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INFLUENCE OF CCC ON SUNFLOWER GROWTH, DEVELOPMENT AND YIELD UNDER CONTROLLED ENVIRONMENT AND FIELD CONDITIONS

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Sunflower (*Helianthus annuus* L.) has been adopted into some cropping areas of New South Wales in the past five years. Over this period a number of problems has become apparent including a limited genetic base in available cultivars, poor adaptation to environment and the lack of a suitable crop technology. More specifically, research and commercial experience in the north-west of New South Wales suggests that moisture stress during seedfill frequently restricts the yield potential of this crop. In addition, the relatively tall cultivars available present difficulties during harvest and have been known to lodge severely, compounding the harvesting problem. A possible means of overcoming these adaptive and technological difficulties, at least until alternative genetic material becomes available, may be to apply the chemical CCC (2 chloroethyltrimethylammonium chloride) to the crop.

The stem-shortening properties of CCC are well known. Cathey (1964), and Whitehead (1965) have indicated that both shortening and xeromorphism can be induced in sunflower through CCC application. It has been reported that CCC decreases transpiration in cereals (Wünsche 1970, 1971), improves the drought tolerance of beans (Halevy & Kessler 1963) and can have favourable effects on the yield of wheat under dry conditions (Humphries et al. 1967). Furthermore, it has been suggested that CCC has significant effects on the rate of physiological development of crops (Humphries 1968).

On the basis of available information the hypothesis was advanced that, given further data on timing, rate and method of application, CCC could be used to counter problems associated with height of cultivars currently in use. The literature also suggests that CCC modifies water use of a number of crops, including sunflower. The mechanisms involved, however, remain obscure and require further investigation before their possible significance under field conditions can be assessed.

EFFECT OF TIME AND METHOD OF CCC APPLICATION ON PLANT HEIGHT

Method. Individual plants of sunflower (cv. Peredovik) were grown in 23 cm diameter pots containing coarse sand and placed in a controlled environment cabinet (day temperature 25° C; night temperature 15° C; daylength 12 h). Plants were treated with 50 ml of a solution of CCC at 4,000 ppm, applied either as a foliar spray or as a soil drench, at the following stages: two expanded leaves, ten expanded leaves and 50% anthesis.

Results. Plants treated at the two leaf stage showed a significant reduction in height ($p<0.01$) three weeks after spraying (figure 1). This effect had disappeared at maturity. Treatment at the ten leaf stage produced a significant reduction in height after one week ($p<0.01$). This reduction continued throughout the experiment for the spray treatment but had disappeared by maturity for the drench application. No reduction in height was effected by either form of application at 50% anthesis.

Discussion. It has previously been shown that sunflowers can be shortened by spray and drench application (Whitehead 1965, Lovett & Campbell, 1973), although in neither case was height at maturity reported. Application at an early stage appears to result in plants outgrowing the treatment such that final hieght is no different from untreated plants. However, spraying at the ten leaf stage produces significant shortening and is apparently more effective than soil drenching. A similar observation has been made by Wünsche (1971) in respect of wheat. The reduction in height of sunflower achieved by this treat-

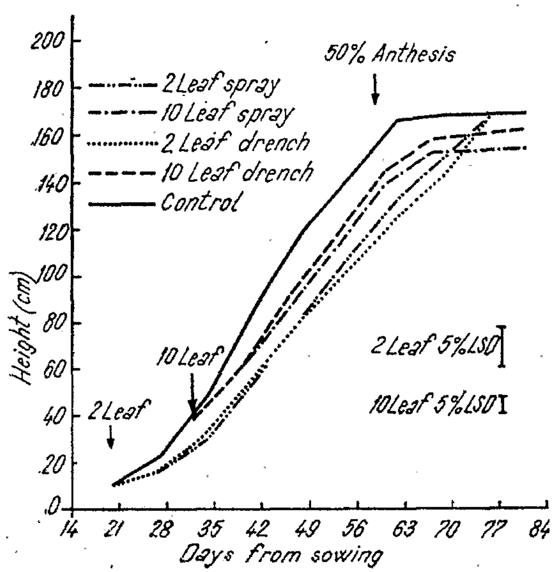

Fig. 1 — Effect of time and method of application of CCC on plant height.

ment was of the order of 10% and it has previously been demonstrated with similar plant material that a concomitant thickening of the stem also occurs (Lovett & Campbell, 1973). The resulting shorter, sturdier plant under field conditions could be expected to be more easily harvested and to be less prone to lodging.

EFFECT OF CCC ON TRANSPIRATION

In the previous experiment a spray application of CCC at the ten leaf stage was established as an effective means of shortening the plant. Such a method would be applicable under field conditions. Accordingly a further experiment was carried out using similar techniques in order to assess the effect of CCC on transpiration.

Method. Seeds were sown into 23 cm diameter pots containing 5,000 g of dried, sieved sand in a polyethylene bag. Pots were placed in a glass-house for the period 9 October 1973 to 5 February 1974 (mean maximum temperature 30° C; mean minimum temperature 15° C; mean daylength 12 h).

CCC was applied as a foliar spray to half the plants at the ten leaf stage, at a rate of 50 ml per plant of 4,000 pmm solution, the remaining plants being sprayed with distilled water. Prior to CCC application the pots were watered up to 90% of the pre-determined field capacity of the sand and were sealed by tying round the base of the stem. Daily weighings were carried out to determine water use, after which pots were watered up to their original weight.

Results. There was a significant decrease in water use for two weeks following CCC application after which transpiration rose to the level of the control plants (table 1). Through this two week period actual average levels of transpiration were 358 g/pot/day (treated) and 399 g/pot/day (control). With the exception of Week 11, where senescence was advanced and slight differences between treatments were magnified, treated plants used more water than controls for the remainder of the experiment. There was no significant difference between treatments in respect of total water use.

Table 1

Water-use of CCC-treated plants (as % of control)

Weeks	1	2	3	4	5	6	7	8	9	10	11	Total
Control	100	100	100	100	100	100	100	100	100	100	100	100
CCC	87,8	89,0	99.9	98,0	99,3	101,0	101,1	101.7	105.7	100.3	87.3	98.2
P	<0,01	<0,02	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S

Discussion. Treatment with CCC was followed by an immediate reduction in water use. For example, on the first day after CCC was applied treated plants showed a reduction of 14% relative to controls. Such a reduction cannot be accounted for on morphological grounds. A more direct effect on plant metabolism is suggested, such as that put forward by Mishra & Pradhan (1968, 1972). These workers postulated that CCC, by inhibiting pyrophosphatase activity could bring about stomatal closure, as there is a direct relationship between pyrophosphatase activity, transpiration and stomatal width. The result of stomatal closure would be conservation of water due to a slower demand by the plant. Stomatal closure may also result in reduced photosynthesis and lead to a delay in development. This could account for delays in maturity noted in some crops (Humphries 1968) and explain the lateral displacement in patterns of water use obtained by Wünsche (1971).

Despite the rapid effect of CCC in limiting transpiration loss, over the total experimental period water use levels were similar. It is suggested that a delay in the rate of development in the period immediately following CCC application was compensated by more rapid growth at later stages since there was no actual delay in maturity.

The postulated, rapid effects of CCC on stomatal closure were succeeded by the effects of morphological changes of the type reported by Whitehead (1965) and by Lovett & Campbell (1973). Such changes, which were of a generally xeromorphic nature, may render the plant less susceptible to wilting. Dear (pers. comm.) noted that although daily water use of treated and untreated plants was similar, transpiration by treated plants was spread more evenly over the day and when watering was withheld for 24 hours untreated plants wilted (as indicated by lower relative water content) whilst treated plants did not (figure 2).

Taken in conjunction, these findings indicate that the application of CCC may effectively increase the efficiency of water use through two mechanism :

a) by conserving water soon after CCC application, which in a field situation would be available for use later in the growth cycle, and

b) by improving control over transpiration at later stages of development, thereby curtailing wilting and obviating the deleterious effects of moisture stress on growth.

EFFECTS OF CCC ON A FIELD CROP OF SUNFLOWER

Method. The experiment was carried out at Armidale, New South Wales (Lat. 30°32' S, long. 151°38' E, alt. 1016 m) on a blackearth soil type. Seed was sown on 23 October 1973 in a trial area comprising eight plots, 8 m × 18 m, giving 12 rows per plot at a 67 cm spacing. A population of 98,000 plants per hectare was attained by subsequent thinning. CCC was applied to half the plots at the ten leaf stage (5 weeks after sowing) at a rate of 700 litres/hectare of a 4,000 ppm solution.

A 3 m section of row was harvested from each plot on the day of treatment and at fortnightly intervals throughout the growing period. Plant height and leaf area together with dry weights of the plant fractions were determined. The final harvest was made on 7 March 1974.

Moisture conditions during the experiment were very favourable for crop growth. In the 8 weeks prior to sowing there was a small positive balance of precipitation over estimated evapotranspiration. During November, December, and January the water balance was —7 mm, +19 mm and +24 mm compared to long term average values of —42 mm, —46 mm and —31 mm respectively. Only in February, during the last two to three weeks of the experiment, would severe moisture stress be likely to have occurred.

Results. Differences due to CCC treatment were relatively small, however, morphological effects similar to those obtained under controlled environment conditions were observed in the field. Dry weights of stems, leaves and petioles, were lower and leaf area was smaller with CCC treatment until the final stages of the experiment (figure 3). Three weeks after CCC application the treated plants had significantly ($p<0.05$) lower head dry weight than had control plants, but dry weight of heads in treated plants subsequently exceeded that of controls.

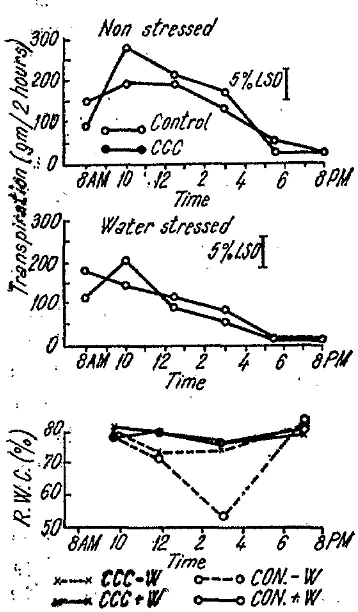

Fig. 2 — Diurnal variation in transpiration and relative water content.

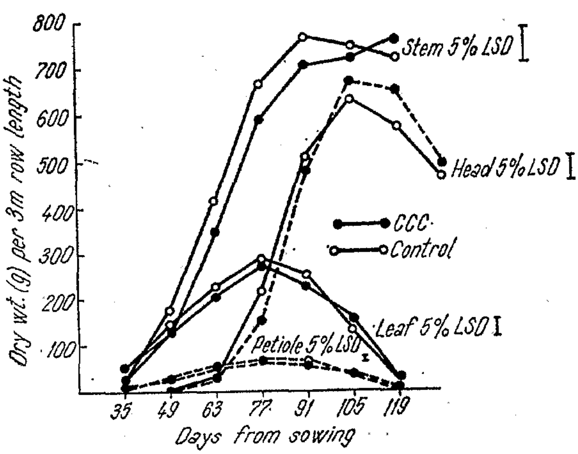

Fig. 3 — Distribution of dry matter.

Yields of seed obtained were equivalent to 2,434 kg/ha (treated) and 2,289 kg/ha (control). This represents an increase to the CCC treatment of 6.3% which failed, however, to attain statistical significance.

Discussion. In addition to confirming the morphological effects of CCC, the experiment indicated that development of the treated plants was somewhat retarded initially but was subsequently compensated by, for example, greater leaf area during the period of final head-fill. The observed yield increase suggests that the head may have received a greater supply of assimilates during this final period of growth.

The main advantage of CCC in commercial practise appears to have been in increasing the yield of cereals during dry seasons (Humphries 1968). In this experiment although a high plant density was deliberately used little water stress was experienced. Despite this a yield increase was attained in a crop which compared favourably in yield with an estimated average yield of 400 kg/ha for New South Wales in 1973/4.

CONCLUSIONS

In terms of the problems outlined in the introduction to this paper the data presented indicate that CCC can be employed to shorten the stems of tall sunflower cultivars. Under Australian conditions this finding may be of particular significance in overcoming difficulties experienced in harvesting, particularly where lodging of the crop is likely to occur.

CCC has been shown to have potentially important effects on transpiration, which may in the short term result in an actual reduction of water loss through transpiration and in the longer term suggest a better control over water loss, though this may *in toto* be similar in treated and non-treated plants. Under field conditions an effective redistribution of available soil moisture through the first mechanism, and more efficient utilisation of moisture through the second mechanism could be of significance in alleviating the effects of moisture stress frequently experienced under Australian conditions. Further work is necessary to define more precisely the limits within which CCC can usefully be employed, taking into account not only the strategy of spraying in relation to growth stage, but also the status of available soil moisture.

At ruling Australian prices the costs of CCC application on a field scale would be offset by an increase in average yield (i.e. 400 kg/ha) of only 2%, (Cyanamid International, personal communication). Whilst the yield increase reported in an atypically wet season faield to attain statistical significance, it may be of considerable biological and economic significance.

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