633.88 Matricaria chamomilla: 581.134.3.035:669.527.93

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EFFECTS OF LIGHT UPON QUANTITY AND QUALITY OF *MATRICARIA CHAMOMILLA* L. - OIL

I. PRELIMINARY STUDY OF DAYLENGTH EFFECTS UNDER CONTROLLED CONDITIONS

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1. Introduction

Matricaria chamomilla L. is an annual plant (fam. Compositae), native to Europe and western Asia.

The part used of the *M. chamomilla* plant is the dried flower heads for its essential oil which contains several physiologically active substances. The main one is a sesquiterpene named chamazulene, $C_{15}H_{18}$ which is not present as such in the chamomile flowers but is formed as a secondary product from a precursor which is a constituent of the essential oil (Koch, 1), and during distillation is converted into chamazulene.

The study of the chamomile plant as well as of other medicinal plants from the physiological point of view is comparatively scanty and confused. Since the formation of the volatile oils is likely to be intimately connected with vital processes in the plant, some experiments have been carried out which attempted to establish correlations between oil secretion and known metabolic processes in the plant. Examples of this angle of research are only found in rather old studies, such as Lubimenko and Norvikoff (2) and Rabak (3) on shaded and unshaded plants; they found that light favours formation of oil.

As to the physiological processes involved in formation of essential oils, certain observations seem to point towards light affecting essential oil production, and its content of active ingredients. To gain a deeper insight into these connections, the present author carried out a series of experiments to establish

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the effect of daylength, light intensity and light quality on *Matricaria chamomilla* L.-oil and its active principal content with regards to plant growth and flower production.

In this paper the effect of daylength is prelimiarily discussed.

2. Material and Methods

Seeds of *Matricaria chamomilla* L. (produced in the experimental farm of the Medicinal and Aromatic Plants Unit, National Research Centre, Cairo, U.A.R.) were sown in a seed box. Five weeks later, the seedlings were transplanted into plastic pots, 40 cm. in height. Each pot was filled with fertile loam soil.

All transplanted plants at different daylengths received the same basic irradiation during 8 hours of a 24 hours cycle. This has been realised by the use of 120 watt daylight type fluorescent tubes, yielding a light intensity at the top of the plants of approximately 1×10^5 ergs/cm^2 sec., measured with a flat radiation meter. Immediately after the main daily light period, the plants received different durations of white light (6, 8 or 16 hours) with an intensity of about 1.5×10^3 ergs/cm^2 sec. The temperature during the experimental period was 15°C (± 1°C.).

The flower heads of the plants of each treatment were collected at different intervals during the period of growth, and subjected to chemical analysis.

The determination of chamomile oil required the use of a B.P. apparatus (4), applying a fixed amount of xylol to collect the drops of oil dispersed in the water distillate in the measuring tube of the apparatus. The chamazulene content was determined according to Kaiser and Frey (5, 6, 7, 8) and Ognianov Lesseva (9). The moisture content in the drug was determined according to Bidwell and Sterling's method (Guenther, 10).

3. Results

In figure 1, the average dry weight of vegetative growth per plant is plotted against the duration of treatment. In the period between 45 and 70 days, the dry weights of plants in the 18 and 24 hours treatments were practically equal, and obviously higher than those of the plants in the 14 hours treatment. After 105 days of growth, the plants at 18 hours daylength were higher in dry weight than those at 14 hours, and dry weight at the latter treatment was higher than that reached in continuous light. Afterwards, the plants in the 24 hours treatment had attained their maximum weight, and shortly thereafter also those in the 18 hours treatment, whereas those in the 14 hours day still increased in dry matter production.

The number of flower heads per individual plant, due to various durations of day light is illustrated in figure 2. Already after 70 days, the number of mature flower heads per plant is higher at longer daylengths, and the differences between the three treatments subsisted with time, but the plants in the 24 hours treatment and those in the 18 hours daylength attained their maximum flower heads pro-

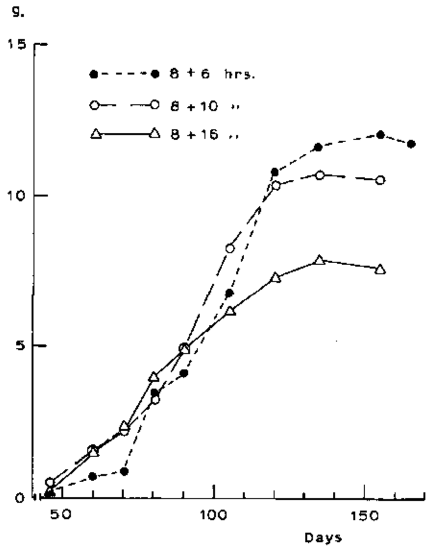


FIG. 1. Effect of daylength on dry weight of vegetative growth during the growth period.

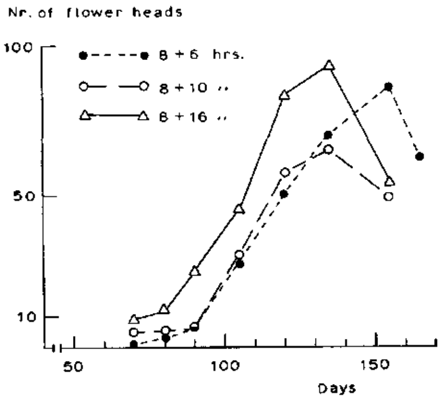


FIG. 2. Effect of daylength on number of mature flower heads during the growth period.

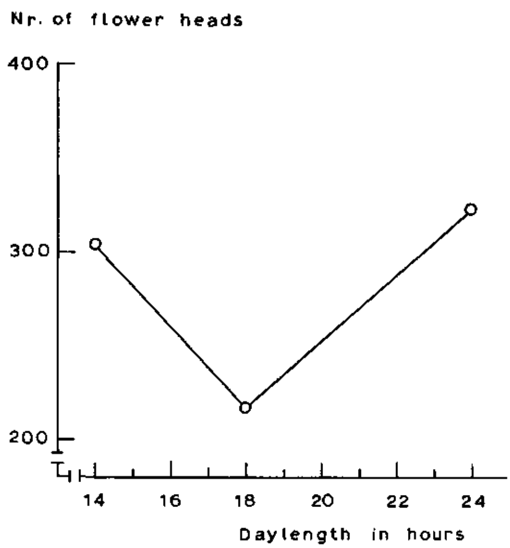


FIG. 3. Effect of daylength on total number of mature flower heads per plant.

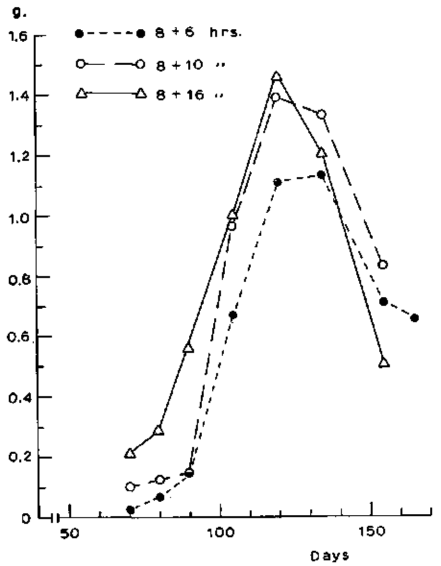


FIG. 4. Effect of daylength on dry weight of mature flower heads per plant during the growth period.

duction after 135 days, whereas those in the 14 hours daylength increased their flower production until the age of 155 days.

Calculation of the total number of flower heads per plant during the experimental period shows that the highest number of mature flower heads is attained in the 24 hours daylength, followed by the 14 and 18 hours treatments respectively (Figure 3).

The dry weights of flower heads per plant are plotted in figures 4 and 5. It appears that the trend of dry weight of flowers coincides with the number of flowers per plant in general. Although the total number of flower heads in the 14 hours treatment is higher than that in the 18 hours one, the dry weight of flowers per individual plant during the experimental period is higher in the latter treatment. This is due to the fact that the 18 hours daylength seems to favour the production of larger flower heads than in the 14 hours photoperiod, while they are still smaller in the 24 hours light treatment (Figure 6).

The daily flower head production rate due to various daily photoperiods during the experiment is given in figure 7. After 80 days, the rate increased with prolongation of the daily exposure to light. Later, after 125 days, the 18 hours daylength resulted in a higher rate of daily flower production per individual plant than the 24 and 14 hours respectively. After 155 days, the daily flower production in the 14 hours treatment dropped to 37 mg/plant/day, while at the end of plant growth cycle it increased again to 65 mg/plant/day. This may be attributed to the fact that the flower heads quality (weight) at 165 days was higher than that at 155 days (c.f. fig. 6). The mean flower head production during the growth cycle of the individual plant reached its highest value at the longest

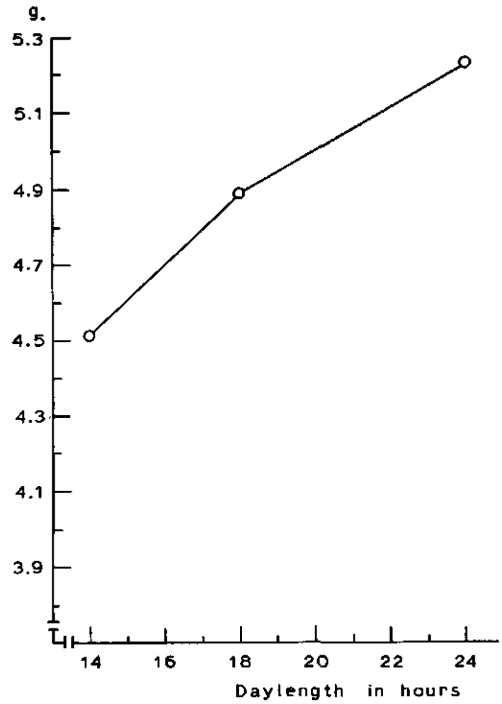


FIG. 5. Effect of daylength on total dry weight of mature flower heads per plant.

daily photoperiod, and decreased with decreasing the duration of supplemental light (figure 8).

The previous data have been summarized in figure 9. Already after 70 days, the ratio of dry weights of flower heads to vegetative growth is higher at longer day lengths. Afterwards the flower heads/vegetative growth ratio of the 18 hours treatment seems to be surpassed by that at the daylength of 14 hours, after 90 days this ratio for the latter treatment was equal to that of the 18 hours daylength. After 105 days the same trend of the ratio of dry weight of flower heads to vegetative growth which is observed in the earlier growth period, returned for the three daylength treatments and subsisted with time in general.

In figure 10, the oil percentage in the flower heads is plotted against duration of treatment. Although it was observed that the oil percentage increases with daylength, shortly after 105 days the highest oil percentage is obtained at the 14 hours daylength followed by 18 and 24 hours respectively. The plants at continuous light had attained their maximum percentage of essential oil after 90 days, while those at the 18 and 14 hours treatments had attained their optimum oil percentage after 105 and 120 days respectively.

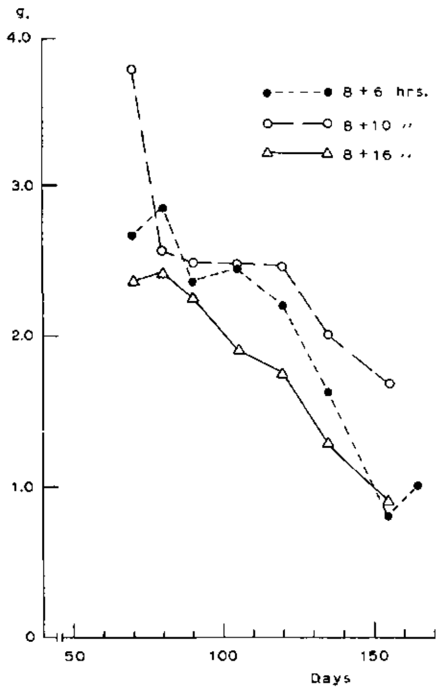


FIG. 6. Effect of daylength on dry weight of one hundred mature flower heads during the growth period.

At earlier periods of growth, the higher amounts of essential oil were obtained in continuous light, followed by 18 and 14 hours daylength respectively; shortly after 115 days the maximum amounts of ethereal oil was attained at 18 hours daylength and approximately was equal to that at the 14 hours treatment, as shown in figure 11.

Although the total amount of volatile oil per plant is highest at 18 hours daylength, followed by 24 and 14 hours daylengths respectively, the differences were not significant. (figure 12).

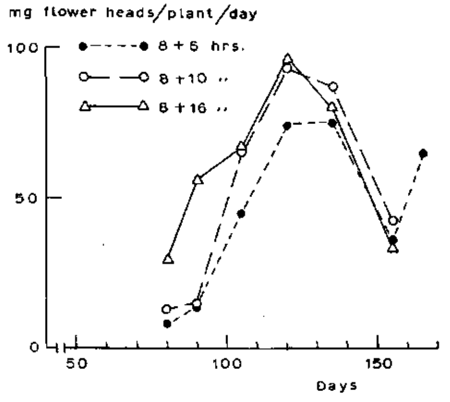


FIG. 7. Effect of daylength on daily flower heads production per plant during the growth period.

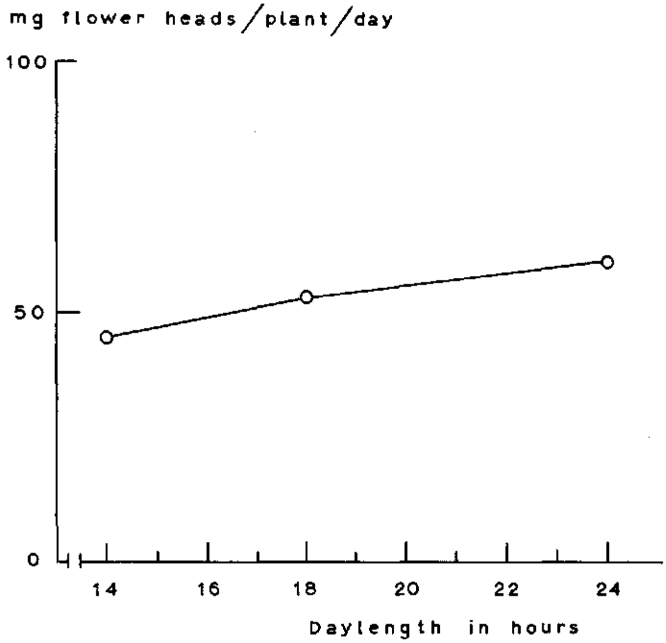


FIG. 8. Effect of daylength on mean flower heads production over the whole season.

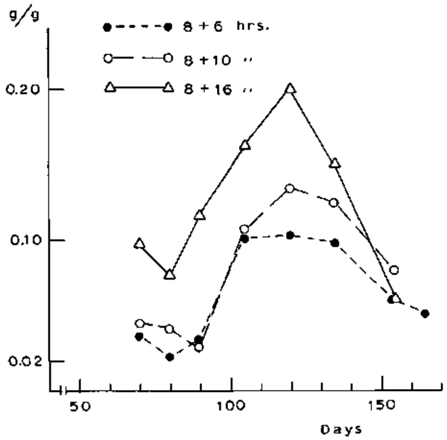


FIG. 9. Effect of daylength on the ratio of dry weights of mature flower heads to vegetative growth per plant during the growth period.

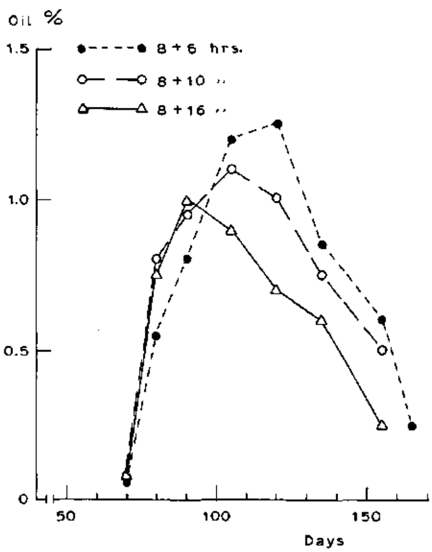


FIG. 10. Effect of daylength on volatile oil percentage in chamomile flower heads during the growth period.

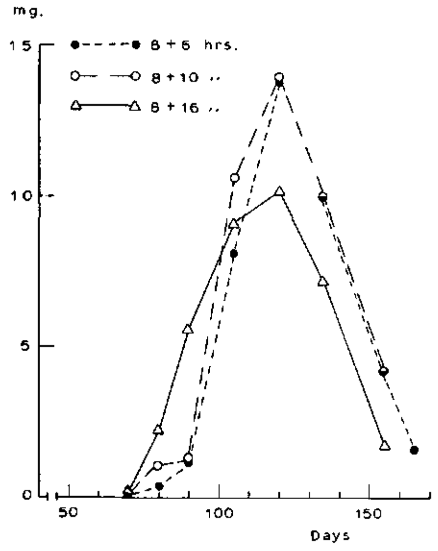


FIG. 11. Effect of daylength on amount of volatile oil per plant during the growth period.

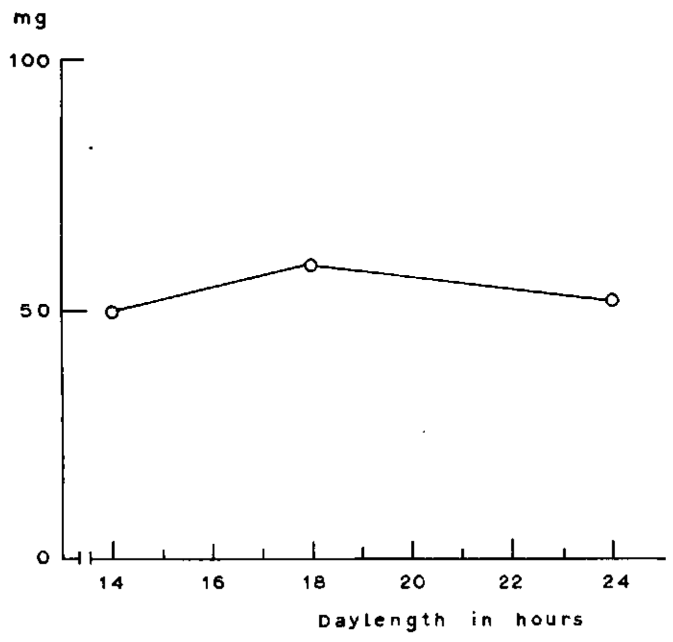
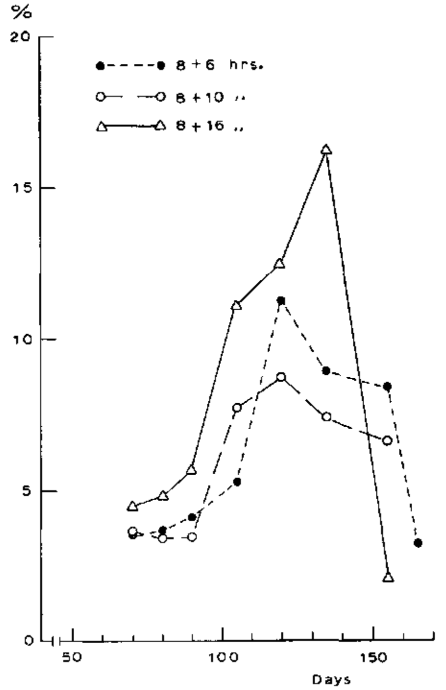


FIG. 12. Effect of daylength on total amount of volatile oil per plant over the whole season.

FIG. 13. Effect of daylength on chamazulene percentage in the volatile oil during the growth period.



Data illustrated in figure 13 shows that prolonging of exposure to light favours chamazulene formation. After 112 days, the chamazulene percent in the volatile oil for the 18 hours daylength is surpassed by that at the daylength of 14 hours. So, the average chamazulene percent in the volatile oil during the experimental period is highest in continuous light, followed by 14 and 18 hours daylength respectively (figure 14).

The chamazulene percent in the chamomile drug (the dried flower heads) attained its maximum value at 24 hours daylength, followed by 18 and 14 hours respectively (figure 15). After 120 days, the chamazulene percentage reached its maximum under 14 hours daylength, but shortly the percentage at 14 hours was surpassed by that attained by plants in continuous light. The mean chamazulene percent in the chamomile drug during the whole experimental period is highest in continuous light (figure 16).

Concerning the active ingredient content per plant, it is clear from figure 17 that the values of chamazulene content in various durations of light are quite near to each other during the experimental period. Although the highest absolute amount of chamazulene per plant is attained in continuous light, followed by 14 and 18 hours daylengths, the observed differences were not significant (figure 18).

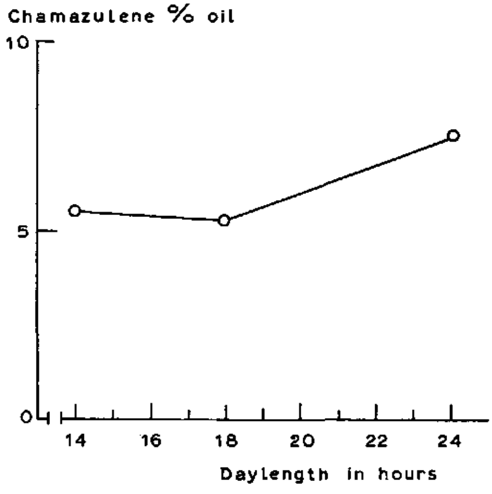


Fig. 14. Effect of daylength on mean chamazulene percentage in the volatile oil over the whole season.

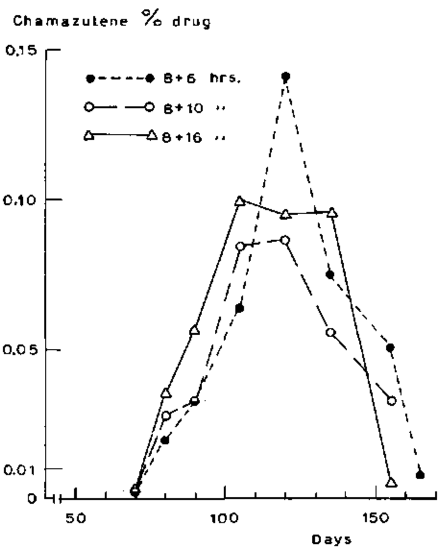


Fig. 15. Effect of daylength on chamazulene percentage in the chamomile drug during the growth period.

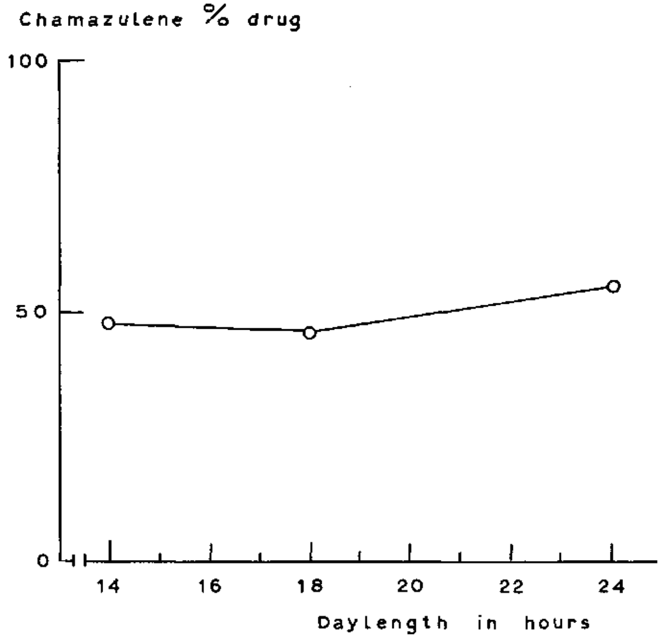


FIG. 16. Effect of daylength on mean chamazulene percentage in the chamomile drug over the whole period.

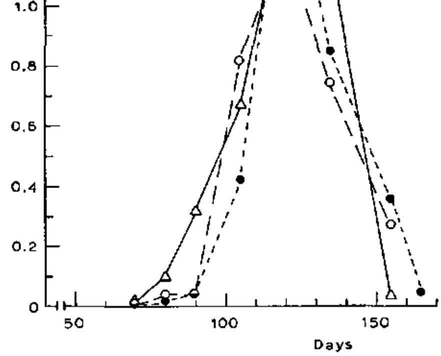


FIG. 17. Effect of daylength on the amount of chamazulene per plant during the growth period.

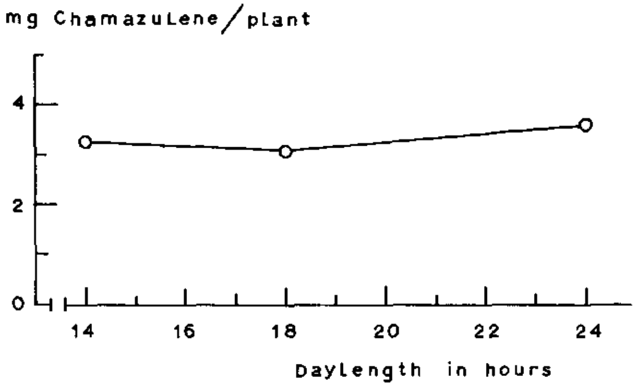


FIG. 18. Effect of daylength on total amount of chamazulene per plant over the whole season.

4. DISCUSSION

From the growth curves in figure 1, it is evident that under short days the weight of the chamomile plants ultimately increases above that under long daily duration of light. Under the same conditions of experiments, the vegetative growth in early growth periods proceeded more rapidly due to application of long daylight duration than under short duration. WASSINK and STOLWIJK (11) and BODLAENDER (12, 13) observed that in potatoes, after a certain period of growth, higher weights were reached for plants growing at a long daily photoperiod.

From figure 9, it is obvious that the dry weight of flower heads per unit dry weight of vegetative growth increases with daylength, while also the highest number of flower heads is obtained in continuous light (figure 5). This increase in flower head production may be considered as a formative effect of the daylength.

Although it is evident from figure 12 that the highest percentage of oil was found at the longer photoperiod in the earlier stages of growth, shortly thereafter the highest oil percentage is obtained at the 14 hours daylength, followed by 18 and 25 hours respectively, and the oil percentage as an average appears to proceed against the daily duration of irradiation.

The highest amount of ethereal oil per individual plant is obtained at 18 hours daylength, followed by 14 and 24 hours. The differences between the three treatments, however, are not significant. (figure 13).

In the earlier periods of growth, the highest average chamazulene percentage in the volatile oil was obtained in continuous light, followed by 14 and 18 hours daylengths respectively, during the whole period of growth, and differences between the latter treatments were not significant (figure 14).

Data in figure 16 show distinctly that the effect of various daylenghts on the chamazulene percent in the chamomile drug* showed the same trend as the data concerning the chamazulene percent in the volatile oil.

* i.e. the dried mature flower heads.

Data illustrated in figure 18 corroborate the previous results concerning the influence of various daylengths on the average chamazulene percent in both chamomile oil and drug, showing that the highest amount of chamazulene was produced by plants in continuous light followed by those in 14 and 18 hours daylengths, and the differences between the latter two treatments were not significant.

5. Summary

Some experiments on the effect of daylength upon the production of oil and its active principle in *Matricaria chamomilla* L. have been carried out under controlled conditions, with observations on vegetative growth and flower head production. Different daylengths have been applied, making use of supplementary irradiation of low intensity. The growing points and flower heads production have been examined, while ethereal oil and chamazulene content have been determined after various periods of growth.

It was found that exposure of chamomile plants to different daylengths affected their yield of flower heads, and quantity and quality of the volatile oil.

Prolonging of the daily exposure to light resulted in a decrease in the vegetative growth, in the yield of flower heads, and in the quality of the volatile oil. It led to an increase in chamazulene percentage in the oil, and at the same time caused a decrease in the oil percentage of the flower heads.

Exposure of the plant for a rather short period (14 hours) of light per day resulted in an increase in vegetative growth and oil percentage, but decreased the yield of flower heads; in the meantime the quality of the volatile oil, viz., its chamazulene content, dropped.

In sum, the various definite effects that could be established, more or less compensate each other, so that not much effect of daylength remained with respect to the total amount of chamazulene produced per plant under the different daylengths, at least under the controlled conditions applied in our experiment.

6. Acknowledgement

This investigation was carried out at the suggestion of and under supervision of Prof. Dr. E. C. Wassink, director of the Laboratory of Plant Physiological Research of the Agricultural University, to whom the author is much indebted for stimulating advice and valuable help and criticism.

7. References

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Postscript. – During a number of years a section of our laboratory has done work on the effects of single environmental factors on properties of plants grown for almost the entire season under conditions with serial variation of a single factor. In this respect, so far, especially light intensity, daylength, plant density, and to a lesser extent temperature and water stress have been studied. Differences in productivity and morphogenetic effects have been examined in periodic harvests during the season. Also anatomical characteristics, and, e.g., carbohydrate constituents have been examined (see, e.g., M. A. BUTT, this Journal **68-10**, 1968).

During his stay in this laboratory, Dr. M. SALEH has added an interesting aspect to this type of work in applying our methods to the study of the effect of environment on the formation of specific chemicals, characteristic for certain plants, and often of medical or pharmaceutical value. For the plant physiologist, they belong to the large and varied group of 'secondary plant substances'. Apart of Dr. SALEH's study, published herewith, he has examined e.g., effects of light intensity and temperature, on which we hope, he will be able to publish preliminary results also.

The field still seems to be largely unexplored, and seems to offer almost unlimited possibilities for further research, both in field and phytotron studies, and may yield results which can be of interest for pharmaceutical purpose, as well as constitute an introduction to the elucidation of the biochemical pathways of the synthesis of these substances in the plant's metabolism. – E. C. WASSINK.