THE EFFECT OF EARLY SEASON TEMPERATURES ON MAIZE GROWTH AND ITS RELATION TO GRAIN YIELD

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ABSTRACT

Average annual yield in Waikato relates closely to temperatures in the month following planting. The nature of the response was investigated by raising temperatures about the crop for 14 and 28 days after planting using polythene tunnels.

In each of the two years temperatures were normal and covering raised soil and air temperatures by an average of 3°C. After 14 and 28 days covering respectively, both plant dry weight and leaf area, in each year, were two and threefold greater than control. At maturity in year two, the early differences in plant growth had disappeared. Lengthening the warming period in either year resulted in a tendency for the number of primary cob kernels and the number of secondary cobs bearing grain to increase while kernel weight remained unchanged. In neither year was grain yield significantly increased by warming. Yield was lower in year one (8 t/ha) than year two (14 t/ha) as a result of moisture stress during grain filling which may have influenced the response.

No evidence was provided that above normal temperatures during early growth increased yield directly by affecting the number of kernels formed or the ability of the crop to fill the grain. It was argued that reduced yields with below normal temperatures may still result from a reduction in kernel numbers and the ability of the crop to fill the grain both directly through the temperature effect on plant growth but also, indirectly, through the increased incidence of root rot and reduced plant growth.

INTRODUCTION

Average annual yield of maize grain in the Waikato has ranged from 6.5 to 8.2 t/ha over the past 10 years. The yield variation can be accounted for predominantly by seasonal differences in temperature during the first month of growth, November, with low temperatures reducing yield (McCormick, 1979). Hybrid cultivars more tolerant of cool temperatures during early growth could reduce annual yield variation and increase average yield. To aid in the selection of such cultivars, information on the manner in which early season temperatures affect grain yield is required.

Increased grain yield resulting from higher early season temperatures has been related both to an increased number of kernels available for filling (sink size) and a greater extent of leaf area and plant reserves to effect the filling of the grain (source size). With maize grown at relatively constant photoperiod near the equator, increased yield at different sowing dates was associated with higher temperatures in the first five weeks of growth and greater plant dry weight at five weeks and grain filling (Cooper and Law, 1977). However, given the same sowing date and higher temperatures, increased grain yield was associated with a higher percentage of the kernels initiated being fertilised (Cooper and Law, 1978). Later, in altitudinal trials, Cooper (1979) showed that higher temperatures with the same sowing date could also increase the number of kernels initiated.

Under changing photoperiod at higher latitudes, with higher temperatures and the same sowing date, increased grain yield has been associated with a greater leaf area and plant dry weight at filling but no change in the number of kernels initiated or filled (Iremerin and Milbourn, 1978). At higher latitudes, different temperatures for the same sowing date not only affect the extent of crop growth but, through altering the rate of development, change the date of occurrence of the crop's growth phases in relation to the seasonal patterns of changing photoperiod and insolation to produce sowing date effects. Various authors have shown that early sowing at low temperatures reduces the extent of plant growth, leaf number, leaf area and dry matter at the filling stage (Bunting, 1968; Pendleton and Egli, 1969; Watts, 1973; McCormick, 1974).

Variations in either or both sink or source size could explain the close relationship between yield and temperatures in the month following planting in the Waikato. The nature of the relationship was investigated by studying the effect of raising early season temperatures on vegetative and reproductive growth.

MATERIALS AND METHODS

The trials were conducted on plantings made in spring 1978 and 1979 on the Rukuhia Research Farm. Block plantings of Pioneer 3709 were made on November 17 and October 24 respectively in the two years using a row spacing of 45cm and a seeding rate of 90 000/ha. Additional rows were sown between the main rows in the treatment plots to provide for destructive samplings during the early growth stages. Differential temperature treatments were imposed by covering 6m x 0.9m plots with clear polythene tunnels. Each treatment was replicated four times and the plots were arranged in a randomised block design. The treatments were as follows:

	Treatment	Code
1.	Uncovered control	0/0
2.	Covered first 14 days	14/0
3.	Covered second 14 days	0/14
4.	Covered for 28 days	14/14

Treatments were started at sowing in 1978 and 21 days after sowing in 1979 when the crop was at the third, visible leaf stage.

At 14 then 28 days after the first application of the covers, ten plants per plot were harvested and leaf number, leaf area and dry weight of both leaf and stem determined. In 1979, prior to mid-silk, a count was made of the number of kernel sites on the primary cob using a sample of five cobs per plot. At crop maturity in each year the number of kernels filled on the primary cob, kernel weight, cob number per plant and grain yield per plant were determined. In year two, the dry weight yield of stalk, leaf and cob were also determined. In each case a sample of ten plants was used with an additional grain yield estimate made from a 5m sample of row.

In both years soil (50mm) and air (250mm) temperatures were recorded half hourly for each treatment during the period of covering and thereafter standard meteorological temperature data from the site was referred to.

RESULTS

In both springs prevailing temperatures were close to normal with 399 and 395 heat units (mean daily temperature -10°C) accumulated during November and December in the two years respectively compared to 377 heat units accumulated in the normal year. Soil and air temperatures within the canopies averaged 3°C higher than outside in both years. Accumulated heat units from January to March inclusive were 804, 727 and 750 respectively for the two years and the normal.

In year one, moisture stress during early grain filling resulted in a lower average grain yield (8 t/ha compared to 14 t/ha) though the reduction in yield may have, in part, been due to the lower plant population in year one (7.5pl/m^2) compared to year 2 (8.8pl/m^2).

The first 14 days of crop warming approximately doubled the plant dry weight and leaf area in both years and significantly increased the number of visible leaves (Tables 1a and 1b). The change in total plant dry weight reflected similar changes in both the leaf and stalk weight. Where the crop was covered for 28 days, plant weight and leaf area were increased approximately three fold and the visible leaf number raised by two. Whether the crop was given additional warming for the first or second 14 days of the 28 day period made little difference to the extent of the growth promotion achieved. Between-plant variation at this stage of growth was very high which is a characteristic frequently observed in the field.

TABLE 1: Plant dry weight, leaf area and leaf number for covered and uncovered maize 14 (a) and 28 (b) days after covering in two years.

Covered period days	Dry weight per plant (g)		Leaf area (cm^2)		Leaf number	
	1978	1979	1978	1979	1978	1979
(a)						
0/0	0.34a*	0.64a	74b	127b	4.2b	5.9b
14/0	0.64b	1.55b	123a	257a	5.1a	6.7a
(b)						
0/0	2.40d	6.5b	350c	859c	6.9c	8.8b
14/0	4.22c	11.9ab	586b	1372bc	7.8b	9.7ab
0/14	5.57b	11.8ab	829 b	1545ab	8.2ab	9.4ab
14/14	7.74a	20.0a	1109a	1985a	8.9a	10.4a
C.V.%	15	41	15	26	5	9

*Duncan's test: refers to colums only within (a) and (b)

Where the number of kernel sites on the primary cob was recorded at mid-silk in 1979 there was no significant differences amongst treatments (Table 2). However, the number of kernels formed per row did show a small, progressive increase as the period for which the crop was covered was extended but the response was not significant ($P < 0.05$).

TABLE 2: Number of kernel sites per cob prior to silking for maize covered for 14 and 28 days during early growth (1979).

Covered period days	Number of rows/cobs	Number of kernel sites/row	Total kernel sites per cob
0/0	14.6	43.0	268 a
14/0	13.8	44.1	609 a
0/14	14.5	44.4	644 a
14/14	14.2	45.3	643 a

At crop maturity the differences in plant growth had disappeared (Table 3). A slight, though insignificant, rise in grain dry weight yield per plant occurred in both years with increased exposure to the higher temperatures which was reflected in the yield in 1979 but not in 1978.

A significant rise in the number of kernels filled on the primary cob in 1979 occurred after treatment (Table 4). A similar tendency was shown in 1978 but the increase was not significant. Kernel weight remained unchanged with treatment while the number of cobs per plant tended to be higher. The individual contribution of the primary and secondary cobs to the total grain yield was not assessed.

DISCUSSION

Higher temperatures following planting increased early growth in each year but failed to produce the increase in grain yield observed by Cooper and Law (1978). In both years there were reasons why the yield response might have been restricted. Drought in year one reduced yield and in year two, the crop was not covered until 21 days after planting whereas the most pronounced response observed by Cooper and Law (1978) was from added warming in the two weeks after emergence.

While yield increases were absent, the tendency in both years for the number of primary cob kernels filled and the secondary cobs bearing grain to increase with higher temperatures reflected changes similar to those associated with increased yield by Cooper and Law (1978). The similarity of these changes suggest that a cool temperature restriction on the kernel numbers available for filling might operate to some extent in the Waikato.

The magnitude of the response, calculated from the components of yield in the current trial, ranged from 0.13 to 0.50 t/ha/°C while in the Cooper and Law (1978) study, it was of the order of 0.5 t/ha/°C. In neither case is the level sufficient to account for the 1 t/ha/°C response recorded for the Waikato (McCormick, 1979). There is no indication that the response level could be expected to be greater in years with below normal early season temperatures. The maximum response calculated from this trial, conducted with an average soil temperature for control of 17°C, was only equal to that in the Cooper and Law (1978) study where control soil temperatures averaged 20°C.

Evidence for the alternative effect of cool early season temperatures reducing the extent of the crop canopy at mid-silk and the rate of grain filling was completely lacking in the present trial as plant growth at mid-silk was not recorded. A

TABLE 3: Plant and grain yields at maturity in relation to the period of covering from 14 to 28 days.

Covered period days	Plant DM (g) 1979			Grain/plant (g)		Grain proportion (% of DW)	Grain yield t/ha 14% m.c.	
	Lf	Stem	Rachis	1978	1979	1979	1978	1979
0/0	28 a	90 a	37 a	99 a	140 a	49.9	7.7 a	13.7 a
14/0	26 a	90 a	38 a	102 a	147 a	48.1	7.9 a	13.7 a
0/14	29 a	88 a	36 a	112 a	146 a	49.2	8.3 a	14.0 a
14/14	29 a	86 a	39 a	114 a	151 a	50.0	7.9 a	14.1 a

TABLE 4: Components of grain yeild of maize warmed by covering for 14 to 28 days during early growth.

Covered period	Cobs /plant		Kernel weight (g/100)		Kernels /1° cob	
	1978	1979	1978	1979	1978	1979
0/0	0.96 a	1.01 a	29.4 a	29.8 a	429 a	494 b
14/0	1.00 a	1.05 a	29.5 a	29.6 a	435 a	502 b
0/14	1.02 a	1.05 a	28.6 a	28.8 a	438 a	514 b
14/14	1.05 a	1.04 a	28.0 a	28.8 a	480 a	555 a

previously observed reduction of leaf area at mid-silk resulting from early sowing at low temperatures was for sowings made from mid September to mid October in the Waikato (McCormick, 1974). In that instance, soil temperatures in the first month of growth averaged 3°C lower than those for control in the current trial.

Certainly when early season temperatures were below normal and yields were low from 1975 to 1977 in the Waikato, it was observed that the crops were generally not "well grown" at the mid-silk stage. In these years, a further, indirect, effect of temperatures on maize growth was also apparent in that root rot, caused by Rhizoctonia, was prevalent. With the return of normal to above normal November temperatures the root rot problem largely disappeared. There would appear to be strong circumstantial evidence for a progressive effect in cool seasons of poor maize growth at low temperatures, fungal root attack and an inability of the crop to out-grow the disease and produce normal growth.

CONCLUSION

There is some slight evidence that cool temperatures during the first month to six weeks of maize growth in the Waikato could reduce grain yield through affecting the number of kernels available for filling. However, the direct and close relationship between November temperatures and grain yield appears more likely to express the sum of this effect and various other direct and indirect effects of temperature on the extent of the crop's vegetative growth and the ability of the crop to fill the grain.

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