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Technical Bulletin 1987-2E

Sorghum and Sudangrass on the Prairies

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D.J. MAJOR
Crop Physiologist
Agriculture Canada Research Station
Lethbridge, Alberta

H.H. JANZEN
Soil Scientist
Agriculture Canada Research Station
Lethbridge, Alberta

D.A. GAUDET
Plant Pathologist
Agriculture Canada Research Station
Lethbridge, Alberta

Lethbridge Research Station Contribution No. 10

Research Branch
Agriculture Canada
1987

Copies of this publication are available from:
Dr. D.J. Major
Plant Science Section
Research Station
Research Branch, Agriculture Canada
Lethbridge, Alberta
T1J 4B1

Produced by Research Program Service

Cat. No. A54-8/1987-2E
ISBN 0-662-15134-8

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SUMMARY

Grain sorghum (Sorghum bicolor L.) was evaluated as a new crop on the southern Prairies because of its reputation as a drought-tolerant crop. Dates of seeding, row spacing, stand density, fertility, dates and herbicide efficacy, diseases, methods of harvesting, and other agronomic studies were conducted. Under dryland conditions, sorghum had no better drought resistance than wheat and yields were not high enough to compete with conventional cereals. A need for breeding early, higher-yielding hybrids with resistance to seedling blight is indicated, and would require a heavy resource commitment to a high risk research venture. Sorghum-sudangrass (S. sudanese [Piper Stapf.]) hybrids appear to have a place as a dryland and irrigated forage crop on the southern Prairies.

RESUME

Le sorgho grain (Sorghum bicolor L.) a été évalué comme culture éventuelle dans le sud des Prairies en raison de sa réputation de tolérance à la sécheresse. On a conduit des essais sur les dates de semis, l'écartement des lignes, la densité de peuplement, la fertilisation, les traitements herbicides, les maladies, les méthodes de récolte, ainsi que sur d'autres caractères agronomiques. En culture sèche, le sorgho n'a pas démontré une meilleure résistance à la sécheresse que le blé et ses rendements n'ont pas été assez hauts pour lui permettre de faire concurrence aux céréales classiques. On se trouve devant la nécessité de sélectionner des hybrides précoces, plus productifs et possédant de la résistance à la brûlure (fonte) des semis et, par ailleurs, les ressources à engager dans les recherches seraient considérables en regard des chances de succès. Les hybrides sorgho-soudan (S. sudanense (Piper Stapf.)), en revanche, semblent offrir des possibilités pour cette région, tant en culture sèche qu'en régime irrigué.

INTRODUCTION

Grain sorghum (Sorghum bicolor L.) is a potential alternative to traditionally grown cereal and forage crops in southern Alberta because of its C4-dicarboxylic acid photosynthetic pathway, which is believed to enhance adaptation to environments where water limits growth. Where sorghum is commonly grown, practical experience indicates that sorghum exhibits more drought resistance than most other crops (18).

This report represents the culmination of 15 years of research at Lethbridge to assess the potential of sorghum in southern Alberta. It began with the selection of early sorghums from CIMMYT and, ultimately, early hybrids such as Pride P130 and Northrup King X8102. Studies were conducted on row spacings and densities (6), growth analysis (11), comparisons with other crops (7, 11), photoperiod responses (10), feeding value (1, 2), the effect of chilling temperatures on sorghum growth (12) and, most recently, the role of pathogens in stand establishment of sorghum (4, 5).

Throughout these studies and in on-farm experiments in southern Alberta, stand establishment has been a problem. This has also been alluded to in many other studies. Ross and Webster (18) stated that the top 5-cm soil temperature should be about 20°C before seeding. Gaudet and Major (5) found that pathogenicity of seed-borne Pseudomonas and seed- and soil-borne fungi is increased by exposure to low temperatures. Consequently, the future of sorghum in the short-season regions ultimately depends on the selection of sorghums resistant to seedling blight (Pseudomonas syringae). A concentrated breeding effort is required to accomplish this.

The results of the current study indicate that, even when successfully established, sorghum yields may not be high enough to compete economically with wheat. The hope that sorghum would have higher drought resistance than wheat has not been realized. Rather, the ability of sorghum to thrive in arid conditions would appear to be related more to heat tolerance than to drought resistance (16). A breeding program might also be aimed at achieving a higher water-use efficiency.

SORGHUM TYPES

Sorghum and sudangrass (Sorghum sudanense [Piper Stapf]), close relatives of corn and sugar cane, evolved in Ethiopia and the Sudan. They are widely grown in the southern U.S. (Nebraska south to Texas), northeast Africa, and India. Grain sorghums usually have dwarf genes associated with them so they only grow about 1 meter tall, whereas forage sorghums have no dwarf genes and grow to a height of about 2 meters. Three types are used for forage: forage sorghum, sudangrass, and sorghum-sudangrass hybrids. Forage sorghum has the highest dry matter yield under irrigation, but sudangrass, and sorghum-sudangrass hybrids are better on dryland.

Initial research at Lethbridge was concentrated on dryland grain sorghum. This was aimed at developing early maturing sorghum cultivars and hybrids, a goal which was accomplished in less than 10 years.

GROWTH HABITS AND ADAPTATION

A major problem with sorghum production in southern Alberta is the poor stand establishment that results from reduced germination, emergence, and seedling growth at chilling temperatures. Sorghum requires a minimum soil temperature of 8-10°C for germination, while the optimum temperature is 24-28°C. The minimum temperature for seedling emergence is 10-12°C but a dramatic increase in percentage emergence occurs at temperatures above 20°C.

In southern Alberta, soil temperatures after early seeding are generally less than 15°C and, hence, limit germination and emergence. Consequently, early seeding to make use of the whole growing season may not necessarily be a good practice. Due to low soil temperatures, germination and seedling emergence are delayed, thus increasing the risk of seed decay and leaving the emerging seedling vulnerable to soil-borne disease. Further, prolonged exposure to chilling temperatures can kill sorghum seedlings. However, at locations in high latitudes such as Lethbridge, delaying seeding to allow the soil to warm increases the risk of frost before maturity.

In order to assess the effects of short-duration chilling temperatures, an early maturing sorghum (Pride P130) was grown in a greenhouse with day/night temperatures of 23/18°C and transferred to a controlled environment chamber with day/night temperatures of 13/8°C for 3-, 7-, or 10-day periods starting at seedling emergence and continuing to maturity (12). Reductions in leaf number and plant height caused by chilling temperatures were only temporary. Chilling temperature 28 days after emergence caused tiller numbers to increase from three to as many as eight per plant.

Most of the tillers appeared in a 14-day period starting about 10 days after emergence (Fig. 1). Exposure to chilling temperature during the short period when the plants were reaching maximum tiller number promoted tillering. The maximum enhancement of tillering occurred at about day 28, when all of the tillers were visible in the control treatment. Exposure to chilling temperatures caused the production of about two, five, or four additional tillers for the 3-, 7-, and 10-day exposures. This is consistent with previous reports that tillering response of sorghum to chilling treatment is dependent on the plant's age.

To determine if above-freezing temperatures affected emergence, P130 sorghum and Pride 1108 corn were planted in sand and left for 3 days in the greenhouse. The flats were exposed to 0.5°C, 5°C, or 10°C for various lengths of time and then returned to the greenhouse. The percentage of seedlings killed at the three temperatures indicated that Pride 130 sorghum was much more sensitive to cold temperature exposure than Pride 1108 corn. Figure 2 demonstrates how the percentage of seeds that germinate increases from zero at about 4°C to 98% at 14°C and how the time to germinate decreases from 7 days to less than 1 day. Other experiments clarified the role of low temperatures on emergence. Low temperatures per se are not a problem but they do reduce the vigour of the sorghum seedling and its ability to resist soil- and seed-borne pathogens. Thus, there was no physiological damage or chilling injury due to low temperatures so reduced emergence was the result of a number of factors such as inability to overcome soil impedence and to withstand soil-borne pathogens and the infection of _Pseudomonas syringae_.

USES

Grain

Grain sorghum is not currently recommended for Alberta but there have been situations in which it has been produced. Sorghum is a coarse grain with nutritional characteristics very similar to those of corn. However, it generally does not command as high a price as does corn. The consumption of grain corn is primarily in two distilleries (52 000 tonnes) and in feed manufacturing (18 000 tonnes). The sorghum used in feed would likely be mainly in poultry feed. The grain used for distilling is used for producing whiskey, gin, and vodka and for other commercial alcohol uses.

Forage

Forage sorghum trials have been conducted at Lethbridge, Brandon, Morden, and Ottawa since 1980. A summary of these trials indicated that forage sorghums will provide a competitive alternative to the cereals for dryland forage production on the southern Prairies (Table 1).

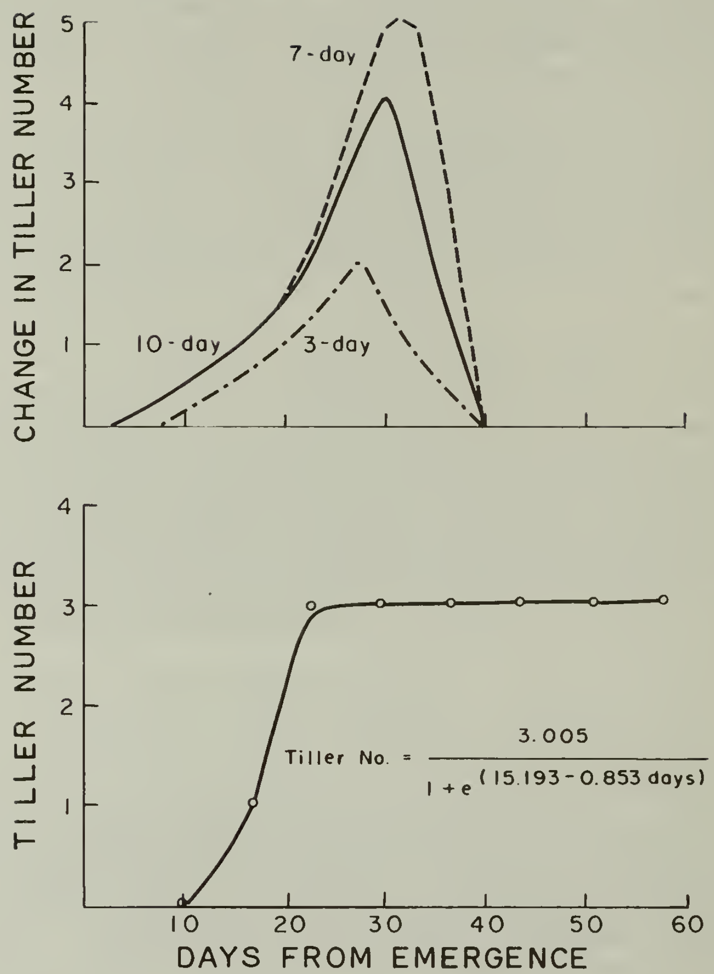

Fig. 1. Non-linear regression analysis of tiller number (excluding the primary tiller) vs. days from seedling emergence and changes in tiller number caused by the chilling temperature vs. days from seedling emergence for Pride P130 soybeans.

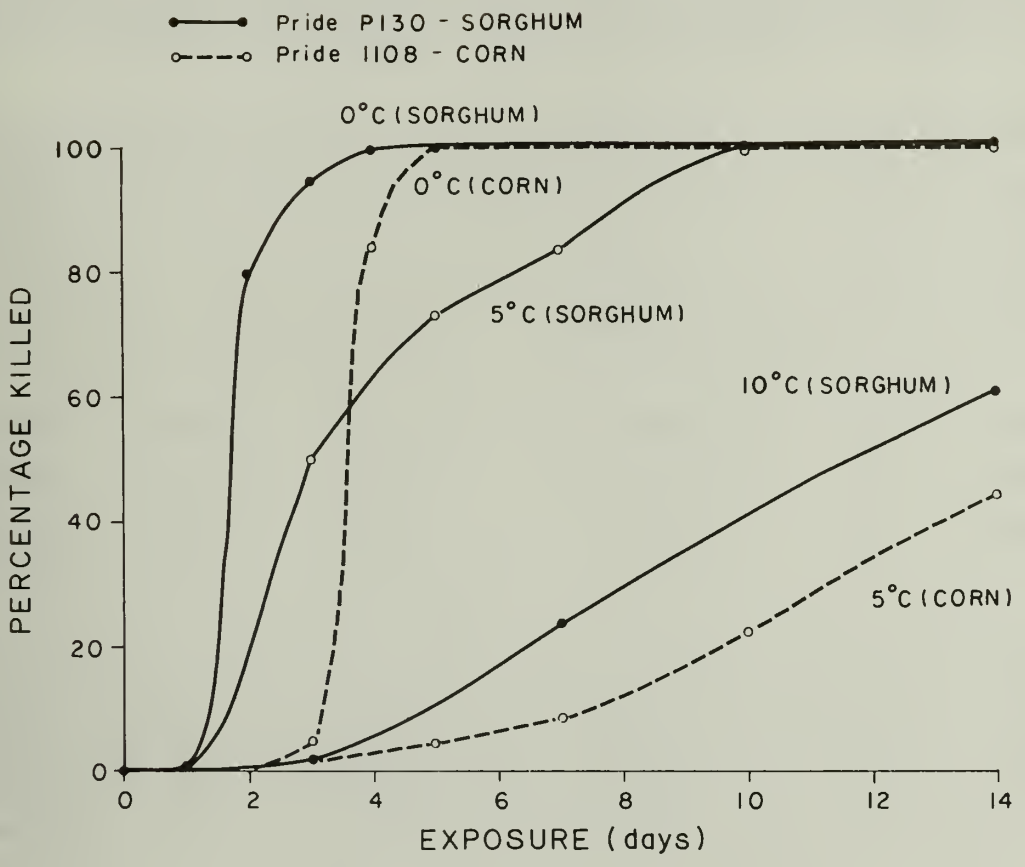

Fig. 2. The effect of length of exposure to various temperatures after germination but prior to emergence on percentage of seedlings of Pride P130 sorghum killed at 0, 5, and 10°C and of Pride 1108 corn killed at 0 and 5°C.

Table 1. Average performance of selected forage sorghums (FS), sorghum-sudangrass (SS) hybrids and sudangrass (SG) at Morden, Brandon, Ottawa, and Lethbridge from 1978-1984.

Year/Hybrid	Type	Lethbridge	Brandon	Morden	Ottawa
		------ tonnes/ha ------			
1980					
Pioneer 988	SS	4.39			16.4
Pride PF70	FS	5.22			15.3
Pioneer 931	FS	5.12			16.6
Pioneer 988	SS	4.39			16.4
Trudan	SG	4.33			11.7
1981					
Pride PF70	FS	6.69	11.98	14.08	19.85
Pioneer 931	FS	7.01	7.87	12.10	17.41
Pioneer 988	SS	5.77	8.93	9.33	12.64
Sordan	SG	6.12	10.48	10.02	12.38
1982					
Pride PF70	FS	7.85	7.18		16.59
Pioneer 931	FS	8.40	9.13		16.89
Pioneer 988	SS	8.24	8.60		13.52
Sordan	SG	8.68	7.24		10.43
1983					
Pride PF70	FS	9.61	12.79	7.62	13.55
Pioneer 931	FS	9.80		6.21	14.86
Pioneer 988	SS	8.29	14.77	4.54	12.03
Sordan	SG	7.59	16.61	4.88	11.81
1984					
Pride PF70	FS	4.57	7.20	16.34	18.14
Pioneer 931	FS	4.61	12.60	21.12	16.82
Pioneer 988	SS	3.92	9.60	15.62	14.28
Sordan	SG	3.43	12.16	16.00	11.20

The combination of fall rye followed by sorghum-sudangrass is ideal for double cropping where irrigation is available. The fall rye heads out in late May and is ready to harvest for silage by the third week of June. This is followed immediately by seeding sorghum-sudangrass, which is harvested in late August or early September. Yields of double cropping have been similar to yields of maize grown at Lethbridge (Table 2). There are still some difficulties such as slow growth of sorghum immediately following the rye harvest. Additional research is required to determine the cause of this.

Table 2. Component yield of various crops grown in double cropping and of maize grown under irrigation at Lethbridge in 1984-86.

	Crop		
Year	Winter cereal	Sorghum-sudangrass	Maize
	tonnes/ha		
1983-84	7.0	8.1	12.7
1984-85	4.3	6.7	13.5
1985-86	8.7	7.9	17.9

Prussic acid poisoning mainly occurs when livestock are fed green-chop sorghum-sudangrass or are pastured on young sorghum or regrowth. It is caused by dhurrin, a cyanogenic glucoside, which hydrolyzes to form the respiratory poison, hydrogen cyanide, when ingested by animals. A 450-kg cow will be killed by 1 gram of hydrogen cyanide, which could be present in less than 2 kg of plant material. Most sudangrasses have been bred for reduced levels of dhurrin but there are circumstances in which lethal levels may still occur. Young regrowth, particularly after a killing frost, is most dangerous. Nitrogen fertilization increases the levels of dhurrin and levels can also increase when growth is slowed by injury, moisture stress or cold temperatures. A New Zealand study (8) indicated that irrigated crops contained 30-40% less prussic acid than those on dryland. This difference would be magnified in southern Alberta because of our extreme drought on dryland. In a crop containing lethal levels of HCN, cattle will succumb within half an hour. Therefore, in potentially dangerous situations, the feed should be analyzed before free access to the crop is given. Where sorghum green-feed constitutes a major part of the animals' diet, dietary supplementation with sulfur (1.2 g sulfur/g HCN) will detoxify the feed (8). Cutting the crop for hay or silage will result in disappearance of most or all of the dhurrin.

PRODUCTION PRACTICES

Seeding

Sorghum-sudangrass hybrids will produce more dry matter than annual cereals such as barley or oats. The crop should be seeded between 25 May and 15 June. Seeding too early into cold soils can result in poor emergence due to cool soil. Later seeding may not allow enough time for the crop to make maximum growth before frost. The crop should be ready for harvest in late August.

Seeds of sorghums of all types are susceptible to damage in adverse soil conditions, particularly when the soil is cool. Therefore, seeding should not begin until the day-time temperature of soil at 5-cm depth is about 20°C. As a rule of thumb, this will be after 25 May. In a date-of-planting study conducted at Lethbridge, the percentage seeds established increased as planting date was delayed after 15 May. However, yield decreased due to later maturity of late-seeded sorghum. In practice, the most appropriate course of action is to delay seeding. Therefore, a hybrid chosen for seeding in late May must be capable of reaching maturity before fall frost.

To assess the effect of stand on yield, a seeding rate experiment was conducted with P130 in 1980 and P145 in 1981 and 1982. Seeding rates ranged from 5 to 90 kg/ha and the variables measured were stand establishment (plants/m^2) and yield. Population densities increased with seeding rate but the percentage emergence was generally constant (Table 3). The positive relationship between seeding rate and population density decreased in 1982 compared with 1980 and 1981. This reduction may have been due to increased interplant competition at the high seeding rates in 1982. There were essentially no differences in yield in spite of an 18-fold difference in population density. In 1981 and 1982, there were slight reductions in yield at the 5, 10, and 90 kg/ha rates but not at the 15 to 60 kg/ha rates. These results indicated that a seeding rate of about 15 or 20 kg/ha should be suitable in short-season areas.

The relationship between the number of heat units and relative yield was determined from data on the effect of seeding and harvest dates collected at Lethbridge from 1978 to 1982 (13). For the hybrid in question, Pride P145, 2400 corn heat units (CHU) were required to get maximum yield (Fig. 3). Coincident with a reduction in yield was a reduction in test weight. If the crop did not receive sufficient CHU to mature then the seed was light and shrunken. Only the regions around Bow Island and Medicine Hat would have sufficient CHU to allow seeding in late May and still reach maturity. For dryland situations, sorghum-sudangrass hybrids seeded in late May will have extracted most of the available soil moisture by the end of August, in most years. Thus, the main criterion for sorghum-sudangrass is not when grain maturity can be reached but how long it takes the crop to extract all of the available moisture.

Table 3. The effect of seeding rate on final population density and grain yield of P130 (1980) and P145 (1981 and 1982) sorghum grown at Lethbridge, Alberta.

Seeding rate (kg/ha)	Seeding rate (Kernels/ m^2)	Population density ($plants/m^2$) 1980	1981	1982	Yield (kg/ha) 1980	1981	1982
5	24	10.2	14.1	12.0	1409	4400	844
10	47	16.4	25.9	19.6	1709	4754	1080
15	71	29.7	35.2	21.6	1765	5407	1419
20	95	31.1	43.9	34.0	1561	5517	1550
25	118	42.6	55.7	41.0	1590	5579	1634
30	142	52.8	62.1	43.4	1572	5763	1332
40	189	58.6	85.3	52.6	1566	5484	1610
50	236	91.0	96.9	61.8	1731	5353	1284
60	284	106.3	90.2	63.8	1843	4973	1387
90	426	132.1	152.3	87.6	1664	4775	1100
Mean		57.1	66.2	43.8	1641	5201	1324
LSD_{05}		19.1	25.3	4.9	386	591	298

The critical factor in depth of seeding is to place the seed into sufficient moisture for it to emerge before the soil dries out. If seeded 2-3 cm deep in late May, sorghum will emerge in about 7 days. In a depth-of-seeding experiment in 1982 we found that the optimum seeding depth was about 4 cm. At shallower seeding depths, stand establishment was reduced because of soil drying; at deeper seeding depths, poor emergence and stresses introduced by late emergence reduced yield. If the soil is too dry, deeper seeding will be necessary.

Disc drills are preferable to hoe drills in a double cropping system because they appear to place the seed more gently into the soil than hoe drills. Discers are generally not recommended for sorghum, but if they must be used the seeding rate should be increased. To date, the biggest problem has been providing a good seed bed immediately after the harvest of the first crop. An irrigation followed by zero-till seeding into the stubble will give the best results. Forage sorghum should be seeded at 15 kg/ha (about 15 lb/acre), sorghum sudangrass hybrids at 20 kg/ha and

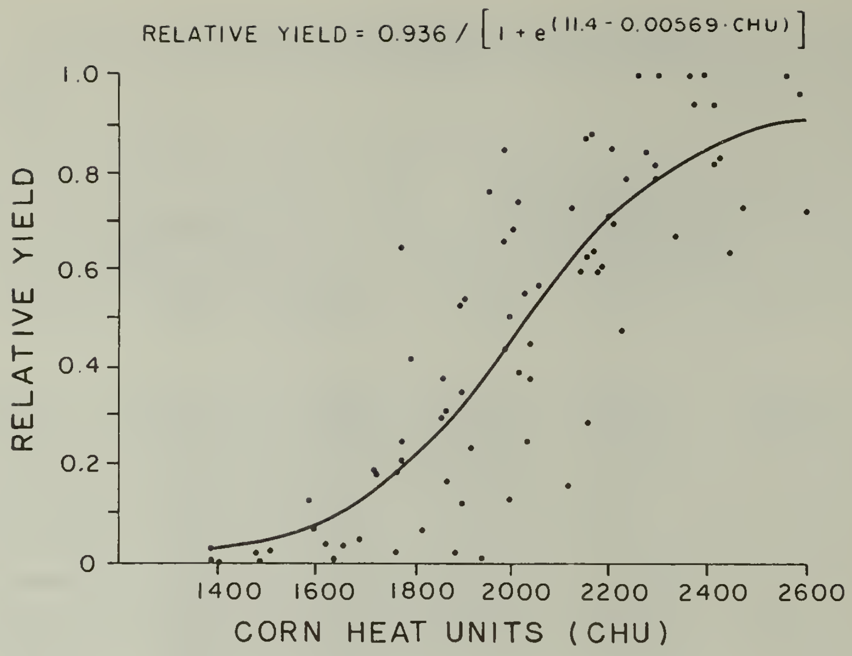

Fig. 3. The relationship between relative yield of sorghum and the number of corn heat units accumulated between planting and harvest for four planting and four harvest dates at Lethbridge in 1978-1982.

Table 4. Effect of row spacing on grain yield and grain yield components of Pride X4004 and Pride X4053 sorghums in experiment 1 and 2, 1973 and in experiment 3, 1974.

Experiment	Hybrid	Row spacing (cm)	Grain yield (kg/ha)	Yield per panicle (g)	Panicles per	
					Plant	m^2
1	Pride X4004	36	2,904a	4.78c	3.52	61.2a
		72	2,444b	4.83c	2.87b	52.4b
	Pride X4053	36	2,150b	7.62b	1.59c	28.4c
		72	2,372b	9.07a	1.54c	27.1c
2	Pride X4004	36	1,799a	2.94c	4.43a	62.6a
		72	1,544ab	2.72c	4.24a	57.9a
	Pride X4053	36	1,321b	4.72b	2.15b	27.9b
		72	1,396b	5.66a	1.82b	24.6b
3	Pride X4004	18	3,808a	6.57a	4.24a	57.6a
		36	3,427a	6.63a	3.87a	51.6a
		72	3,458a	6.73a	3.88a	50.9a

a-c Within columns, within experiments, means followed by the same letter do not differ at the P = 0.05 probability level using Duncan's multiple range test.

sudangrass at 25 kg/ha using a row spacing of approximately 40 cm. For most drills, it is desirable to plug or tape over the openings above every other run to provide wider row spacings. If corn equipment is available, seeding can be done in 75-cm (30") rows with no loss of yield.

Sorghum yields are not generally affected by row spacing. Three experiments were conducted at Lethbridge in 1973 and 1974 to determine the effect of row spacing and plant densities on sorghum yield (6).

The only effect of row spacing on grain yield was in experiment 1, which resulted in higher grain yield for X4004 (Table 4). The yield component results, however, indicated a differential response of the two hybrids X4004 and X4053 to row spacing. As row spacing increased, panicles per plant and panicles per square meter decreased for X4004 but yield per panicle remained unchanged. The hybrid X4053, in contrast, had increased yield per panicle as row spacing increased but panicles per plant and panicles per square meter remained unchanged.

Increased population density had no consistent effect on grain yield in experiments 1 and 3, but in experiment 2 yield increased as population density increased (Table 5). Experiment 2 was on the driest of the three sites. The plants established slowly and were always smaller than the plants in the other experiments at comparable times during the season. In all experiments, as population density increased, panicles per plant decreased but panicles per square meter increased. Yield per panicle decreased with increasing population density in experiments 1 and 3, but there was no significant response in experiment 2.

Significant hybrid X population density interactions were detected for panicles per plant and panicles per square meter in experiment 2. The hybrid X4004 appeared to have a greater capacity to produce seed-bearing tillers at low population densities. No significant interactions of row spacing X population density were detected for yield or its components.

It was evident that tillering capacities of X4004 and X4053 were important in stabilizing grain yields over a wide range of population densities.

On dryland, 75-cm wide rows will allow for some early season competition within the row and conserve the moisture between the rows for late season growth. These wide rows will also allow cultivation of the crop, which has some value in weed control, allowing more uniform infiltration of moisture and aeration of the soil. The disadvantage of wide rows comes at harvest time since the stubble will not support a swath and a corn head may be required for the forage harvester.

The seasonal pattern of sorghum whole-plant dry weight accumulation, studied at Lethbridge in 1976 and 1977, was similar for wheat and barley but growth started later and continued later in the season (Fig. 4). 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 (11).

Whole-plant growth of sorghum continued well into September in both years but the increase was small after 15 Aug. in 1977. Sorghum grain yield increased until 15 Sept. During the period 15 Aug.-15 Sept. of both years, sorghum leaf, stem, and head dry weight decreased. Growth of leaves and stems of barley maximized about 1 July in 1976 and 1977, and only seed yield and whole-plant yield continued to increase. Wheat leaf, stem, and head dry weights stayed the same or decreased after 15 Aug. and 15 July in 1976 and 1977, respectively, while seed dry weight continued to increase.

Whole-plant and grain growth rates were estimated during the linear phase of growth (Fig. 4). Sorghum had significantly higher whole-plant growth rate than wheat but not barley. Grain growth rate did not differ among the three species in 1976 but barley grain growth rate was highest in 1977. In 1976, yields of barley and sorghum were similar because grain growth rates and filling periods were similar. Wheat grain growth rate and filling period tended to be lower than both barley and sorghum, although not always significantly different. Nevertheless, the grain yield of wheat was consistently lower.

Although sorghum matured 40 days later than either wheat or barley, its effective whole-plant duration (58 days) was not significantly greater than that of barley (50 days). The effective filling period duration was the same (31 days) for the three species in 1976, but longer for sorghum (40 days) than for barley in 1977 (26 days). Barley had a higher daily grain growth rate (150 kg/ha) than sorghum (109 kg/ha) in 1977, but, because of a shorter filling period, grain yield was not significantly lower.

Fertility

Sorghums are highly responsive to nitrogen if there is sufficient soil moisture for crop growth as demonstrated by Hobbs and Krogman (7) at Vauxhall. In a double-cropping situation, N should be applied in split applications or with the irrigation system to minimize leaching. On dryland, sorghum should be fertilized in the same manner as cereal crops. For every metric tonne of dry matter per hectare there will be 15 kg of N and 6 kg of P_2O_5 removed from the crop. A 5.6 tonne/ha crop of sorghum hay at 15% moisture translates to 70 kg of N/ha and 30 kg of P_2O_5/ha. For a double crop with a yield of 22 wet tons/ha of fall rye and 27 wet tonne/ha of sorghum, nutrient uptake from the soil will be 200 kg N/ha and 80 kg P_2O_5/ha.

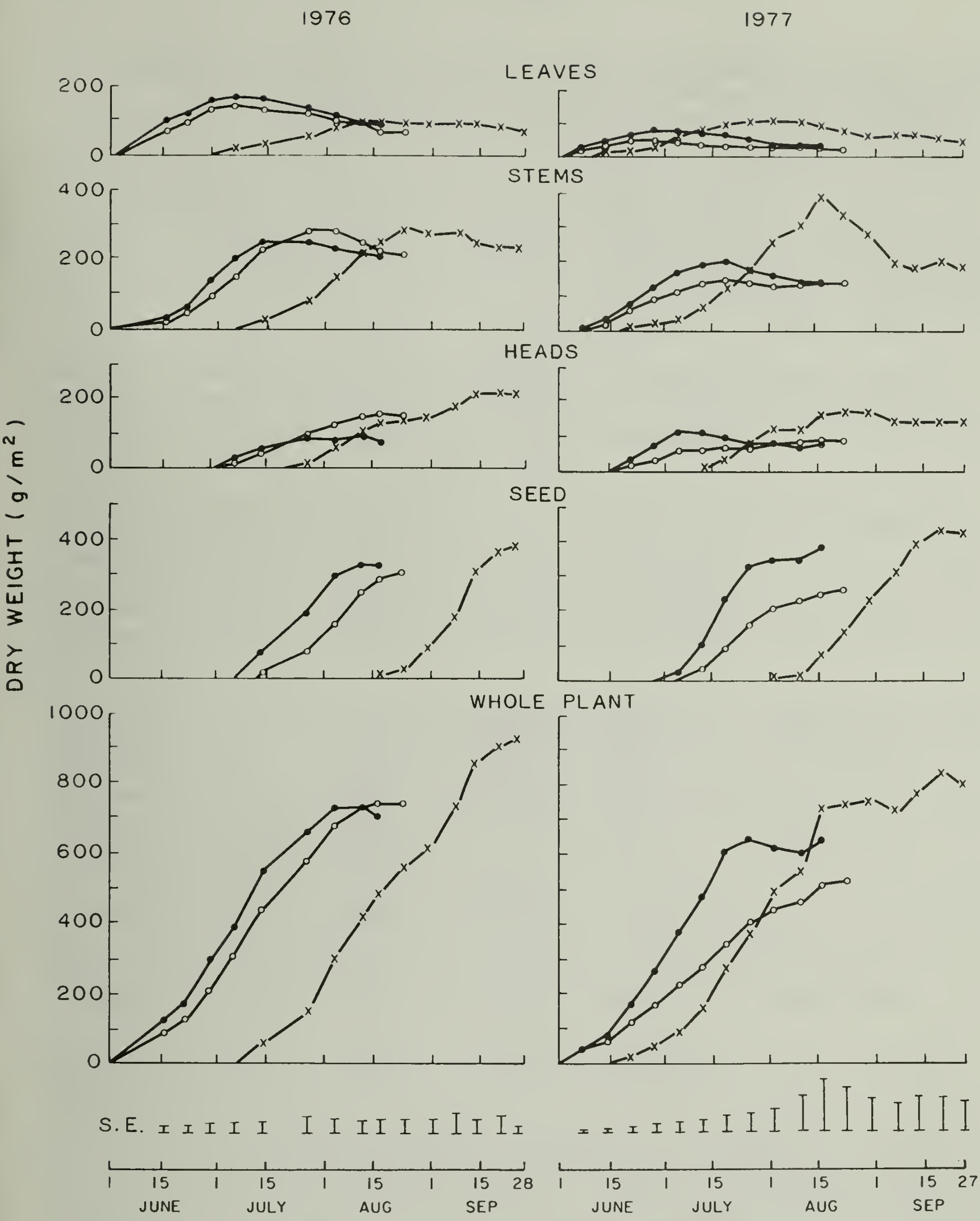

Fig. 4. Seasonal changes in dry weight of plant components and standard errors of whole plant dry weights for sorghum (x——x), wheat (o——o), and barley (●——●) in 1976 and 1977.

Table 5. Effect of population density on grain yield and grain yield components of Pride X4004 and Pride X4053 sorghum hybrids in experiment 1 and 2, 1973 and in experiment 3, 1974.

Experiment	Hybrid	Population density (plants/ha)	Grain yield (kg/ha)	Yield per panicle (g)	Panicles per	
					Plant	m^2
1	Pride X4004	87,000	2,827a	6.25bc	5.19a	44.9b
		173,000	3,009a	5.04cd	3.45b	59.7a
		260,000	2,494a	4.07d	2.34d	60.8a
		346,000	2,366a	3.86d	1.79e	61.9a
	Pride X4053	87,000	2,146a	8.88a	2.78c	24.0d
		173,000	2,299a	9.67a	1.41ef	24.4d
		260,000	2,180a	7.98ab	1.06f	27.5d
		346,000	2,419a	6.86bc	1.02f	35.2c
2	Pride X4004	80,000	1,462abc	3.15b	5.87a	46.5c
		150,000	1,708ab	2.91b	3.94b	58.4b
		240,000	1,846a	2.44b	3.19c	75.7a
	Pride X4053	80,000	1,120c	4.82a	2.98c	23.6d
		150,000	1,343bc	5.38a	1.69d	25.1d
		240,000	1,612ab	5.36a	1.27d	30.1d
3	Pride X4004	75,000	3,677a	7.87a	6.22a	46.7b
		150,000	3,670a	6.11b	3.96b	59.3a
		300,000	3,344a	5.96b	1.80c	54.1ab

a-f Within columns, within experiments, means followed by the same letter do not differ at the P = 0.05 probability level using Duncan's mutiple range test.

Weed Control

Weed control studies to determine if conventional sorghum weed control practices are effective in short-season areas have been conducted at the Lethbridge Research Station. Atrazine is the most effective herbicide but the persistent residue may be of concern. The most consistent weed control is achieved by a fall application of atrazine at a rate of 1 kg a.i./ha. Spring applications without incorporation with a double disc and harrow have not always been successful because of the low, unpredictable rainfall. Other effective herbicide treatments are bromoxynil plus MCPA or 2,4-D up to the 6-leaf stage.

Two major weed problems are Russian thistle, which has some atrazine resistance, and green foxtail. Green foxtail can be controlled in rotation with cereals or by using a pre-plant incorporated treatment of atrazine + metolachlor and a seed safener.

Sorghum growing in short-season areas requires protection from weed infestations for the entire summer as it does not provide enough ground cover to provide competition against weeds even late in the year. The development of early sorghum hybrids should allow delayed seeding to be combined with a late cultivation to control late-emerging weeds. Weed control problems in Alberta are similar to those described by Ross and Webster (18) in Nebraska.

Weeds can be a problem on double cropping but usually both the winter and summer crops, when adequately supplied with water and fertility, provide ample competition to eliminate all weed growth. In some situations, broadleaf weeds such as lamb's quarters and red-root pigweed are a problem in the summer crop. On dryland, Russian thistle, in particular, has been the primary problem.

If a commitment is made to sorghum production then atrazine provides the best and cheapest form of weed control. This should be applied in the fall at the rate of about 2 kg/ha in the first year and then lesser amounts in subsequent years. One application of about 1 kg/ha of atrazine is sufficient to control most weeds.

Atrazine appears to break down in southern Alberta soil at a rate of about 75%/year depending on rainfall. Breakdown will occur when the soil is moist but will be delayed in dry soil. An annual application of atrazine at 1 kg/ha will result in a buildup in the soil so it should only be applied the fall before seeding. An ideal rotation including sorghum is a winter wheat/sorghum/fallow rotation. Atrazine is applied after the winter wheat harvest at 1.5 kg/ha. This provides weed control through the sorghum year and into the summerfallow year. At the time of the sorghum harvest there will be about 0.4 kg/ha of atrazine and when the winter wheat is seeded the following year there will be about 0.1 kg/ha of atrazine.

If atrazine is not used, then herbicides such as 2,4-D and Buctril M will provide control of many broadleaf weed problems.

Diseases

A study conducted to assess the factors influencing seedling emergence (5) showed that the type of soil and seed source affected seedling emergence. Autoclaving the soil to kill soil-borne organisms resulted in higher emergence at 15/5°C regime (Table 6) compared with unautoclaved soil. Cornell mix, which is a greenhouse mixture of equal parts of sand, peat, and vermiculite, was very porous and caused less impedance to the seedling than did soil. In this study, two soil-borne organisms, *Fusarium tricinctum* and *F. oxysporum*, were used to inoculate soil planted to disease-free seed. It was clear from these results that the capacity of soil-borne fungi to infect sorghum seedlings was enhanced at low temperatures. This explains why only about 30% of the seed emerges when the crop is seeded in early May and about 90% emerges when it is seeded in early June. Another pathogen infects the flower at heading time and it may also be involved in reduced seed set, shrivelled seeds and low test weight. Infected seed will also exhibit reduced vigour and lead to poor emergence of the following crop.

Table 6. The combined percent emergence of three sorghum cultivars grown in two autoclaved rooting media at 30/20°C and 15/5°C day/night temperatures when inoculated with *Fusarium oxysporum* and *F. tricinctum*.

	Percentage emergence	
	30/20°C	15/5°C
Rooting medium		
Cornell mix	94a	70a
Lethbridge loam soil	78b	40b
Isolate		
Check	90a	82a
F. oxysporum (No. 1)	93a	46bc
F. oxysporum (No. 2)	79a	57b
F. tricinctum	82a	35c

a-c Means within columns and within treatments followed by the same letter did not differ at the $P = 0.05$ probability level using Duncan's Multiple Range Test.

Table 7. Percentage germination, root and shoot length, percentage discoloration, and incidence of *P. s. syringae* in surface-sterilized and unsterilized sorghum seedlots.

Seedlot	Treatment†	Germination‡ (%)	Root length (mm)	Shoot length (mm)	% of seedlings with Discoloration	*P. s. syringae*
CL-12	US	99	24**§	12**	10++¶	21++
CL-12	SS	100	32	18	2	9
CL-16	US	83	28**	13**	31++	67++
CL-16	SS	82	45	30	13	15
X8101	US	92	28**	21**	32	47++
X8101	SS	96	47	29	22	0
P145	US	78	32	19	35++	51++
P145	SS	78	34	21	11	19
LB	US	59++	18	14	n.d.#	62++
LB	SS	78	20	16	n.d.#	11
F-1 (1983)	US	75	21	9	30+	8
F-1 (1983)	SS	77	22	8	18	6
F-1 (1984)	SS	18	15	6	5	61++
F-1 (1984)	US	18	18	8	16	27
F-2	US	46	25	14	32	26+
F-2	SS	29	26	15	35	10
F-3	US	76	23	8	26	18
F-3	SS	83	26	12	13	12
100M	US	100	42	22	0	0
100M	SS	98	45	20	0	0

†SS = surface sterilized, US = unsterilized.
‡A seed was considered germinated if extension of the coleoptile and/or coleorhiza was observed.
§Means within lots significantly different at *, P = 0.05 and **, P = 0.01 using analysis of variance.
¶Means within lots significantly different at +, P = 0.05 and ++, P = 0.01 using chi-square test for homogeneity.
#n.d. = no data

A seed-born bacterium, Pseudomonas syringae pv. syringae (P. s. syringae), was identified as a cause of stunting and discoloration of the roots and coleoptiles of sorghum seedlings (4). The incidence of P. s. syringae in nine lots of field-grown sorghum seed (Table 7), produced in 3 different years in southern Alberta, varied from 8 to 67% (average = 38%). Surface sterilization of seed with 10% sodium hypochlorite reduced stunting and necrosis of root and shoot tissues from hand-harvested, but not from mechanically harvested, seedlots. This indicated that the bacteria were internally borne within the seed of mechanically harvested seeds and on the surface of hand-harvested seedlots. Internal infection of the seed by P. s. syringae may be promoted by mechanical damage to the seed which occurs during harvesting. Sorghum seedlings from seed inoculated with strains of P. s. syringae developed stunted and discolored roots and coleoptiles when placed on moist filter paper and yielded fewer emerged seedlings than uninoculated controls when sown in autoclaved or untreated field soil in a growth chamber. Strains of the pathogen differed markedly in the severity of symptoms produced in sorghum seedlings.

However, there is still a problem with disease. Due to its susceptibility to cold temperatures, sorghum can be infected by soil- and seed-borne pathogens that seriously reduce emergence.

Crop Rotation

Agriculture in the nonirrigated areas of southern Alberta is primarily limited to cereal production because of low precipitation (400 mm per year) and a short growing season length (117 frost-free days). This virtual monoculture production system results in excessive reliance on summerfallowing, overdependence on economic returns from single crops, and reduced opportunity for weed and pest control. Consequently, the introduction of new crops and diversification of cropping systems would potentially provide both economic and agronomic benefits to southern Alberta agriculture.

Thus, while the potential to develop sorghum hybrids to reach maturity in southern Alberta has been demonstrated (10) and many of the production practices such as dates of seeding, rates of seeding, and row spacing have been defined (6, 13), the agronomic and economic feasibility of sorghum production as an integral part of dryland agriculture in the southern Canadian Prairies has not been adequately considered. Therefore an intensive long-term rotation experiment was conducted from 1978 to 1984, to determine the response of sorghum in rotation with other crops grown in southern Alberta (9).

Sorghum yields ranged from 1161 to 2474 kg/ha in the various rotations averaged over the 5-year period (Table 8). Highest yields were observed when sorghum followed fallow in the rotation, regardless of rotation length. Significantly lower sorghum yields were observed in 3-year rotations where sorghum followed spring or winter wheat. Still lower yields were observed when sorghum succeeded sorghum and lowest yields occurred when sorghum followed barley in the rotation. The high yields observed after fallow were probably almost entirely attributable to greater availability of moisture. The relatively good performance of sorghum after winter wheat may be partially the result of a disease outbreak in the winter wheat during 1981 which required plowing down of the winter wheat in midseason and resulted in a partial fallow period prior to sorghum establishment. The relatively low yields observed in the continuous sorghum and sorghum-barley rotations were attributed to increased infestation of weeds such as Russian thistle and kochia. On average, the ratio of yield on stubble to yield on fallow was 0.63 for sorghum and 0.69 for spring wheat. The number of crops preceding the fallow year had no effect on sorghum yield after fallow as is evident in the comparable sorghum yield for rotations S-SW-F and S-F (Table 9).

Table 8. Effect of the preceding crop on the yield of sorghum in a study comparing six sorghum rotations grown at the Lethbridge Research Station (1978-1984).

Rotation†	Preceding crop	Sorghum yield‡ (kg/ha)
S-SW-F	Fallow	2474a
S-F	Fallow	2415a
S-F-WW	Winter wheat	1849b
S-F-SW	Spring wheat	1712b
S	Sorghum	1466c
S-B	Barley	1161d

†S = sorghum, SW = spring wheat, F = fallow, WW = winter wheat, B = barley.

‡Yield values followed by the same letter are not significantly different at P = 0.05 based on calculated LSD.

Highest overall rotation yields were obtained for the continuous cropping rotations, the sorghum-barley rotation, and the continuous sorghum rotations. The lowest total yield was obtained for the sorghum-fallow rotation (Table 9). The 30-year mean total precipitation at Lethbridge was 405 mm and all but one of the years of this study had crop year precipitation that was at least 75% of average. Thus, it is probable that over a 100-year period there would be years with considerably less precipitation than was encountered in this study. Also, the region of southern Alberta which would be most likely to produce sorghum receives even less precipitation than does Lethbridge. Therefore, it would not be prudent to recommend continuous cropping throughout southern Alberta based on the results of our research.

Table 9. Yields in a study comparing six sorghum rotations grown at the Lethbridge Research Station (1978-1984).

Rotation	Crop	Yield (kg/ha)† Per crop	Per rotation
S	Sorghum	1466	1466b
S-F	Sorghum	2415	1207d
	Fallow	0	
S-B	Sorghum	1161	1670a
	Barley	2180	
S-SW-F	Sorghum	2474	1374bc
	Spring wheat	1649	
	Fallow	0	
S-F-SW	Sorghum	1712	1334cd
	Fallow	0	
	Spring wheat	2450	
S-F-WW	Sorghum	1849	1433bc
	Fallow	0	
	Winter wheat	2450	

†Yield values followed by the same letter are not significantly different at P = 0.05 based on calculated LSD.

Mean rotation yields ranged from 577 kg/ha in 1984 to 1968 kg/ha in 1980, probably reflecting differences in levels of available soil moisture. The differences attributable to variability in precipitation were greater than any differences detected among the rotations. This emphasizes the critical role played by rainfall in the dryland agriculture of southern Alberta.

The major limitation to crop production in southern Alberta is the availability of moisture. Between 44 and 79% of the variability in yields of sorghum and wheat in this study was accounted for by differences in growing season precipitation and the relationship was strongest in stubble crops, where moisture deficits were most severe. The effect of moisture on yield was best demonstrated in the relationship between yield and total available moisture levels (Fig. 5), defined as available spring soil moisture plus growing season precipitation. For wheat fallow, total available moisture accounted for 97% of the variability in yield. The regression coefficients for the relationship between yield and total available moisture were similar for sorghum (1.30 kg/m^3) and for wheat (1.35 kg/m^3) when seeded on fallow. The regression coefficients were also similar to each other but lower when seeded on stubble: 1.11 and 1.12 kg/m^3, for sorghum and wheat, respectively. The X-intercept of the relationship represented the minimum available moisture required to produce sorghum yields. The values obtained were 95 and 102 m^3/ha for sorghum on stubble and fallow, respectively. The corresponding values for spring wheat were 85 and 124 m^3/ha, respectively. Based on these estimates, there was no evidence that sorghum possessed an advantage in drought resistance or water-use efficiency over wheat under southern Alberta conditions. While our estimates of total available moisture may not have been an accurate estimate of total evapotranspiration, our water-use efficiencies were reasonably close to those published by Porter et al. (17), Olson (15), Garrity et al. (3) and Stewart et al. (19). Our values were within the range of values that Garrity et al. (3) obtained for a crop that used about 300 mm of water. They found that water-use efficiency increased as total evapotranspiration increased. This would be the case when comparing our fallow with stubble conditions. The values that Neild (14) obtained were somewhat higher than our 2 kg/m^3 but he obtained his estimate for sorghum grown in a higher rainfall region than occurs in southern Alberta. The relationship that Stewart et al. (19) obtained was very much like the one obtained in this study. Theirs had an X-intercept of 143 m^3/ha as minimum evapotranspiration for crop production.

The results of this study demonstrated that consistent production of early maturing grain sorghum was possible under southern Alberta conditions and that yields corresponded closely to those of spring wheat. The yield of sorghum in rotation was similar to that of wheat; sorghum yields on stubble were 63% of those on fallow compared with 69% for wheat. From an economic standpoint, a 3-year rotation including sorghum in the first year, spring wheat or winter wheat in the second year, and fallow in the third year is likely to be most desirable. Because of the low price of sorghum relative to that of wheat, however, economic returns from rotations including sorghum would likely be considerably lower than from conventional spring wheat or winter wheat rotations. As well, its inconsistent stand establishment in spring predisposes sorghum to weed and disease infestations so that agronomic management requirements for sorghum are more intensive than those of traditional cereals. Consequently, the inclusion of sorghum in crop rotations in southern Alberta cannot currently be recommended until the problems of stand establishment and low yield have been overcome.

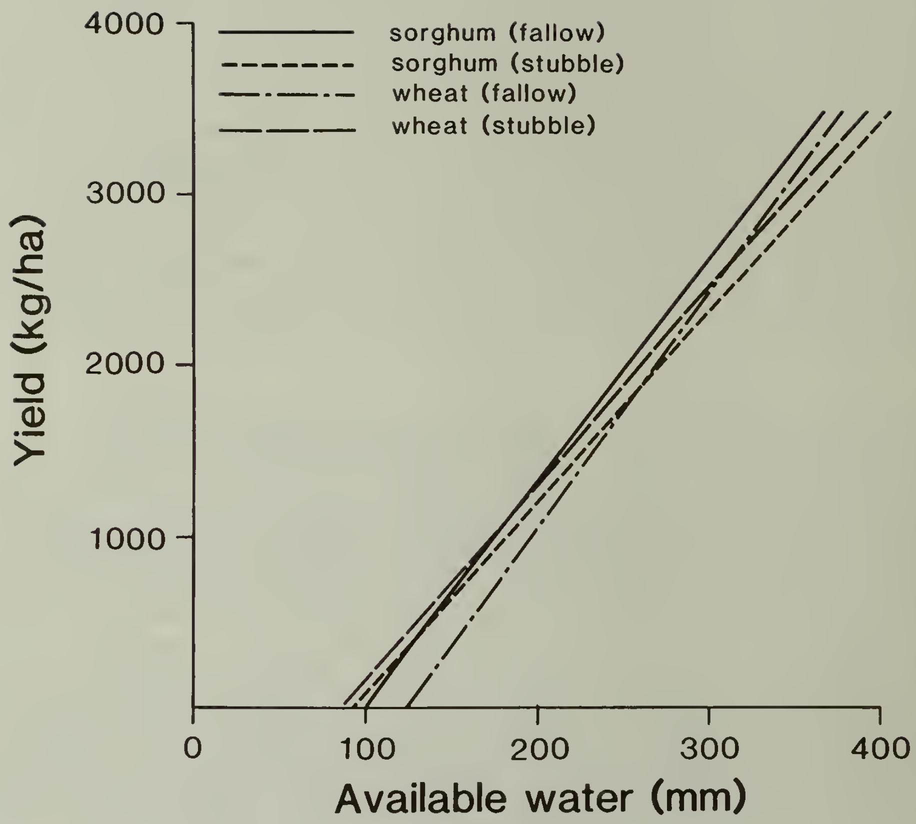

Fig. 5. Relationship between yield and total available water (soil moisture + growing season precipitation) for sorghum and spring wheat grown on fallow and stubble from 1978-1984. (R^2 for the relationships in the order in which they appear in the legend: 0.78, 0.64, 0.97, 0.84).

Harvest

The forage sorghums have the coarsest stems and the sudangrasses have the finest stems. Thus the sudangrasses are the easiest to harvest for hay as they will dry in the swath more rapidly. They are also more suitable for grazing. There is seldom sufficient moisture available for regrowth in southern Alberta so the harvest date should be dependent on the time when growth ceases so that yield is maximized. Sorghum-sudangrass hybrids grown on irrigation will have a high moisture content and it may not be possible to dry the swath. Irrigated sorghum should probably be preserved as silage.

Grain sorghum should be direct-combined with the cutter bar raised so that only the heads enter the combine. If a frost has not killed the stems they will remain green even when the grain is mature so it is important to minimize the amount of tissue entering the combine. The ideal moisture content for combining grain sorghum in southern Alberta is between 18 and 25%. If the crop is allowed to dry to 14% or less, some stalk breakage may occur and yield will be reduced. If the crop is harvested at moistures greater than 14%, aeration or drying will be necessary. The cylinder speed has to be carefully adjusted so that the hulls are removed from the seed.

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