BIOSOLIDS-BASED FERTILIZERS AS A NITROGEN SOURCE IN CALIFORNIA SMALL GRAINS SYSTEMS

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ABSTRACT

As more California municipalities begin to prioritize the diversion of waste products from landfills into agricultural systems, it is pressing for growers to understand how to utilize new inputs such as liquid-injected biosolids-based fertilizer (LBF) in their operations. Biosolids-based fertilizers can generally provide subsidized and therefore cost-effective sources of nitrogen (N) for small grains and other agronomic crops. However, while there have been long-term biosolids studies using materials derived from biosolids, near-term performance needs to be understood and documented to improve grower confidence and capacity in the utilization of these products. The objective of this research is to evaluate the performance of LBF as an N source in small grains relative to conventional forms of N fertilizer. Field trials took place over the course of three planting seasons. Laboratory incubations were also carried out to examine the behavior of the LBF relative to a pelletized biosolids-based fertilizer (PBF), and conventional urea. Results indicate that LBF produces equivalent yield and protein results in small grains when compared to conventional forms of fertilizer as an N source. Other findings indicate that there may be some ancillary benefits associated with the use of LBF as an N source by way of providing a source of phosphorous (P), carbon, micronutrients, and water.

INTRODUCTION

In response to regulatory and economic pressure, California growers are becoming more familiar with nitrogen (N) budgets. In addition to seeking out ways to improve N management strategies, growers can possibly benefit by incorporating alternative sources of N to support their crops. Liquid injected or pelletized biosolids-based fertilizers from local waste streams and processing facilities are one source that growers are beginning to explore.

These fertilizers can be subsidized and are therefore cost-effective sources of N, but their performance needs to be understood and documented to improve grower confidence and capacity in their utilization. Previous studies have documented the long-term impacts of biosolids sludge applications, but processing technology and local forms of biosolids-based fertilizers have changed in recent decades. Therefore, single-season studies should be considered in tandem with more long-term studies to understand near-term impacts on crop performance.

The objective of this research is to evaluate the performance of liquid-injected biosolids-based fertilizers (LBF) as an N source in small grains relative to conventional forms of N fertilizer. Field trials took place over the course of three planting seasons. Laboratory incubations were also carried out to examine the behavior of the LBF relative to a pelletized biosolids-based fertilizer (PBF), and conventional urea.

METHODS

Between 2018 and 2021 UC Cooperative Extension conducted on-farm trials in the southern Sacramento Valley to measure yield and protein outcomes in fall-planted wheat fertilized with biosolids-based materials across different soil types and moisture regimes. LBF ("Lystegro" by Lystek) was compared side-by-side with similar rates of conventional mineral N fertilizers. Treatments were 2 or 3 rates of LBF and an application of conventional fertilizer (anhydrous ammonia, UAN32, or urea) at a rate that matched one of the biosolids rates in terms of total N applied per acre (Table 1). LBF was injected and integrated to a depth of 6 inches on 22.5 inch spacing, although some of the material stayed on the surface depending on soil conditions. LBF total N percentages were between 3.5 and 4.6%. LBF material was roughly 90% water. All treatments were applied pre-plant to determine the relative performance of each material under similar conditions.

Yield and protein data were collected from grain harvest using grower-collaborator combines and weigh wagons. Soil and plant tissue data were collected to document the material's impact on soil and plant nutrients in-situ.

Among other tests, lab incubations were carried out to document changes in key soil attributes (N mineralization rate, Olson P, EC, and pH) between LBF, PBF, and urea. A Yolo loam (Fine-silty, mixed, superactive, thermic Fluventic Haploxerepts) was homogenized and mixed thoroughly with each of the materials separately. Soils were kept at field capacity at 75° F over the course of 12 weeks. Measurements were taken at 1, 3, 6, and 12 weeks.

Table 1: Information on three growing sites/ years where trials took place.

	2018	2019	2021
Rates applied lbs N/ acre			
LBF Low	57	66	73
LBF Medium	90	82	146
LBF High	NA	98	219
Conventional Fertilizer	90 'med'	120 'high'	130 'med'
Fertilizer Type	Anhydrous	UAN 32	Anhydrous
Relative Rainfall Pattern	Average-Droughty	Above Average	Extreme Drought
Location	Upland: Bird's Landing	Valley: Dixon Area	Valley: Rio Vista

RESULTS

Two of the three years experienced lower-than-average rainfall with extended drought periods at the tillering stage of the wheat growth cycle. In 2019, rains were above average, with sustained rainfall throughout the growing season.

Yield and Protein

Yield was equivalent between LBF and conventional N fertilizers in all years when the same or similar rates of total N were applied (Figure 1). In 2018 and 2019 there was a positive yield response to N, and some of the treatments resulted in higher yields than the control. In 2021 there was no yield response to any of the N treatments.

Protein was equivalent across all treatments in 2018 (Figure 1). In 2019 protein was relatively low across all treatments, but rates were equivalent among high-rate treatments and the low LBF treatment. In 2021 protein was higher in the LBF treatment than in the conventional N fertilizer treatment at the same N rate.

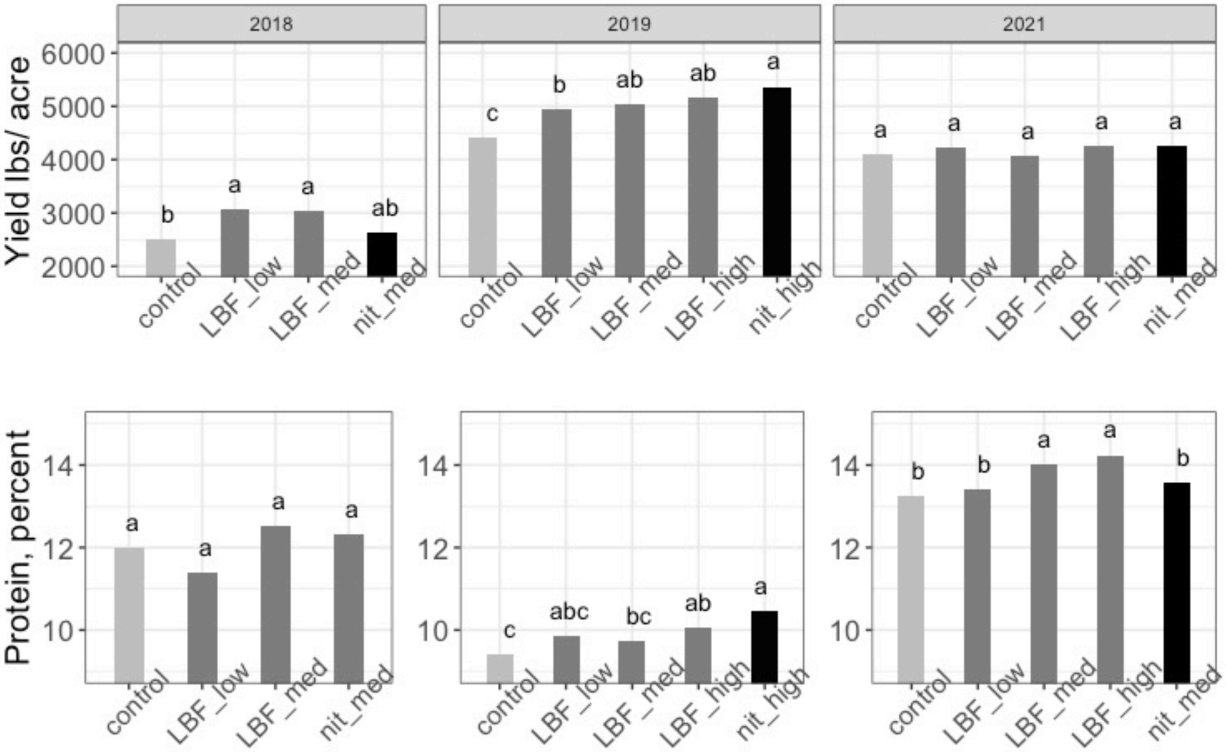

Figure 1: Yield and protein data from field trials over three site years in the Southern Sacramento Valley. Conventional N fertilizer "nit" rates are expressed as either "nit_high" or "nit_med". LBF rates are expressed similarly. See Table 1 for exact amounts of N added for each treatment. Significant difference between treatments is indicated within a given year by different letters.

Incubations

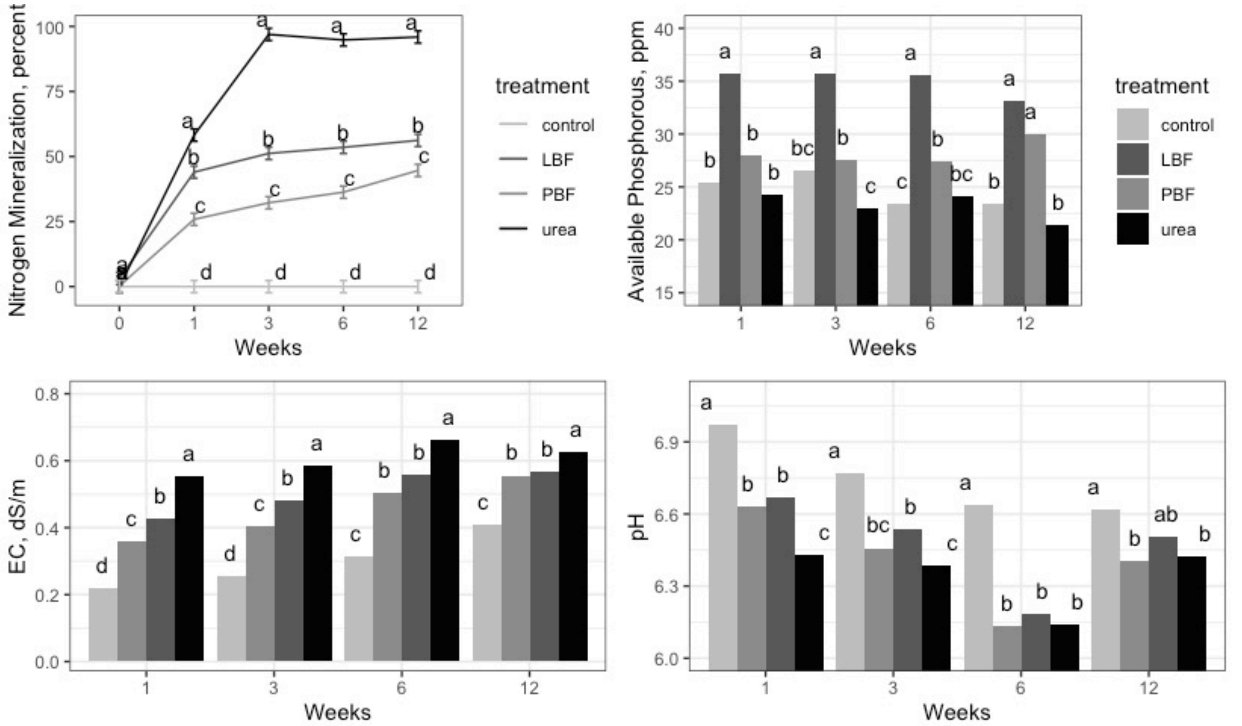

Figure 2: N mineralization, available phosphorous, salinity (as electrical conductivity, EC), and pH results from 12-week lab incubations comparing LBF, PBF, and pelletized urea mixed into a Yolo loam. Significant difference between treatments is indicated within a given week by different letters.

In the laboratory incubations, nearly all of the urea had mineralized after 3 weeks. LBF and PBF mineralized quickly in the beginning, but the rate of mineralization tapered off after several weeks. PBF maintained a higher rate of mineralization into week 12, where it approached mineralization levels comparable to that of the LBF (Figure 2).

Available phosphorus, measured as Olsen-P, was higher in the LBF than in any other treatments for the first 6 weeks. At 12 weeks, LBF and PBF became insignificantly different. P remained insignificantly different between control and urea treatments throughout the duration of the measurements (Figure2).

EC was highest in urea treatments, and remained significantly so throughout the course of the measurements; however, LBF and PBF EC increased slowly over the course of the measurements (Figure 2).

All treatments reduced pH relative to the control by about 0.3 within the first week. pH continued to decrease throughout the first six weeks before rebounding slightly in the 12th week (Figure 2).

DISCUSSION

Yield and Protein

In field trials, yield LBF treatments were equivalent to conventional forms of N when applied at similar rates of total N per acre. In some cases, yields from lower rates of LBF were also equivalent to higher rates of conventional N. In 2018 and 2021 this was possibly due to the droughty conditions that led to water limitations in the crop, reducing yield, and thus reducing the overall N uptake potential.

In 2019 however, high rainfall removed much of the N from the profile across all treatments at tillering, but lower rates of LBF still managed to produce similar yields compared to conventional treatments where 46% more N was applied (Table 1). The slower release of the mineralizable N in the LBF may have provided late-season N to make up for the difference in pre-plant application rates of total N. This is supported by the fact that protein, which typically increases with late-season applications of N, remained insignificantly different between 82 lbs/acre of N as LBF and 120 lbs/acre of N as UAN 32. In 2021 protein was also higher in the LBF treatment than that of the conventional N treatment with the same rate of N. This may also suggest late-season N mineralization or some other interaction that increased protein in the grain.

A note on application and N management

It is understood that a 100% preplant application is not the most efficient N management strategy for small grains. Rather, best practices would suggest that growers should be using N reference zones, canopy reflectance data, in-season soil nitrate measurements, and split-applications. The reality on the ground however is that many growers in the Southern Sacramento Valley are applying the majority, if not all of their N fertilizer preplant. Testing these materials provides a worst-case scenario analysis for growers who may not be able to apply in-season N.

Furthermore, given that incubations show that, relative to urea, only about 50% of total N is released by the LBF and PBF by week 12, it may be the case that the carbon applied with the LBF and PBF is increasing microbial activity over time. Increased microbial activity may be triggering a release of mineral N from labile pools of organic N already in the soil. Alternatively, there may be other mechanisms that are increasing the uptake efficacy of N by plants in LBF relative to forms of mineral N.

Growers should feel confident in using LBF and possibly PBF sources for N applications. However, best practices such as N reference zones, canopy reflectance, soil nitrate testing, and integrated in-season N management techniques should be utilized in-season. Because LBF and PBF cannot effectively be applied in-season, growers should strongly consider the combined use of pre-plant LBF with in-season applications of conventional N as needed.

Water

The fact that the 2018 site was relatively dry may have meant that the extra water applied with the LBF treatments, roughly 0.1” to 0.25” in the injection rows may have helped every other row of wheat seed access a substantial amount of water early in the season that encouraged stand establishment and root development to a greater depth in the soil. Depending on the distance from the source it may or may not be energy efficient to de-water the material. In the case where dewatering does not pencil out economically, the addition of moisture through an LBF may provide growers with a buffer against severe drought during the seedling stage, particularly during seedling establishment in dryland crops (as in the 2018 site).

Additional nutrients, pH, OM, EC

P-limited soils are rare in California, but P additions from organic waste streams could provide a side benefit to growers. The incubations document higher P availability from LBF and PBF relative to urea, and soil and plant tissue data from the field trials suggest that those differences in availability occasionally manifest as higher P concentrations in soil and plant biomass. The P applied with LBF and PBF may also support root development of seedlings, improving stand establishment. It is also the case that LBF and PBF will likely provide some amount of micronutrients to plants, but the specific range of those nutrients will likely vary depending on changes in source material and is beyond the scope of this study. Field trials indicate that there was no change in organic matter percentages (OM), but carbon changes in OM in other biosolids trials have typically only been visible over longer periods of time. Even if detectable levels of stable organic carbon are not being formed, it is likely that a portion of the carbon from LBF is being utilized by the microbial community in the field within a growing season.

EC was slightly lower in the LBF and PBF treatments as compared to urea, indicating that salt load should not be more of an issue than it is with the use of urea as an N source. In addition, pH eventually dropped and was similar among all treatments despite higher early values in the LBF and PBF treatments compared to urea. Both EC and pH behavior with these materials should serve as a reminder of the importance of good soil management and monitoring techniques.

CONCLUSION

Small grain growers working in the Sacramento Valley or in similar climates should feel confident that LBFs will likely perform as well as conventional sources of N when applied at similar rates of total N. LBFs may also provide additional benefits to growers in the form of increased P, micronutrients, or additional soil moisture. Growers should also consider the combined use of biosolids and in-season conventional N additions.