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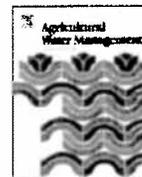
Simulated yield and profitability of five potential crops for intensifying the dryland wheat-fallow production system

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ARTICLE INFO

ABSTRACT

Greater precipitation use efficiency (PUE) and economic returns by increasing cropping frequency through the addition of summer crops to the dryland winter wheat-fallow (WF) cropping system have been reported in the semiarid Central Great Plains of USA. However, due to the highly variable nature of precipitation and uncertain water availability, selection of a crop with assured positive net returns to add to the system to increase cropping frequency is a challenge in the absence of reliable seasonal precipitation forecasts. The objective of this study was to evaluate long-term yields and net returns of several potential summer crops at various soil water contents at planting to assess their potential use in increasing dryland cropping frequency. Three grain crops [corn (*Zea mays* L.), canola (*Brassica napus*), and proso millet (*Panicum miliaceum* L.)] and two forage crops [foxtail millet (*Setaria italica* L. Beauv.) and spring triticale (*X Triticosecale* rimpaui Wittm.)] for which the Root Zone Water Quality Model (RZWQM2) had been calibrated at Akron, CO and/or Sidney, NE, were selected for investigation through modeling. The calibrated model was used to simulate yield responses of the crops to 25, 50, 75 and 100% of plant available water (PAW) in the soil profile at planting using recorded weather data from Akron, CO and Sidney, NE (1948-2008). Average costs of production and 10-yr average commodity prices for northeast Colorado were used to calculate net returns for each of the crops at the varying PAW levels. All crops showed significant ($p < 0.05$) simulated yield increases in response to increasing initial PAW levels when those changes occurred in the entire 0–180 cm soil profile. The two forage crops gave greater net returns than the three grain crops for all initial PAW levels when calculated with 10-yr average prices received. Among the grain crops, proso millet was slightly more profitable than corn at Akron, while corn was the least profitable crop at Sidney. Using current commodity prices (13 September 2011) resulted in proso millet being the least profitable crop at Sidney, while corn was the most profitable grain crop at Akron and showed net returns that were similar to those found for the forage crops. The results of this study may guide the selection of a spring- or summer-planted crop and help farmers assess risk as they contemplate intensifying the WF system by using a measure or estimate of PAW at planting.

Published by Elsevier B.V.

1. Introduction

Successful dryland agricultural production in semiarid areas requires efficient utilization of the variable precipitation for crop water use (Nielsen et al., 2005). In the semiarid Central Great Plains of the USA, nearly 80% of the annual precipitation is received during the spring and summer months from April to September. Fallowing the tilled field between wheat crops (about 14 months) has been a widely used soil management practice to increase PAW at planting and reduce variability in crop yields (Greb, 1979; Nielsen and Calderón, 2011; Tanaka and Anderson, 1997). However, even

with no-till management an average of only 35% of the precipitation received during the fallow period in this region is stored for use by the next crop (Nielsen and Vigil, 2010). Precipitation received in the two-year period of a WF rotation (average values of 831 mm at Akron, Colorado and 846 mm at Sidney, Nebraska) on average supplies more water than a single wheat crop can use. Consequently the potential exists to crop more frequently than once every two years. The economics of intensifying cropping frequency can be positively affected because of the increased income from an additional crop (Lyon et al., 2004). The conventionally tilled WF system has also often been cited as a cause for severe soil erosion and soil quality degradation in the region (Black, 1983; Anderson, 1998; Bowman et al., 1990, 1999; Dhuyvetter et al., 1996; Nielsen and Calderón, 2011; Norwood et al., 1990; Peterson and Westfall, 2004). Hence, for both economic improvement and water and soil

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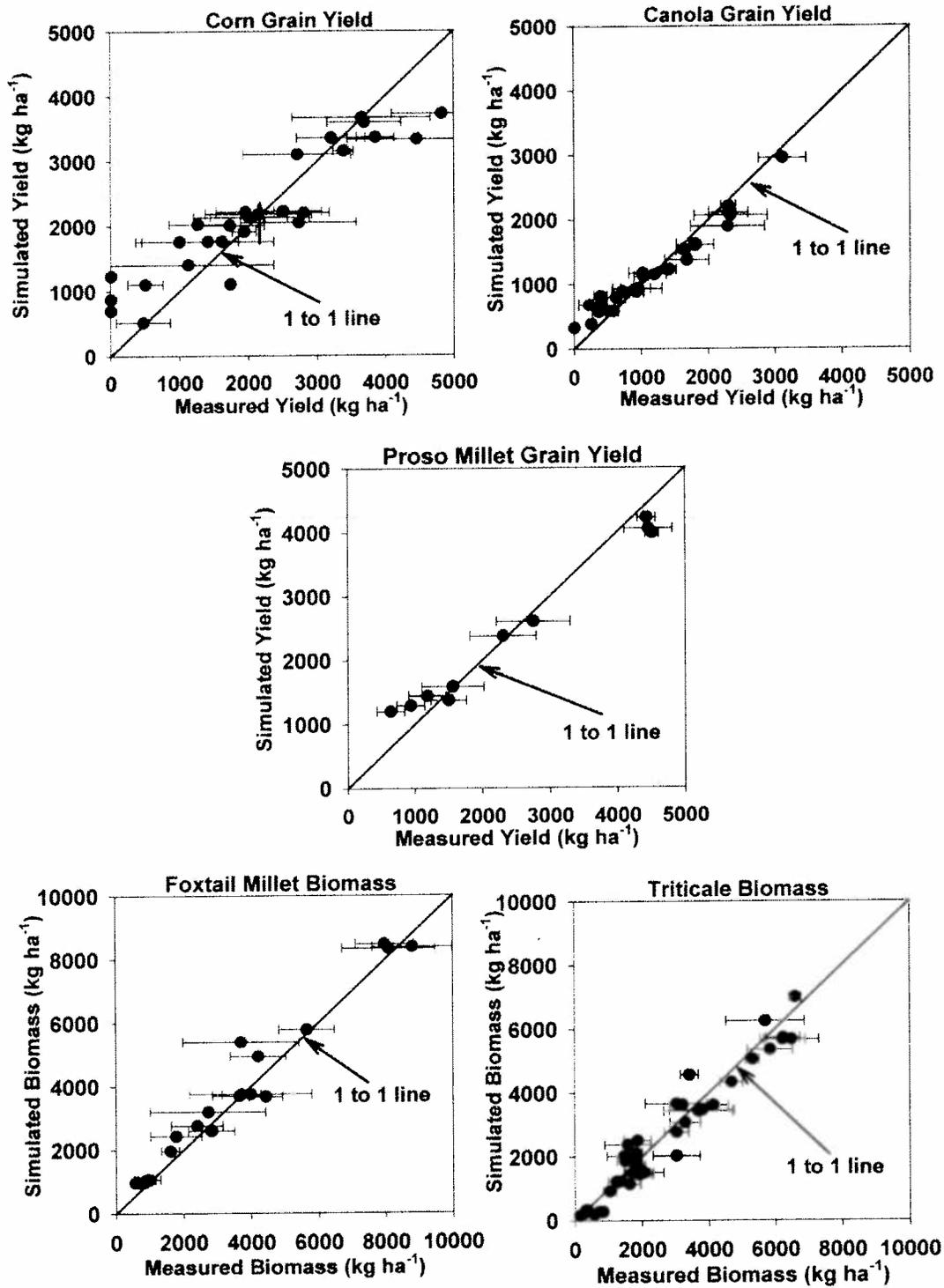E-mail address: david.nielsen@ars.usda.gov (D.C. Nielsen).

Fig. 1. Measured and simulated grain yield of corn, canola, and proso millet and biomass of foxtail millet and spring triticale at Akron, CO and Sidney, NE. Simulations were done with RZWQM2. For details see Saseendran et al. (2010a) for corn, Saseendran et al. (2010b) for canola, and Saseendran et al. (2009) for proso millet, foxtail millet and spring triticale.

Table 2

Crop management practices adopted for simulating grain yields of corn, canola, and proso millet, and forage yields of foxtail millet and spring triticale at Akron, CO and Sidney, NE.

Crop	Cultivar	Planting density (seeds ha^{-1})	Planting date	Row spacing (cm)	N (kg ha^{-1})	Harvest date
Corn	NK4242BT	35,000	May 19	76	67	Simulated
Canola	Westar/Hyola	630,000	April 08	19	67	Simulated
Proso millet	Huntsman	2,810,000	June 13	25	67	Simulated
Forage foxtail millet	White Wonder	5,300,000	June 13	25	67	August 30
Forage triticale	Trical 2700	2,580,000	April 05	25	67	June 25

3. Results and discussion

3.1. Crop responses to PAW in the whole profile (WP)

In our long-term simulations at both Akron and Sidney with initial soil water variations in the whole profile (WP), corn, canola and proso millet grain yields, and triticale and foxtail millet forage yields increased significantly ($p < 0.05$) in response to all four PAW levels at planting in all years (Figs. 2–6 and Table 4). The model simulated a higher probability of obtaining at least a given grain yield with increasing initial PAW level. For example, for corn grown at Akron a grain yield of at least 3763 kg ha^{-1} (the breakeven yield identified by Nielsen et al., 2010) would be expected 17% of the time with initial PAW of 25% and 86% of the time with initial PAW at 100% (Fig. 2a). Average grain yields (reported at a moisture content of 0.155 g g^{-1}) simulated at Akron in response to the four PAW levels at planting were between 2679 kg ha^{-1} (SD = 1259 kg ha^{-1}) and 5803 kg ha^{-1} (SD = 1649 kg ha^{-1}), respectively (Fig. 2b and Table 4). Corresponding mean grain yields simulated for Sidney were between 2416 kg ha^{-1} (SD = 1183 kg ha^{-1}) and 4140 kg ha^{-1} (SD = 1460 kg ha^{-1}) (Fig. 2d and Table 4). The probability of obtaining at least a yield of 3763 kg ha^{-1} at Sidney was 10% of the time with initial PAW of 25% and 59% of the time with initial PAW of 100% (Fig. 2c).

The probability of achieving at least the breakeven canola yield of 1120 kg ha^{-1}, as designated by Nielsen et al. (2010), was 26% of the time with 25% PAW increasing to 91% of the time with 100% PAW at Akron under the WP scenario (Fig. 3a). Mean canola grain yields (reported at a moisture content of 0.10 g g^{-1}) simulated at Akron increased with increasing PAW at planting from 882 kg ha^{-1} (SD = 510 kg ha^{-1}) to 1779 kg ha^{-1} (SD = 431 kg ha^{-1}) (Fig. 3b and Table 4). Mean grain yields simulated at Sidney varied between 975 kg ha^{-1} (SD = 475 kg ha^{-1}) and 1775 kg ha^{-1} (SD = 324 kg ha^{-1})

(Fig. 3d and Table 4). Uncertainty in yields, due to inter-annual weather variability, as reflected in the range or spread of percentile distributions (5 and 95 percentiles) of simulated long-term grain yields, in the box plots decreased with increasing initial PAW at Akron but not at Sidney (Fig. 3b and d).

Delgado et al. (2000) reported an average root depth at harvest of 76 cm for canola grown on loamy sands and sandy loams in south-central Colorado. In the current simulations, we had about 80% of the root distribution to this depth. With a shallow rooting depth, less stored soil water is available to the crop for consumptive use and this may explain the lower response of canola to increasing PAW compared with corn (Fig. 3 vs. Fig. 2). Additionally, a C3, oil-producing species such as canola will have a much lower response to water availability than a C4 species such as corn (Fisher and Turner, 1978; Hanks, 1983; Nielsen et al., 2005). Nielsen et al. (2010) reported that the corn grain yield response to water use was 3.33 times the canola grain yield response to water use. We found the simulated response of corn grain yield to soil water availability at Akron to be 3.48 times the canola response (15.47 kg ha^{-1} mm^{-1} vs. 4.44 kg ha^{-1} mm^{-1}). At Sidney corn grain yield response to PAW was only 2.35 times greater than the canola response (12.43 kg ha^{-1} mm^{-1} vs. 5.30 kg ha^{-1} mm^{-1}). The lower response of corn to PAW at Sidney compared with corn at Akron is likely a result of differences in rainfall distribution between the two locations. Akron averaged 10% greater precipitation in July and August than Sidney (Table 1). Nielsen et al. (2009) showed how the response of dryland corn grain yield to PAW at planting increased with increasing amount of precipitation between 15 July and 25 August. Additionally, the cooler and wetter conditions during the canola growing season at Sidney compared with Akron (Table 1) likely resulted in the increased yield response of canola to soil water at planting at Sidney relative to Akron.

Table 3

Production costs and crop prices used for calculating net returns of summer crops planted at Akron, Colorado and Sidney, Nebraska under no-till soil management. Production costs are taken from Nielsen et al. (2010) and prices come from www.nass.usda.gov (verified 1 March 2010).

Operation	Costs				
	Corn	Canola	Proso millet	Forage foxtail millet	Forage triticale
Planting ($/ha)	24.70	22.30	22.30	22.30	22.30
Seed ($/ha)	48.13	5.62	0.26	0.26	0.26
Spraying ($/ha)	12.97	12.97	12.97	12.97	12.97
Glyphosate ($/ha)	12.35	12.35	12.35	12.35	12.35
Fertilizer N ($/ha)	54.94	54.94	54.94	54.94	54.94
Fertilizer P ($/ha)	7.14	7.14	7.14	7.14	7.14
Swathing ($/ha)	0.00	19.76	19.76	24.70	24.70
Harvesting ($/ha) (if corn or proso millet yield exceeds 1254 kg ha^{-1}, additional cost of $2.07 per 1000 kg ha^{-1}) (if canola yield exceeds 1120 kg ha^{-1}, additional cost of $2.32 per 1000 kg ha^{-1})	32.11	32.11	32.11	32.11	32.11
Baling hay ($/T)[a]	0.00	0.00	0.00	14.70	14.70
Hauling ($/T)[a]	2.07	5.51	2.07	3.23	3.23
Average crop price, 1992-2001 ($ kg^{-1})	0.0941	0.2147	0.127	0.0937	0.0937
Crop price, 13 September 2011 ($ kg^{-1})	0.2831	0.5580	0.2701	0.1653	0.1653

[a] Forage baling and hauling charges assume hay at 12% moisture. Hay hauling charges (Edwards, 2007) assume a 20 mile loaded distance.
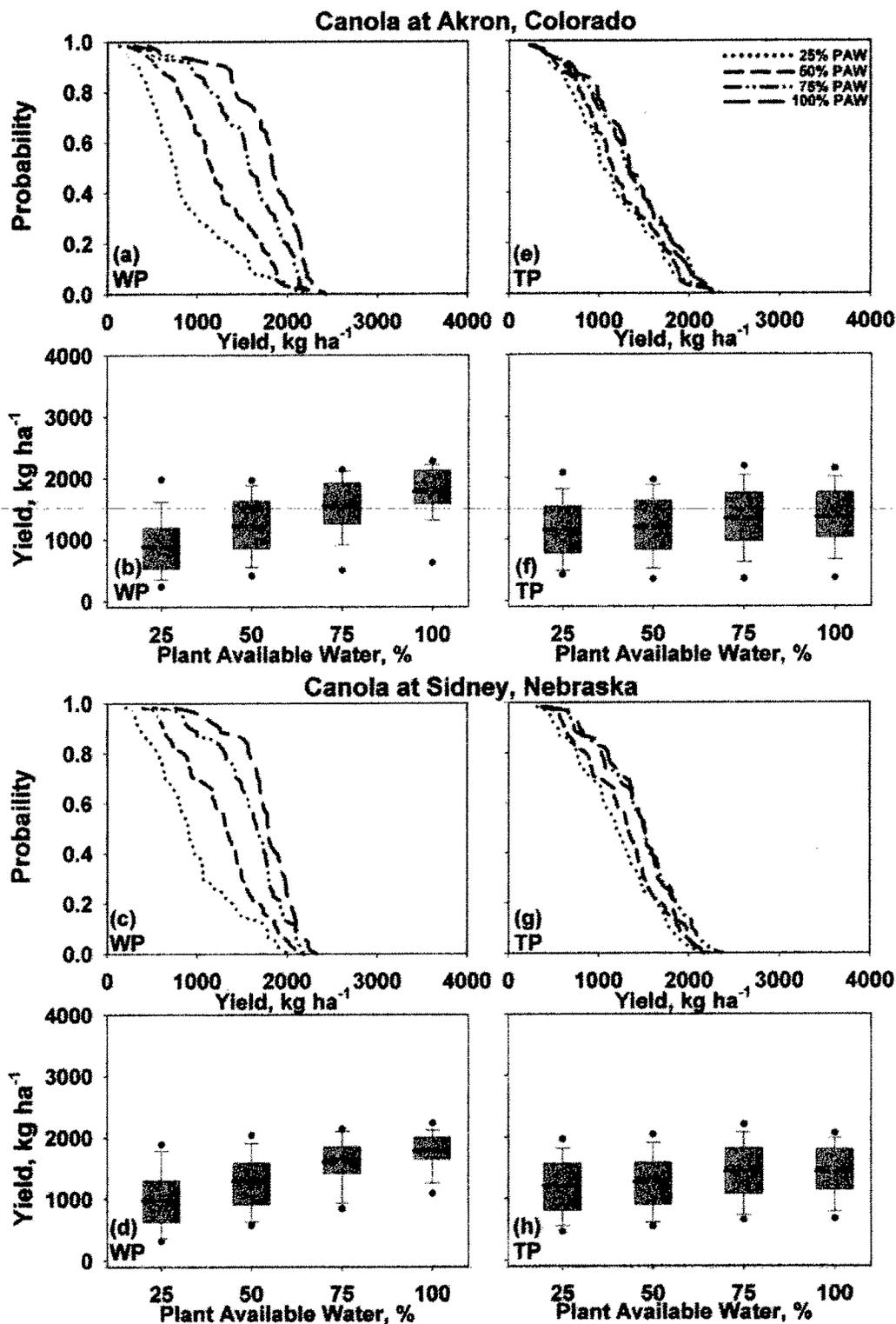
Fig. 3. (a, c, e, g) Probability of obtaining at least a given canola grain yield (reported at 0.10 g g^{-1} moisture content) as influenced by 25, 50, 75 and 100% plant available water at planting in the whole 180 cm soil profile (WP) and top 45 cm soil profile (TP) at Akron, Colorado and Sidney, Nebraska. In TP case, soil moisture content below 45 cm (45–180 cm) was kept constant at 50% of maximum plant available water. Panels b, d, f, h: Box plots of canola grain yield as influenced by plant available water at planting. The boundary of the box closest to zero indicates the 25th percentile, a solid line within the box marks the median, the dashed line within the box marks the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (bars) above and below the box indicate the 90th and 10th percentiles. The dot closest to zero indicates the 5th percentile and farthest from zero indicates the 95th percentile.

Forage foxtail millet at Akron, Colorado

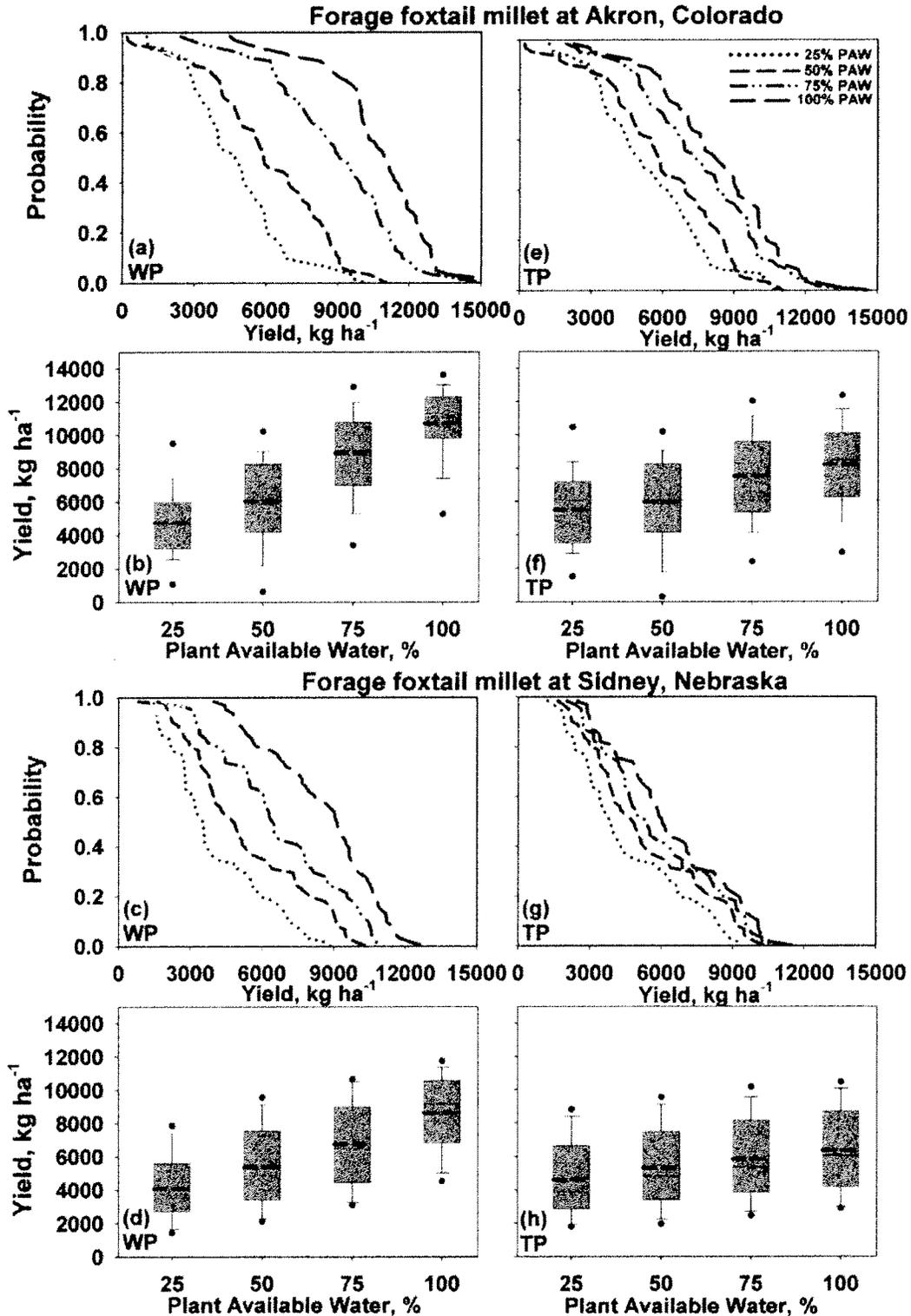## Forage foxtail millet at Sidney, Nebraska

Fig. 5. (a, c, e, g) Probability of obtaining at least a given foxtail millet forage yield (reported at 0.12 g g⁻¹ moisture content) as influenced by 25, 50, 75 and 100% plant available water at planting in the whole 180 cm soil profile (WP) and top 45 cm soil profile (TP) at Akron, Colorado and Sidney, Nebraska. In TP case, soil moisture content below 45 cm (45–180 cm) was kept constant at 50% of maximum plant available water. Panels b, d, f, h: Box plots of foxtail millet forage yield as influenced by plant available water at planting. The boundary of the box closest to zero indicates the 25th percentile, a solid line within the box marks the median, the dashed line within the box marks the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (bars) above and below the box indicate the 90th and 10th percentiles. The dot closest to zero indicates the 5th percentile and farthest from zero indicates the 95th percentile.
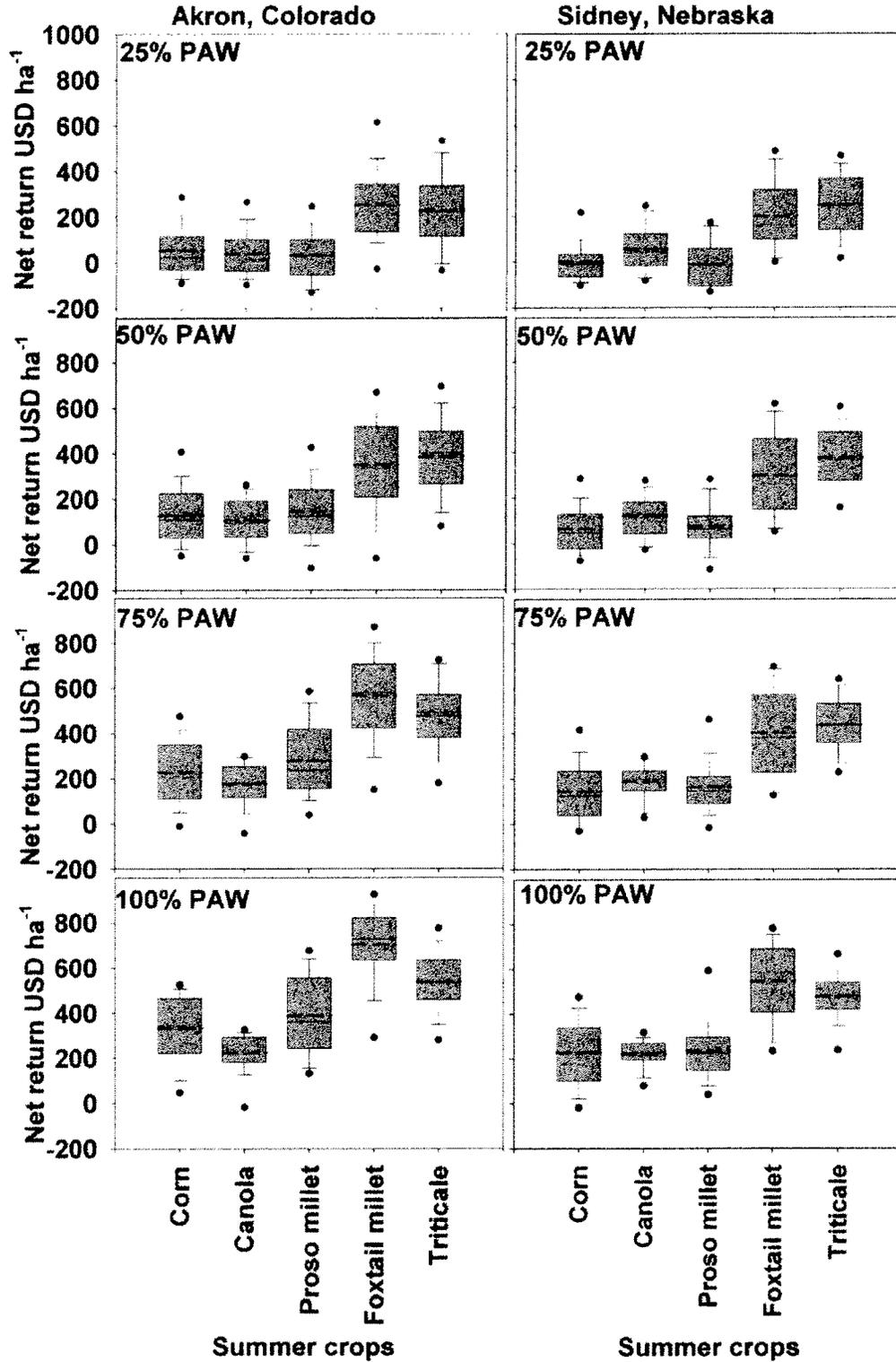
Fig. 7. Comparison of net returns from corn, canola and proso millet (for grain), and foxtail millet and spring triticale (for forage) planted in response to 25, 50, 75 and 100% plant available water (PAW) at planting in the 180 cm soil profile (WP scenario) at Akron, Colorado and Sidney, Nebraska. The boundary of the box closest to zero indicates the 25th percentile, a solid line within the box marks the median, the dashed line within the box marks the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (bars) above and below the box indicate the 90th and 10th percentiles. The dot closest to zero indicates the 5th percentile and farthest from zero indicates the 95th percentile. Net returns were calculated using 10-yr average commodity prices (1992-2001) and custom farm rates from 2006 from northeast Colorado. USD = US dollars.

triticale to increasing PAW at planting. They reported dry weights of about 1000 kg ha^{-1} with 11% PAW at planting increasing to about 7000 kg ha^{-1} with 89% PAW at planting.

3.2. Crop responses to PAW in the top profile (TP)

Under soil water variations only in the top 45 cm profile (TP), mean corn, canola and proso millet grain yields, and foxtail millet and triticale forage yields at both locations increased numerically in response to the four increasing PAW levels at planting, but those increases were not significant for corn and canola at Akron (Fig. 2e, g; 3e, g; 4e, g; 5e, g; and 6e, g) (Table 4). The probability of obtaining at least the breakeven corn grain yield of 3763 kg ha^{-1} ranged from 0% (with 25% PAW) to 41% (with 100% PAW) at Akron and from 12% (with 25% PAW) to 30% (with 100% PAW) at Sidney. Simulated average corn grain yields in response to PAW at planting variations were between 3395 kg ha^{-1} (SD = 1391 kg ha^{-1}) and 3915 kg ha^{-1} (SD = 1575 kg ha^{-1}) at Akron (Fig. 2f and Table 4), and between 2617 kg ha^{-1} (SD = 1241 kg ha^{-1}) and 3185 kg ha^{-1} (SD = 1319 kg ha^{-1}) at Sidney (Fig. 2h, Table 4). A somewhat different situation was reported by Lyon et al. (1995). In their experiment with fairly uniform soil water contents at planting in the top 45 cm of the soil profile, but with widely varying soil water content at the lower depths, dryland corn grain yield was not well predicted by available soil water at planting. Our simulation results indicate that, in the case of corn, initial PAW influences grain yield when those differences in initial PAW occur throughout the whole 180 cm soil profile (assumed root zone). But if the water content at planting varies only in the TP (45 cm soil profile, considered in the present study), simulations show that there was no major yield response. Nielsen et al. (2009) reported that the production functions derived from yield and soil water content at planting data for dryland corn grown in various crop-rotation sequences in the Great Plains were highly variable, with values ranging from 0.0 to 67.3 kg ha^{-1} grain yield per mm of available soil water in the 0–180 cm soil profile at planting. The differences in yield response to soil water were attributed to the amount and timing of precipitation that fell during the critical reproductive and early grain-filling period. Our simulations indicate that the distribution of the soil water in the profile at planting may also be a factor.

In general, corn grain yield variability due to weather during the crop growing season, as depicted in the range or spread of simulated long-term yields in the box plots of Fig. 2 (differences in 5 and 95 percentiles of long-term simulations along the y-axis), did not decrease appreciably with increasing initial PAW at either Akron or Sidney under both the WP and TP scenarios (Fig. 2f and h). This simulation result again confirms the observation that variability of corn grain yield is more influenced by growing season precipitation timing and amount than by soil water content at planting (Nielsen et al., 2009).

Mean canola grain yields simulated in response to the four PAW levels at planting were between 1148 kg ha^{-1} (SD = 493 kg ha^{-1}) and 1375 kg ha^{-1} (SD = 479 kg ha^{-1}) at Akron (Fig. 3f and Table 4). Average yield increase when increasing the PAW at planting from 25% to 50% in the TP was only 67 kg ha^{-1}. Mean grain yields simulated at Sidney varied between 1206 kg ha^{-1} (SD = 461 kg ha^{-1}) and 1455 kg ha^{-1} (SD = 408 kg ha^{-1}) (Fig. 3h and Table 4). At both Akron and Sidney, the variability in grain yield due to weather variability at all initial PAW levels in the TP remained more or less constant as reflected in the nearly identical vertical range (spread) of the percentile distributions shown in the box plots (Fig. 3f and h).

Simulated proso millet grain yields at Akron ranged from 1817 (SD = 1087 kg ha^{-1}) to 2982 kg ha^{-1} (SD = 1174 kg ha^{-1}) in response to the four PAW levels in the TP at planting (Fig. 4f and Table 4). Proso millet grain yields at Sidney increased in response to increasing PAW at planting from 1340 (SD = 939 kg ha^{-1}) to 2219 kg ha^{-1}

(SD = 912 kg ha^{-1}) (Fig. 4h and Table 4). Average yield increase with each 25% increase in initial PAW was 388 kg ha^{-1} at Akron and 293 kg ha^{-1} at Sidney. These increases are equivalent to 23.3 kg ha^{-1} (Akron) and 17.6 kg ha^{-1} (Sidney) per mm of PAW at planting, which are much larger than the 8.3 kg ha^{-1} per mm response reported by both Lyon et al. (1995) and Felter et al. (2006) from field studies with proso millet in which 79% (Lyon et al., 1995) and 58% (Felter et al., 2006) of the variation in grain yield was explained by variation in PAW at planting. Unpublished data from an analysis of 15 years of proso millet grain yield and water use data by D.C. Nielsen at Akron, Colorado indicated a greater yield response to water use (23.4 kg ha^{-1} mm^{-1}) than reported in previously published short-term field studies (Shanahan et al., 1988; Felter et al., 2006). Those greater yield responses occurred when precipitation in the middle of August was high, wind speed during the week prior to harvest was low (minimizing shattering losses), and daily maximum temperatures throughout the growing season rarely exceeded 36 °C. Hence greater yield response to PAW at planting from the long-term simulations compared with the 2-yr field studies of Lyon et al. (1995) and Felter et al. (2006) is not unreasonable.

At Akron, average foxtail millet forage yields (reported at a moisture content of 0.12 g g^{-1}) simulated in response to the four PAW at planting levels were between 5515 (SD = 2372 kg ha^{-1}) and 8353 kg ha^{-1} (SD = 2571 kg ha^{-1}) (Fig. 5f and Table 4). The simulated forage yield response to PAW was 57 kg ha^{-1} per mm, which was greater than the field-measured foxtail millet biomass response to soil water at planting (40 kg ha^{-1} per mm) reported by Felter et al. (2006). Under the TP scenario, inter-annual variability in forage yield did not decrease with increases in initial PAW, as reflected in the similar ranges of percentile distributions (spread along the vertical axis) in the box plots of Fig. 5f. Average foxtail millet forage yields simulated at Sidney were between 4600 (SD = 2349 kg ha^{-1}) and 6454 kg ha^{-1} (SD = 2479 kg ha^{-1}) (Fig. 5h and Table 4).

At Akron, in response to the 25, 50, 75 and 100% PAW at planting levels, the model simulated mean triticale forage yields (reported at a moisture content of 0.12 g g^{-1}) between 5074 (SD = 2284 kg ha^{-1}) and 7569 kg ha^{-1} (SD = 2111 kg ha^{-1}) (Fig. 6f and Table 4). Average forage triticale yields simulated at Sidney increased from 5239 (SD = 1828 kg ha^{-1}) to 7112 (SD = 1653 kg ha^{-1}) in response to the four PAW levels at planting (Fig. 6h and Table 4).

3.3. Net returns from plantings at various PAW levels in the whole profile (WP)

In general, using the 2006 average production costs (Nielsen et al., 2010) and 10-yr average (1992–2001) grain and forage prices for northeast Colorado given in Table 4, the simulated long-term (61 yrs) net economic returns from all five crops increased significantly (p < 0.01) with increasing PAW at planting under the WP scenario (Fig. 7). At the 25% PAW level, all five crops showed negative net dollar returns in some years. At this starting PAW at Akron, these negative returns were most frequent for corn and proso millet (43% of the crop seasons for both crops), followed by canola (39% of the crop seasons), forage triticale (9% of the crop seasons) and forage foxtail millet (7% of the crop seasons). However, the number of negative return years decreased considerably with increases in PAW at planting. In general, for all five crops at both locations, when plantings were made with 75% or 100% PAW at planting, our simulations showed greater than 90% probability for positive net returns. In general, at both Akron and Sidney, average net return from crops planted in response to all PAW levels at planting were much higher for the forage crops (foxtail millet and triticale) than for the grain crops (corn, canola, and proso millet) (Fig. 7). For instance, average
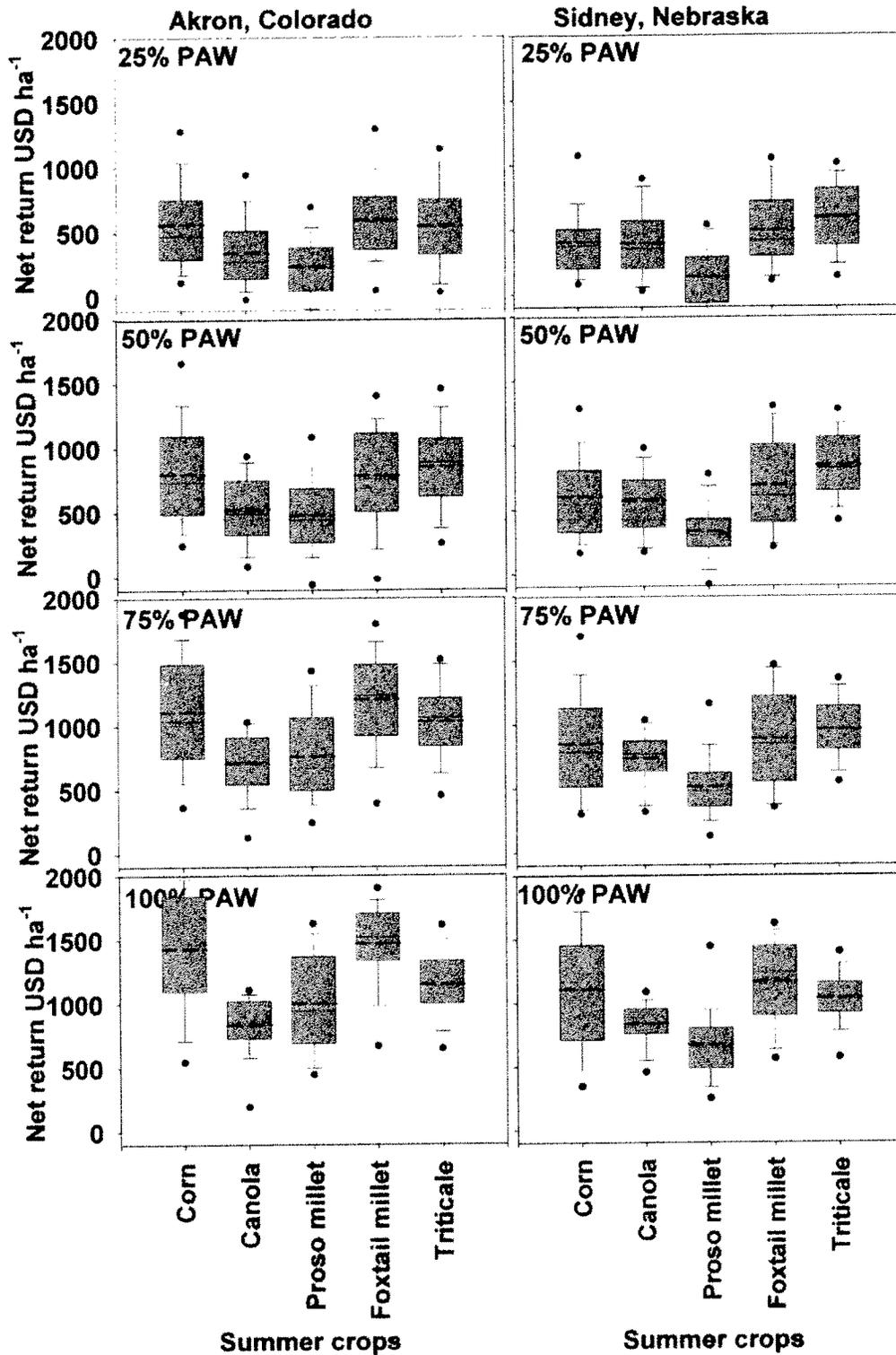
Fig. 9. Comparison of net returns from corn, canola and proso millet (for grain), and foxtail millet and spring triticale (for forage) planted in response to 25, 50, 75 and 100% plant available water (PAW) at planting in the 180 cm soil profile (WP scenario) at Akron, Colorado and Sidney, Nebraska. The boundary of the box closest to zero indicates the 25th percentile, a solid line within the box marks the median, the dashed line within the box marks the mean, and the boundary of the box farthest from zero indicates the 75th percentile. Whiskers (bars) above and below the box indicate the 90th and 10th percentiles. The dot closest to zero indicates the 5th percentile and farthest from zero indicates the 95th percentile. Net returns were calculated using 13 September 2011 commodity prices and custom farm rates from 2006 from northeast Colorado. USD = US dollars.

net return from crops planted with 25% PAW at planting at Akron was $252 for forage foxtail millet, $227 for forage triticale, $53 for corn, $36 for canola, and $32 for proso millet. When comparing the two forage crops at Akron, foxtail millet gave nearly identical net returns as triticale for 25% and 50% PAW, and greater net returns than triticale for 75% and 100% PAW. Forage triticale generated greater average net returns than foxtail millet at Sidney under all initial PAW conditions except under the 100% PAW condition. When considering only the grain crops, net returns averaged over all starting water conditions at Akron were highest for proso millet ($211) followed by corn ($185) and then canola ($136). At Sidney the greatest net returns for the grain crops (averaged over all starting water conditions) were found for canola ($147) and proso millet ($115) followed by corn ($108).

3.4. Net returns from plantings at various PAW levels in the top profile (TP)

Net returns of all crops except corn increased significantly ($p < 0.05$) with increasing PAW at planting at both Akron and Sidney under the TP scenario. However, the increases with increasing PAW at planting were much less than under the WP scenarios (Fig. 8). Similar to the WP scenario, at 25% PAW under the TP conditions, all five crops showed negative net dollar returns in some years. At this low 25% PAW starting water content at Akron, the negative returns were most frequent for proso millet (26% of the time) followed by canola, corn, spring triticale, and foxtail millet. At Sidney the negative returns with 25% PAW in the TP were most frequent for proso millet (48% of the time) followed by corn (45%), canola (17%), foxtail millet (1%), and spring triticale (1%). Also, when plantings were made with 75% or 100% PAW at planting there was a greater than 82% probability for positive net returns for all crops at both locations except for corn at Sidney where the probability of obtaining a positive net return was 70–75%. At both Akron and Sidney, average net returns from crops planted in response to all PAW levels at planting were much higher for the forage crops (foxtail millet and triticale) than for the grain crops (corn, canola, and proso millet). Foxtail millet showed similar average net returns as triticale for the 25%, 50%, and 75% PAW levels at planting at Akron. Under the 100% PAW level at planting at Akron foxtail millet gave higher average net returns than triticale (Fig. 8). At Sidney net returns were slightly higher for triticale than for foxtail millet under all four PAW levels. Under the 25% PAW at planting condition at Akron the net return was similar for all three grain crops, but the average net return at Sidney was highest for canola. Under the 100% PAW at planting condition average net return for proso millet at Akron was higher than for corn and canola, while at Sidney under this high starting soil water condition the average net return was highest for canola and lowest for corn with proso millet showing intermediate net returns.

3.5. Net returns using commodity prices for 13 September 2011

Prices for grains and forages have recently been much higher than the 10-yr average prices shown in Table 3. We recomputed the net returns for all five crops based on prices that could be received for the crops on 13 September 2011 in northeastern Colorado as a "snapshot in time" to see if there were notable differences in the relative crop order of net returns. For both Akron and Sidney under the WP scenario (Fig. 9) forages were still generally more profitable than the grain crops. Corn was clearly the most profitable grain crop at Akron with average net returns under all four starting PAW levels that were very similar to average net returns for foxtail millet. Corn was less profitable at Sidney than at Akron under all four PAW levels, and was the most profitable of the three grain crops. Triticale was more profitable than foxtail millet with 25, 50, and 75% PAW

at planting, but at 100% PAW foxtail millet was the more profitable forage crop. Similarly under the TP scenario, corn at Akron was more profitable than the other two grain crops, but the forage crops were more profitable than corn at 75% and 100% PAW (Fig. 10). At Sidney the higher average profitability of corn was also simulated, and the forages similarly remained more profitable under all four PAW levels than the grain crops. Using the more current higher crop prices mainly had the effect of increasing the overall net profitability of all five crops as well as increasing corn profitability relative to the other crops at both locations.

4. Conclusions

At both Akron, Colorado and Sidney, Nebraska in the central Great Plains, USA, simulated grain yields of corn, canola, and proso millet and forage yields of foxtail millet and triticale increased as PAW at planting increased, especially when PAW changes were considered for the whole soil profile. When the five crops considered here were planted under similar initial PAW conditions, they differed in yield and economic returns due not only to price differences of their harvest products but also to differences in harvest yields resulting from differences in growing season lengths and associated precipitation received. Greater net returns were found for the two forage crops than for the three grain crops. The data and figures generated in this study can be used to estimate relative crop yields, net returns, and risk involved in selecting one of the five studied spring- or summer-planted crops to intensify the WF system into, potentially, a winter wheat-spring/summer crop-fallow rotation, when a measure or estimate of the PAW at planting is available. Intensifying the wheat-fallow system to two crops in three years is not likely to greatly influence wheat yields following the production of the spring or summer crop, as the 12–14-month fallow period prior to wheat planting allows for significant recharge of soil water. Nielsen et al. (2002) showed 9-yr average soil water contents at wheat planting and wheat yields that were the same for both wheat-fallow and wheat-corn-fallow no-till production systems. However, farmers would need to be aware of the fact that changes in net returns are likely to occur when intensifying from a wheat-fallow system to a three-year rotation where a crop is planted in the growing season following wheat production. These changes in net returns will be a result of the productivity and expenses associated with producing both crops in the system rather than from any of the individual crops involved (wheat or the summer crop) (Peterson et al., 1993, 1996; Halvorson et al., 2002; Peterson and Westfall, 2004).

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