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Effect of Sowing Dates on Morphological Characteristics, Root Yield and Chemical Composition of the Root of *Withania Somnifera* Grown in the Semi-Arid Regions of Andhra Pradesh, India

Pandu Sastry Kakaraparthi[1*], Dharmendra K Rajput[1], Karnati Komaraiah[1], Niranjan Kumar[1] and Ramesh R Kumar[2]

[1]Central Institute of Medicinal and Aromatic Plants [CIMAP], Research Centre, Boduppal, Hyderabad-500092, Andhra Pradesh, India.
[2]Central Institute of Medicinal and Aromatic Plants [CIMAP], Research Centre, Allalasandra, G.K.V.K. [PO], Bangalore 560065, Karnataka, India.

Authors' contributions

This work was carried out in collaboration between all authors. Author PSK designed the study, wrote the protocol, and wrote the first and final draft of the manuscript. Authors DKR and RRK managed the experimental process, helped in literature search and field work. Authors NK and KK analyzed the root samples and helped in literature search. All authors read and approved the final manuscript.

Research Article

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ABSTRACT

The present study was undertaken to study the effect of sowing date on morphology, yield and chemical composition of root of *Withania somnifera* grown in the semi arid regions of Andhra Pradesh, India. The experiment was carried out in the research farm of Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP), Research Centre, Hyderabad, India during 2009-2011. The experimental material included two morphologically different ashwagandha cultivars i.e. Poshita [variety developed by CIMAP] and Nagore [local variety grown in Madhya Pradesh, India]. Treatments consisted of two varieties [Poshita and Nagore] sown at ten different sowing dates [June

**Corresponding author: E-mail: kp.sastry@cimap.res.in, sastry.kakaraparthi@gmail.com;*

to October at 15 days interval] replicated thrice in a randomized complete block design. The influence of treatments on morphological characters, root yield, seed yield, starch, fibre content and the total alkaloid content of the roots were studied. Among the varieties tested, Poshita produced significantly more number of roots having more dry weight which ultimately resulted in significantly higher root yield compared to variety Nagore. Variety Poshita exhibited superiority over Nagore in all the morphological characters studied also. Early sowings (June-July) resulted in higher root yield. The yield variation in the varieties in relation to sowing time is discussed in this paper.

Keywords: Withania; dry root yield; root fibre; Poshita; Nagore.

1. INTRODUCTION

Withania somnifera (Fam. Solanaceae) commonly known as 'ashwagandha' is one of the most important medicinal plants which is used alone or in combination with other medicinal plants in various ayurvedic formulations [traditional Indian system of medicine]. It is a dry land medicinal plant and the dried roots are the primary economic part. The medicinal properties of ashwagandha have been studied well and reviewed in detail [11]. All parts of the plant contain chemical compounds called Withanolides/steroidal lactones to which most of the pharmacological activity is attributed [3,6,8,9,16,24]. Reports on accumulation pattern of total alkaloids [5]; withaferin-A and withanone [7] at different crop growth stages that aided to determine suitable harvest stage for better medicinal properties are available. Starch and fibre contents of ashwagandha root play a dominant role in determining root quality. Brittle roots having high starch and low fibre are highly priced because of their ease in making powder and are quoted to be characteristic root textural features of commercial ashwagandha [3,22]. Morphological, chemical and molecular variability of different ashwagandha morphotypes have been studied by several researchers [2,10,18,19].

In India the plant grows wild in North Western regions extending to mountainous regions of Punjab, Himachal Pradesh and Jammu up to an altitude of 1500 m. It is also cultivated approximately in 5000 ha in Rajasthan, Madhya Pradesh and Andhra Pradesh [15].

In the semi-arid to arid Central and Southern States of India comprising Madhya Pradesh, Maharashtra, Andhra Pradesh, Karnataka and Tamil Nadu about 76-82% of the cultivated area is under rainfed agriculture. In Andhra Pradesh, Anantapur district accounts for 6.7% of the total geographical area of the State and was found to be one of the driest parts of the country with aridity index of 72.5% with second lowest average rainfall of 520.4 mm after Jaisalmer district in Rajasthan. Central Institute of Medicinal and Aromatic Plants (CSIR-CIMAP) started pilot scale cultivation of aswagandha as an alternative crop to replace groundnut and the area under its cultivation started increasing.

Rainfall is the single most important natural resource input under this form of cropping in the rainfed areas. Proper and timely tillage, sowing method, sowing time, planting geometry, new crop varieties, use of fertilizers, pesticides and herbicides in suitable crop rotations are some of the practices that contribute to the increase and stabilization of agricultural production. In this experiment an attempt was made to study the influence of sowing date on the root yield and plant morphology in two varieties of *Withania somnifera.*

2. MATERIALS AND METHODS

2.1 Experimental Material and Design of Experiment

The experiment was carried out in the research farm of CSIR-CIMAP, Research Centre, Hyderabad, India during 2009-2011. The experimental material included two morphologically different ashwagandha cultivars i.e. Poshita (variety developed by CIMAP) and Nagore (local variety grown in Madhya Pradesh, India). These are widely cultivated in dry land districts of Andhra Pradesh, India.

The two varieties were studied for dry root yield and root physical quality parameters [starch content and crude fibre content] at ten different sowing dates. Experimental materials were raised in a randomized block design with factorial concept. Varieties (Poshita and Nagore) were taken as factors and sowing dates (ten dates, once in every fifteen days starting from June to October) constituted the levels in the factorial experiment. The treatments were replicated three times. The crop was sown in the first and third weeks of a month starting from June, 2009. The experiment was repeated during 2010-11.

The seeds were sown with a row to row distance of 30 cm. and thinning was done 15 days after sowing to maintain 10 cm distance between plants in a row. Normal cultural practices were followed throughout the crop season. The crop was harvested 135 calendar days after sowing and observations on root parameters recorded. The same pattern was followed for all the treatments. Poshita is tall, with red coloured berries and non-wavy leaves. Nagore is medium tall, with yellow berries and wavy leaves. The harvest indicators suggested for the varieties are yellow (Nagore) /red (Poshita) coloured berries with yellow colour fruiting calyx. It was suggested that harvesting these two varieties between 135-150 days after sowing results in higher dry root yield Harvesting started in case of first treatment in the last week of October as recommended by Ramesh Kumar and his co-workers [22].

2.2 Observation on Morphometric Traits

Data were recorded on fifteen competitive plants in each plot for eight morphometric traits viz., plant height, plant weight, leaf area, number of leaves /plant, weight of leaves /plant, number of branches/plant, dry weight of root/plant (g). Leaf length and width were measured in 10 leaves / plant and leaf area was arrived by multiplying leaf length and width by constant value [0.7028] as per the method suggested by Patidar and his co-workers [21].

2.3 Observations on Root Textural Quality Parameters

For chemical analysis the root material of the plants in each treatment plot was collected and the samples from the replications were then bulked and dried under shade. Finally the root samples were dried at 45–50ºC in oven for 48–50 hr to constant dry weight. The dried root material was ground in pulveriser, sieved and fine root powder was used for the analysis. Root starch content was determined as per methodology suggested by Hodge and Hofrieter [8] and crude fibre content was quantified according to Maynard [16].

2.4 Statistical Analysis

Analysis of variance was performed to determine the effect of varieties, sowing dates, and interaction (varieties x sowing dates) on root yield and quality parameters using statistical

software IRRISTAT (IRRI, Manila, Philippines). Means were compared using least significant differences (LSDs) at 5% probability levels.

3. RESULTS

3.1 Effect of Different Sowing Dates on Plant Height, Plant Weight, Number of Leaves /Plant, Leaf Area and Leaf Weight in Aswagandha Varieties

Comparison of means of morphological characters like plant height, plant weight, number of leaves /plant, leaf weight and leaf area in the two varieties at different sowing dates and their interaction effects are presented in Table 1. Among the varieties higher values for plant height [93.61 cm] and plant weight (166.98 g) were observed for variety Poshita compared to Nagore (60.10cm and 80.13 g, respectively). The results indicated that sowing date significantly influenced all evaluated traits. The highest values for plant height and plant weight were obtained from the early dates of sowings (1st June to 1st July) compared to the later sowings (August to October). These results indicated that among the measured characters, the effect of sowing date was highest on plant weight compared to plant height. Number of leaves /plant, leaf area (cm^2) and leaf weight (g/plant) in the two varieties were significantly influenced by sowing dates (Table 1). Among the varieties significantly higher values for these parameters were observed for variety Poshita compared to Nagore. The mean leaf number/plant (205.1), leaf weight (54.34g) and leaf area [33.30 cm^2] was more in the variety Poshita compared to variety Nagore (145.45, 20.95g and 15.18 cm^2, respectively). The mean leaf number decreased from 251.69 /plant in 1st June sowing to 96.88 /plant in 15th October sowing. Similar decreases were also observed in case of leaf weight /plant (51.33 g/plant to 20.70 g/plant) and leaf area (22.26 cm^2/ leaf to 20.30 cm^2 /leaf).

3.2 Effect of Different Sowing Dates on Number of Branches, Number of Berries, Number of Roots, Root Length and Dry Weight of Roots/Plant

Data presented in Table 2 indicate that different sowing dates significantly influenced the number of branches, number of berries, number of roots, root length and dry weight of roots/plant in both the aswagandha varieties. Among the varieties, significantly higher values were observed for variety Poshita compared to Nagore. The highest values for number of branches /plant and number of berries /plant were obtained from the first date of sowing (1st June).

Comparison of means of morphological characters pertaining to number of roots /plant, root length /plant and dry weight of roots/plant in two varieties at different sowing dates and their interaction effect are presented in Table 2. Among the varieties significantly higher values for these parameters were observed for variety Poshita compared to Nagore. The mean number of roots/plant (11.06) , length of root (16.29 cm) and dry weight of root /plant (5.01g) was more in the variety Poshita compared to variety Nagore (8.06, 11.21 and 2.96 g/plant, respectively). Decreases were also observed in case of number of roots/plant (11.42 to 8.08), length of root (15.37 to 11.61 cm) and dry weight of root /plant (5.03 to 3.47 g/plant) with advancement in sowing dates. These results indicated that among the measured characters, the effect of sowing date was highest on dry weight of root. The differences are more pronounced in the varieties.

Table 1. Effect of different sowing dates on plant height, plant weight, no of leaves, leaf weight and leaf area in two aswagandha varieties

Treatments	Plant height, cm			Plant weight, g			No of leaves/plant			Leaf weight ,g			Leaf area , cm^2		
	I*	II**	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.
Varieties (V)															
Poshita	87.99	99.23	93.61	163.55	170.41	166.98	207.83	202.51	205.17	51.97	56.71	54.34	34.03	32.56	33.30
Nagore	55.59	64.62	60.10	75.50	84.77	80.13	146.63	144.27	145.45	19.30	22.60	20.95	16.53	13.82	15.18
C.D.*(P=.05)*	1.42	1.42		1.74	1.45		1.56	1.30		0.87	1.17		1.08	0.99	
Sowing dates(D)															
1st June	83.20	97.77	90.48	163.68	174.76	169.22	271.65	231.73	251.69	49.67	52.98	51.33	25.83	18.68	22.26
15th June	83.53	97.07	90.30	149.30	170.24	159.77	228.48	207.98	218.23	48.33	52.83	50.58	28.33	20.00	24.17
1st July	77.00	89.52	83.26	142.02	153.60	147.81	207.78	198.00	202.89	45.50	51.83	48.67	28.33	30.24	29.29
15th July	72.28	86.73	79.51	139.45	149.83	144.64	203.48	191.23	197.36	42.67	48.33	45.50	27.00	28.83	27.92
1st August	69.77	82.23	76.00	131.28	131.04	131.16	195.61	184.85	190.23	37.50	42.50	40.00	26.67	25.17	25.92
15th August	70.17	82.10	76.13	120.65	120.17	120.41	174.86	179.80	177.33	32.17	38.83	35.50	26.33	22.00	24.17
1st September	68.62	76.13	72.38	99.25	115.97	107.61	162.37	168.48	165.43	31.33	33.17	32.25	25.17	22.50	23.83
15th September	67.63	74.77	71.20	92.45	106.31	99.38	150.28	148.67	149.48	28.00	30.33	29.17	23.00	22.33	22.67
1st October	65.65	69.58	67.62	78.88	87.53	83.21	88.78	118.39	103.59	20.17	25.33	22.75	22.00	21.70	21.85
15th October	60.02	63.37	61.69	78.28	66.44	72.36	89.00	104.75	96.88	21.00	20.40	20.70	20.17	20.44	20.30
C.D.*(P=.05)*	3.17	3.18		3.89	3.25		3.49	2.91		1.95	2.61		2.43	2.22	
Interaction VXD															
C.D.*(P=.05)*	4.49	4.50		5.50	4.59		4.94	4.12		2.75	3.69		3.43	3.14	
C.V%	3.55	3.11		2.61	2.04		1.58	1.35		4.38	5.27		7.69	7.68	

I- 2009-10 II**- 2010-11*

Table 2. Effect of different sowing dates on number of branches /plant, number of berries /plant and weight of berries/plant

Treatments	No of branches /plant			No. of berries/plant			Number of roots/plant			Length of root, cm			Dry weight of root, g		
	I*	II**	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.	I	II	Ave.
Varieties (V)															
Poshita	20.50	16.67	18.58	236.49	231.80	234.14	10.70	12.50	11.60	13.04	19.54	16.29	5.79	4.22	5.01
Nagore	16.60	13.08	14.84	180.70	161.60	171.15	7.47	8.66	8.06	9.05	13.38	11.21	3.13	2.79	2.96
C.D.*(P=.05)*	1.21	1.10		1.37	1.62		0.44	0.97		1.23	1.45	..	0.57	0.63	
Sowing dates(D)															
1st June	21.83	16.33	19.08	274.33	254.83	264.58	11.33	11.50	11.42	12.41	18.33	15.37	5.46	4.67	5.06
15th June	22.33	15.17	18.75	275.08	258.00	266.54	11.17	11.50	11.33	12.35	17.96	15.16	5.10	3.84	4.47
1st July	21.00	18.00	19.50	248.34	217.50	232.92	10.00	12.45	11.23	12.76	22.37	17.57	5.07	3.85	4.46
15th July	20.17	16.33	18.25	243.17	222.67	232.92	9.50	11.50	10.50	11.56	19.24	15.40	4.55	4.73	4.64
1st August	19.50	18.83	19.17	217.67	214.00	215.83	9.33	11.33	10.33	11.09	16.27	13.68	4.55	3.57	4.06
15th August	18.17	15.55	16.86	212.33	210.17	211.25	8.50	8.67	8.58	10.70	15.50	13.10	3.72	2.51	3.12
1st September	17.50	15.33	16.42	177.83	162.83	170.33	8.33	10.67	9.50	10.67	14.92	12.80	4.27	2.88	3.58
15th September	15.50	12.83	14.17	159.83	184.33	172.08	7.82	9.50	8.66	9.77	14.88	12.33	4.17	3.13	3.65
1st October	14.83	8.67	11.75	161.33	142.33	151.83	8.01	9.33	8.67	9.53	11.50	10.52	3.85	2.82	3.33
15th October	14.67	11.67	13.17	116.00	100.33	108.17	6.83	9.33	8.08	9.60	13.62	11.61	3.89	3.05	3.47
C.D.*(P=.05)*	2.70	2.45		3.06	3.62		0.98	2.18		2.76	3.24	..	1.28	1.40	
Interaction VXD															
C.D.*(P=.05)*	3.81	3.47		4.32	5.13		1.38	3.08		3.90	4.58	..	1.81	1.98	
C.V%	11.66	13.21		1.18	1.48		8.63	16.50		20.03	15.79	..	22.98	32.01	

I- 2009-10 II**- 2010-11*

Table 3. Effect of different sowing dates on fibre content, starch and total alkaloid content

Sowing date	Fibre content, %			Total alkaloids content (%)			Starch content , %		
	Nagore	Poshita	Average	Nagore	Poshita	Average	Nagore	Poshita	Average
1st June	5.36	4.82	5.09	0.49	0.54	0.52	15.33	19.55	17.44
15th June	5.72	6.21	5.97	0.91	0.85	0.88	13.33	18.34	15.84
1st July	6.27	5.88	6.08	1.32	1.44	1.38	11.95	18.25	15.10
15th July	7.91	8.24	8.08	1.32	1.56	1.44	10.82	13.86	12.34
1st August	7.28	8.34	7.81	1.24	1.67	1.46	9.55	12.67	11.11
15th August	8.23	9.23	8.73	0.91	0.88	0.90	14.32	14.71	14.51
1st September	21.24	18.56	19.90	0.66	0.73	0.70	14.20	16.39	15.30
15th September	23.62	17.85	20.74	0.58	0.84	0.71	12.60	15.72	14.16
1st October	24.62	22.24	23.43	0.73	0.66	0.70	10.44	15.80	13.12
15th October	23.10	24.76	23.93	0.16	0.24	0.20	12.54	16.14	14.34

Data not analysed statistically. Data averages of composite samples for the second year of experimentation only.

3.3 Effect of Different Sowing Dates on Fibre Content, Starch and Total Alkaloid Content

Comparison of means of morphological characters pertaining to fibre content, starch and total alkaloid content in two varieties at different sowing dates and their interaction effect are presented in Table 3. The results indicated that sowing date significantly influenced all evaluated traits.

The differences in the fibre content noticed on an average over all sowing dates (Table 3) between the two varieties Poshita (12.61 %) and Nagore (13.34%) were marginal. Similar observations were noticed in case of total alkaloid content and starch content. The differences noticed between varieties were marginal only.

On an average, in both the varieties with advancement in sowing date from 1st June to 15th of October there was a study increase in the fibre content (from 5.36 to 23.10% in case of Nagore and from 4.82 to 24.76 % in case of Poshita). The total alkaloid content increased with advancement in sowing date from June to August in both the varieties and decreased in late sowings up to October. The starch content showed decrease-increase-decrease pattern with delay in sowings. By and large on an average there is a study decrease in starch content with advancement in sowings from June to October. The effect of sowing dates is more pronounced in case of Nagore compared to Poshita.

4. DISCUSSION

Poshita is a tall variety with red coloured berries and non-wavy leaves. Nagore is medium tall, with yellow berries and wavy leaves [17,22].

Among the varieties Poshita was found to be superior to the locally cultivated variety. Early sowing dates resulted in morphologically superior plants that gave better root yields. The advantage in terms of root yield was a manifestation of morphological parameters like plant height, leaf number, leaf weight, stem weight, leaf area and also root characters like root number and length. Similarly, in case of winter wheat also it was observed that the influence of sowing date occurred during ear emergence to heading stages and yield components such as kernel weight and kernels per spike were reduced with the delay in sowing date [13].

Besides the morphological advantage, variety Poshita also had higher total alkaloid and starch contents. This was substantiated earlier [22,23]. Crop which was sown with the onset of monsoon and early rainy season (June-July sowings) experienced higher day/ night temperatures (Table 4) and adequate rainfall during early stages of crop growth that resulted in better crop growth compared to later sowings [August – October sowings]. Low day and night temperatures during later stages of crop growth before harvest in early sown crop also resulted in quality root development. In experiments conducted to study the method of sowing for aswagandha it was found that harvesting time had pronounced effect on productivity and morphology of roots [1,20]. It was suggested that harvesting these two varieties between 135-150 days after sowing results in higher dry root yield with better root textural parameters [22] compared to late harvesting.

Table 4. Monthly average weather parameters at the experimental site

Month	Maximum temp., ºc	Minimum temp., ºc	Rainfall, mm
January	28	16	5.0
February	32	18	10.0
March	35	21	15.0
April	38	24	17.8
May	39	26	40.6
June	34	24	116.8
July	31	23	154.9
August	30	22	162.6
September	31	22	152.4
October	31	21	96.5
November	28	17	27.9
December	28	15	2.5

Crop which was sown in June to August the root development took place during September to November and the crop was harvested during November to December period. Higher day night temperatures and adequate rainfall during early stages of crop growth and low day and night temperatures during later stages resulted in lower fibre content in the root.

In late sown crop, high temperatures during the later crop stages especially during root development stage resulted in higher fibre and starch contents. High temperature resulted in decrease in the total alkaloid content in root. In potato crop also it was suggested that the structure of the starch granules became less ordered with later planting [25]. Lower temperatures throughout crop growth and root formation in late sown crops might have lead to the present results. Similarly, the effects of sowing and harvest date on root yield and total sugar content were assessed in three chicory varieties during 1992 and 1993. In both years the sugar yield was at least 30% higher at an early sowing date (before mid-April) than sowing one month later [14].

5. CONCLUSION

Variety Poshita developed by CSIR-CIMAP was found to yield higher root yield compared to the locally cultivated variety Nagore. Variety Poshita also had higher total alkaloid and starch contents compared to the local variety.

Early sowing dates (June to August) resulted in morphologically superior plants that gave better root yield. Crop which was sown in June to August period produced roots with lower fibre content. Low day and night temperatures during later stages of crop growth before harvest in early sown crop resulted in quality root development.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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