SOYBEAN YIELD RESPONSE TO P FERTILIZER PLACEMENT AS AFFECTED BY SOIL PARAMETERS: A REVIEW

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ABSTRACT

In the last decades, several studies were conducted to evaluate more efficient P fertilizer management with emphasis on placement. Many of these studies report contrasting results, suggesting that a general recommendation may not be appropriate and specific factors of soils, crops, and weather should be considered. A literature search was completed using Google Scholar, and published papers that met our selection criteria included 62 experiments, with 95 site-years. Approximately 9.8% of the studies showed higher soybean yields when P was placed in band as compared to broadcast placement (5%). Most of the studies (85.2%) showed no difference between P placement strategy on soybean yield. Nevertheless, evaluation of multiple soil factors suggests that P fertilization in the band may be best suited in situations with low soil pH, low organic matter, low soil P test, low rates of P fertilizer application, and higher soil clay content and H +Al level.

INTRODUCTION

Soybean is the second major crop in the USA, accounting for about 90 percent of U.S. oilseed production (USDA, 2016a). Projected soybean production for 2016/17 shows a record of 4,201 million bushels and a continuous increase of the harvested area around 13 % in the last 14 years (USDA, 2016b).

Phosphorus fertilizer placement can have significant implications for optimum crop yields as well as environmental loss. Generally, band-applied P fertilizer is considered as more efficient, however, this efficiency may be affected by soil conditions as well as production systems including crop and soil management such as tillage. Under no-till systems, due to absence of soil disturbance, broadcast P (B) tends to contribute to high concentrations of P and therefore stimulate shallow root growth (Williamson, 2001). As a consequence, is possible that nutrient availability would decrease during drought periods (Borges & Mallarino, 2000). On the other hand, B have been used in large scale due to their simplicity, low price, easy maintenance and fairly large working width (Villete et al. 2008; Serrano et al., 2011). Also, B is still the main strategy to allow variable rate technology to be used by precision agriculture (Franzen and Mulla, 2015).

In turn, banding P (R) at planting near the rows, can reduce P fixation in soils with high Al and Fe content (Balastreire & Coelho, 2000) and increases P availability near the root system. On the other hand, this could generate loss of operational capacity during the planting season (Villete et al., 2010). Phosphorus limitation during early growth season can also impact crop production, particularly for crops like corn (Grant et al., 2001).

In the last decades, several studies aiming to investigate more efficient P managements have been conducted worldwide and reporting contrasting results, which does not allow for general recommendations for P management (Sá et al. 2013). The reason for that could be related to changes in soil conditions, which can drive P availability in the soil. In general, five factors are considered to drive P availability in the soil: soil test P levels, soil texture, soil organic matter (SOM), soil management and microorganisms (Barber, 1984). Thus, the objective of this study was to complete a literature review to evaluate tends between soil test parameters (such as soil pH, soil clay content, soil P level, soil organic matter and soil aluminum) and soybean yield response to band and broadcast P placement.

MATERIALS AND METHODS

A literature review was performed including a wide range of published information (62 experiments, 95 site-years) using Google Scholar (Table1). The key words used in the search were: phosphorus placement, phosphorus broadcast, band phosphorus, phosphorus management, soybean phosphorus. The target parameters, in addition to soybean yield were: soil test P level, soil pH, soil clay content, organic matter content, and soil Al. Some parameters were not shown in all articles. The literature search included publications from 2000 to 2015.

To better understand the relationship between P placement and soil parameters, the response ratio of soybean yield was calculated dividing soybean yield when fertilizer was applied in band by soybean yield when the fertilizer was applied by broadcast.

RESULTS AND DISCUSSION

Studies evaluating soybean response to phosphorus placement that were included in this study are shown in table 1. These studies provided a wide range of soil types, climate conditions, initial P levels, soil texture, soil organic matter content, soil pH, aluminum, etc. contrasting results, suggest that a general recommendation may not be appropriate and specific factors of soils, crop species, and weather should be considered. In our review, 62 studies with 95 site-years were gathered and grouped by statistical response of soybean yield to P placement. Approximately 9.8% of the studies resulted in higher soybean yields when P was placed in band as compared to broadcast placement (5%). However, most of the studies (85.2%) showed no difference between P placement strategy on soybean yield. In many cases, different responses to P placement were found even within the same range of a given soil parameter. For instance, yield was increased by both broadcast and band P at pH ranging from 6- to 6.5 and from 5- to 5.5. Figure 1 show the yield response in each study to P placement and the soil test P, soil pH and soil OM.

Analyzing the relative yield difference as affected by P placement (Figure 2), it is possible observe a tendency to greater P efficiency between P management strategies for some soil characteristics. In lower soil pH range, the use of band P placement strategy could be the better alternative. Greater yield results for broadcast P were found for soil pH of 6. Soil pH drive changes in the ionic species of soil P which modifies the diffusivity of phosphate in the soil altering the capacity of P adsorption. Thereby, low pH will result in decrease of P availability in the soil (Lewis and Quirk, 1967).

Under high soil clay and H+Al levels, band P placement shows better performance (Figure 2). The phosphate anion reacts with reactive groups of OH- surface (non-crystalline aluminosilicates, oxides and hidroxides of Fe, Al and Manganese (Mn) and the edges of silicate clay minerals), specifically absorbing the anion in the form of inner-sphere complexes (Meurer et al., 2006). This reaction turns the P present in the soil solution unavailable. Higher P concentration promoted by band placement strategy would likely minimize this effect (Hansel et al., 2014).

Similar tendency was found for organic matter, soil test P levels and phosphorus fertilizer rate (Figure 2). In these cases, when the levels of this parameters are low it is recommended the application of P in a band. Higher P content in the soil and P fertilizer rate would favor P diffusion to the roots (Lewis and Quirk, 1967). In soils with lower soil test P level, band P may generate a concentration gradient, increasing P diffusion and consequently, improving P availability to the plants (Barber, 1984). Organic matter in the soil works as a chelate, bonding with silicates and others cations forming structures with low reactivity (Garrou, 1981). As a resultant of this reaction, negative energy balance occurs in the soil, reducing the adsorption of the anions $H_2PO_4^-$ or HPO_4^{-2} and increasing P availability (Stewart and Tiessen, 1987).

SUMMARY

Most of the studies included in this review showed no effect of P placement strategy on soybean yield. In some cases, band P showed higher soybean yields (9.8%) compared to broadcast placement (5%). Nevertheless, P fertilization in the band may be best suited in situations with lower soil pH, low organic matter, low soil test P, low rates of P fertilizer application, and higher soil clay content and H +Al level.

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Table 1. List of publications included in the review.

References	Country	Number of site-years
Barbosa et al. (2015)	Brazil	1
Bergamin et al. (2008)	Brazil	2
Borges and Mallarino (2000)	US	21
Buah et al. (2000)	US	11
Farmaha et al. (2011)	US	3
Guareschi et al. (2008)	Brazil	1
Guareschi et al. (2011)	Brazil	1
Jerke et al. (2012)	Brazil	8
Lana et al. (2003)	Brazil	3
Moterle et al. (2009)	Brazil	1
Motomiya et al. (2004)	Brazil	2
Nunes et al. (2011)	Brazil	14
Olibone and Rosolem (2010)	Brazil	5
Pauletti et al. (2010)	Brazil	7
Rosolem and Merlin (2014)	Brazil	3
Salvagiotti et al. (2013)	Argentina	11
Teixeira et al. (2013)	Brazil	1
TOTAL		95

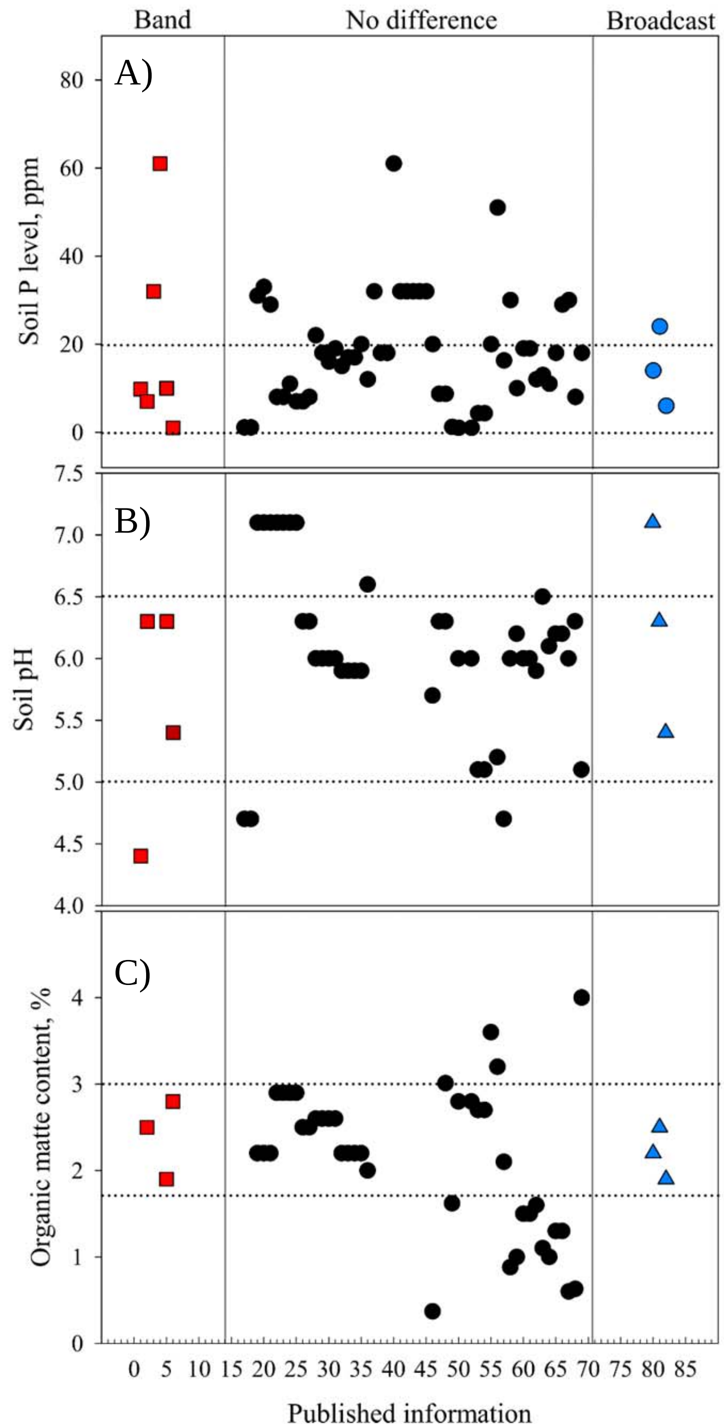

Figure 1. Comparison between band and broadcast P placement and the effect on soybean yield under different (A) soil test P, (B) soil pH and (C) organic matter content. The published information is grouped by yield response to P placement. Red squares represent studies where band treatments resulted in statistical greater yield; solid circles indicate no yield difference between treatments; and blue triangles represent studies where broadcast treatment resulted in statistical greater yields. Some information was not showed in all the papers.

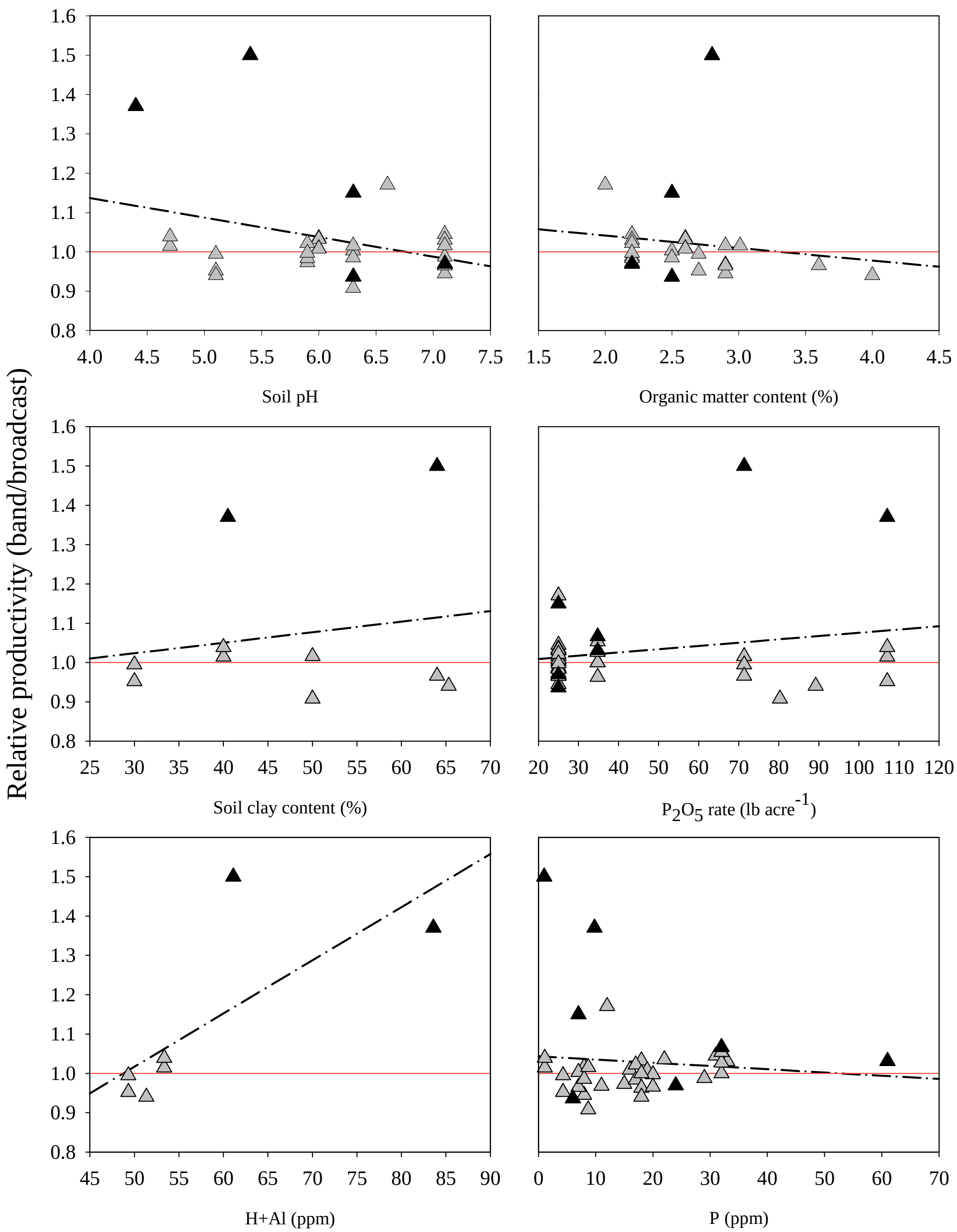

Figure 2. Soybean yield response to P placement in different soil parameters. Relative soybean yield was calculated dividing soybean yield when fertilizer was applied in band by soybean yield when the fertilizer was applied by broadcast. Solid triangles indicate no statistical difference and blue triangles mean significant statistical difference. Some information was not showed in all the papers.

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