COMPARISON OF SORGHUM WITH WHEAT AND BARLEY GROWN ON DRYLAND

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Sorghum (Sorghum bicolor Moench ‘Pride P130’), wheat (Triticum aestivum L. ‘Neepawa’), and barley (Hordeum vulgare L. ‘Galt’) were harvested at 1-wk intervals on dryland at Lethbridge, Alberta, in 1976 and 1977 and separated into leaves, stems, heads, and seed. Whole-plant yields were higher in 1976 than in 1977 and sorghum whole-plant yields were higher than barley or wheat in both years. Sorghum grain yields were similar to those of barley, but were greater than those of wheat. Although sorghum is about 40 days later maturing than barley or wheat, its whole-plant and filling-period durations were not very different from the other two crops. Sorghum used water more efficiently than wheat or barley under drought conditions. The biggest disadvantage of present sorghum hybrids appears to be slow growth in spring.


Early cultivars of sorghum (Sorghum bicolor Moench) such as Pride P130 appear to be adapted to those regions in the southeast corner of Alberta that have at least 2200 corn heat units (Major et al. 1976). Since this region also happens to be the driest part of the province, sorghum’s tolerance of drought stress (Sanchez-Diaz and Kramer 1971; Beadle et al. 1973) also suggests that it may be suited to this area of Alberta.

Water-use efficiency, measured as yield produced per unit of water used, is a useful measure of crop performance at low soil moisture availability and, apparently, increases as stored soil moisture increases (Brown and Shrader 1959). Water-use efficiency for sorghum in southern Alberta is highest at low population densities and narrow row spacings (Hedge et al. 1976).

Although estimates of water-use efficiency in the literature (Grimes and Musick 1960; Porter et al. 1960; Olson 1971; Hegde et al. 1976) are generally higher for sorghum than for barley (Hobbs and Krogman 1974; Singh and Ramakrishna 1977; Sepaskhah 1978) or for wheat (Hobbs and Krogman 1974; Singh and Ramakrishna 1977; Thill et al. 1978), direct comparisons are rare. Barley apparently has higher water-use efficiency than wheat (Hobbs and Krogman 1974; Singh and Ramakrishna 1977) and sorghum is a more efficient user of water than corn (Olson 1971).
As an alternative crop to temperate cereals in southern Alberta, sorghum would offer market advantages in addition to drought tolerance because it could replace corn in feed rations and as a distilling grain. Additional information is required on how sorghum grows in southern Alberta, however, to decide if it is a viable alternative to spring wheat or barley. Growth analyses have been used by Kebede (1976) and Gibson and Schertz (1977) to study sorghum growth and have been used at Lethbridge on rape and corn (Major 1977a,b) to obtain information on how these crops grow under irrigation in southern Alberta.

Therefore, the objective of this study was to compare rates and duration of growth and water-use efficiencies of sorghum, wheat, and barley on dryland.

MATERIALS AND METHODS
Sorghum (Sorghum bicolor Moench 'Pride P130'), spring wheat (Triticum aestivum L. 'Neepawa'), and barley (Hordeum vulgare L. 'Galt') were grown on a Chernozemic Orthic Dark Brown Lethbridge silty clay loam at the Lethbridge Research Station. These three cultivars are commonly grown in southern Alberta. The plots, 40 rows each, 6 m long and 0.23 m apart, were seeded on 13 May 1976 and 3 May 1977 using a randomized complete block design with four replicates.

The plot land had been fallowed the previous summer and was fertilized with 26-13-0 broadcast at 224 kg/ha in 1976 and 240 kg/ha in 1977 and incorporated using disc and harrow before seeding. Seeding rates were 10 kg/ha for sorghum and 60 kg/ha for barley and wheat. The number of tillers with heads at maturity for sorghum, barley, and wheat were 60, 410, and 310/m² in 1976 and 15, 180, and 250/m² in 1977. Bromoxynil sprayed at 0.56 kg/ha post-emergence and periodic hoeing gave good weed control.

A sample of plants was taken weekly from 1 m of two rows of each species from 15 June 1976 and 7 June 1977 until maturity. Plants were separated into green leaves, stems, and heads, dried at 70°C for 5 days, and weighed. Heads were then threshed and the seed weighed. As the season progressed, the samples became too large to separate entirely so the fresh weight of the whole sample was measured and a subsample of at least 10 plants was weighed, separated into component parts, dried, and reweighed. These data were used to estimate the distribution of dry weight in leaves, stems, heads (panicles or spikes) and seed of the fresh weight sample.

The means and standard errors of the weight of each plant component were calculated for each sampling date and a three-point moving mean of the dry weights was calculated for graphic presentation of the data. Whole-plant growth rates (expressed as kg/ha/day) were estimated for the period of linear dry matter accumulation, and divided into final yield to determine effective duration of the crop. This was called effective whole-plant duration (EWPD). Similarly, grain yields were divided by grain growth rates to obtain estimates of the effective filling period duration (EFPD). This technique has been described in detail for the filling period of corn (Daynard et al. 1971).

Soil moisture was monitored at depths of 23, 46, 75, and 105 cm each week, using a Nuclear Chicago Model 5810 neutron probe in each of the plots. The soil had a field capacity of 23% by weight and a permanent wilting point of 13%. The water table was at a depth of about 3 m.

Analysis of variance was used to compare soil moisture content for the three species with species as mainplot, depth as subplot, and sample date as sub-subplots. Between any two sampling dates, evapotranspiration was estimated by adding rainfall to the reduction in soil moisture content. Water use efficiencies were calculated by dividing whole-plant or grain yields into total evapotranspiration.

RESULTS
Whole-plant yields were higher in 1976 than in 1977 for all three species (Table 1) but grain yields were slightly higher for sorghum and barley in 1977 than in 1976. Sorghum whole-plant and grain yields were significantly higher than wheat in both years.

The seasonal pattern of whole-plant dry weight accumulation was similar for wheat and barley but sorghum growth started later and continued later in the season (Fig. 1). In 1976, whole-plant growth of barley and wheat levelled off about 1 Aug. and, in 1977, about 15 July for barley and 15 Aug. for wheat. Whole-plant growth of sorghum
Fig. 1. Seasonal changes in dry weight of plant components and standard errors of whole plant dry weights for sorghum (x—x), wheat (o—o), and barley (•—•) in 1976 and 1977.
Table 1. Yields and growth rates for whole-plant and grain and effective duration for the whole-plant and filling period of sorghum, wheat, and barley grown at Lethbridge, 1976 and 1977

<table>
<thead>
<tr>
<th>Species</th>
<th>Yield (kg/ha)</th>
<th>Growth rate (kg/ha/day)</th>
<th>Effective duration (days)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Whole-plant</td>
<td>Grain</td>
<td>Whole-plant</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1976</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P130 sorghum</td>
<td>9266a</td>
<td>3940a</td>
<td>144.6a</td>
</tr>
<tr>
<td>Neepawa wheat</td>
<td>7440b</td>
<td>3098b</td>
<td>169.6b</td>
</tr>
<tr>
<td>Galt barley</td>
<td>7328b</td>
<td>3331ab</td>
<td>128.5ab</td>
</tr>
<tr>
<td>1977</td>
<td>8271a</td>
<td>4294a</td>
<td>163.5a</td>
</tr>
<tr>
<td>P130 sorghum</td>
<td>5061b</td>
<td>2623b</td>
<td>70.4b</td>
</tr>
<tr>
<td>Neepawa wheat</td>
<td>6537ab</td>
<td>3834a</td>
<td>149.4a</td>
</tr>
</tbody>
</table>

a-b Within columns and years, means followed by the same letter do not differ (P = 0.05) using Duncan’s new multiple range test.

The continued growth of sorghum after whole-plant growth stopped, particularly in 1977, suggests that carbohydrates were translocated from other plant parts to the filling period (EFPD) was the same for the three species in 1976, but longer for sorghum than barley in 1977. Barley had a higher grain growth rate than sorghum in 1977, but, because of a shorter filling period, grain yield was not significantly lower.

Precipitation for May, June, and July was 85 and 55% of the 30-yr average (173 mm) in 1976 and 1977, respectively, and 95 and 78% of the 30-yr average for May through September (249 mm) in the 2 yr, respectively. The initial soil moisture readings indicated 334 and 297 mm in 1976 and 1977 in the top 1.22 m of soil. Seasonal evapotranspiration paralleled growth, with peak use occurring when the respective species were heading (Table 2). There was no interaction between species and soil moisture content at the four depths measured. In 1977, evapotranspiration rates declined in July and remained low until near maturity. The slight increase in evapotranspiration rates in August 1977, as a result of 80 mm of rainfall, was accompanied by an apparent resumption of growth in sorghum and barley.

**DISCUSSION**

The continued growth of kernels of sorghum after whole-plant growth stopped, particularly in 1977, suggests that carbohydrates were translocated from other plant parts to the filling period.
Table 2. Evapotranspiration (ET) and water-use efficiency for whole-plant and grain of sorghum, wheat, and barley grown at Lethbridge, 1976 and 1977.

<table>
<thead>
<tr>
<th>Date</th>
<th>P130 sorghum</th>
<th>Neepawa wheat</th>
<th>Galt barley</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 May–9 June</td>
<td>0.92</td>
<td>1.43</td>
<td>1.47</td>
</tr>
<tr>
<td>10–22 June</td>
<td>0.91</td>
<td>2.78</td>
<td>3.63</td>
</tr>
<tr>
<td>23 June–6 July</td>
<td>3.87</td>
<td>4.48</td>
<td>4.10</td>
</tr>
<tr>
<td>7–20 July</td>
<td>3.87</td>
<td>4.48</td>
<td>4.10</td>
</tr>
<tr>
<td>4–17 Aug.</td>
<td>4.04</td>
<td>3.25</td>
<td>2.22</td>
</tr>
<tr>
<td>18–31 Aug.</td>
<td>4.34</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>1–27 Sept.</td>
<td>1.93</td>
<td>–</td>
<td>–</td>
</tr>
<tr>
<td>Total (mm)</td>
<td>332.60</td>
<td>282.30</td>
<td>260.10</td>
</tr>
</tbody>
</table>

Whole-plant efficiency (kg/ha/mm)  
1976: 27.9  26.4  28.2  
1977: 11.8  26.4  12.8  

Grain efficiency (kg/ha/mm)  
1976: 1.02  2.68  3.33  
1977: 2.06  2.94  3.27  

the kernels. Translocation has been observed previously for sorghum (Gibson and Schertz 1977). Translocation was not apparent in this study for wheat or barley (Fig. 1). Thorne (1965) concluded that there was no mobilization and translocation of carbohydrates for kernel growth of wheat or barley, that carbohydrates came from current photosynthesis, and that all new photosynthetic matter was translocated to the kernels. In this study, wheat and barley appeared to reach maximum leaf and stem weight and then all dry matter production must have been diverted to kernel growth, as suggested by Thorne (1965). Although the calculated grain growth rate of wheat was higher than the whole-plant growth rate in 1977, the two growth rates were calculated over different times (15 June–15 Aug. for whole-plant and 15 July–15 Aug. for grain). The results presented in Fig. 1 suggest that in wheat, there was no evidence that kernel growth was at the expense of other tissues.

The whole-plant and grain yields and growth rates obtained in this study showed that sorghum is similar to wheat or barley, the two most important dryland crops in southern Alberta. The most obvious difference among the three crops was the long lag in sorghum between seeding and the onset of rapid dry matter accumulation. In spite of this, however, the EWPD and EFPD did not differ greatly among the three crops. The EFPD values obtained in this study were not unlike those reported by Daynard et al. (1971) for corn, but the EWPD values were higher than the crop duration values reported by Hobbs and Krogman (1974) for wheat, oats, and barley. However, their values of 117 days and 99 days for wheat and barley were from planting to maturity, which was similar to the crop duration of wheat and...
barley in this study. The average EWPD values were 67 and 50 days for wheat and barley, 50 days shorter than the time from planting to maturity. Of these 50 days, there were about 40 days between planting and the onset of rapid dry matter accumulation, and about 10 days between the time when maximum kernel dry weight had been reached and when maturity was recorded. Sorghum water-use efficiency for grain production was only slightly greater than that of barley, which, in turn, was greater than that of wheat in 1977, but differences were small in 1976. The difference may simply be due to the fact that sorghum was able to make use of the rainfall received in August 1977, whereas wheat and barley were very close to maturity. Efficiency of all three species was higher in 1977 than in 1976 and this may have been related to the lower consumption, since Blum and Naveh (1976) found that as interplant competition increased and plant water availability decreased, sorghum became more efficient in its use of water. On the other hand, Brown and Shrader (1959) found that water-use efficiency increased as stored soil moisture increased. In their study, however, moisture stress may have been greater during the seed-filling period since the evaporation demand in Kansas is much greater than in Lethbridge.

Consumptive use of water has been reported to be related to crop duration (Pojhakas et al. 1967) and this was the case in this study in 1976, and for sorghum and barley in 1977. However, water use by wheat was very low in 1977 compared to its long EWPD of 72 days.

Stout and Simpson (1978) found that sorghum avoided drought by decreasing the leaf osmotic potential and by leaf senescence. In this study, 30% of the leaves of sorghum senesced after the beginning of August in the wetter year of 1976 compared to 55% in 1977. Leaf senescence for wheat was 37 and 50% and for barley was 52 and 48% in 1976 and 1977, respectively. This avoidance mechanism was, therefore, apparent in sorghum and wheat but not in barley, because it had the same percentage each year.

This study revealed that sorghum has an EWPD and an EFID the same length as, or only slightly longer than, those of wheat or barley but has similar growth rates and therefore has the potential to produce yields equal to barley or wheat. In addition, sorghum has water-use efficiency similar to wheat or barley. The primary disadvantage of sorghum is the long lag period in the spring before rapid growth begins, but despite this, it still appears to have sufficient merit to justify its incorporation as an alternate cash crop in the dryland agriculture of southern Alberta.


KEBEDE, Y. 1976. Growth and yield of


