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Planting Date Effect on No-till Proso Millet

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Producers in the Central Great Plains are changing their cropping systems to include summer annual crops after winter wheat (*Triticum aestivum* L.). Proso millet (*Panicum miliaceum* L. —hereafter referred to as proso) is well adapted to this region, especially when planted after winter wheat. This study examined the response of proso to planting date in a no-till system. 'Cope' proso was planted at six weekly intervals, starting on 18 May. Proso yielded highest when planted on 8 June and will yield greater than 95% of its potential if planted between 2 June and 12 June. Water use efficiency (WUE) reflected grain yield trends, with WUE highest when proso was planted in early June. Total crop water use (soil water + growing season precipitation) ranged between 13 and 14 in. for all planting dates. Proso initiated stem elongation and anthesis after approximately 600 and 1100 growing degree days, respectively, regardless of planting date. Based on this study, producers should plant proso during early June to maximize yield potential in no-till systems.

WINTER WHEAT-FALLOW is the most common rotation in the Central Great Plains. Producers fallow their land to store precipitation in the soil for future crop use, thus stabilizing winter wheat production. Replacing tillage operations during fallow with herbicides, however, has improved precipitation storage (Nielsen and Anderson, 1993; Smika, 1990) such that producers are now cropping more intensively. Crops such as proso, corn (*Zea mays* L.), and sunflower (*Helianthus annuus* L.) are being grown after winter wheat (Anderson, 1990b; Lyon and Anderson, 1993; Peterson et al., 1993a), and have increased total grain production. For example, a wheat-corn-fallow rotation produced 70% more grain than winter wheat-fallow over a 6-yr period, and 20 to 30% more profit (Peterson et al., 1993b).

Producers also are changing rotations because winter annual grass weed infestations (Wicks and Smika, 1990), such as volunteer rye (*Secale cereale* L.), jointed goatgrass (*Aegilops cylindrica* Host.), and downy brome (*Bromus tectorum* L.) proliferate in a winter wheat-fallow rotation (Anderson, 1994). Because no herbicides are available to control these weeds in winter wheat, producers insert summer-annual crops in rotations to deplete the weed seed bank in the soil before winter wheat is planted again (Wicks and Smika, 1990).

Up until the 1970s, proso was grown in Colorado, Kansas, Nebraska, Wyoming, and South Dakota as a replacement crop when winter wheat was killed by either severe winters or hail. As market availability increased in the 1970s, producers began growing proso after winter wheat in a 2-crop-in-3-yr rotation (Shanahan et al., 1988). Historically, producers planted proso in late June and early July to avoid weeds (Hinze, 1977). With development of residual and foliarly applied herbicides for in-crop weed control (Anderson and Greb, 1987; Grabouski, 1971; Lyon and Baltensperger, 1993), producers can plant proso earlier, and consequently increase grain yield. For example, in southwestern Nebraska, proso yield increased 10 and 40% when planted on 15 May compared with early June and early July, respectively (Nelson, 1990). This response was similar for several varieties.

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Abbreviations: EPIC, Erosion Productivity Impact Calculator; WUE, water use efficiency.

Proso is commonly grown in a tilled system. Producers sweep plow their fields for weed control after winter wheat harvest, then disk in the spring to prepare a seedbed (Anderson et al., 1986; Hinze, 1977). To meet government program requirements, however, producers now must minimize tillage to maintain crop residues on the soil surface. Proso responds positively to reduced- and no-till production systems: grain yield increases by 10 to 25% over the conventional sweep plow system (Anderson, 1990a; Anderson, 1990b; Anderson et al., 1986).

Crop residue on the soil surface, however, slows crop development because it reduces soil warming in the spring. For example, high residue levels delayed early season development of corn (Phillips, 1984) and wheat (Greb et al., 1970; Tanaka, 1989), and in some years, reduced grain yield. The optimum planting date for proso grown in a tilled system is 15 May (Hinze, 1977; Nelson, 1990). However, because residue on the soil surface delays plant development, proso may respond differently to planting date in no-till production systems. Therefore, this study tested the effect of planting date on no-till proso grain yield, biomass production, and water use.

MATERIALS AND METHODS

Site Description

The study was conducted at Akron, CO, on a Weld silt loam (fine, montmorillonitic, mesic Aridic Paleustoll) with 1.2% organic matter and a pH of 6.9 (0 to 3 in. depth). The 85-yr average yearly precipitation is 16.3 in., and growing season precipitation by month ranges from 2.0 in. during August to 2.7 in. during July (Fig. 1). Average air temperature is 67, 73, and 71 ° F for June, July, and August, respectively.

Study Procedures

Proso response to planting date was evaluated in 1988, 1989, and 1990. Intended planting dates were 18 May, 25 May, 1 June, 8 June, 15 June, and 22 June. Actual planting dates varied within 4 d of each date, due to untimely precipitation delaying field operations.

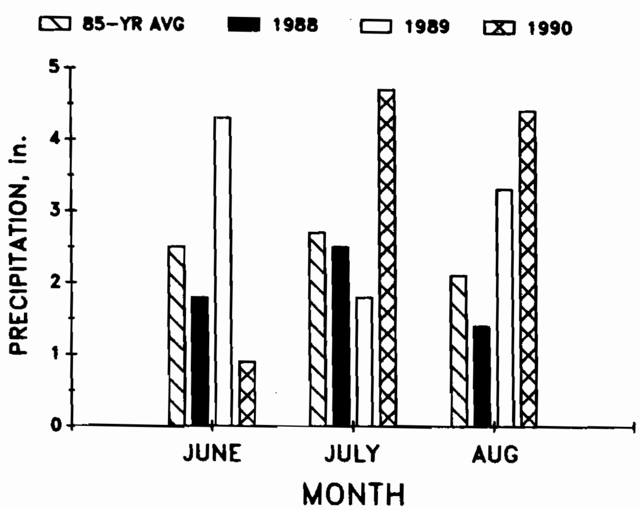

Fig. 1. Growing season precipitation by month during 1988, 1989, and 1990, and the long-term (85 yr) average at Akron, CO.

All studies were established in winter wheat stubble. Clomazone (tradename: Command) + atrazine at 0.5 + 0.5 lb a.i./acre was applied after winter wheat harvest for fallow weed control, with atrazine at 0.5 lb/acre applied in early May for in-crop weed control. Plots were weed-free in all years of the study. At the time of this study, atrazine was labeled for use in proso, but this label has since been withdrawn.

Cope proso was planted at 10 lb/acre with a deep-furrow hoe drill having a row spacing of 12 in. Plot size was 6 ft by 50 ft. Treatments were arranged in a randomized complete block design with four replications. Ammonium nitrate at 30 lb N/acre was broadcast in all plots before planting.

Soil water content was determined gravimetrically for all treatments before planting and after harvest. Sampling depth was 4 ft, in 1-ft increments. Two samples were collected per plot, with after-harvest samples being taken within 2 ft of preplant samples. Water use efficiency was calculated by dividing grain yield by crop water use (soil water use from planting until harvest + growing season precipitation).

Plant samples at harvest were hand-harvested from 60 sq ft to determine grain yield and biomass production. Harvest index was calculated by dividing grain yield by biomass production. Plant height at maturity was recorded from nine plants randomly selected per plot.

Development of 10 plants randomly selected per plot was recorded weekly based on the Zadoks-Chang-Konzak scale (Bauer et al., 1983). This scale assigns a number for each developmental stage, with the entire life cycle defined between 0 and 100. Development was measured until plants reached anthesis. Growing degree day accumulation by development stage was calculated from daily air temperatures using a base temperature of 50°F and a maximum of 86°F.

All data were subjected to analyses of variance, with differences among treatments determined at the 0.05 level of probability.

RESULTS AND DISCUSSION

Growing Season Precipitation

Precipitation during the growing season varied among years, with 1988 being dry (80% of normal) whereas 1989 and 1990 received 30 and 39% more precipitation than normal (Fig. 1). Plant available soil water in 0 to 4 ft depth at planting averaged 8.8, 5.6, and 4.8 in. for 1988, 1989, and 1990, respectively. Grain yield also varied among years, ranging from 2390 to 3780 lb/acre. There was, however, no year × planting date interaction, therefore, data were averaged over years.

Grain Yield Response to Planting Date

Proso yields were highest when planted on 8 June (Fig. 2). Yield decreased at earlier and later plantings, 20% when planted on 18 May, and 22% when planted on 22 June, compared with the 8 June planting. Proso response to planting date differs with the tillage system used. In our no-till system, proso yields were within 5% of the maximum when planted between 2 June and 12 June (Fig. 3), but Nelson (1990) reported that highest yield in a tilled system occurred 3 wk earlier (15 May), with yield decreasing by 10 to 15% when planted on 1 June.

Response of Other Plant Characteristics to Planting Date

Planting date affected proso biomass, plant height, and WUE similarly to grain yield. Proso produced the greatest biomass and tallest plants when planted between 1 June and 15 June (Table 1). When planted on 8 June, proso produced 260 lb grain/acre per inch, with WUE decreasing by 18% when planted on 22 June and 20% when planted 18 May (Table 1). Harvest index did not change after 1 June.

Total water use by proso ranged from 12.8 in. when planted on 18 May to 14.2 in. when planted on 8 June. Crop water use in this study was similar to previous studies, where total water use by proso averaged 13 to 14 in. (Anderson, 1990a; Anderson and Greb, 1987; Anderson et al., 1986; and Shanahan et al., 1988).

Proso developed more slowly at earlier plantings. When planted on 15 May, proso initiated stem elongation 45 d later, but when planted on 22 June, proso began stem elongation after 32 d (Table 1). Similar trends occurred with anthesis (Table 1), as well as with heading and inflorescence emergence (data not shown). This difference in development among planting dates was related to temperature, as proso required approximately 600 and 1100 GDD to initiate stem elongation and anthesis, respectively, regardless of planting date (Fig. 4).

Management Implications

Producers in the Central Great Plains are changing their cropping systems to minimize the duration of fallow (Halvorson et al., 1994; Peterson et al., 1993a). More intensive cropping, however, may increase crop sensitivity to erratic precipitation in this drought-prone region. To minimize drought impacts on crop success, producers can use two crop management strategies: (i) maximize WUE for each crop grown, and (ii) match cropping system to probability of water availability (Loomis, 1983).

For proso, WUE varied from 260 lb grain/acre per inch when planted on 8 June to 208 lb grain/acre per inch when planted on 18 May, a difference of 20% in efficiency. With limited water, producers can lower risk of crop failure by planting near 8 June. Matching a cropping system to water availability requires knowledge of crop water use, soil water level at planting, and precipitation probabilities (Loomis, 1983). Compared over several years and tillage systems, proso water use ranges from 13 to 14 in., thus, using this knowledge in conjunction

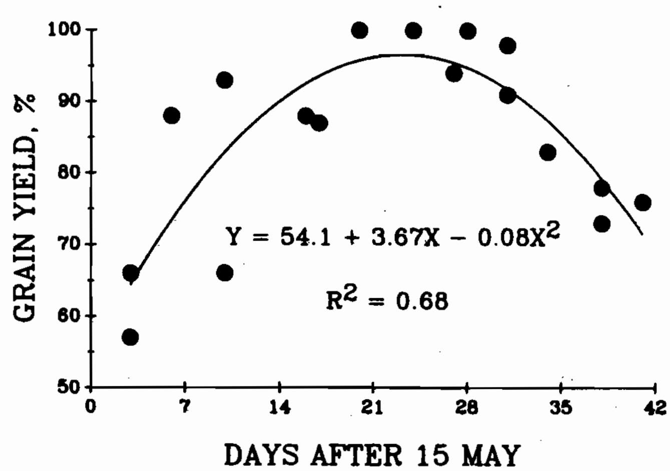

Fig. 3. Proso millet grain yield response to planting date. Y axis data represent treatment yield adjusted to a percentage of the maximum yield within each year.

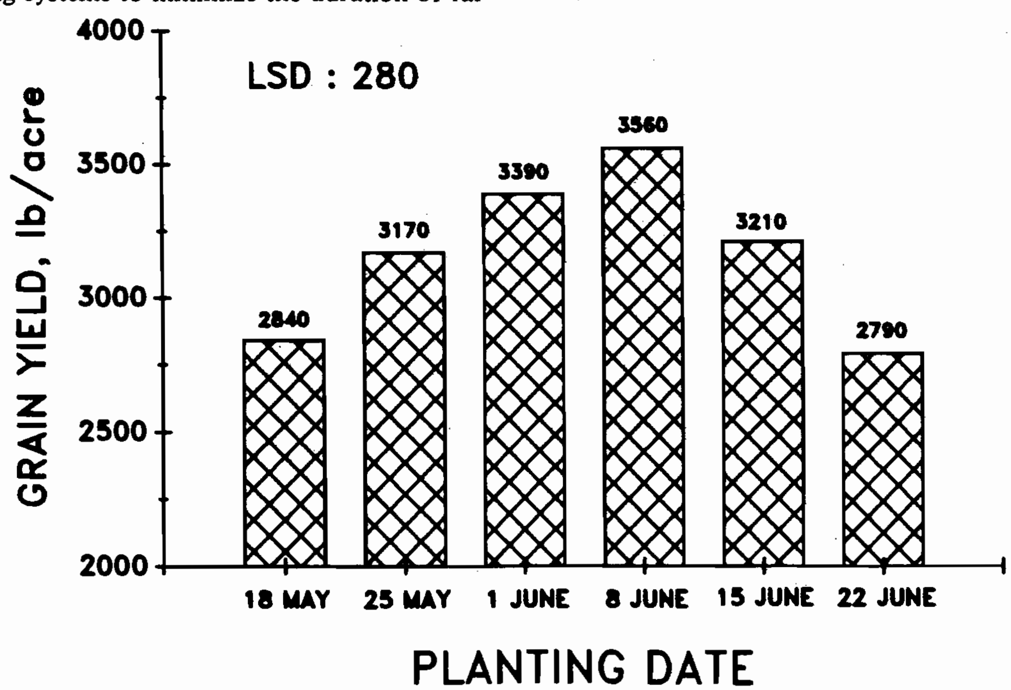

Fig. 2. Proso millet grain yield at six planting dates. Data averaged over all years of the study.

Table 1. Proso millet response to planting date as expressed by various agronomic characteristics.

Planting date	Biomass	Harvest index	Plant height	Total water use	WUE	Plant development: Stem elongation	Plant development: Anthesis
	lb/acre		-- in.	—	lb/acre per in.	—— d	——
18 May	6370	0.41	39.2	12.8	208	45	64
25 May	6850	0.42	40.5	12.9	214	41	61
1 June	7230	0.44	42.5	13.7	245	35	59
8 June	7910	0.44	42.3	14.2	260	34	57
15 June	7310	0.43	41.9	13.2	236	33	51
22 June	5960	0.45	39.0	13.2	212	32	45
LSD (0.05)	540	0.03	1.2	1.2	25	2	4

with anticipated water availability enables producers to assess risk in their crop decisions.

An alternative cropping strategy to winter wheat-proso-fallow could be planting winter wheat after proso harvest, without a fallow period. In this study, available soil water (4-ft depth) remaining at proso harvest ranged from 2.3 to 3.2 in., even though late crop season precipitation varied dramatically among years (Fig. 1). Winter wheat grain yields of 45 to 50 bushels require 14 to 16 in. of total water in northeastern Colorado (Greb, 1979; Nielsen and Halvorson, 1991). Average crop season precipitation for winter wheat at this location is 11.7 in., thus, if a producer matched this cropping strategy to 80% of expected precipitation, an assessment of low to moderate risk (Loomis, 1983), grain yield-water use equations for this area predict a winter wheat yield of 37 to 43 bu/acre (Nielsen and Halvorson, 1991).

Rotation research has demonstrated the potential of a winter wheat-proso cropping strategy (Halvorson et al., 1994). Wheat yield in this rotation averaged 70% of wheat after fallow, while combined proso and wheat yields in this rotation yielded 64% more grain on an annualized basis than wheat-fallow.

Crop growth models, such as the Erosion Productivity Impact Calculator (EPIC) model, simulates crop development based on weather variables (Williams et al., 1989). Integrating the development equation for proso (Fig. 4) into EPIC will enable this model to predict proso development for a location by inputing the location's heat unit accumulation.

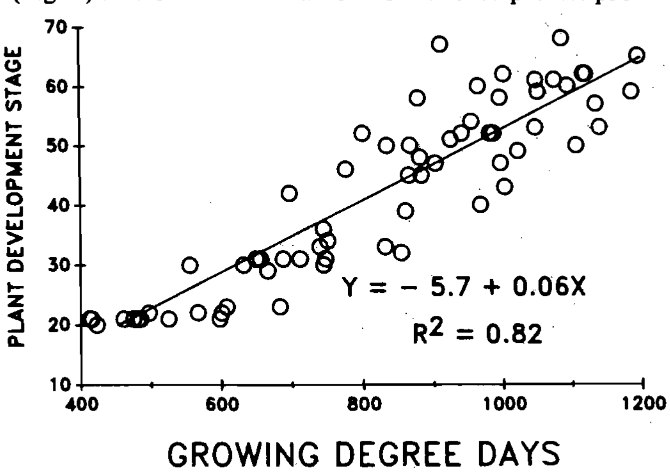

Fig. 4. Proso millet development as affected by growing degree day accumulation. Development characterized by the Zadoks-Chang-Konzak scale (Bauer et al., 1983), where 20 = tillering, 30 = stem elongation, 40 = heading, 50 = inflorescence emergence, and 60 = anthesis.

Seedling emergence models for individual weeds are being developed (Harvey and Forcella, 1993). Integrating crop development, planting date response, and emergence pattern for a selected weed may enable crop growth models to guide management decisions to favor proso over that weed. Altering crop planting date to avoid peak emergence periods of weeds is a component of low-input crop production systems (Forcella et al., 1993), and offers promise for proso. For example, planting proso on 3 June or 22 June reduced kochia (*Kochia scoparia*) population by 60 and 90%, respectively, compared with a 15 May planting (Anderson, 1988).

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