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Effect of Different Spacing and Time of Harvesting on Vegetative Growth and Oil Yield of *Artemisia annua* L. in Garhwal Himalayas

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Abstract

A field experiment was conducted during April 2007 to October 2007 to study the effect of different spacing (45 × 45, 45 × 60, 60 × 30, 60 × 45 and 60 × 60 cm) and time of harvesting 0600 h, 1200 h and 1800 h) on vegetative growth and oil yield of *Artemisia annua.* The vegetative growth parameters and oil yield per plant were maximum under low plant density (0.28×10^5 plants/ha), except herbage yield per plot and oil yield per plot, which was maximum at higher plant density (0.56×10^5 plants/ha). Harvesting of herbage at evening time (1800 h) resulted in maximum oil yield per plant and oil yield per plot of *A. annua*.

Key words : *Artemisia annua*, Spacing, Vegetative growth, Oil yield.

Artemisia annua L. also known as quinghao (Chinese) or sweet wormwood, a member of the family A steraceae, is a highly aromatic annual herb of Asiatic and Eastern European origin. It is native to China and widely grown in Asia, Europe and USA (1). It is widely distributed throughout the temperate region of the world (2). In India, it is found in the Himalayan region between an altitude of 2,500—3,000 m amsl. (3). Recent researches in the China on traditional herbal medicine has brought attention to *Artemisia annua*, the source of artemisinin or quinghaosu a compound that showed promise as an antimalarial agent (4). Growing incidence of malaria in many parts of the tropical world, especially the Chloroquin resistant material strain in South East Asia, has necessitated increased production of A. annua, raw material for deriving the effective antimalarial drugs, such artemether and arteether (5, 6). It has also been reported to be a potent plant inhibitor with potential as a natural herbicide (7, 8). Apart from sesquiterpene from *A. annua*, essential oils are another active research interest as it could be potentially used in perfumery, cosmetics and aromatherapy (9). Chemical synthesis of astemisinin is complicated and hare resulted in poor yield (10), so the production of astemisinin can be increased by enlarging the area under *A. annua* cultivation. In the filed of the various agronomic traits, factors affecting the yield and quality of the oil, the plant density and optimum harvesting time are considered to be the important one. Very meager information is available about the effect of plant density and time of harvesting on yield and quality of *A. annua*, so the present study was conducted to generate data on this aspect.

Methods

A field experiment was conducted at G. B. Pant University of Agriculture & Technology, Hill Campus, Ranichauri, Tehri Garhwal (Uttarakhand) located at $30^0 15'$, $70^0 50'$ E and 1900 m above mean sea level. The elimate of experimental site is moist temperate type with 1,343.1 mm mean annual rainfall. The experiment was laid out in a factorial randomized block design with three replications, in which the treatments consisted of five densities (0.49, 0.37, 0.56, 0.37 and 0.28×10^5 plants/ha) and three harvesting time (morning at 0600 h afternoon at 1200 h and evening at 1800 h).

About 45 days old seedlings of *A. annua* were transplanted, as per the treatment combination in the experimental plots at 45 × 45, 45 × 60, 60 × 30, 60 × 45

Table 1. Effect of spacing and time of harvesting on vegetative parameters of *Artemisia annua.*

Character	Time of harvesting	Spacing levels (cm) 45 × 45	45 × 60	60 × 30	60 × 45	60 × 60	Mean (T)
Plant height (cm)	0600 h	190.7	194.3	181.3	196.1	203.9	193.2
	1200 h	189.3	192.3	185.4	195.5	200.4	192.6
	1800 h	192.8	194.7	182.3	198.9	206.6	195.1
	Mean (S)	190.9	193.7	182.9	196.8	203.7	
CD at $P = 0.05$ spacing (S) = 2.44 (CD_1)		Time of harvesting (T) = 1.89 (CD_2)			S × T = 4.22 (CD_3)		
Stem girth (mm)	0600 h	13.7	14.5	13.9	15.0	14.6	14.3
	1200 h	13.5	14.7	13.6	15.1	14.6	14.3
	1800 h	14.1	14.8	13.8	14.9	14.9	14.5
	Mean (S)	13.8	14.7	13.8	15.0	14.7	
CD at $P = 0.05$ spacing (S) = 0.24 (CD_1)		Time of harvesting (T) = NS (CD_2)			S × T = 0.41 (CD_3)		
No. of branches	0600 h	44.3	46.3	42.7	49.7	51.7	46.9
	1200 h	43.7	46.7	43.7	49.0	51.0	46.8
	1200 h	46.3	47.0	41.3	50.0	52.0	47.3
	Mean (S)	44.8	46.7	42.6	49.6	51.6	
CD at $P = 0.05$ spacing (S) = 0.59 (CD_1)		Time of harvesting (T) = NS (CD_2)			S × T = 1.04 (CD_3)		
Herbage yield per plant (g)	0600 h	376.7	300.0	276.7	396.7	426.7	355.3
	1200 h	326.7	353.3	333.3	386.7	433.3	366.7
	1800 h	380.0	353.3	373.3	446.7	410.0	392.7
	Mean (S)	361.1	335.5	327.7	410.0	423.3	
CD at $P = 0.05$ spacing (S) = 49.43 (CD_1)		Time of harvesting (T) = NS (CD_2)			S × T = 85.62 (CD_3)		
Herbage yield per plot (kg)	0600 h	12.1	7.2	9.9	9.5	7.6	9.3
	1200 h	10.5	8.5	12.0	9.3	7.8	9.6
	1800 h	12.2	8.5	13.4	10.7	7.4	10.4
	Mean (S)	11.6	8.1	11.8	9.8	7.6	
CD at $P = 0.05$ spacing (S) = 1.25 (CD_1)		Time of harvesting (T) = 0.97 (CD_2)			S × T = 2.17 (CD_3)		
Dry weight per plant (g)	0600 h	94.4	81.9	72.3	103.0	121.0	94.5
	1200 h	81.6	96.6	87.6	100.3	122.6	97.7
	1800 h	95.0	96.8	97.6	116.1	115.8	104.3
	Mean (S)	90.3	91.8	85.8	106.5	119.9	
CD at $P = 0.05$ spacing (S) = 16.06 (CD_1)		Time of harvesting (T) = NS (CD_2)			S × T = 27.83 (CD_3)		

and 60 × 60 cm plant spacing. The individual plot size was 3.6 m × 1.8 m. Immediately after the transplanting a light irrigation was provided for the better establishment of the seedlings. Vermicompost was applied as basal dose at 50 q/ha and all other cultural operation were timely followed for successful growth of the crop. The harvesting was done at three different time i.e. 0600 h, 1200 h and 1800 h on the same day according to the treatment combinations. The fresh and dry weight of the herb was measured and the essential oil content in fresh herb was estimated through water distillation in Clevenger's apparatus. The data were recorded for vegetative growth and oil yield parameters and statistically analyzed.

Results and Discussion

Effects of different spacing and time of harvest-

Table 2. Effect of spacing and time of harvesting on oil yield parameters of *Artemisia annua.*

Character	Time of harvesting	Spacing Levels (cm) 45 × 45	45 × 60	60 × 30	60 × 45	60 × 60	Mean (T)
Oil yield per plant (ml)	0600 h	1.2	1.1	0.9	1.3	1.4	1.2
	1200 h	1.3	1.5	1.3	1.6	2.0	1.6
	1800 h	1.8	1.6	1.6	2.0	2.1	1.8
	Mean (S)	1.5	1.4	1.3	1.7	1.8	
CD at $P = 0.05$ spacing (S) = 0.31 (CD_1)		Time of harvesting (T) = 0.24 (CD_2)			S × T = 0.54 (CD_3)		
Oil yield per plot (ml)	0600 h	39.5	25.6	33.6	31.7	25.2	31.1
	1200 h	42.7	33.6	46.8	37.7	35.4	39.2
	1800 h	57.6	36.8	56.4	48.8	37.2	47.4
	Mean (S)	46.6	32.0	45.6	39.4	32.6	
CD at $P = 0.05$ spacing (S) = 8.76 (CD_1)		Time of harvesting (T) = 6.78 (CD_2)			S × T = 15.15 (CD_3)		

ing on vegetative growth and oil yield parameters are presented in Tables 1 and 2, respectively.

Vegetative Growth Parameters

The results show that there was significant difference among different density with respect to plant height, stem girth, number of branches, herbage yield per plant, dry weight per plant and herbage yield per plot (Table 1). Maximum plant height, number of branches, herbage yield per plant and dry weight per plant was found with widest spacing 60 cm × 60 cm and minimum with narrowest spacing of 60 cm × 30 cm. Whereas, stem girth of plant was recorded highest at a spacing of 60 cm × 45 cm, which was at par with 60 cm × 60 cm spacing. A plausible explanation of these trends of results may be attributed to the reason that at lower plant density good growth observed due to availability of more space and less competition among the adjacent plants, which helped the individual plant to utilize more water, nutrition, air and light to help them to put better growth. It was found that herbage yield per plot was obtained from closer spacing due to more plants per unit area. Similar results were also reported by Acton and Klayman (11) in 1985 in *Artemisia annua*, Pal et al. (12) in lemon grass and Sastry et al. (13) in pyrethrum.

Oil Yield Parameters

The data on oil yield per plant and oil yield per plot of *A. annua*, is presented in Table 2. It was observed that there was significant effect of different plant spacing and time of harvesting on oil yield of *A. annua*. The oil yield per plant was found maximum at widest spacing (60 cm × 60 cm), whereas oil yield per plot increased with increased plant density, although maximum oil yield per plot was recorded at narrow spacing of 45 cm × 45 cm but it was at par with narrowest spacing 60 cm × 30 cm and this was due to the more herbage yield per plot in these two spacing compared to others. The results are in conformity with the results reported by many workers (14, 15). The plants which were harvested at evening time yield maximum oil yield per plant as well as on per plot basis, compared to morning and afternoon harvest. During the harvesting period the morning temperature of experimental site was low as compared to afternoon and evening harvesting time temperature, so due to increase in temperature between afternoon and evening period, it lead to more volatile oil percent in *A. annua* plant.

The interaction effect of spacing and time of harvesting was found to be significant for both vegetative and oil yield parameters. The combination of 60 cm × 45 cm spacing and harvesting of plant at evening time resulted in maximum herbage yield per plant and was at par with best combination treatment for herbage yield per plot, oil yield per plant and oil yield per plot.

Conclusion

It may be inferred that the spacing of 60 cm × 45

cm (37,038 plants/ha) and harvesting of herbage at evening time (6.00 pm) seemed to be optimum for obtaining a remunerative yield and higher oil yield of *A. annua* under the agro-climatic condition of Garhwal Himalayas.

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