# Expanding Production Area and Alternative Energy Crop Market of Proso Millet for Water Deficient Lands

Final Report for the Sun Grant Initiative, South Central Region

Kevin Larson, Rick Kowenhower, and Jeffrey Tranel

Proso millet (*Panicum miliaceum* L.) is reported to produce well under dry, low input conditions (Baltensperger, 1996) (Blumenthal and Baltensperger, 2002) (Lyon et. al, 2008) (Witt, 1983). In 2007 three states, Colorado, Nebraska, and South Dakota, produced 99% of the nation's total proso millet production (16.9 million bushels) (NASS, USDA, 2009). Colorado is the leading state for proso millet production; however, proso millet production is limited to the northeastern part of the state, where evaporative demand is lower than the southeastern part of Colorado. Proso millet appears to be an ideal crop for the water-deficient Southern High Plains region with focus on southeastern Colorado, northwestern Oklahoma, southwestern Kansas, northwestern Texas, and northeastern New Mexico. Expansion of proso millet into the drier Southern High Plains would require adapted agronomic production practices and market growth.

Currently, proso millet is primarily marketed as birdseed. The birdseed market is thin and easily oversupplied. If expansion of this low-water and low-fertilizer crop is to proceed, a new market for proso millet needs to be developed. One feed grain market that has been linearly growing is the ethanol market. According to the US Energy Information Administration, corn used for ethanol production increased from 174.3 million bushels in January 2007 to 398.3 million bushels in August 2010 (O'Brien, 2010). If proso millet could capture even a small portion of this ethanol market, there would be fewer consumer complaints about rising food cost, allegedly due to ethanol production from corn. In addition, the ethanol market for proso millet would increase demand and price, providing the impetus for production expansion into drier, nontraditional areas.

Reports of ethanol production from proso millet are nearly nonexistent. In fact, we could find only one report of ethanol production from proso millet (Santra, Ratnayake, and Burgener, 2010). Santra, Ratnayake, and Burgener reported that the proso millet cultivars, Huntsman and Plateau, averaged 147.44 ml/lb (2.18 gal/bu) of ethanol yield. This is similar to the 2.15 gal/bu for Huntsman that we initially obtained and reported for our Sun Grant proposal in 2009.

To determine if proso millet is an economically viable ethanol crop for the Southern High Plains, we evaluated four cultivars (to see which cultivars are adapted to this drier region), we tested multiple planting dates (to determine the optimum planting window), and we developed crop enterprise budgets (as production decision tools for proso millet as a birdseed crop compared to proso millet as an ethanol crop).

## Materials and Methods for 2009

We planted proso millet at two sites, the Plainsman Research Center at Walsh, Colorado and the Oklahoma Panhandle Research and Extension Center at Goodwell, Oklahoma. We planted four proso millet cultivars at four incremental planting dates throughout July 2009. Three of the cultivars were standard starch cultivars: Huntsman, Sunrise, and Horizon. The fourth cultivar was a waxy starch cultivar, Plateau. The four

planting dates at Walsh were: PD1, July 1; PD2, July 10; PD3, July 20; and PD4, July 31, 2009. The four planting dates at Goodwell were: PD1, July 7; PD2, July 14; PD3, July 21; and PD4, July 28, 2009.

The experimental designs were split-plots with planting dates as the main plot and cultivars as the subplots with four replications. The plot size at Walsh was 10 ft. by 50 ft. (harvested 10 ft. by 44 ft.). The plot size at Goodwell was 5 ft. by 35 ft. (harvested 5 ft. by 30 ft.). Both sites were irrigated to assure seed germination. All cultivars and planting dates were seeded at 15 lb/a. Nitrogen was the only fertilizer applied, 50 lb/a at Walsh and 100 lb/a at Goodwell. For weed control at Walsh, the entire site had a preplant application of glyphosate 24 oz/a and 2,4-D ester 0.5 lb/a, and a post emergence application of dicamba 4 oz/a and 2,4-D amine 0.38 lb/a. For weed control at Goodwell, the entire site had a preplant application of atrazine 1.0 lb/a, and no post emergence herbicides were applied. Both sites were harvested with a self-propelled combines equipped with conventional grain heads.

For both sites at harvest, we recorded grain yield, test weight, and seed moisture. The harvest dates at Walsh were: PD1, September 29; PD2, October 16; PD3 and PD4, October 17. The harvest dates at Goodwell were: PD1, September 14 and PD3 October 19. At Goodwell, the July 14 planting date (PD2) did not establish an adequate stand and was eliminated from the study, and the July 28 planting date (PD4) was not harvested because of excessive rainfall.

To determine ethanol production, grain samples (7.00 lb of cleaned seed) were milled three times with a grain mill set at 0.008 in. The milled grain was diluted with water (20 gal/bu). The mash was boiled and alpha amylase was added to liquefy it. The mash was cooled and alpha amylase was again added to breakdown the starches into dextrins. The mash was further cooled and gluco amylase was added to convert the dextrins into sugars. The temperature of the mash was further lowered, yeast was added, and the mash was allowed to ferment for five days in air-locked containers. After fermentation was completed, the beer in the mash was pressed out with a fruit press. To extract the remaining beer, water was added and the dilute beer was pressed (this step was repeated twice). The alcohol in the beer was distilled in a stainless steel still with a refraction column. Ethanol production is reported at 100% ethanol. After alcohol extraction, the wet distiller's grain was oven dried; however no analysis was performed on the dry distiller's grain.

Materials and Methods for 2010

All cultural practices in 2010 were similar to the cultural practices we used in 2009, except we planted the proso millet cultivars at four monthly planting dates from May to August. The four planting dates at Walsh were: PD1, May 12; PD2, June 3; PD3, July 2; and PD4, August 2, 2010. The four planting dates at Goodwell were in early May, June, July, and the August planting date was not planted due to bird damage in the previous planting dates. The location of the study at Goodwell was near urban dwellings with trees. Birds used the trees for roosting, which provided easy feeding access and subsequent damage to the millet study. The Goodwell site was not harvested because of severe bird damage. Grain yield, test weight, seed moisture, plant height, and seed shattering measurements were recorded at harvest for Walsh.

The harvest dates at Walsh were: PD1, August 30; PD2, August 30; PD3, September 21; and PD4, November 5.

The procedure for ethanol determinations were the same in 2010 as outlined in 2009.

Crop enterprise budgets were generated from the optimum planting date in 2010 (June 3) at Walsh. Data for proso millet as a birdseed crop and as an ethanol crop are based on the average grain production, ethanol yield (gal/bu), and ethanol production (gal/a) of the four cultivars tested for the June 3, 2010 planting date. In our area, proso millet as an ethanol crop would compete with grain sorghum as an ethanol crop. Therefore, as a comparison, we included a crop enterprise budget based on a study of grain sorghum as an ethanol crop conducted at the Plainsman Research Center at Walsh during 2007 and 2008 (Larson, et. al, 2009).

Results for 2009

The first planting dates at both sites produced the highest average grain yield, 1645 lb/a at Walsh and 1450 lb/a at Goodwell (Tables 1 and 2). The planting date ranking for grain yield at Walsh was: PD1>>PD2>PD3=PD4 (Table 3). The planting date ranking at Goodwell was PD1>PD3 (Table 4). Huntsman produced the highest yield at all harvested planting dates at both sites, although Huntsman was not significantly different than Sunrise at Walsh, and Huntsman only significantly out yielded Plateau at Goodwell. Grain yield ranking of the four cultivars was consistent for all four planting dates at Walsh: Huntsman=Sunrise>Horizon>Plateau (Table 3 and Figure 1). The relative ranking of the four cultivars for the two harvested planting dates at Goodwell was: Huntsman>Sunrise=Horizon>Plateau, although the only significant difference was between Huntsman and Plateau (Table 4 and Figure 3).

At both sites, the first planting date produced the highest ethanol production, 59.5 gal/a for Walsh and 50.0 gal/a for Goodwell (Tables 3 and 4). The ethanol production rankings for the planting dates were: PD1>>PD2>PD3=PD4 at Walsh, and PD1>PD3 at Goodwell. These planting date ethanol production rankings have the same order and magnitude as the grain yield rankings. At both sites, Huntsman had the highest ethanol production at each planting date (Tables 1 and 2) and highest overall production, 36.6 gal/a for Walsh and 56.8 gal/a for Goodwell. Plateau produced the highest per bushel ethanol yield for each planting date at Walsh. Horizon had the highest overall ethanol yield at Goodwell with 1.98 gal/bu, and Plateau had the highest overall ethanol yield at Walsh with 2.11 gal/bu.

Test weights significantly decreased with later planting dates at Walsh (Table 3 and Figure 2), but increased, although not significantly, between the two harvested planting dates (PD1 and PD3) at Goodwell (Table 4 and Figure 3). Huntsman had the highest overall test weight at both sites, 56.9 lb/bu at Goodwell and 54.6 lb/bu at Walsh.

Plant height consistently decreased with later planting dates at Walsh (Table 1). The plant height ranking from tallest to shortest was: Huntsman, Sunrise, Horizon, and Plateau.

At Walsh, date to 50% heading averaged 33 days after planting (DAP) for all planting dates and cultivars (Table 1). With later planting dates, date of 50% heading became increasingly earlier for all cultivars, except Plateau. Plateau was the earliest maturing cultivar tested and its date to 50% heading remained at 30 to 31 DAP for the

first three planting dates then dropped to 29 DAP at the last planting date. Date to 80% maturity, when the crop was ready for swathing, averaged 61 DAP for all planting dates and cultivars. Like heading, date to 80% maturity was earlier with later planting dates for all cultivars, except Plateau. Date of maturity of Plateau remained 58 to 59 DAP for all four planting dates.

Results for 2010

All the yield results for 2010 are from the Walsh site only, because the Goodwell site was lost to bird damage. The bird damage at Goodwell was due to the planting location (the study was too close to trees that the birds used for roosting) and is not indicative that the Goodwell area was a poor location for millet. At Walsh, the June planting date had the highest grain yield of 1891 lb/a, but it was not significantly higher than the May planting date with 1783 lb/a (Table 6 and Fig. 4). The May and June plantings dates were significantly higher than the July planting date, and the July planting date was significantly higher than the August planting date. The grain yield ranking for the planting dates was PD2=PD1>>PD3>>PD4. Huntsman had the single highest yield of 2170 lb/a with the June planting date, although it was not significantly different from Sunrise, which had the second highest yield of 2045 lb/a with the May planting date (Table 5). Huntsman and Sunrise produced significantly higher yield than Plateau and Horizon. The yield ranking for the cultivars was Huntsman=Sunrise>Plateau=Horizon.

The highest single ethanol production was 86.0 gal/a with Huntsman at the June 3 planting date, PD2 (Table 5). There was a tie for the second highest single ethanol production of 79 gal/a with Huntsman at May 12 (PD1) and Sunrise at June 3 (PD2). The June 3 planting date produced the highest average ethanol production, 74.0 gal/a, and the highest average ethanol yield, 2.19 gal/bu, compared to the average of all four cultivars in PD1 and PD3 (Table 6). There was insufficient plot yield of the August 2 (PD4) to conduct ethanol determinations; therefore, all ethanol analyses were performed with the first three planting dates only. Ethanol production ranking of the cultivars corresponded to the yield ranking with Huntsman=Sunrise>Plateau=Horizon. The highest single ethanol yield was 2.27 gal/bu with Horizon at the May 12 planting date (Table 5). Horizon is the only cultivar that did not increase ethanol yield with the June 3 planting date, but Horizon did increase ethanol production with the June 3 planting date. Plateau consistently had the lowest ethanol yield for the first three planting dates. Overall, Horizon had the highest average ethanol yield of 2.20 gal/bu for the first three planting dates. The ethanol yield ranking of the cultivars was Horizon>Huntsman=Sunrise>Plateau.

The average test weight for the July planting was significantly higher than May and August planting dates, but it was not significantly higher than the June planting date (Table 6 and Fig. 5). The test weight ranking for the planting dates was PD3=PD2>PD4>PD1. Test weight for PD4 was based solely on Huntsman because there was insufficient plot yield from the other three cultivars for test weight measurements. The highest test weight of 56.4 lb/bu occurred with Huntsman at the July planting date, and the lowest test weight was 50.9 lb/bu with Plateau at the May planting date (Table 5). Huntsman had the highest average test weight, 55.7 lb/bu. The test weight of Huntsman was significantly higher than Sunrise and Horizon, which were

significantly higher than Plateau. The test weight ranking for the cultivars was Huntsman>Sunrise=Horizon>Plateau.

Plant height remained relatively constant at about 25 in. for the first three planting dates, but it was only half as high for the last planting date (Table 5). Huntsman was the tallest cultivar. Huntsman was an inch taller than the second tallest cultivar, Sunrise, in three of the four planting dates.

It took an average of 5 to 8 days longer for the cultivars planted in May to reach 50% heading and 80% maturity than the other three planting dates (Table 5). The cultivars in the July planting date had the fewest days to heading and maturity. Huntsman required an average of an extra day more than Sunrise to reach 50% heading and 80% maturity.

Crop enterprise budgets for proso millet as a birdseed crop and as an ethanol crop were developed using the average production of the optimum planting date, June 3 (PD2). The June 3 planting date produced an average of 74.0 gal/a from 33.8 bu/a seed yield with an ethanol yield of 2.19 gal/bu (Table 7). Proso millet as an ethanol feedstock in the Southern High Plains will be a direct replacement for grain sorghum as an ethanol feedstock. The average ethanol yield of the four proso millet cultivars at the optimum planting date was 2.19 gal/bu. The average ethanol yield of twelve grain sorghum hybrids from a previous study was 2.44 gal/bu (Larson et. al, 2009). We used 2.19/2.44 (2.19 gal/bu ethanol yield of proso millet divided by 2.44 gal/bu ethanol yield of grain sorghum), or 89.8% of the grain sorghum market price as the market price for proso millet as an ethanol crop. The 2010 market price for grain sorghum was $7.61/bu, therefore we used $6.83/bu ($7.61 * 0.898) as the market price for proso millet as an ethanol crop. For proso millet as a birdseed crop, we used the 2010 local market price of $4.48/bu. Using 2010 market prices, proso millet as an ethanol crop produced $137.41/a in net income compared to $57.50/a for proso millet as a birdseed crop (Table 8).

## Discussion

In 2009, we evaluated only July planting dates for proso millet production. The first planting dates (July 1 for Walsh and July 7 for Goodwell) produced the highest grain yield and ethanol production (Tables 3 and 4). There was a significant yield decrease between the July 1 and July 10 planting dates at Walsh (990 lb/a yield drop), and the yield difference between the two harvested planting dates (July 7 and July 21) at Goodwell of 267 lb/a was also significant. This suggests that, when planting in July, early July planting is critical for high yields at Walsh and Goodwell, but with the small yield decrease, the planting window may be longer at Goodwell. Highest ethanol production corresponded with highest grain yield. Huntsman planted in early July had the highest grain yield and ethanol production at both Walsh and Goodland (Tables 1 and 2). Test weights decreased significantly with later planting dates at Walsh, but they actually increased at Goodwell, although the test weight increase was not significant. Moreover, at Walsh, Plateau consistently had the lowest test weight for all four planting dates; however, Plateau had the highest per bushel ethanol yield. Delayed planting, past early July, did not appear to have the severe yield and test weight penalty at Goodwell as it did at Walsh. Nonetheless, the highest grain yield and ethanol

production averages were from the first planting dates (July 1 for Walsh and July 7 for Goodwell) at both sites.

The 2010 yield results were from the Walsh site only, and ethanol yield and production analyses were from the first three planting dates (plot yields were too small to perform ethanol analyses for the fourth planting date, August 2). Huntsman at the June 3 planting date had the single highest yield of 2170 lb/a (Table 5). The optimum planting date for Huntsman was late May (Fig. 4). There was no significant seed yield difference between the May 12 planting date and the June 3 planting date. Although not significantly higher, seed yield, ethanol yield, and ethanol production were highest for the June 3 planting date. Therefore we chose June 3 as the optimum planting date. Since there was no significant yield difference between the May 12 planting date and the June 3 planting date, but there was a significant yield decrease for the July 2 planting date, the optimum planting window for yield would encompass the first two planting dates. Obviously, the very low seed yields of the August 2 planting date indicate that August is too late for acceptable yields.

Overall in 2010, Huntsman produced slightly higher, but not significantly higher, seed yield and ethanol production than Sunrise. This suggests that Huntsman and Sunrise are well-adapted cultivars at Walsh. Horizon and Plateau produced significantly less seed yield than Huntsman and Sunrise. Horizon and Plateau are not as well adapted and would be on the second tier of cultivar choices compared to Huntsman and Sunrise. Plateau is a waxy type cultivar; whereas, Huntsman, Sunrise and Horizon are non-waxy type cultivars. Waxy type cultivars lack amylose (Graybosch and Baltensperger, 2009). This change in starch composition did not increase ethanol yield (gal/bu) or ethanol production (gal/a) of Plateau compared to the non-waxy type cultivars tested.

High grain production corresponded with high ethanol production. For the 2010 planting dates, ethanol yield ranged from 2.11 gal/bu to 2.19 gal/bu. This 0.08 gal/bu range was quantitatively too small to change the ethanol production rankings of the planting dates. The 1.9 bu/a seed yield difference between the first and second plantings was not significantly different. It would require an ethanol yield of 2.32 gal/bu (0.05 gal/bu higher than any single proso millet ethanol yield obtain) just to compensate for the 1.9 bu/a seed yield difference and make the first and second planting dates equal in ethanol production.

The highest test weights for the three planting dates and four cultivars tested did not produce the highest ethanol yields (Fig. 6). Conventional wisdom suggests that high test weights coincide with high ethanol yields; however, our results indicated that this was not the case. For both years of this study, 2009 with four July planting dates and 2010 with four monthly planting dates, highest test weights did not culminate in highest ethanol yields.

Crop enterprise budgets for proso millet as birdseed and proso millet as an ethanol feedstock were developed from the second planting date, June 3, 2010 at Walsh, which produced the highest grain and ethanol production. Proso millet when marketed as an ethanol crop (and priced as an ethanol feedstock replacement for grain sorghum) provided higher net income than proso millet as a birdseed crop. The ethanol yield of the four cultivars for the June 3 planting date averaged one quart less per bushel than the twelve grain sorghum hybrids from an earlier study (Larson et. al, 2009)

and the proso millet produced 10 bu/a less than the grain sorghum. The net income of proso millet as an ethanol crop was much less than grain sorghum. However, the price differential of $2.35/bu between proso millet marketed as birdseed and proso marketed as an ethanol grain should provide economic incentive for ethanol production facilities to incorporate proso millet as part of their ethanol feedstock. If sufficient ethanol production facilities switch from grain sorghum to proso millet, the demand for proso millet would increase its price as an ethanol grain and as birdseed. These marketing scenarios are beyond the scope of this study; nonetheless, at some price point, proso millet would become competitive with grain sorghum as an ethanol crop.

Before the ethanol boom, which elevated grain prices, the price difference between proso millet and grain sorghum frequently favored proso millet. If the feed grain market reverts back to pre-ethanol production levels, the decision point for growing proso millet compared to grain sorghum would be $3.99/bu. With grain sorghum prices below $3.99/bu, it would be more advantageous to grow proso millet than grain sorghum, if the proso millet price remains at $4.48/bu (Tables 9 and 10).

## Conclusion

Of the four proso millet cultivars studied, Huntsman and Sunrise provided higher grain and ethanol production than Horizon and Plateau. Therefore for the drier and warmer Southern High Plains region, Huntsman and Sunrise appear well adapted.

The June 3 planting date produced the highest grain production, ethanol production, and ethanol yield of the monthly May to August planting dates tested. The two earliest planting dates, May 12 and June 3, produced highest grain and ethanol production, then dropped precipitously for the two later planting dates, July 2 and August 2. From our results, the planting date window for proso millet in at Walsh is late May to mid June, which is similar to the planting date window reported for the Northern High Plains (Lyon et. al, 2008).

Proso millet is an undervalued crop. The price of proso millet is limited because it is almost entirely marketed as birdseed. From our analysis, proso millet marketed as an ethanol crop was worth $2.35/bu more than proso millet as a birdseed crop. It would be profitable for ethanol plants to include proso millet as part of their ethanol feedstock, even if they paid premiums up to $2.35/bu above the current proso millet price (birdseed price), the income advantage would be worth their effort. Furthermore, in 2010, Santra, Ratnayake, and Burgener reported that inclusion of proso millet as part of the ethanol feedstock had a synergetic increase on ethanol production. They found that 10% and 25% proso millet to corn mixtures produced 0.17 gal/bu more than when using corn alone. However, the ethanol yield of their 100% corn fermentation was 2.11 gal/bu, which is much lower than the standard commercial ethanol yield of 2.8 gal/bu (O'Brien, 2010).

Because of the price differential between the birdseed market and the ethanol market for proso millet, ethanol production facilities seeking the least cost grain would make profitable decisions by including proso millet as part of their fermentation feedstock. If ethanol plants include proso millet as a feedstock, then the demand and price would increase, and proso millet would expand into nontraditional production areas. This possible crop expansion of proso millet would offer more cropping options and more income stability to growers in the water-deficient lands of the Southern High

Plains. Results from dryland sequence rotation studies conducted at Walsh showed that rotations with proso millet produced highest four-year variable net incomes (Larson, et. al, 2008). Ethanol production from proso millet will increase the income of producers and the economies of rural communities in the Southern High Plains will strengthen. According to the Department of Energy (DOE, 2001), ethanol production in rural communities stabilizes and even increases agriculturally based economies. Expanding ethanol production from proso millet will lessen our nation's dependence on foreign oil and will further our national goal of greater energy independence based on renewable feedstocks.

Literature Cited

Baltensperger, D.D. 1996. Foxtail and proso millet. p. 182-190. In: J. Janick (ed.), Progress in New Crops. ASHS Press, Alexandria, VA.
http://www.hort.purdue.edu/newcrop/proceedings1996/v3-182.html.
Accessed: February 9, 2009.

Blumenthal, J.M. and D.D. Baltensperger. 2002. Fertilizing proso millet. NebGuide G924. Institute of Agriculture and Natural Resources, Extension, Univ. of Neb., Lincoln, Nebraska.
http://www.ianrpubs.unl.edu/epublic/pages/publicationD.jsp?publicationId=151
Accessed: February 9, 2009.

Dept. of Energy. 2001. Rural economies benefit from bioenergy and biobased products. Biomass Research & Development Initiative Newsletter, Nov. 2001. USDA, Dept. of Energy.
http://www.bioproducts-bioenergy.gov/1101.html
Accessed: January 31, 2006.

Graybosch, R.A. and D.D. Baltensperger. 2009. Evaluating of the Waxy Endosperm Trait in Proso Millet (Panicum miliaceum). Plant Breeding 128, 70-73 (2009).
http://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1367&context=agronomyfacpub&sei-redir=1#search="proso+millet+waxy"
Accessed: May 7, 2011.

Larson, K.J., D.L. Thompson, D. Harn, C. Thompson, C. Walker, J.J. Johnson, S. Haley, G.A. Peterson, D. Westfall, N. Hansen, M. Brick, and S. Brase. 2008. Plainsman Research Center 2007 research reports. Technical Report, TR08-05. Plainsman Research Center, Extension, Dept. of Soil and Crop Sci., AES, CSU, Fort Collins. 123p.

Larson, K., D. Thompson, D. Harn, T. Macklin, and J. Whittler. April, 2009. Expanding Bio-based Energy Crop Options for Dryland Systems. AES, CSU, Fort Collins, Colorado. Colorado Experiment Station web publication. 27p.
http://www.colostate.edu/depts/prc/pubs/CIGFinalRepNum09.pdf

Lyon, D.J., P.A. Burgener, K.L. DeBoer, R.M. Harveson, G.L. Hein, G.W. Hergert, T.L. Holman, J.J. Johnson, T. Nleya, J.M. Krall, D.C. Nielsen, and M.F. Vigil. 2008. Proso millet in the Great Plains. EC137 Producing and Marketing. SDSU, Univ. of Wyoming, CSU, USDA, ARS, Institute of Agriculture and Natural Resources, Extension, Univ. of Neb., Lincoln, Nebraska.

NASS, USDA. 2009. 2009 Agricultural Statistics Annual Report, Chapter 1: Feed and Grain. 46p.
http://www.nass.usda.gov/Publications/Ag_Statistics/2009/chp01.pdf
Accessed: May 7, 2011.

O'Brien, Daniel. September, 2010. Comparing Corn Ethanol Use data Sources from US Government Agencies. KSU. 6p.
http://www.agmanager.info/energy/DataSource_CornRefiningProcesses_09-24-10.pdf
Accessed: May 7, 2011.

Santra, D.K., W. Ratnayake, and P. Burgener. 2010. Increasing NE Wheat Productivity by Expanding Proso Millet Market. Progress Report for Nebraska Wheat Board, July 1, 2009 to June 30, 2010. Univ. of Neb. 2p.
http://cropwatch.unl.edu/c/document_library/get_file?uuid=81a27f2c-7123-4210-ae64-5e6274e30f91&groupId=465948
Accessed: May 4, 2011.

Witt, M. 1983. Proso millet as a crop Alternative. SRL70. Keeping Up with Research. AES, KSU, Manhattan, Kansas. http://www.oznet.ksu.edu/library/crpsl2/SRL70.pdf
Accessed: February 9, 2009.

Final Report for the Sun Grant Initiative, South Central Region

Kevin Larson, Research Scientist**,** Plainsman Research Center, Colorado State University, Walsh, Colorado

Rick Kochenower, Area Research and Extension Specialist, Oklahoma Panhandle Research and Extension Center, Oklahoma State University, Goodwell, Oklahoma

Jeffrey Tranel, Extension Economist, Agriculture and Business Management, Colorado State University, Pueblo, Colorado

Corresponding Author: Kevin Larson
Email address: kevin.larson@colostate.edu

Published: June 2011

Table 1.--Proso Millet: Planting Dates and Cultivars at Walsh, CO, 2009.

| Cultivar | Seed Yield | Test Weight | Ethanol Yield | Total Ethanol Production | Plant Height | 50% Heading | 80% Maturity |
|---|---|---|---|---|---|---|---|
| | lb/a | lb/bu | gal/bu | gal/a | in | DAP | DAP |
| **PD1 - July 1** | | | | | | | |
| Huntsman | 2137 | 56.5 | 2.04 | 77.8 | 27 | 39 | 66 |
| Sunrise | 1956 | 56.3 | 1.96 | 68.5 | 26 | 38 | 65 |
| Horizon | 1411 | 56.0 | 2.03 | 51.1 | 24 | 36 | 64 |
| Plateau | 1076 | 53.5 | 2.10 | 40.4 | 21 | 30 | 58 |
| **PD1 Average** | **1645** | **55.6** | **2.03** | **59.5** | **25** | **36** | **63** |
| **PD2 - July 10** | | | | | | | |
| Huntsman | 981 | 55.8 | 2.04 | 35.7 | 21 | 36 | 63 |
| Sunrise | 940 | 54.5 | 2.04 | 34.2 | 20 | 35 | 62 |
| Horizon | 490 | 54.4 | 2.07 | 18.1 | 19 | 34 | 61 |
| Plateau | 208 | 54.1 | 2.10 | 7.8 | 16 | 30 | 58 |
| **PD2 Average** | **655** | **54.7** | **2.06** | **24.0** | **19** | **34** | **61** |
| **PD3 - July 20** | | | | | | | |
| Huntsman | 429 | 54.1 | 2.08 | 15.9 | 18 | 34 | 62 |
| Sunrise | 399 | 53.9 | 2.01 | 14.3 | 16 | 34 | 62 |
| Horizon | 139 | 55.0 | 2.08 | 5.2 | 16 | 33 | 61 |
| Plateau | 151 | 53.5 | 2.18 | 5.9 | 13 | 31 | 59 |
| **PD3 Average** | **280** | **54.1** | **2.09** | **10.3** | **16** | **33** | **61** |
| **PD4 - July 31** | | | | | | | |
| Huntsman | 365 | 51.9 | 2.00 | 13.0 | 16 | 32 | 59 |
| Sunrise | 316 | 51.5 | 1.94 | 10.9 | 14 | 32 | 59 |
| Horizon | 229 | 51.3 | 2.06 | 8.4 | 15 | 30 | 58 |
| Plateau | 201 | 50.7 | 2.07 | 7.4 | 12 | 29 | 58 |
| **PD4 Average** | **278** | **51.4** | **2.02** | **10.0** | **14** | **31** | **59** |
| Average | 714 | 53.9 | | | 18 | 33 | 61 |
| LSD 0.05 | 272.1 | 0.94 | | | | | |

Harvested: PD1, Sept. 29; PD2, Oct. 16; PD3, Oct. 17; PD3, Oct. 17, 2009.
DAP is days after planting.
Seed yields adjusted to 13% seed moisture content.
Ethanol Production is 100% ethanol.

Table 2.-Proso Millet Planting Dates and Cultivars, Seed Yield and Ethanol Yield at Goodwell, OK, 2009.

| | PD1 - July 7 | | | | PD3 - July 21 | | | |
|---|---|---|---|---|---|---|---|---|
| Cultivar | Seed Yield | Test Weight | Ethanol Yield | Total Ethanol Prod. | Seed Yield | Test Weight | Ethanol Yield | Total Ethanol Prod. |
| | lb/a | lb/bu | gal/bu | gal/a | lb/a | lb/bu | gal/bu | gal/a |
| Huntsman | 1686 | 56.4 | 1.95 | 58.7 | 1558 | 57.3 | 1.97 | 54.8 |
| Sunrise | 1498 | 54.8 | 1.88 | 50.3 | 1065 | 57.6 | 2.03 | 38.6 |
| Horizon | 1450 | 55.4 | 1.97 | 51.0 | 1234 | 55.5 | 1.98 | 43.6 |
| Plateau | 1168 | 52.4 | 1.91 | 39.8 | 873 | 54.7 | 1.98 | 30.9 |
| Mean | 1450 | 54.8 | 1.93 | 50.0 | 1183 | 56.3 | 1.99 | 42.0 |
| LSD 0.05 | NS | NS | | | NS | NS | | |
| CV % | 23 | 3 | | | 27 | 3 | | |

Seed Yield is adjusted to 13.0% seed moisture content.
Ethanol Production is 100% ethanol.

Table 3.--Proso Millet Planting Dates and Cultivar Summary at Walsh, 2009.

| | Total Ethanol Production | Seed Yield | | Ethanol Yield | Test Weight | | Seed Moisture | |
|---|---|---|---|---|---|---|---|---|
| | gal/a | lb/a | | gal/bu | lb/bu | | % | |
| **Planting Date** | | | | | | | | |
| PD1 - July 1 | 59.5 | 1645 | a | 2.03 | 55.6 | a | 13.0 | a |
| PD2 - July 10 | 24.0 | 655 | b | 2.06 | 54.7 | b | 14.4 | b |
| PD3 - July 20 | 10.3 | 280 | c | 2.09 | 53.9 | c | 14.7 | b |
| PD4 - July 31 | 10.0 | 278 | c | 2.02 | 51.3 | d | 17.0 | c |
| PD LSD 0.05 | | 160.8 | | | 0.44 | | 0.35 | |
| **Cultivar** | | | | | | | | |
| Huntsman | 35.6 | 978 | a | 2.04 | 54.6 | a | 14.8 | a |
| Sunrise | 32.0 | 903 | a | 1.99 | 54.0 | b | 14.8 | a |
| Horizon | 20.7 | 567 | b | 2.06 | 53.9 | b | 14.7 | a |
| Plateau | 15.4 | 409 | c | 2.11 | 53.0 | c | 14.8 | a |
| Cultivar LSD 0.05 | | 135.2 | | | 0.49 | | 0.37 | |
| Average | 26.0 | 715 | | 2.05 | 53.9 | | 14.8 | |

Seed Yield is adjusted to 13% seed moisture content.
Ethanol is adjusted to 100% alcohol.

Table 4.--Proso Millet Planting Dates and Cultivar Summary at Goodwell, 2009

| | Total Ethanol Production | Seed Yield | | Ethanol Yield | Test Weight | | Seed Moisture | |
|---|---|---|---|---|---|---|---|---|
| | gal/a | lb/a | | gal/bu | lb/bu | | % | |
| **Planting Date** | | | | | | | | |
| PD1 - July 7 | 50.0 | 1450 | a | 1.93 | 54.7 | b | 13.8 | a |
| PD3 - July 21 | 42.0 | 1183 | b | 1.99 | 56.3 | a | 12.9 | a |
| PD LSD 0.05 | | 91.2 | | | 2.31 | | 2.33 | |
| **Cultivar** | | | | | | | | |
| Huntsman | 56.8 | 1622 | a | 1.96 | 56.9 | a | 13.8 | a |
| Sunrise | 44.5 | 1282 | ab | 1.96 | 56.3 | a | 13.5 | a |
| Horizon | 47.3 | 1342 | ab | 1.98 | 55.4 | ab | 13.3 | a |
| Plateau | 35.4 | 1021 | b | 1.95 | 53.5 | b | 12.8 | a |
| Cultivar LSD 0.05 | | 354.0 | | | 1.97 | | 1.88 | |
| Average | 46.0 | 1317 | | 1.96 | 55.5 | | 13.4 | |

Seed Yield is adjusted to 13% seed moisture content.
Ethanol is adjusted to 100% alcohol.

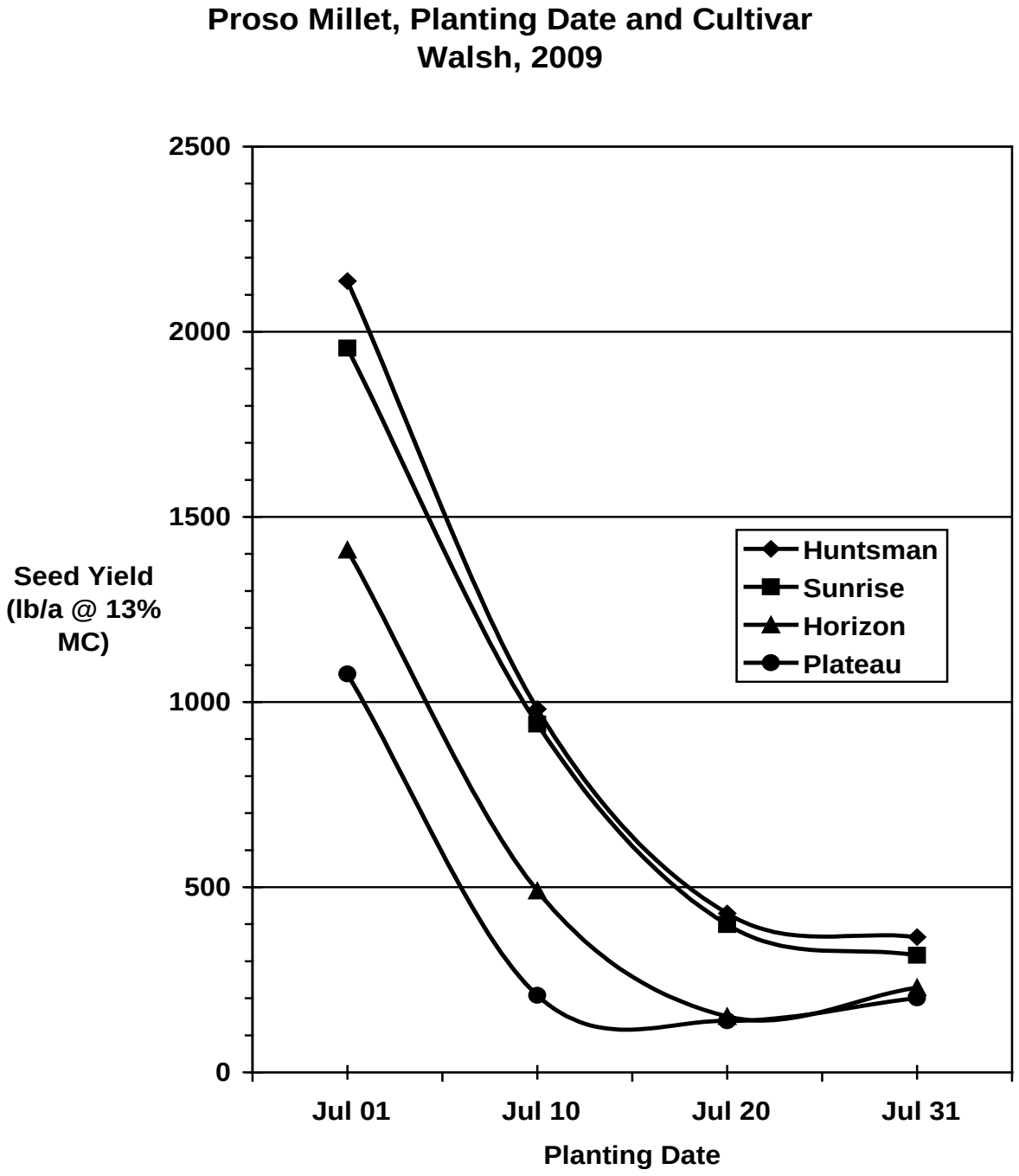


Fig. 1. Seed yield of proso millet planting dates and cultivars for ethanol production study at Walsh, CO, 2009. The planting dates were: PD1, July 1; PD2, July 10; PD3, July 20; and PD4, July 31. The cultivars were: Huntsman, Sunrise, Horizon, and Plateau. All planting dates and cultivars were seeded at 15 lb/a. Harvest dates were: PD1, September 29; PD2, October 16; PD3 and PD4, October 17.

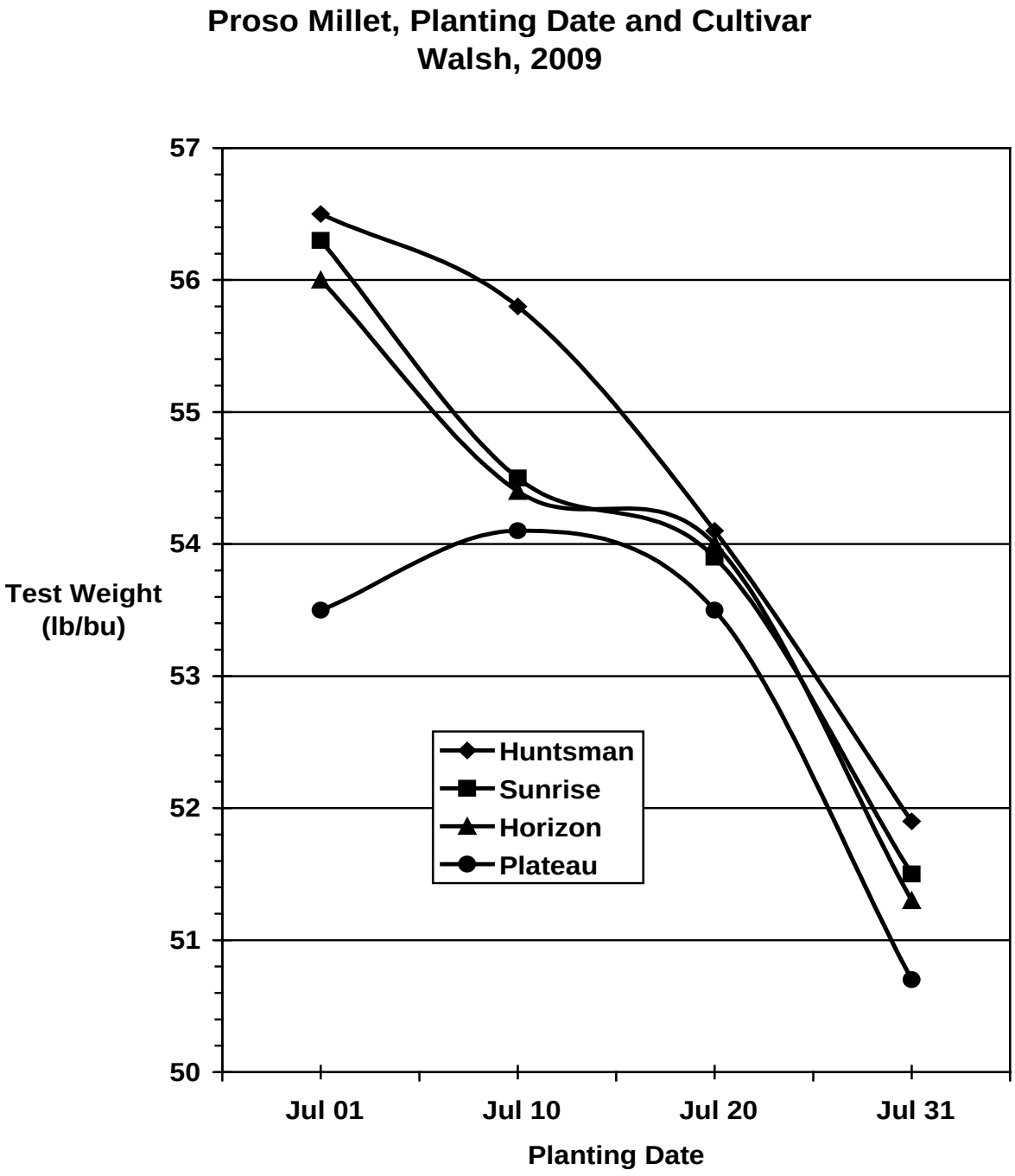


Fig. 2. Test weight of proso millet planting dates and cultivars for ethanol production study at Walsh, CO, 2009. The planting dates were: PD1, July 1; PD2, July 10; PD3, July 20; and PD4, July 31. The cultivars were: Huntsman, Sunrise, Horizon, and Plateau. All planting dates and cultivars were seeded at 15 lb/a. Harvest dates were: PD1, September 29; PD2, October 16; PD3 and PD4, October 17.

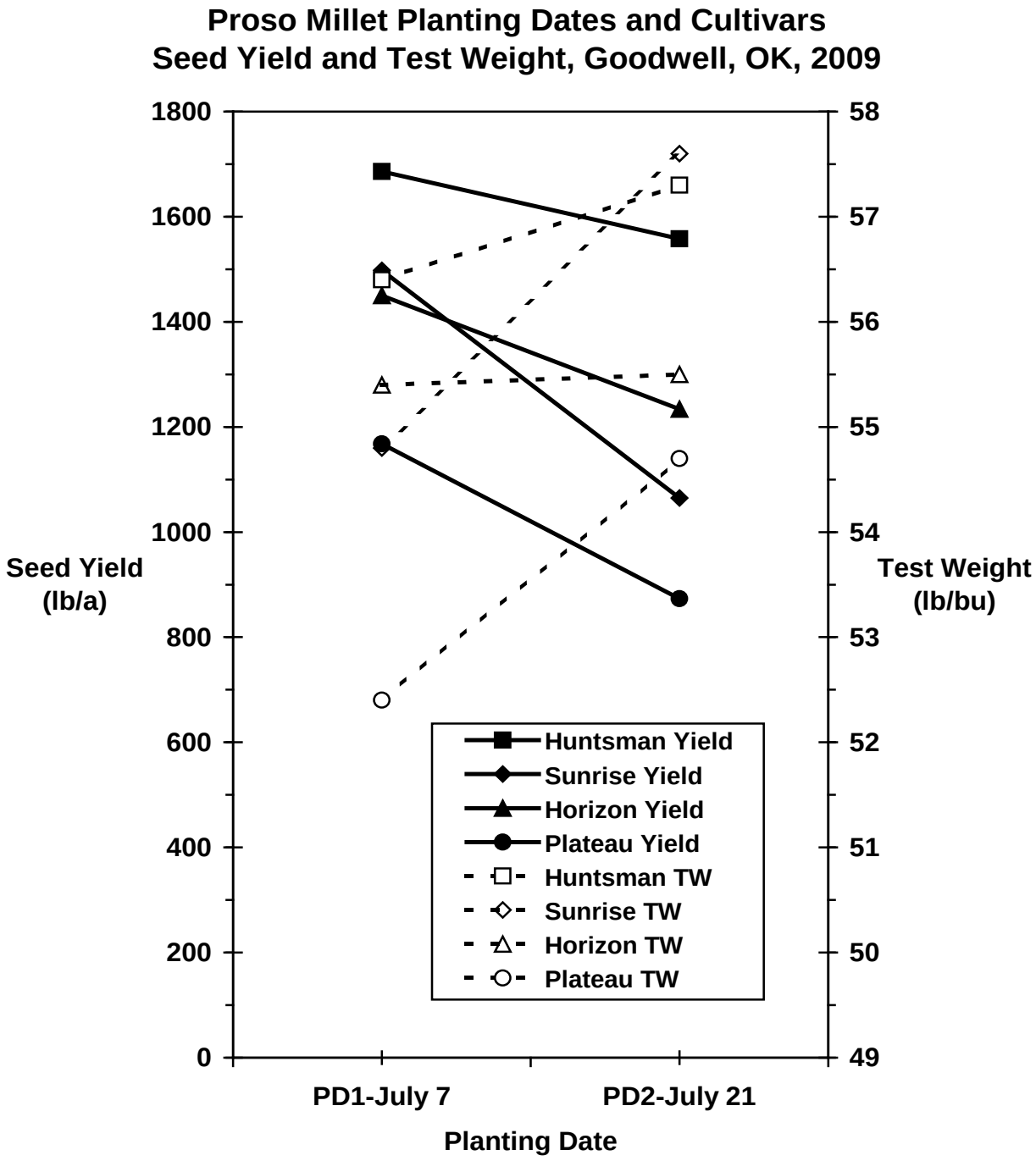


Fig. 3. Seed yield and test weight of proso millet planting dates and cultivars for ethanol production study at Goodwell, OK, 2009. The harvested planting dates were: PD1, July 7; and PD3, July 21, 2009. The cultivars were: Huntsman, Sunrise, Horizon, and Plateau. All planting dates and cultivars were seeded at 15 lb/a. Harvest dates were: PD1, September 14; and PD3, October 19. Seed yield is adjusted to 13.0% seed moisture content.

Table 5.--Proso Millet: Planting Dates and Cultivars at Walsh, CO, 2010.

| Cultivar | Seed Yield | Test Weight | Ethanol Yield | Total Ethanol Production | Plant Height | 50% Heading | 80% Maturity |
|---|---|---|---|---|---|---|---|
| | lb/a | lb/bu | gal/bu | gal/a | in | DAP | DAP |
| **PD1 - May 12** | | | | | | | |
| Huntsman | 2101 | 54.9 | 2.10 | 78.8 | 26 | 54 | 87 |
| Sunrise | 2045 | 54.4 | 2.11 | 77.1 | 25 | 53 | 86 |
| Horizon | 1466 | 53.7 | 2.27 | 59.4 | 22 | 51 | 84 |
| Plateau | 1519 | 50.9 | 2.06 | 55.9 | 22 | 47 | 80 |
| **PD1 Average** | **1783** | **53.5** | **2.14** | **67.8** | **24** | **51** | **84** |
| **PD2 - June 3** | | | | | | | |
| Huntsman | 2170 | 56.0 | 2.22 | 86.0 | 29 | 47 | 78 |
| Sunrise | 1985 | 55.1 | 2.22 | 78.7 | 28 | 46 | 77 |
| Horizon | 1717 | 55.5 | 2.20 | 67.5 | 25 | 44 | 75 |
| Plateau | 1692 | 51.9 | 2.12 | 64.1 | 23 | 40 | 73 |
| **PD2 Average** | **1891** | **54.6** | **2.19** | **74.1** | **26** | **44** | **76** |
| **PD3 - July 2** | | | | | | | |
| Huntsman | 1126 | 56.4 | 2.12 | 42.6 | 26 | 38 | 66 |
| Sunrise | 1143 | 55.4 | 2.12 | 43.3 | 25 | 38 | 65 |
| Horizon | 766 | 55.1 | 2.12 | 29.0 | 22 | 36 | 62 |
| Plateau | 926 | 53.5 | 2.06 | 34.1 | 21 | 32 | 62 |
| **PD3 Average** | **990** | **55.1** | **2.11** | **37.2** | **24** | **36** | **64** |
| **PD4 - Aug. 2** | | | | | | | |
| Huntsman | 79 | 54.3 | -- | -- | 12 | 49 | 77 |
| Sunrise | 40 | -- | -- | -- | 13 | 48 | 76 |
| Horizon | 17 | -- | -- | -- | 11 | 45 | 76 |
| Plateau | 30 | -- | -- | -- | 11 | 43 | 75 |
| **PD4 Average** | **42** | **54.3** | **--** | **--** | **12** | **46** | **76** |
| Average | 1177 | 54.4 | 2.15 | 59.7 | 22 | 44 | 75 |
| LSD 0.05 | 221.1 | 0.86 | | | | | |

Harvested: PD1, Aug. 30; PD2, Aug. 30; PD3, Sep. 21; PD4, Nov. 5, 2010.
DAP is days after planting.
Seed yields adjusted to 13% seed moisture content.
Ethanol Production is 100% ethanol.

Table 6.--Proso Millet Planting Dates and Cultivar Summary at Walsh, 2010.

| | Total Ethanol Production | Seed Yield | | Ethanol Yield | Test Weight | | Seed Moisture | |
|---|---|---|---|---|---|---|---|---|
| | gal/a | lb/a | | gal/bu | lb/bu | | % | |
| **Planting Date** | | | | | | | | |
| PD1 - May 12 | 68.1 | 1783 | a | 2.14 | 53.5 | c | 14.1 | b |
| PD2 - June 3 | 74.0 | 1891 | a | 2.19 | 54.6 | ab | 15.6 | a |
| PD3 - July 2 | 37.3 | 990 | b | 2.11 | 55.1 | a | 13.9 | bc |
| PD4 - August 2 | -- | 42 | c | -- | 54.3 | b | 13.7 | c |
| PD LSD 0.05 | | 134.6 | | | 0.71 | | 0.37 | |
| **Cultivar** | | | | | | | | |
| Huntsman | 52.6 | 1369 | a | 2.15 | 55.7 | a | 14.7 | a |
| Sunrise | 50.0 | 1303 | a | 2.15 | 55.0 | b | 14.7 | a |
| Horizon | 38.9 | 991 | b | 2.20 | 54.8 | b | 14.5 | ab |
| Plateau | 38.7 | 1042 | b | 2.08 | 52.1 | c | 14.3 | b |
| Cultivar LSD 0.05 | | 113.5 | | | 0.45 | | 0.23 | |
| Average | 59.8 | 1177 | | 2.15 | 54.4 | | 14.3 | |

Seed Yield is adjusted to 13% seed moisture content.
Ethanol is adjusted to 100% alcohol.
PD4 test weight and seed moisture of Huntsman only.

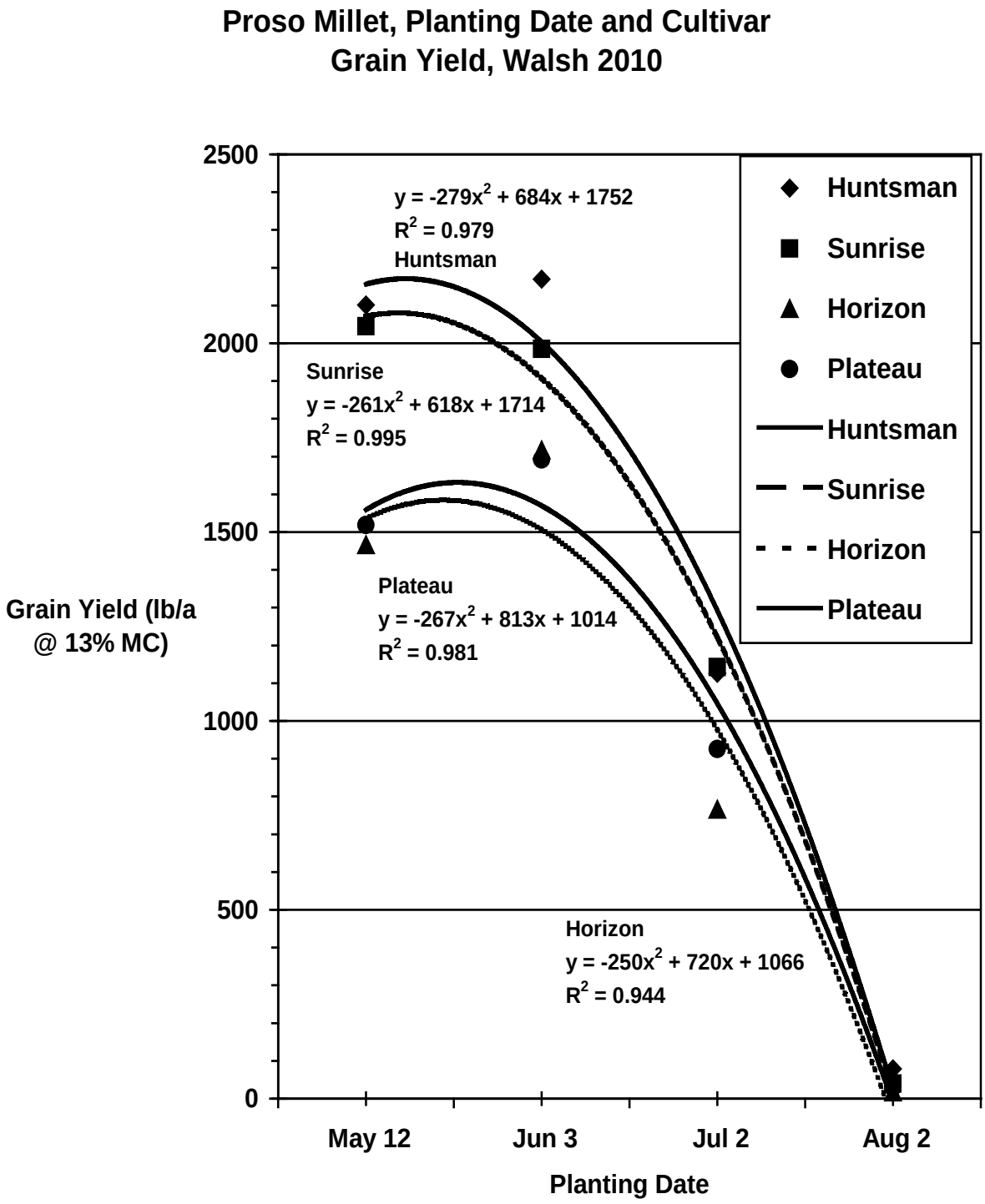


Fig. 4. Seed yield of proso millet planting dates and cultivars for ethanol production study at Walsh, CO, 2010. The planting dates were: PD1, May 12; PD2, June 3; PD3, July 2; and PD4, August 2. The cultivars were: Huntsman, Sunrise, Horizon, and Plateau. All planting dates and cultivars were seeded at 15 lb/a. Harvest dates were: PD1, August 30; PD2, August 30; PD3, September 21; and PD4, November 5.

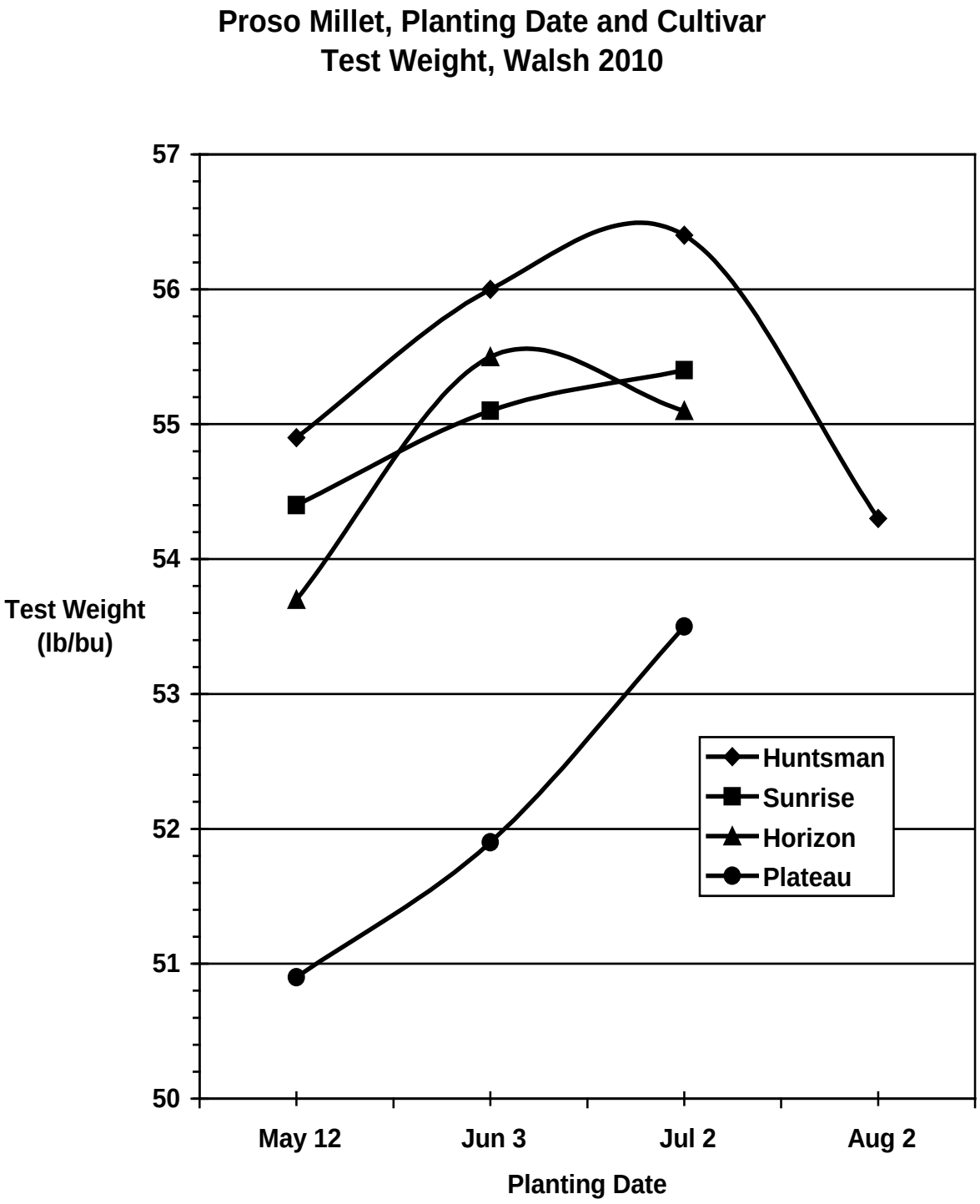


Fig. 5. Test weight of proso millet planting dates and cultivars for ethanol production study at Walsh, CO, 2010. The planting dates were: PD1, May 12; PD2, June 3; PD3, July 2; and PD4, August 2. The cultivars were: Huntsman, Sunrise, Horizon, and Plateau. All planting dates and cultivars were seeded at 15 lb/a. Harvest dates were: PD1, August 30; PD2, August 30; PD3, September 21; and PD4, November 5.

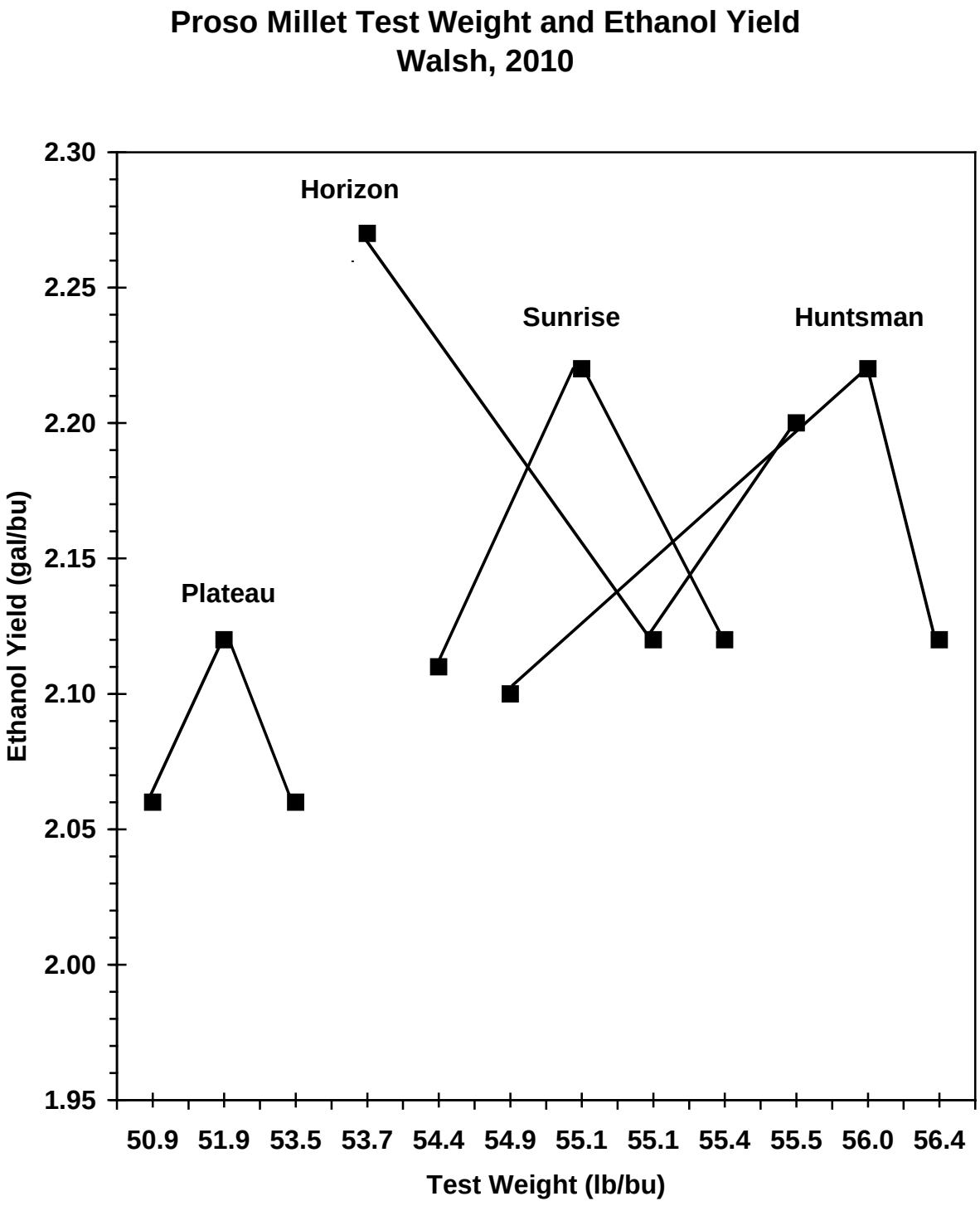


Fig. 6. Test weight and ethanol yield of proso millet planting dates and cultivars at Walsh, CO, 2010. The planting dates tested were: PD1, May 12; PD2, June 3; and PD3, July 2. The cultivars were: Huntsman, Sunrise, Horizon, and Plateau. All planting dates and cultivars were seeded at 15 lb/a. Harvest dates were: PD1, August 30; PD2, August 30; and PD3, September 21.

**Table 8. Potential Profitability of Millet for Birdseed, Millet for Ethanol, and Grain Sorghum for Ethanol in 2010**
**Plainsman Research Center**

| | | MILLET FOR BIRDSEED | | | MILLET FOR ETHANOL | | | GRAIN SORGUM FOR ETHANOL | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Quantity | Price | Value | Quantity | Price | Value | Quantity | Price | Value |
| | Unit | Per Acre | Per Unit | Per Acre | Per Acre | Per Unit | Per Acre | Per Acre | Per Unit | Per Acre |
| **GROSS RECEIPTS** | | | | | | | | | | |
| Grain | bu | 34.00 | 4.48 | 152.32 | 34.00 | 6.83 | 232.23 | 44.00 | 7.61 | 334.84 |
| **TOTAL RECEIPTS** | | | | 152.32 | | | 232.23 | | | 334.84 |
| **DIRECT COSTS** | | | | | | | | | | |
| Operating - PreHarvest | | | | | | | | | | |
| Herbicide | | | | | | | | | | |
| "Glyphosate" | oz | 24.00 | 0.11 | 2.64 | 24.00 | 0.11 | 2.64 | 24.00 | 0.11 | 2.64 |
| "2,4-D" | oz | 0.50 | 0.11 | 0.06 | 0.50 | 0.11 | 0.06 | 0.50 | 0.11 | 0.06 |
| Custom Applicatior | ac | 1.00 | 6.00 | 6.00 | 1.00 | 6.00 | 6.00 | 1.00 | 6.00 | 6.00 |
| Seed | lbs | 15.00 | 0.14 | 2.14 | 15.00 | 0.14 | 2.14 | 3.00 | 1.70 | 5.10 |
| Planting (no till) | ac | 1.00 | 12.00 | 12.00 | 1.00 | 12.00 | 12.00 | 1.00 | 18.00 | 18.00 |
| Fertilizer | | | | | | | | | | |
| Nitrogen | lbs | 50.00 | 0.50 | 25.00 | 50.00 | 0.50 | 25.00 | 60.00 | 0.50 | 30.00 |
| Custom Applicatior | ac | 1.00 | 12.00 | 12.00 | 1.00 | 12.00 | 12.00 | 1.00 | 12.00 | 12.00 |
| Herbicide | | | | | | | | | | |
| "Dicamba" | oz | 4.00 | 0.42 | 1.68 | 4.00 | 0.42 | 1.68 | | | |
| "2-4-D" | oz | 0.38 | 0.11 | 0.04 | 0.38 | 0.11 | 0.04 | | | |
| Custom Applicatior | ac | 1.00 | 6.00 | 6.00 | 1.00 | 6.00 | 6.00 | | | |
| Herbicide | | | | | | | | | | |
| "Atrazine" | oz | | | | | | | 32.00 | 0.13 | 4.19 |
| "Crop Oil" | oz | | | | | | | 32.00 | 0.05 | 1.75 |
| "Dicamba" | oz | | | | | | | 4.00 | 0.42 | 1.68 |
| Custom Applicatior | ac | | | | | | | 1.00 | 6.00 | 6.00 |
| Interest (7%, 6 mo) | dollars | | | 2.06 | | | 2.06 | | | 2.28 |
| Subtotal | | | | 69.62 | | | 69.62 | | | 89.69 |
| Operating - Harvest | | | | | | | | | | |
| Combine (custom hire) | | | | | | | | | | |
| Fixed | ac | 1.00 | 15.00 | 15.00 | 1.00 | 15.00 | 15.00 | 1.00 | 15.00 | 15.00 |
| Variable | bu | 34.00 | 0.15 | 5.10 | 34.00 | 0.15 | 5.10 | 44.00 | 0.15 | 6.60 |
| Hauling (custom hire) | bu | 34.00 | 0.15 | 5.10 | 34.00 | 0.15 | 5.10 | 44.00 | 0.15 | 6.60 |
| Subtotal | | | | 25.20 | | | 25.20 | | | 28.20 |
| **TOTAL DIRECT OPERATING COSTS** | | | | **94.82** | | | **94.82** | | | **117.89** |
| **NET RECEIPTS** | | | | **57.50** | | | **137.41** | | | **216.95** |

**Net Receipts:** Gross receipts less direct operating costs does not include "factor payments" including general farm overhead, real estate taxes, land payments, income taxes, etc.)
**Grain Price**: USDA Market News, CO/NE/WY Elevator Bids, 2010 November 16
**Grain Yield:** Plainsman Agri-Search, plot study results, millet = 1645 lbs/ac (56 lbs/bu)
**Ethanol Yield:** Kevin Larson, 2.19 gal/bu (millet) and 2.44 gal/bu (grain sorghum)
**Seed Price:** $8.00 per bushel, includes $3.00 for seed cleaning
**Custom Applications**: CSU, 2009 Custom Rates Survey Results

**Table 9. SUMMARY OF 'NET RECEIPTS' COMPARISON.**

| | Millet for Birdseed | Millet for Ethanol | Grain Sorghum |
|---|---|---|---|
| Price | 4.48 | 6.83 | 7.61 |
| Grain Yield | 34.00 | 34.00 | 44.00 |
| Gross Receipts | 152.32 | 232.23 | 334.84 |
| Total Direct Costs | 94.82 | 94.82 | 117.89 |
| Net Receipts | 57.50 | 137.41 | 216.95 |

**Table 10. SENSITIVITY ANALYSIS.**

| Grain Sorghum | | Difference Of Net Receipts |
|---|---|---|
| Price | Net Receipts | |
| 3.500 | 36.11 | (21.39) |
| 3.600 | 40.51 | (16.99) |
| 3.700 | 44.91 | (12.59) |
| 3.800 | 49.31 | (8.19) |
| 3.900 | 53.71 | (3.79) |
| 4.000 | 58.11 | 0.61 |
| 4.100 | 62.51 | 5.01 |
| 4.200 | 66.91 | 9.41 |
| 4.300 | 71.31 | 13.81 |
| 4.400 | 75.71 | 18.21 |
| 4.500 | 80.11 | 22.61 |
| 4.600 | 84.51 | 27.01 |
| 4.700 | 88.91 | 31.41 |
| 4.800 | 93.31 | 35.81 |
| 4.900 | 97.71 | 40.21 |
| 5.000 | 102.11 | 44.61 |
| 5.100 | 106.51 | 49.01 |
| 5.200 | 110.91 | 53.41 |
| 5.300 | 115.31 | 57.81 |
| 5.400 | 119.71 | 62.21 |
| 5.500 | 124.11 | 66.61 |
| 5.600 | 128.51 | 71.01 |
| 5.700 | 132.91 | 75.41 |
| 5.800 | 137.31 | 79.81 |
| 5.900 | 141.71 | 84.21 |
| 6.000 | 146.11 | 88.61 |
| 6.100 | 150.51 | 93.01 |
| 6.200 | 154.91 | 97.41 |