633. 88Matricaria chamomilla: 581.192.036

MEDEDELINGEN LANDBOUWHOGESCHOOL
WAGENINGEN • NEDERLAND • 70-15 (1970)

THE EFFECT OF AIR TEMPERATURE AND THERMOPERIOD ON THE QUALITY AND QUANTITY OF *MATRICARIA CHAMOMILLA* L. OIL

M. SALEH

Laboratory of Plant Physiological Research,
Agricultural University, Wageningen, The Netherlands,
287th Communication

(Received 10–XII–1968)*

1. INTRODUCTION

In spite of the extensive work on the effect of temperature on classical plants in general, there are very few reviews on the effect of this factor on the medicinal plants, with regard to their chemical composition.

We can distinguish between direct temperature effects on physiological partial processes which allow us to obtain conclusions about its effect on plant growth in general, and the different effects of temperature on the metabolic processes involved, which lead to accumulation of the desired secondary products, i.e. essential oils, alkaloids, glycosides, etc.

The effects of temperature on the plant are largely mediated by their effects on chemical reactions. In only few instances has the biochemistry of the plant been studied in relation to temperature, although in many cases biochemical differences have been attributed to temperature. For instance, the content of aromatic compounds in the tea plant increases with decrease of the temperature during growth (NANNINGA 1913) (1).

The diurnal thermoperiodicity effect on *Capsicum* and the tobacco plant was studied by DORLAND and WENT 1947 (2) and CAMUS and WENT 1952 (3). They found that the vegetative growth of Chili pepper gradually decreased with decrease in temperature during growth. On the other hand, CAMUS and WENT stated that night temperature is the most critical factor influencing developmental processes of tobacco.

To arrive at a deeper insight in the connection between accumulation of physiologically active substances in the medicinal plants, their growth and ecolo-

* This paper was ready in the hands of the editorial Committee at this date. Publication was delayed because Dr. SALEH supplied the figures in printable form only much later.

gical factors, namely air temperature, the present author carried out experiments on the effects of air temperature and thermoperiodicity on *Matricaria chamomilla* L. (fam. Compositae), with regard to its essential oil and principal active substance, chamazulene ($C_{15}H_{18}$), content.

2. Material and Methods

Seeds of chamomile (*Matricaria chamomilla* L.) were sown in a seed box. Four weeks later, the seedlings were transplanted in plastic pots; 10 cm in diameter and 20 cm in height. Each pot was filled with fertile loam soil.

In the first experiment on the effect of air temperature on chamomile plants, the pots were transferred to three compartments, adjusted at 25°, 20° and 15°C. ± 1°C. during the entire 24 hours cycle.

The night temperature investigation was realized by exposing all chamomile plants to the same day temperature (25°C. ± 1°C.) and in series of 30 plants, to different night temperatures (25°, 20° and 15°C. ± 1°C. respectively). During 16 hours in every 24 hours cycle, the pots of both experiments were in compartments illuminated by 'day light' fluorescent tubes producing a light intensity at the top of the plants of approximately 9.5×10^4 ergs/cm^2 sec, measured with a flat radiation meter. By interchanging the places of the pots every day, differences in light intensity were eliminated.

The mature 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). The method of chamomile oil estimation was developed by us, the details will, in due time, be published elsewhere, The determination of the chamazulene and moisture contents in the drug was described in our previous paper (5).

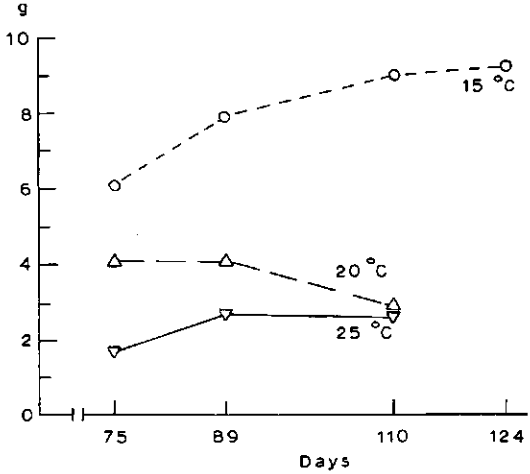
3. Results

Data illustrated in figure 1, shows the average dry weight of vegetative growth plotted against air temperature. Plants in the 25° and 20°C. air temperature treatments attained their maximum growth after 89 days, whereas plants at 15°C increased their vegetative growth until the age of 124 days.

The number of flower heads per individual plant at different air temperatures is shown in figure 2. After 89 days the highest number of flower heads per plant was attained at 25°C. The same holds for plants growing at 20°C air temperature, whereas those in the 15°C treatment increased their flower head number until the age of 110 days. The total number of mature flowerheads per plant during the whole growth cycle is higher at 25°C, followed by 20° and 15°C respectively (fig. 3)

Data illustrated in figure 4 indicate that the average dry weight of flower heads per plant is against the air temperature treatments. After 75 days, the highest mature flower head production was at 20°C treatment; after 89 days, the

Fig. 1. Effect of temperature on dry weight of vegetative growth during the period of growth.



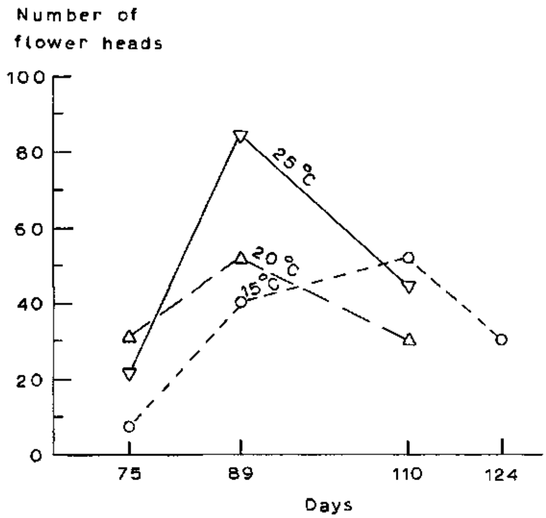


Fig. 2. Effect of temperature on the number of flower heads per plant during the period of growth.

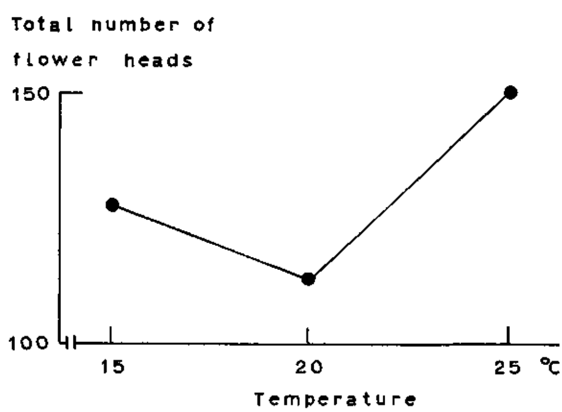


Fig. 3. Effect of temperature on the total number of flower heads per plant over the whole season.

points indicating the dry weight of flower heads per individual plant are lower the higher the air temperature is, the differences between the three treatments subsisting with time. The plants in the 25 °C treatment and those in the 20 °C one attained their maximum flower head production after 89 days, whereas the plants in the 15 °C treatment increased their flower head yield until the age of 110 days, reaching substantially higher values than those at the higher temperatures.

Calculation of the total dry weight of mature flower heads during the growth period of the individual plants shows that the highest weight of flowers is attained in the 15 °C treatment, followed by the 20° and 25 °C air temperature treatments respectively (figure 5).

Data plotted in figure 6 shows the size of mature flower heads produced by plants growing in various air temperature treatments. The largest size of flower heads is attained in the 15 °C treatment, followed by 20° and 25 °C treatments respectively. This may be attributed to the fact that the flower head initiation rate was higher at the higher temperatures around 25 °C, while the later part of flower head development appears optimal around 15 °C.

Although the highest flower head production and vegetative growth were obtained at 15 °C, the dry weight of flower heads per unit of vegetative growth per plant reached its lowest point at this temperature as compared with the other treatments. After 110 days, however, the dry weight of flower heads per unit of vegetative growth for 25 °C treatment was surpassed by that at 20° and 15 °C respectively (figure 7).

Data illustrated in figure 8 indicates that the essential oil percentage is concurrent with the air temperature. The highest percentage of the essential oil is

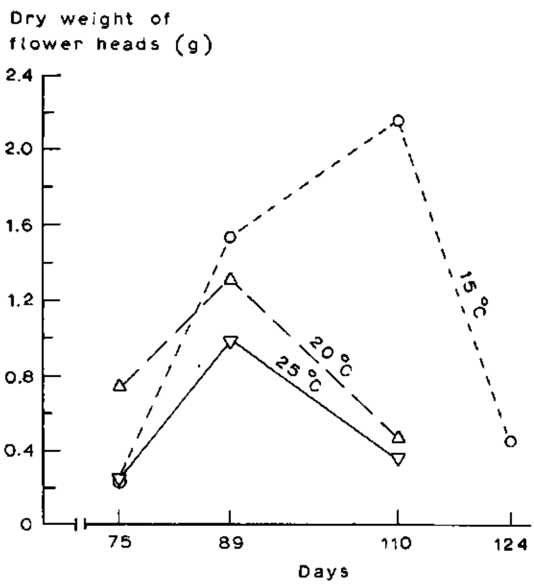


FIG. 4. Effect of temperature on dry weight of flower heads per plant during the period of growth.

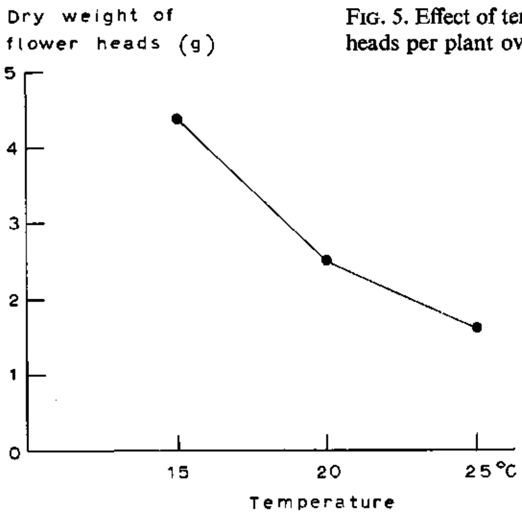


FIG. 5. Effect of temperature on total dry weight of flower heads per plant over the whole season.

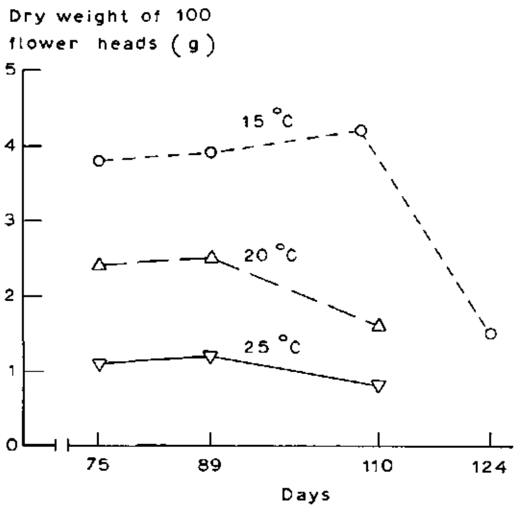


FIG. 6. Effect of temperature on dry weight of 100 flower heads during the period of growth.

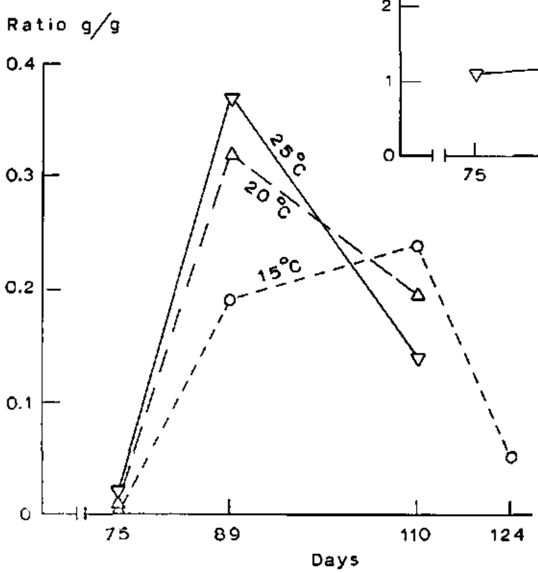


FIG. 7. Effect of temperature on dry weight of flower heads per unit dry weight of vegetative growth during the period of growth.

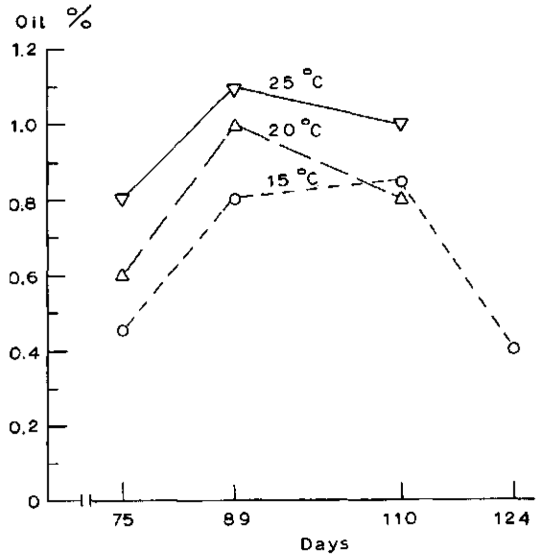


FIG. 8. Effect of temperature on oil percentage in the flower heads during the period of growth.

attained at 25° and 20°C after 89 days, whereas it reached its maximum point after 110 days at 15°C.

Figure 9 shows clearly that 20°C air temperature favours chamazulene formation in the chamomile plant, followed by the 25° and 15°C treatments respectively. After 89 days, the optimum chamazulene percentage in chamomile oil was obtained in the 25° and 20°C treatments whereas at 15°C, the maximum percentage of chamazulene was reached after 110 days from the start of the cultivation.

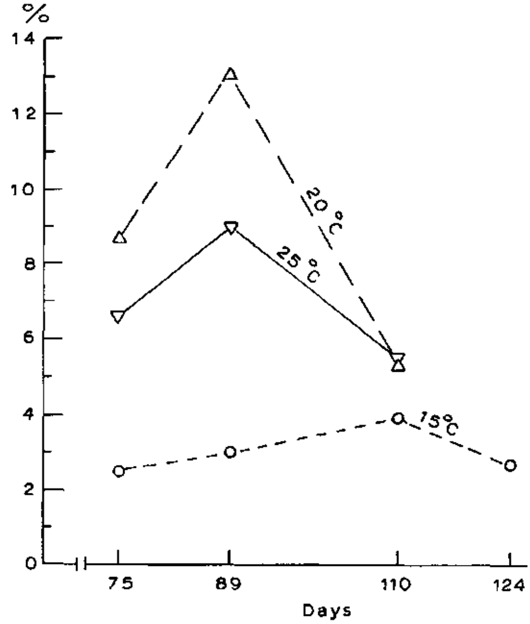
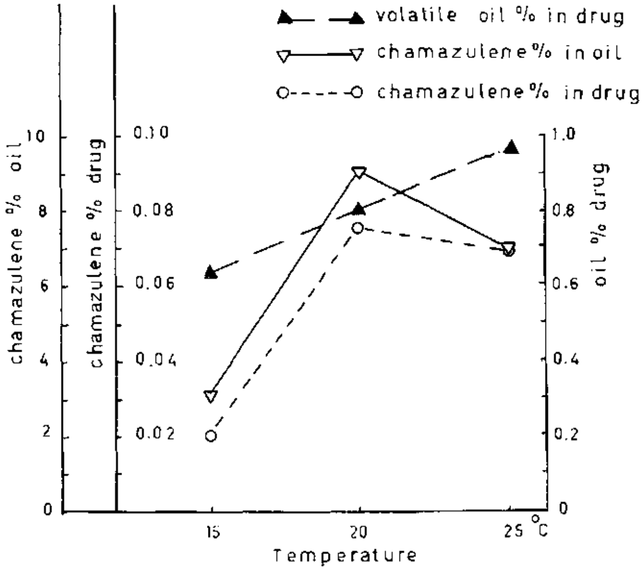


FIG. 9. Effect of temperature on chamazulene percentage in chamomile oil during the period of growth.

FIG. 10. Effect of temperature on mean values of oil percentage, chamazulene percentage in the oil and chamazulene percentage in the drug over the whole season.



The previous data have been summarized in figure 10, the oil percentage in the drug, as average values during the growth cycle, concurs with air temperature, while the chamazulene percentage in both ethereal oil and drug attained their maxima at 20 °C, followed by 25° and 15 °C respectively.

Data illustrated in figure 11 indicates that the highest production of essential oil per plant was at 15 °C, followed by 20° and 25 °C treatments respectively. This may be attributed to the highest yield of flower heads per plant in the 15 °C treatment, (c.f. figure 5). With regard to the chamazulene production per plant, it seems obvious that at 20 °C this percentage reached its maximum value, followed by 25° and 15 °C respectively (fig. 12). The plants in the 20° and 25 °C treatments attained their optimum oil and chamazulene productions after 89

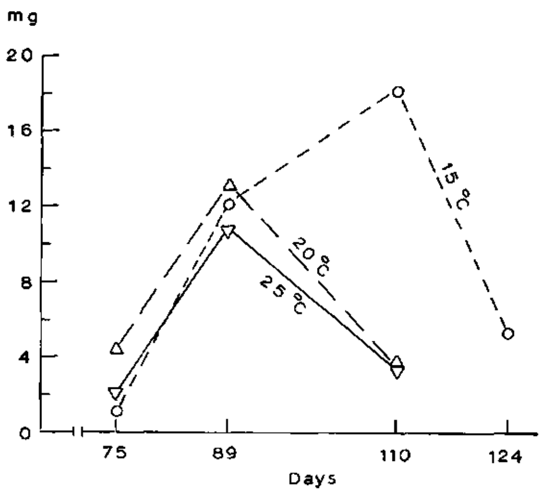


FIG. 11. Effect of temperature on the amount of essential oil per plant during the period of growth.

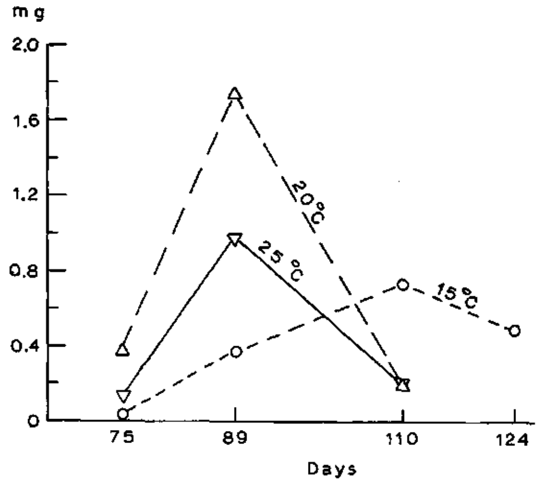


FIG. 12. Effect of temperature on the amount of chamazulene per plant during the period of growth.

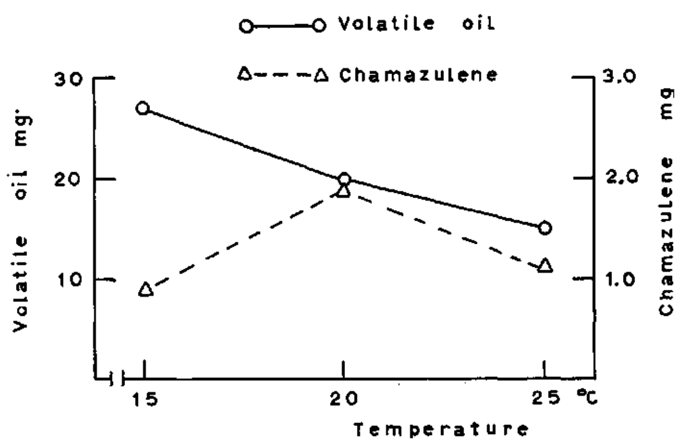


FIG. 13. Effect of temperature on chamazulene and volatile oil content in chamomile flower heads per plant over the whole season.

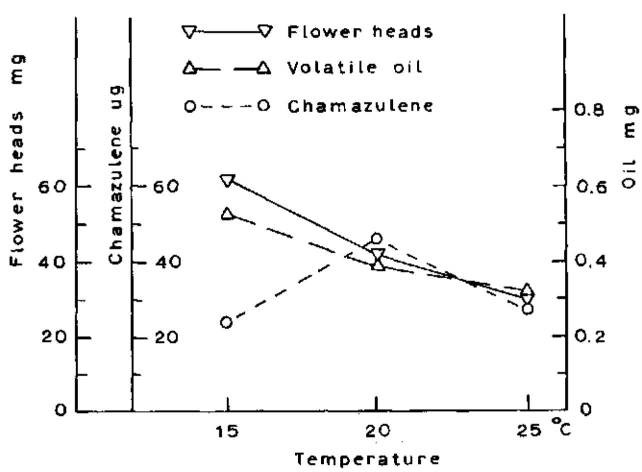
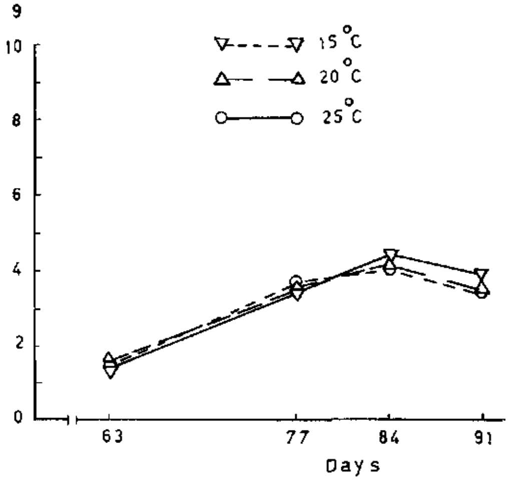


FIG. 14. Effect of temperature on mean daily flower head, volatile oil, and chamazulene production per individual plant over the whole season.

FIG. 15. Effect of night temperature on dry weight of vegetative growth during the period of growth.



days, whereas those in the 15 °C treatment attained their optimum production of both volatile oil and chamazulene after 110 days.

Data collected in figures 11 and 12 have been summarized in figure 13. The total amount of chamomile oil per plant during the entire growth cycle is plotted against air temperature, the highest production is reached in the 15 °C treatment, followed by 20° and 25 °C respectively. The maximum chamazulene content during the experimental period was reached at 20 °C air temperature, followed by the 25° and 15 °C treatments respectively.

The average daily flower head and volatile oil production of the entire growth cycle indicate that both characteristics increase with decreasing air temperature, as shown in figure 14. Concerning the mean daily production of the active ingredient, chamazulene, the maximum value was obtained at 20 °C, followed by 25° and 15 °C respectively. The observed differences between the two latter treatments are insignificant.

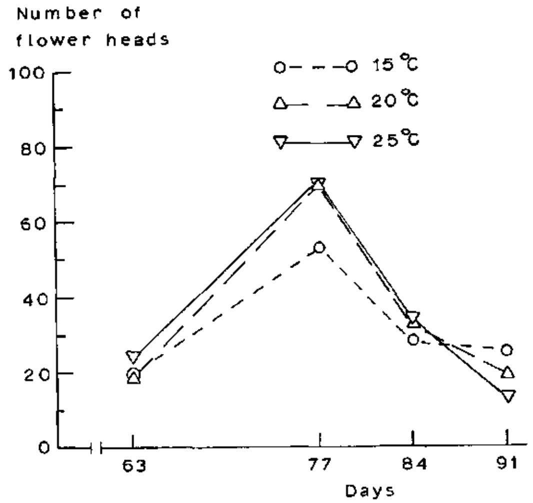
The following figures refer to experiments in which only the night temperature was different.

In figure 15, the average dry weight of vegetative growth as affected by night temperature indicates that there are no obvious differences between the treatments, expecially not in the early periods of growth.

The number of flower heads per individual plant during the growth period at various night temperatures is illustrated in figure 16. Already after 63 days, the number of mature flower heads per plant is higher at 25 °C night temperature treatment, but at the end of the growth period, the number of flower heads for this treatment is surpassed by that at night temperatures 15° and 20 °C respectively. This may be attributed to the fact that the plant at higher night temperature completes its growth cycle more rapidly.

Data illustrated in figure 17 shows that the lowest total number of flower heads per plant during the whole growth period is attained at 15 °C night tem-

FIG. 16. Effect of night temperature on the number of flower heads per plant during the period of growth.



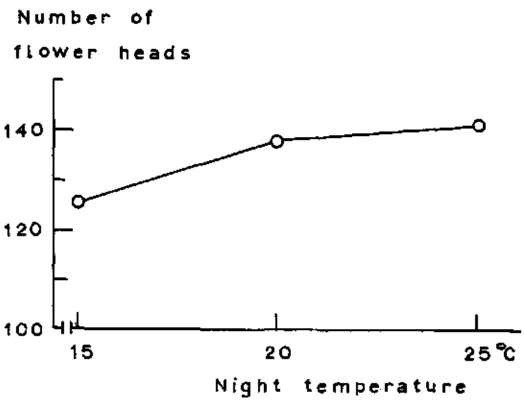


FIG. 17. Effect of night temperature on the total number of flower heads per plant over the whole season.

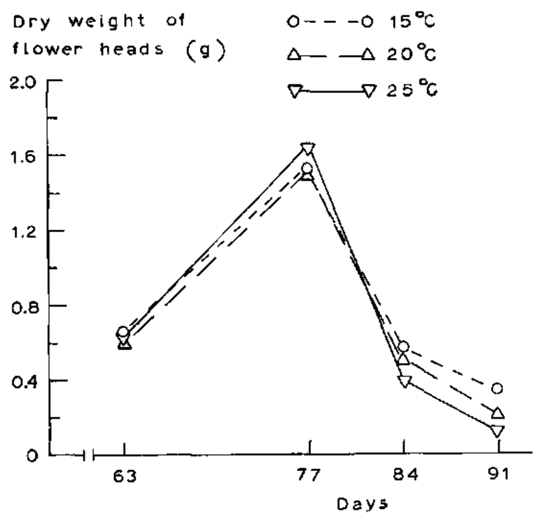


FIG. 18. Effect of night temperature on dry weight of flower heads per plant during the period of growth.

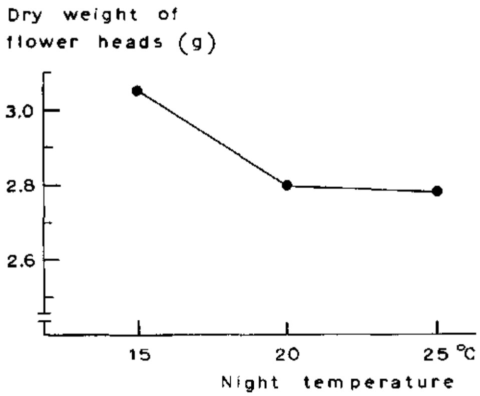


FIG. 19. Effect of night temperature on total dry weight of flower heads per plant over the whole season.

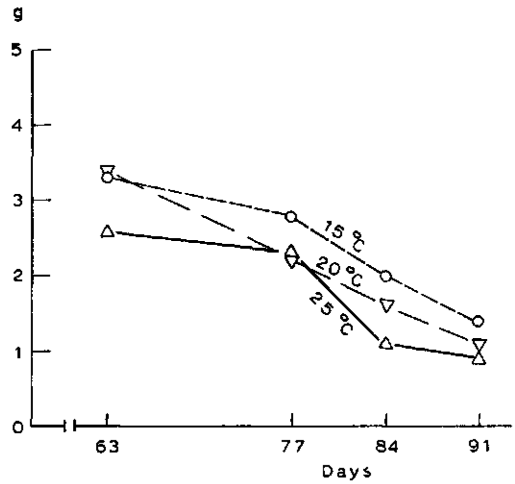


FIG. 20. Effect of night temperature on dry weight of 100 flower heads during the period of growth.

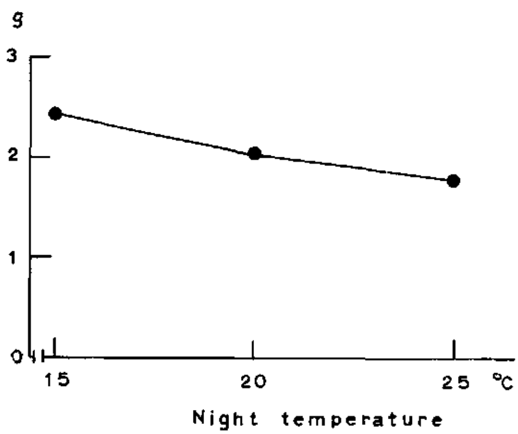


FIG. 21. Effect of night temperature on mean dry weight of 100 flower heads over the whole season.

perature, whereas the highest total number of mature flower heads is obtained in the 25 °C night temperature treatment, followed by 20 °C. The observed differences between the two latter treatments were not significant.

The dry weights of flower heads per individual plant during the period of growth are plotted in figure 18. After 77 days, the highest production of flower heads was obtained at 25 °C night temperature, whereas the dry weight of flower heads per plant in the 20° and 15 °C night temperature treatments were practically equal. Afterwards, the plants in the 15 °C night temperature treatment had the highest flower head production after 84 days, followed by 20° and 25 °C respectively. This may be attributed to the fact that the quality of the flower heads after 84 days was better in the 15 °C night temperature treatment than that at 20° and 25 °C respectively (c.f. figures 20, 21).

Although the total number of flower heads per plant at 25 °C night temperature was higher than that in the 15 °C night temperature treatment, the calculation of total dry weight of flower heads per individual plant during the experimental period shows that this is highest at 15 °C night temperature (figure 19). This is due to the fact that the 15 °C night temperature treatment seems to favour the production of larger flower heads as compared with 25 °C (figures 20, 21).

The mean daily flower head production rate expressed as dry weight in the various night temperature treatments is given in figure 22. The effect of night temperature on this feature is exponential and declining and led to a simple negative regression for the mean daily flower heads production rate.

In figure, 23, the oil percentage in the chamomile flower heads is plotted against night temperature. After 63 days, the plants in 15 °C night temperature treatment had attained their maximum percentage of essential oil, followed by the 20° and 25 °C night temperature treatments respectively, which trend subsisted with time. The volatile oil percentage in the flower heads decreased with increasing plant age for all three treatments.

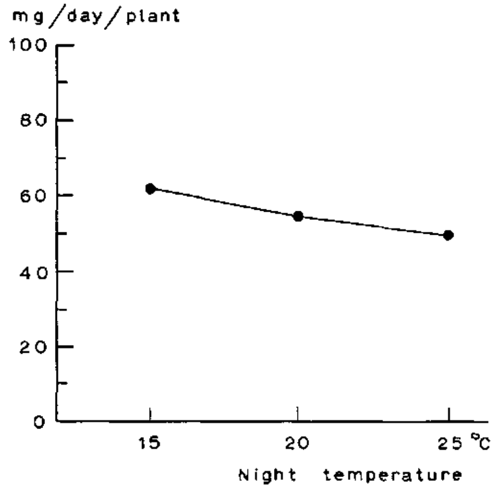
The previous data have been summarized in figure 24; it is obvious that the highest mean volatile oil percent during the experiment is obtained by plants growing at 15 °C night temperature treatment, followed by those at 20° and 25 °C respectively.

As it is shown in figures 19 and 24, both the highest production of flower heads and oil percentage occur in the 15 °C night temperature treatment, it is expected that the maximum oil production per individual plant also occurs in this treatment, followed by the 20° and 25 °C night temperature treatments respectively. That this is so, follows from figure 25.

Data illustrated in figure 26 corroborate the previous results; it shows that the highest total volatile oil production during the entire season is attained at 15 °C night temperature, followed by 20° and 25 °C respectively.

The percentage of chamazulene in the essential oil during the growth period coincides with the essential oil percentage in the chamomile flower heads. The highest chamazulene percentage is obtained at 15 °C night temperature, followed by 20° and 25 °C respectively (figures 27 and 28).

FIG. 22. Effect of night temperature on mean daily flower head production per plant during the whole season.



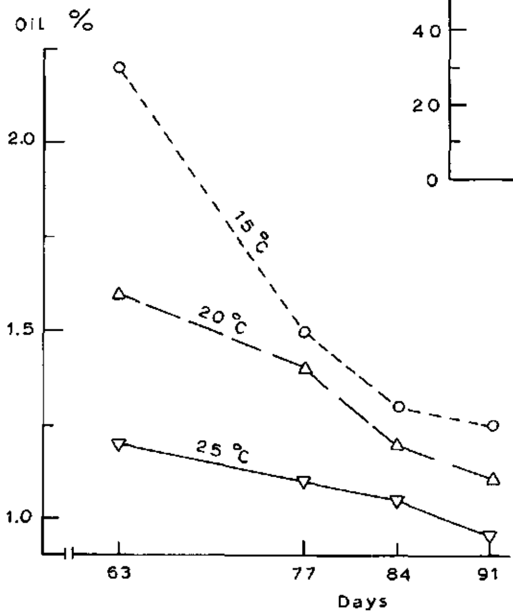


FIG. 23. Effect of night temperature on oil percentage in the flower heads during the period of growth.

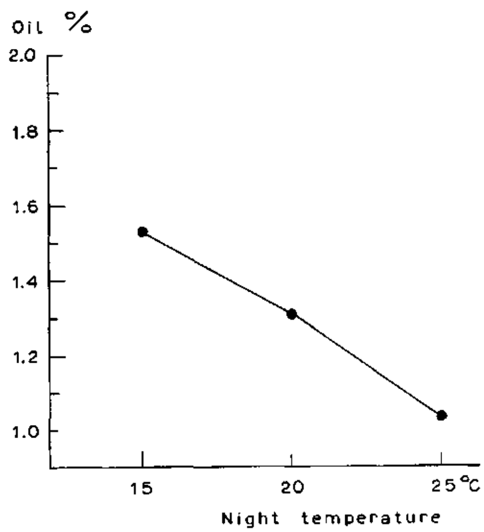
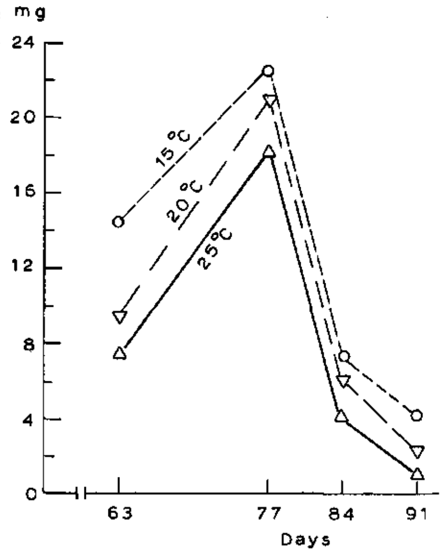


FIG. 24. Effect of night temperature on mean values of oil percentages in the chamomile drug.

FIG. 25. Effect of night temperature on the amount of essential oil per plant during the period of growth.



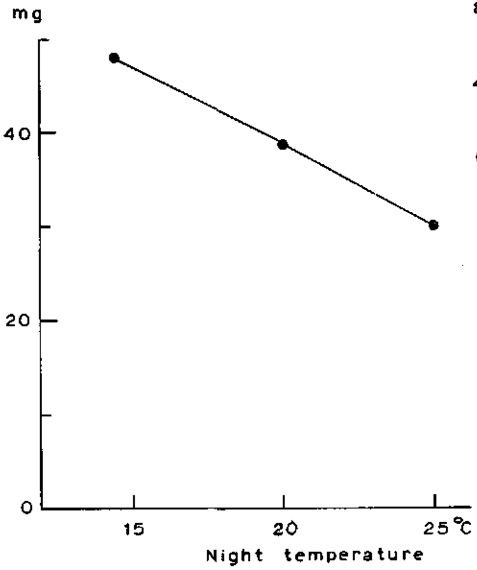


FIG. 26. Effect of night temperature on volatile oil content per plant over the whole season.

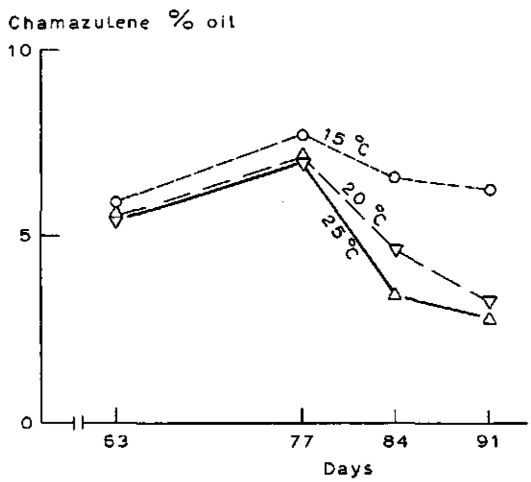


FIG. 27. Effect of night temperature on chamazulene percentage in chamomile oil per plant during the period of growth.

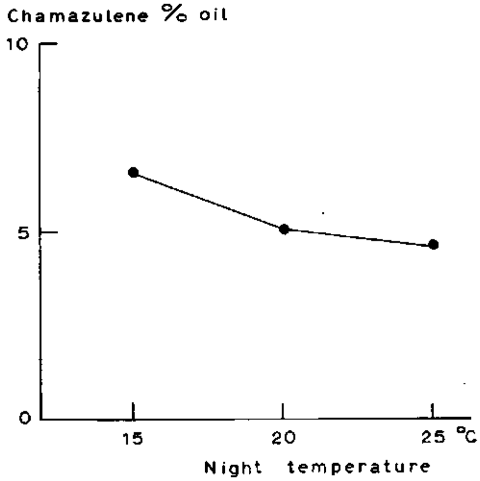


FIG. 28. Effect of night temperature on mean values of chamazulene percentage in the volatile oil over the whole season.

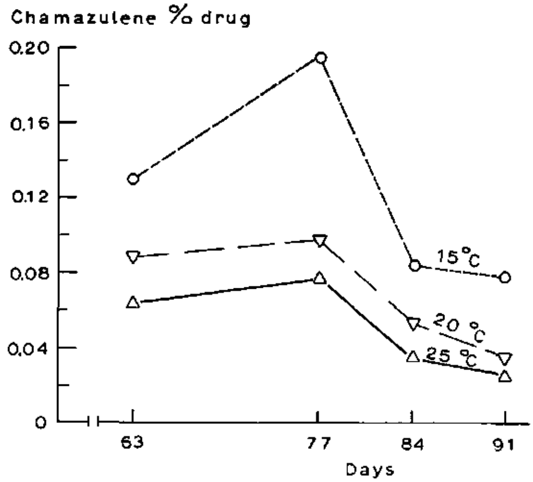


FIG. 29. Effect of night temperature on chamazulene percentage in the chamomile drug during the period of growth.

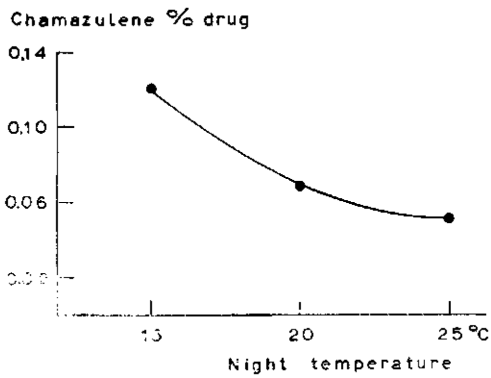


FIG. 30. Effect of night temperature on mean values of chamazulene percentage in the chamomile drug over the whole season.

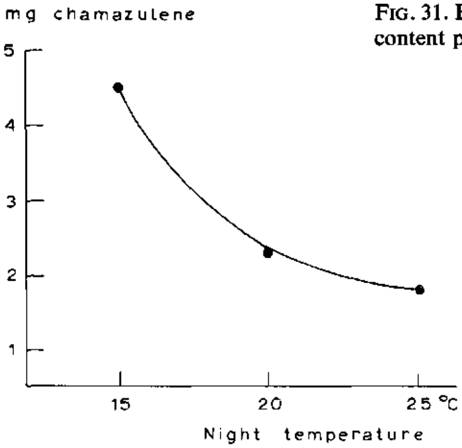


FIG. 31. Effect of night temperature on chamazulene content per plant during the period of growth.

In figures 29 and 30, the chamazulene percentage in the drug is plotted against night temperature. The maximum percentage of chamazulene is obtained in the 15°C night temperature treatment, followed by 20° and 25°C night temperature respectively.

The course of the chamazulene content per plant plotted against night temperature is exponential, as follows from figure 31. The highest total amount of chamazulene per individual plant is attained in the 15°C night temperature treatment, followed by 20° and 25°C night temperature respectively during the entire season (figure 32).

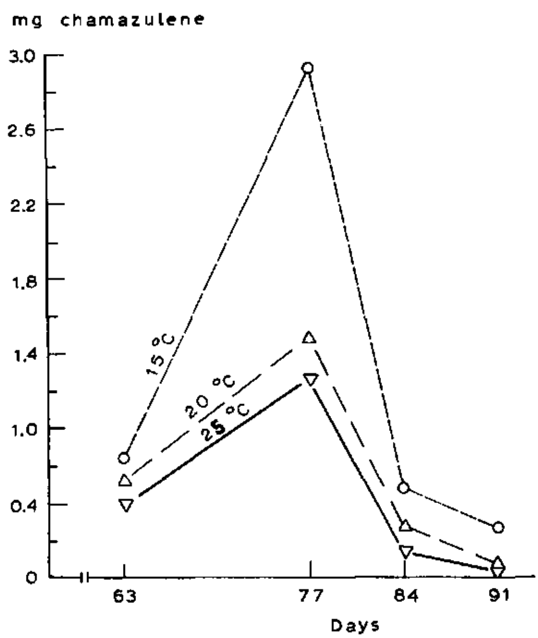


FIG. 32. Effect of night temperature on chamazulene content in chamomile flower heads per plant over the whole season.

Summary and Conclusion

Two experiments were carried out to investigate the effect of air temperature and thermoperiodicity on the growth of *Matricaria chamomilla* L., with regard to essential oil and active ingredient contents.

The study of the air temperature effect was realized by placing the plants in compartments in the phytotron at different air temperatures (25°, 20° and 15°C) during the 24 hours cycle. For the night temperature experiment, the plants were placed at a constant temperature of 25°C during the light period. In the night period one set was kept in the same chamber at 25°C, and the others transferred to compartments of 20° and 15°C respectively. During 16 hours in every 24 hours cycle, the pots of both experiments were in compartments illuminated by 'day light' fluorescent tubes producing a light intensity at the top of the plants of approximately 9.5×10^4 ergs/cm^2 sec.

The effect of air temperature on the vegetative growth of the chamomile plant is exponential and declining, while there was no obvious influence of night temperature on the rate of vegetative growth, specially in the earlier part of the growth cycle.

Although it is evident that high temperature treatment (25°C) during a 24 hours cycle in both experiments resulted in a maximum number of flower heads per individual plant, the size of the flower heads was small. Consequently, the total dry weight of flower heads per plant during the growth period decreased at higher temperature.

Concerning the trend of volatile oil percentage as influenced by constant temperature and thermoperiodicity, it is incontestable that there is a positive correlation between oil secretion and both higher temperature during the 24 hours cycle and lower night temperature, as constant 25°C air temperature, and 15°C night temperature most favoured the oil formation in chamomile flower heads.

The response of chamazulene accumulation in the chamomile oil glands to constant air temperature is contestable, whereas the trend of chamazulene formation in relation to the effect of the thermoperiodicity factor gives a clear picture in as much as lower night temperature favours chamazulene synthesis; it occurs optimally at 15°C night temperature.

5. References

1. NANNINGA, A. W., Van Gorkums Oost-Indische Cultures **2,** 255 (1913).
2. DORLAND, R. E., and WENT, F. W., Am. Jour. Botany **34,** 393 (1947).
3. CAMUS, G. C., and WENT, F. W., Am. Jour. Botany **39,** 521 (1952).
4. British Pharmacopoeia (B.P.), 1948.
5. M. SALEH, Meded. Landbouwhogeschool Wageningen, Neth., **68-21** (1968), pp. 1–14.