

MAXIMIZING FORAGE PRODUCTION IN A POORLY-DRAINED, BLACKOAR SOIL WITH SUBSURFACE DRAINAGE SYSTEMS

Patrick Nash
Research Technician

Kelly Nelson
Research Agronomist

Background

The United States beef cattle industry has increased in value by 32% from 2002 to 2011 and is presently estimated to be worth \$79 billion dollars (USDA, 2013). As livestock demand and production continue to rise, there is a greater need for increased forage production and improved forage quality. Missouri ranks second in the number of cows in the United States (USDA, 2014). Forage production on soils with production restrictions, such as poorly-drained, floodplain soils, may have the greatest potential to increase to meet future demands.

The greatest production concern with forage in poorly-drained soils is growth and survival under saturated soil conditions. Extended periods of saturated soil conditions during a growing season may severely lower forage production by inhibiting seed germination (University of Missouri Extension, 2013), plant growth (Licht and Al-Kaisi, 2005), and increase the incidence of disease, and nutrient loss (Drury et al., 1999; Drury et al., 2006). The potential for soil compaction increases with water content (Unger and Kaspar, 1994) and can be a major concern in forage grazing systems due to the traffic of livestock and farm equipment. Soil compaction has been found to reduce root growth and crop yield (Sweeney et al., 2006).

A high concentration of nitrate in forage biomass can pose serious health risks to livestock if consumed including suppressed appetite, lower rate of weight gain, lower milk production (Hibbs et al., 1978; Osweiler et al., 1985; Undersander et al., 1999), and death in severe instances (MacKown and Weik, 2004) (Table 1). Forage biomass with nitrate-N concentration below 1000 ppm is generally considered safe for livestock consumption (Undersander et al., 1999). Sorghum that is bred with a trait for reduced lignin content for animal feed, termed “forage sorghum” is thought to have a higher potential for nitrate accumulation in the plant biomass compared to most other forage crops grown in Missouri (University of Missouri Extension, 2012). Drought conditions are common during the summer months in Northeast Missouri and may increase the potential for nitrate accumulation in forage sorghum biomass (Larson, 2006).

Free subsurface drainage (FD) has been found to increase row crop production in many poorly-drained soil environments (Fausey et al., 1983; Kladvko et al. 2005; Nelson et al., 2009; Nelson and Smoot, 2012; Nelson and Motavalli, 2013). Recent advances in subsurface drainage technology now allow for the management of the tile outlet height with the addition of a water level control structure, thereby effectively allowing for the regulation of the water table height and drainage outflow (Fouss et al., 1999). During dry periods of a cropping season, managed subsurface drainage (MD) has been reported to increase the retention of crop-available water and crop nutrients in the root zone (Wesström and Messing, 2007). A two year study conducted in Canada reported increased corn grain yield (1-5%) and soybean grain yield (3-10%) with MD compared to FD (Drury et al., 2009).

Research evaluating FD and MD has been limited to field crops, such as corn and soybeans. No research has evaluated the impact of subsurface drainage systems on forage production. We hypothesize that improving soil drainage in poorly-drained soils with tile drainage should improve plant growth conditions and subsequent forage yields as commonly reported with field crop systems. As forage prices continue to increase, the potential to improve forage quality and production in poorly-drained soils with the addition of subsurface drainage could become an economically viable management option. The objective of this study was to evaluate the impact of FD and MD on N uptake and yield of winter rye and forage sorghum compared to ND in a poorly-drained soil. Additionally, due to the severe drought in 2012 and the continued concern over nitrate concentration in forage crops, forage samples were analyzed for nitrate concentration to determine whether and when toxic nitrate levels were present in winter rye and sorghum biomass, as well as the impact subsurface drainage may have had on the issue of nitrate toxicity in forage crops.

Experiment Information

The four-year study was initiated in September 2009 at the University of Missouri's Greenley Memorial Research Center (40° 1' 17" N, 92° 11' 24.9" W) in Northeastern Missouri. The soil series was a Blackoar silt loam (fine-silty, mixed, superactive, mesic Fluvaquentic Endoaquolls). Subsurface tile drainage systems, including the managed drainage control structures were installed in Aug., 2009. The subsurface tile drains run 300 to 1000 ft long with 60 ft spacing at a depth of 3 ft. Each plot is 120 ft wide, 300 and 1000 ft long in rep 1 and rep 2, respectively. In each replication, there is a free subsurface drainage (FD), managed subsurface drainage (MD), and no subsurface drainage (ND) treatment.

The experimental field site was in a winter rye and brown mid-rib forage sorghum rotation and was grazed under a rotational beef cattle (*Bos taurus* Aberdeen angus) grazing program. The field site was divided into sections perpendicular to the plots in order to maintain a uniform cattle stocking rate (8 head/acre) across the entire field site. Vertical tillage was done directly before winter rye cultivar 'VNS' was broadcast at 99 lbs seed/acre with a fertilizer cart. Brown midrib forage sorghum cultivars (NUTRI+PLUS in 2011, TD7000 in 2012, and Trophy II in 2013) were NT seeded in the summer at 16 to 20 lbs/acre with 30 inch spacing in 2011 and 2012, and 15 inch spacing in 2013. Sorghum was not planted in the summer of 2010 due to wet soil conditions. Prior to cattle grazing events, aboveground biomass was randomly collected throughout each plot representing a total area of 25 ft². Biomass samples were dried and weighed to determine biomass yields. Biomass samples were ground and analyzed for nitrate-N concentration.

Results

Managed subsurface drainage and FD yielded 2.5 and 2.6 tons/acre of total annual biomass on average, respectively (Fig. 1). The ND treatment averaged 2.0 tons/acre of total annual biomass, which was significantly less with the presence of drainage (FD or MD). Increased biomass production with the addition of a subsurface drainage represented a 27 and 32% increase compared to ND with MD and FD, respectively.

In 2010-11, there were three winter rye harvests (Nov., Apr., and July) and two sorghum harvests (Aug. and Sept.) (Fig. 2). There was no significant difference in biomass production among drainage treatments at any individual harvest date. However, although not significant, the

first winter rye harvest that occurred in the fall did increase from 0.05 to at least 0.22 tons/acre with the presence of subsurface drainage. Sorghum biomass production was not affected by the presence or absence of subsurface drainage in 2011.

In 2011-12, there were three winter rye harvests (Mar., April, and June) and only a single sorghum harvest that occurred in September due to abnormally dry conditions in the summer. The first winter rye harvest was the only harvest to have a significant difference in biomass production among the drainage treatments. At the March harvest of winter rye, biomass was found to be significantly increased from 0.31 to 0.71 tons/acre with FD compared to ND. Although not significant, the presence of a subsurface drainage system (FD or MD) produced 79% greater sorghum biomass than ND. Increased sorghum production with subsurface drainage in a generally dry year was likely due to wet field conditions early in the growing period.

There were two winter rye harvests (Nov. and May) and three sorghum harvests (July, Aug., and Sept.) in 2012-13. Similar to 2011-12, the first winter rye harvest was the only harvest in which a significant difference in biomass production was observed among drainage treatments. At the November harvest, forage biomass increased from 0.58 to 0.76 tons/acre with FD compared to ND.

Unlike biomass yield and plant N uptake analysis, the whole plant nitrate concentration averaged over a study year was not significantly ($P \leq 0.10$) increased by the presence of subsurface drainage (Fig. 3). However, whole plant nitrate concentration response did vary over the three years due to the type of forage crop and weather. Whole plant nitrate concentration in winter rye never exceeded 1040 ppm at any time over the study and there were no significant differences in nitrate concentration in winter rye biomass among treatments at any harvest date. Therefore, nitrate toxicity does not appear to be a concern with winter rye under the conditions observed during this study. However, nitrate concentration in forage sorghum over two of the three years, regardless of the drainage treatment, ranged from 1310 to 4520 NO_3^- -N ppm which corresponded to toxic to extremely toxic levels (Evans et al., 2012). High nitrate accumulation in forage sorghum biomass may have been due to the extreme drought conditions experienced during the summer months in 2012 and 2013.

Conclusions

The presence of subsurface drainage (FD or MD) increased overall biomass production in the annual pasture system including winter rye and sorghum. However, MD did not increase biomass production compared to FD and factoring in the extra cost with installation of MD compared to FD, and the limited potential environmental concerns with nitrate loss with this type of forage production system, FD is the more practical and economical management option to increase forage production. Nitrate toxicity in whole plant samples of winter rye was not observed under the conditions of this study, but was a concern with forage sorghum. This result was likely due to the climate in Northeast Missouri, which typically experiences excessive precipitation over the winter rye growth period and a lack of precipitation in combination with high air temperatures over the sorghum growth period. Subsurface tile drainage provides farmers with an opportunity to increase annual forage production that may be important for typical cool-season, tall fescue production areas.

Table 1. The potential for nitrate (NO_3^-) toxicity of livestock due to forage crops. This image is courtesy of the University of Missouri, College of Veterinary Medicine.

NO_3^- -N	NO_3^- ppm	Category	Recommendation
0 to 550	0 to 2,500	SAFE	Forage is generally safe to feed to all classes of livestock.
550 to 1,100	2,500 to 5,000	CAUTION	Forage with this nitrate (NO_3^-) content can cause a problem with pregnant and young animals. Do not feed forage with nitrate levels this high in combination with non-protein nitrogen supplements, and limit forage with NO_3^- levels this high to one-half of total ration.
1,100 to 3400	5,000 to 15,000	DANGER TOXIC	Limit forage with this NO_3^- level to one-fourth of total ration. Should supplement forage of this type with energy, minerals and vitamin A.
More than 3,400	More than 15,000	EXTREMELY TOXIC	Forage with this NO_3^- level or higher is toxic and should not be fed under any circumstance. If forage with this NO_3^- concentration must be fed, it should be mixed with other feed and make up no more than 15 percent of the total ration.

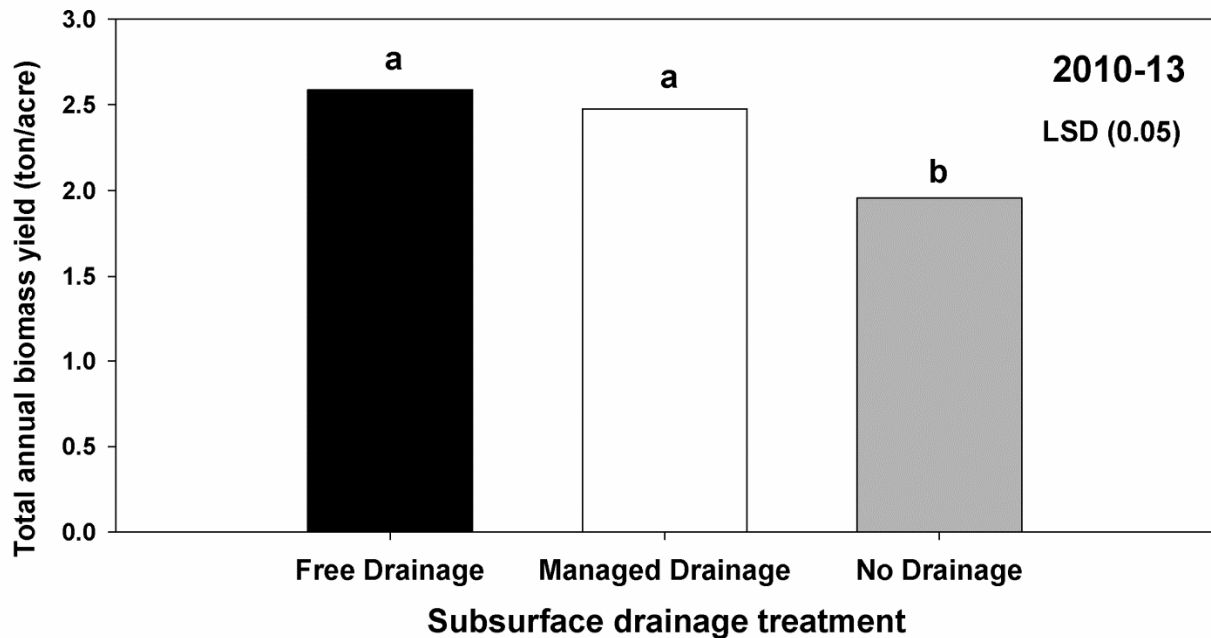


Figure 1. Total annual forage yield (winter rye and sorghum) over the period of October through September, averaged over 2009-10, 2010-11, 2011-12, and 2012-13. Letters over drainage treatments (FD, free subsurface drainage; MD, managed subsurface drainage; ND, no subsurface drainage) represent differences in yield using Fisher's Protected LSD ($P \leq 0.05$).

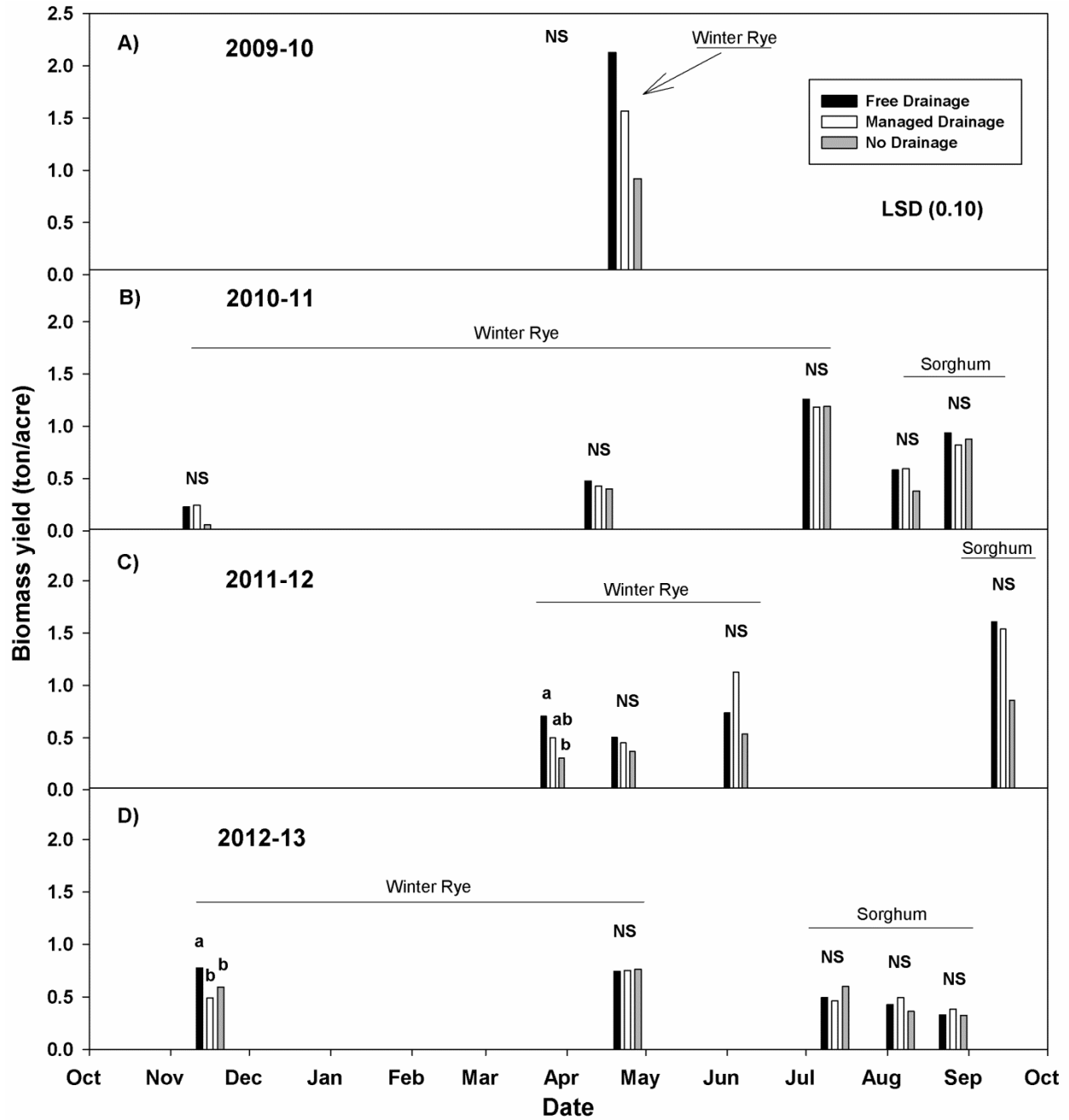


Figure 2. Individual annual forage winter rye and sorghum biomass yields harvested prior to cattle grazing events from October, 2009 through September, 2013. Letters over drainage treatments (FD, free subsurface drainage; MD, managed subsurface drainage; ND, no subsurface drainage) represent differences in biomass yields within individual forage harvests using Fisher's Protected LSD ($P \leq 0.10$).

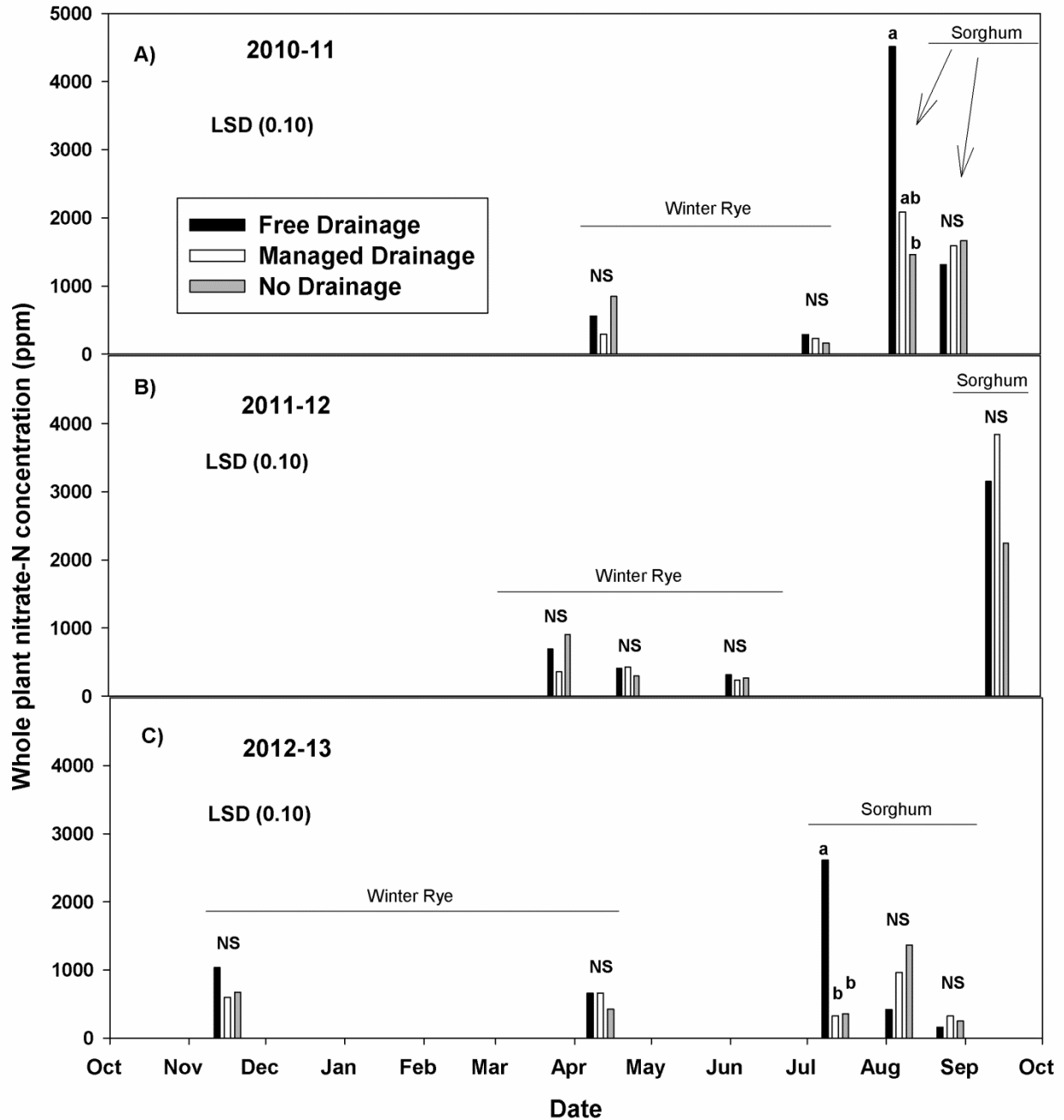


Figure 3. Nitrate-N concentration in whole plant samples of winter rye and sorghum collected prior to cattle grazing events over the period of October, 2009 through September, 2013. Letters over drainage treatments (FD, free subsurface drainage; MD, managed subsurface drainage; ND, no subsurface drainage) represent differences in nitrate-N concentration within individual forage harvests using Fisher's Protected LSD ($P \leq 0.10$).

References

- Drury, C.F., W.D. Reynolds, C.S. Tan, T.W. Welacky, W. Calder, and N.B. McLaughlin. 2006. Emissions of nitrous oxide and carbon dioxide: influence of tillage type and nitrogen placement depth. *Soil Sci. Soc. Am. J.* 70:570-581.
- Drury, C.F., C.S. Tan, W.D. Reynolds, T.W. Welacky, T.O. Oloya, and J.D. Gaynor. 2009. Managing tile drainage, subirrigation, and nitrogen fertilization to enhance crop yields and reduce nitrate losses. *J. Environ. Qual.* 38:1193-1204.
- Drury, C.F., C.S. Tan, T.W. Welacky, T.O. Oloya, A.S. Hamill, and S.E. Weaver. 1999. Red clover and tillage influence soil temperature, moisture and corn emergence. *Agron. J.* 91:101-108.
- Evans, T.J., G.E. Rottinghaus, R.L. Kallenbach, and B.R. Landers. 2012. Veterinary medical diagnostic laboratory forage toxicant update. Univ. of Missouri. http://vmdl.missouri.edu/VMDL_FORAGE_TOXICANT_UPDATE.pdf (accessed 12 April 2014).
- Fausey, N.R. 1983. Shallow subsurface drain performance in Clermont soil. *Trans. ASAE* 26:782-784.
- Fouss, J.L., R.O. Evans, and H.W. Belcher. 1999. Design of controlled drainage and Subirrigation facilities for water table management. *Agricultural Drainage. ASA-CSSA-SSSA.* 719-742.
- Hibbs, C.M., E.L. Stencel, and R.M. Hill. 1978. Nitrate toxicosis in cattle. *Veterinary Human Toxic.* 20:1-2.
- Kladivko, E.J., G.L. Willoughby, and J.B. Santini. 2005. Corn growth and yield response to subsurface drain spacing on Clermont silt loam soil. *Agron. J.* 97:1419-1428.
- Larson, B. 2006. Precautions when utilizing sorghum/sudan crops as cattle feed. Univ. of Missouri. <http://agebb.missouri.edu/drought/sudan.htm> (accessed 26 Sept. 2013).
- Licht, M., and M. Al-Kaisi. 2005. Strip-tillage effect on seedbed soil temperature and other soil physical properties. *Soil Tillage Res. J.* 80:233-249.
- MacKown, C.T., and J.C. Weik. 2004. Comparison of laboratory and quick-test methods for forage nitrate. *Crop Sci.* 44:218-226.
- Nelson, K.A., and P.P. Motavalli. 2013. Nitrogen source, drainage, and irrigation affects corn yield response in a claypan soil. *Appl. Eng. Agric.* 29:875-884.
- Nelson, K.A., and R.L. Smoot. 2012. Corn hybrid response to water management practices on claypan soils. *Int. J. Agron.* 2012:1-10.
- Nelson, K.A., S.M. Paniagua, and P.P. Motavalli. 2009. Effect of polymer coated urea, irrigation, and drainage on nitrogen utilization and yield of corn in a claypan soil. *Agron. J.* 101:681-687.
- Osweiler, G.D., T.L. Carson, W.B. Buck, and G.A. Van Gelder. 1985. *Clinical and diagnostic veterinary toxicology.* 3rd ed. Kendall/Hunt Publ. Co., Dubuque, IA.
- Sweeney, D.W., M.B. Kirkham, and J.B. Sisson. 2006. Crop and soil response to wheel-track compaction of a claypan soil. *Agron. J.* 96:637-643.
- Undersander, D., D. Combs, T. Howard, R. Shaver, M. Siemens, and D. Thomas. 1999. Nitrate poisoning in cattle, sheep, and goats. Univ. Wisconsin Coop. Ext. <http://www.uwex.edu/ces/forage/pubs/nitrate.htm> (verified 19 Feb. 2014).
- Unger, P.W., and T.C. Kaspar. 1994. Soil compaction and root growth: A review. *Agron. J.* 86:759-766.

- University of Missouri Extension. 2012. Drought-related issues in forage, silage and baleage. Univ. of Missouri. <http://extension.missouri.edu/p/agw1017> (accessed 28 Aug. 2013).
- University of Missouri Extension. 2013. Missouri historical agricultural weather database. Univ. of Missouri. http://agebb.missouri.edu/weather/history/index.asp?station_prefix=nov (accessed 2 Sept. 2013).
- United States Department of Agriculture. 2013. Economic Research Service. USDA. http://www.ers.usda.gov/topics/animal-products/cattle-beef/statistics-information.aspx#.UhuLDT_ueSo (accessed 26 Aug. 2013).
- United States Department of Agriculture. 2014. Cattle inventory by class – States and United States: January 1, 2013 and 2014. USDA. <http://usda.mannlib.cornell.edu/usda/current/Catt/Catt-01-31-2014.pdf> (accessed 7 Apr. 2014).
- Wesström, I., and I. Messing. 2007. Effects of controlled drainage on N and P losses and N dynamics in a loamy sand with spring crops. *Agric. Water Manage.* 87:229–240.