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Extent and Causes of Low Yield in Maize Planted Late by Smallholder Farmers in Sub-humid Areas of Zimbabwe[1]

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Abstract

Diagnostic work was undertaken during 1987-91 to determine the area of maize planted late by smallholder farmers in sub-humid (Natural Regions 2 and 3) communal areas of Zimbabwe, the grain yield losses encountered, and the causes of the low yield. From a survey of 10 communal areas in 1989-90 it was estimated that smallholders in Natural Regions 2 and 3 planted around 175,000 ha of maize four or more weeks after the start of maize plantings. This represents some 32.9% of the total maize area planted in sub-humid communal areas each year. From detailed agronomic monitoring in Mangwende Communal Area during 1987-88 and 1988-89, the first quartile of fields planted (mean planting date 14 November) averaged a grain yield of 4.9 t ha^{-1} against only 1.1 t ha^{-1} for the last quartile of fields planted (mean of 22 December). This was equivalent to around 310,000 t of maize grain foregone each year in sub-humid parts of Zimbabwe because of late planting. Observations on farmers' fields in Mangwende, confirmed in an on-station experiment at Harare, showed that the late planted maize crop developed more quickly than early plantings, with two to three more emerged leaves at any time during the early and middle pre-tasselling phase and up to five fewer days to tassel emergence. Many minor and several major input and management differences were noted for late plantings versus early plantings. Input and management differences likely to be major contributors to the low grain yield of late planted maize were: 1) delayed application of basal fertilizer (by around six days, three leaves later) at a reduced rate (around 20 kg ha^{-1} N, 15 kg ha^{-1} P only); 2) topdress N fertilizer was applied at just 60 % of the rate given to early plantings, and two leaves later in crop development; and 3) the late planted crop suffered weed competition longer than did early plantings, with greater weed burden at planting, and was first weeded at the 10-leaf stage (four leaves later than with first plantings). The diagnostic results reported here proved useful in planning a research project to generate technologies to improve the productivity of late planted maize in Zimbabwe.

Background and Objectives

The late planting of maize is responsible for large losses of grain yield each year for smallholder farmers in sub-humid zones of Zimbabwe, but late planting has been poorly researched. Most current input and management recommendations for smallholder maize production assume early planting.

As early as the 1920s, research had shown the yield advantage of planting maize early in Zimbabwe (see Weinmann 1975). Many more recent studies showed that later plantings of maize generally give lower grain yields than plantings made on the early rains (Spear 1968, Wilson and Williams 1974, Anon. 1983, Metelerkamp 1988, Shumba 1989a and b). From farmer assessments of yield in their fields and from on-farm trials, Shumba (1989b) reported a yield reduction of about 1.3% per day of delay in planting between early November and mid-December in Mangwende Communal Area, Zimbabwe.

Because it has been well established for many years that earlier plantings of maize give higher grain yields, the emphasis of much previous research has been to devise ways to help farmers bring forward their planting dates. Recent research for smallholder farmers in Zimbabwe has focused on reduced tillage using a tine (Shumba 1989a and b). But for a variety of reasons (given below) farmers continue to plant some maize late and so obtain lower yields.

[1] This paper is a synthesis of work reported in: Mudhara, M., and S. Waddington. 1990. *Study of Maize Planting Dates in Natural Region 2 and 3 Communal Areas of Zimbabwe, 1989-90 Season.* Preliminary Report, CIMMYT and AGRITEX Harare; and in Waddington, S.R., and M. Hlatshwayo. 1991. *Agronomic Monitoring to Determine Causes of Low Yield in Later Planted Maize, Mangwende Communal Area, Zimbabwe, 1987-88 and 1988-89 Seasons.* Harare: CIMMYT.

Maize is the dominant crop for smallholder farmers in sub-humid regions of Zimbabwe. The average farmer plants 2-3.5 ha of maize by hand into a wet seedbed after using an ox-drawn mouldboard plough to prepare the predominantly sandy soil. Yet many farmers do not have ready access to oxen and are short of labour. In one typical communal area, Mangwende, 54% of farmers did not own draught animals in 1982 (Rukuni 1986, Shumba 1989b). Such farmers are reported to have to delay even their first planting of maize until oxen owners have finished preparing their land and then decide to hire out their animals (e.g., Shumba 1988, 1989b). Even oxen owners can experience problems planting on time if their draught animals are weak. Erratic rainfall at the start of the season and slow methods for planting by hand also may mean that farmers cannot plant all their maize when the first good rains fall. It may be two or more weeks before a second good rain allows planting to continue. So farmers find it impracticable to plant all their maize early in the season. Also, many farmers deliberately stagger plantings as a way of reducing the risk from dry spells experienced shortly after planting and midway through the season.

Planting rains usually occur in late October to mid-November, but because of the reasons listed above, over half the maize area is planted in December and some even in early January. A recent study (Mudhara and Low 1990) showed that late planted maize is an economically viable crop in Mangwende, compared to alternatives such as sunflower.

This diagnostic study was initiated to:

- Determine the extent of late planted maize in sub-humid communal areas in Zimbabwe (Natural Regions 2 and 3; Vincent and Thomas 1961) and establish reasons for late planting.

- Quantify grain yield reductions resulting from late planting of maize in Mangwende, a communal area typical of the sub-humid Natural Region 2 of Zimbabwe, where maize is the dominant crop for smallholders.

- Determine the main crop input, management, or climatic reasons for the low grain yields from late plantings of maize.

This work was undertaken by CIMMYT in cooperation with the Farming Systems Research Unit (FSRU) of the Department of Research and Specialist Services, and AGRITEX extension service, Ministry of Lands, Agriculture, and Rural Resettlement, Zimbabwe. Results of this study were used to formulate an agronomic research programme designed to develop technologies to improve the productivity of maize planted late in Natural Regions 2 and 3 communal areas of Zimbabwe.

Methods Used in Diagnosis

The diagnostic work was of three types:

- A wide survey of smallholder farmers in 10 communal areas during 1989-90 to estimate the land area of late planted maize in Natural Regions 2 and 3 and to find reasons for late planting (Mudhara and Waddington 1990).

- Detailed agronomic monitoring of smallholder maize fields in Mangwende communal area during 1987-88 and 1988-89 to determine yield losses associated with late planting and the causes of those losses (Waddington and Hlatshwayo 1991).

- A station experiment at Harare in 1990-91 to compare the crop development and growth of late versus early plantings of maize (based on previous monitoring data from farmers' fields in Mangwende that late plantings develop more quickly).

Survey of late planted maize in 10 communal areas

The survey was carried out during January-March 1990 by a CIMMYT field team working closely with AGRITEX District staff.

Sampling procedure. A list of the communal areas in Natural Regions 2 and 3 was compiled with estimates from AGRITEX of their land areas under maize cultivation during the 1987-88 season. The area under maize was used as a weight for each communal area in its selection at random from a sampling frame. The 10 communal areas selected are listed in Table 1. Maize area in the 10 communal areas sampled was 217,195 ha in 1987-88 (Table 1), approximately 41% of the total communal maize area in Natural Regions 2 and 3 (529,930 ha).

From each sampled communal area, two villages were randomly selected for the survey (giving a total of 20 villages) and five households were selected from each village. Total sample size was thus 100 households, which had a total of 240 maize fields.

Information collected. A questionnaire was administered to each household head to obtain the following data for each maize field:

- Dates on which the maize field was planted and the area of the field (by pacing the field, or from farmer recall)
- Main farmer inputs and management practices
  - seed type and quantity
  - fertilizer types, amounts, and time of application
  - weeding methods and times

Additional data were obtained on farmers' reasons for delaying the planting of maize and on draught power ownership by the household.

Agronomic monitoring of late planted maize in Mangwende

Detailed agronomic monitoring, involving observations and measurements on farmers' early and late planted maize crops and discussions with farmers, was done in Mangwende Communal Area during the 1987-88 and 1988-89 rainy seasons.

Table 1. Zimbabwe communal areas surveyed during 1989-90 and corresponding maize areas

	Communal Area	District	Province	1987-88 Maize area, (ha)
1	Bushu	Bindura	Mash. Cent	1,712
2	Chipuriro	Guruve	Mash. Cent	7,819
3	Chiweshe	Mazoe	Mash. Cent	27,854
4	Hurungwe	Hurungwe	Mash. West	65,825
5	Mondoro	Umniati	Mash. West	26,360
6	Mukwichi	Karoyi	Mash. West	18,185
7	Chinyika	Murewa	Mash. East	17,491
8	Nyamaropa	Nyanga	Manicaland	6,034
9	Zhombe	Kwekwe	Midlands	41,334
10	Sanyati	Sanyati	Mash. West	4,581
Total area				217,195

Mangwende is 50-80 km east northeast of Harare. Its natural circumstances and the farming system in Mangwende have been described by Shumba (1988, 1989b).

Farmer selection. With the help of extension staff in 1987-88, 10 farmers were selected from each of three wards (Muchinjike, Zihute, and Musami) that contained a Farming Systems Research Unit (FSRU) trial cluster in Mangwende. Farmers were selected from within a 2-3 km radius of each of the three FSRU trial clusters. The monitoring was done with 28 farmers and yield data were collected from 24 farmers (the remaining farmers had mixed their maize from different plantings before it could be weighed). Sixty-two percent of the farmers monitored owned draught oxen. All the farmers selected planned to have at least two distinct plantings and in practice had an average of three. For 1988-89, a reduced sample total of 12 new farmers from the same three wards was used. In practice, the monitoring was slightly biased towards better farmers and earlier plantings because several non-owners of cattle with poor crops did not cooperate as the season progressed, and several very late planted fields were only discovered after most monitoring observations should have been done.

Data collected. In both years, background information was collected on each farmer before planting. This information included resource endowment (income sources, implements, draught oxen, labour available), normal maize farming practices and inputs, and an assessment of the general state of each farmer's fields.

1987-88 monitoring

The following attributes were monitored for early, middle, and late plantings in 1987-88:

- Maize genotypes used
- Land preparation: timing of tillage and type of implement(s) used.
- Plantings:
  - timing of maize plantings done on the farm
  - state of seedbed at planting (tilth, wet/dry, weed percentage, cover and type)
  - method of planting (implements used, seed spatial arrangement, and seeding depth)

- Stand establishment
  - plant counts to establish plant population density
  - observations on plant losses, etc.
- Crop development and growth
  - emerged leaf number
  - tasselling and silking dates
- Fertilizer use
  - types, amounts used, timing of application, method of application, use of organic manure (all from direct observation where possible and farmer recall where not)
- Weeds and weeding
  - timing of each weeding (from direct observation where possible)
  - implements used
  - weed height and cover (using quadrats) just before first weeding
  - weed height and cover (using quadrats) versus stage of development of crop
- Soil depth and plough layers, etc., measured by digging pits in late and early planted maize fields to observe crop rooting and compaction
- Areas of maize fields in survey, by measuring dimensions and approximate angles of fields after harvest (to help calculate fertilizer rates, plant densities, and crop yield)
- Yield analysis
  - grain yield/ha by weighing ears from entire field after harvest by the farmer: sub-samples were collected for shelling percentage and for grain moisture (grain yields are reported at 12.5% moisture)

1988-89 monitoring

In 1988-89 emphasis was placed on inputs and management practices that the previous year of monitoring had shown to vary with planting date. These were:

- Fertilizer inputs (basal and topdress)
- Weed burden and weeding practices
- Grain yields

In 1988-89 more data were collected from observing farmers weeding or applying fertilizer rather than from farmer recall. Soil samples were collected from each proposed maize field (for early, middle, and late plantings) in October/November 1988 and tested for pH using a portable pH meter. Plant development x planting date was monitored closely with 10 farmers. The number of emerged leaves was taken for each planting approximately every week. Tasselling and silking dates were also recorded.

Multiple linear regression of grain yield on quantitative input and management data from the monitoring was attempted, but variation was such that sets of explanatory variables were unable to account for most of the variation in grain yield. It was decided to present the differences in inputs and management by planting date simply as mean values for planting date quartiles. The quartiles were developed by dividing all the sampled fields into four equal numbers of fields arranged by planting date, irrespective of farmer planting sequence, i.e., the first 25% of fields planted (from the fields sampled) comprised quartile 1, the second 25% quartile 2, etc.; the last quartile contained the last 25% of fields planted.

To determine whether late plantings were subject to longer or more frequent water deficits, dates of planting, tasselling, and physiological maturity for early and late planted crops of R201 were superimposed on daily rainfall records from Murewa for the years 1950-51 to 1988-89. It was estimated that R201 takes 138 days to reach physiological maturity at 1,350 masl when planted early in the rainy season. Late planted crops were considered to mature in around 130 days (based on observations in farmers' fields during the monitoring and data from the crop development x planting date experiment, Harare 1990-91).

Air temperature data were examined as a possible reason for changes in the rate of crop development by planting date. Daylengths were obtained from tables and examined as another possible reason.

Maize crop development x planting date experiment

This experiment was developed to determine the effect of planting date (and climatic factors that vary with planting date, such as daylength and irradiance) on the development, growth, and yield of several maize genotypes suitable for smallholder farmers in Natural Regions 2 and 3 of Zimbabwe.

The experiment was planted at the CIMMYT Maize Research Station, University of Zimbabwe Farm, Harare, 1990-91 season. Experimental factors were four planting dates (8 November, 28 November, 18 December, and 7 January) and five maize genotypes (R215, R201, SC501, EXP.POP.ZM609, and POP 49), but data reported here are for R215 and R201 only, because these are the hybrids the farmers plant.

The experiment was in two parts. A yield trial measured final grain and above-ground dry matter yield, and researchers used destructive monitoring on a separate set of plots to measure plant growth and development. The yield trial was in a randomized complete block design with split plots. Main plots were allocated to the four planting dates and sub-plots for the five maize genotypes, with three replicates. Sub-plot size was four rows 75 cm apart x 4.5 m long, with an established plant population density of approximately 53,000 plants ha^{-1}.

A blanket basal dressing of 32 kg ha^{-1} N, 25 kg ha^{-1} P, and 23 kg ha^{-1} K as Compound D fertilizer was applied in October and supplemented by 5.3 kg ha^{-1} N, 4.1 kg ha^{-1} P, and 4.0 kg ha^{-1} K as Compound D, placed in each planting hole at each planting. When plants sown on each planting date reached the 8-leaf stage, 50 kg ha^{-1} N as ammonium nitrate fertilizer was applied. Plots were hoe weeded as necessary. Each planting was irrigated as needed by sprinklers to ensure good germination and emergence. Dates of tasselling and physiological maturity, and grain yield were recorded for the yield trial.

For each planting date and for each maize material on the monitoring plots, the number of fully emerged leaves (most recently emerged leaf with fully visible collar) was counted on around 16 plants per plot every seven days until silking. To allow this, the fifth and tenth leaves were marked with paint on each selected plant. Two plants were removed from each plot each 7th day for determination of above-ground dry weight.

Information on daylength was obtained from tables. Data on photosynthetically active radiation came from an adjacent farm belonging to the Agricultural Research Trust of Zimbabwe and from the Meteorological Office, Harare.

Results and Discussion

Extent of late planting

Distribution of maize plantings over time. What constitutes a "late planting" will always be somewhat subjective. Commonly some interpretation of "first effective rains" (FER) is used to denote the theoretical beginning of the maize cropping season. This is the first period of sufficiently wet weather at the start of the season during which a farmer, whose inputs of seed, fertilizer, labour, etc., are ready, can till the land and start planting maize. For a given season the date of FER should fit closely to first planting dates observed from farmer practice. The delay with later plantings can then be measured against FER. For the survey of 10 communal areas, a late planting was defined as one made four or more weeks after FER.

For the analysis of data from the survey, the FER were assumed to fall during the first week after 1 October when, from rainfall records, at least 25 mm of rain fell. The dates for the week containing the 1989-90 FER for the weather stations nearest to the 10 communal areas were given by the Zimbabwe Meteorological Office (Table 2). In general these dates coincided well with those of first maize plantings obtained during the 1989-90 season (Figure 1).

Reasons for large areas planted before FER in Hurungwe and Mukwichi may be that the nearest rainfall station (Karoi) is 60 km from the more distant parts of these communal areas. Rainfall recorded at Karoi may not represent that for those communal areas, particularly early in the season when rains often have a patchy distribution.

Table 2. Dates of first effective rains for the 10 Natural Region 2 and 3 communal areas surveyed in Zimbabwe, 1989-90 season

Communal Area	Nearest weather station	First effective rains
Sanyati	Gokwe	19.10.89 - 25.10.89
Mhondoro	Mhondoro	19.10.89 - 25.10.89
Chinyika	Arcturus	19.10.89 - 25.10.89
Bushu	Bindura	12.11.89 - 18.11.89
Hurungwe	Karoi	26.11.89 - 2.12.89
Mukwichi	Karoi	26.11.89 - 2.12.89
Chipuriro	Guruve	09.11.89 - 15.11.89
Nyamaropa	Nyanga	30.9.89 - 05.10.89
Chiweshe	Mvurwi	17.11.89 - 21.11.89
Zhombe	Kwekwe	02.11.89 - 06.11.89

Figure 1 shows the cumulative land area planted to maize from the date of FER in the 1989-90 cropping season for the 10 communal areas, presented in two random groups of five. Plantings occurred as late as 12 weeks after FER (second week of January in Mondoro and Sanyati). Of the total maize areas, 32.9% were late planted (four or more weeks after FER) and 8.9% were very late planted, i.e., planted eight or more weeks after FER. Thus about 175,000 ha of maize were planted late by smallholder farmers during 1989-90 in Natural Regions 2 and 3 of Zimbabwe.

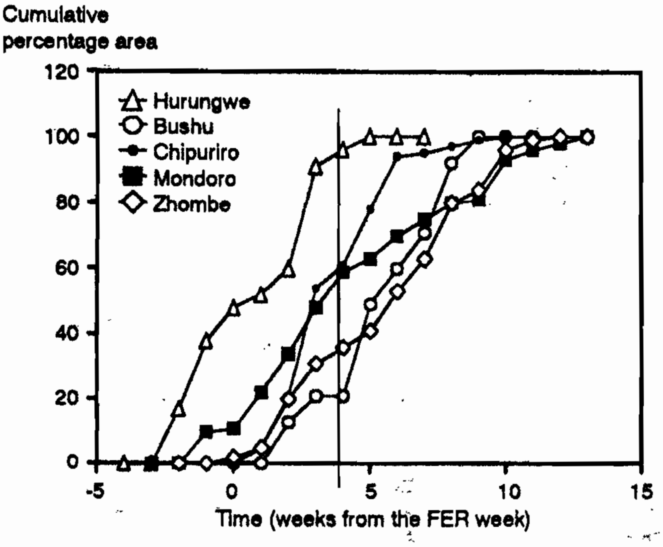
For Mangwende the percentage of total sampled field area by planting dates (grouped into 10-day periods from 1 November) for monitored fields planted to maize during 1987-88 and 1988-89 is shown in Figure 2. In 1987-88 observed planting dates ranged from 8 November 1987 to 4 January 1988 and in 1988-89 from 3 November 1988 to 4 January 1989. In both years, over 50% of the sampled field area was planted four or more weeks after the start of planting in Mangwende (Figure 2). In 1987-88, on average the first planting on a farm was made around 25 November, the second planting around 9 December (a difference of 14 days) and the third around 14 December (5 days).

Reasons for delayed planting. In the wider survey, farmers gave various reasons for delaying some of their maize plantings (Table 3). The unpredictability of rainfall and therefore the need to spread out plantings was by far the most common reason given for delays. The lack of draught power or shortage of labour were less common reasons for delays. Thus for many farmers the planting of some maize late is a deliberate strategy.

Table 3. Reasons given by farmers for delaying the planting of some maize fields, 10 communal areas of Natural Regions 2 and 3, Zimbabwe, 1989-90

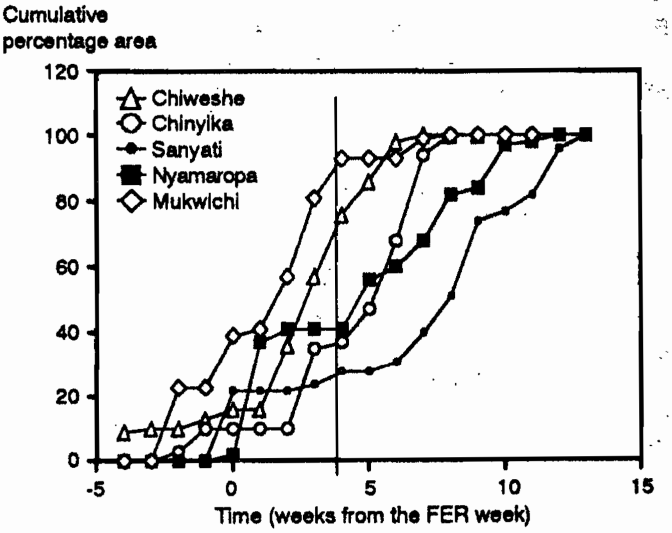
Reason	Percentage of farmers[a]
Unpredictability of rainfall	51
Draught power shortage	24
Labour shortage	24
Lack of seed at start of season	5
Does not wish to plant an alternative crop	4
Problems related to excessive rains	4
Avoiding stalkborer damage	1

a Percentages sum to more than 100% because more than one response could be given by a farmer.



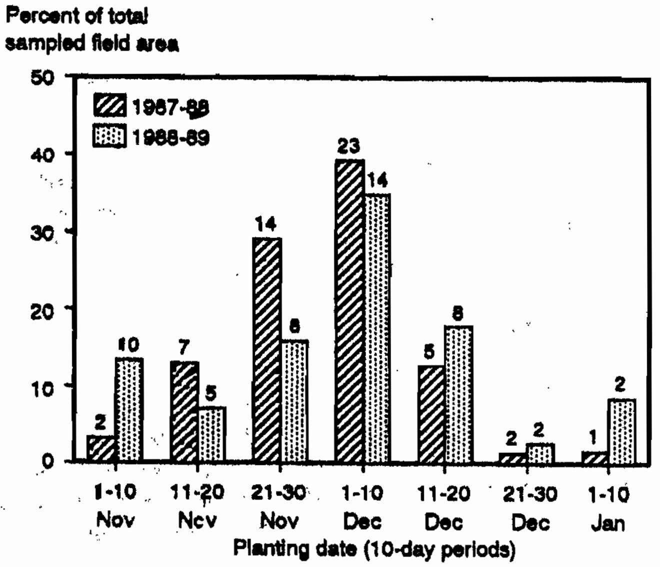
FER = First Effective Planting Rains. Vertical line indicates four weeks after FER.

Figure 1a. Cumulative percent maize area planted in five Natural Region 2 and 3 communal areas, Zimbabwe, 1989-90.



FER = First Effective Planting Rains. Vertical line indicates four weeks after FER.

Figure 1b. Cumulative percent maize area planted in five Natural Region 2 and 3 communal areas, Zimbabwe, 1989-90.



Number above each bar is number of fields planted in period.

Figure 2. Pecentage of total sampled maize field area by planting date in Mangwende, 1987-89.

Grain yield x planting date

Data on the relationship between grain yield (from the whole field area) and planting date were obtained for Mangwende (Figure 3a for 1987-88 and Figure 3b for 1988-89). While previous reports of a near linear decline in yield with later planting (e.g., Shumba 1989b) were not supported by the data, there was a clear trend towards lower grain yield with late plantings. Planting late almost always meant a lower grain yield (<2.5 t ha^{-1}) but around 30% of early plantings also performed poorly. As a simplification of the trend, average grain yield is given by planting date quartiles (yields divided into four equal numbers of fields arranged by planting date) in Figure 4 for the two seasons separately. A similar marked decline in grain yield with planting date was seen in both years. The first quartile of plantings yielded 4.9 t ha^{-1} (planted 3 - 24 November) over the two years against only 2.7 t ha^{-1} for the third quartile and 1.1 t ha^{-1} for the last quartile (planted 14 December - 4 January, and just 22.4 % of first quartile yield) (Figure 4). The mean for all plantings in 1987-88 (3.1 t ha^{-1}) was confirmed by local AGRITEX staff to represent the maize yields farmers obtain in Mangwende.

From the survey it was calculated that a total of around 175,000 ha of maize was late planted in all Natural Region 2 and 3 communal areas of Zimbabwe (based on 1987-88 maize areas). Using the 1.3% per day reduction in grain yield with late planting obtained by Shumba (1989b) and the yield losses reported from the current monitoring in Mangwende, and assuming an average early planting grain yield of 3 t ha^{-1} in Natural Regions 2 and 3, and an average delay of five weeks for 33% of the total maize area, then the grain yield forgone

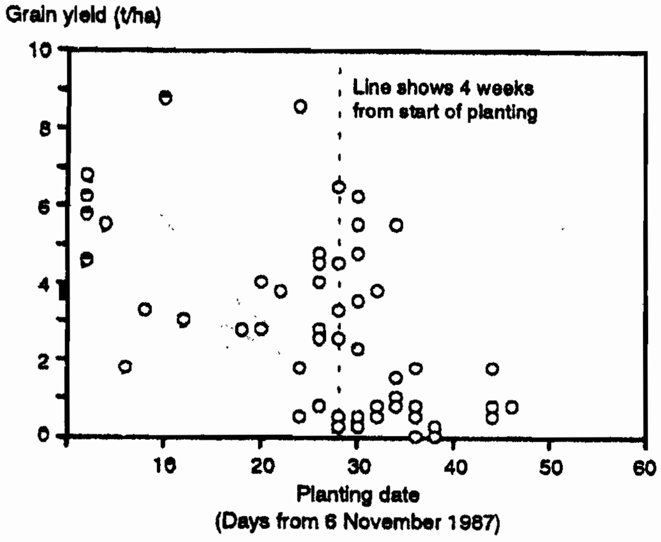


Figure 3a. Relationship between grain yield and planting date, Mangwende, 1987-88.

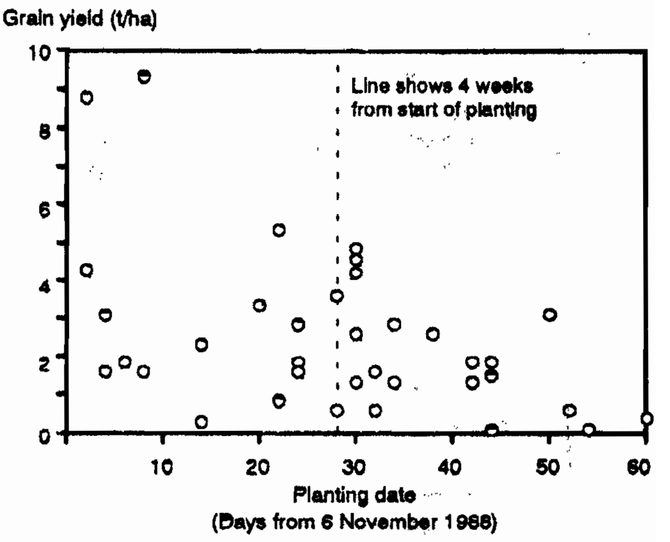
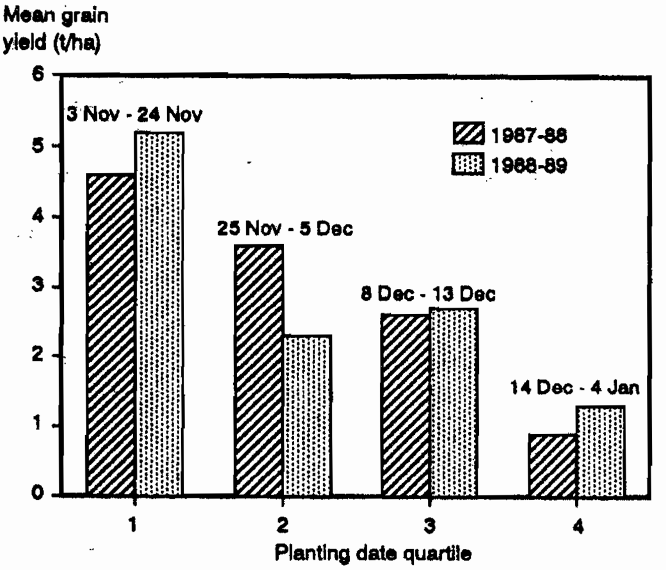


Figure 3b. Relationship between grain yield and planting date, Mangwende, 1988-89.

through late planting of maize in all communal areas of Natural Regions 2 and 3 in Zimbabwe is between 240,000 t and 310,000 t per annum. Additional "losses" of maize grain must occur through late planting in Natural Region 4, but were not addressed in this study.



Data from 1987-88 are mean grain yields from 13 fields per quartile, and from 9 fields per quartile in 1988-89.
Data above yield bars show range of planting dates for a quartile.

Figure 4. Mean grain yield per field by planting date quartile, Mangwende, 1987-89.

In an attempt to explain why late plantings of maize gave lower grain yield, the relationship between planting date and a wide range of farmer inputs or practices (measured on each field), plus some environmental/climatic factors, was examined. Because of large amounts of variation among farms, few clear relationships were seen, and as a helpful simplification many inputs or practices were examined for fields with their planting dates grouped into quartiles.

Only low levels of diseases or pests were encountered. A few late planted maize fields had higher incidences of stalkborer (*Busseola fusca*) but over all late planted fields stalkborer did not appear to be a major reason for reduced grain yields.

Environmental/climatic factors x planting date

Maize crop development and growth. Visual assessments in farmers' fields suggest that late planted crops tasselled fewer days after emergence than earlier planted crops. Plant height in late planted crops was reduced at tasselling and plants had shorter internodes and lower ear placement. In 1987-88 a crude comparison of leaf emergence rate for early and late planted maize crops showed that on 13 out of 16 farms, the late planted crop developed more quickly. The last quartile of plantings had on average already reached the 12-leaf stage in the time taken for the first quartile plantings to reach nine leaves. Although there was much variation, last

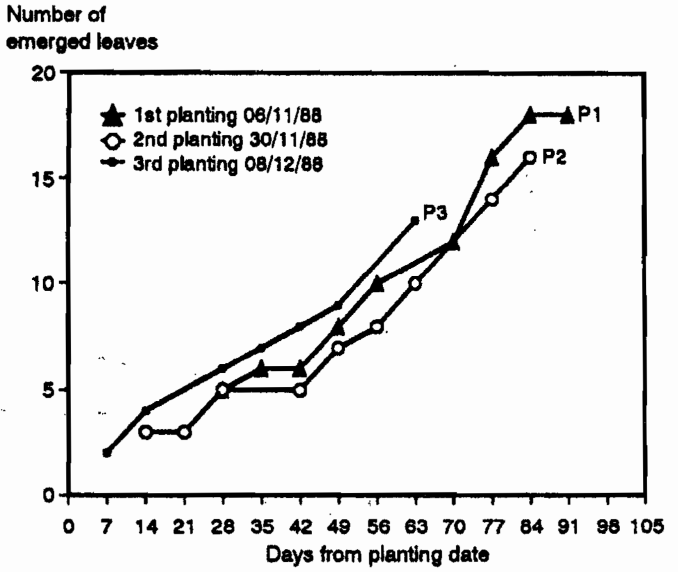


Figure 5a. Rate of leaf emergence on different maize planting at the Mrs. E. Nyahwata farm, Mangwende, 1988-89.

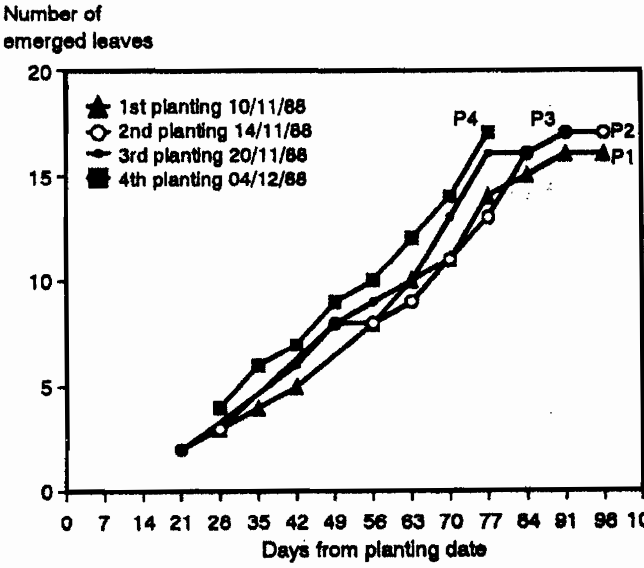


Figure 5b. Rate of leaf emergence on different maize plantings at the Mr. Pasirayi farm, Mangwende, 1988-89.

plantings reached tasselling in up to 15 fewer days than first plantings. More detailed records were kept in 1988-89.

Although there was considerable variation in the results from individual farms in both years, generally the later plantings developed at the same rate or more quickly than did the earlier plantings. In 1988-89, late plantings developed at about the same rate as early plantings on five out of 10 farms. On the other five farms late plantings developed more quickly (see Figures 5a and 5b for two examples where R201 was planted). In 1988-89 the last quartile of plantings reached tasselling around the same time as early plantings or up to around 10 fewer days than did earlier plantings.

Data from the experiment at Harare showed that late plantings of R201 and R215 had two to three more leaves emerged at any given time after sowing during the early and mid pre-tasselling phase, but final leaf number was not affected and late planting reduced days to 50% tassel emergence only by 4-5 days (Figures 6a and 6b). Little difference in the rate of above-ground dry matter accumulation pre-anthesis was detected between the second, third, and last plantings, but the first planting accumulated dry matter more slowly (see Figure 7 for R201 and R215 combined).

Average air temperatures experienced by late plantings in Mangwende were slightly lower than for early plantings, both before and after tasselling (Figure 8), and should have reduced the rate of crop development slightly. Decreasing daylength may be a reason for the faster development and the shorter

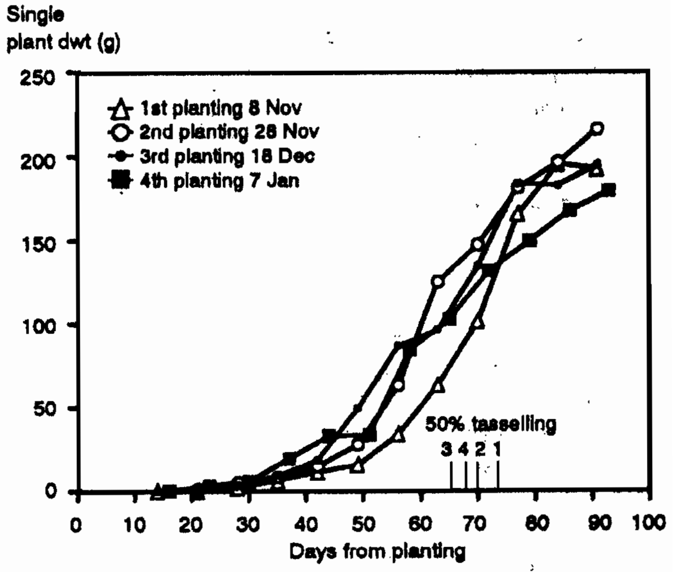


Figure 7. Single plant above-ground dry weight by planting date for R201 and R215 maize combined, Harare, 1990-91.

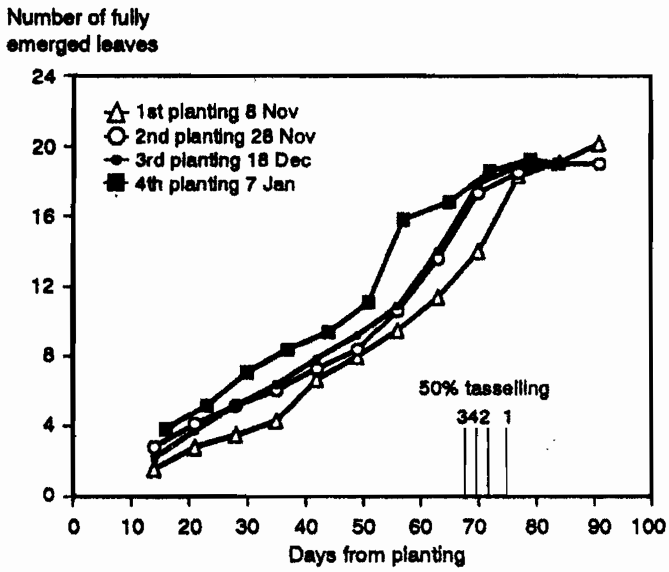


Figure 6a. Number of fully emerged leaves by planting date for R201 maize, Harare, 1990-91.

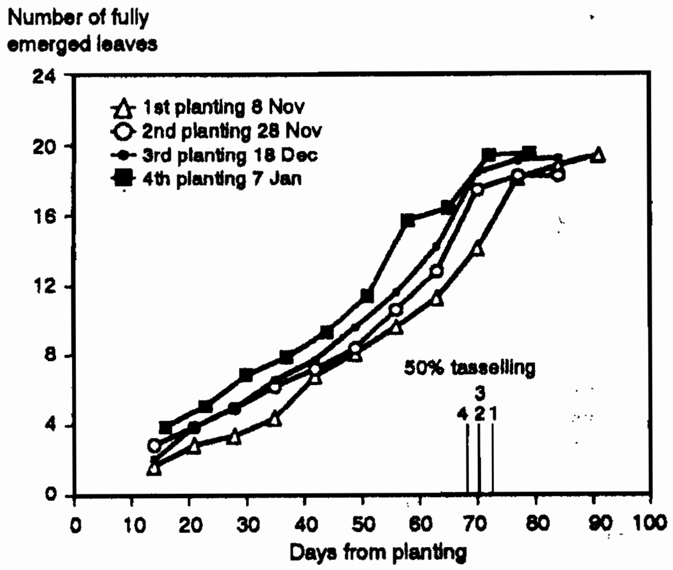


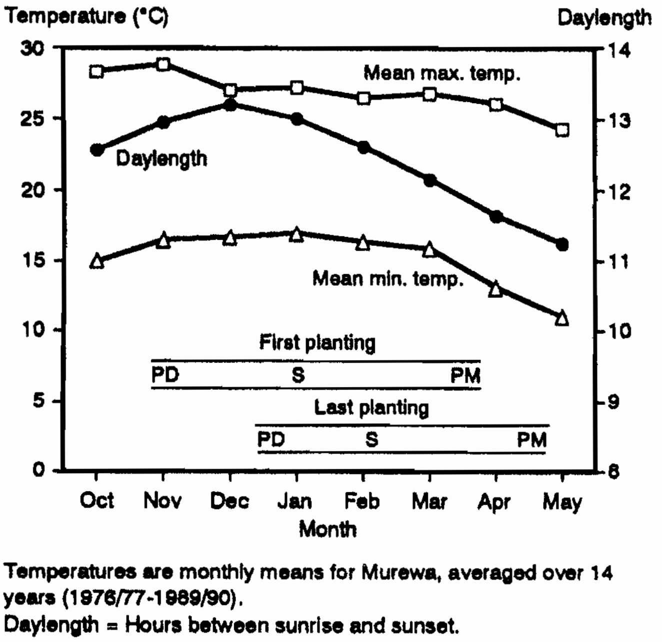
Figure 6b. Number of fully emerged leaves by planting date for R215 maize, Harare, 1990-91.

plants prior to silking found with late planting, since late planted maize plants emerged into already decreasing daylengths and experienced them throughout crop development (Figure 8). But final leaf number was not reduced with late planting in the experiment at Harare as would be expected with a large daylength effect. Accumulated photosynthetic photon flux densities from planting to 50% tasselling at Harare during 1990-91 were similar for all four plantings (at an average of 2,523 mM m^{-2}). Air temperatures within the crop canopy and soil tempertures were not measured and these may provide the reason for the slightly faster rate of leaf emergence with late planting.

Water deficit. An analysis of rainfall patterns during 1987-88 and 1988-89 was done in relation to the crop development cycle of late planted R201 (planted on 23 December, the median planting date for the last quartile of plantings in the two years) (Figure 9). There was adequate rainfall during silking to mid grain filling in 1987-88 but grain filling coincided with a three-week dry spell in 1988-89 (Figure 9). Some late planted crops were observed to be suffering a mild water deficit during grain filling in 1988-89, yet most farmers felt water shortage was not a common reason for low yield in their late plantings.

A wider assessment was made over 38 years of rainfall data to decide how frequently late or early planted maize in Mangwende may experience a long dry spell during the period two weeks before silking to mid-grain filling. A late planting would be affected in 11 out of 38 years (29%) against five out of 38 years (13%) for an early planting. Thus, late planting doubled the probability of a water deficit during silking and early grain filling, and in one out of three or four years moisture shortage during silking and grain filling may be a major cause of low grain yield in late planted maize in Mangwende. However, it was clear from the monitoring (including the monitoring in 1987-88 when there was no water deficit) that the yield potential of late planted maize was much reduced well prior to silking, due to factors other than water deficit.

From the above, while climatic factors appear to contribute to low yield of late planted maize crops, measured grain yield reductions were far too great to be explained by the climatic differences alone. The next sections examine farmer input and management differences as likely causes of low yield.



Temperatures are monthly means for Murewa, averaged over 14 years (1976/77-1989/90).
Daylength = Hours between sunrise and sunset.
PD = planting date, S = silking, and
PM = physiological maturity.

Figure 8. Mean maximum and minimum temperatures, and daylength, Mangwende.

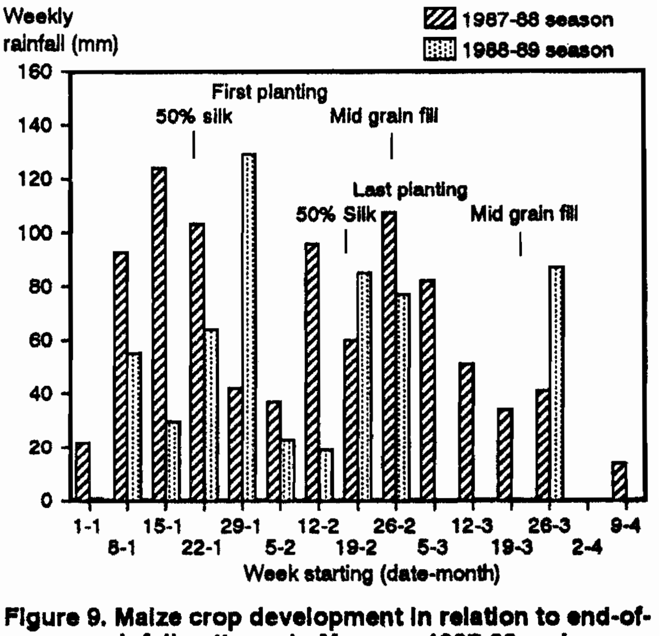


Figure 9. Maize crop development in relation to end-of-season rainfall patterns in Murewa, 1987-88 and 1988-89.

Land preparation and planting practices x planting date
Most land preparation and planting practices monitored in Mangwende showed little variation with planting date and so were likely to be minor contributors to the low grain yields of late plantings. Accordingly these practices are only summarized here (see Waddington and Hlatshwayo, 1991, for details).

The choice of fields for early planting was not related to field slope, soil type and depth, or potential rooting depth of a crop in the field. Soil pH, which ranged from 4.9 to 6.4 (mean 5.5) showed no difference with planting date. Instead, farmers said they site the early planted crop close to the homestead to minimize risk of damage by uncontrolled livestock early in the rainy season. Fields close to the homestead also appeared to have higher organic matter since some household waste was deposited there.

The mouldboard plough was the major tool for land preparation regardless of planting date. Evidence from soil pits dug during 1987-88 showed no hard pan impediment to root development on late or early planted fields, with most plants reaching rooting depths of 80-100 cm or more.

There was no relationship between planting method and planting date, with a) use of a marking wire, holing with a hoe, placing the seed and covering with a hoe or foot, or b) planting in a furrow directly behind the mouldboard plough, the most common methods. There was a slight decrease in average depth of seed placement with late planting from 45 mm in the first quartile of plantings to 38 mm in the last two quartiles. Such small differences were probably not important.

Maize genotype. The hybrids R215 and R201 (142 and 140 days to physiological maturity, respectively, at 1,350 masl), which made up 77% of the maize area planted in the wider survey and over 95% of plantings in Mangwende, were evenly spread over early and late planting dates. The long-season hybrid, SR52 (158 days to physiological maturity at 1,350 masl), was always planted early, yet it made up only 13% of the 241 maize fields sampled in the wider survey.

Plant population density. There was just a slight decline in plant density with late planting, from about 46,000 plants ha^{-1} in the first quartile to around 41,000 plants ha^{-1} in the last quartile. Farmers said they planted approximately the same number of seeds per hectare in a similar spatial arrangement, regardless of planting date.

Ownership of draught oxen. One resource previously reported to have a large influence on land preparation and thus on the timing of planting is access to draught oxen (e.g., Shumba 1988, 1989b). Considering all the plantings, farmers owning cattle for draught power got higher yields than non-owners in both seasons of monitoring: 3.5 t ha^{-1} versus 2.6 t ha^{-1} in 1987-88, and 2.9 t ha^{-1} versus 2.1 t ha^{-1} in 1988-89. For earlier plantings, cattle owners achieved yields of 5.6 t ha^{-1} while non-owners got only 3.3 t ha^{-1}. However, ownership of cattle for draught power had surprisingly little effect on dates of ploughing or planting. In 1987-88, oxen owners had, on average, ploughed fields for their first plantings by 15 November 1987 while non-owners had ploughed by 23 November 1987; just seven days later. First maize fields were planted by 22 November 1987 for owners and around 30 November 1987 (eight days later) for non-owners. During 1987-88 there was no difference between owners and non-owners in ploughing and planting dates for later plantings. The last quarter of fields were ploughed by 10 December for the whole sample, and cattle owners planted two days later than non-owners. Of those planting late, seven were owners of draught animals and six were non-owners. In 1988-89 (with a small sample of just 12 farmers) non-owners of cattle planted their first maize field 1-2 weeks earlier than cattle owners. Somewhat surprisingly, in the wider survey ownership of draught power was associated with both a slightly reduced final land area planted to maize per household and slightly delayed progress of planting.

Thus draught ownership may not now be the important direct determinant of planting date and maize yield reported in studies conducted in the early 1980s (Rukuni 1986; Shumba 1988, 1989b). Increases in oxen numbers in Mangwende during the 1980s have probably meant that non-owners find timely access to oxen easier now. Assuming two draught oxen are the minimum required to make a span, then from the wider survey only 22% of the communal households surveyed did not possess adequate draught for land preparation. The lower yields by non-owners appear largely the result of factors other than draught ownership effects *per se* on planting date. Shumba (1989b) concluded that draught power owners in Mangwende had better land husbandry and crop management practices (including use of some manure). Factors such as management of weeds and fertilizer appear more critical for yield, as shown later in this report.

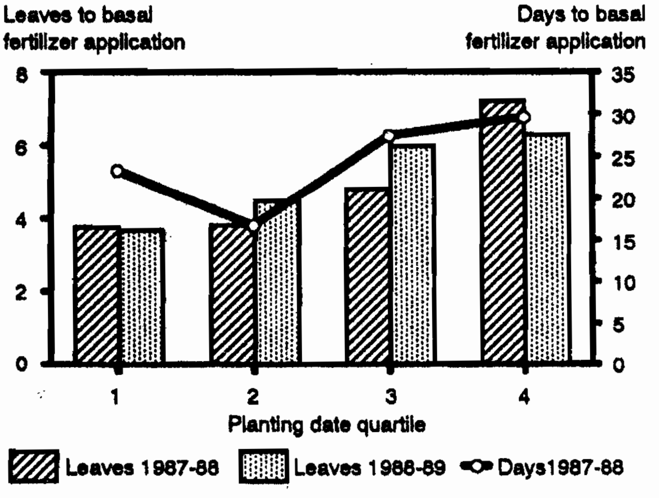
Fertilizer management x planting date

In the wider survey there was large variation in amounts of N fertilizer applied to individual fields but some trends were clear. Farmers said they applied a total (basal plus topdress) of around 65 kg ha^{-1} N fertilizer to their first and early late planted maize crops. There was little evidence of a reduction in N fertilizer application until plantings made around six weeks after FER. After that the rate of decline in N application was over 7 kg ha^{-1} N per week. More detailed data were obtained in Mangwende.

Timing of basal fertilizer. Late planted and early planted fields in Mangwende were equally likely to receive cattle manure, but only 15% of fields received cattle manure in 1987-88. During 1987-88, basal fertilizer, as Compound D (8:14:7 N, P_2O_5, K_2O), was applied on average 23 days after planting (d.a.p.) (4-leaf stage) to early plantings and 29 d.a.p. to later plantings (7-leaf stage), giving a six-day difference between the plantings (Figure 10). A similar increase in the number of leaves to basal fertilizer application was seen in the later plantings in 1988-89 (Figure 10). For first plantings, basal Compound D was applied at 20 d.a.p. by cattle owners while for later plantings it was 23 d.a.p. For non-owners, applications were 24 and 30 d.a.p., respectively, showing delayed application for late plantings by non-owners of cattle.

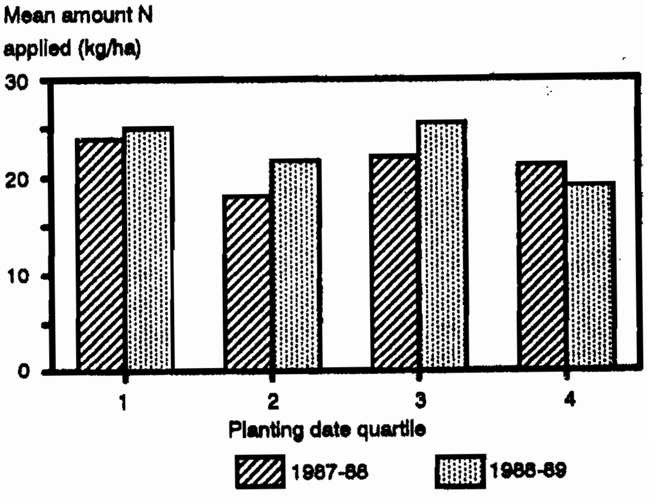
Shumba (1989b) found that applying basal fertilizer to maize in Mangwende 14 days after crop emergence versus at planting reduced grain yield by just 8%. The delay in application to late plantings of around 6 days was likely to be a contributor to the lower yield from later plantings, especially when the faster development of later plantings (basal applied three leaves later) is considered.

Rate of basal fertilizer. Besides basal fertilizer being applied later in crop development in the later plantings, less basal fertilizer was applied to those plantings; around 20 kg ha^{-1} N in the last quartile against 25 kg ha^{-1} N in first plantings (Figure 11). The first quartile of plantings received 19 kg ha^{-1} P, compared to 15 kg ha^{-1} P for the last quartile.



Data for # of days are from 13 fields per quartile in 87-88. Number of leaves are from 7 fields per quartile in 1987-88 and 6 1988-89.

Figure 10. Mean number of leaves and days to basal fertilizer application by planting date quartile, Mangwende, 1987-89.



Data are mean amout of nitrogen applied as Compound D. 13 fields per quartile in 1987-88 and 8 fields in 1988-89.

Figure 11. Mean amout of N basal fertilizer (kg/ha) applied, by planting date quartile, Mangwende, 1987/88-88/89.

The combination of later application of basal fertilizer at lower rates is likely to be an important contributor to the lower yield of the late plantings by reducing early growth while, in contrast, crop development is speeded up.

Timing of topdress N fertilizer. Unlike the trend observed in basal fertilizer application, averaged over both years, topdress N fertilizer was applied onto the first plantings at 55 d.a.p. while later plantings received the topdressing earlier, at 42 d.a.p., a difference of 13 days (Figure 12). But, when the number of leaves to topdress was measured, later plantings (which developed faster) received topdress N at the 11-leaf stage against only nine leaves for the first quartile of plantings (Figure 12).

In 1987-88 topdress N fertilizer was applied to first plantings at about the same time irrespective of draught power endowment. However, for subsequent plantings, farmers who did not own cattle applied topdress three days later than did cattle owners.

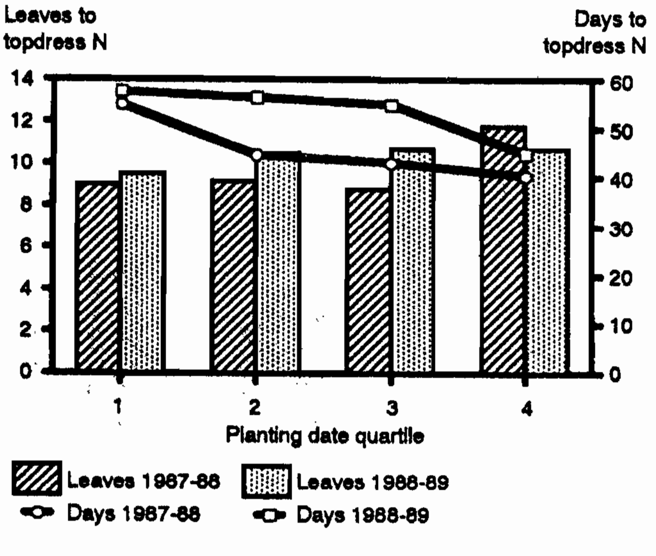
Rate of topdress N fertilizer. The estimates of the amount of topdress N fertilizer applied in 1987-88 were much higher than the values for 1988-89 (Figure 13). This was in part because the 1987-88 figures mainly came from farmers' estimates of amounts applied while the 1988-89 data were mainly derived from field measurements of amounts applied by farmers, with just a few values obtained from farmer recall. The 1988-89 data were more accurate. Another reason for the large difference was that fewer farmers received credit for fertilizer in 1988-89 compared to 1987-88. Despite the variation, it was clear in both years that the last quartile of plantings received only about 60% of the topdress amount applied to first plantings (Figure 13).

The combination of topdress N fertilizer applied about one week later in crop development and at just 60% of the rate applied to early plantings is likely to be an important cause of the reduced yield from later plantings.

Weed management x planting date

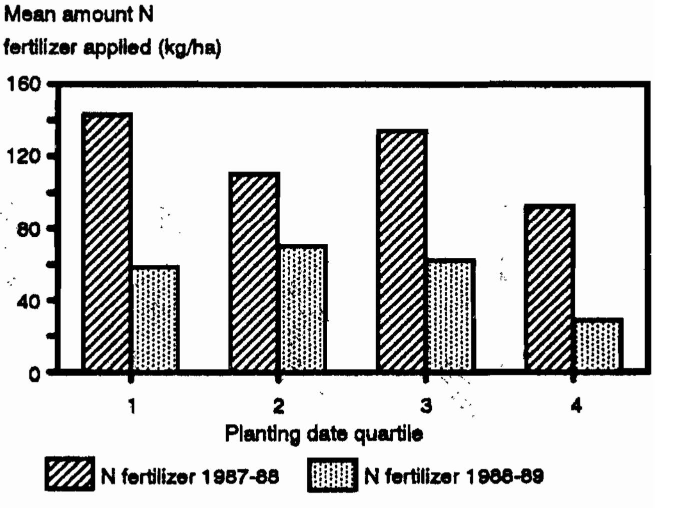
Weed burden at planting and first weeding. Weeds on the seedbed at planting, measured in 1987-88, were taller (43 mm) and covered more of the ground area (32.1%) for later plantings than for the first plantings (29 mm and 11.5%) (Figure 14). Weed cover at planting in 1988-89 was much lower (Figure 14). In 1988-89 weed cover just before first weeding was lowest for the last quartile of plantings (Figure 15) (data not available for 1987-88).

Data from 1987-88 showed the mean weed height at first weeding for the early plantings and later plantings to be similar at 102 and 108 mm, respectively. However, it was observed that the



Data are mean number of leaves to topdress N. There were 7 fields per quartile in 1987-88 and 6 field in 1988-89.

Figure 12. Mean number of leaves and days to topdress N fertilizer application by planting date quartile, Mangwende, 1987-89.



Data are N fertilizer levels from 13 fields per quartile in 1987-88 and 11 fields per quartile in 1988-89.

Figure 13. Mean amount of N fertilizer (kg/ha) applied, by planting date quartile, Mangwende, 1987/88-88/89.

weeds in the later planted crop were at a more advanced stage of development (at first weeding) compared to weeds in the early planted maize. Thus, just before first weeding late planted crops appeared to have fewer but larger, more developed weeds than did earlier plantings.

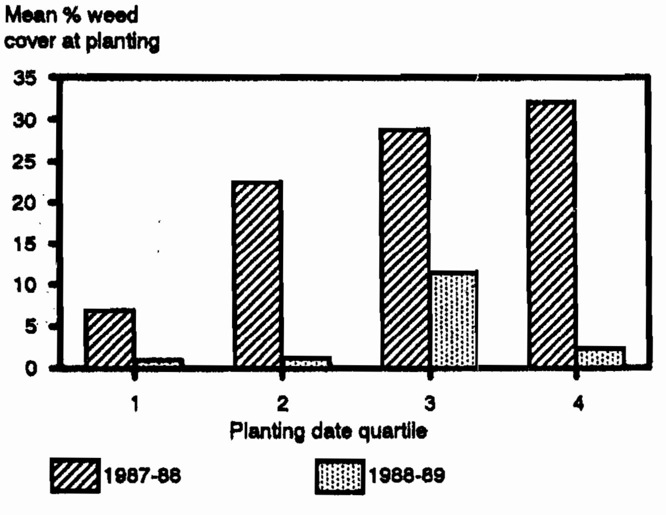
Form of weeding. While about half of both first and second plantings included some hand weeding, only 30% of the later plantings, compared to 42% of the early plantings, were both ox-cultivated and hand weeded. Just 8% of the early plantings were weeded by ox-drawn cultivators only, but this rose to 17% for later plantings. This indicates early plantings receive a more thorough weeding than do the later plantings, but this may be a function of fewer weeds in the later plantings. Weeding solely with an ox-drawn cultivator between the crop rows only was seen to leave weeds undisturbed in the crop row and these may have contributed to lower yield of the later plantings. Even where hand weeding was eventually done on late plantings after ox-drawn cultivation, observations in the field showed that some weeds had already set seed when the maize was early in the grain filling phase.

Timing of first weeding. On average, the first weeding was done around 33 d.a.p. in 1987-88 and around 49 d.a.p. in 1988-89. The greater delay in 1988-89 probably reflected the lower incidence of weeds around planting in that year (Figure 14). Farmers may have decided weeding was not necessary until later. However, the number of days to the first weeding did not differ much between plantings in 1987-88, but the later planted crop was at a later stage of development when weeded in both seasons, compared to first plantings (around four leaves later) (Figure 16). The first two quartiles of plantings were weeded at six leaves and the last quartile at around 10 leaves.

The increased duration of weed competition in the late planted maize crop (weeded later in crop development) is likely to have been important in reducing grain yields.

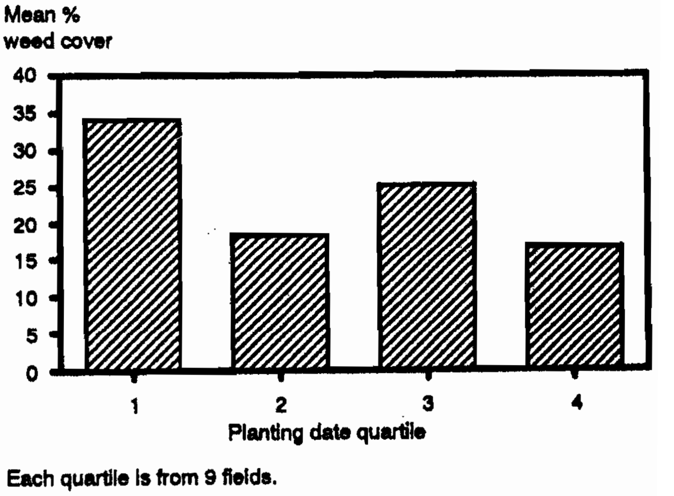
Summary and Conclusions from the Diagnosis

From results presented here, late planted maize represents a major source of lower physical productivity in the maize enterprise of smallholder farmers living in sub-humid communal areas of Zimbabwe. Large declines in average grain yields with late planting were measured in Mangwende. These represent a grain yield loss of between 240,000 and 310,000 t/yr throughout the sub-humid (Natural Region 2 and 3) communal maize areas in Zimbabwe.



Data are % weed cover from 6 fields per quartile in 1987-88 and 10 fields per quartile in 1988-89.

Figure 14. Mean percentage weed cover at planting, by planting date quartile, Mangwende, 1987/88-88/89.



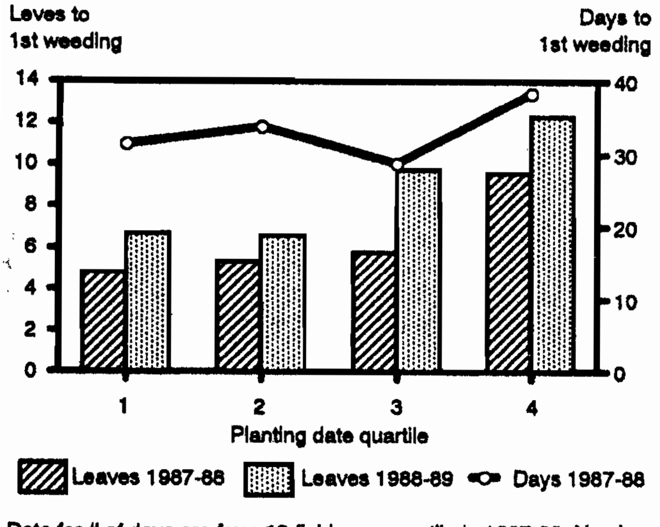
Each quartile is from 9 fields.

Figure 15. Mean percentage weed cover just before first weeding, by planting date quartile, Mangwende, 1988-89.

Multiple causes of the low yield in late planted crops were identified. Late planted crops developed more quickly than early plantings and this may have reduced the yield potential of late planted crops. Many management and input compromises were noted on late plantings. However, most represented small delays in operations or reductions in inputs, not likely to be major reasons for the low yield. The monitoring methods used in this study did not allow a clear decision on whether farmers reduced management and inputs because they knew late planted maize had a lower yield potential, or whether the low yield was largely the result of the poorer management given. A few farmers suggested that a perception of lower yield potential (due to climatic factors) directed a shift to lower management, but for most farmers it seemed that resource shortages (fertilizer, labour) compromised the management of their late plantings.

The management and input factors identified as likely major contributors to lowering the realized grain yield of late plantings were:

1. Delayed application of basal fertilizer (by around six days, three leaves later) at a reduced rate (around 20 kg ha^{-1} N, 15 kg ha^{-1} P) on last plantings against 25 kg ha^{-1} N, 19 kg ha^{-1} P on first plantings.



Data for # of days are from 12 fields per quartile in 1987-88. Number of leaves are from 7 fields per quartile in 1987-88 and 9 in 1988-89.

Figure 16. Mean number of leaves and days from planting to first weeding, by planting date quartile, Mangwende, 1987-89.

2. Topdress N fertilizer was applied to late plantings at just 60% of the rate given to early plantings, and two leaves later in crop development.

3. The late planted crop suffered weed competition longer than did early plantings. Weed burden at planting was greater for late plantings and the late planted crop was first weeded at the 10-leaf stage (four leaves later than with first plantings) and was less thoroughly weeded.

Directions for Research to Improve Late Planted Maize

Because the diagnostic work suggested multiple causes for the low grain yield with late plantings, research to develop technology to improve the productivity of the late plantings must focus on several aspects to be effective. These aspects are discussed below.

Diagnostic aspects

There is still much uncertainty about the relative importance of climatic/environmental factors (soil and air temperatures, radiation intercepted, shorter daylength, rainfall/occurrence of water deficit) versus management and inputs (less N and P fertilizer, late weeding, lower plant population density) in reducing the yield of late plantings. Among the several possible climatic factors, determining which are the more important contributors to the reduced grain yield potential is also of concern. The importance of a soil N flush at the start of the season for good yield of early plantings was not examined in this study and it merits attention. Leaching losses of mineralized N may be large on the granitic sands. Experimental work is needed to separate out such effects. For example, a date of planting x rate of N fertilizer trial could check the N flush and N leaching losses.

The degree to which resource constraints (such as insufficient fertilizer and labour), versus a deliberate decision by farmers to reduce management of late planted crops because of reduced yield potential, cause compromised management of late plantings, needs assessing. This can be done through interviews with farmers.

Technology generation and testing

Maize germplasm. Since around 150,000 ha of maize are planted late in Zimbabwe to hybrids such as R215 and R201, it may be justifiable to develop and test hybrids (and possibly open-pollinated materials) specifically for late plantings. Such materials probably should have the following characteristics useful for late plantings: 125-135 days to physiological maturity at 1,350 masl to better escape water deficits; ability to emerge from variable seeding depths; tolerance of weedy seedbeds, waterlogging, and low radiation levels; and be more responsive to N and P so that farmers can justify applying more fertilizer to their later plantings (Waddington and Kunjeku 1989).

Inputs and management practices for late plantings. On-farm trials to develop economic amounts and timings of N and P fertilizer for current and for new maize genotypes to be late planted are required. These practices may include use of straight fertilizers rather than compound fertilizers for basal application, amount of topdress N, earlier application of topdress N, and combining fertilizer with weed control. Possible ways of bringing forward the time of first weeding in relation to crop development merit attention, as do ways of reducing the labour requirement for weeding late maize plantings, such as just weeding on the crop row using a hand hoe. Appropriate plant population densities also need attention for new maize materials.

Maintaining and improving soil fertility. Given the dominance of maize in the current farming system, establishment of fixed rotations on more than a minor portion of the arable area and increased intercropping with annual legumes may prove difficult. Groundnuts are the only current possibility for intercropping without changing the crop mix. Modified alley cropping systems of maize with *Cassia spectabilis, Calliandra calothyrsus, Tephrosia candida* or *Leucaena leucocephala* may offer a way of improving soil fertility for late plantings but have yet to be tested on the granite-derived sandy loam soils found in communal areas of Zimbabwe. Similar systems tested on heavier soils in Malawi have been shown to input about 60 kg ha^{-1} N from alley crop prunings per year (and to cycle amounts of P and K as well as to add organic matter) (Bunderson et al. 1991). Areas of uncertainty with such systems relate to the establishment of the legume on sandy soils with a seven-month dry season and cattle, and how to prepare the land with an ox plough and control weeds. Trials over three to five years are needed with smallholder farmers under their conditions to examine benefits from such a technology and how it will fit into the existing cropping system.

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