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CHLORMEQUAT INDUCED DROUGHT AVOIDANCE IN SUNFLOWERS

The favourable effects of Chlormequat (CCC, 2-Chloroethyltrimethylammoniumchloride) on plant water relations has been documented on a number of occasions with a range of crop plants. CCC can thus induce a measure of drought avoidance by delaying the depletion of soil moisture.

In the experiment reported here an attempt was made to induce moisture stress by manipulating plant population and to test the effect of CCC under such conditions.

Plots were thinned to densities of 12,500 (D1), 25,000 (D2), 50,000 (D3) or 100,000 (D4) plants per hectare, each population being represented eight times. The experiment was performed on a chocolate soil type at Armidale, New South Wales on a previously fallowed area. Seed was sown on 9 December 1974 in a trial area consisting of 32 plots, each plot having 12 by 12 m. rows at a spacing of 60 cm.
An aqueous solution of CCC (4000 ppm) was applied to the plots at the ten leaf stage of growth as a foliar spray.

Crop development was recorded by observations of plant height, leaf number and the rate of appearance of senescent leaves. Green leaf number was calculated by the difference of the last two observations. The onset of anthesis was noted and the percentage of plants at the anthesis stage observed until post-anthesis was reached.

On the day of spraying and at fortnightly intervals thereafter a destructive growth analysis was performed to determine the dry weight of the various plant fractions (leaves, stems, petioles and heads) together with leaf area. At maturity heads only were sampled and head, seed and 1000-seed weights measured. Oil percentage and linoleic acid content of the oil were found from nuclear magnetic resonance (NMR) and gas liquid chromatography (GLC) techniques respectively.

Soil moisture was monitored throughout the experiment using the neutron probe technique. Changes in soil moisture and evapotranspiration were determined by subsequent computer analysis.

Relative water content and leaf water potential (using a Scholander Pressure Chamber) were measured at intervals throughout the experiment. Also stomatal resistance was monitored using a Diffusion Porometer.

During the experiment the maximal temperature varied from 20 to 30°C and the minimal at about 10°C. Little effective rainfall was received during the first ten weeks of growth and within this period no rainfall was recorded between 18 January and 9 February. Considerable rainfall was only observed in the latter half of February.

At all densities CCC reduced water use immediately after application, although greater usage at later stages of growth led to total water use being unaffected.

The higher densities tended to use more water than the lower densities initially but this situation was reversed towards the end of the experiment such that total evapotranspiration was similar for all densities.

The greatest rates of evapotranspiration occurred during the anthesis stage of development for all densities irrespective of treatment.

Between the time of the first measurement (7 January) and 6 February soil moisture declined, with a greater depletion being observed at the higher densities and in untreated plots (Fig. 1).

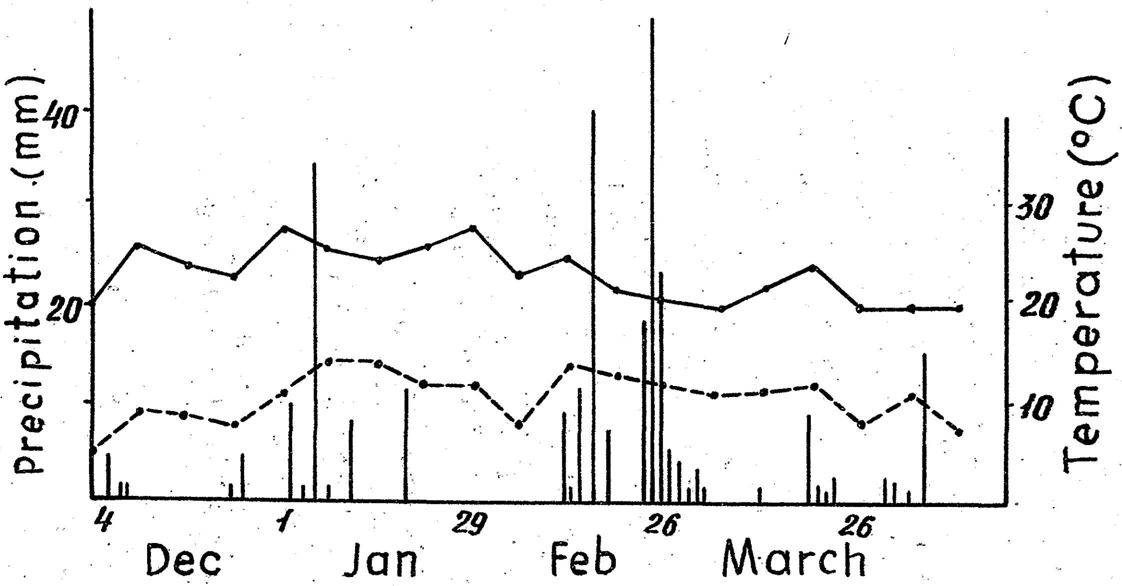

Fig. 1. Maximum and minimum temperatures and rainfall incidence during the experimental period

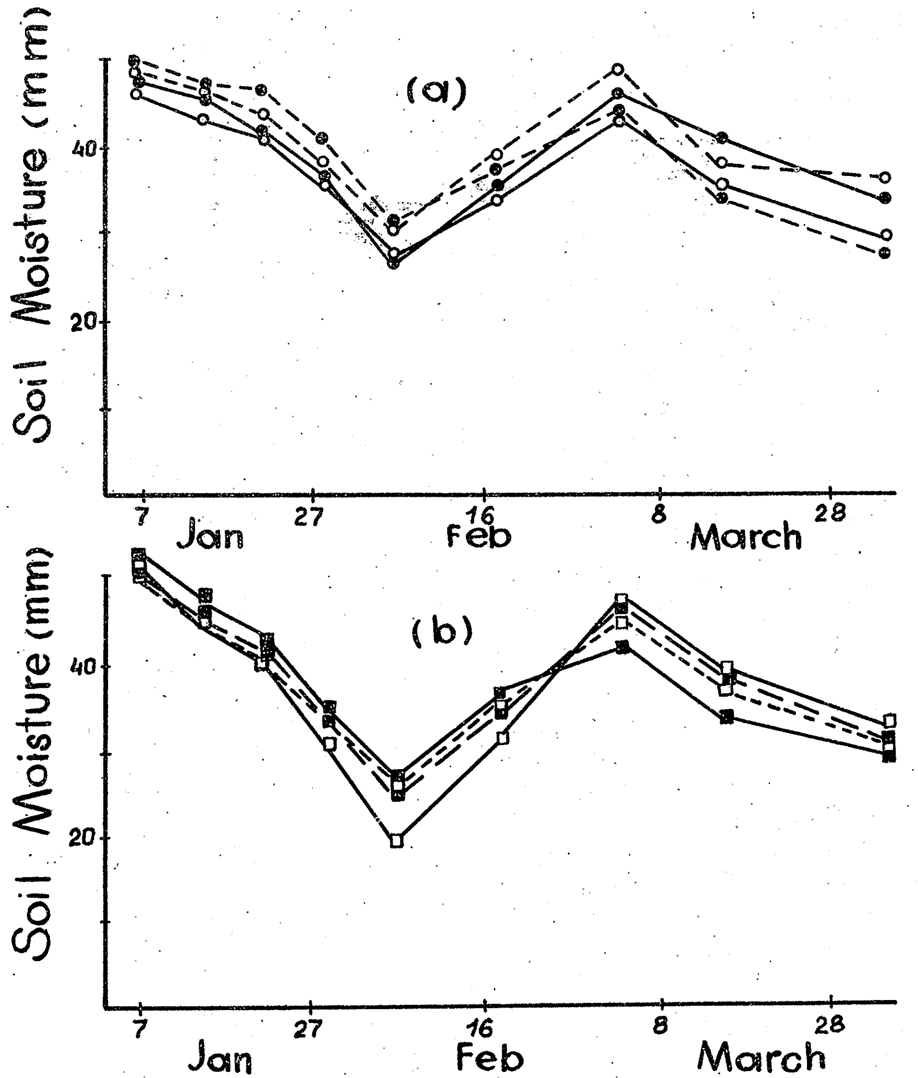

Fig. 2. (a) (b) Effect of CCC and density on changes in soil moisture (solid lines control, broken lines CCC; ● D1, o D2, ■ D3, □ D4)

CCC reduced plant height ($p < 0.001$), this effect being most pronounced during the two weeks following application and at the lower densities (D1 and D2). Plants at the lower densities were, however, generally taller than those at the higher densities (D1 > D2 > D3 and D4; $p < 0.001$).

At the lower densities plants produced more leaves than those at the higher densities (D1 and D2 > D3 > D4; $p < 0.05$) (Fig. 2). Leaf senescence was also slower at the lower densities resulting in plants possessing more green leaves than those at the higher densities at most stages of growth (D1 and D2 > D3 > D4; $p < 0.01$). CCC had no effect on leaf production but significantly reduced senescent leaf number ($p < 0.01$) (Fig. 3) by initially slowing the rate of senescence.

A significant reduction in leaf dry weight ($p < 0.05$) and leaf area ($p < 0.001$) resulted from CCC treatment. The effect of density was more marked, with highly significant differences being recorded for all parameters ($p < 0.001$). CCC treatment significantly increased head weight ($p < 0.001$) and seed yield ($P < 0.01$) but had little effect on oil percentage and linoleic acid content (Table 1). The highest yields were obtained at D4 for CCC-treated plants and D2 for control, these being 0.089 kg m^2 and 0.062 kg m^2 respectively. Ratios of CCC/control seed yield were D1-1.37; D2-1.34; D3-1.72 and D4-1.56.

Data from the diffusion porometer are presented in Table 2 and represent the mean stomatal resistance 3 and 13 days after CCC application (23 January and 2 February). Visible wilting occurred in the high density control plots from 2 February to 9 February and although stomatal resistance was increased on 2 February, relative to 23 January, differences between treatments and densities were small.

In contrast, RWC measurements on 2 Fe-

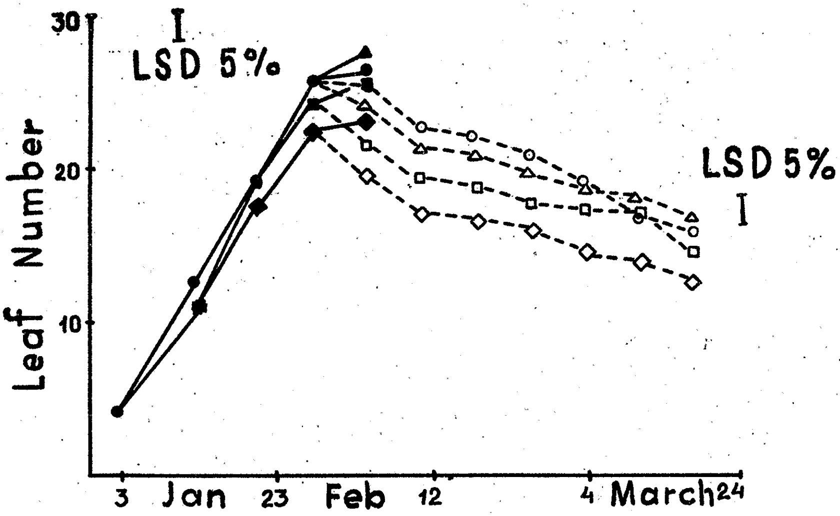

Fig. 3. Effect of density on leaf production and green leaf number (solid lines leaf production, broken lines green leaf number; (o● D1, △▲ D2, □■ D3, ◇◆ D4)

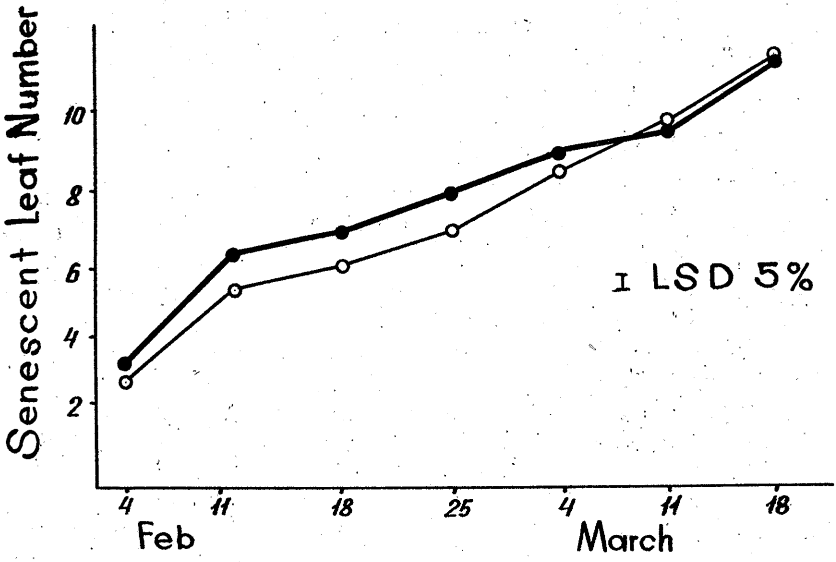

Fig. 4. Effect of CCC on rate of leaf senescence (● control, o CCC)

Table 1

The Effect of CCC and Density on Yield Parameters

Treat-ment	Density	Head weight (grams/m^2)	Seed weight (grams/m^2)	1000-seed weight (grm.)	Oil, %	Linoleic acid content
C	D1	159.9 bc	58.9 ab	51.7 c	50.3	73.1
	D2	159.3 bc	82.2 cd	49.8 c	50.0	74.2
C	D3	168.0 bc	63.3 bc	36.0 ab	49.7	72.8
C	D4	250.3 d	88.8 d	35.7 ab	51.4	72.9
CONTROL	D1	98.2 a	43.2 ab	41.1 ab	51.0	72.1
	D2	124.1 ab	61.5 bc	44.4 bc	49.4	74.6
	D3	131.3 ab	37.2 a	39.1 ab	49.3	71.1
	D4	200.7 c	56.9 ab	32.8 a	49.4	73.7

Table 2

The Effect of CCC and Density on Mean Daily Stomatal Resistance ($s\ cm^{-1}$)

	CCC				Control			
	D1	D2	D3	D4	D1	D2	D3	D4
23.1.75	0.9	1.0	1.1	1.1	1.1	1.0	0.9	0.8
2.2.75	1.5	1.5	1.7	1.7	1.6	1.5	1.4	1.6

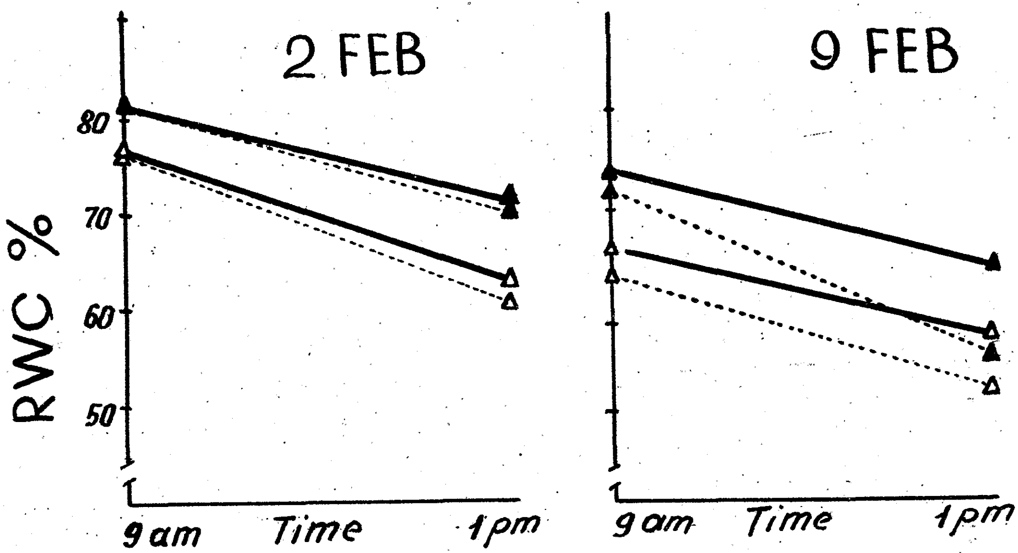

Fig. 5. Effect of CCC on relative water content (solid lines CCC, dotted lines CCC; ▲ D1, △ D4)

bruary indicated that the higher densities developed a greater leaf water deficit during the measured period (9 a.m. - 1 p.m.), which was partially ameliorated by CCC treatment. Seven days later a similar pattern was also evident with the lowest RWC's being recorded in the untreated D3 and D4 plants (Fig. 4).

Further measurements were prevented by rainfall which commenced on the afternoon of 9 February and continued intermittently until 14 February. During this period approximately 70 mm were recorded and a further 100 mm were received between 22 and 28 February. Soil moisture measurements indicated that little further stress might be expected for the remainder of the experiment.

The pattern of water use following CCC treatment in this experiment was similar to that previously observed (2) under glasshouse conditions. In both cases a reduction in water use followed treatment which, in the field, resulted in a slower depletion of soil moisture.

The significance of this was demonstrated in the present experiment where CCC imparted a measure of drought avoidance on the crop and ameliorated the effects of stress experienced prior to anthesis. This was exhibited in both morphological and physiological variable such as plant height, leaf senescence and RWC. Further, the increased rate of anthesis of treated plants at the higher densities, relative to control plants, indicates that the development of the latter may have been interrupted by stress.

CCC treatment led to significant increases in yield at all densities. At D3 and D4 these increases were largely due to greater seed number, while at D2 both seed size and seed number were responsible. This would suggest that the untreated plants experienced a greater moisture stress during initiation and head expansion, when floret number was being determined, than comparable treated plants. At D1, CCC reduced leaf senescence and treated plants possessed a greater leaf area than controls, particularly during the later stages of growth. Increases in yield were largely due to higher 1000-seed weights, indicating that treated plants had a greater supply of assimilates available during seed-fill.

The mechanism by which CCC confers drought avoidance is unclear from these experiments. Stomatal resistance was unaffected and, indeed, only small increases were noted during stress periods. There was, however, an initial reduction in leaf area which would tend to reduce the amount of radiation intercepted by the plant and, hence, transpiration.

While the drought tolerance of sunflowers may be improved in the future by plant breeding, the results of this experiment indicate that application of CCC to current varieties may provide a short term solution. This may be particularly important under Australian conditions where crops frequently experience moisture stress during their growth cycle.

The induction of a measure of drought avoidance by CCC has been demonstrated in both the glasshouse and the field and, in the latter situation, may lead to marked increases in yield. Further work is necessary to substantiate these results and to determine the flexibility of treatment in relation to time of application and the occurrence of stress.

References

1. Humphries, E.C. (1968). The beneficial effect of CCC on wheat yields in dry conditions. Euphytica Suppl. 1, 275-279.

2. Lovett, J.V. and Orchard, P.W. (1974). Influence of CCC on sunflower growth, development and yield under controlled environment and field conditions. Proc. 6th Internat. Sunflower Conf. Bucharest, 153-159.
3. Muriel, J.L. and Downs, R.W. Effect of periods of moisture stress during various phases of growth of sunflowers in the greenhouse. Proc. 6th Internat. Sunflower Conf. Bucharest, 127-131.