Drought Stress and Corn Silage Quality: Is it Just a Matter of Rainfalls?

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INTRODUCTION

When I request a memory from 2012 to dairy farmers, almost unanimously they respond “drought stress.” According to the US Department of Agriculture (USDA, 2013), the spring and summer drought of 2012 will be remembered as one of the “worst agricultural calamities” in the United States (USDA, 2013). The drought of 2012 reduced the national corn grain and silage yields by 16.2 and 16.3%, respectively, when compared to 2011 (USDA, 2013). These reductions incurred in more than $1 billion in additional feed expenses to the dairy industry.

Even though drought stress occurred in Virginia during 2012, its effects on dry matter yield and nutritional composition of corn for silage varied depending on the region (Behl et al., 2012). This manuscript integrates climate with agronomic data and shows that abiotic factors, other than drought stress, affect dry matter yield and nutritional composition of the corn plant.

CORN HYBRID PERFORMANCE TRIALS

The Extension Service from the Department of Crop and Soil Environmental Sciences at Virginia Tech performs hybrid performance trials for corn silage on a yearly basis. In these performance trials, several varieties of corn are planted in small plots at different locations. For this retrospective analysis, I analyzed data from corn hybrid performance trials completed at two sites in the 2012 growing season within the state of Virginia. The first site is referred to as the Southern Piedmont region (Blackstone, VA). The second site is referred to as the Shenandoah Valley region (Lynnwood, VA).

For 2012, whole-plant dry matter (DM) yields ranged from 1.87 to 2.27 ton/acre in the Southern Piedmont region, and from 4.18 to 7.97 ton/acre in the Shenandoah Valley region (Figure 1). Despite these great differences in dry matter yields, total rainfalls were slightly different with 9.0 inches for the Southern Piedmont region and 10.3 inches for the Shenandoah Valley region. The small difference in total rainfalls indicates that differences in dry matter yields were due to more than seasonal rainfalls.

The nutritional composition of the whole plants also differed substantially between these sites in 2012 (Table 1). For example, DM concentration was substantially lower in the Southern Piedmont region (21.1 to 28.2% DM) than in the Shenandoah Valley region (28.1 to 48.8% DM). This difference is likely due to a reduced proportion of the grain component in the whole plant. Similarly, crude

| Table 1. Nutritional composition of eight corn hybrids tested in the Southern Piedmont and Shenandoah Valley regions in Virginia during 2012. (data from Behl et al., 2012) |
|---------------------------------|------------------|------------------|-----------------|------------------|------------------|------------------|
|                                | Southern Piedmont | Shenandoah Valley |
| Dry matter, %                  | Mean  | Max  | Min  | Mean  | Max  | Min  |
| Crude protein, %               | 10.9  | 11.5 | 10.2 | 7.1   | 7.5  | 6.7  |
| Neutral detergent fiber, %     | 56.6  | 58.8 | 55.4 | 43.0  | 45.3 | 40.3 |

Figure 1. Dry matter yields (ton DM/acre) of corn hybrids grown in the Southern Piedmont and Shenandoah Valley regions of Virginia. Columns represent the means of 8 hybrids. Error bars represent the maximum and minimum values observed.
protein (CP) ranged from 10.2 to 11.5% CP in the Southern Piedmont, and from 6.7 to 7.5% CP in the Shenandoah Valley region. These differences in CP concentrations also support that corn plants in the Southern Piedmont had lower proportions of grain than in the Shenandoah Valley region. Finally, neutral detergent fiber (NDF) ranged from 47.6 to 57.7% NDF in the Southern Piedmont and from 40.3 to 45.3% NDF in the Shenandoah Valley region. All these observations suggest that spring and summer drought in 2012 in the state of Virginia affected corn whole-plant dry matter yields and composition in different ways. The key question to be answered is what happened in the different regions that affected yields and composition that much.

**KERNEL DEVELOPMENT**

Fiber concentration in whole-plant corn silage is highly and negatively correlated to starch concentration (Ferreira and Mertens, 2005). It is likely that kernel development explains the difference in NDF concentrations between these regions for 2012. An inferior kernel development for the Southern Piedmont region during 2012 is also supported by the low DM concentration (25.3% DM) and the relatively high CP concentration (10.9% CP) of the whole-plant (Table 1).

Heat stress during kernel development can greatly affect corn grain yield (Hanft and Jones, 1986; Cheikh and Jones, 1994). Kernel development is divided into a lag phase with little kernel growth and a linear growing phase with major accumulation of DM. The lag phase, which starts immediately after pollination and lasts 10 to 12 days after pollination, is critical for kernel development (Cheikh and Jones, 1994). The endosperm is the structure of the corn kernel that contains starch granules. Cell division of the endosperm cells during the lag phase determines the capacity of the endosperm to accumulate starch within the grain (Cheikh and Jones, 1994). Cheikh and Jones (1994) cultured corn kernels in vitro at different temperatures and observed that heat stressed kernels (i.e., kernels cultured at 35°C) accumulated 18 to 75% less DM than non-stressed kernels (i.e., kernels cultured at 25°C). Reduced DM accumulation can be related to reductions in starch synthesis within the endosperm when kernels are subjected to temperatures greater than 35°C (Hanft and Jones, 1986). In addition to reduced kernel growth, Cheikh and Jones (1994) reported 23 to 97% kernel abortion when subjected to heat stress.

Under the assumption that silking occurred at 1,400 growing-degree days (Neild and Newman, 1987), I accessed maximum and minimum daily temperatures records and estimated the date at which pollination occurred (Figure 2). In 2012, the Southern Piedmont region had maximum daily temperatures above 35°C for an extended period (11 days) after silking (Figure 2A), whereas maximum daily temperatures were 7.1 ± 2.3°C lower in the Shenandoah Valley region around silking (Figure 2B). It is therefore likely that heat stress had a major effect on kernel development in the Southern Piedmont region but not in the Shenandoah Valley region. Therefore, in the Southern Piedmont region, heat stress exacerbated the effects of drought, substantially reducing DM yields.

**IMPLICATIONS**

The observations from this analysis suggest that heat stress can affect the nutritional composition of corn silage even in crops with adequate water status. Data from the field also support this observation. For example, Ferreira...
(unpublished data) observed concentrations of 28.1% DM, 11.6% CP, and 59.9% NDF for corn silage originating from an irrigated corn field suffering heat stress (i.e., temperatures > 35°C) immediately after pollination, suggesting that silage quality is not assured exclusively by water status.

Dairy farmers, agronomists, and dairy consultants should also not overlook the regional temperatures when planning a strategy to insure forage stocks for dairy farms. In regions with high summer temperatures, choosing early maturity corn hybrids or delaying planting date should be considered to avoid high temperature stress during silking and kernel development. Regarding harvest management, monitoring daily temperatures might help to better decide whether harvesting and chopping should be anticipated when drought occurs. High temperatures around pollination might be considered as an indicator that silage yield or quality would not increase or improve substantially after a relieving rain.

Finally, planting alternative forages, such as sorghum species, should also be considered to minimize the risk associated with growing corn in regions with high summer temperatures (Aydin et al., 1999; Amer et al., 2011). Sorghum species are characterized as having greater resistance to drought stress than corn. Compared to corn, sorghum species usually require a delayed planting date; therefore, they escape high summer temperatures during kernel development.

REFERENCES