SPECIALTY FERTILIZERS AND MICRONUTRIENTS, DO THEY PAY?

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ABSTRACT

With sustainable agriculture and biomass production being emphasized and input costs continuing to increase, products and programs that claim more environmental compatibility, safer crop production, cheaper input costs, agronomically better in efficiency, byproduct use or reuse potential for covering input needs, or even better growth promotion for the money have continued to be pushed into the market. With such a diversity of products showing up through fertilizer dealers, chemical manufacturers and independent retailers, it is difficult for farmers to sort through the myths and realities of non-traditional products or specialty fertilizers, including micronutrient products. In order to decide if specialty fertilizers and micronutrient packaged products pay, an evaluation of research trials across the United States reveals that getting back to the basics—soil sampling—pays back in profit over prepackaged miracle mixes.

Key Words: fertilizer, micronutrients, sustainable, soil sample, management, alfalfa

INTRODUCTION

Soil and plant additives can be classified in different ways based on use of function, method of application, quantity to be applied or even origin of the material (Kelling and Schulte, 1991). Back in the early 1990s, a group of university scientists in the north-central United States developed a system to evaluate specialty products by dividing these products into five different categories based on the product nature or claim (Kelling, et al., 1991). A current compilation of many of these products are available online at: http://frec.cropsci.uiuc.edu/1991/report1/index.htm . The five categories the science group divided new fertilizer and additive products into include:

1. Products advertised as “natural” or “organic” or that “work with nature” on the label. As the organic and sustainable emphasis has been placed within agriculture more of these types of products are seen, some of which follow organic standards and some of which are questionable under these diverse labels.
2. Products may also be found that are sold under a variety of different names, but with similar or different mixtures of one or more combinations of chemicals—usually at a very low content rate.
3. Across many of these products, low rates of application are used, although when penciled out the cost of the application will be in the $6 to $15 range per acre as this is often the cost farmers are willing to spend.

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4. In some cases, these products have a mode of action that is unspecified or is a “trade secret” or that merely is less than five percent of the active ingredients and thus may indeed be a mystery product, unproclaimed on the label.
5. And, in some cases the sales promotion and campaigns are poorly replicated, promoted primarily before any replicated experiment station or Extension trials are run and often are sold on testimonial advice. Sales are usually linked to the skill of the salesperson more than the efficacy or amount of replicated research run on the product.

Although, the five categories suggested above often can help sort bogus nonconventional additives from growth promoting fertilizers even down to identifying some nonconventional system products such as “electromagnetic” seed treatments as compared to some of the modern encapsulated fertilizer and chemical treatments that are being promoted with seed sales today, it is becoming more difficult not only to sort out the enhancing products from those that just take profit from your piggy bank but to also place true value on keeping a maintenance program when unusual additives are added to fields.

In fact, several trials have been run that indeed show that the use of several non-traditional soil amendments that currently are marketed in the western United States as products that can increase forage production, quality, fertility or even beneficial soil properties are not fulfilling these claims. Indeed, in some cases, testing has shown that forage quality and soil fertility are not significantly affected and that in some instances treatments yielded less than control plots or showed greatly varying results (Drake, et al., 2006). And, in some studies, the additional costs of these applied products was not recovered in yield or quality increases of alfalfa (*Medicago sativa*) as compared to maintaining adequate soil pH and fertility through traditional amendments (Hall, et al., 2002). An example case study shows this point below and is supported by additional research from across the United States through the years.

PROCEDURES

Case study. In a series of eight treatments including controls for our example case study pulled from research, a series of foliar applied applications were made in order to determine if any of the products increased alfalfa stem density, yield or quality of the alfalfa where initial or adjusted soil pH were used in a study run through the Department of Crop and Soil Sciences in Pennsylvania (Hall, et al., 2002). In October of 1999, uniform stands of established alfalfa at two locations, designated as Farm 1 and Farm 2, were divided into four replicates of eight 6 x 15 foot plots in a randomized complete block design. A similar design and plan was also implemented at a third location, Farm 3, in October of 2000. These locations were on a Hagerstown silt loam (fine-loamy, mixed, mesic Typic Hapludalfs) soil and soil pH and soil tests were taken. The alfalfa stand was older at Farm 1 and was at only about 30 percent plant density relative to the other sites (Table 1).

Table 1. The alfalfa stand age, plant density and soil nutrient levels at the three studies.

	Farm 1	**Farm 2**	**Farm 3**
Stand age (years)	5	3	2
Density (plants per foot^2)	5	14	17
pH	5.9	6.5	6.8
-- pound per acre --			
P_2O_5*	251	130	122
K_2O_4	309	309	262
-- meq per 100g--			
Acidity	2.0	2.0	0.0
K	0.33	0.33	0.28
Mg	0.5	1.1	1.4
Ca	4.5	6.8	6.3
CEC	7.4	10.2	8.0
-- % saturation --			
K	4.4	3.2	3.5
Mg	7.2	10.8	18.0
Ca	60.8	66.1	78.1

* This reading was determined using the Mehlich 3 method.

Foliar nutrient treatments were applied as specified by the company (Table 2) on the products on Farm 1 and 2 in 2000 and applied again on Farms 2 and 3 in 2001 (Farm 1 was rotated out in 2001 due to thin stands).

Table 2. The foliar and lime treatments applied to alfalfa at the three farm locations over the two-year testing period.

Treatment	**Lime***	**Foliar applied materials****	**Cost*** ($/A/yr)**
1	None	None	0
2	Yes	None	0
3	Yes	Water at 20 gal/A (gallons/acre)	25
4	Yes	5 pound/A 18-18-18	65
5	Yes	Miller Chemical & Fertilizer Corp. (Hanover, PA)	100
		Applied at green-up in spring: 7.5 pound/A ‘Nutrient Express 18-18-18’ 1 quart/A ‘Tech-Flo-Cal Bor’	
		Applied at seven days after each cutting: 4.0 pound/A Nutrient Express 18-18-18 3.0 pound/A 20-5-5-17S 1 quart/A Tech-Flo-Cal Bor	
		Applied in the fall:	

		7.5 pound/A Nutrient Express 4-41-27 1.0 pint/A Cytokinin product	
6	Yes	Stoller Chemical of Florida (Eustis, FL)	60
		Applied within two days after each cutting: 1.0 gallon/A ‘Foli-zyme’ 4.0 ounce/A ‘Stimulate’	
7	Yes	Conklin Company, Inc. (Shakopee, MN)	234
		Applied at green-up in spring and seven days after each cutting: 4.0 gallon/A ‘Feast’ 3-18-18 2.0 quart/A ‘Sidekick’ 0-0-25-175 1.0 pint/A calcium 1.0 pint/A boron 1.0 pint/A zinc 8.0 ounce/A ‘Foliar x-cyto’	
8	Yes	Growers Nutritional Solutions (Milan, OH)	87
		Applied at green-up in spring and two days after each cutting: 2.0 gallon/A ‘Growers’ fertilizer solution 0.2 gallon/A vinegar	

*Lime was applied only on Farm 1 in the fall, prior to any foliar treatments. This raised the soil pH to 6.5.
**The foliar treatments were applied in a water solution at 20 gallons/A except for the Conklin Company product which was applied in a water solution at 5 gallons/A as stated as the recommendation on the product label.
***The cost included the foliar material applied and a charge of $5/A for each application. These costs do not include the cost on Farm 1 for the addition of the lime.

For further analyses of the forage, samples were taken from two randomly selected one foot by one foot areas within each plot. These samples were hand-harvested to within three inches of the soil surface and the herbage from the two areas was combined. The leaves and stems were separated and the stem number determined. Samples were dried in a forced-air oven at 140^{o}F for 48 hours, weighed and then ground to pass a 0.04-inch screen prior to analysis. Only during the third harvest of each year were the plots hand-sampled for morphological and quality determinations. This last sampling was chosen as differences in these traits were greatest during this summer growth (Hall, et al., 2000).

Forage quality was analyzed using near-infrared reflectance spectroscopy (NIRS) and samples were also analyzed using the SELECT computer program (Shenk and Westerhaus, 1994) for crude protein (CP), acid detergent fiber (ADF) and neutral detergent fiber (NDF). The CP was determined as Kjeldahl N x 6.25, and ADF and NDF concentrations were measured using the procedures of Goering and Van Soest, 1970. The samples collected in 2000 were used to create a calibration equation to predict the constituents of the samples and to devise the coefficients of determination (r^2) which exceeded 0.968 for all NIRS prediction equations. The samples taken in 2001 were also predicted using the derived 2000 equations. Homogeneity of variance was tested using Hartley’s F-max test (Milliken and Johnson,

1984) allowing the data from each location-year environment to be analyzed separately. The statistical analyses used SAS Institute (SAS Inst., Cary, NC) software. Tukey's multiple comparison procedure was used for the mean separations and reported as differences at the $P<0.05$ level of significance.

RESULTS

Within the Hall foliar fertilizer trials, differences in yield between treatments occurred in only one of the four location-year environments. At Farm 1, the no-lime treatment yielded less than all the other treatments (Table 3).

Table 3. The seasonal dry matter (total) yield and the third-harvest plant morphology results at Farm 1 in 2000.

Treatments	Yield (ton/A)	Stems (per foot^2)	Leaf:Stem ratio
None	4.8	43	1.5
Lime	5.3	39	1.5
Lime and water	5.4	41	1.6
Lime and 18-18-18	5.3	43	1.4
Lime and Miller products	5.6	45	1.5
Lime and Stoller products	5.7	44	1.4
Lime and Conklin products	5.4	43	1.4
Lime and Growers products	5.4	44	1.6
LSD (0.05)	0.4	NS	NS

When lime was within the treatment, yields were not different regardless of the foliar fertilizer or growth regulator treatments. The only difference across the trials, where no lime was added on Farm 1, was simply due to the low pH at that location. When the pH is at acceptable levels (as shown at Farm 2 and Farm 3) or at least adjusted to acceptable levels (where lime was added at Farm 1), the other treatments had no effect on yield. Yields at Farm 2 and 3 averaged 6.4 tons/A and 8.3 tons/A, respectively. Even the number of stems per unit area and the leaf:stem ratio were not affected by the treatments across any location-year environment. The average number of stems per unit area at Farm 1 was 42 stems per foot^2 and the other locations averaged 68 stems per foot^2. These differences can be attributed to simply fewer plants per foot^2 at Farm 1. There were no differences in any of the forage quality parameters measured. CP, ADF and NDF were 22.2, 32.6 and 42.9 percent of dry matter, respectively, when averaged across all treatments, locations and years. Indeed, the foliar-applied products did not increase alfalfa yield or quality or even alter plant morphology when soil pH and fertility levels were at recommended levels. However, the additional cost of these products could not be justified over maintaining adequate soil pH and fertility through traditional fertilization management programs as these costs ran from $60 up to $234 per acre per year.

Like this foliar fertilizer trial, our own trials across various crops this year, have also revealed that specialty fertilizers and micronutrients packaged in small booster, chemical-additive promotion packages usually do not pay. In fact, using simple soil testing and following the general laboratory recommendations can pay off more with less cost to the farmer than any of these pie-in-the-sky miracle mixes. In testing several products from seaweed emulsion to root stimulants to packaged foliar fertilizer mixtures in the Midwest over several years and particularly during the flood of 1992, even extreme situations of nutrient leaching losses, fertility based on good soil testing and analysis paid back better dividends.

However, new products are constantly emerging on the market and must be tested. Just this last month, another presentation was given at the Agronomy Society Meetings-2006 in Indianapolis, IN again testing soil amendments in alfalfa production (Drake, et al., 2006). Within these results, researchers found that non-traditional soil amendments of unknown or unproven utility are being marketed to western U.S. alfalfa producers as products to increase forage production, forage quality, soil fertility and beneficial soil properties. Generally, the products contain low percentages of macro- and micro-nutrients, cultured substances and various raw or extracted materials. Five commercial products were evaluated for alfalfa forage yield and quality in 2004, 2005 and 2006 in Richfield and Salina, UT. Amendments were applied in early spring as a spray application mixed with the herbicide, hexazinone, to dormant alfalfa or applied by fertigation to vegetative stage alfalfa in the spring. The treatments were applied as field strips in a randomized complete block design with four replications or randomized complete block segments with six replications on a center pivot irrigation system. The alfalfa forage was harvested four times during the growing season and the response to the soil amendments varied by treatment, application method, cutting and year. Some treatments, however, yielded less than the control with others showing varying responses. It was found that forage quality and soil fertility were not significantly affected.

In order to truly evaluate true fertilizer and micronutrient needs, some simple steps should be taken. A proper soil test should be taken to evaluate true soil nutrient needs for a cropping season (McWilliams, 2001d). Soil tests allow the producer to maintain fertility status needed in a given field. It also allows you to predict the probability of obtaining a profitable response to fertilizer (McWilliams, 2001a; McWilliams, 2001e). Soil testing also provides a basis for recommendations on the amount of fertilizer to apply (McWilliams, 2001b). And, finally, a soil test allows you to evaluate the fertility status of soils on a county, soil area or even state-wide basis through the use of soil-test summaries previously run. These comparisons then allow you to develop plans for production needs and effectiveness and persistence of a fertilizer treatment.

In other words, soil testing allows you to gain a handle on the facts about a given area of land relative to nutrient needs or special conditions such as acidity or alkalinity. It gives you clear-headed, straight advice on nutrients needed to develop a supply, supplement or buildup program, usually at a cheaper cost—than providing a shotgun approach to needs that bulk, ratio-applied specialty fertilizers or micronutrients may try to tap at without the basic benefit of knowing true needs or at trying to provide one formulation that fits all situations (Kelling and Matocha, 1990). The shotgun approach just doesn't work unless you happen on a lucky micronutrient need that is available in the right place at the right time and if you don't mind paying much more for the same elements. A bulk fertilizer mix rate applied in a timely manner to provide availability for the crop at the proper time can be cheaper and more effective. The proper selection of adequate fertilization practices do indeed depend on the requirement of the crops, weather and the soil characteristics and requires finding the deficiencies in the soil for that crop and determining how best to supply those requirements (Kelling and Speth, 1998).

Since plants can also be luxury users of nutrients, it becomes even more important to determine fertilizer needs based on good soil testing and laboratory analysis followed by fertilizer addition as needed in order to better identify that point at which there is no further economic yield increase, or for that matter, income loss from frivolous, unneeded nutrient or chemical additives (Peters, et al., 2005). The soil testing procedure is your hold on your input costs or losses and should be considered the most important step in your operation. Another reason soil and later plant analyses—if more tweaking of the inputs are needed--are important is that balance among nutrients may be just as important as actual amounts added (McWilliams, 2001f). The relationships among Ca, Mg, K and NH_4, Mn and Fe, as well as Zn and P are examples (Tisdale and Nelson, 1975). Some over-the-counter specialty fertilizers and micronutrient mixes may not consider this balance needed. The principle of soil testing and use of prescribed fertilizers is to obtain a value that will help to predict the amount of nutrients needed to supplement the supply in the soil and then to utilize soil testing to calibrate nutrient use toward sustainable crop production. The goal is to maintain soil fertility at a level for top profit yields. This goal is even more important when working with additions of micronutrients. Micronutrients may have to be added to a mixed fertilizer for effective dispersion and availability such as boron use in alfalfa. In other cases, such as with zinc or copper, these nutrients may be broadcast separately or placed in a slower release or special formulation addition to crops.

If only small amounts of micronutrients are needed, sometimes a prescribed micronutrient mixture is added to bulk fertilizers in order to add the material in “insurance” forms and quantities that will not harm more sensitive crops but will take care of the needs over possibly multiple cropping seasons and under certain soil conditions where it might be very difficult to impossible to a) determine the needs across soil types within a field, b) where the absence of visual symptoms does not preclude hidden hunger for the micronutrient in the crop plants, c) where it is better to anticipate needs rather than to wait and lose production and money and d) as a low-cost insurance for a particular field that is notorious for micronutrient limitations. Soil pH of a field can also make availability or seeming loss of micronutrient availability a problem in some fields, requiring more detailed analysis of the micronutrient needs.

Another reason indiscriminate use of minor elements should be avoided with unconfirmed specialty or micronutrient potions are that this can be hazardous. On an acid soil, for instance, the addition of manganese usually will not be beneficial and might even be detrimental. Using a mixture of many different micronutrients can also depress uptake of some needed macronutrient such as the case of no copper response where the nutrient was needed in a wheat field where an additional supply of copper, iron, manganese and zinc were added on top of the recommended copper addition and the interaction with lime on a high organic matter soil showed the only response to the needed copper was where the field had very low lime levels. Or in the case in more of the western United States where higher pHs prevail you might find that availability of calcium, magnesium, phosphorus, manganese, iron, zinc, copper, molybdenum and boron can all be greatly affected.

The balance of these pH-affected nutrients greatly influences our production in the western United States (Haby, 2002; Berrada and Westfall, 2005). Generally, calcium is able to counteract or detoxify an unbalance in the concentration of a number of other minerals but with the balance of nutrients in the soil skewed to such an extent that it can not, deficiency may be seen with death of crop apical meristems, root tips and even buds as well as stunting of plants, and poor yield or forage production. With magnesium, as a mobile element in the plant, any deficiency developed can be very hard to correct. Plants may show chlorosis, yellowing, even showing necrotic spots with possible plant necrosis if the deficiency is not corrected. With phosphorus, a highly mobile element in the plant, a deficiency or uncalibrated mixture onto land can result in reddening of the forage, sometimes yellowing, flower inhibition, plant stunting and even poor root or seed development. Manganese is essential for chloroplast production in the plant and reduced or masked amounts can reduce plant root systems as well as increase plant susceptibility to disease. Immobile, manganese can show chlorosis of the plant as well as reduce the sugar-starch content of leaves, possibly making them also more susceptible to insect injury and attack. Iron, on the other hand, is relatively immobile in the plant but can be greatly antagonized by manganese and can show deficiencies with this problem through interveinal chlorosis, poor plant growth, stunting and with the young leaves showing the first symptoms in a dramatic manner. Zinc also affects the plant composition when deficient. It can lead to less starch accumulation in the plant, impairing protein synthesis, causing chlorosis, shortening plant internodes, making smaller leaves, causing the onset of premature axillary bud set, resulting in poor seed production and eventually leading to leaf necrosis. Likewise, in excess, zinc can be toxic to plants causing many of problems also seen in limitation. Copper is essential in plant nitrification and while not readily mobile in the plant can, with deficiency, cause plant withering or wilting, stunting, chlorosis or even poor seed production. Since it may also increase protein content in the plant, it may cause the plants to become more attractive to insects that could be detrimental to forage production. Molybdenum is necessary for nitrogen fixation. Immobile, with deficiency, it can show nitrogen deficiency, symptoms that will not always be relieved by NH_3 or Mo when nutrient balance is not there. Boron contributes to plant growth and is required for nodule formation on legumes. Being immobile, deficiencies can lead to death of terminal meristems, growth being inhibited, internal plant breakdown of structure such as the cambium, phloem and xylem, and a yellowing or mottling on the plant may appear under slight deficiencies.

Because the decision to provide the input cost to fertilizer and micronutrient additions on fields is so important not only through economics but through plant health, production and longevity in crops, the collection, preparation, extraction and analysis of elements needed for fertilizer applications is critical to your operation. Whether you are just considering a deficiency correction philosophy for fertilization or going into a maintenance or nutrient removal or balance philosophy, it is important to return those nutrients, and only those nutrients, that are removed and should be replaced to maintain productivity and balance to your fields. In fact, future research on applying micronutrients should pay closer attention to determining their effect not only on nutrient balance but also on consumption considerations for livestock utilizing the forage, not just the health of the crop plant. Properly applied fertilizer improves feed or food quality through the higher quality of vegetative products (indirectly through to animal products) so that it ultimately contributes to the health of the end users within the food chain (Gupta and Gupta, 2005). The use of micronutrients is also greatly affected by drought stress in plants such as alfalfa especially if arbuscular mycorrhizae and *Rhizobium* are affected (Goicoechea, et al., 1997). While drought will decrease the nutrient content of alfalfa leaves and roots of noninoculated plants, an enhancement of nutrient content—even under drought conditions—in mycorrhizal alfalfa plants can be found. Thus, fertilizing to optimum standards for alfalfa growth can help in continuing arbuscular mycorrhizae and *Rhizobium* influences on the plant, even during drought, to continue to enhance plant quality. It can also enhance alfalfa growth under salinity stress (Esechie and Rodriguez, 1999). As increased salinity and semi-arid land use continues in the western United States for alfalfa, studies have shown that an application of an external nutrient solution, especially the full-strength solution, produced an increase in leaf growth and leaf nutrient element concentration. The conclusion drawn from this study suggests that reduced leaf nutrient concentration may be one of the primary causes of inhibition of leaf growth in alfalfa under salinity stress and that complete fertilizer additions (McWilliams, 2001c), including all the micronutrients needed in balance, may lessen the reduction in nutrient concentrations in salinity-stressed alfalfa, particularly with micronutrients (Esechie and Rodriguez, 1998).

The critical decision to make fertilizer applications, particularly with regard to micronutrients, is important to crop health, longevity, production and stand and will affect your production for years to come. It is essential then, that you utilize a soil test and interpretation that will help your enterprise and not steep it in excess overhead costs and mismanagement prior to the first harvest by simply jabbing in a suggested but not prescribed fertility treatment. Particularly when working with micronutrients and other additives that can affect the nutrient balance and needs of the crop, you need to take a straight shot approach that will not scatter your resources, your crop health and your multiple-year balance out in left field.

Find out exactly what specialty fertilizers and micronutrient mixtures have in them and determine if they contain exactly the prescription analysis that you need to optimize your operation before using them. Don't waste your time or money on low-rate fertilizer programs that often produce lower yields at a higher cost (Franzen and Gerwing, 1997). Balance the buck in your operations, to insure smoother management, longer productivity and a better balance of quality forages.

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