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**Studies on impact of organic and inorganic  
fertilizers on growth and yield of Ashwagandha  
[*Withania somnifera* (L.) Dunal]**

**Aishwarya Routray, Kaushal Kumar and Jai Kumar**

**Abstract**

The positive impact of fertilizers on growth and yield parameters of many medicinal plants has been widely documented, but it is lacking in plants like Ashwagandha under the edapho-climatic conditions of Jharkhand. Since Ashwagandha is used extensively in many ayurvedic preparations and it is one of the highly commercial crops grown by the farmers, hence a research trial was conducted by taking different combinations of organic and inorganic fertilizers to study its impact on growth and yield parameters of Ashwagandha at BAU, Ranchi. Standardization of fertilizer application is necessary for remunerative cultivation and one of the primary aims of scientific cultivation of medicinal & aromatic plants. Significant impact of fertilizer combinations was observed on different growth and yield parameters of Ashwagandha. Karanj cake @ 5q/ha<sup>-1</sup>+ N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha yields maximum height while the FYM @ 5q/ha +N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha yield lowest height. The maximum leaf length was 7.55cm given by Neem cake@5q/ha + N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha and the minimum length was observed in FYM @ 5q/hq + N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (6.02cm). The highest number of branches (10.05), highest stem collar diameter (24.35mm), maximum primary root length (50.10cm), highest primary root diameter(21.36mm) was observed in Karanj cake @ 5q/ha + N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha. The maximum dry root yield was obtained (908.04kg/ha) in Karanj cake @ 5q/ha + N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha and the lowest yield (390.96kg/ha) in FYM @ 5 q/ha + N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha. Dry root yield showed significant correlation with stem collar diameter, number of berries per plant, seed yield per plant and with the primary root diameter. The path analysis value showed that the direct effect was given by plant height (0.605), stem collar diameter (1.087), number of branches per plant (-0.422), leaf length(0.411), leaf width(0.211), number of berries per plant(0.765), number of seeds/berry (0.652), seed yield per plant (-0.624), primary root length (-0.229), primary root diameter (-0.253) and the number of secondary roots per plant (-0.756) shows direct effect with dry root yield.

**Keywords:** organic and inorganic fertilizers and Ashwagandha

**Introduction**

*Withania somnifera*, commonly known as 'Ashwagandha', 'Indian Ginseng', 'Poison Gooseberry', 'Winter cherry' is a plant belonging to Solanaceae family. Ashwagandha is grown primarily for its roots. In worldwide market, Ashwagandha has recently acquired considerable significance and having tremendous marketing potential owing to demand of its roots to the tune of 7000 tons and estimated production of 1500 tonnes (Umadevi *et al.*, 2012)<sup>[9]</sup>. The roots, which contain number of alkaloids including withanine and somniferine having medicinal properties along with reducing sugar and phytosterol and mixture of saturated and unsaturated fatty acids which are present in different parts of the plants. The root is a tonic, stimulant, alliterative, aphrodisiac, narcotic, diuretic and abortifacient. In US market, Ashwagandha has recently acquired considerable significance on account of its large demand

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due to its reported male sex stimulating properties (Joshi *et al.*, 1981)<sup>[4]</sup>. The biologically active chemical constituents of *Withania somnifera* include alkaloids (isopelletierine, anaferine, cuseohygrine, anahygrine, etc.), steroidal lactones (withanolides, withaferins) and saponins (Singh *et al.*, 2011)<sup>[8]</sup>. Powdered leaf suspensions can increase total serum protein synthesis two fold (Gupta *et al.*, 2000)<sup>[3]</sup>. Generally Ashwagandha is cultivating in the states namely Madhya Pradesh, Rajasthan, Punjab, Uttar Pradesh, Haryana, Gujarat and Maharashtra among which Madhya Pradesh alone is having more than 4000 ha area. This crop is generally taken in late *kharif* season only on conserved soil moisture and can be grown on any type of soils having good drainage with 7.5 to 8.0 pH. It requires dry climate for better growth and root development but winter temperatures are known to improve the root quality (Kahar *et al.*, 1991)<sup>[5]</sup>. The interactive advantage of combining inorganic and organic sources of nutrients generally results in better use of each component (Manna *et al.*, 2005)<sup>[6]</sup>.

## Material & Methods

The research work was conducted during the year 2018-19 at the Experiential Learning Unit- Medicinal Plants, Nursery site of Faculty of Forestry, Birsa Agricultural University, Kanke, Ranchi under the climatic and edaphic condition of Jharkhand through its qualitative and quantitative parameters. The experiment was laid out with Split Plot Design with three main plot treatment namely M<sub>1</sub>, M<sub>2</sub> & M<sub>3</sub> with organic fertilizers and three sub plot treatments are S<sub>1</sub>, S<sub>2</sub> and S<sub>3</sub> which comprises different combinations of inorganic fertilizers, replicated five times. Spacing adopted was 50cm x 50cm and number of plants in subplot was 12. The Poshita variety was used for the experiment. Before transplanting of the seedlings, the field was ploughed properly with an arrangement of the field in split plot design. At the time of transplanting seedlings, entire dose of phosphoric and potassic fertilizers were applied as basal dose. Similarly entire dose of organic fertilizer and half of nitrogenous fertilizer was applied as basal dose and remaining half dose of nitrogenous fertilizer was applied at initiation of flowering time.

**Table 1:** Details of the treatment combinations used in the experiment

Symbol	Details
M <sub>1</sub> S <sub>1</sub>	FYM@5 q ha <sup>-1</sup> +N <sub>30</sub> :P <sub>40</sub> :K <sub>50</sub> kg ha <sup>-1</sup>
M <sub>1</sub> S <sub>2</sub>	FYM@5 q ha <sup>-1</sup> +N <sub>40</sub> :P <sub>50</sub> :K <sub>30</sub> kg ha <sup>-1</sup>
M <sub>1</sub> S <sub>3</sub>	FYM@5 q ha <sup>-1</sup> +N <sub>50</sub> :P <sub>30</sub> :K <sub>40</sub> kg ha <sup>-1</sup>
M <sub>2</sub> S <sub>1</sub>	Karanj cake @ 5 q ha <sup>-1</sup> + N <sub>30</sub> :P <sub>40</sub> :K <sub>50</sub> kg ha <sup>-1</sup>
M <sub>2</sub> S <sub>2</sub>	Karanj cake @ 5 q ha <sup>-1</sup> + N <sub>40</sub> :P <sub>50</sub> :K <sub>30</sub> kg ha <sup>-1</sup>
M <sub>2</sub> S <sub>3</sub>	Karanj cake @ 5 q ha <sup>-1</sup> + N <sub>50</sub> :P <sub>30</sub> :K <sub>40</sub> kg ha <sup>-1</sup>
M <sub>3</sub> S <sub>1</sub>	Neem cake@ 5 q ha <sup>-1</sup> + N <sub>30</sub> :P <sub>40</sub> :K <sub>50</sub> kg ha <sup>-1</sup>
M <sub>3</sub> S <sub>2</sub>	Neem cake@ 5 q ha <sup>-1</sup> + N <sub>40</sub> :P <sub>50</sub> :K <sub>30</sub> kg ha <sup>-1</sup>
M <sub>3</sub> S <sub>3</sub>	Neem cake@ 5 q ha <sup>-1</sup> + N <sub>50</sub> :P <sub>30</sub> :K <sub>40</sub> kg ha <sup>-1</sup>

The parameters recorded were plant height (cm), leaf length (cm), leaf width (cm), number of branches/plant, stem collar diameter (mm), primary root length (cm), primary root diameter (mm), number of secondary roots per plant, number of berries per plant, berries diameter (cm), number of seeds per berry, fresh root weight (kg/ha), dry root weight (kg/ha), seed yield (kg/ha) - Average of five randomly selected samples was recorded when the berries were fully matured and harvested. The data pertaining to root and shoot characters was tabulated treatment & replication wise and statistically analyzed. Analyzed data was subjected to ANOVA with critical difference values tabulated at five per cent level of significance of corresponding degree of freedom.

## Results & Discussion

In plant height, Karanj cake @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha gave highest plant height (68.87cm) followed by Karanj cake

@ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (65.67cm) while the FYM @5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha gave lowest height (49.86cm) followed by Neem cake@5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha and Neem cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha with the value 53.27cm and 53.63cm respectively and with a grand mean of 61.04 cm. Maximum leaf length was observed in the fertilizer combination of Neem cake @ 5 q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (7.55cm) followed by Neem cake @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (7.05cm) and the minimum leaf length was recorded in FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (6.02cm) followed by FYM @5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (6.29cm) with a grand mean 6.71cm. Maximum leaf width was recorded in Neem cake @ 5 q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (4.53cm) followed by Neem cake @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (4.17cm) and the minimum leaf width was recorded in FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (3.41cm) followed by FYM @5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (3.52cm) with a grand mean 3.97cm.

**Table 2:** Plant height (cm) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	49.68 <sup>b</sup>	68.06 <sup>ab</sup>	65.67 <sup>ab</sup>	61.13 <sup>ab</sup>
Karanj cake @5 q/ha	62.53 <sup>ab</sup>	65.67 <sup>ab</sup>	68.87 <sup>a</sup>	65.69 <sup>a</sup>
Neem cake @ 5 q/ha	62.00 <sup>ab</sup>	53.63 <sup>b</sup>	53.27 <sup>b</sup>	56.29 <sup>b</sup>
Mean	58.07	62.45	62.60	Grand Mean-61.04
	C.V. (%)	SE( ±m)	C.D. <sub>5%</sub>	
Main plot(M)	11.26	2.70	8.832	Significant
Sub plot(S)		1.77	5.184	Non-significant
Interaction (M*S)		3.69	8.979	Significant

**Table 3:** Leaf length (cm) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	6.02 <sup>b</sup>	6.76 <sup>ab</sup>	6.29 <sup>b</sup>	6.35
Karanj cake @ 5q/ha	6.89 <sup>ab</sup>	6.56 <sup>ab</sup>	6.33 <sup>b</sup>	6.59
Neem cake @ 5 q/ha	7.05 <sup>ab</sup>	6.98 <sup>ab</sup>	7.55 <sup>a</sup>	7.19
Mean	6.65	6.77	6.72	Grand Mean -6.71
	C.V. (%)	SE(±m)	C.D. <sup>5%</sup>	
Main plot(M)	12.80	0.27	0.88	Non-significant
Sub plot(S)		0.22	0.64	Non-significant
Interaction (M*S)		0.41	1.12	Significant

**Table 4:** Leaf width (cm) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	3.41 <sup>c</sup>	3.52 <sup>c</sup>	4.06 <sup>b</sup>	3.66
Karanj cake @ 5 q/ha	4.16 <sup>ab</sup>	3.96 <sup>bc</sup>	3.86 <sup>bc</sup>	3.99
Neem cake @ 5 q/ha	4.17 <sup>ab</sup>	4.09 <sup>ab</sup>	4.53 <sup>a</sup>	4.26
Mean	3.91 <sup>ab</sup>	3.85 <sup>b</sup>	4.15 <sup>a</sup>	Grand Mean -3.97
	C.V. (%)	SE(±m)	C.D. <sup>5%</sup>	
Main plot(M)	9.23	1.83	0.59	Non-significant
Sub plot(S)		0.94	0.27	Significant
Interaction (M*S)		3.21	0.47	Significant

The highest number of branches was observed in Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (10.05) followed by Karanj cake @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha where as the minimum number of branches were observed in FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (6.70) followed by FYM @ 5 q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha with a grand mean 8.62 number of branches per plant. Patil *et al.*, (2014)<sup>[7]</sup> revealed on use of organic and chemical fertilizers showed that significant effect on growth parameters in Ashwagandha. Among different nutrients treatment, M<sub>2</sub>V<sub>2</sub>F<sub>2</sub> (2 t FYM/ha + 0.5 t VC/ha + 20:30:20 kg NPK/ha) showed significantly maximum plant height (70.81 cm), number of leaves (45.09), number of branches per plant (8.89), which was followed by M<sub>2</sub>V<sub>1</sub>F<sub>2</sub> (2 t FYM/ha + 0.25 t VC/ha + 20:30:20 kg NPK/ha) because the nutrient released

from both organic and inorganic fertilizers would have resulted in the increased nutrient availability, which helped in improvement in soil health and supplied both micro nutrients as well as macro nutrients. Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (24.35mm) showed the highest stem collar diameter followed by Karanj cake @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (23.66mm) and FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (18.23cm) gave lowest stem collar diameter followed by FYM @ 5 q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (18.45cm) with a grand mean 20.93mm. Anand *et al.* (2014)<sup>[1]</sup> reported that average collar diameter, dried root diameter, primary shoot and root branches were observed 1.39 cm, 0.73 cm, 3.21 and 0.64, respectively.

**Table 5:** Number of branches per plant of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	6.70 <sup>c</sup>	6.95 <sup>c</sup>	7.05 <sup>c</sup>	6.90 <sup>b</sup>
Karanj cake @ 5 q/ha	9.85 <sup>ab</sup>	10.05 <sup>a</sup>	9.10 <sup>ab</sup>	9.66 <sup>a</sup>
Neem cake @ 5 q/ha	8.60 <sup>b</sup>	9.75 <sup>ab</sup>	9.55 <sup>ab</sup>	9.30 <sup>ab</sup>
Mean	8.38	8.91	8.56	Grand Mean -8.62
	C.V. (%)	SE(±m)	C.D. <sup>5%</sup>	
Main plot(M)	11.10	0.41	1.34	Significant
Sub plot(S)		0.24	0.72	Non-significant
Interaction (M*S)		0.54	1.25	Significant

**Table 6:** Stem collar diameter (mm) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	18.23 <sup>b</sup>	18.45 <sup>b</sup>	22.66 <sup>ab</sup>	19.78 <sup>b</sup>
Karanj cake @ 5q/ha	18.97 <sup>b</sup>	24.35 <sup>a</sup>	23.66 <sup>ab</sup>	22.32 <sup>a</sup>
Neem cake @ 5 q/ha	19.25 <sup>b</sup>	21.10 <sup>ab</sup>	21.73 <sup>ab</sup>	20.69 <sup>b</sup>
Mean	18.82 <sup>b</sup>	21.30 <sup>ab</sup>	22.68 <sup>a</sup>	Grand Mean -20.93
	C.V. (%)	SE(±m)	C.D. <sup>5%</sup>	
Main plot(M)	13.95	0.48	1.57	Significant
Sub plot(S)		0.75	2.20	Significant
Interaction (M*S)		1.17	3.81	Significant

Karanj cake @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (50.10cm) gave the highest primary root length followed by Neem cake @ 5 q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (47.70cm) where as the minimum

primary root length was recorded in FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (38.60cm) followed by Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (41.40cm) with a grand mean

44.17cm. Maximum root diameter was recorded Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (21.36mm) followed by Karanj cake @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (21.19mm) where as the minimum root diameter was recorded in FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (16.31mm) followed by Karanj cake @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (16.70 mm) with a grand mean 18.57mm. Maximum number of secondary roots per

plant was found in Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (15.20) followed by Neem cake @ 5 q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (14.90) where as the minimum number of secondary roots per plant was found in FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (12.10) followed by Neem cake @ 5 q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha(12.30) with a grand mean of 13.79 number of secondary roots.

**Table 7:** Primary root length (cm) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @ 5 q/ha	38.60 <sup>b</sup>	42.10 <sup>b</sup>	42.80 <sup>b</sup>	41.16
Karanj cake @ 5q/ha	44.10 <sup>ab</sup>	41.40 <sup>b</sup>	50.10 <sup>a</sup>	45.20
Neem cake @ 5 q/ha	45.85 <sup>ab</sup>	47.70 <sup>ab</sup>	44.90 <sup>ab</sup>	46.15
Mean	42.85	43.73	45.93	Grand Mean -44.17
	C.V. (%)	SE(m)	C.D. <sub>5%</sub>	
Main plot(M)	12.16	1.75	5.73	Non-significant
Sub plot(S)		1.39	4.06	Non-significant
Interaction (M*S)		2.63	7.03	Significant

**Table 8:** Primary root diameter (mm) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @ 5 q/ha	16.31 <sup>b</sup>	17.03 <sup>b</sup>	20.18 <sup>ab</sup>	17.84 <sup>b</sup>
Karanj cake @ 5q/ha	16.70 <sup>b</sup>	21.36 <sup>a</sup>	21.19 <sup>ab</sup>	19.75 <sup>a</sup>
Neem cake @ 5 q/ha	17.06 <sup>b</sup>	17.80 <sup>ab</sup>	19.53 <sup>ab</sup>	18.13 <sup>ab</sup>
Mean	16.69 <sup>b</sup>	18.73 <sup>ab</sup>	20.30 <sup>a</sup>	Grand Mean -18.57
	C.V. (%)	SE(±m)	C.D. <sub>5%</sub>	
Main plot(M)	14.98	0.56	1.82	Significant
Sub plot(S)		0.71	2.09	Significant
Interaction (M*S)		1.16	3.63	Significant

**Table 9:** Number of secondary roots per plant of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @ 5 q/ha	12.10 <sup>b</sup>	13.70 <sup>ab</sup>	14.30 <sup>ab</sup>	13.36
Karanj cake @ 5q/ha	14.20 <sup>ab</sup>	15.20 <sup>a</sup>	12.90 <sup>ab</sup>	14.10
Neem cake @ 5 q/ha	14.60 <sup>ab</sup>	14.90 <sup>ab</sup>	12.30 <sup>b</sup>	13.93
Mean	13.63	14.60	13.16	Grand Mean -13.79
	C.V. (%)	SE(±m)	C.D. <sub>5%</sub>	
Main plot(M)	14.35	0.36	1.34	Non significant
Sub plot(S)		0.51	1.48	Non significant
Interaction (M*S)		0.80	2.57	Significant

Maximum number of berries per plant was collected from the treatment Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (309.53) followed by Neem cake @ 5 q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (239.93) and the minimum number of berries per plant was collected from the treatment FYM @ 5 q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (119.93) followed by FYM @ 5 q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (140.20) with a grand mean of 188.54 number of berries per plant. The maximum berries diameter was found in Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (0.67 cm) and in Karanj cake @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (0.67 cm) followed by Karanj cake @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub>

kg/ha (0.63cm) and Neem cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (0.63 cm) where as the minimum berries diameter was found in FYM @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (0.56cm) and FYM @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (0.56 cm) with a grand mean of 0.61cm. The highest number of seeds per berry was collected Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (25.13) followed by Neem cake @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (24.13) where as the lowest number of berries was collected from FYM @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (18.40) followed by FYM @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (19.20) with a grand mean of 21.93 seeds per berry.

**Table 10:** Number of berries per plant of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @ 5 q/ha	119.93 <sup>d</sup>	140.20 <sup>d</sup>	146.13 <sup>d</sup>	135.42 <sup>c</sup>
Karanj cake @ 5 q/ha	180.80 <sup>c</sup>	309.53 <sup>a</sup>	215.13 <sup>bc</sup>	235.15 <sup>a</sup>
Neem cake @ 5 q/ha	170.13 <sup>cd</sup>	239.93 <sup>b</sup>	175.13 <sup>cd</sup>	195.06 <sup>b</sup>
Mean	156.95	229.88 <sup>a</sup>	178.80 <sup>b</sup>	Grand Mean -188.54
	C.V. (%)	SE(±m)	C.D. <sub>5%</sub>	
Main plot(M)	12.85	8.90	29.02	Significant
Sub plot(S)		6.25	18.26	Significant
Interaction (M*S)		12.55	31.63	Significant

**Table 11:** Berries diameter (cm) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	0.60	0.56	0.56	0.57
Karanj cake @ 5 q/ha	0.67	0.67	0.63	0.65
Neem cake @ 5 q/ha	0.59	0.63	0.62	0.61
Mean	0.62	0.62	0.60	Grand Mean -0.61
	C.V. (%)	SE(±m)	C.D. <sub>5%</sub>	
Main plot(M)	8.37	0.20	0.66	Non-significant
Sub plot(S)		0.13	0.39	Non-significant
Interaction (M*S)		0.35	0.67	Non-significant

**Table 12:** Number of seeds per berry of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	19.20 <sup>c</sup>	19.27 <sup>c</sup>	18.40 <sup>c</sup>	18.95
Karanj cake @ 5 q/ha	23.60 <sup>ab</sup>	25.13 <sup>a</sup>	23.93 <sup>ab</sup>	24.22
Neem cake @ 5 q/ha	24.13 <sup>ab</sup>	22.27 <sup>b</sup>	21.53 <sup>bc</sup>	22.64
Mean	22.31	22.22	21.28	Grand Mean -21.93
	C.V. (%)	SE(m)	C.D. <sub>5%</sub>	
Main plot(M)	7.90	0.79	2.59	Non-significant
Sub plot(S)		0.44	1.30	Non-significant
Interaction (M*S)		1.01	2.26	Significant

Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (1902.24 kg/ha) gave highest fresh root yield followed by Karanj cake @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (1815.28 kg/ha) where as FYM @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (1054.72 kg/ha) provide lowest amount of fresh root yield followed by FYM @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (1172.76 kg/ha) with a grand mean of 1440.18 kg/ha. Patil *et al.*, (2014) [7] founded that there was a significant maximum fresh and dry root yield (13.68 q/ha and 11.09 q/ha, respectively) were recorded in M<sub>2</sub>V<sub>2</sub>F<sub>2</sub> (2 t FYM/ha + 0.5 t VC/ha + 20:30:20 kg NPK/ha) followed by M<sub>2</sub>V<sub>1</sub>F<sub>2</sub> (2 t FYM/ha + 0.25 t VC/ha + 20:30:20 kg NPK/ha) and M<sub>2</sub>V<sub>0</sub>F<sub>1</sub> (2 t FYM/ha + 0 t VC/ha + 20:30:20 kg NPK/ha). Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (908.04 kg/ha) gave highest dry root yield followed by Karanj cake @ 5q/ha

with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (801.76 kg/ha) where as FYM @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (390.96 kg/ha) provide lowest amount of dry root yield followed by FYM @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (436.04 kg/ha) with a grand mean of 596.41kg/ha. Karanj cake @ 5q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha (580.24 kg/ha) gave highest seed yield followed by Karanj cake @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (471.28 kg/ha) where as FYM @ 5q/ha with N<sub>50</sub>:P<sub>30</sub>:K<sub>40</sub> kg/ha (113.76 kg/ha) provide lowest amount of seed yield followed by FYM @ 5q/ha with N<sub>30</sub>:P<sub>40</sub>:K<sub>50</sub> kg/ha (157.95 kg/ha) with a grand mean of 340.19 kg/ha. Basavanagowda (1998) [2] in sorghum combined application of RDF + vermicompost @ 2.5 t ha<sup>-1</sup> and azospirillum @ 10 kg ha<sup>-1</sup> resulted in significant increases in yield (5.08 t ha<sup>-1</sup>) when compared to the application of RDF alone.

**Table 13:** Fresh root weight (kg/ha) of Ashwagandha under different treatment combination

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	1054.72 <sup>c</sup>	1172.76 <sup>c</sup>	1483.92 <sup>bc</sup>	1237.13 <sup>c</sup>
Karanj cake @ 5 q/ha	1352.68 <sup>bc</sup>	1902.24 <sup>a</sup>	1815.28 <sup>ab</sup>	1690.06 <sup>a</sup>
Neem cake @ 5 q/ha	1273.72 <sup>bc</sup>	1413.12 <sup>bc</sup>	1493.28 <sup>b</sup>	1393.37 <sup>b</sup>
Mean	1227.04 <sup>b</sup>	1496.04 <sup>ab</sup>	1597.49 <sup>a</sup>	Grand Mean -1440.18
	C.V. (%)	SE(±m)	C.D. <sub>5%</sub>	
Main plot(M)	12.39	23.24	75.96	Significant
Sub plot(S)		45.96	134.49	Significant
Interaction (M*S)		69.03	232.94	Significant

**Table 14:** Dry root weight (kg/ha) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @5 q/ha	436.04 <sup>d</sup>	390.96 <sup>d</sup>	529.36 <sup>cd</sup>	452.12 <sup>c</sup>
Karanj cake @ 5 q/ha	409.68 <sup>d</sup>	908.04 <sup>a</sup>	801.76 <sup>b</sup>	706.49 <sup>a</sup>
Neem cake @ 5 q/ha	557.20 <sup>c</sup>	556.20 <sup>cd</sup>	778.48 <sup>bc</sup>	630.62 <sup>b</sup>
Mean	467.64 <sup>c</sup>	618.40 <sup>b</sup>	703.20 <sup>a</sup>	Grand Mean -596.41
	C.V. (%)	SE(±m)	C.D. <sub>5%</sub>	
Main plot(M)	11.79	10.20	33.28	Significant
Sub plot(S)		18.16	53.02	Significant
Interaction (M*S)		27.64	91.83	Significant



**Table 15:** Seed yield (kg/ha) of Ashwagandha under different treatment combinations

Organic fertilizers	Inorganic fertilizers N:P:K (kg/ha)			Mean
	30:40:50	40:50:30	50:30:40	
FYM @ 5 q/ha	157.95 <sup>ef</sup>	186.11 <sup>e</sup>	113.76 <sup>f</sup>	152.60 <sup>c</sup>
Karanj cake @ 5 q/ha	449.84 <sup>bc</sup>	580.24 <sup>a</sup>	471.28 <sup>b</sup>	500.45 <sup>a</sup>
Neem cake @ 5 q/ha	255.31 <sup>d</sup>	377.68 <sup>c</sup>	469.60 <sup>bc</sup>	367.53 <sup>b</sup>
Mean	287.70 <sup>c</sup>	381.34 <sup>a</sup>	351.54 <sup>b</sup>	Grand Mean -340.19
	C.V. (%)	SE(±m)	C.D.5%	
Main plot(M)	11.079	12.09	39.448	Significant
Sub plot(S)		9.72	28.397	Significant
Interaction (M*S)		18.32	49.186	Significant

The stem collar diameter (0.868) and primary root diameter (0.861) showed highly positively significant correlation with dry root yield per plant where as number of berries per plant (0.733) and seed yield per plant (0.731) showed a positive significant correlation with dry root yield per plant. The maximum direct positive effect on dry root weight per plant was observed through stem collar diameter (1.087) followed by number of berries per plant (0.765). Maximum direct negative effect on dry root weight per plant was observed

through number of secondary roots (-0.756) followed by seed yield per plant (-0.624). Parameters like plant height (0.105), leaf length (0.411) and leaf width (0.211) showed a direct positive effect on dry root weight per plant. Similarly parameters like number of branches per plant (-0.422), primary root length (-0.229) and primary root diameter (-0.253) showed a negative direct effect on dry root weight per plant.

**Table 16:** Correlation analysis of the yield and growth parameters of Ashwagandha

	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	V <sub>4</sub>	V <sub>5</sub>	V <sub>6</sub>	V <sub>7</sub>	V <sub>8</sub>	V <sub>9</sub>	V <sub>10</sub>	V <sub>11</sub>	V <sub>12</sub>
V <sub>1</sub>	1.000											
V <sub>2</sub>	0.354 <sup>NS</sup>	1.000										
V <sub>3</sub>	-0.007 <sup>NS</sup>	0.450 <sup>NS</sup>	1.000									
V <sub>4</sub>	-0.207 <sup>NS</sup>	-0.091 <sup>NS</sup>	0.548 <sup>NS</sup>	1.000								
V <sub>5</sub>	-0.179 <sup>NS</sup>	0.201 <sup>NS</sup>	0.947 <sup>**</sup>	0.722 <sup>*</sup>	1.000							
V <sub>6</sub>	0.213 <sup>NS</sup>	0.703 <sup>*</sup>	0.785 <sup>*</sup>	0.132 <sup>NS</sup>	0.614 <sup>*</sup>	1.000						
V <sub>7</sub>	0.226 <sup>NS</sup>	0.371 <sup>NS</sup>	0.843 <sup>**</sup>	0.301 <sup>NS</sup>	0.749 <sup>*</sup>	0.754 <sup>*</sup>	1.000					
V <sub>8</sub>	0.093 <sup>NS</sup>	0.552 <sup>NS</sup>	0.921 <sup>**</sup>	0.379 <sup>NS</sup>	0.798 <sup>*</sup>	0.810 <sup>**</sup>	0.819 <sup>**</sup>	1.000				
V <sub>9</sub>	0.233 <sup>NS</sup>	0.358 <sup>NS</sup>	0.523 <sup>NS</sup>	0.353 <sup>NS</sup>	0.417 <sup>NS</sup>	0.311 <sup>NS</sup>	0.481 <sup>NS</sup>	0.398 <sup>NS</sup>	1.000			
V <sub>10</sub>	0.440 <sup>NS</sup>	0.978 <sup>**</sup>	0.339 <sup>NS</sup>	-0.120 <sup>NS</sup>	0.085 <sup>NS</sup>	0.596 <sup>NS</sup>	0.295 <sup>NS</sup>	0.496 <sup>NS</sup>	0.306 <sup>NS</sup>	1.000		
V <sub>11</sub>	0.395 <sup>NS</sup>	0.234 <sup>NS</sup>	0.369 <sup>NS</sup>	0.111 <sup>NS</sup>	0.352 <sup>NS</sup>	0.577 <sup>NS</sup>	0.412 <sup>NS</sup>	0.169 <sup>NS</sup>	0.124 <sup>NS</sup>	0.117 <sup>NS</sup>	1.000	
V <sub>12</sub>	0.158 <sup>NS</sup>	0.868 <sup>**</sup>	0.583 <sup>NS</sup>	0.136 <sup>NS</sup>	0.386 <sup>NS</sup>	0.733 <sup>*</sup>	0.575 <sup>NS</sup>	0.731 <sup>*</sup>	0.329 <sup>NS</sup>	0.861 <sup>**</sup>	0.051 <sup>NS</sup>	1.000

**Table 17:** Path analysis of the yield and growth parameters of Ashwagandha

	V <sub>1</sub>	V <sub>2</sub>	V <sub>3</sub>	V <sub>4</sub>	V <sub>5</sub>	V <sub>6</sub>	V <sub>7</sub>	V <sub>8</sub>	V <sub>9</sub>	V <sub>10</sub>	V <sub>11</sub>
V <sub>1</sub>	0.105	0.037	-0.001	-0.021	-0.018	0.022	0.023	0.009	0.024	0.046	0.041
V <sub>2</sub>	0.384	1.087	0.488	-0.099	0.219	0.764	0.403	0.600	0.389	1.062	0.254
V <sub>3</sub>	0.003	-0.189	-0.422	-0.231	-0.399	-0.331	-0.355	-0.388	-0.220	-0.143	-0.155
V <sub>4</sub>	-0.085	-0.037	0.225	0.411	0.297	0.054	0.123	0.156	0.145	-0.049	0.045
V <sub>5</sub>	-0.038	0.042	0.200	0.153	0.211	0.130	0.158	0.169	0.088	0.018	0.074
V <sub>6</sub>	0.163	0.538	0.600	0.101	0.470	0.765	0.577	0.620	0.238	0.456	0.441
V <sub>7</sub>	0.147	0.242	0.549	0.195	0.488	0.491	0.652	0.533	0.313	0.192	0.268
V <sub>8</sub>	-0.058	-0.344	-0.575	-0.236	-0.498	-0.505	-0.510	-0.624	-0.248	-0.309	-0.105
V <sub>9</sub>	-0.053	-0.082	-0.120	-0.081	-0.095	-0.071	-0.110	-0.091	-0.229	-0.070	-0.028
V <sub>10</sub>	-0.111	-0.247	-0.085	0.030	-0.021	-0.150	-0.074	-0.125	-0.077	-0.253	-0.029
V <sub>11</sub>	-0.299	-0.177	-0.279	-0.083	-0.266	-0.436	-0.311	-0.127	-0.094	-0.088	-0.756

Where dependent variable is V<sub>12</sub> – Dry root weight per plant and independent variables are V<sub>1</sub> – Plant height, V<sub>2</sub> – Stem collar diameter, V<sub>3</sub> – Number of branches per plant, V<sub>4</sub> – Leaf length, V<sub>5</sub> – Leaf width, V<sub>6</sub> – Number of berries per plant, V<sub>7</sub> – Number of seeds per berry, V<sub>8</sub>–Seed yield per plant, V<sub>9</sub>–Primary root length, V<sub>10</sub>–Primary root diameter, V<sub>11</sub>- Number of secondary roots per plant.

## Conclusion

Karanj cake @ 5 q/ha with N<sub>40</sub>:P<sub>50</sub>:K<sub>30</sub> kg/ha showed higher results than other two treatment combinations i.e. Neem cake and FYM. Karanj cake with above N: P: K levels showed significant results in parameters; collar diameter, primary root length, primary root diameter, secondary roots per plant, fresh root weight, dry root weight and seed yield per plant. This particular treatment combination produced good results in terms of growth and yield characteristics. The above study will be significant to the farmers and medicinal plant growers interested for the commercial cultivation of Ashwagandha in Jharkhand. The above data presented in the thesis would be a

base for the more researches on fertilizer trial of Ashwagandha plant and analysis of yield of crop.

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