119

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The Effect of Air Temperature on Growth and Alkaloidal Yield of *Hyoscyamus muticus* L.

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With one figure and 7 tables

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Abstract

The effect of natural air temperature on the vegetative growth and alkaloidal yield of *H. muticus* L. was studied. The highest number of branches, diameter, fresh and dry weights of stem and roots occurred in September sowing at full-flowering and fruiting stages. Relatively higher temperature in Sept. sowing favoured leaf growth (number, area and dry weight). Hyoscyamine yield in different organs of the plants sown in Sept., excessively exceeded all other sowings during flower budding and full-flowering stages. Hyoscine yield was quantitatively very small as compared with that of hyoscyamine and even could not be detected in the leaves of winter sowings during full-flowering stage.

Introduction

Cremer (1975) found that the highest growth of *Eucalyptus regnans* was closely related to weekly maximum air temperature with peak rates at 25 °C. Smith (1970) reported that air temperature had considerable influences on the hop quality of many European sites. Hale and Battrose (1975) reported that thermoperiodicity influenced the anthocyanin accumulation (quantitatively and qualitatively) in the berries of *Vitis vinifera* L.

Hyoscyamus muticus L. (Egyptian henbane), Fam. Solanaceae naturally grown in sandy districts of Egypt. The plant contained fifteen times, at least, of total alkaloidal content more than *Hyoscyamus niger* L. grown at Europe. Reda et al. (1984) reported that the alkaloidal status of *H. muticus* was highly altered by air temperature prevailing during different stages of growth. The present work aimed to study the effect of natural air temperature on vegetative growth and alkaloidal yield of *Hyoscyamus muticus* L.

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Materials and Methods

Experimental design and growing the plants: An experiment was conducted in the experimental farm of Botany Lab., Nat. Res. Cent., Dokki, Cairo. The soil of the experimental area is loamy clay of high fertility. The total area was 14 m in length and 12 m in width and it was divided into 36 equal plots (each was 3.0 m × 1.5 m). Each plot consisted of 4 rows, and represented a replicate. Uniform seeds of *Hyoscyamus muticus* L. were sown on 14th every month (from 14 Oct. till 14 Sept.) in three randomized plots. After about three months, plants were thinned leaving only five plants in every row. Irrigation was regularly carried out every two to four days. Fertilization began after two months by giving each plot 100 g of $Ca(NO_3)_2$ (15.5% N), 100 g of Ca superphosphate (16% P_2O_5) and 50 g of potassium sulphate (48% K_2O) in the first and second fertilization with one month interval between them. The third fertilization was carried out 15 days later and only 100 g $Ca(NO_3)_2$ was applied to each plot.

Sampling and vegetative growth: Four samples were randomizedly collected from each replicate at four physiological stages of growth and development, representing seedling, flower budding, flowering and fruiting stages (Fig. 1). Criteria of vegetative growth of the plant samples were determined. These criteria are stem-length, of diameter of main stem, number of branches, fresh and dry weight of roots, stem and leaves and leaf area.

Alkaloidal yield: Alkaloidal content (mg/g) of different parts of the four plant samples was determined and reported by the same authors (REDA et al. 1984). Alkaloidal yield (as mg/total dry weight/organ/plant) given in this paper was calculated on the basis of these results of REDA et al. (1984).

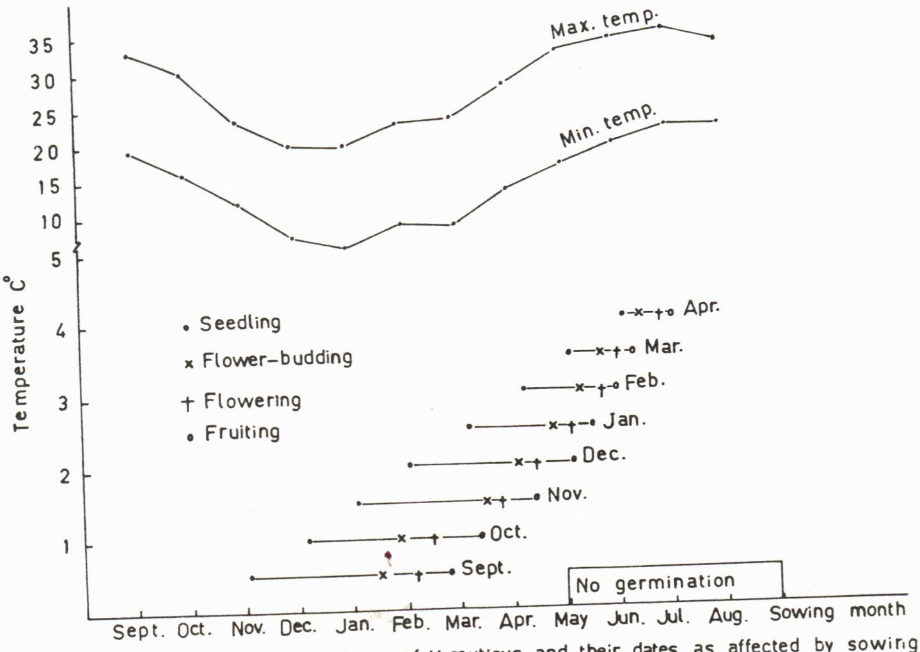

Fig.(4)-C: Developmental stages of H. muticus and their dates as affected by sowing month and air temperature.

Fig. 1. Developmental stages of *H. muticus* and their dates as affected by sowing month and air temperature

Table 1 Stem-length and diameter of main stem and number of branches of H. muticus *plants as affected by sowing months*

Treatments		Stem-length (cm/plant)				Diameter of main stem (cm/plant)				No. of branches/plant		
Month of sowing	Max.*, Min.** air-temp. °C	Seedling	Flower budding	Flowering	Fruiting	Seedling	Flower budding	Flowering	Fruiting	Flower budding	Flowering	Fruiting
Sept. 1973	32.8* 19.6**	–	35.17	61.66	66.17	–	12.83	14.18	14.50	9.50	13.66	15.00
Oct. 1972	30.3 15.8	–	23.75	44.44	61.22	–	7.70	8.90	9.40	4.75	8.22	10.33
Nov. 1972	23.2 11.8	–	27.50	54.44	79.89	–	7.10	8.60	10.16	0.75	4.99	6.22
Dec. 1972	19.7 6.9	–	27.07	51.80	72.44	–	6.20	6.50	6.90	0.66	3.00	4.44
Jan. 1973	19.6 5.4	–	37.47	77.44	80.22	–	5.50	8.60	9.30	1.07	3.55	4.11
Feb. 1973	22.5 8.4	3.17	23.20	62.77	65.33	2.00	4.70	9.00	9.50	1.00	3.33	5.88
March 1973	23.0 8.3	6.17	19.55	58.11	80.66	2.20	4.90	7.80	10.30	1.44	4.99	6.78
April 1974	27.5 12.9	11.08	14.93	32.50	65.33	4.30	5.10	7.40	10.90	1.75	3.33	7.17
L.S.D. at	5%	4.53	5.43	8.04	9.05	0.56	0.76	1.21	0.73	1.29	1.21	2.11

*, ** Max. and Min. of monthly mean air-temp. °C at Dokki district.

Results and Discussion

Table 1 shows that the change in stem-length generally show irregular trends of different sowing months. The diameter of main stem of plants of September sowing was nearly double that of other months during flowering stages (Table 1). Stems of December sowing had the smallest diameter among all sowings at fruiting stage. Moreover, branching began earlier for plants sown in September and October (Table 1). The number of branches belonging to these two months was almost three to four folds that of other treatments. All these reponses of the length, diameter of stem and number of branches were reflected on the dry matter accumulation of the stem (Table 2). The highest dry weights of stems were obtained with plants of September and October sowings during full flowering and fruiting stages respectively, while the lowest dry weight were recorded by plants sown in December, January and February. The stem dry weight of September sowing was approximately ten-fold that of December one. In this connection, LANGRIDGE and MCWILLIAM (1967) stated that the minimum temperature for growth of sorghum and melons required a temperature from 15 °C to 18 °C to make appreciable growth. Likewise, the maximum temperature for growth of temperate-zone crops ranged from 35 °C to 40 °C with the more thermophilic species such as corn and cotton.

Table 3 indicated that the fresh and dry weight of leaves showed a similar response to temperature as those of the stems. The highest significant dry weight of leaves was attained by plants sown in September where the maximum and minimum temperatures were 32.8 °C and 19.6 °C respectively. The increase in dry weight of leaves in September sowing

Table 2 Fresh and dry weights of stem (g/plant) of H. muticus *as affected by sowing months*

Treatments		Fresh weight (g/plant)				Dry weight (g/plant)			
Month of sowing	Max.*, Min.** air-temp.	Seedling	Flower budding	Flowering	Fruiting	Seedling	Flower budding	Flowering	Fruiting
Sept. 1973	32.8* 19.6**	–	392.20	1396.66	1532.33	–	18.76	82.12	86.88
Oct. 1972	30.3 15.8	–	66.75	263.33	530.55	–	3.24	14.44	42.99
Nov. 1972	23.2 11.8	–	21.25	123.22	166.72	–	1.38	11.22	17.32
Dec. 1972	19.7 6.9	–	22.36	51.27	73.33	–	1.49	3.83	8.53
Jan. 1973	19.6 5.4	–	24.60	79.97	94.82	–	2.28	7.93	11.13
Feb. 1973	22.5 8.4	0.12	12.20	135.83	130.33	0.002	0.98	12.39	12.97
March 1973	23.0 8.3	0.75	12.67	156.57	371.67	0.080	0.88	13.69	36.20
April 1973	27.5 12.9	3.86	8.02	67.61	324.03	0.360	0.71	4.92	27.13
L.S.D. at 5%		0.98	39.94	104.61	140.99	0.08	1.53	6.47	10.68

*, ** Max. and Min. of monthly mean air-temp. °C at Dokki district.

was the resultant of the increased production of leaves and higher leaf area (Table 4), which also obviously appeared in April sowing (air temp. max. 27.5°C and min. 12.9°C). The decrease in air temperature during winter months obviously resulted in significant decrease of leaf growth. From the present results, it could be concluded that the leaves' growth during flowering and fruiting stages parallelly followed the maximum and minimum air temperature prevailing during these stages. In accordance, FRIEND et al. (1962 and 1965) found that increasing temperatures for wheat between 10°C and 25°C caused progressively higher rates of leaf initiation, emergence and expansion and resulted in an increased leaf-area ratio (leaf area/plant weight). The same author (1962) concluded that the net effect of an increase in the temperature on the whole plant thus depended on the difference between the increase in dry matter resulting from an increase in the active assimilating surface, and the loss of dry weight through increased respiration.

Table 5 shows that the root growth of plants sown in winter months was one fifth those of September during flowering stage. The present results indicated that the response of root growth to air temperature might be interpreted by the change in the pattern of translocation and redistribution of carbohydrates within the plant, being retarded and even inhibited or accelerated at relatively lower or higher temperature respectively.

One could explain the favourable influence of the relative rise of temperature during the course of growth period on the growth of the stem, leaf and root by the facts that: 1. The rate of photosynthesis was significantly decreased by decrease of temperature below a certain level. 2. The direct action of temperature on the activities of enzymic systems and plant growth regulators.

Table 3 Fresh and dry weights of leaves of H. muticus *plant as affected by sowing months*

Treatments		Fresh weight (g/plant)				Dry weight (g/plant)			
Month of sowing	Max.*, Min.** air-temp.°C	Seedling	Flower budding	Flowering	Fruiting	Seedling	Flower budding	Flowering	Fruiting
Sept. 1973	32.8* 19.6**	6.40	660.17	1246.66	1686.66	0.280	32.41	64.95	83.04
Oct. 1972	30.3 15.8	3.57	158.75	366.66	511.33	0.233	8.29	20.39	37.61
Nov. 1972	23.2 11.8	0.37	63.67	137.89	138.56	0.024	3.77	11.44	11.95
Dec. 1972	19.7 6.9	2.04	56.60	71.73	55.89	0.113	3.55	4.80	7.23
Jan. 1973	19.6 5.4	1.15	37.47	68.90	164.67	0.079	3.10	6.28	11.66
Feb. 1973	22.5 8.4	0.69	41.53	148.07	209.00	0.002	2.80	8.27	14.01
March 1973	23.0 8.3	5.61	56.44	169.00	266.17	0.440	3.81	11.20	23.57
April 1973	27.5 12.9	20.67	49.67	127.17	433.99	1.730	3.69	8.31	32.16
L.S.D. at 5%		2.21	50.82	194.04	241.45	0.30	0.68	9.52	8.80

*, ** Max. and Min. of monthly mean air-temp. °C at Dokki district.

From the above mentioned discussion, it could be concluded that the optimum vegetative growth of *Hyoscyamus muticus* L. was obtained at the following maximum and (minimum) average monthly air temperature: 32.8°C (19.6°C), 30.3°C (15.8°C) and 23.0°C (8.3°C) before flowering stage and relatively lower temperature during proceeding developmental stages (flowering and fruiting) which ranged between 19°C to 23°C. This condition of change in air temperature to fulfil maximum growth indicated that the concept of optimum temperature for growth could be a dynamic one depending on the stage of development, the duration of exposure and the particular growth criterion used to evaluate growth of specific plant. RAO et al. (1970) stated that each stage of the development of a plant seemed to have a different optimal temperature e.g. for the initiation of flower primordia of Tulip 20°C is best suited, for flower parts to develop into a complete flower, the optimal temperature is 8—9°C.

Alkaloidal yield: Table 6 shows that in both summer and winter sowings, the total alkaloidal content and hyoscyamine and hyoscine contents (mg/plant organ) in all plant organs progressively increased with the development of plants from seedling to flower-budding, full-flowering then to fruiting stage. The leaves showed the highest yield of total alkaloids, hyoscyamine and hyoscine during flower-budding. At flowering and fruiting stages, the yield of different alkaloids in the leaves and stems was mostly ten-fold those of the roots. This was mainly attributed to the higher dry matter accumulation of the leaves and stems in comparison with those of the roots.

Hyoscyamine yield in plants of winter sowing was higher than summer one at flower-budding and flowering stages, while during seedling and fruiting stages, the opposite was

Table 4 Number of leaves and leaf area per plant of H. muticus *plant as affected by sowing month*

Treatments		No. of leaves/plant				Leaf area (cm² /plant)			
Month of sowing	Max.*, Min.** air-temp.°C	Seedling	Flower budding	Flowering	Fruiting	Seedling	Flower budding	Flowering	Fruiting
Sept. 1973	32.8* 19.6**	9.00	179.67	338.50	378.83	77.50	4705.00	7865.00	8200.00
Oct. 1972	30.3 15.8	7.47	88.17	167.30	266.60	35.80	1400.00	3600.00	5634.00
Nov. 1972	23.2 11.8	4.70	27.75	69.14	117.22	6.20	647.00	1862.00	1952.00
Dec. 1972	19.7 6.9	7.10	26.80	40.66	61.66	29.70	619.00	901.00	1122.00
Jan. 1973	19.6 5.4	6.40	31.20	92.77	76.33	40.00	507.00	1264.00	1957.00
Feb. 1973	22.5 8.4	7.66	19.20	53.33	103.10	28.80	458.00	1771.00	2618.00
March 1973	23.0 8.3	10.00	24.78	97.63	182.80	88.60	643.00	1948.00	3911.00
April 1973	27.5 12.9	12.00	24.66	66.33	237.33	287.00	703.00	1548.00	4385.00
L.S.D. at 5%		1.16	110.99	41.16	58.62	36.62	270.00	420.00	770.00

*, ** Max. and Min. of monthly mean air-temp. °C at Dokki district.

true. For hyoscine yield, inspite that its amount in different organs was higher for plants sown in winter than summer one during seedling and flower-budding, this yield declined in the leaves of winter sowing to null during flowering and fruiting stages. It is apparent from the literature that the relation between climate and alkaloid synthesis has not been well investigated as that involving nutritional conditions. Hills and Rodwell (1951) indicated that climatic factors exerted a strong influence upon alkaloid content of *Duboisis myoperoids*.

Of special interest is the yield of alkaloids in the leaves (the main organ for economic alkaloid production) as affected by air temperature. Table 7 shows that hyoscyamine yield (mg/total dry weight) in the leaves of plants of Sept. sowing excessively exceeded all other sowings. This can be mainly attributed to the natural air temperature prevailed in Giza province, Egypt during germination, seedling, flowering and fruiting stages for Sept. sowing which were highly efficient and favourable for higher production of hyoscyamine in the leaves of *H. muticus* L.

The response of hyoscine yield to air temperature was greatly depending on the stage of development, as no hyoscine was detected in the leaves of all sowings except those of Sept. and April sowings at seedling and flower-budding stages. On the other hand, at later stages minute amounts (3—6 mg/total dry weight) were found in the leaves of Feb., Jan., Nov., Dec. and Mar. sowings respectively. In general, the yield of hyoscine was very small and was known to be not economic product as compared with hyoscyamine the chief alkaloid of H. muticus L.

Table 5 Fresh and dry weights of roots (g/plant) of H. muticus *plant as affected by sowing month*

Treatments		Fres weight (g/plant)				Dry weight (g/plant)			
Month of sowing	Max.*, Min.** air-temp.°C	Seedling	Flower budding	Flowering	Fruiting	Seedling	Flower budding	Flowering	Fruiting
Sept. 1973	32.8* 19.6**	0.21	12.12	25.69	32.07	0.020	1.30	3.03	3.53
Oct. 1972	30.3 15.8	0.09	4.50	10.03	13.67	0.020	0.46	1.39	1.96
Nov. 1972	23.2 11.8	0.01	2.26	7.67	8.67	0.002	0.32	1.15	1.52
Dec. 1972	19.7 6.9	0.06	2.26	3.12	5.30	0.008	0.28	0.48	1.14
Jan. 1973	19.6 5.4	0.03	2.34	5.82	9.10	0.011	0.39	0.99	1.31
Feb. 1973	22.5 8.4	0.02	2.28	5.95	8.00	0.003	0.34	0.86	1.26
March 1973	23.0 8.3	0.22	3.11	6.95	32.27	0.043	0.39	1.19	5.77
April 1973	27.5 12.9	2.00	3.75	12.12	21.70	0.310	0.53	1.60	3.50
L.S.D. at 5%		0.31	1.17	7.82	10.30	0.002	0.18	0.76	1.15

*, ** Max. and Min. of monthly mean air-temp. °C at Dokki district.

Table 6 Hyoscyamine, hyoscine and total alkaloidal yield (mg/each plant organ) of H. muticus *plant in winter and summer sowings*

Develop. stage	Plant part	Winter (A)	Winter (B)	Winter (C)	Summer (A)	Summer (B)	Summer (C)
Seedling	Leaves	2.17	0.28	2.45	1.14	0.16	1.30
	Roots	0.15	0.01	0.16	0.20	0.08	0.28
	Stems	——	——	——	0.56	0.05	0.61
Flower-budding	Leaves	35.65	1.74	37.39	10.78	0.00	10.78
	Stems	15.55	1.26	16.81	4.14	0.51	4.65
	Roots	2.41	0.40	2.81	1.36	0.09	1.45
	Fl.-buds	0.88	0.00	0.88	1.32	0.15	1.47
Flowering	Leaves	97.87	0.00	97.87	61.60	6.61	68.21
	Stems	100.07	2.89	102.96	86.25	7.12	93.37
	Roots	9.45	0.47	9.92	7.28	0.67	7.95
	Fl.-buds	8.88	0.60	9.48	6.42	0.89	7.31
	Flowers	4.86	0.09	4.95	3.50	0.68	4.18
Fruiting	Leaves	149.31	29.34	178.65	122.56	9.43	131.99
	Stems	180.56	81.25	261.81	184.62	26.06	210.68
	Roots	11.62	4.57	16.19	36.35	5.42	41.77
	Fl.-buds	11.11	0.75	11.86	14.79	1.12	15.91
	Flowers	4.40	6.08	10.48	11.10	0.82	11.92
	Fruits	9.02	7.39	16.41	43.00	10.20	53.20

	Hyoscyamine yield (A)	Hyoscine yield (B)	Total alkaloidal yield (C)
L.S.D. Treat.	3.37	1.87	1.94
at 5% Stages	4.75	2.66	2.75
level Treat. X Stages inter.	6.72	3.74	3.89

Zusammenfassung

Der Einfluß der Lufttemperatur auf das Wachstum und den Alkaloidertrag von *Hyoscyamus muticus* L.

Der Einfluß der natürlichen Lufttemperatur auf das vegetative Wachstum und den Alkaloidgehalt von *H. muticus* L. wurde untersucht. Die größte Anzahl von Seitentrieben sowie der stärkste Durchmesser, das höchste Frisch- und Trockengewicht der Sproß- und Wurzelorgane konnte für die September-Aussaat zum Zeitpunkt der Vollblüte und des Fruchtstadiums nachgewiesen werden. Eine vergleichsweise höhere Temperatur bei der September-Aussaat begünstigte das Blattwachstum (Anzahl, Fläche und Trockengewicht). Der Ertrag an Hyoscyamine in den verschiedenen Organen der Pflanzen bei der September-Aussaat war allen anderen Aussaat-Terminen während der Blüte und der Vollblüte überlegen. Der Ertrag an Hyoscine war relativ klein im Vergleich zum Hyoscyamine-Ertrag und konnte nicht in den Blättern der Winteraussaaat während des Vollblütestadiums nachgewiesen werden.

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Table 7 Hyoscyamines, hyoscine and total alkaloidal yield mg per leaves of H. muticus *plant as affected by sowing month*

Treat.	Max.*, Min.** air-temp. °C	Seedling			Flower-budding			Flowering			Fruiting		
		Hyosc-yamine	Hyoscine	Total	Hyosc-yamine	Hyoscine	Total	Hyosc-yamine	Hyoscine	Total	Hyosc-yamine	Hyoscine	Total
Sept. 1973	32.8 19.6	0.98	0.04	1.02	318.59	50.24	368.83	331.25	0.00	331.25	398.59	49.82	448.42
Oct. 1972	30.3 15.8	2.17	0.28	2.45	35.65	1.74	37.39	97.87	0.00	97.87	149.31	29.34	178.65
Nov. 1972	23.2 11.8	0.29	0.05	0.34	13.80	0.75	14.55	62.92	4.58	67.50	31.79	1.55	33.34
Dec. 1972	19.7 6.9	0.76	0.09	0.85	9.76	0.00	9.76	24.00	5.81	29.81	32.75	0.00	32.75
Jan. 1973	19.6 5.4	0.30	0.01	0.31	6.91	0.00	6.91	24.49	4.21	28.70	31.48	8.05	39.53
Feb. 1973	22.5 8.4	0.02	0.00	0.01	4.48	0.00	4.48	36.39	3.97	40.36	40.63	0.00	40.63
March 1973	23.0 8.3	1.14	0.16	1.30	10.78	0.00	10.78	61.60	6.61	68.21	122.56	9.43	131.99
April 1973	27.5 12.9	3.81	1.83	5.64	21.88	6.05	27.93	48.61	0.00	48.61	101.30	0.00	101.30

		Hyoscyamine yield (A)	Hyoscine yield (B)	Total alkaloidal yield (C)
L.S.D.	Treat.	2.22	1.00	1.65
at 5%	Stages	1.56	0.71	1.18
level	Treat. X Stages inter	4.43	1.99	3.31

*, ** Max. and Min. of monthly mean air-temp. °C at Dokki district.

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