J.R. McWilliam, H.C. Harris
and W.K. Mason, Australia

INFLUENCE OF TEMPERATURE ON THE OIL CONTENT AND COMPOSITION OF SUNFLOWER

During the last decade, the introduction of high-oil varieties of sunflower of Russian origin into Australia has provided the basis of a new and potentially important oilseed industry. Most of the crops are grown under dryland conditions in summer rainfall areas between latitudes 23° to 32°S which are considerably lower than those for which the crop was developed in southern Russia.

Among the problems encountered in adapting sunflower to these areas are low seed yields, reduced oil percentage and a change in the composition of the oil caused by a reduction in the proportion of the polyunsaturated linoleic acid. One common feature of these environments is the high temperature experienced during the summer growing season. For this reason, in this study, we have investigated the effect of temperature experienced during the development of achenes, on the yield and composition of the oil produced under a wide range of thermal environments.

The synthesis of oil in the developing achenes was followed from pollination to physiological maturity in three different populations of the variety Peredovik. This was achieved by synchronizing pollination and sampling the developing achenes at regular intervals under known temperature conditions, using nuclear magnetic resonance (N.M.R.) and gas liquid chromatography (G.L.C.) to measure oil yield and fatty acid composition respectively.

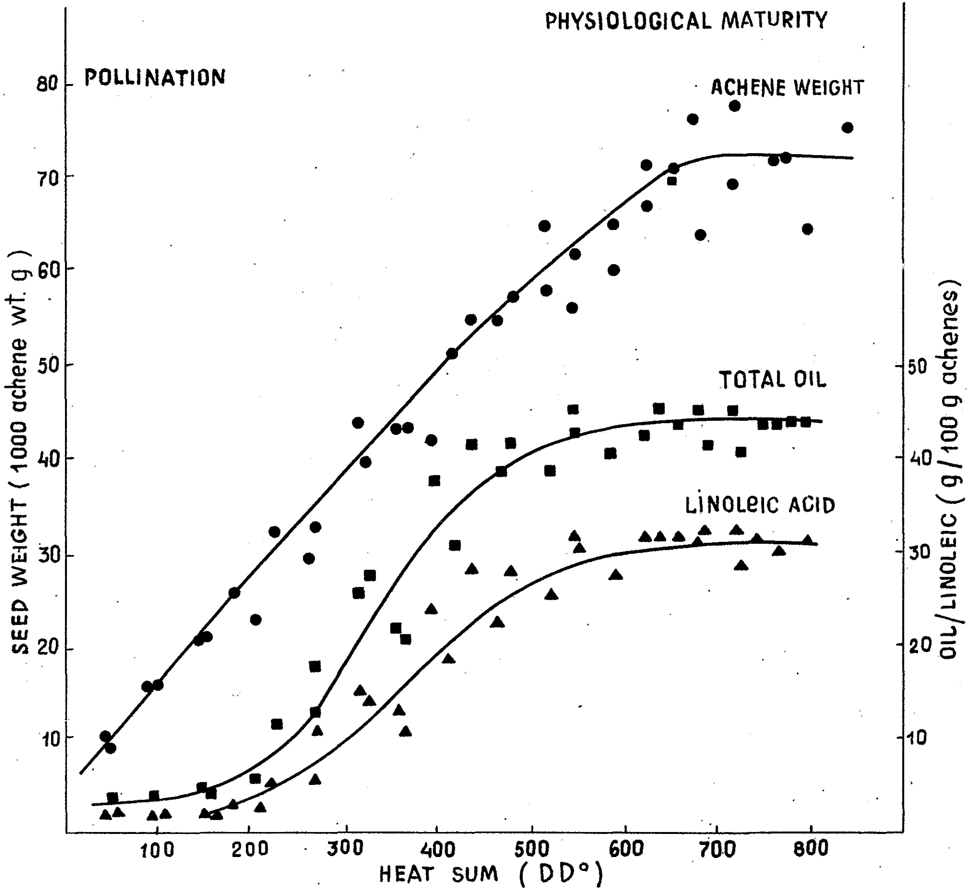

Fig. 1. Increase in achene (seed) weight (1000 achene wt.g) total oil and linoleic acid (g/100 g achenes) during the development of the achenes from pollination to physiological maturity, measured in day degrees

Heat sums, representing a summation of the day degrees (D.D.°)[1] were used to follow development in place of conventional time, as temperature conditions, and hence rates of development, varied between the three populations sampled.

It has been bound that the maximum dry weight, or physiological maturity, is reached at about 650 D.D.° after pollination. During this same period the moisture content of the developing achenes declined from 78% immediately after pollination, to 39% at physiological maturity.

Oil was detectable within 3 days of pollination much of which is probably in the pericarp which is well developed at this stage, but there was a lag of approximately 150 D.D.° before significant production occurred. Linoleic acid constituted the major component of the oil at all stages, increasing from approximately 50% early in achene development to 70-73% at maturity. In all cases this increase in linoleic acid was at the expense of oleic acid which declined over the same period. The maximum values for both total oil and linoleic acid were reached just prior to physiological maturity.

The effect of temperature, experienced during the development of achenes, on the yield and composition of oil was measured in the variety Peredovik for thirty field crops sampled over two consecutive summer seasons in northern New South Wales. Continuous temperature measurements were made at the site of each crop throughout the period of achene development from first anthesis until seed maturity.

---

[1] D.D.° - Heat sum calculated in day °C. as

$$\sum_{n}^{1}\left(\frac{\text{daily max } ^{\circ}C - \text{min } ^{\circ}C}{2} - \text{base } ^{\circ}C\right)$$

Base temperature used for this stage of development was 0°C.

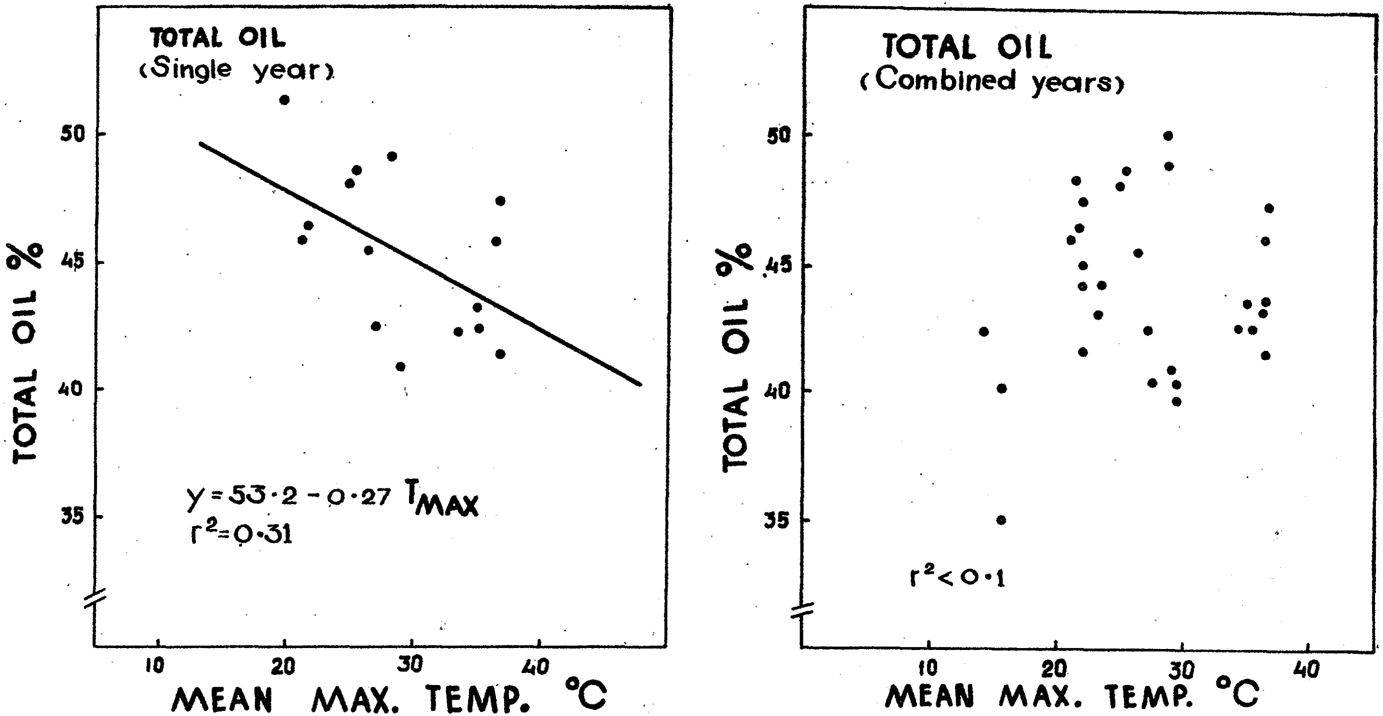

Fig. 2. Effect of the mean temperature (°C) experienced during the period of achene development on the yield of oil from field grown crops. Data for a single year and for a combination of two years are shown

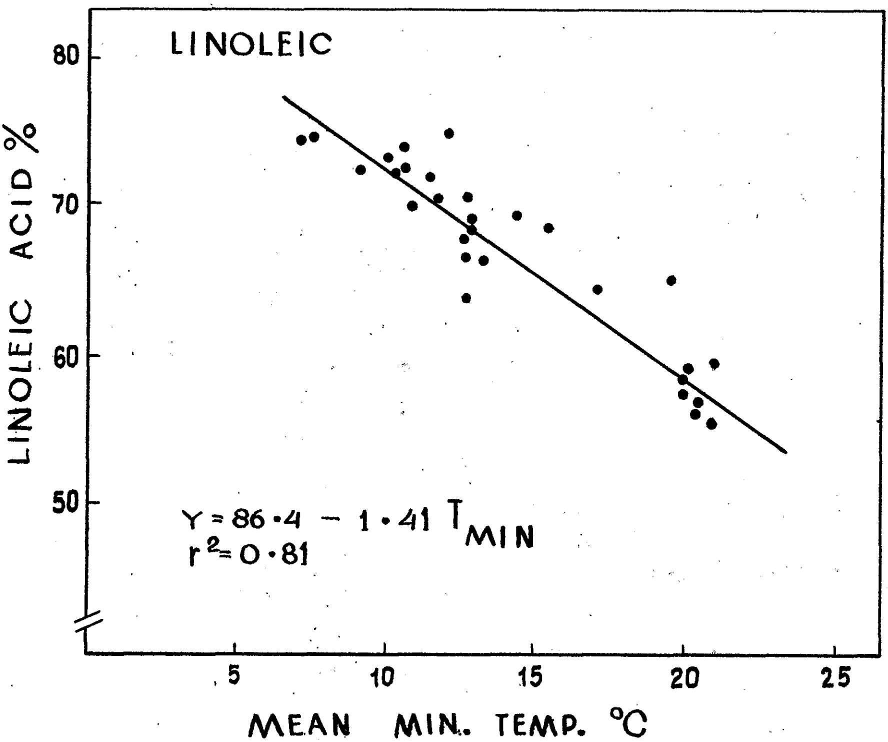

Fig. 3. Effect of mean minimum (night) temperature experienced over the period of achene development on the proportion of linoleic acid present in the oil produced by field grown crops

The yield of oil when plotted against mean max. temperature showed a decline with increasing temperature when based on a single year's results. When the data for both years were combined there was no relationship between temperature and oil yield which suggests that, although temperature is of some significance in determining oil yield, other factors such as water stress are confounded with temperature effects and are also influencing oil yield through their effects on growth and development of the achenes.

The proportion of linoleic acid in the oil was closely related to the mean minimum temperature, with the regression accounting for slightly over 80% of the variation observed in crops grown over a wide range of sites and seasons. The increase in the percentage of linoleic acid with reduction in the minimum (night) temperature occurs at the expense of oleic acid, which declined at a rate equal to the rate of increase in linoleic. This provides further evidence for the synthesis of linoleic acid (18:2) by direct desaturation of oleic acid (18:1), (1).

To obtain further evidence for the role of temperature in controlling oil yield and composition, plants of the variety Peredovik were also grown in controlled environments in the Canberra phytotron. All plants were grown under similar optimum conditions until anthesis, after which they were exposed to a range of five day/night temperatures from 35/25°C down to 15/8°C during the period of achene development. Plants were grown during the summer under natural daylight in a twelve hour photoperiod and were hand pollinated to ensure high seed set.

As found in the field survey, the maximum temperature (in this case day temperature) was negatively correlated with total oil percent and a similar relationship was clearly apparent for minimum temperature (night temperature) and percent linoleic acid. These relationships are more pronounced under the uniform conditions of controlled environments, especially the maximum temperature/total oil relationship, which under these conditions is not confounded by other environmental variables.

It is clear from this study of achene development that the production of oil, after an initial lag period, follows a similar pattern to dry weight accumulation. Both total oil and linoleic acid reached a maximum just prior to physiological maturity of the seed, approximately 650 D.D.° after pollination. Both oleic and linoleic acid are present at all stages of seed development, however, under favourable temperature conditions, linoleic is the dominant fatty acid present, ranging from 50% soon after pollination to more than 70% at physiological maturity.

Environmental factors are known to influence the quantity and quality of oil produced by temperature oilseed crops (3), (4). In Sunflower, although the effect of temperature on oil content varies, depending on the conditions under which the crop is grown (5), (3), there is evidence that reduced temperature during achene development leads to an increase in the proportion of linoleic acid and a reduction in the oleic component of the oil (6), (7), (5), (8). This appears to result from the direct effect of temperature on the activity of the desaturase enzymes involved in the conversion of oleic to linoleic acid and also on the solubility of O_2 which has a regulatory function in the desaturation activity (8). Field and phytotron studies of the effect of temperature on oil yield and composition support the hypothesis that reduced yield of oil and linoleic acid in crops matured under mid-summer conditions in low latitudes is due to the effect of high temperature on the bio-

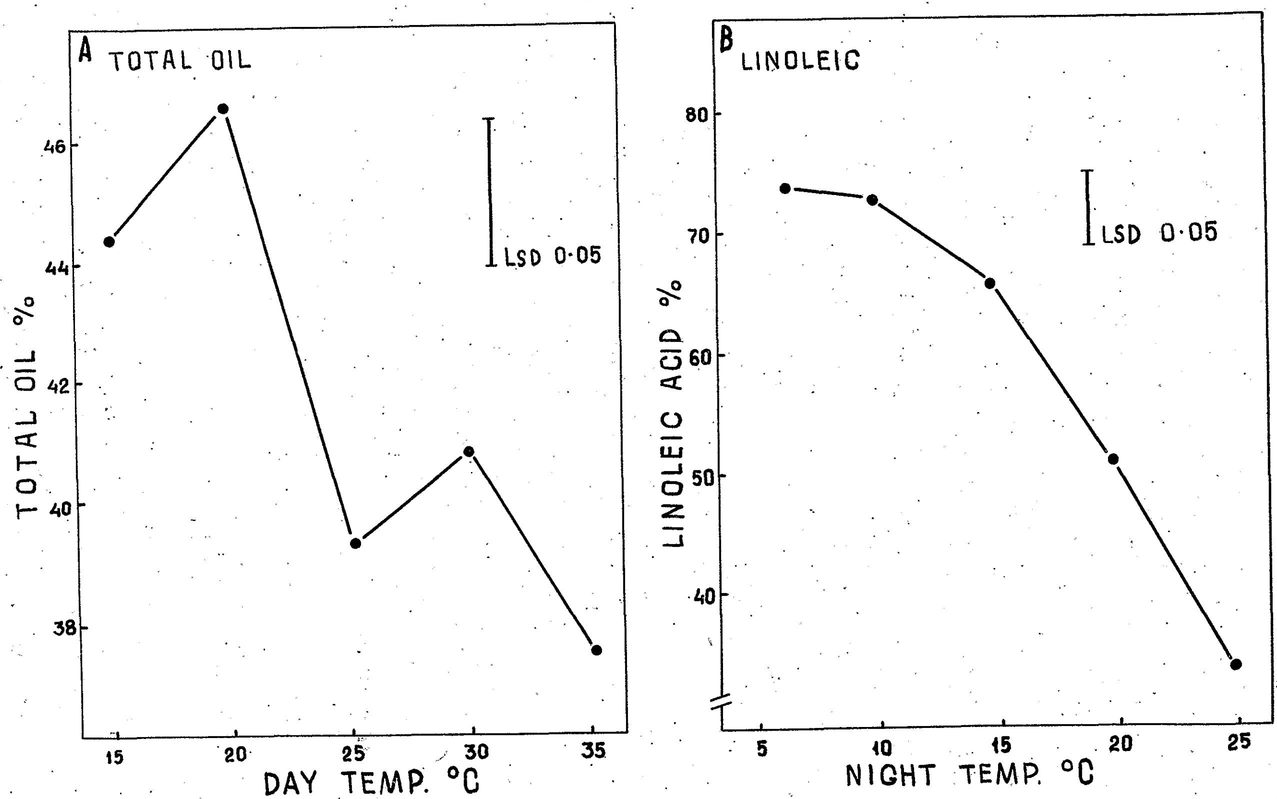

Fig. 4. Effect of temperature on the yield and composition of oil from plants grown in controlled environments. (A) Effect of max. (day) temperature on the yield of oil (% dry wt.); (B) Effect of min. (night) temperature on the percentage of linoleic acid in the oil

synthesis of fatty acids in the developing achenes. In the field, the reduction of oil by high temperature is confounded with the effect of other environmental variables, including moisture stress, which can influence grain size, pericarp to kernel ratio and total grain yield, all of which can have an effect on oil yield per unit weight of grain and per hectare. Temperature effects can therefore be used to explain only a proportion of the reduction in oil yield often observed under high temperatures in the field.

The close negative relationship between temperature and percent linoleic acid suggests that the various desaturases which are responsible for the synthesis of oleic acid and its conversion to linoleic acid during seed maturation are adapted to function best under cool temperature conditions characteristics of the climate under which this crop is considered to have evolved (9). Thus to achieve the maximum yield of polyunsaturated oil the crop should be exposed to moderate temperatures, especially cool night temperatures, during the seed ripening phase, either by selecting a suitable locality or by sowing at a particular time of the year to avoid high temperature stress during the flowering period.

References

1. McMahon, V. and Stumpf, P.K. (1964). Biochim. Biophys. Acta. 84:359:361.
2. Fowler, D.B. and Downey, R.K. (197). Can. J. Plant Sci. 50: 233-247.
3. Schuster, W. and Boye, R. (1971). Ztschr. Acker Pflanzenbau. 133:321-334.
4. Barker, C. and Hilditch, T.P. (1950). J. Sci. Food Agric. 1:118-122.
5. Canvin, D.T. (1965). Can. J. Bot. 43:63-69.
6. Grindley, D.N. (1952). J. Sci. Food Agric. 3:82-86.

7. Hilditch, T.P. and Williams, P.N. (1964). "The Chemical Composition of Natural Fats", 4th Ed. Chapman and Hall, London.
8. Harris, R.V. and James, A.T. (1969). Biophys. Acta 187:13-18.
9. Heiser, C.B. (1965). IN "The Genetics of Colonizing Species". (H.G. Baker and G.L. Stebbins eds.), p. 391-398, Academic Press, N.Y.