Factors affecting germination of sunflowers under low temperature conditions

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Summary

Genetic and environmental variation were utilized to generate sunflower seed lots with a range in linoleic acid content which was related to rate of germination at 4°C. A population exposed to three generations of selection for fast germination at 4°C followed by field growth in winter and spring was also evaluated. Lines with ability to germinate fast at 4°C established best in the field when sown in winter when the average daily temperature was 10°C. Field establishment in winter was superior in lines containing high linoleic acid. The consequences of these findings in agronomic and breeding strategies are discussed.

Introduction

Sunflowers are grown on 0.2 million hectares in Australia each year but the yield is less than 0.7 t ha^{-1}, partly because of variable summer rains. Conditions are more reliable in the winter rainfall zone where 15 million ha of cereals yield about 1.3 t ha^{-1}. A consideration of environmental conditions and the physiology of sunflower led Downes (1974) to propose that sunflowers be modified for growth in winter and spring to allow this crop to compete with, or complement, wheat.

Radford and Nielsen (1982) evaluated sunflowers sown in winter in southern Queensland and found that their yield was about 60% of that of wheat but the difference in grain value made sunflowers the more profitable crop. In their experiments, linoleic acid content in the oil varied from 52-70% while the oil percentage varied from 34 to 47% in different seasons, possibly reflecting episodes of moisture stress (Muriel and Downes, 1974).

Winter sown sunflowers took up to 30 days to emerge in studies reported by Potter (1983). Like Gimeno (1974), he observed variation among lines in rate of germination. In time of planting studies, Potter recorded maximum yield and oil percentages with winter sowings and that these produced seed containing 62-64% linoleic acid.

Despite the promise of winter-sown sunflowers, slow germination can reduce the number of seedlings emerging in cold wet soil. Slow establishment can also reduce the capacity of winter sunflowers to compete with weeds. This problem was investigated in the study reported here.

Materials and Methods

Two experiments were conducted to determine the effects of genetic constitution of seed and of environmental conditions during seed development, on germination rate under cool conditions. In each case the experimental and variable open-pollinated germplasm "Siroleo" was used. This was developed in the CSIRO Division of Plant Industry from early flowering segregates from a large number of accessions.

1. Growth under controlled conditions

The germplasm used traced to "Siroleo" plants that had been selected for ability to produce seed containing high levels of linoleic acid at high temperatures, or had been pollinated by such plants. Seed was sown in 15 cm pots containing a mixture of vermiculite and perlite. Plants were provided with a Hoaglands nutrient solution and were watered twice daily. Development took place at 24/19°C (16 hour photoperiod) before flowering at which time plants were randomly cross pollinated. Seed development took place at 27/22, 21/16 or 15/10°C day/night temperatures.

At maturity each plant was harvested separately and assayed for oil quality. Seeds were crushed and the fatty acids were methylated with sulphuric acid-methanol (Welch, 1977). Chromatography of the esters was carried out using a Varian Aerograph 204 B gas chromatograph equipped with a stainless steel column packed with Silar 10 C on Gas Chrom Q. Peak areas were obtained using a Varian CDS-111 C data system. Standard methyl esters were obtained from Applied Science Laboratories Inc.

The seeds harvested from individual plants were allocated to the following categories:

(a) Seed lots from plants grown at 15/10°C during seed maturation and therefore containing high linoleic acid because of the low temperature environmental conditions (Downes and Tonnet, 1982).

(b) From plants grown at 24/19 or 27/22°C while seed was developing, those seed lots containing more than 65% linoleic acid are likely to carry genes allowing the accumulation of high linoleic acid at high temperatures.

(c) Of the seed lots grown at 24/19 or 27/22°C, those containing less than 65% linoleic acid are less likely to be capable genetically of producing high linoleic acid at high temperatures.

Twelve single plant progenies were selected at random from each of these three categories. From each progeny, two replications of 25 seeds were placed on filter papers in petri dishes and incubated at 4°C. Seeds were considered to have germinated when the radicle had achieved a length of 5 mm. An estimate of days to median germination was derived by summing, over the germination period, the product of number of days to germination and the proportion of viable seeds which germinated on the particular day.

2. Selection under laboratory and field conditions

During three generations of selection, seeds of "Siroleo" were exposed to 4°C conditions during germination in petri dishes. In the first selection cycle the fastest germinating seedlings were transferred to a glasshouse at 24°C for growth, random pollination within the population, and maturation. For the second and third cycles, selected seedlings were transplanted to soil in a nursery area in winter when the average daily temperature was about 10°C. Plants were randomly pollinated by bees and matured when the average daily temperature was about 20°C. Ultimately plants were selected on agronomic characteristics and oil percentage in seed (>45% oil in the second cycle and >50% oil in the third). In the third cycle of selection 40 elite plants produced seeds containing 63.2 ± 4.7% (range 54 to 71%) linoleic acid in the oil.

Seeds of each of the 40 plants used in this study were placed in petri dishes (2 x 25 seeds per dish) in a cold room at 4°C. Rate of germination was determined as in experiment 1. All lines exhibited a high viability. Seed of each of the 40 plants was also sown in a field trial with 100 seeds per plot and with two replications. Planting was effected in a prepared seedbed in winter when the average daily temperature was approximately 10°C. Stand counts were made about 8 weeks after sowing which allowed adequate time of all viable seeds to germinate.

Results

It was possible to produce seed of three categories. Seed containing 70 to 80% linoleic acid was obtained by allowing plants to experience cool (15/10°C) temperature conditions during the reproductive stage. Seeds containing oil of this quality were also produced on plants growing at higher temperatures (e.g. 27/22°C) after flowering if plants had been previously selected to produce high levels of linoleic acid at high temperatures. The third class of plants, lacking the potential to accumulate high levels of linoleic acid at elevated temperatures, typify the usual situation (Downes and Tonnet, 1982). When these categories of seed were germinated at 4°C, those containing high linoleic acid germinated faster than those with low content of linoleic acid according to the equation $Y = 38-0.3X$ where Y is the median number of days to germinate and X is % linoleic acid ($r = -0.88$) (figure 1).

In the population obtained by three generations of selection for ability to germinate under cold conditions, there was a relationship between the rate of germination at 4°C and field establishment according to the equation $Y = 114-2.5X$ where Y is field establishment (per cent) and X is the median number of days to germinate at 4°C. The correlation coefficient ($r = -0.69$) reflects the considerable variation in the population (figure 2a).

A close agreement was observed between linoleic acid content of seed and field establishment (figure 2b). In this case the data fitted the equation $Y = 41X-204$ where Y is percent field establishment and X is % linoleic acid in seed ($r = 0.76$). If seeds contained high levels of linoleic acid, there was greater likelihood of good field establishment in a winter sowing at 10°C.

The data from the two experiments are compared in table 1. It is clear that if seed contained high levels of linoleic acid, germination was fastest at 4°C. There was little difference in germination rate at 4°C between plants in which high linoleic acid was induced by seed development at low temperature, or by genetic means in seed produced under high temperature conditions. Seed produced by 3 generations of selection in the field contained a lower level of linoleic acid then did seed produced by plants selected for high linoleic acid. Thus the field population did not carry a high proportion of the genes allowing high levels of linoleic acid accumulation under hot conditions (Downes and Tonnet, 1982).

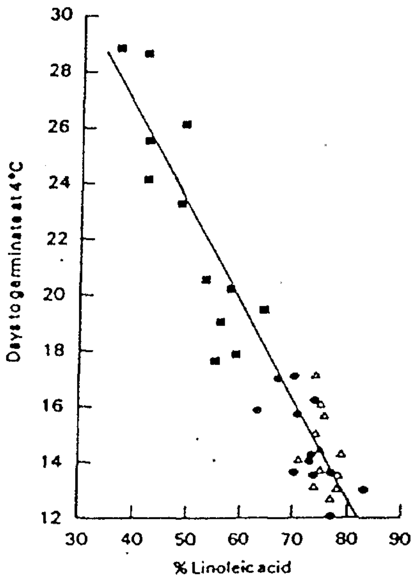
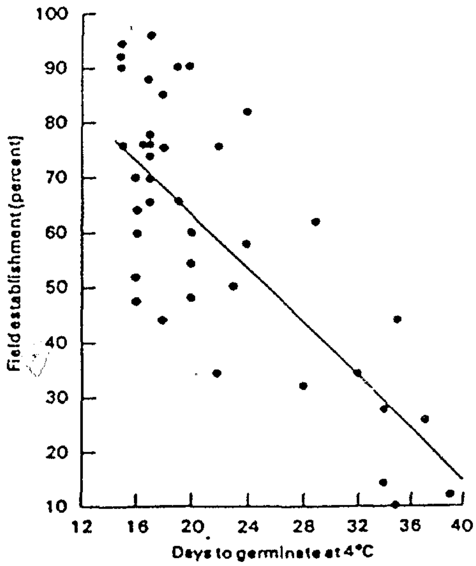


Figure 1.

Effect of linoleic acid content of seed on rate of seed germination at 4°C (■, △ seed produced at high temperature, with low and high linoleic acid content respectively, ● seed produced at low temperature).



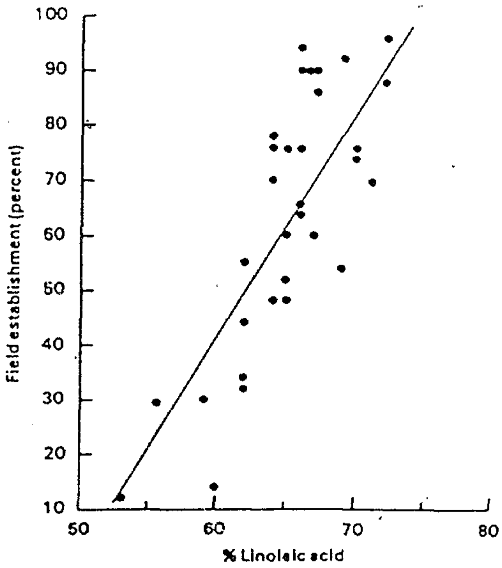


Figure 2

(a) Relationship between days to germinate at 4°C and field establishment.

(b) Effect of linoleic acid content of seed on field establishment.

Table 1

Linoleic acid content and days to median germination at 4°C of sunflower seed produced in various environments

Treatment	Linoleic acid content in oil (%)	Days to germinate at 4°C
Seed produced at low temperature (15/10°C)	74.1 ± 2.7	14.3 ± 1.5
Seed produced at high temperature		
(a) containing high linoleic acid	71.9 ± 4.3	13.9 ± 1.8
(b) containing low linoleic acid	45.4 ± 7.7	21.9 ± 4.0
Seed produced in the field in spring at about 20°C	63.2 ± 4.7	19.6 ± 2.8

Gimeno, V. 1974 Variation in rate of germination at low temperature as a basis for selection in sunflowers. Proceedings 6th International Sunflower Conference. Bucharest. 471-472.

Muriel, J.L. and Downes, R.W. 1974 Effect of periods of moisture stress during various phases of growth of sunflowers in the greenhouse. Proceedings 6th International Sunflower Conference. Bucharest. 127-131.

Potter, T.D. 1983 An agronomic evaluation of sunflower (*Helianthus annuus* L.) in a Mediterranean-type environment. M. Agr. Sc. Thesis, University of Adelaide. 127 pp.

Radford, B.J. and Nielsen, R.G.H. 1982 Winter sown sunflowers on the Darling Downs, Queensland. Queensland Journal of Agricultural and Animal Sciences, 39, 73-80.

Welch, R.W. 1977 A micro-method for the estimation of oil content and composition in seed crops. Journal Science Food and Agriculture, 28, 635-638.

Discussion and Conclusions

The experiments reported here show that high levels of linoleic acid can accumulate in sunflower seed if seed is produced under low temperature conditions, or, if plants have the appropriate genetic constitution, high linoleic acid seed is produced under high temperature conditions. Linoleic acid content of seed is associated with the ability to germinate quickly under controlled 4°C temperature conditions (figure 1).

Under field conditions, high linoleic acid in sowing seed appears to confer an advantage in the final stand achieved with a sowing in winter when the average daily temperature is about 10°C. It is likely that since high linoleic acid seed germinates rapidly, seed and young seedlings are less likely to be exposed to insect and fungal attack in adverse soil conditions. Variation in figure 2a indicates that although there is a close relationship between rate of germination under sterile conditions at 4°C and field establishment at 10°C, other factors are significant. Small seed size, lack of seedling vigour and susceptibility to fungal attack, for example, may not affect germination at 4°C but may reduce emergence from seed sown in soil at 5 cm depth.

Selection for fast germination at 4°C was followed by seed production at about 20°C. Under these circumstances, a linoleic acid content of 63% was recorded. This is in close agreement with the findings of Potter (1983) and within the range observed by Radford and Nielsen (1982). Oil containing 63% linoleic acid allows the seed to germinate rapidly. This makes it difficult to reliably select those plants containing genes for high linoleic acid accumulation irrespective of temperature conditions. Selection of sunflower plants with the ability to germinate under cold conditions is most readily achieved if plants are matured under hot conditions and the seed germinated under cold conditions (Downes and Tonnet, 1982).

Suitable seed for sowing crops in winter could be obtained by inducing high linoleic acid oil using cool post-flowering conditions. This is a short term option which could be replaced by selecting genotypes with stable high linoleic acid content. In either system, superior genotypes for use as winter crops can be identified. There is variation in sunflowers for vigour of growth under cool conditions, variation in the extent of cold-induced distortions of vegetative growth, frost damaged and male sterile inflorescences, and in plant height and harvest index.

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References

Downes, R.W. 1974 Environmental and physiological characteristics affecting sunflower adaptation. Proceedings 6th International Sunflower Conference. Bucharest. 197-204.

Downes, R.W. and Tonnet, M.L. 1982 Selection of sunflower plants containing high linoleic acid, and its agronomic significance. Proceedings 10th International Sunflower Conference, Surfers Paradise. 258-261.