J. Hortl. Sci.
Vol. 7(2):161-165, 2012

Analyzing the efficacy of organic and inorganic sources of nitrogen and phosphorus on growth of ashwagandha (*Withania somnifera* Dunal.)

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ABSTRACT

Ashwagandha (*Withania somnifera* Dunal.) is an important medicinal plant whose roots are prescribed as medicine for several disorders of females, bronchitis, dropsy, stomach problems, lung inflammation, tuberculosis, arthritis, skin diseases and male impotency. The present experiment was designed to work out a suitable dose of organic manures and fertilizers for ashwagandha. Treatments consisted of nitrogenous (N) and phosphatic (P) fertilizers at 20 kg ha^{-1} and 40 kg ha^{-1} each, and two levels of farm yard manure (FYM) and vermicompost and combinations thereof, along with control. The treatments were replicated thrice in Randomized Block Design. Results revealed that application of 40 kg ha^{-1} of N and P each as urea and SSP + 2.5 t ha^{-1} vermicompost registered significant values for plant height, number of branches per plant, leaf area, yield attributing traits, root (8.60 q ha^{-1}) and seed yield (85.6 kg ha^{-1}) as well as soil physical properties like organic carbon, hydraulic conductivity and water retention at 33 and 1500kpa besides the highest B:C ratio (2.57).

Key words: Organic, inorganic, nitrogen, phosphorus, yield attributes, *ashwagandha,* withanolides

INTRODUCTION

Ashwagandha (*Withania somnifera* Dunal.) is an important medicinal plant, of the family Solanaceae. It is a perennial branched, evergreen shrub of 30-120 cm height. It is native to the Mediterranean region and is also found growing naturally in forests, particularly, in arid and semi-arid parts of the world.

Roots of this plant are mostly used in Ayurvedic and Unani medicines. These are stout, fleshy, cylindrical, but not thicker than 1-2 cm in diameter and are whitish brown in colour. Pharmacological activity of the plant is attributed to presence of several alkaloids like withanine which ranges from 0.13 to 0.31% (Nigam and Kandalkar, 1995). Research has revealed that ashwagandha possesses anti-inflammatory, anti tumor, anti-stress, antioxidant, immuno-modulatory, hemopoeitic and rejuvenating properties. Ashwagandha roots are prescribed as medicine for hiccups, several female disorders, bronchitis, dropsy, stomach and lung inflammation, tuberculosis, arthritis and skin diseases. It is also known to improve male potency (Vijayabharati, 2002).

Although an important medicinal plant, it is still seen growing on waste and marginal lands, with little or no manures and fertilizers. Use of organic manures and inorganic fertilizers has assumed great importance for sustainable production and for maintaining soil health. These not only supply macro- and micro-nutrients, but also improve the physical, chemical and biological health of soil, leading to good crop production. The interactive advantage of combining inorganic and organic sources of nutrients generally results in better use of each component (Manna *et al*, 2005). Hence, the present experiment was designed to optimize the dose of organic manures and fertilizers in ashwagandha crop.

MATERIAL AND METHODS

The field experiment was conducted in 2004-05 at Horticulture Farm, Department of Horticulture, S.K.N. College of Agriculture, Jobner (Rajasthan). Results were verified by repeating the experiment under similar soil and climatic conditions for two consecutive years (2005-06 and 2006-07) on progressive farmers' field. Treatments consisted of two levels of nitrogenous and phosphatic fertilizers, i.e., 20 kg ha^{-1} and 40 kg ha^{-1} each, and two levels of farm yard manure (FYM) and vermicompost each and combinations thereof, along with control. Urea (containing 46% N) and single super phosphate (containing 16% P) were used as sources of nitrogenous and phosphatic fertilizers. The treatments were replicated thrice in Randomized Block Design.

Full dose of organic manures, SSP and urea was applied prior to sowing (as basal dose, irrespective of treatments) and thoroughly mixed in soil. Seeds of *ashwagandha* variety WS-20 were sown in rows (20 x 7.5cm) in the first week of September, after treating them with Bavistin @ 3g kg^{-1}. Light irrigation was applied immediately after sowing, followed by irrigations as required. At 35-40 days after sowing, one hand-weeding and hoeing was done to reduce crop-weed competition. Subsequently, manual weeding was also done when required. Maturity of the crop was judged by drying up of leaves and development of red colour on berries (170 DAS). Prior to uprooting the plant, light irrigation was applied to ease the harvesting operation. Above ground parts were cut and roots were left for drying.

Five plants were randomly selected in each plot and tagged. Observations were recorded on plant height (cm), number of branches per plant and leaf area per plant (cm^2), length of root (cm), diameter of root (cm), fresh root yield, dry root yield and seed yield. Besides, transpiration rate (µgcm^{2}s^{-1}) was measured in leaves of ashwagandha by a steady-state porometer (Scholander *et al*, 1965), leaf area measured with a leaf area meter, relative leaf water content through the formula of Salvik (1974), and total chlorophyll content (mg g^{-1}) calculated using the method of Hiscox and Israelstom (1979) with slight modifications. Total withanolide content (%) in *ashwagandha* roots was analyzed by the modified spectrophotometer method of Mishra (1994); organic carbon by Walkely and Black's rapid titration method (Jackson, 1967), hydraulic conductivity through constant head method and moisture retention per cent at 33 and 1500 kPa using pressure membrane apparatus described by Singh (1980) were also recorded in experimental field.

RESULTS AND DISCUSSION

Findings of present investigation show that application of nitrogen and phosphorus regardless of sources applied, either alone or in combination of organic and inorganic materials, influenced plant height, number of branches per plant and leaf area (Table 1). Though all the treatments exhibited significant increase in growth parameters over the control, application of nitrogen and phosphorus @ 40 kg ha^{-1} each through urea and SSP + 5.0 t ha^{-1} Vermicompost (T_{14}), closely followed by T_{13} (40 kg ha^{-1} of N & P each + VC 2.5 t ha^{-1}) was found superior with respect to these growth parameters. These results are in close conformity to those of Muthumanickam *et al* (2002) and Vijayabharati (2002).

Data on various yield and yield attributes revealed that application of integrated sources of nitrogen and phosphorus significantly increased root length, root diameter, fresh root yield, dry root yield and seed yield per hectare

Table1. Effect of organic and inorganic sources of nitrogen and phosphorus on plant height, number of branches per plant, leaf Area (LA) transpiration rate (TR), total chlorophyll content (TCC) and relative leaf water content (RLWC) in leaves of *Ashwagandha*

Treatment	Plant height (cm)	No. of branches/ plant	LA (cm^2)	TR (µgcm^{2}s^{-1})	TCC (mg g^{-1})	RLWC (%)
T_0 (Control)	43.67	9.70	154.41	5.65	1.188	51.3
T_1 (FYM 5 t ha^{-1})	61.87	11.53	166.48	6.12	1.190	55.2
T_2 (FYM 10 t ha^{-1})	63.87	12.00	168.92	6.45	1.275	60.1
T_3 (VC 2.5 t ha^{-1})	62.40	12.03	178.72	6.20	1.213	57.5
T_4 (VC 5 t ha^{-1})	70.00	12.63	242.20	6.38	1.370	63.5
T_5 (N P 20 kg ha^{-1})	63.87	12.96	200.25	6.14	1.612	52.2
T_6 (N P 20 kg ha^{-1} + FYM 5 t ha^{-1})	67.27	13.03	232.48	6.20	1.405	58.3
T_7 (N P 20 kg ha^{-1} + FYM 10 t ha^{-1})	68.20	13.17	277.85	6.62	1.690	60.5
T_8 (N P 20 kg ha^{-1}+ VC 2.5 t ha^{-1})	67.53	13.10	289.05	6.35	1.752	59.5
T_9 (N P 20 kg ha^{-1}+ VC 5 t ha^{-1})	72.80	14.51	262.96	6.45	1.770	62.5
T_{10} (N P 40 kg ha^{-1})	69.87	14.04	268.86	6.65	1.850	55.8
T_{11} (N P 40 kg ha^{-1}+ FYM 5 t ha^{-1})	70.14	14.20	281.66	6.80	2.111	63.7
T_{12} (N P 40 kg ha^{-1}+ FYM 10 t ha^{-1})	70.67	15.20	249.15	8.15	2.274	67.8
T_{13} (N P 40 kg ha^{-1}+ VC 2.5 t ha^{-1})	70.40	14.72	338.79	7.15	2.290	66.2
T_{14} (N P 40 kg ha^{-1}+ VC 5 t ha^{-1})	75.40	16.80	361.49	7.84	2.380	70.4
SEm±	3.89	1.07	16.51	0.36	0.04	1.7
CD *(P=0.05)*	11.26	3.09	47.82	1.05	0.124	4.9

FYM – Farm Yard Manure; VC – Vermicompost; N - Nitrogen, P - Phosphorus

(Table 2). However, among different combinations, maximum values for most of these traits were seen in treatment T_{14} (40 kg ha^{-1} of N & P each + 5 t ha^{-1} Vermicompost). This treatment combination was closely followed by T_{13} (40 kg ha^{-1} of N & P each + VC 2.5 t ha^{-1}) and T_{12} (40 kg ha^{-1} of N & P each + FYM 10 t ha^{-1}) whereas, maximum B:C ratio (2.57) was recorded in treatment T_{13}. Thus, combined application of inorganic fertilizers (N & P) and organic manures (FYM and Vermicompost) may have supplied adequate amount of nutrients and favoured metabolic rate and auxin activities in the plant, resulting in better yield attributes and higher root and seed yield. Positive response by application of inorganic fertilizers on root yield in ashwagandha was also reported by Muthumanickam *et al* (2002) and Pakkiyanathan *et al* (2004).

Total withanolide content was found to be significant among treatments in all the experiments (Table 2). Highest withanolide content was reported in treatment T_{14} (40 kg ha^{-1} of N & P each + 5 t ha^{-1} Vermicompost), closely followed by T_{13} (40 kg ha^{-1} of N & P each + VC 2.5 t ha^{-1}), T_8 (20 kg ha^{-1} of N & P each + VC 2.5 t ha^{-1}) and T_9 (20 kg ha^{-1} of N & P each + VC 5 t ha^{-1}). Withanolides, being alkaloids, are products of nitrogen metabolism. Hence, production of withanolides is related to nitrogen supply to the plant. Therefore, application of higher N level may have resulted in higher total withanolide content in roots of *ashwagandha*. Vijayabharati (2002) and Pakkiyanathan *et al* (2004) also reported significant increase in total withanolide content in roots of *ashwagandha* with fertilizer application, compared to the control.

Physiological parameters such as total chlorophyll content, transpiration rate and relative leaf water content also improved with application of organics. This may be attributed to better root growth, resulting in higher water and nutrient uptake. Higher root density had a large influence on plant water status (TR and RLWC) through its effect on water uptake from soil. These results get support from findings of Aggarwal *et al* (1995) who reported that increase in root and leaf growth with organic manures is likely to increase transpiration loss. Soil physical properties like organic carbon, hydraulic conductivity and water retention at 33 and 1500 kPa possibly improved with application of FYM or vermicompost. This indicates that increase in these parameters may have helped increase absorption of nutrients from soil, enhanced carbohydrate assimilation and production of new tissues which, ultimately, increased vegetative growth. Such findings are also reported by Vijayabharati (2002). Vermicompost also improved physical condition of the soil by accelerating porosity, aeration, drainability and water-holding capacity, justified by our findings where significant effect of vermicompost along with urea and SSP has been recorded on organic carbon of soil, hydraulic conductivity and water retention at 33 and 1500 kPa (Figs. 1 and 2). This is also supported by existence of significant positive correlation between these soil parameters and root yield. Higher root yield arising from organic material

Table 2. Effect of organic and inorganic sources of nitrogen and phosphorus on length and diameter of root, fresh root yield, dry root yield, seed yield, total withanolide content and B:C ratio

Treatment	Root length (cm)	Root diameter (cm)	Fresh root yield (q ha^{-1})	Dry root yield (q ha^{-1})	Seed yield (kg ha^{-1})	Total withanolide content (%)	B:C ratio
T_0 (Control)	14.40	0.94	6.90	2.78	51.3	0.197	1.09
T_1 (FYM 5 t ha^{-1})	22.09	1.08	11.83	4.08	64.6	0.207	1.41
T_2 (FYM 10 t ha^{-1})	22.11	1.11	13.01	4.70	68.3	0.212	1.46
T_3 (VC 2.5 t ha^{-1})	22.16	1.07	12.56	4.89	65.6	0.215	1.61
T_4 (VC 5 t ha^{-1})	23.75	1.14	13.12	5.14	67.6	0.218	1.38
T_5 (N P 20 kg ha^{-1})	21.62	1.13	13.14	5.75	71.9	0.219	2.35
T_6 (N P 20 kg ha^{-1} + FYM 5 t ha^{-1})	21.86	1.17	15.02	6.22	74.6	0.232	1.97
T_7 (N P 20 kg ha^{-1} + FYM 10 t ha^{-1})	25.00	1.19	15.49	6.33	76.6	0.239	1.86
T_8 (N P 20 kg ha^{-1}+ VC 2.5 t ha^{-1})	22.28	1.18	15.48	6.29	75.9	0.274	2.03
T_9 (N P 20 kg ha^{-1}+ VC 5 t ha^{-1})	28.05	1.20	16.90	6.89	77.3	0.287	1.78
T_{10} (N P 40 kg ha^{-1})	22.67	1.19	17.28	6.92	81.9	0.224	1.63
T_{11} (N P 40 kg ha^{-1}+ FYM 5 t ha^{-1})	23.85	1.22	18.04	8.14	83.6	0.258	2.22
T_{12} (N P 40 kg ha^{-1}+ FYM 10 t ha^{-1})	25.89	1.25	19.41	8.65	85.9	0.271	2.20
T_{13} (N P 40 kg ha^{-1}+ VC 2.5 t ha^{-1})	24.58	1.23	19.22	8.60	85.6	0.313	2.57
T_{14} (N P 40 kg ha^{-1}+ VC 5 t ha^{-1})	26.26	1.28	20.28	9.63	87.3	0.336	2.35
SEm$\pm$	1.76	0.08	0.90	0.46	6.08	0.020	-
CD *(P=0.05)*	5.09	0.23	2.61	1.33	17.62	0.063	-

FYM – Farm Yard Manure; VC – Vermicompost; N - Nitrogen, P - Phosphorus

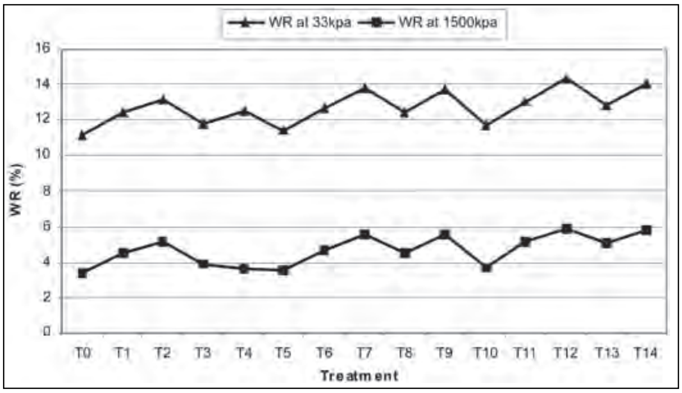

Fig 1. Effect of organic and inorganic sources of nitrogen and phosphorus on Water Retention (WR) in soil at 33 kPa and 1500 kPa at crop harvest

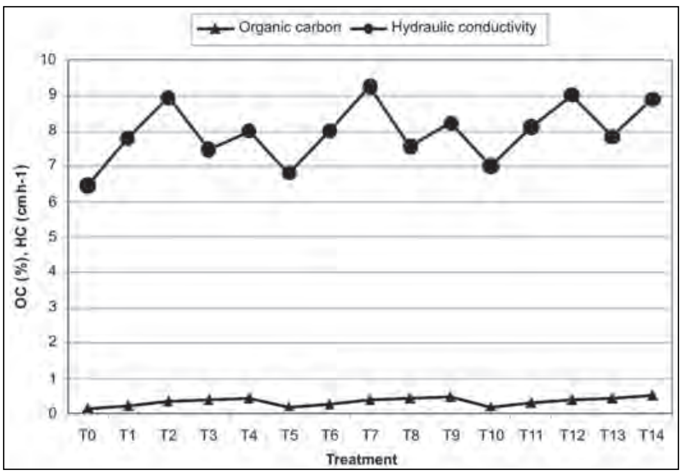

Fig 2. Effect of organic and inorganic sources of nitrogen and phosphorus on Organic Carbon (OC) and Hydraulic Conductivity (HC) of soil at harvest

was further substantiated by significant and positive correlation (Table 3) between root yield and organic carbon (r=0.590*), water retention at 33 kPa (r=0.717**) and at 1500 kPa (r=0.669**), relative leaf water content (r=0.836**) and transpiration rate (r=0.857**). Favourable effect on soil properties caused by formation of higher humus colloidal complex was coupled to higher nutrient content of organic compared to inorganic fertilizers. Test of significance further indicated that coefficient of regression of organic carbon, water retention at 33 and 1500 kPa, relative leaf water content and transpiration rate on root yield was positive and significant. This indicates that root yield in *ashwagandha* increased by 8.038, 1.095, 1.095, 0.232 and 1.873 q ha^{-1} by a unit increase in organic carbon, water retention at 33 and 1500 kPa, relative leaf water content and transpiration rate, respectively (Tables 4 and 5). The X_1, X_2, X_3, X_4, X_5, X_6 and X_7 jointly contributed to dry root yield, and, variation in the yield owing to these parameters was 92.1% (Table 5). Therefore, these parameters may have contributed to root yield in *ashwagandha* (Muthumanickam *et al*, 2002).

Table 3 shows that organic carbon content of the soil is positively and significantly correlated with hydraulic conductivity (r=0.981**), water retention at 33 kPa (0.937**) and 1500 kPa (r=0.878**), relative leaf water content (r=0.714**) and transpiration rate (r=0.605**). In fact, plants do not utilize all of the available nutrients in soil. Unutilized nutrients remain in the soil. This increases their availability to the next crop after harvest. Highest value for hydraulic conductivity and water retention at 33 and 1500 kPa was

Table 3. Relationship [correlation coefficients (r) matrix] between Dry Root Yield (DRY) and Organic Carbon (OC), Water Retention (WR) at 33 kPa and 1500 kPa, Relative Leaf Water Content (RLWC) and Transpiration Rate (TR)

Variable	Dry root yield	Organic carbon	W R at 33kPa	W R at 1500kPa	RLWC	TR
Dry root yield	1.000	0.590*	0.717**	0.669**	0.836**	0.857**
Organic carbon		1.000	0.937**	0.878**	0.714**	0.605*
W R at 33kPa			1.000	0.960**	0.837**	0.743**
W R at 1500kPa				1.000	0.744**	0.710**
RLWC					1.000	0.822**
TR						1.000

*Significant at 0.05 level; **Significant at 0.01 level

Table 4. Relationship [correlation coefficients (r) matrix] between Organic Carbon (OC) and Bulk Density (BD), Hydraulic Conductivity (HC), Water Retention (WR) at 33 kPa and 1500 kPa, Relative Leaf Water Content (RLWC) and Transpiration Rate (TR)

Variable	Organic carbon	Bulk density	HC	WR at 33kPa	WR at 1500kPa	RLWC	TR
Organic carbon	1.000	-0.969**	0.981**	0.937**	0.878**	0.714**	0.605**
Bulk density		1.000	-0.958**	-0.950**	-0.859**	-0.816**	-0.623*
HC			1.000	0.939**	0.877**	0.756**	0.630*
WR at33 kPa				1.000	0.960**	0.837**	0.743**
WR at1500 kPa					1.000	0.744**	0.710**
RLWC						1.000	0.822**
TR							1.000

*Significant at 0.05 level; **Significant at 0.01 level seen under the treatment T_{14} (40 kg ha^{-1} of NP each + VC 5 t ha^{-1}), which was statistically at par with T_{13} and T_{12} (Fig. 2). These results are in close conformity with those of Srikanth *et al* (2000).

Table 5. Effect of various soil and physiological parameters on dry root yield and organic carbon in soil

Variable	Regression equation	R^2
Dry root yield(Y) =	- 166.169-8.851 (X_1) + 4.171 (X_2) – 0.941 (X_3) + 0.574 (X_4) – 1.169 (X_5) + 66.237 (X_6) + 0.772 (X_7)	0.921
Dry root yield	Y = 3.567 + 8.038 (X_1)	0.348
	Y = -7.703 + 1.095 (X_2)	0.514
	Y = 1.124 + 1.095 (X_3)	0.448
	Y = -7.698 + 0.232 (X_4)	0.675
	Y = -6.158 + 1.873 (X_5)	0.714
Organic carbon	Y = 2.624 – 1.594 (X_6)	0.938
	Y = -0.667 + 0.125 (X_7)	0.962
	Y = -1.006 + 0.105 (X_3)	0.877
	Y = -0.161 + 0.106 (X_4)	0.772
	Y = -0.543 + 1.454 (X_5)	0.510
	Y = -0.311 + 9.696 (X_6)	0.366

X_1, X_2, X_3, X_4, X_5, X_6 and X_7 denotes organic carbon, water retention at 33kPa, water retention at 1500kPa, relative leaf water content, transpiration rate, bulk density and hydraulic conductivity, respectively.

On the basis of our results, it may be concluded that application of organic manures either alone or in combination with urea and SSP enhanced growth, yield and quality attributes in *ashwagandha* over control. A comparison of various treatments revealed that application of 40 kg ha^{-1} of NP + 2.5 t ha^{-1} vermicompost (T_{13}) registered significantly higher values for growth and yield characteristics as also physical properties of soil, besides maximum B:C ratio.

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(MS Received 28 December 2011, Revised 04 July 2012)