J. Farm Sci., 35(2): (259-265) 2022

RESEARCH PAPER

Root development, root yield and quality parameters as influenced by plant density and harvesting stages in shatavari (*Asparagus racemosus* Willd.)

MAHANTESH ILAGER, J. S. HIREMATH, D. SRIKANTAPRASAD, VIJAYAKUMAR NARAYANAPUR, R. T. PATIL AND SACHINKUMAR T. NANDIMATH

Department of Plantation, Spices, Medicinal and Aromatic crops, KRC College of Horticulture, Arabhavi University of Horticultural Sciences, Bagalkot - 587 103, Karnataka, India
E-mail : mantuilager@gmail.com

(Received: April, 2022 ; Accepted: June, 2022)

Abstract : The present study, effect of plant density and harvesting stage on shatavari was carried out during 2019-2021 at Kittur Rani Channamma College of Horticulture, Arabhavi. The results revealed that, maximum number of roots (209.10/plant), root volume (3346.66 cc), root length (37.64 cm), root girth (13.99 mm), higher fresh and dry root yield per plant (3.47 and 0.56 kg, respectively) and maximum fresh to dry root recovery (16.54 %) were recorded at wider spacing of 1.2 m × 1.5 m (D_4). Maximum fresh and dry root yield per hectare (402.00 and 59.24 q, respectively) and total saponin content (6.06 %) were obtained at closer spacing of 1.2 m × 0.6 m (D_1). Among harvesting stages, H_4 (18 MAP) recorded more number of roots per plant (210.00), maximum root length (45.78 cm), root girth (14.87 mm), root volume (3712.50 cc), maximum fresh and dry root yield per hectare (359.73 and 55.20 q, respectively). D_1H_4 recorded maximum fresh and dry root yield per plot and per hectare and also higher gross returns (₹ 7,58,250), net returns (₹ 4,43,038) and returns per rupee of investments (2.41).

Key words: Harvesting stages, Plant density, Saponin, Shatavari

Introduction

The use of plants to cure or combat illness is most likely as old as humankind. For hundreds of years native people of different cultures have used plants as medicine for various types of healing. India is known as one of the world's richest troves of treasure of medicinal plants. India is also one of the important medico-culturally diverse countries in the world, where the usage of medicinal plants for illness is a part of time honoured tradition, which is respected even today (Goyal *et al*., 2003).

Asparagus racemosus is one of the important medicinal plant, which is regarded as a 'rasayana', that means a plant drug which promotes general well-being. It is one of the important medicinal plants of tropical and subtropical region and it belongs to the newly created family Asparagaceae. The genus *Asparagus* moved from the subfamily Asparagae in the liliaceae family to the Asparagaceae family (Oketch-Rabah, 1998; Batchelor and Scott, 2009). In India it is commonly known as shatavari, satmuli or satawar, sheetveerya, narayani, shatapadi, shatavar, shatamuli, bahusta, majjige gadde (Kannada) *etc*. It is distributed in Asia, tropical Africa and Australia. In Himalaya, it naturally grows below 4000 ft from Kashmir Eastwards (Collet, 1921; Anon, 1948). *Asparagus racemosus* is a climbing, tall woody, abundantly branched undershrub. Roots are many, smooth, fusiform, perennial fasciculated tubers, which are the economic parts. The leaves are minute scales, often spinescent, with tufts of needle like or flattened branchelets in their axils (Cladodes). Flowers are tiny, axillary, racemed, pedicillate and jointed in the centre.

Bioactive compounds are rich in shatavari containing phytoestrogens in large amount. The major phytoestrogens group present is steroidal saponins. It also contains diosgenin and other saponins such as shatavarin I and IV in both leaves and roots and also shatavarin V to X in roots. Roots are the economic part due to presence of high amount of bioactive compounds (Sharma, 1998). The tuberous roots are primarily used in Ayurvedic medicine for the preparation of Shatmulyadi lehya, Shatavari ghrita, Narayan tail, Shatavari panak, Vishnu tail, Shatavari kalpa, Musli pak, Phalaghrita, Brahma Rasayana *etc*. Shatavari is mainly known for its phytoestrogenic and galactopoietic properties. It is said to be both a general tonic and female reproductive tonic. In Ayurvedic texts, it is recommended for prevention and treatment of inflammation, gastric ulcers, liver diseases and other infectious diseases (Goyal *et al*., 2003). Traditionally, the plant has been used as a galactagogue which promotes the secretion of breast milk.

So far medicinal plants have been mainly collected from wild sources. Moreover, the plant materials obtained from wild sources have the problem of adulteration and misidentification. Hence, cultivation of authentic, genuine variety of plants is the only way to get the material of desired quality. Presently, the area under shatavari crop is growing day by day and it is being cultivated in many districts of Karnataka like Kalaburgi, Belagavi, Bagalkot, Haveri, Bellary *etc*. But due to lack of availability of proper agro-techniques its cultivation in India is very less.

Material and methods

Details of the experimental site

The field experiment was conducted during 2019-2021 at the Department of Plantation, Spices, Medicinal and Aromatic Crops, Kittur Rani Channamma College of Horticulture, Arabhavi, University of Horticultural Sciences, Bagalkot, Karnataka, India. Arabhavi is situated in Northern dry zone (Zone No. 3; Region-2) of Karnataka at 16°15' N latitude and 74°45' E longitude, at an altitude of 612 m above mean sea level,

in Ghataprabha Left Bank Canal (GLBC) command area. The experimental site receives, on an average, about 362.90 mm rainfall annually. The soil of the experimental site was sandy clay loam with pH 7.42.

Experimental details

The experiment was laid out in Factorial Randomized Block Design (FRBD) with three replications, considering plant density and harvesting stages as factors. Local, white type shatavari was used for the experiment. The plots of 6 m width and 7.2 m length were laid out and the ridges were formed at 120 cm apart in each plot. The seedlings were planted at hole dug by pickaxe at different spacing according to different treatments (60, 90, 120 and 150 cm) at mid of the ridges. The crop received 60:80:100 kg/ha NPK in the form of Urea, SSP and MOP. FYM was supplied at the rate of 20 t/ha. The crop was harvested at different stages starting from 12 months after planting to 18 months after planting at the intervals of 2 months.

Observations on root development, root yield and quality parameters like number of roots, root volume, root length, root girth, fresh and dry root yield, fresh to dry root recovery, harvesting index and total saponin content were recorded at each harvesting stage. Root diameter was measured by using digital vernier caliper at middle bulge portion of the root. Fresh roots were taken, washed and outer peel was removed for easy drying by using peeler. Then the roots were dried in hot air oven at 60 °C for about 24 hours. Dry weight was recorded. The procedure given by Dini *et al*. (2009) was followed to estimate the total saponin content.

Treatment details

Factor I: Plant density

D_1. 1.2 m x 0.6m (13888 plants/ha)

D_2. 1.2m x 0.9 m (9259 plants/ha)

D_3. 1.2 m x 1.2 m (6944 plants /ha)

D_4. 1.2 m x 1.5 m (5555 plants /ha)

Factor II: Harvesting stages

H_1: 12 MAP

H_2: 14 MAP

H_3: 16 MAP

H_4: 18 MAP

MAP: Months After Planting

Results and discussion

Root development parameters

Observations on root development parameters are presented in Table 1. Among plant densities, D_4 (1.2 m × 1.5 m) recorded maximum number of roots (209.10) per plant, root volume (3346.66 cc), root length (37.64 cm) and root girth (13.99 mm) and was on par with D_3 (1.2 m x 1.2 m) for root length (42.31 cm) and root girth (13.45 mm). While, D_1 (1.2 m × 0.6 m) recorded minimum number of roots (124.21) per plant, root volume (2231.67 cc), root length (37.64 cm) and root girth (11.66 mm). The increase in root development characters at wider spacing might be due to the enhanced growth of plants producing more number of cladophylls, which inturn increased the exposure of more photosynthetic area into sunlight and ultimately produced more number of photosynthates. It is also might be due to availability of more ground area for proper growth and development of roots at wider spacing. These results are in agreement with Suresh *et al*. (2010) in medicinal coleu; Phatak *et al*. (2014) in glory lily and Mehera *et al*. (2016) in sarpagandha.

Harvesting stages also manifested significant effect on root development parameters (Table 2). Harvesting the crop at 18 MAP (H_4) resulted in more number of roots per plant (210.00), maximum root length (45.78 cm), root girth (14.87 mm) and root volume (3712.50 cc). While, lesser number of roots per plant (124.21), minimum root length (35.36 cm), root girth (11.70 mm) and root volume (1660.83 cc) were obtained when early harvesting of crop was done at 12 MAP (H_1). The increase in values of yield attributing characters could be due to higher length of growing period. Kubsad and Palled (2008) also recorded maximum root length and girth of ashwagandha plants when harvested at 180 days after sowing. Similar results were obtained by Thakur (2016) in shatavari and Nagve *et al*. (2016) in safed musli. Interaction effect of plant density and harvesting stage had shown non-significant effect on root development characters.

Root yield parameters

Higher fresh and dry root yield per plant (3.47 and 0.56 kg, respectively) and maximum fresh to dry root recovery (16.54 %) were recorded at wider spacing of 1.2 m × 1.5 m (D_4) (Table 2 & 3). While, lower fresh and dry yield of roots per plant (2.29 and 0.33 kg, respectively) and minimum fresh to dry root recovery (14.67 %) were recorded at closer spacing of 1.2 m × 0.6 m (D_1). The increase in fresh and dry root yield per plant might be due to availability of more amount of nutrients and more area for spreading and proper development of roots. It is also due to the production of more number of roots, lengthy and thicker roots per plant at wider spacing. Thakur (2016) also reported maximum fresh (246.79 g) and dry root yield (32.08 g) at wider spacing in shatavari. These findings are in line with Suresh *et al*. (2010) in medicinal coleus, Mehera *et al*. (2016) in sarpagandha and Pavitra (2021) in menthol mint.

Maximum fresh and dry root yield per plot (144.89 and 21.35 kg, respectively) and per hectare (402.00 and 59.24 q, respectively) was obtained at closer spacing of 1.2 × 0.6 m (D_1). Minimum fresh and dry root yield per plot (75.51 and 12.44 kg, respectively) and per hectare (208.94 and 34.43 q, respectively) was recorded in D_4. This might be due to more number of plants per unit area at closer spacing, which led to the maximum fresh and dry root weight per plot and per hectare (Phatak *et al*., 2014). These results are in line with Suresh *et al*. (2010) in medicinal coleus; Eragegowda *et al*. (2021) in isabgol; Thakur (2016) in shatavari; Pooja *et al*. (2018) in sacred ocimum. However, plant density showed non-significant variation on harvest index.

Table 1. Influence of plant density and harvesting stages on number of roots, root volume, root length and root girth

Treatments	Number of roots/plant	Root volume (cc)	Root length (cm)	Root girth (mm)
Plant density (D)				
D_1 (1.2 m x 0.6 m)	136.39	2231.67	37.64	11.66
D_2 (1.2 m x 0.9 m)	149.42	2522.08	40.11	12.59
D_3 (1.2 m x 1.2 m)	180.92	2889.83	42.31	13.45
D_4 (1.2 m x 1.5 m)	209.10	3346.66	43.28	13.99
S.Em±	5.05	101.40	0.66	0.24
C.D. @ 5 %	14.58	292.86	1.90	0.69
Harvesting stages (H)				
H_1 (12 MAP)	124.21	1660.83	35.36	11.70
H_2 (14 MAP)	165.56	2255.25	40.47	12.16
H_3 (16 MAP)	176.06	3361.66	41.75	12.98
H_4 (18 MAP)	210.00	3712.50	45.78	14.87
S.Em±	5.05	101.40	0.66	0.24
C.D. @ 5 %	14.58	292.86	1.90	0.69
Interaction (D x H)				
D_1H_1	110.33	1543.33	30.20	10.18
D_1H_2	120.50	1786.67	39.90	11.32
D_1H_3	139.25	2650.00	38.30	11.80
D_1H_4	175.50	2946.67	42.18	13.36
D_2H_1	105.67	1390.00	34.00	11.72
D_2H_2	149.75	1981.67	38.33	11.74
D_2H_3	148.75	3270.00	41.60	12.47
D_2H_4	193.50	3446.67	46.53	14.43
D_3H_1	132.17	1903.33	39.15	12.58
D_3H_2	177.00	2152.67	40.68	12.55
D_3H_3	198.00	3606.67	42.35	13.38
D_3H_4	216.50	3896.67	47.08	15.29
D_4H_1	148.67	1806.67	38.08	12.32
D_4H_2	215.00	3100.00	42.97	13.02
D_4H_3	218.25	3920.00	44.75	14.27
D_4H_4	254.50	4560.00	47.35	16.39
S.Em±	10.10	202.80	1.31	0.48
C.D. @ 5 %	NS	NS	NS	NS

MAP : Months After Planting NS: Non Significant

Maximum yield of fresh and dry root per plant (3.74 and 0.57 kg, respectively), per plot (134.28 and 20.59 kg, respectively) and per hectare (359.73 and 55.20 q, respectively) was recorded at 18 months after planting (H_4) while minimum yield of fresh and dry root per plant (1.66 and 0.26 kg, respectively), per plot (63.63 and 9.77 kg, respectively) and per hectare (176.41 and 27.08 q, respectively) was recorded at 12 months after planting (H_1). Harvest index was found higher (94.53 %) at H_4 (18 MAP) and lower (84.92 %) at H_2 (14 MAP). The reason behind higher yield of roots at later stages could be due to availability of maximum period for proper growth and development of roots interms of number, length and diameter. These results are in agreement with Singh *et al*. (1999). They recorded higher tuber yield of 11.1 kg/plant after 51 months of planting and lowest tuber yield (2.5 kg/plant) after 15 months of planting. These results are in accordance with findings of Singh and Guleria (2013) in rosemary, Thakur (2016) in shatavari; Nagve *et al*. (2016) in safed musli.

Interaction effect of plant density and harvesting stages had non-significant effect on fresh and dry root yield per plant and on harvest index. However, higher fresh and dry root yield per plot (195.00 and 30.33 kg, respectively) and per hectare (541.67 and 84.25 q, respectively) was recorded in D_1H_4, while minimum fresh and dry root yield per plot (49.70 and 7.99 kg, respectively) and per hectare (137.40 and 22.08 q, respectively) was reported in D_4H_1. This might be due to the higher number of plants per unit area and availability of more period for growth and development of roots. These results are in agreement with Badi *et al*. (2004) in thyme; Kumar and Kumar (2013) in Kalmegh, Mansoori (2014) in peppermint.

Quality parameters

Total saponin content (%)

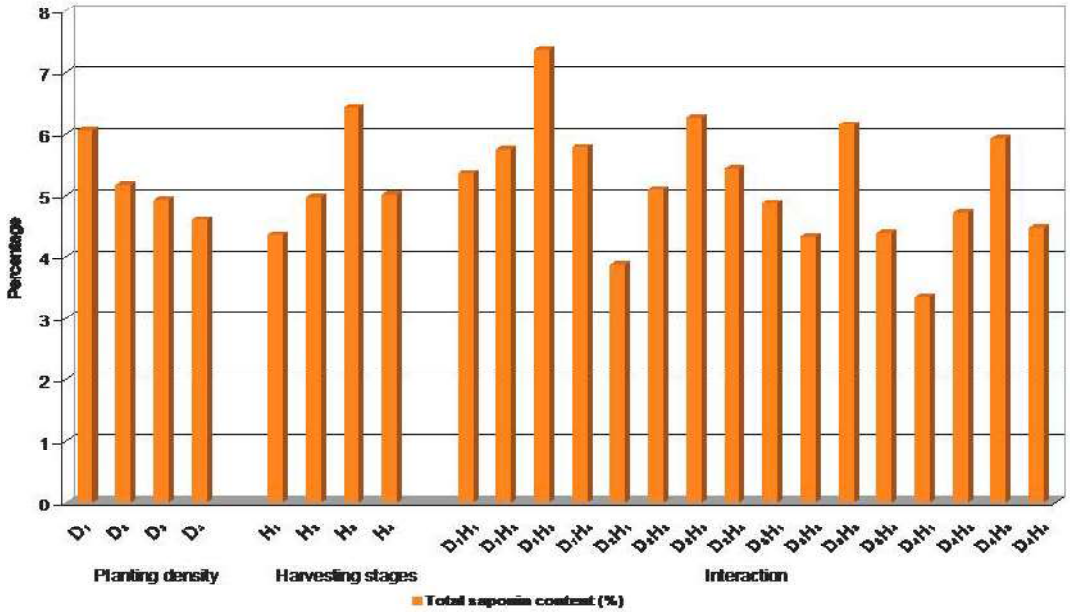
Higher amount of total saponin (6.06 %) was observed in D_1 (1.2 m × 0.6 m) while, lesser amount of total saponin (4.63 %) was observed in D_4 (1.2 m × 1.5 m) (Fig 1). This might be due to less starch content in roots of narrow spaced crop there was an inverse relationship between starch and alkaloid content of root crops.

Harvesting the crop at 16 MAP (H_3) reported higher total saponin content of 6.43 per cent, while minimum total saponin content of 4.36 per cent was reported at early stage (12 MAP) of harvest (H_1). At initial time plants are in active growth stage which resulted in accumulation of more food material. Whereas,

Table 2. Influence of plant density and harvesting stages on fresh root yield and harvest index

Treatments	Fresh root yield			Harvest index
	kg/plant	kg/plot	q/ha	(%)
Plant density (D)				
D_1 (1.2 m x 0.6 m)	2.29	144.89	402.00	89.20
D_2 (1.2 m x 0.9 m)	2.67	93.80	259.98	89.56
D_3 (1.2 m x 1.2 m)	2.96	84.87	222.38	90.37
D_4 (1.2 m x 1.5 m)	3.47	75.51	208.94	89.57
S.Em±	0.10	4.10	11.36	1.44
C.D. @ 5 %	0.28	11.83	32.81	NS
Harvesting stages (H)				
H_1 (12 MAP)	1.69	63.63	176.41	86.03
H_2 (14 MAP)	2.58	86.44	239.52	84.92
H_3 (16 MAP)	3.39	114.71	317.64	93.20
H_4 (18 MAP)	3.74	134.28	359.73	94.53
S.Em±	0.10	4.10	11.36	1.44
C.D. @ 5 %	0.28	11.83	32.81	4.17
Interaction (D x H)				
D_1H_1	1.54	76.81	212.85	87.60
D_1H_2	2.05	124.82	346.12	79.15
D_1H_3	2.65	182.93	507.37	94.92
D_1H_4	2.95	195.00	541.67	95.13
D_2H_1	1.39	63.45	176.43	84.73
D_2H_2	2.38	80.25	222.44	85.85
D_2H_3	3.37	103.35	286.02	93.39
D_2H_4	3.55	128.15	355.07	94.25
D_3H_1	1.90	64.58	178.98	86.78
D_3H_2	2.45	75.60	209.23	88.52
D_3H_3	3.61	89.05	246.62	92.13
D_3H_4	3.90	110.25	254.68	94.04
D_4H_1	1.94	49.70	137.40	85.03
D_4H_2	3.47	65.09	180.31	86.17
D_4H_3	3.92	83.52	230.53	92.36
D_4H_4	4.56	103.75	287.51	94.68
S.Em±	0.19	8.19	22.72	2.18
C.D. @ 5 %	NS	23.66	65.62	NS

MAP : Months After Planting NS : Non Significant



D: Plant density: D_1: 1.2 m x 0.6 m D_2: 1.2 m x 0.9 m D_3: 1.2 m x 1.2 m D_4: 1.2 m x 1.5 m

H: Harvesting stages: H_1: 12 MAP H_2: 14 MAP H_3: 16 MAP H_4: 18MAP

Fig. 1. Total saponin content as influenced by plant density and harvesting stages

Table 3. Influence of plant density and harvesting stages on dry root yield and fresh to dry root recovery

Treatments	Dry root yield			Fresh to dry root recovery
	Kg/plant	Kg/plot	q/ha	(%)
Plant density (D)				
D_1 (1.2 m x 0.6 m)	0.33	21.35	59.24	14.67
D_2 (1.2 m x 0.9 m)	0.41	14.46	40.08	15.32
D_3 (1.2 m x 1.2 m)	0.45	13.28	34.88	15.68
D_4 (1.2 m x 1.5 m)	0.56	12.44	33.93	16.54
S.Em±	0.02	0.70	1.91	0.26
C.D. @ 5 %	0.05	2.01	5.52	0.87
Harvesting stages (H)				
H_1 (12 MAP)	0.26	9.77	27.08	15.22
H_2 (14 MAP)	0.41	13.20	36.49	15.76
H_3 (16 MAP)	0.50	17.98	49.36	15.94
H_4 (18 MAP)	0.57	20.59	55.21	15.29
S.Em±	0.02	0.70	1.91	0.26
C.D. @ 5 %	0.05	2.01	5.52	NS
Interaction (D x H)				
D_1H_1	0.24	11.78	32.64	15.33
D_1H_2	0.26	15.94	44.19	12.79
D_1H_3	0.36	27.37	75.91	15.02
D_1H_4	0.46	30.33	84.25	15.55
D_2H_1	0.22	9.13	25.36	13.80
D_2H_2	0.40	13.47	37.32	16.91
D_2H_3	0.48	15.93	44.07	15.51
D_2H_4	0.53	19.33	53.56	15.06
D_3H_1	0.30	10.18	28.22	15.67
D_3H_2	0.39	12.06	33.37	15.92
D_3H_3	0.54	14.34	39.72	16.17
D_3H_4	0.59	16.55	38.22	14.98
D_4H_1	0.31	7.99	22.08	16.07
D_4H_2	0.60	11.34	31.09	17.41
D_4H_3	0.63	14.27	37.73	17.08
D_4H_4	0.71	16.17	44.80	15.59
S.Em±	0.04	1.39	3.82	0.52
C.D. @ 5 %	NS	4.02	11.04	1.50

MAP : Months After Planting NS : Non Significant

Table 4. Influence of plant density and harvesting stages on economics of shatavari

Treatments	Total cost of cultivation (₹)	Gross returns (₹)	Net returns (₹)	Returns per rupees of expenditure (₹)
D_1H_1	213390	293760	80370	1.38
D_1H_2	249823	396630	146807	1.59
D_1H_3	301975	676710	374735	2.24
D_1H_4	315212	758250	443038	2.41
D_2H_1	188318	228240	39409	1.21
D_2H_2	225889	335880	109991	1.49
D_2H_3	234745	396630	161885	1.69
D_2H_4	252771	482040	229269	1.91
D_3H_1	201002	253980	52978	1.26
D_3H_2	213672	300330	86658	1.41
D_3H_3	220386	357480	137094	1.62
D_3H_4	235248	343980	108732	1.46
D_4H_1	171577	198720	27143	1.16
D_4H_2	206739	282780	76041	1.37
D_4H_3	213548	354510	140962	1.66
D_4H_4	227359	403650	176291	1.80

Plant densities (D) Harvesting stages (H)

D_1 : 1.2 m x 0.6 m H_1 : 12 MAP

D_2 : 1.2 m x 0.9 m H_2 : 14 MAP

D_3 : 1.2 m x 1.2 m H_3 : 16 MAP

D_4 : 1.2 m x 1.5 m H_4 : 18 MAP

MAP : Months After Planting Price of dry roots – ₹ 90 per kg

at later stage starch is converted into saponin. These results are in line with Wankhade *et al*. (2010) in ashwagandha, Singh and Guleria (2013) in rosemary and Kumar and Kumar (2013) in kalmegh.

Among the interactions, D_1H_3 recorded maximum (7.37 %) total saponin content and D_4H_1 recorded minimum (3.35 %) total saponin content. In Kalmegh, Kumar and Kumar (2013) observed higher and rographolide content (2.63 %) at a planting distance of 30 cm × 15 cm and harvesting at 135 days after planting.

Economics

Higher gross returns (₹ 7,58,250), net returns (₹ 4,43,038) and returns per rupee of investment (2.41) was recorded in D_1H_4 (Table 4). Increase in gross and net returns might be related to increase in fresh and dry root yield due to more number of plants per hectare at 1.2 m × 0.6 m spacing and harvesting the crop at 18 MAP. The labour cost was the major (upto 50 %) component of total cost of cultivation due to higher labour usage in harvesting and peeling of shatavari roots. The similar results were also obtained by Jayalakshmi (2003) and Mastiholi *et al*., (2010) in medicinal coleus, Saravanan et *al*. (2019) in sarpagandha and Thakur (2016) in shatavari.

Conclusion

Based on the results of present experiment it can be concluded that, taking into consideration of higher dry root yield, quality and returns per rupee of expenditure, maintaining the plant spacing of 1.2 m × 0.6 m and harvesting the crop at 18 MAP can be recommended for adoption in cultivation of shatavari.

References

Anonymous, 1948, Wealth of India: a dictionary of Indian raw materials and industrial products: raw materials Delhi: CSIR, pp. 1:132.

Badi H N, Yazdani D, Ali S M and Nazari F, 2004, Effects of spacing and harvesting time on herbage yield and quality/quantity of oil in thyme (*Thymus vulgaris* L.). *Industrial Crops and Products*, 19(3): 231-236.

Batchelor K L and Scott J K, 2009, Review of the current taxonomic status and authorship for Asparagus weeds in Australia. *Plant Protection Quarterly*, 21(3): 128-130.

Collet H, 1921, Flora Similensis: A handbook of the flowering plants of simla and the neighbourhood. *London: Thacker, Spink & Co.*, pp. 522-523.

Dini I, Tenore G C and Dini A, 2009, Saponins in *Ipomea Batatus* Tubers: Isolation, Characterization, quantification and anti-oxidant properties. *Food Chemistry*, 113: 411-419.

Eragegowda M, Gouda M A P, Maruthiprasad B N, Pushpa T N, Thimmegowda M N and Smitha G R, 2021, Effect of planting geometry and nutrient levels on growth and yield of isabgol under eastern dry zone of Karnataka. *International Journal of Chemical Studies*, 9(2): 1136-1140.

Goyal R K, Singh J and Lal H, 2003, *Asparagus racemosus* – an update. *Indian Journal of Medical Science.,* 57(9): 408-414.

Jayalakshmi S, 2003, Effect of spacing and nitrogen levels on growth, tuberous root yield and alkaloid content of medicinal coleus (*Coleus forskohlii* Briq.). *M.Sc. Thesis, Tamil Nadu Agriculture University, Coimbatore.*

Kubsad, V. S. and Palled, Y. B., 2008, Effect of date of sowing and stage of harvest on root yield and quality of ashwagandha (*Withenia somnifera* Dunal) under rainfed conditions. *Journal of Medicinal Aromatic Plants*, 31: 13-16.

Kumar S and Kumar A, 2013, Spatial and harvesting influence on growth, yield, quality, and economic potential of kalmegh (*Andrographis paniculata* Wall Ex. Nees). *Journal of Agriculture and Rural Development in the Tropics and Subtropics*, 114(1): 69-76.

Mansoori I, 2014,The effect of plant density and harvesting time on growth and essential oil of peppermint (*Mentha piperita* L.). *Journal of Medical and Biological Engineering*, 3(2): 113-116.

Mastiholi A B, Hiremath S M, Patil P L, Chittapur B M, Hegde L and Mathad J C, 2010, Economics of pashanbhedi (*Coleus forskohlii* Briq.) as influenced by spacing, time of harvest and their interaction under irrigated condition. *International Journal of Agricultural Research*, 44(3): 221-224.

Mehera B, Kumar H, Ramachandra Maurya C B and Lal S B, 2016, Effect of different fertility levels and plant spacing on growth and yield of Sarpgandha (*Rauvolfia serpentine* (L), Benth. ex Kurz) under poplar-based agroforestry system. *International Journal of Farm Sciences*, 6(4): 188-192.

Nagve T B, Upadhyay N V, Gaikawad V P and Chavada J C, 2016, Influence of harvesting time on growth, yield and quality of Safed musli (*Chlorophytum borivilianum* Santapu & Fernandes). *Green Farming*, 7(1): 176-178.

Oketch-Rabah H A, 1998, Phytochemical constituents of the genus *Asparagus* and their biological activities. *Hamdard*, 41:33-43.

Pavitra M, 2021, Studies on effect of spacing, bioformulations and biofertilizers on growth and yield of menthol mint (*Mentha arvensis*). *M. Sc. (Horti) Thesis,* University Horticultural Sciences, Bagalkot, Karnataka, India.

Phatak R S, Hegde L, Hegde N K, Jholgiker P and Narayanpur V, 2014, Effect of spacing on growth, seed yield and tuber yield of glory lily (*Gloriosa superb* L.). *Indian Journal of Ecology*, 41(2):382-384.

Pooja M R, Hiremath J S, Nadukeri S, Mahantesh P S, Nishchitha M and Lokesh C H, 2018, Influence of inorganic fertilizer and spacing on yield and quality of sacred basil (*Ocimum sanctum* Linn.). *Journal of Pharmacognosy and Phytochemistry*, 3: 5-8.

Saravanan S S, Lall D, Bahadur V and Kumar S, 2019, Response of different levels of plant spacing on vegetative growth and yield attributes of ashwagandha (*Withania somnifera*) var. Poshita and sarpagandha (*Rauvolfia serpentina*. Benth) var.

Sheel under open environment and orchard conditions. *International Journal of Current Microbiology and Applied Sciences*, 8(7): 2065-2074.

Sharma, P. V., 1998, *Dravya guna –Vijnana, Chaukhamba. Varanasi: Bharti Academy*, 2: 562-564.

Singh M and Guleria N, 2013, Influence of harvesting stage and inorganic and organic fertilizers on yield and oil composition of rosemary (*Rosmarinus officinalis* L.) in a semi-arid tropical climate. *Industrial Crops and Products*, 42: 37-40.

Singh O P, Singh T P and Yadav A L, 1999, Effect of age on tuber yield in Shatavar (*Asparagus racemosus*). *Advances in Plant Sciences,* 12(2): 475-477.

Suresh M S, Koppad A G and Shivanna H, 2010, Effect of spacing, manure and fertilizers on growth and yield of *Coleus forskohlii* under teak plantation. *Karnataka Journal of Agricultural Sciences,* 23(2):397-399.

Thakur U, 2016, Studies on development of cultivation practices of *Asparagus racemosus* Willd. Under mid hill conditions of Himachal Pradesh. *Phd Thesis Dr. Y. S. Parmar University of Horticulture and Forestry Solan.*

Wankhade S G, Gholap C V and Patil M, 2010, Harvesting period management for production of quality roots of ashwagandha (*Withania somnifera*. Dunal). *Annals of Pharmacology and Pharmaceutical Sciences*, 2(10): 71-73.