with application of every additional unit of fertilizer from control to 24-21.2 kg N-P/ha. The increase in N uptake at 24-21.2 kg N-P/ha was to the extent of 51.5, 29.6, 1.3 and that of P uptake was 43.5, 23.9, 5.1 % over control, 12-10.6 and 18-15.9 kg N-P/ha respectively. The higher dry root yield was associated with maximum uptake through the application of 24-21.2 kg N-P/ha and was statistically at par with 18-15.9 kg N-P/ha. The increase in nutrient uptake may be related to higher N and P content, higher total dry matter production and higher dry root yield/ha which was due to availability of higher N and P to plants through fertilizers. Patel (2001) observed significantly higher uptake of N, P and K by *ashwagandha* at 75 kg N/ha compared to control. Further, it was observed that the P uptake by the crop was less than its application in all the treatments. This was due to higher content of CaCO₃ (170.5 g/kg) and exchangeable Ca+Mg (53.17 cmol/kg) in vertisols of experimental site which led to fixation of major quantity of applied P in the soil. Similar findings have been reported by Goroji (2000). Poor root growth and low dry matter production in control plot resulted in less uptake of nutrients. Similar trend was also observed with interaction effects.

Residual soil fertility

The availability of N was significantly lower at closer spacing of 15 cm × 5 cm when compared with wider spacing of 45 cm × 10 cm. This was mainly attributed to higher uptake of N by the crop which was due to more number of plants/ha at closer spacings. There was no significant treatment effects on available P due to different spacings (Table 1). The available N and P in soil increased with increase in N and P fertilizer levels from 12-10.6 to 24-21.2 kg N-P/ha. This was due to addition of N and P through fertilizers. However, the availability of N and P in soil in all the treatments was low at harvest when compared with initial nutrient status. This was mainly attributed to uptake of the nutrients by *ashwagandha*.

Quality of dry roots

The spacing of 15 cm × 10 and 30 cm × 10 cm, being comparable recorded significantly higher total withanolide content than 15 cm × 5 cm and 45 cm × 10 cm during both the seasons (Table 2). While significantly higher total withanolide content was noticed at a spacing of 15 cm × 10 cm compared to others. The magnitude of increase in total withanolide content was to the extent of 20.8, 58.8, 125.0 and 11.6, 60.4, 129.7% higher over 15 cm × 5 and 30 cm × 10 and 45 cm × 10 cm respectively during 2004-05 and 2005-06 (Table 2). A linear and significant increase was noticed in both the total withanolide content and total withanolide yield with increase in fertilizer levels from control to 24-21.2 kg N-P/ha during both the seasons. The total withanolide content was maximum at 24-21.2 kg N-P/ha which was 11.5 and 13.4% higher than

Table 1. Yield components, dry root yield, nutrient uptake of ashwagandha and residual soil fertility as influenced by spacing and fertilizer levels

Treatment	Root length (cm)		Root diameter (cm)		Dry root weight (g/plant)		Dry root yield (kg/ha)		Nutrient uptake* (kg/ha)		Residual soil fertility* (t/ha)	
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	N	P	N	P
Spacing (cm)												
15 × 5	46.4	46.0	0.99	0.97	2.40	2.26	1.25	1.31	76.4	12.5	186.2	17.1
15 × 10	48.5	48.6	0.93	0.89	3.04	2.46	1.38	1.44	115.9	19.5	180.8	17.5
30 × 10	45.3	45.9	1.00	0.99	3.33	3.36	0.88	0.93	76.5	10.0	191.1	16.5
45 × 10	46.7	46.8	1.03	1.01	3.28	3.38	0.67	0.69	51.4	8.2	196.1	17.3
SEm±	0.7	1.1	0.01	0.02	0.04	0.11	0.01	0.03	1.2	0.2	1.1	0.4
CD (P=0.05)	1.9	NS	0.03	0.05	0.12	0.31	0.03	0.08	3.5	0.6	3.4	NS
Fertilizer level (N-P kg/ha)												
Control	38.5	38.5	0.90	0.85	2.34	2.27	0.92	0.98	58.6	10.1	184.5	17.7
12-10.6	43.5	42.7	0.95	0.92	2.97	2.94	1.00	1.06	68.5	11.7	186.7	16.1
18-15.9	51.6	52.2	1.04	1.03	3.32	3.11	1.13	1.16	87.7	13.8	191.6	17.2
24-21.2	53.4	53.9	1.07	1.05	3.42	3.16	1.14	1.18	88.8	14.5	191.4	17.4
SEm±	0.8	1.2	0.01	0.02	0.05	0.12	0.02	0.04	1.3	0.2	1.1	0.4
CD (P=0.05)	2.3	3.1	0.03	0.06	0.14	0.34	0.05	0.11	3.7	0.6	3.3	1.1

*Mean of 2 years

control in 2004-05 and 2005-06 respectively. Thus indicated the direct and positive relationship between N and P nutrients and total withanolide content. Similar trend was observed with total withanolide yield (Table 2). The total withanolides content in roots of *ashwagandha* was significantly higher with spacing of 15 cm × 10 cm supplied with 24-21.2 kg N-P/ha over others except 15 cm × 10 cm with 18-15.9 kg N-P/ha, 30 cm × 10 cm with 18-15.9 kg N-P/ha and 30 cm × 10 cm with 24-21.2 kg N-P/ha with which it was on par (Table 3). The total withanolides being the products of nitrogen metabolism, the production of total withanolides is directly related to nitrogen supply to the plants. Thus higher N levels might have resulted in higher total withanolides content in the roots of *ashwagandha*. *Ashwagandha* sown at 15 cm × 10 cm spacing supplied with 24-21.2 kg N-P/ha recorded significantly higher total withanolides yield compared to others except 15 cm × 10 cm with 18-15.9 kg N-P/ha with which it was on par. The higher total withanolides yield was attributed to higher total withanolides content in

roots and higher root yield of *ashwagandha*.

Economics

The closer spacing of 15 cm × 10 cm realized the highest net returns and net benefit : cost ratio due to maximum dry root yield followed by 15 cm × 5 cm during both the years (Table 2). The highest level of fertilizer (24-21.2 kg N-P/ha) realized the maximum net returns, which was significantly higher than other fertilizer levels and it was on par with 18-15.9 kg N-P/ha during both the years. The net returns at 24-21.2 kg N-P/ha were 26.3 and 15.0% higher during 2004 and 18.8 and 13.0% higher during 2005 over control and 12-10.6 kg N-P/ha respectively. While, the net benefit: cost ratio was maximum at 18-15.9 kg N-P/ha when compared with other fertility levels during both the years (Table 2). The net returns were the lowest from the crop sown without fertilizers. Due to maximum dry root yield of *ashwagandha*, application of 24-21.2 kg N-P/ha with a spacing of 15 cm × 10 cm resulted in at par net returns with 18-15.9 kg N-P/ha at same spacing and sig-

Table 2. Quality of roots and economics of *ashwagandha* as influenced by spacing and fertilizer levels

Treatment	Total withanolides content (%)		Total withanolides yield (kg/ha)		Net return (x 10 ³ Rs/ha)		Net B:C ratio		Cost of cultivation* (x 10 ³ Rs/ha)
	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	2004-05	2005-06	
<i>Spacing (cm)</i>									
15 × 5	0.53	0.55	6.7	7.3	39.89	41.29	3.66	3.78	10.91
15 × 10	0.59	0.59	8.1	8.5	44.76	47.12	4.21	4.42	10.66
30 × 10	0.58	0.57	5.1	5.3	24.82	26.91	2.36	2.55	10.54
45 × 10	0.53	0.53	3.6	3.7	16.54	17.38	1.58	1.65	10.49
SEm±	0.01	0.02	0.2	0.3	0.66	0.33	0.05	0.09	
CD (P=0.05)	0.03	0.05	0.5	0.8	1.99	1.02	0.13	0.29	
<i>Fertilizer level (N-P kg/ha)</i>									
Control	0.52	0.52	4.8	5.1	27.84	30.06	2.93	3.17	9.43
12-10.6	0.55	0.56	5.5	5.9	30.58	31.60	2.85	2.99	10.55
18-15.9	0.57	0.58	6.5	6.7	34.88	35.34	3.09	3.19	11.06
24-21.2	0.58	0.59	6.7	6.9	35.17	35.72	2.96	3.08	11.56
SEm±	0.01	0.02	0.2	0.3	0.66	0.47	0.05	0.09	
CD (P=0.05)	0.03	0.06	0.5	0.9	1.99	1.42	0.13	NS	

*Mean of 2 years

Table 3. Dry root yield, net return and total withanolide content of *ashwagandha* as influenced by interaction effects of spacing and fertilizer

Spacing (cm)	Dry root yield (t/ha)				Net returns (x 10 ³ Rs/ha)				Total withanolide content (%)			
	F ₀	F ₁	F ₂	F ₃	F ₀	F ₁	F ₂	F ₃	F ₀	F ₁	F ₂	F ₃
15 × 5	1.15	1.24	1.37	1.40	36.43	38.75	43.42	43.79	0.51	0.53	0.55	0.58
15 × 10	1.24	1.35	1.53	1.55	40.19	43.38	50.03	50.14	0.53	0.58	0.61	0.62
30 × 10	0.78	0.87	0.99	1.00	21.92	24.31	28.52	28.67	0.52	0.58	0.59	0.59
45 × 10	0.66	0.68	0.70	0.72	16.80	16.93	16.98	17.15	0.50	0.51	0.55	0.55
SEm±		0.06				0.78				0.02		
CD (P=0.05)		0.17				2.28				0.05		

F₀: Control, F₁: 12-10.6 kg N-P/ha, F₂: 18-15.9 kg N-P/ha, F₃: 24-21.2 kg N-P/ha

nificantly higher over rest of treatment combinations. It was 24.7 and 15.6% higher over control and 12-10.6 kg N-P/ha at same spacing respectively (Table 3). These results confirm the findings of Saudan Singh *et al.* (2003) in *ashwagandha*.

Thus, it can be concluded that a spacing of 15 cm × 10 cm with a fertilizer application of 24-21.2 kg N-P/ha was found optimum for *ashwagandha* crop for getting higher dry root yield, total withanolides content and net returns in vertisols of Northern dry zone of Karnataka.

REFERENCES

- Ajay, P., Ramesh, K., Sammi Reddy, P., Ramana, S. and Maji, B. 2005. Effect of nitrogen and farmyard manure on physiological parameters in *ashwagandha* (*Withania somnifera* Dunal) under vertisol soil type. *Indian Journal of Plant Physiology* **10**(4): 389–393.
- Goroji, P.T. 2000. Transformation of phosphorus in a vertisol in sunflower – jowar cropping sequence. Ph.D. Thesis, Division of Soil Science, University of Agricultural Sciences, Dharwad, India. pp. 48.
- Gupta, A.P., Verma, R.K., Misra, H.O. and Gupta, M.M. 1996. Quantitative determination of withaferin – a different plant parts of *Withania somnifera* by TLC densitometry. *Journal of Medicinal and Aromatic Plant Sciences* **18**: 788–790.
- Joshi, B.G., Gupta, R.K., Kakade, J.R. and Dahatonde, B.N. 1981. Investigations into the medicinal properties of *Withania somnifera*. In: *Proceedings of 4th All India Seminar on Medicinal and Aromatic Plants* held at Madurai from 31st August to 3rd September, pp.389–390.
- Maheshwari, S.K., Sharma, R.K. and Gangrade, S.K. 2000. Response of *ashwagandha* to organic manures and fertilizers in shallow black soil under rainfed conditions. *Indian Journal of Agronomy* **45**(1): 214–216.
- Mishra, S.N. 1994. Calorimetric method for estimation of total withanolides. In: *10th All India Workshop Report on Medicinal and Aromatic Plants*. Trichur. pp. 379–381.
- Patel, D.H. 2001. Effect of methods of sowing, nitrogen levels and time of harvesting on yield and quality parameters of *ashwagandha* var. WS-100. Ph.D. Thesis, Gujarat Agricultural University, Anand.
- Puttanna, K., Prakasa Rao, E.V.S, Chandrashekara, R.S. and Ganesha Rao, R.S. 2005. Organic and inorganic nutrition for *Withania somnifera*. *Journal of Tropical Medicinal Plants* **6**(2): 215–219.
- Singh, Saudan, Khanuja, S.P.S., Aparbal Singh, Man Singh and Singh, U.B. 2003. Potential and economics of *ashwagandha* (*Withania somnifera* [Linn.] Dunal) in overlapping cropping system under rainfed conditions of tropical north India. *Journal of Spices and Aromatic Crop* **12**(2): 101–106.
- Tripathi, A.K., Shukla, Y.N. and Kumar, S. 1996. *Ashwagandha* [*Withania somnifera* Dunal (Solanaceae)]: a status report. *Journal of Medicinal and Aromatic Plant Sciences* **18**(1): 46–62.