One Inoculant, Different Climates: Does Wilting Change the Rules of Silage Fermentation?

Alvaro Garcia, DVM, PhD

Forage inoculants are used worldwide to improve silage fermentation, reduce nutrient losses, and enhance aerobic stability. Products containing *Lactiplantibacillus plantarum*, *Pediococcus* species, and *Lentilactobacillus buchneri* are applied across widely different production environments, from northern Europe and Canada to South America, Australia, and tropical Asia. Although these microorganisms have well-established fermentation characteristics, the conditions under which forage is harvested and wilted can differ between regions and seasons. This raises an important question about whether the same inoculant can be expected to perform consistently when the material entering the silo has undergone different biochemical changes.

The issue extends beyond the temperature at which fermentation occurs. Before ensiling, harvested forage remains biologically active, consuming carbohydrates through respiration while losing moisture to the environment. Temperature, solar radiation, relative humidity, and wilting duration influence these processes and potentially alter both the quantity and composition of fermentable sugars. Because lactic acid bacteria depend on available substrates for growth and acid production, differences established during wilting may influence subsequent fermentation and the response to microbial inoculation.

What Happens to Sugars During Wilting?

Immediately after mowing, plant cells continue respiring, consuming soluble carbohydrates, and releasing carbon dioxide, water, and heat. Respiration declines as forage dries, but the rate at which moisture is lost depends heavily on environmental conditions. Warm, dry weather with adequate air movement can accelerate wilting, shortening the period during which plant respiration consumes carbohydrates. Conversely, cool, or humid conditions may prolong drying and extend respiratory losses.

Consequently, warmer weather does not necessarily result in greater sugar depletion. Rapid drying may preserve more fermentable carbohydrates than prolonged wilting under cooler conditions. The relationship becomes more complicated when temperatures approach freezing, when dehydration is slow and freezing injury may affect cell integrity and subsequent microbial activity.

Another consideration is how sugars are measured. Water-soluble carbohydrates (WSC) are expressed as a percentage of forage dry matter. An increase in WSC concentration during wilting does not necessarily mean that additional sugars have been produced or that more of

the original sugars have been preserved. Changes in the concentration of other dry matter constituents and losses during harvesting can influence the final value. Evaluating carbohydrate preservation requires considering both WSC concentration and dry matter recovery.

A 2024 meta-analysis of wilting effects on silage fermentation reported that wilting increased measured WSC concentrations. However, the response varied among forage types and management conditions. These findings reinforce the importance of distinguishing the concentration of fermentable substrates at ensiling from their recovery relative to the standing crop.

Not All Sugars Are the Same

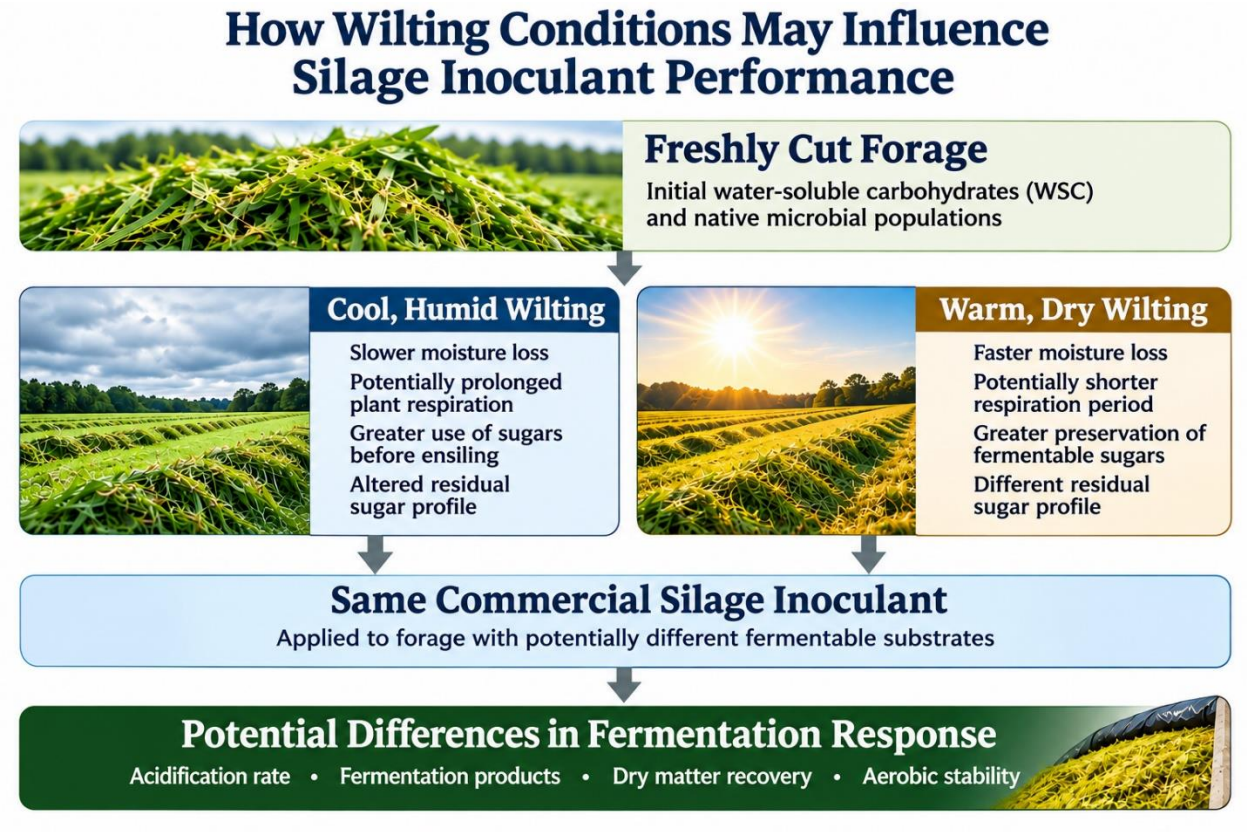
The carbohydrate composition of forage differs among plant species, maturity stages, and environmental conditions. Glucose, fructose, and sucrose contribute to the pool of readily fermentable carbohydrates, while some temperate grasses also contain substantial concentrations of fructans. Warm-season grasses have different carbohydrate profiles, and legumes often contain limited concentrations of readily fermentable sugars combined with considerable buffering capacity.

These differences matter because bacterial strains do not necessarily utilize all carbohydrates with equal efficiency. Their capacity to metabolize individual sugars depends on the enzymes and metabolic pathways they possess. Some strains can ferment a broad range of simple carbohydrates, while their ability to utilize more complex substrates may be limited.

Homofermentative inoculants are selected to promote rapid lactic acid production and pH reduction. Heterofermentative organisms such as *L. buchneri* are commonly used to improve aerobic stability through the production of acetic acid and other fermentation products. Their effectiveness depends not only on the organisms themselves but also on the chemical and microbial environment in which they operate.

This suggests that two batches of the same forage, harvested at similar maturity but wilted under different conditions, could present different fermentation substrates to an identical inoculant.

Figure 1. Conceptual pathways through which environmental conditions during wilting may influence subsequent silage fermentation. Differences in drying rate, plant respiration, and residual carbohydrate composition may alter the substrate available to inoculated lactic acid bacteria. The magnitude and direction of the resulting fermentation response depend on forage characteristics, inoculant formulation, and ensiling conditions.



What Does Research Show?

Recent research provides support for several components of this hypothesis, although direct comparisons of inoculant performance under contrasting wilting climates remain limited.

A 2023 study published in *Grass and Forage Science* evaluated six lactic acid bacterial strains in grass-clover forage with different dry matter and WSC concentrations. The experiment directly addressed inoculant efficacy under differing substrate conditions, highlighting the importance of considering forage composition when evaluating bacterial strains.

In 2025, research published in *Animal Feed Science and Technology* compared ryegrass wilted for 48 or 72 hours, with and without inoculation using *Lentilactobacillus buchneri* and *Lactococcus lactis*. Longer wilting increased WSC concentration but reduced lactic acid bacterial populations and lactic acid production. Inoculation improved dry matter recovery and aerobic stability. These findings illustrate how wilting history can alter fermentation conditions and influence the outcomes associated with microbial inoculation.

Temperature during ensiling introduces another dimension. Research with wilted alfalfa published in 2024 compared fermentation at approximately 25 and 35°C using *L. plantarum*, *L. buchneri*, and their combination. Temperature-by-additive interactions were observed for several chemical composition measurements, indicating that the response to inoculation can depend on fermentation temperature.

Together, these studies establish that forage composition, wilting conditions, and fermentation temperature influence silage outcomes. They do not, however, conclusively demonstrate that inoculants should be selected according to geographic region or hemisphere.

The Temperature Inside the Silo

It is tempting to assume that once forage is packed and oxygen is excluded, fermentation proceeds under uniform conditions regardless of outside temperature. In practice, this assumption is incomplete.

Forage enters storage at a temperature influenced by harvesting conditions. Residual plant respiration and microbial activity can generate heat, particularly when oxygen exclusion is delayed. Silo dimensions, packing density, insulation, and ambient conditions further influence heat retention and dissipation.

The result is that silage produced under cool and warm conditions may experience different temperature profiles, particularly during the initial stages of fermentation.

These differences can influence bacterial growth rates, enzymatic activity, and the balance between desirable and undesirable microorganisms. Nevertheless, the effect of temperature must be distinguished from changes in carbohydrate availability caused by wilting. Both mechanisms may operate simultaneously, making their individual contributions difficult to identify under commercial conditions.

Should Inoculant Recommendations Consider Climate?

Commercial inoculants are commonly recommended according to forage type, dry matter concentration, and the intended fermentation objective. These remain appropriate considerations. However, the conditions experienced between mowing and ensiling may deserve greater attention, particularly when wilting is prolonged or occurs under unusual temperatures.

The most useful approach may not be to develop separate inoculants for northern and southern climates, but to better characterize the forage entering storage. Measuring WSC concentration, dry matter, buffering capacity, and microbial populations could help explain why an inoculant performs differently among harvests.

Research comparing identical forage batches wilted under controlled cool, moderate, and warm conditions would be particularly valuable. Testing several inoculant formulations at a common dry matter endpoint, while also measuring individual sugars and carbohydrate recovery, could determine whether wilting conditions produce meaningful differences in inoculant response.

Such experiments should also separate the effects of wilting temperature from those of fermentation temperature, allowing researchers to identify whether changes originate primarily in the plant substrate or in the microorganisms responsible for fermentation.

A More Precise Approach to Silage Fermentation

The available evidence supports the biological plausibility of climate-related differences in inoculant performance, but it does not justify abandoning established products or making geographic recommendations without further research. Forage species, maturity, dry matter, packing, oxygen exclusion, and storage management remain central determinants of silage quality.

Nevertheless, wilting deserves recognition as more than a moisture-reduction process. It is a period of continuing biological activity during which the chemical characteristics of the forage can change substantially. Those changes may influence how effectively an inoculant establishes the desired fermentation.

An **inoculant does not ferment the forage as it stood in the field. It ferments the substrate that remains after harvesting and wilting.** Understanding how environmental conditions shape that substrate could help make inoculant recommendations more precise and fermentation outcomes more predictable.

Further reading

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