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ENVIRONMENTAL AND PHYSIOLOGICAL CHARACTERISTICS AFFECTING SUNFLOWER ADAPTATION

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Although the wild sunflower and relatives have evolved under diverse conditions in north and central America (Heiser, 1969), intensive selection in the temperate zone may have narrowed the range of conditions to which commercial varieties are adapted. Indeed, when sunflowers are grown in summer in the subtropics and in regions experiencing Mediterranean-type climates yields are low and variable. In both of these situations the summer is characterized by low or unreliable rainfall and high temperature conditions. The latter may have an adverse effect on yield directly or through being associated with conditions of high evaporative demand, lead to inefficient water use (Downes and Connor, 1973), thereby compounding water relations problems.

To illustrate the effect of temperature on sunflower growth and production, and to define the water-use characteristics of sunflower, abstracts of three recent studies will be discussed in relation to the hypothesis that if conditions are unfavourable for sunflower crops, different agronomic and genetic approaches may be both possible and desirable. To help define appropiate alternate strategies to increase and stabilize production, the significance of agroclimatic data in crop adaptation will be discussed.

SIGNIFICANCE OF TEMPERATURE CONDITIONS

The effect of range of temperature conditions from 15° to 33° C on the growth of Peredovik sunflower was observed under phytotron conditions (Downes and Davidson, unpublished). Plants were exposed to temperature treatments during an entire growth cycle, or only during the post-flowering phase, having been grown to flowering at 21° C. In both cases the results were similar. The adverse effect of high tempe-

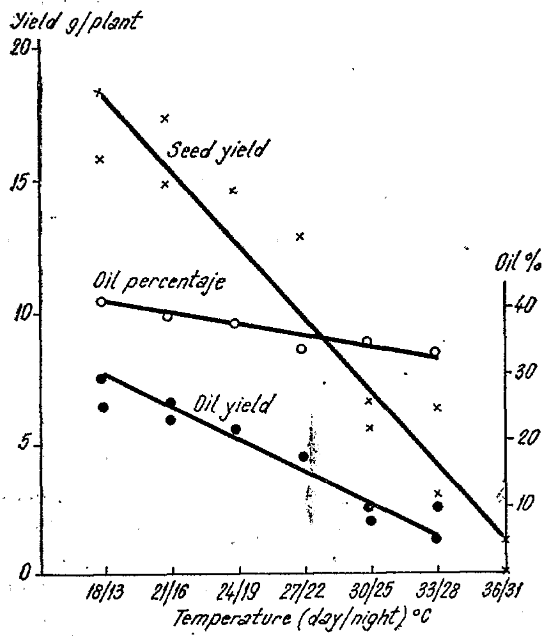

Fig. 1 — Seed yield, oil percentage and oil yield of sunflower plants growing at various temperatures (x, seed yield; o, oil percentage; u, oil yield) (after Downes and Davidson, unpublished).

rature was more marked with respect to seed yield than in the case of oil percentage. Consequently oil yield too, was inversely related to temperature (figure 1).

The composition of oil produced was constant betwwen 21 and 33° C (33% oleic acid, 54% linoleic acid). But at lower temperatures 18 and 15° C, oleic acid increased to 40% while the linoleic acid fraction decreased to 45%. Low temperatures differentially favoured vegetative growth rather than seed production so that the harvest index (ratio of cypsela (seed) weight to total dry weight) was greatest at 21 and 24° C than under either higher or lower temperature conditions.

SUNFLOWER WATER RELATIONS

Since the sunflower has the C-3 pathway of photosynthesis, individual unshaded leaves have lower rates of photosynthesis, but rates of transpiration comparable to those in C-4 species (Downes, 1970). However in C-3 species in dense plantings, rates of water use per unit leaf area are much greater than in C-4 species, while the net assimilation rates are comparable under 20—25° C conditions (Downes, 1969). In both cases, the C-4 species are more efficient in using water than are C-3 species in having higher rates of photosynthesis relative to transpiration.

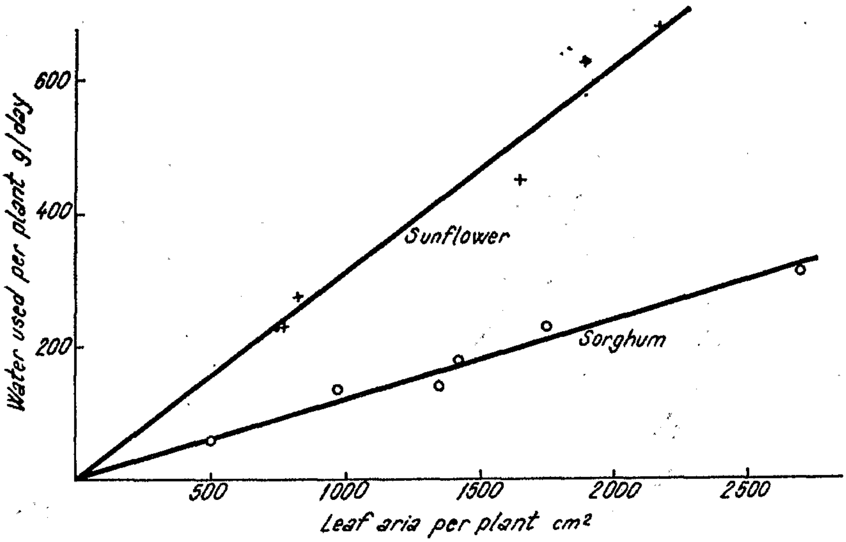

Fig. 2 — Water used by sunflower and sorghum plants per day at 30/25°C in relation to leaf area expanded (×, sunflower; 0, sorghum).

To determine their relative suitability to conditions where water resources are limited, experiments were conducted with both sunflowers and sorghum. Under phytotron conditions, plants of Peredovik sunflowers and sorghum (RS 610) were grown under 30/25° C (day/night temperatures) (D o w n e s, unpublished). During the development of plants, water loss through transpiration was measured during a 24 hour period before plants were harvested and leaf area determined. Data summarized in figure 2 indicate that at any given leaf area, the sunflower uses more than twice as much water as sorghum does.

In other experiments (D o w n e s, unpublished), plants of a range of species were grown under controlled conditions before being transferred to a gas exchange chamber in which CO_2 uptake and water loss were monitored simultaneously and continuously as the ambient temperature conditions were changed automatically, under natural summer radiation conditions at Canberra.

Sorghum and sunflower plants exhibited comparable rates of photosynthesis per unit leaf area, but the sunflower plants offered much less resistance to gas exchange ; the stomatal resistance being 2.5 times as great in sorghum. Other species with the C-3 pathway, *Brassica, Cicer, Triticum* and *Phaseolus* had lower rates of photosynthesis than sunflower but their stomatal resistance was higher. *Panicum,* which like sorghum, has the C-4 pathway of photosynthesis performed as sorghum did. For the various species, the relationship between rate of photosynthesis and resistance to water loss is shown in figure 3.

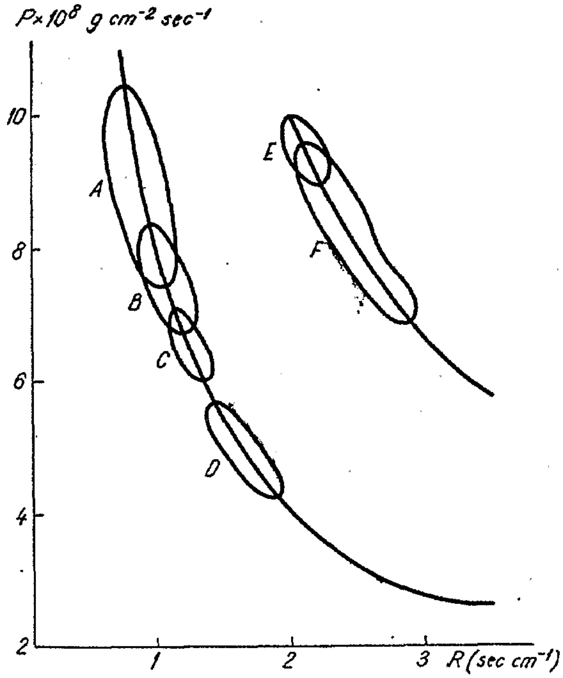

Fig. 3 — Relationship between photosynthetic rate (P) and resistance to water loss (R) of entire plants of various species (species with C—3 pathway of photcsynthesis; A, sunflower; B, Brassica; C, Cicer; D, Phaseolus; species with the C—4 pathway; E, Panicum; F, Sorghum).

The product of the rate of photosynthesis and resistance to water loss gives an estimate of the physiological efficiency with which water is used. Over the entire temperature range 20—40° C, the C-4 species are more than twice as efficient at using water as C-3 species are. In both, there is a slight decrease in biological efficiency as temperature rises. But in the field situation the decrease in efficiency with increased temperature is much more marked due to physical considerations related to evaporative demand.

SIGNIFICANCE OF PHYSIOLOGICAL CHARACTERISTICS OF THE SUNFLOWER

Sunflowers produce more seed and oil under low rather than high temperature conditions suggesting that sunflower crops should be grown under cool conditions. Indeed the data available suggest that cypsela (seed) development might best take place between 21 and 24°C. This is also the case in sorghum (Downes, 1972 a). Data from irrigated time of sowing studies (Lehman et al. 1973; Léon, 1974) support the contention that high temperatures are unfavourable. The earlier sowings which produced the highest yields would have matured under cooler conditions than later sowings.

Where water availability is limiting or unreliable, the sunflower has a definite weakness. Because of its high water requirements, soil moisture reserves are depleted more quickly than is the case in C-4 crops. Indeed, at Córdoba, a complete canopy of sunflower would be capable of drying a deep clay soil from field capacity to wilting point in one month in summer. At low populations, reserves last longer but yield potential is reduced. It appears that sunflowers should not be grown when water is limiting.

These considerations suggest that the sunflower is not an appropriate dryland summer crop in much of the sub-tropics or in the Mediterranean-type zones though it is possible that even with its physiological disadvantages, the sunflower may be a economic crop under these conditions. However, modification of agronomic practices and genotypes in these regions may make greater production possible.

ANALYSIS OF ENVIRONMENTS AND CROP ADAPTATION

Climatic data provide an aid in the identification of conditions during which adverse temperatures and moisture relations are unlikely. Then the necessary phenology of the crop can be defined so that the crop and expected growing season are in balance (Downes, 1972 b). It is also possible to use other highyielding, etablished crops for reference and to attempt to fit sunflowers into the niche that these occupy. Spring weat is a case in point. At Córdoba, wheat is sown in autumm and matures late in May or early June while soil moisture reserves remain. Wheat yields 3000 kg/ha under these conditions while summer sunflowers produce only 25% of this. What might sunflowers yields if they too, matured before moisture reserves were depleted ?

Sunflower selections were grown in winter and spring at Canberra, Australia, in 1972 (Downes, unpublished) after studies the previous year revealed that, provided they were hardened to low temperature conditions plants in the 6 leaf stage were not serionsly affected by temperatures of —7°C except for some leaf distortion and discoloration.

The phenology of early maturing selections in relation to temperature conditions in Canberra is shown in figure 4. Moderate frosts were received during the vegetative stages and distortion of capitula was observed in some genotypes but not in others at comparable stages of development. Early selections were in widely spaced rows but the dwarf plants (0.5 m high) produced, generally occupied less than 400 cm^2 of soil area. Higher yielding plants produced 13—15 g of seed, equivalent to more than 3000 kg/ha at a population of 250,000/ha (a which rate each plant has 400 cm^2 of soil surface). Slower maturing lines like Peredovik appeared unsuitable because they flowered one month later when moisture was becoming limiting.

Maturity time in the early selections was such that they ripened when wheat ripens in Canberra. Yet although weat can be planted before winter, it appears unlikely that this would be a suitable time

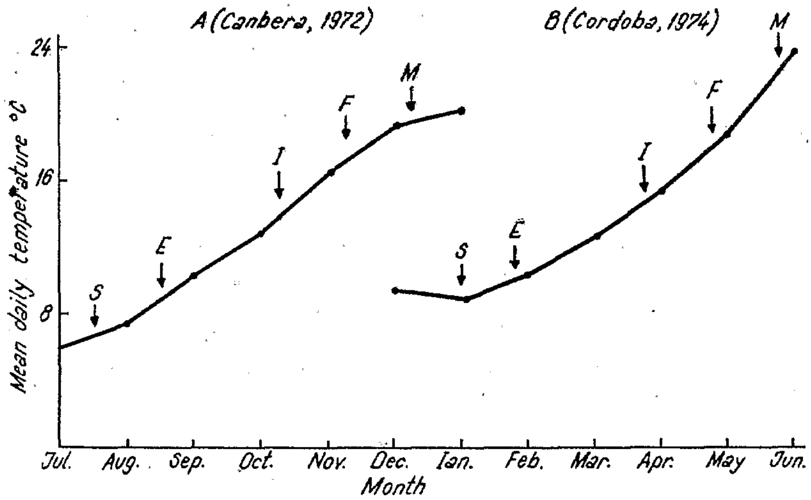

Fig. 4 — Phenology of early maturing varieties of sunflower in relation to temperature in spring at Canberra, Australia (A) and Córdoba, Spain (B). (S, seeding; E, emergence; I, initiation; F, flowering; M, physiological maturity).

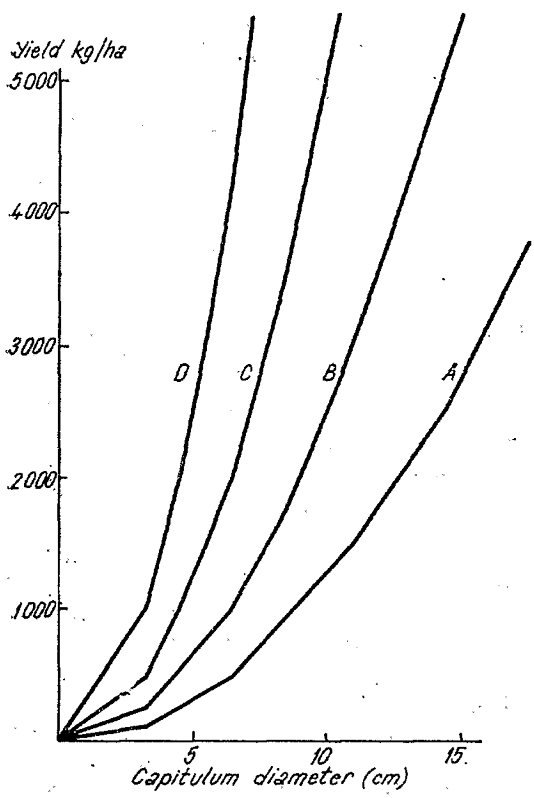

Fig. 5 — Theoretical relationship between capitulum diameter and yield at various populations (A, 62,500 plants/ha; B, 125,000; C, 250,000; D, 500,000).

to sow sunflower. Rather, it seems that sunflowers should not be sown until the average daily temperature reaches 8 or 10° C in the late winter so that they will not produce more than 4 to 6 leaves while frost dangers remain. Using this strategy, weed problems are not severe. Winter weeds have been removed by cultivation and summer ones generally do not germinate until later.

Yield trials using the early variety Morden 1267 and Peredovik were sown throughout Spain at various dates and rates in winter and spring 1974. The development pattern of Morden 1267 sown at Córdoba in mid January 1974 is shown in figure 4. This variety appears to fit well into the desirable growing season.

Early maturing sunflowers develop into small plants, particulary when sown in winter. Yet in spring in environments experiencing appreciable winter rains and on deep soils of high moisture holding capacity, adequate soil moisture is available to support a complete crop canopy for an extended period under conditions of low evaporative demand. Under these circumstances high populations allow maximum use of water and radiation resources so that high yields can be anticipated. A theoretical relationship between yield and capitulum diameter at various populations is shown in figure 5 (this assumes that 1 cm^2 of capitulum carries 0.25 g of seed). It can be seen that to produce 3000 kg/ha, a capitulum diameter of 15.5 cm is necessary at 62,500 plants/ha; but at 250,000 plants/ha, the capitulum needs to be less than 8 cm in diameter. A uniform early crop with small capitula can also be expected to be quickly ready for harvest.

These concepts are currently being evaluated in the field but for maximum production under the radically different conditions which winter/spring sunflowers experience, it appears likely that a breeding programme will be necessary (Downes, 1974).

Jensma (1973) using different criteria concluded that even in established sunflower areas, modification of morphology and populations might increase yield.

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