Effect of Sowing Date on Maize Productivity in Southern Zambia in the 2008/2009 Growing Season

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Abstract

Maize productivity in Zambia is likely to be affected by future climatic changes. To examine the factors responsible for yield variation in maize (*Zea mays* L.) near three villages at different altitudes in Zambia's Southern Province (site A = lowest, B = intermediate, C = highest), we grew maize at three different sowing dates, separated by 10-day intervals, during the 2008/2009 season. Grain yield of the control plants (normal sowing date) was higher at sites A and B (more than 1000 kg ha^{-1}) than at site C (less than 200 kg ha^{-1}). Delayed sowing did not affect grain yield at site A, but greatly reduced grain yield at sites B and C. The duration of the period from sowing to flowering at site A was not affected by the delayed sowing, but the duration increased at sites B and C by 10 to 27 days as a result of the delayed sowing. Lower air temperatures at sites B and C might explain the negative effects of the delayed sowing.

1. Introduction

Maize (*Zea mays* L.) is major food source in southern Africa, including Zambia, but its productivity is low compared to yields obtained elsewhere in the world; the mean yield in Zambia (1742 kg ha^{-1}; 10-year average from 1999 to 2008) is only 37% of the world average (4671 kg ha^{-1}), and the coefficient of variation in Zambia is roughly twice that in other countries (FAO, 2010). A slight decline in maize productivity can have detrimental effects on the lives of local farmers and their families, jeopardizing both their health and their lives. Stabilization of maize productivity in Zambia is therefore essential, particularly given current prospects for future climate change (IPCC, 2007).

The precipitation pattern is one of the most critical factors that affects maize production in southern Africa (Cane *et al.*, 1994; Phillips *et al.*, 1998), where precipitation occurs primarily during the wet season. Choosing the appropriate sowing date is therefore essential for increasing crop productivity by taking advantage of the available climatic resources under conditions in which farmers have no access to inputs such as synthetic fertilizers or pesticides. Farmers in Zambia's Southern Province have learned from experience to plant maize a few days after the second rainfall of the year, which is judged to represent the start of the wet season. However, there has been no scientific validation that this is the optimal sowing date to maximize yield.

In the present study, we examined the effects of sowing date on maize productivity at three different altitudes that differ in the amount and pattern of the precipitation they receive.

2. Materials and Methods

A local maize cultivar ('Jileile') was sown near villages at three different altitudes: A = Sianemba and Siameja villages (17°05'S, 27°30'E, 517 m in altitude), B = Chanzika village (17°05'S, 27°20'E, 769 m in altitude), and C = Siachaya village (16°59'S, 27°20'E, 1075 m in altitude). Sowing was conducted on three sowing dates (at 10-d intervals), at a density of 33.3×10^3 plants ha^{-1} (1 m between rows × 0.3 m between plants; sowing two to three seeds per spot; the plants were thinned after emergence, leaving only a single plant) from late November to early December in 2008 (Table 1). We chose one to three fields per village (A = two farmers, B = one farmer, C = three farmers). We defined the normal sowing date in this region as the control, then chose sowing dates 10 or 20 days later as the delayed sowing treatments. The plot size in the control treatment was 20 × 20 m, whereas those in the 10-d-later or 20-d-later plots were about 10 × 20 m. No fertilizer, herbicide, or pesticide were applied in any field.

We recorded the emergence and flowering dates in each plot. At harvesting time (in early April), maize yield was determined for the whole control plot (divided into 12 subplots), but we used four subplots (2 × 2 m) at each site in the 10-d-later or 20-d-later plots. The yield was expressed as the oven-dried (70°C) seed weight. Air temperature was measured at each site.

No meteorological data excepting for air temperature were available for site B during the study period. In this maize growing season, precipitation from November to April was 1053 mm at site A and 1244 mm at site C. Mean air temperatures during the same period were 25.3°C at site A and 21.6°C at site C, with total solar radiation values of 22.2 and 20.2 MJ m^{-2} d^{-1}, respectively. Wind speed averaged 0.9 m s^{-1} at site A and 1.3 m s^{-1} at site C. Thus, the weather at the higher altitude of site C was cooler, windier, and wetter, with less solar radiation.

3. Results

The flowering date was earlier in the control treatment at sites A and B than at site C, even though the sowing date was earlier at site C (Table 1). At all sites, the flowering date was delayed by 8 to 46 days by the delayed sowing date. At site A, the period from sowing to flowering was not affected by the delayed sowing, but at sites B and C, the period was increased by 10 to 27 days as a result of the delayed sowing.

The grain yield in the control treatment was greater than 1000 kg ha^{-1} at sites A and B, but the yield at site C was less than 300 kg ha^{-1} for all sowing dates (Table 2). This difference resulted from the higher individual grain weight per plant, not from differences in the number of plants that became established. The delayed sowing date did not affect grain yield at site A, but greatly reduced grain yields at sites B and C, by 30 to 100% (Table 2). Figure 1 shows the differences among the maize plants grown at site C after different sowing dates. Delayed sowing clearly reduced both plant height and biomass.

Table 1. Growth stages of maize sown at different sowing dates in the 2008/2009 growing season in southern Zambia.

Site	Farmer's field ID	Treatment	Sowing date		Emergence date		Flowering date		Period from sowing to flowering (days)		Location
A	ASn1	Control	4-Dec		7-Dec		30-Jan		57		Sianemba vill.
		10d later	13-Dec	(+9)	17-Dec	(+10)	7-Feb	(+8)	56	(-1)	
		20d later	23-Dec	(+19)	27-Dec	(+20)	19-Feb	(+20)	58	(+1)	
	ASm2	Control	4-Dec		-		30-Jan		57		Siameja vill. mukuti
		10d later	13-Dec	(+9)	-		-		-	-	
B	BCh2	Control	29-Nov		-		17-Jan		49		Chanzika vill. mukuti
		10d later	8-Dec	(+9)	-		5-Feb	(+19)	59	(+10)	
C	CSa1	Control	28-Nov		-		2-Feb		66		Siachaya vill. Gibson's field
		10d later	7-Dec	(+9)	13-Dec		27-Feb	(+25)	82	(+16)	
		20d later	17-Dec	(+19)	23-Dec		20-Mar	(+46)	93	(+27)	
	CSa2	Control	28-Nov		-		2-Feb		66		Siachaya vill.
		10d later	7-Dec	(+9)	13-Dec		27-Feb	(+25)	82	(+16)	
	CSa3	Control	28-Nov		-		1-Feb		65		Siachaya vill. Alfred's
		10d later	7-Dec	(+9)	13-Dec		27-Feb	(+26)	82	(+17)	

Values in parentheses represent the difference from the value for the control.

Table 2. Grain yield of maize sown at different sowing dates in the 2008/2009 growing season in southern Zambia.

Site	Farmer's field ID	Treatment	Grain yield			Number of plants established		Individual grain weight	
			kg ha^{-1}			10^3 ha^{-1}		g plant^{-1}	
A	ASn1	Control	1157	±105		26.8		43.2	
		10d later	1205	±207	(1.04)	30.0	(1.12)	40.2	(0.93)
		20d later	1214	±115	(1.05)	37.5	(1.40)	32.4	(0.75)
	ASm2	Control	1117	±137		23.7		47.1	
		10d later	740	±162	(0.66)	45.0	(1.90)	16.4	(0.35)
B	BCh2	Control	1956	±166		24.6		79.6	
		10d later	1375	±261	(0.70)	30.0	(1.22)	45.8	(0.58)
C	CSa1	Control	197	±71		22.6		8.7	
		10d later	10	±9	(0.05)	26.3	(1.16)	0.4	(0.04)
		20d later	0	±0	(0.00)	17.5	(0.77)	0.0	(0.00)
	CSa2	Control	252	±45		17.0		14.8	
		10d later	138	±67	(0.55)	33.8	(1.98)	4.1	(0.28)
	CSa3	Control	286	±87		18.9		15.2	
		10d later	26	±11	(0.09)	34.4	(1.82)	0.7	(0.05)

Values in parentheses represent the ratio of the treatment value to the control value. Grain yield ± SE (n =12 plot for Control, n = 4 plot for 10d or 20d later.

Figure 2 illustrates the relationship between two parameters: the difference in the duration of the period from sowing to flowering compared with that in the control, and the ratio of grain yield in the delayed sowing treatments to that in the control (the "relative yield"). There was clearly a close negative correlation between these parameters; that is, the increased duration of the period from sowing to flowering that resulted from delayed sowing reduced the relative yield. Figure 3 illustrates the relationship between the relative yield and the mean air temperature from sowing to flowering. Again, there was a close correlation between the two parameters, but this time the correlation was positive; low air temperatures at site C reduced the yield as a result of the delayed sowing.

Control 10-d-later 20-d-later

Figure 1. Maize plants at harvesting time after sowing on different dates at site C, the high-elevation site near Siachaya village, southern Zambia (Gibson's field; Table 1).

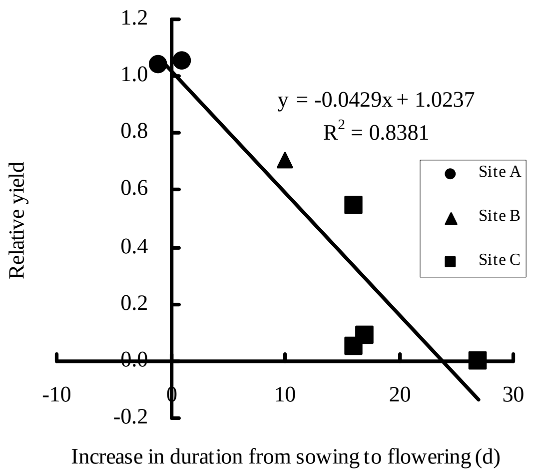

Figure 2. Relationship between the relative yield of maize in southern Zambia (the yield in the 10-d-later and 20-d-later treatments divided by that in the control) and the increase in the duration of the period from sowing to flowering compared with the control (as a result of the delayed sowing) compared with the control.

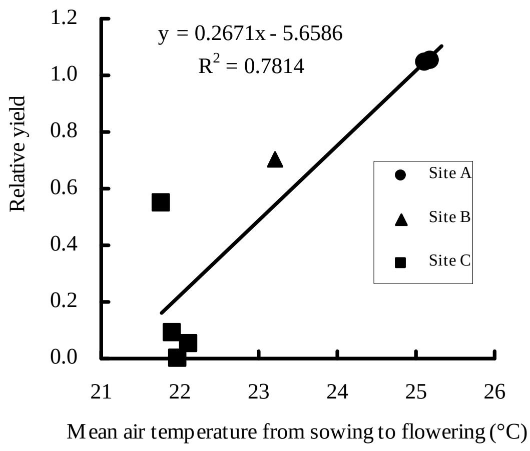

Figure 3. Relationship between the relative yield of maize in southern Zambia (the yield in the 10-d-later and 20-d-later treatments divided by that in the control) and the mean air temperature from sowing to flowering.

4. Discussion

Our study demonstrated that the yield response to delaying sowing differed among the sites (Table 2); at sites B and C (intermediate and higher altitudes, respectively), the delayed planting decreased the yield, but yield did not change at site A (at lower altitude). This confirmed that the current sowing dates used by local farmers were appropriate for growing maize in the study area.

There are several possible explanations for why later sowing decreased the maize yield, especially at sites B and C. First, water availability is one of the most important factors for maize production in Zambia. However, the precipitation during the 10 days after sowing and for the period from sowing to flowering was higher with 20-d-later sowing at site C (Fig. 4). Thus, the precipitation difference could not explain the yield difference. Second, because C_4 plants (including maize) grow better at higher temperatures, site C, with a lower mean temperature than site A (by 3.7°C) because of its higher altitude, might experience delayed early vegetative growth and reduced overall growth. This would lead to a slower rate of canopy development, resulting in lower ability to compete with weed species that are adapted to those conditions, although we did not measure the weed biomass and therefore cannot confirm this hypothesis. Higher wind speeds and lower temperatures at site C would also slow the canopy development. Third, it is possible that soil fertility is lower at site C. The dramatically lower yield at site C than at sites A and B (Table 2) might indicate that later sowing prevents the maize plants from utilizing the lower amounts of nutrient, and the problem may have been exacerbated by weed competition and leaching from the soil. In our future research, we will try to identify the factors responsible for the observed yield variations as a function of sowing date. It should also be noted that the yield level of all the villages in the present study was lower than the national average (1742 kg ha^{-1}). The results at sites B and C suggest that researchers should focus on improving the productivity of maize at earlier sowing dates, because later sowing decreased yield.

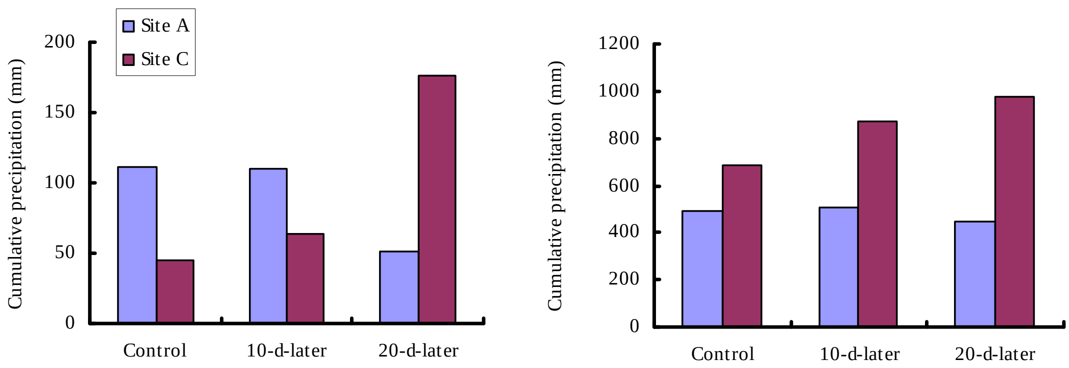

Figure 4. Cumulative precipitation for (left) the 10 days after sowing and (right) the period from sowing to flowering of maize for the control and for the two delayed sowing treatments in the 2008/2009 season in southern Zambia.

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