SUMMARIZATION OF 471 FIELD COMPARISONS OF AVAIL®

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ABSTRACT

Phosphorus (P) is a commonly deficient essential nutrient required for crop production. Economic, environmental, and conservation issues have motivated significant efforts to enhance fertilizer efficiency. AVAIL® is a specialty fertilizer product with claims of enhancing P use efficiency to potentially increase crop yield and quality. There have been at least 471 field comparisons to evaluate the effectiveness of AVAIL with a wide variety of crops. The objective of this summarization is to evaluate the data from these field trials to determine if AVAIL is an effective P fertilizer efficiency enhancement product. All known published and unpublished field trials were collected into a database with their corresponding study, yield, and soil information. Average yield increase was determined for each field comparison by comparing the yields of AVAIL-treated P fertilizers with untreated P fertilizers at identical fertilizer application rates. The average yield increase due to AVAIL was 2.3% for the entire dataset. However, a large number of the trials were conducted under very high P fertilizer rates and/or with soil properties not conducive to a yield response to P fertilization. When including trials with P fertilizer rates that were not excessively high and with soils most likely to respond to P fertilization, the average yield increase for AVAIL was 5.5%. AVAIL seems to increase crop yields, but it is recommended to only be applied with judicious rates of P fertilizer and in soils that have a reasonable probability of responding to P fertilizer.

INTRODUCTION

Hopkins (2013) discusses and provides citations for plant P relations and concerns, as well as much of the research on the purported P fertilizer enhancement product AVAIL® (Specialty Fertilizer Products, Leawood, KS, USA). AVAIL is a long chain dicarboxylic acid (DCA) copolymer. The DCA, composed of maleic and itaconic acids, is reported to have a cation exchange capacity (CEC) of 18 meq g^{-1} of solid polymer. The proposed mode of action claims that this high CEC sequesters Ca, Mg, Al, Fe, Mn, and other multivalent cations, thus reducing their interaction with P in soil solution—although there are claims disputing this mode of action (Chien et al., 2014).

Hopkins (2013) and Chien et al. (2014) review many of the published and unpublished research trials on AVAIL. Many of the studies show significant yield responses, but others show no or negative responses. Notably, application of AVAIL + MAP fertilizer on Russet Burbank potato in 5 grower fields in Idaho showed mixed results—with three fields resulting in modest to strong responses, another field showing no response, and a field having a strong negative response (Hopkins, 2013). This data is a microcosm of the entire data set presented here—with positive, no, and negative responses.

Chien et al. (2014) performed a pseudo meta-analysis of a large number of these field trials and ardently states that AVAIL provides no crop benefit when averaged across all trials—with an average response of near zero. However, the presentation of the meta-analysis is unclear as to which research reports were included and which were excluded. It is likely that at least some well-founded, peer-reviewed data was omitted from their analysis—including the readily accessible published report from Hopkins (2013).

In addition, Chien et al. (2014) did not adequately account for important mitigating soil and P fertilizer rate factors. It is a well understood principle that likelihood of P response diminishes as soil test P (STP) increases. It is also well understood that soil P solubility is dramatically reduced at extremely acidic and extremely alkaline soil pH levels. Also, the law of diminishing rate/return tells us that yield response to a nutrient declines as fertilizer application rate increases until a plateau is reached—where further nutrient addition yields no benefit and, at times, can result in yield decrease. Curiously, many researchers evaluating AVAIL performed their tests under one or more of these scenarios where P response is unlikely and, therefore, response to AVAIL would also likely be unlikely.

Our objective is to summarize 471 field observations with a wide variety of crops to determine if AVAIL is an effective phosphorus fertilizer enhancement product.

MATERIALS AND METHODS

A search for all AVAIL field trials was undertaken by exhaustive literature search and communication with the manufacturer of AVAIL and scientists known to do research with this product. To our knowledge, every trial for which a soil P test could be obtained has been included in this review, regardless of publication status. These data were included into a database with their corresponding study, yield, and soil information.

Yield response was determined by subtracting the untreated yields from the AVAIL-treated yields and dividing by untreated yields. A separate observation was made for each unique P rate in each study. For example, if a field study included a four treatment trial of two rates of P (e.g. 20 and 40 kg P_2O_5 ha^{-1}) with and without AVAIL, there would be two yield observations included in our summary—one at 20 and another at 40 kg P_2O_5 ha^{-1}.

Researchers used a wide variety of soil test extractants to measure residual soil P availability. The International Plant Nutrition Institute STP range equivalents (Table 1 on p. 7 of IPNI, 2011) was used to categorize each soil as to its likelihood of P fertilizer response by assigning each soil into one of the 15 categories ranging from very low to extremely high STP concentrations. Soils were also categorized by pH into three categories of: 1) extremely acidic (<5.7), 2) nearly neutral (5.7-7.7), and, 3) extremely alkaline (>7.7).

Trials were also subjectively separated into low to moderately high vs. very high applied fertilizer P rate. For trials with potato (*Solanum tuberosum* L.), lettuce (*Lactuca sativa* L.), and Chinese cabbage (*Brassica rapa* var. Chinensis Choy sum); the rate was classified as very high when greater than 230 kg P_2O_5 ha^{-1}, regardless of application method. For trials with maize (*Zea mays* L.) and all of the many other crops, the rate was considered very high when greater than 80 and 160 kg P_2O_5 ha^{-1} for banded and broadcast application methods, respectively. Potato is known to respond to fertilizer at STP levels much higher than most other crops regardless of application method. Lettuce and cabbage are similarly shallow-rooted and inefficient in P uptake and, thus, were associated with the potato. For the other crops, applying the P fertilizer in a concentrated band is known to be at least twice as effective in terms of P rate required. The P rate values were selected in an effort to choose rates that would be considered very high by

nearly every expert and entity associated with soil fertility and plant nutrition. This approach likely includes P rate values considered to be high by many in the low to moderately high category, but we chose to error on the high side.

Statistical comparisons were made by ANOVA. A more formal manuscript of a meta analysis of this study is submitted to a respected agricultural journal; therefore a majority of the statistical details are not shown here due to copyright rules.

RESULTS AND DISCUSSION

Averaging the yield response across all 471 field comparisons gives a positive response to AVAIL at 2.3%. The magnitude of this overall response is not large. However, it is positive and is in stark contrast to that of Chien (2014), which publication is highly critical of AVAIL with a report of a near zero average response to AVAIL. In both of these publications, they used a similar approach to this summary, but the number of comparisons included in their reports is less than what is shown here. This is in part due to new reports published this year, but is mostly due to a lack of inclusion for unknown reasons. For example, not all of the data from Hopkins (2013) and Stark and Hopkins (2014) was included in their report despite being published and/or readily available through communication with the authors. They did not include this data as "reliable" but only because they failed to contact the authors who would have been able to inform them that the data was accepted for publication at the time of their publication submission. In an effort to avoid this problem, we contacted every researcher known to be doing work with AVAIL to discover the current status of their research and publication efforts, and to ask if they were aware of others doing work with AVAIL.

In the examination of these many field trials, it became apparent that an inordinate number of the trials were performed in less than ideal circumstances to generate a response to P fertilization. Of the 471 field observations, 427 included a zero P control, which allowed determination of an overall response to P, there were 29% of these at or below zero response to P fertilization and less than half were statistically significant (it was not possible to give an exact percentage for the entire data set because many researchers did not provide adequate information to conduct a valid statistical comparison). The most obvious cause of this lack of response in a high number of these trials is very high STP levels. Although it is appropriate to perform P response trials at moderate and higher soil test values so that farmers can know how fertilizer products will perform under ever-increasing yield levels, it was surprising to see the number of AVAIL trials that were conducted under conditions where a response to P and, thus, AVAIL, was unlikely. It is not surprising to those who are familiar with soil fertility and plant nutrition principles that the response to P fertilizer decreases dramatically as STP levels increase (data for this analysis from our summary is not shown here). Interestingly, the same is true of response to AVAIL compared to untreated P fertilizer when evaluating the percent response by IPNI (2011) STP category (Fig. 1). The average response rate was positive for all IPNI categories of extremely low (1) through moderately high (7). The upper range of "moderately high" as defined here for the four most common STP extractants (accounting for 89% of soil samples tested in North America) was 55, 40, 40, and 30 mg kg^{-1} for the Mehlich 3 (ICP), Bray P1, Mehlich 3 (colorimetric), and Olsen bicarbonate extractants, respectively (IPNI, 2011). In contrast to these relatively lower categories, overall responses were mostly near zero to negative for very high to extremely high categories (8 to 15). There are positive values for category 12 and 15, but these are influenced heavily by potato (which has unique P response properties), as well as some possible outliers.

Based on these STP data, further analysis was performed on the sites with relatively higher likelihood of P response by omitting the 119 field observations with IPNI (2011) STP categories of 8 and above. This selection was strictly guided by the data in Fig. 1, which is a very liberal selection as category 7 would be considered a high STP value by most state cooperative extension STP interpretation guides and by most independent soil test laboratories (IPNI, 2011). The average response to AVAIL over untreated P fertilizer increased to 3.2% when including only these relatively lower STP level field sites.

Another well-known soil fertility principle is that P solubility is strongly influenced by soil pH with a peak of P solubility in the near neutral pH range. Of the 352 site comparisons with IPNI STP categories below 8, there were 23 with strongly acidic (<5.7 pH) and 87 with strongly alkaline conditions (>7.7 pH). Although the sample size is not large, especially for the acidic soils, it is apparent the soil pH did impact crop response to AVAIL (Fig. 2).

Finally, it is well-known that there is a "law of diminishing response/return" which states that increasing rates of a plant nutrient give decreasing increments of yield response and eventually plateau (and often decline at very high levels). If ample P fertilizer is applied to meet crop needs, no amount of P fertilizer solubility enhancement provided by any product or management practice is going to give further yield increases. There is considerable variation in what rate is considered "high" as soil, crop species, environment, yield potential, etc., can all impact this level. A liberally high rate was selected as described previously and the segregated results are shown in Fig. 3. It is interesting that the average yield response to AVAIL increased to 5.5% greater than crop yields from untreated P fertilizer when only evaluating the sites and rates most likely to provide a response to P fertilizer (102 site comparisons). It is also interesting to note the negative response at high P rates, possibly due to a P induced micronutrient deficiency (Hopkins, 2013), however, there was a very small sample size of only 8 comparisons.

It is important to acknowledge that these 471 sites include everything from highly "reliable" data taken from peer-reviewed journal publications to less reliable publications and data sets. When only including the more reliable subset of data, it is interesting to note that the percentages were roughly the same as those reported above (data not shown here but will be available in the associated journal publication). However, the sample size was small.

CONCLUSIONS

Phosphorus fertilizer treated with AVAIL gave a 2.3% increase in yield over untreated P fertilizer applied at equivalent rates when averaged across all 471 known site comparisons. The magnitude of response increased to 5.5% when evaluating the subset of 102 site comparisons which had low to moderate P fertilization rates and soil conditions with relatively higher probability of response (low soil test P and extreme acidity or alkalinity). This is in sharp contrast to a previous review which did not include all of these sites and largely ignored soil and rate parameters.

REFERENCES

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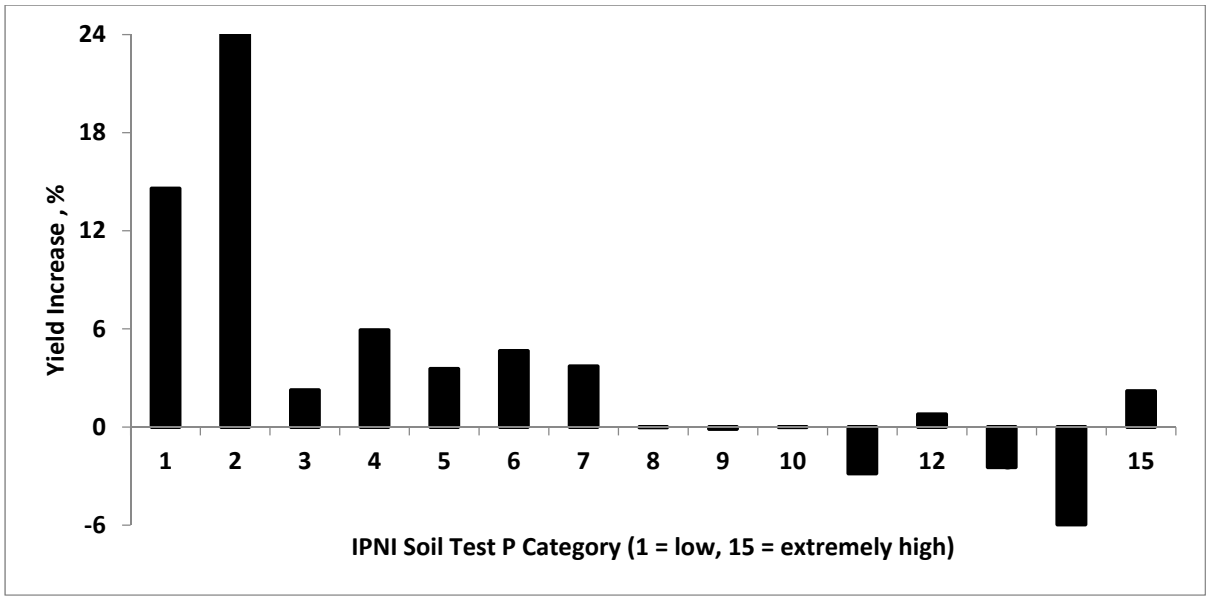

Fig. 1. Relative yield (averaged across all crops evaluated) for P fertilizer treated with AVAIL compared to untreated P fertilizer.

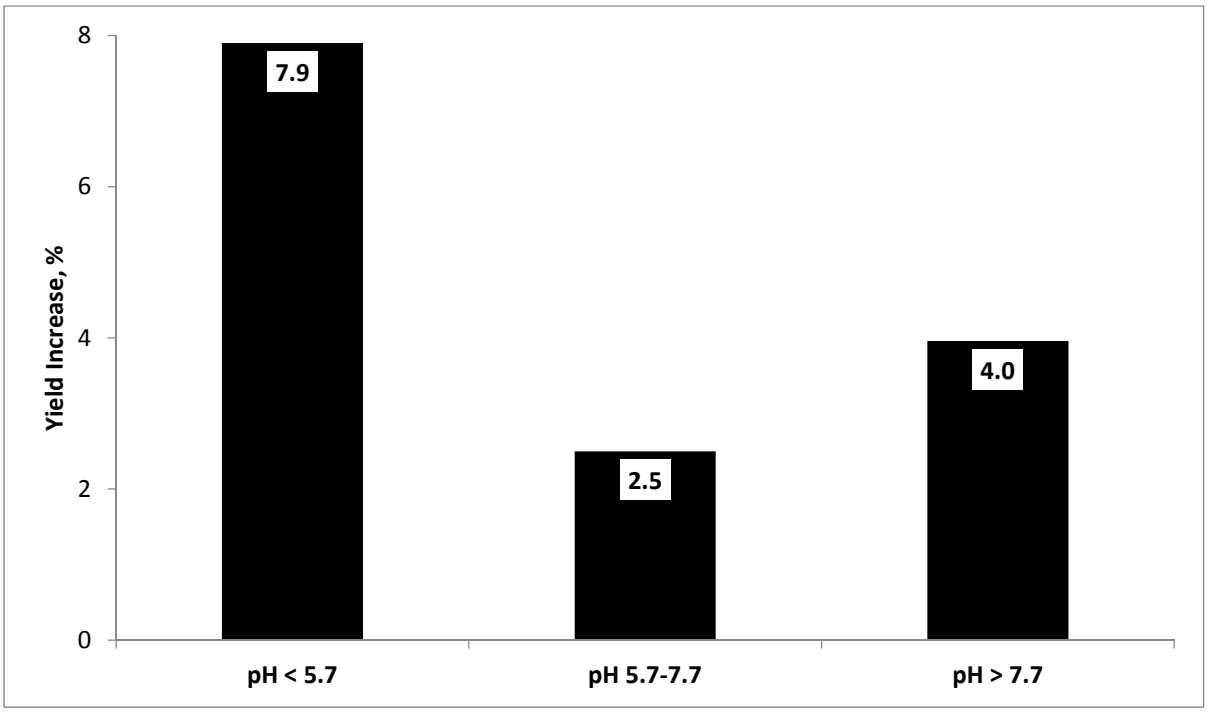

Fig. 2. Relative yield (averaged across all crops evaluated and for sites with moderate to low soil test P) for P fertilizer treated with AVAIL compared to untreated P fertilizer. All of the values shown are statistically greater for AVAIL than for untreated P fertilizer for all three categories.

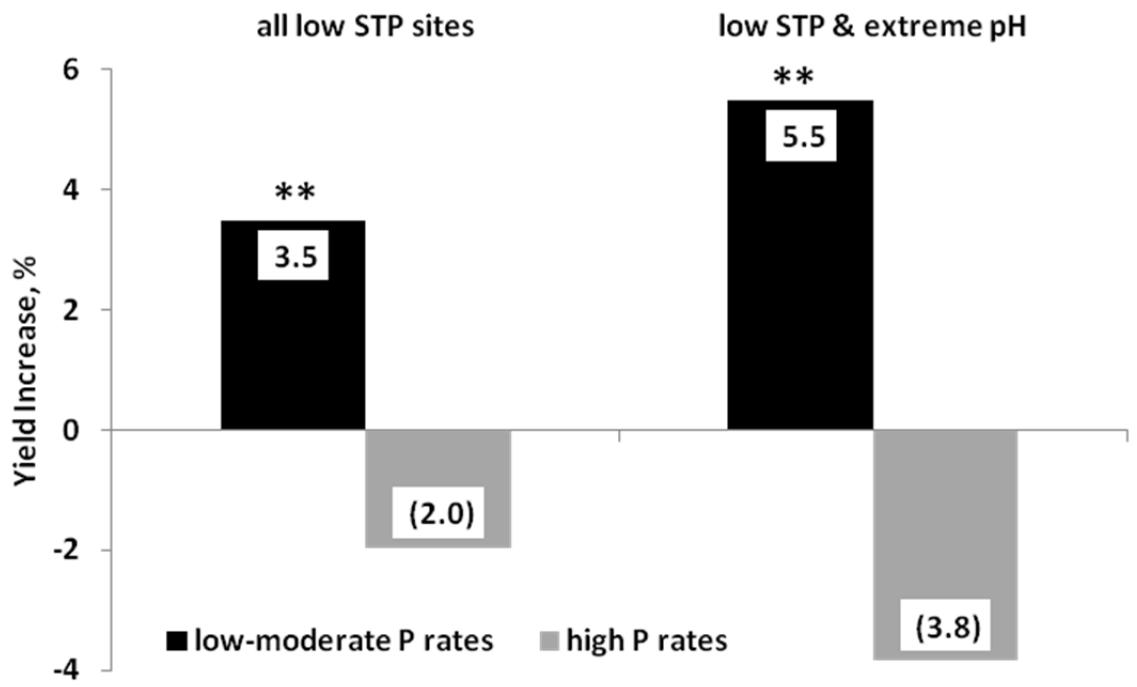

Fig. 3. Relative yield (averaged across all crops evaluated) for P fertilizer treated with AVAIL compared to untreated P fertilizer. Only sites with moderate to low soil test P (low STP) were included. For the bars on the right, only the low STP and extremely acidic (<5.7) and alkaline (>7.7) pH were included. The data was further separated by P rate with "high P rates" >230 kg P_2O_5 ha^{-1} for potato, lettuce, and cabbage regardless of application method and > 80 or 160 kg P_2O_5 ha^{-1} for banded and broadcast, respectively, for all other crops. ** = significant at $P < 0.01$

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