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A ROW CROP PRODUCER'S GUIDE TO APPLYING POULTRY LITTER TO SOYBEAN AT PLANTING

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INTRODUCTION

Poultry manure, and especially broiler (meat chicken) litter, has recently become more readily available in west Tennessee as an alternative row crop fertilizer. In northwest Tennessee a new poultry processing plant has been built in Humboldt, and a large expansion has occurred at an existing poultry processing plant in Union City. The host counties for these plants, plus the surrounding counties that either contain the poultry houses or that have ready access to litter (Gibson, Obion, Dyer, Crockett, Madison, Carroll, Henderson, Henry, Weakley, Haywood and Lauderdale), accounted for half of the entire state soybean crop in 2022.

This publication is a guide for Tennessee row crop producers who are currently using or considering using poultry litter as an alternative fertilizer applied directly to soybean at planting. Research, funded by the Tennessee Soybean Promotion Board and presented here, tested litter as a direct fertilizer for soybean in comparison with commercial fertilizers. Results indicate that litter is an effective soybean fertilizer that most often results in taller plants with more above ground biomass than would otherwise be expected with commercial fertilizers alone. Research in Tennessee and surrounding states indicates that while taller plants are commonly observed when using litter as a fertilizer, increased yields typically do not occur. Trifoliate leaf and seed macro- and micro-mineral nutrient concentration data confirm that litter applied to soybean at planting releases nutrients in sufficient quantities even for low or medium testing soils. Application close to planting is recommended to help reduce the potential for nitrogen losses to the environment that can degrade surface and groundwater quality.

THE VALUE PROPOSITION FOR LITTER APPLIED TO SOYBEAN AT PLANTING

Focus on P & K

The value poultry litter offers as a soybean fertilizer lies primarily in the phosphorus (P) and potassium (K) content. Typically, litter is 2-3 percent P2O5 and K2O on an "as is" basis (supplying = 40-60 lb/ton). If the cost of diammonium phosphate (DAP) is $800/ton ($0.87/unit; discounting the N value) and potash is $650/ton ($0.54/unit), the value of the litter P and K is $56-$85/ton. The litter nitrogen (N) does not add value because additional N is not required to produce soybean agronomically [2, 3].

Soil Tests Establish the Value of Litter as a Direct Soybean Fertilizer

The current year value proposition for using litter as a direct soybean fertilizer depends on your soil test P and K concentrations (Table 1). Litter value is maximized if your soil needs both P and K (testing low or medium). If only one mineral nutrient is required, the litter value is significantly reduced. If your soil does not require P or K, the cost to apply litter decreases current year profitability [4].

Soybean Harvest P & K Removal Rates

A less concrete value proposition for litter is in replacing P and K removed during soybean harvest. Seed P and K concentrations (lb-P2O5/bu; lb-K2O/bu) and harvest removal rates (lb-P2O5/ac; lb-K2O/ac) are presented in Figure 1 for a three-year study in which litter was applied to soybean at planting in soils that had never received litter. Seed P concentrations did not vary significantly by treatment or year (0.81 lb-P2O5/bu); K concentrations did not vary by treatment but did vary slightly by year (1.16-1.28 lb-K2O/bu). Mean crop removal rates (yield 67-76 bu/ac) were 54-61 lb-P2O5/ac and 81-94 lb-K2O/ac (Figure 1). Thus, a single 2 ton-litter/ac application will replace the P and K removed by one to two years of soybean harvest. Alternatively, litter will provide all the P and K required to produce soybean even in low testing soils which would require 40 lb-P2O5/ac and/or 80 lb-K2O/ac (Table 1).

Table 1. University of Tennessee Mehlich 1 (M1) and Mehlich 3 (M3) soil test categories and recommended P2O5 and K2O application rates for soybean.

Phosphorus								Potassium							
Soil Test Category & Range: lb-P/ac								Soil Test Category & Range: lb-K/ac							
Low		Medium		High		Very High		Low		Medium		High		Very High	
M1	M 3	M1	M 3	M1	M 3	M1	M 3	M1	M 3	M1	M 3	M1	M 3	M1	M 3
0 to 18	0 to 30	19 to 30	31 to 60	31 to 119	61 to 210	Over 119	Over 210	0 to 90	0 to 114	91 to 160	115 to 203	161 to 319	204 to 405	Over 319	Over 405
Recommended Rate: lb-P_2O_5/ac								Recommended Rate lb-K_2O/ac							
40		20		0				80		40		0			

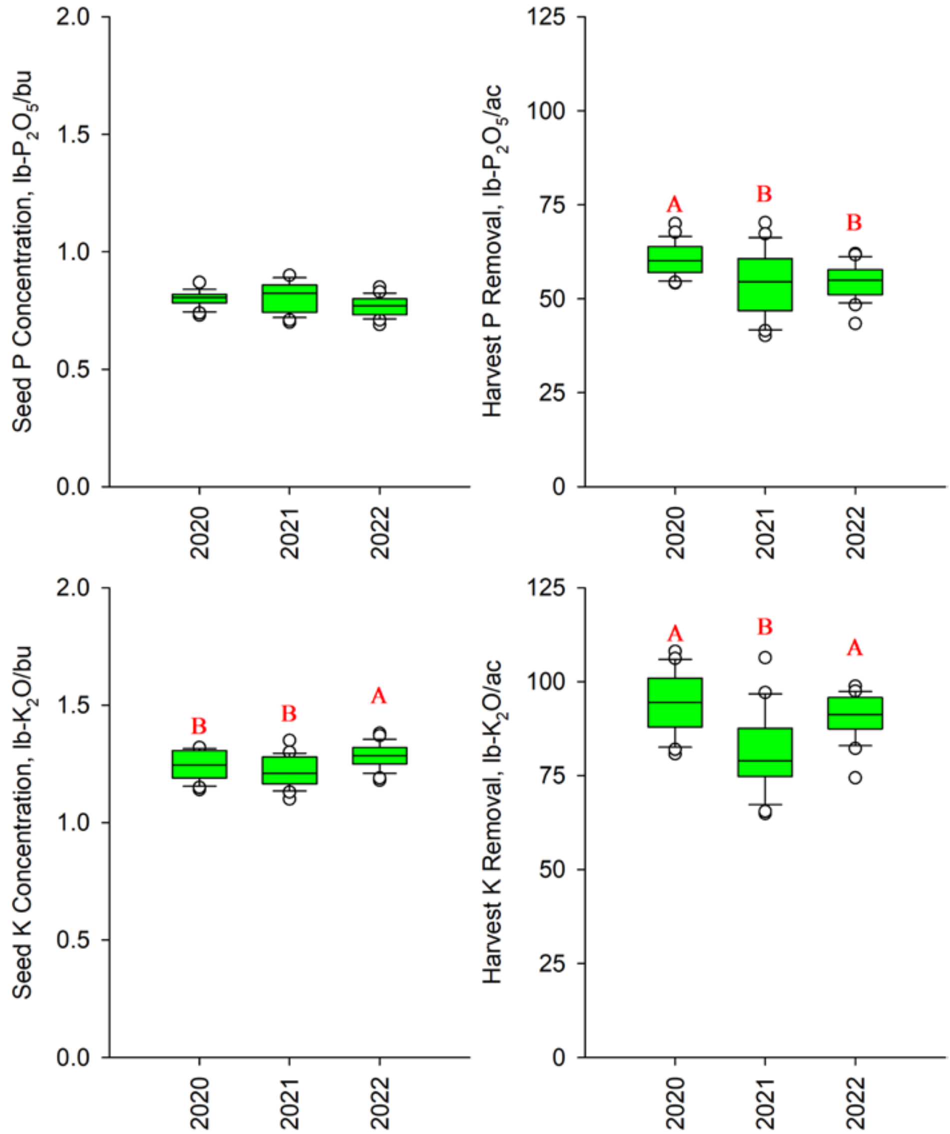

Figure 1. *Phosphorus (P: top) and potassium (K: bottom) concentrations (left) and crop harvest removal rates (right) measured during soybean direct litter application study. Aggregated data by year are presented because no significant differences occurred between seed P and K concentrations and crop removal rates in plots fertilized for the first time with litter (1, 2, and 3 ton /ac) versus negative and positive controls. Years not sharing a common letter are significantly different.*

EXPECT TALLER SOYBEAN WHEN APPLYING LITTER, BUT NOT IMPROVED YIELD

Direct Litter Application to Soybean Often Results in Taller Plants

In Mississippi, soybean above ground biomass at the R6 growth stage was higher (+200 to +800 lb/ac) when incorporated litter versus incorporated commercial fertilizers were used at matching N and P application rates [5]. In North Carolina, the R3 above ground biomass and biomass N concentrations often increased significantly as the litter application rate increased [6]. In Tennessee, soybean fertilized with 3 ton-litter/ac were consistently 3-5 inches taller at R1 and at harvest than plants that received no fertilizer or just commercial fertilizers without N (Figure 2). Thus, it may be prudent to plant soybean varieties with good standability where litter is applied, particularly when planting in early-to-mid May, which tends to result in the tallest beans in a Tennessee growing season.

Direct Litter Application to Soybean Will Occasionally Improve Yield

In one of three crop years, and in the aggregate yield across three years, soybean yield was higher (+5 bu/ac) when fertilized with 3 ton-litter/ac versus a mineral fertilizer without N (Figure 3). In 2019, soybean yield was higher (+9 bu/ac) when fertilized with litter versus mineral fertilizers across a range of planting timing treatments (Figure 6). Thus, a first year application of litter to soybean may occasionally improve yield [5].

Improved Yield with Litter Is Not Reliable and May Not Be Profitable

While the research conducted in Tennessee confirms that soybeans are consistently taller when directly fertilized with litter (Figure 2), the yield benefit is inconsistent (Figure 3). While the difference in 2020-2022 aggregate yield between the 3 ton-litter/ac rate and the mineral control (+5 bu/ac) would have increased crop revenue (+$45 to $75/ac at $9 to $15/bu), the increased revenue could easily be consumed by the litter purchase plus spreading cost [2]. This is particularly true when your soil test does not indicate that P, K and/or micronutrients are required to achieve 100 percent agronomic yield potential. This analysis reinforces the findings of other researchers who emphasize that for soybean a low input management/cost approach is typically more profitable [4].

Applying Litter to Soybean Can Reduce Early Season Nitrogen Fixation

Litter contains plant available N (supplying = 20 to 30 lb-N/ton). Soybean plants produce their own N though biological nitrogen fixation (BNF), so N application to soybean is not recommended or profitable [2, 3]. When N is applied to soybean, the plant can recover that N from the soil and will proportionately reduce the production of "free" nitrogen in the early season by BNF, even as later season nodule production is unharmed [7]. Evidence of this effect is presented in Figure 2: nodule counts at early bloom stage were reduced in one of two years with litter versus a negative control.

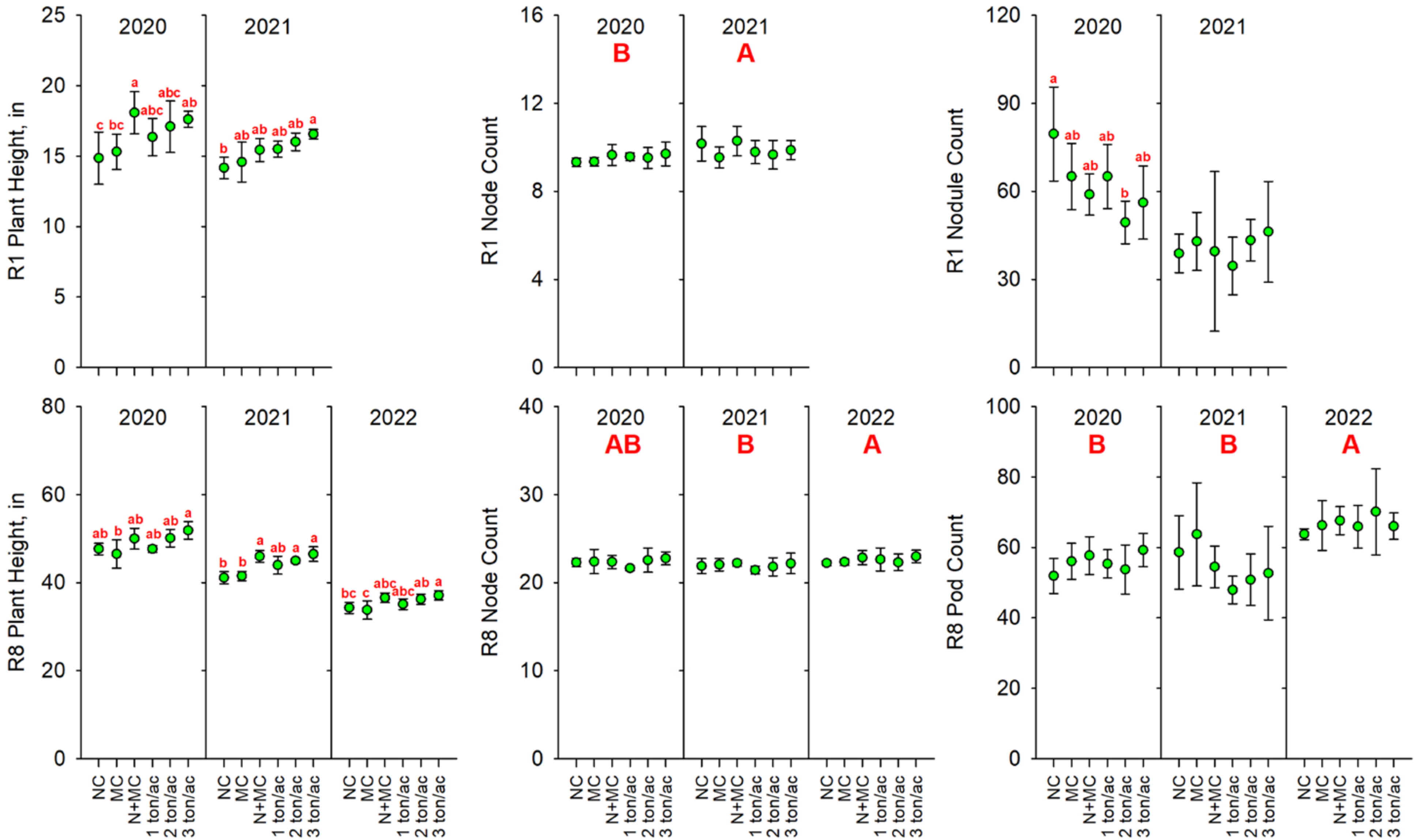

Figure 2. *Soybean R1 plant height, node count and nodule count (top) and R8 plant height, node count and pod count (bottom) in plots fertilized for the first time with litter (1, 2, and 3 tons/ac). Negative controls (NC) received no mineral or N fertilizer; mineral controls (MC) received P, K and S equal to the 2 ton/ac litter application; N+MC treatments received P, K and S + N equal to the 2 ton/ac litter application. Treatments that do not share a common lowercase letter are significantly different. Years not sharing a common capital letter are significantly different.*

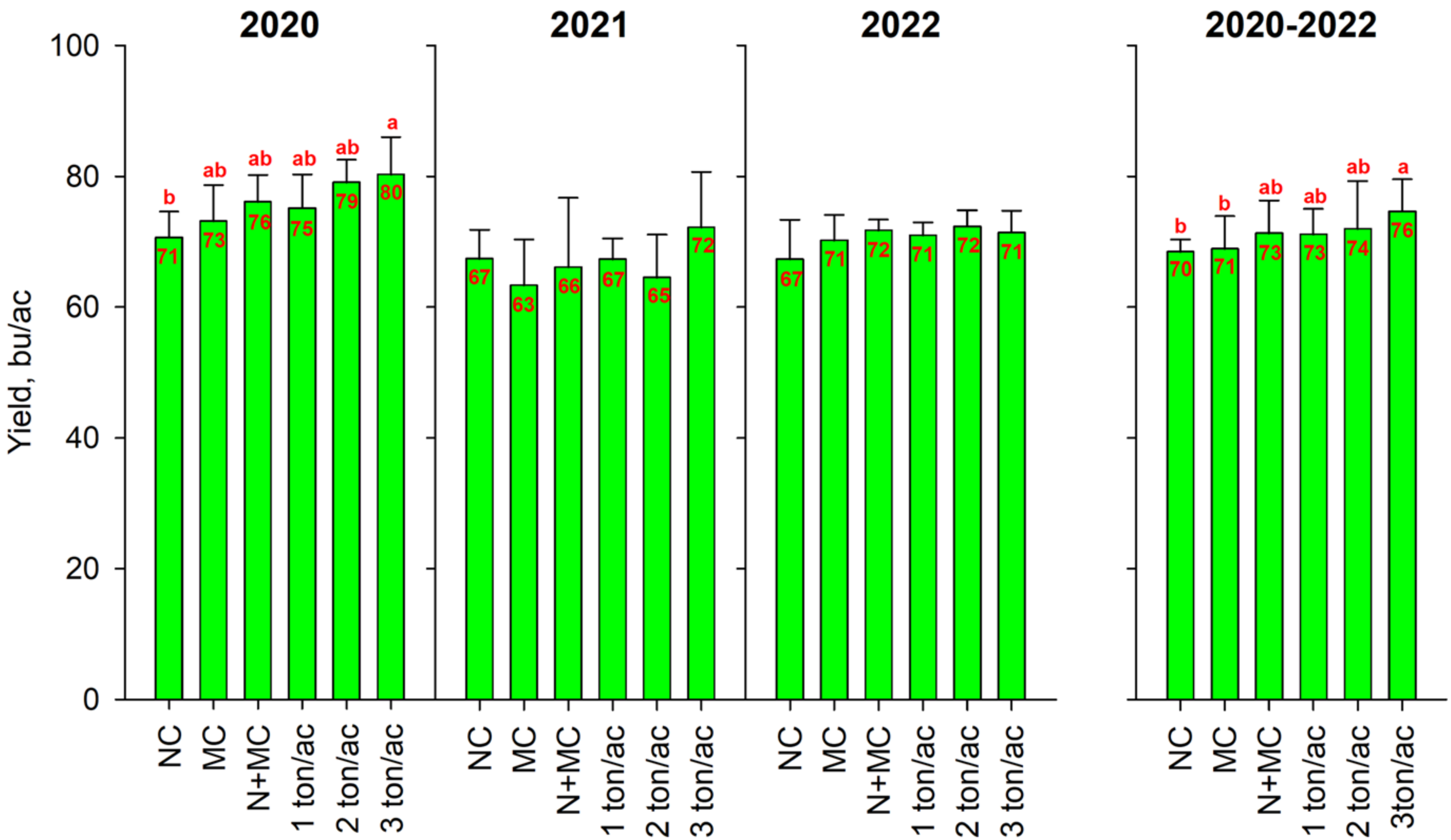

Figure 3. *Mean soybean yield in plots fertilized for the first time with litter (1, 2, and 3 tons/ac) by year (left: 2020, 2021 and 2022) and in aggregate (right: 2020-2022). Negative controls (NC) received no mineral or N fertilizer; mineral controls (MC) received P, K and S equal to the 2 ton/ac litter application; N+MC treatments received P, K, S and N equal to 2 ton/ac litter application. Significant treatment differences were observed at the 90 percent confidence level in 2020 and in the aggregate 2020-2022 data: yields that do not share a common lowercase letter are significantly different.*

MINERAL NUTRIENT AVAILABILITY WHEN LITTER IS APPLIED AT PLANTING

P and K Availability: A Concern When Litter Is Applied to Deficient Soils?

Soybean producers should rightfully question whether litter will provide P and K both in quantity and in time to optimize yield for soils deficient in P and/or K. In the case of N, degradation of organic compounds is required to make the N in litter crop available. Consequently, first year N availability from litter is only 45 percent [8]. However, research has shown that the P availability in litter is similar to that of synthetic mineral fertilizers [9]; litter K is water soluble with an expected availability factor of 100 percent [10].

A recent study in Arkansas examined whether litter applied at planting would produce similar P and K soybean plant tissue concentrations and grain yield as mineral fertilizers [11]. This study included soils with P and/or K concentrations that were very low (<65% yield potential), low (65-85% yield potential), and medium (85-95% yield potential). Both "low" (0.8 to 1.3 ton/ac: 60-80 lb-P2O5/ac + 52-83 lb-K2O/ac) and "high" (1.6-2.6 ton/ac: 120-160 lb-P2O5/ac + 104-166 lb-K2O/ac) direct litter and matching mineral fertilizer applications were investigated. In seven-site years on soils with suboptimal P and/or K concentrations, both litter and mineral fertilizers significantly improved yield (3-9 bu/ac) versus negative P + K controls. No differences were observed in leaf tissue P concentrations or yield for soybean that received P applied as litter or mineral fertilizers. The study clearly indicates that litter readily provides both P and K when applied at planting at a moderate application rate (2-3 ton/ac).

Litter P and K Availability to Soybean in a West Tennessee Soil.

The University of Tennessee conducted a study from 2020-2022 with plots that were relocated each year within a Grenada Silt Loam so that only a single year of litter application was in focus. In 2020, the plot area mean soil test was suboptimal for P (averaging medium) and optimal for K (averaging high). In this year of study, there were no significant differences in mean trifoliate leaf P concentrations between treatments that received litter versus mineral fertilizer controls [1] (Figure 4). In all test years, mean leaf macronutrient (Figure 4) and micronutrient (Figure 5) concentrations exceeded published values for the lower sufficiency threshold, even for the negative controls. The results confirm that for soybean, a minimalist approach to input management is often the most profitable [4].

Seed mineral profiles also were examined in this study and were generally similar whether fertilized with litter or commercial fertilizers (Table 2). In one study year, the seed sulfur concentration for the 3 ton-litter/ac treatment was significantly higher than in the negative control, reinforcing published research which indicates that litter can provide plant available sulfur in the year of application [1]. This adds to the value litter offers as an alternative fertilizer for fields with a known sulfur deficiency.

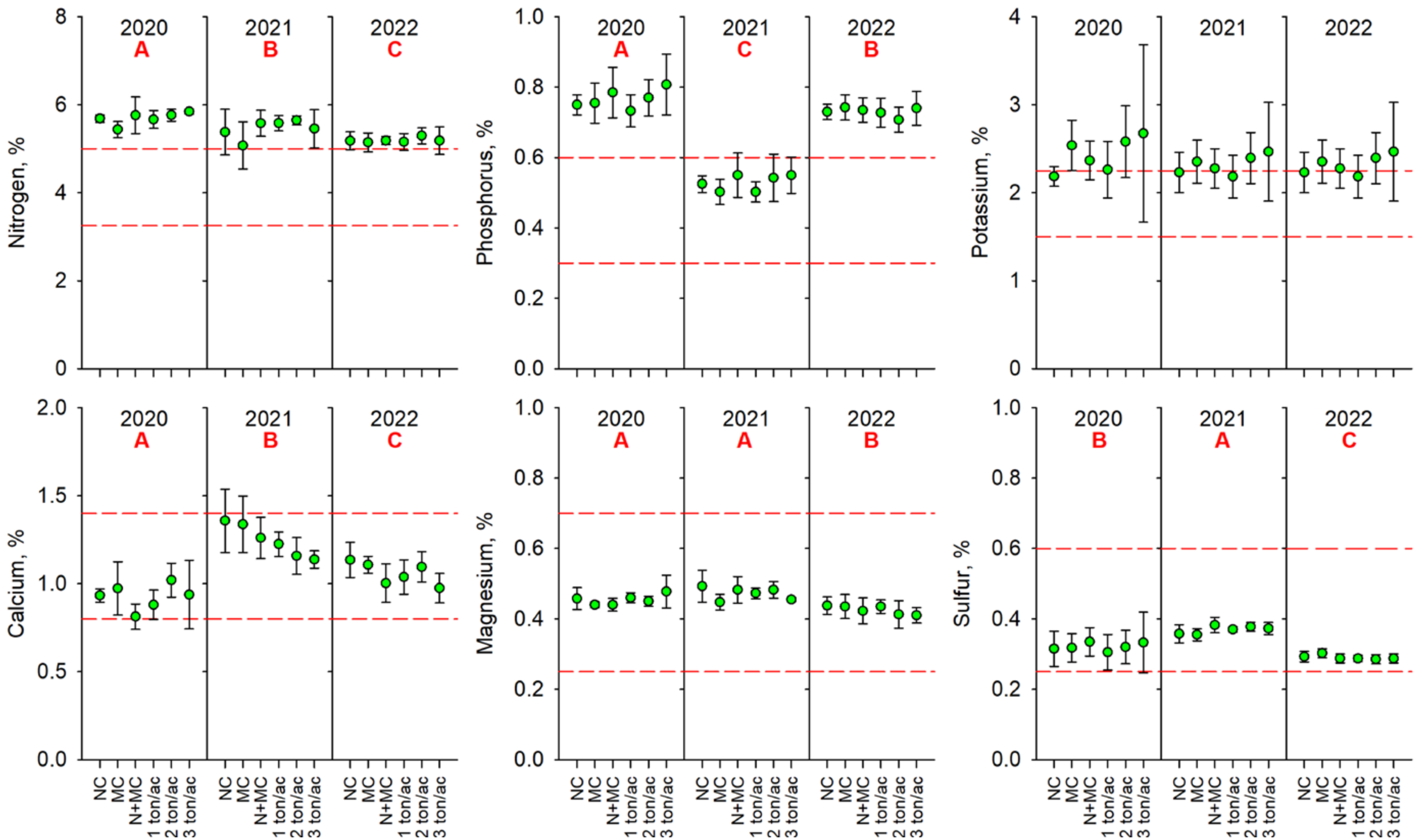

Figure 4. *Mean soybean trifoliate leaf (R1-R3) macronutrient concentrations for plots receiving a first-time direct litter application (1, 2 and 3 tons/ac). Negative controls (NC) received no P, K, S or N fertilizer; mineral controls (MC) received P, K and S equal to the 2 ton/ac litter application; N+MC treatments received P, K, S and N equal to the 2 ton/ac litter application. Nutrient concentrations did not vary significantly by treatment. Average concentrations in years that do not share a common capital letter are significantly different. Dashed red lines show the soybean trifoliate leaf sufficiency concentration range [1].*

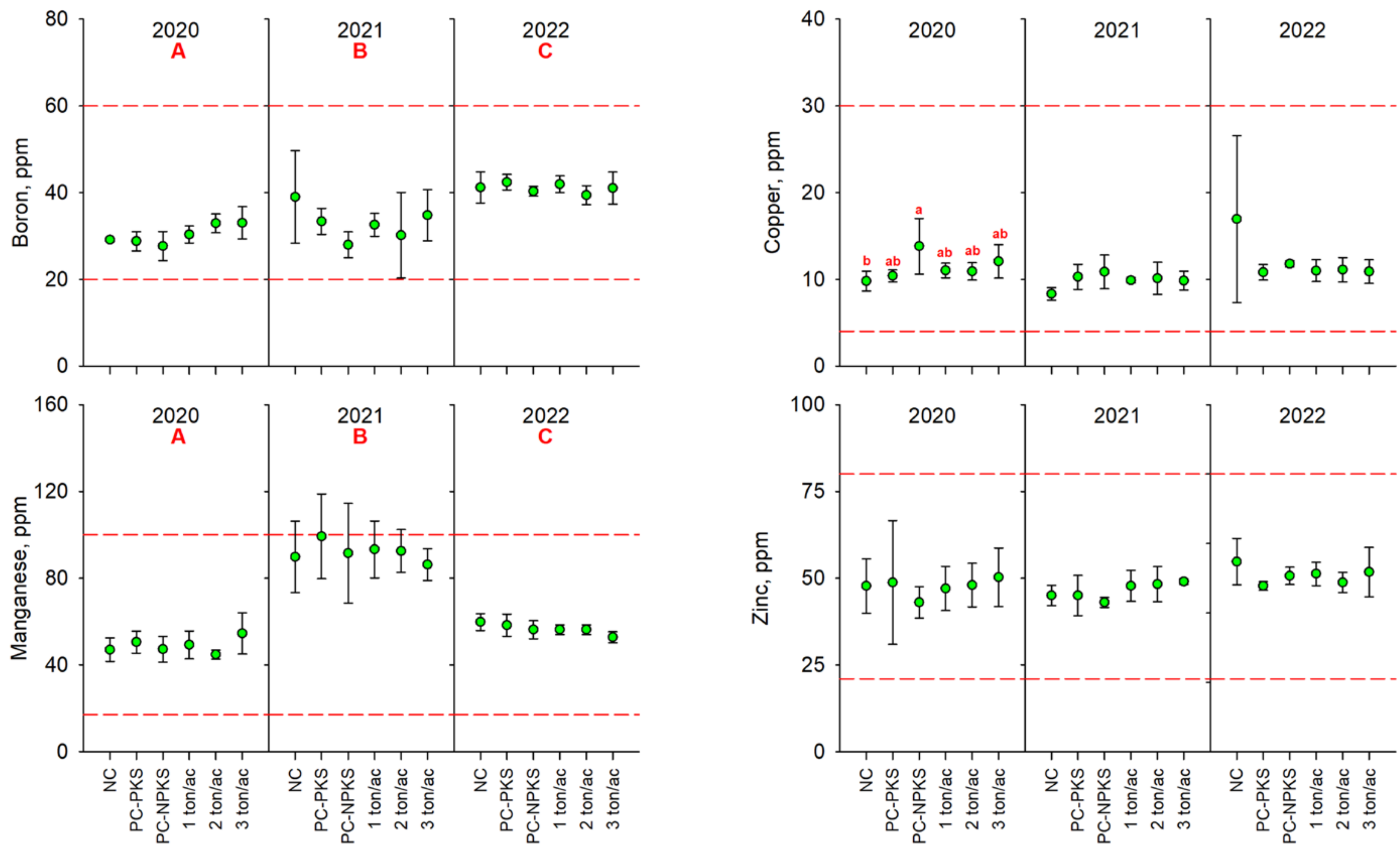

Figure 5. *Mean soybean trifoliate leaf (R1-R3) micronutrient concentrations for plots receiving a first-time direct litter application (1, 2 and 3 tons/ac). Negative controls (NC) received no P, K, S or N fertilizer; mineral controls (MC) received P, K and S equal to the 2 ton/ac litter application; N+MC treatments received P, K, S and N equal to the 2 ton/ac litter application. Nutrient concentrations that do not share a common lowercase letter are significantly different; average concentrations in years that do not share a common uppercase letter are significantly different. A soybean trifoliate leaf sufficiency range is indicated with dashed red lines [1].*

Table 2. Harvested soybean grain nutrient concentrations for plots receiving a first-time direct litter application (1, 2 and 3 tons/ac). Negative controls (NC) received no P, K, S or N fertilizer; mineral controls (MC) received P, K and S equal to the 2 ton/ac litter application; N+MC treatments received P, K, S and N equal to the 2 ton/ac litter application. Grain concentrations that do not share a common letter are significantly different (emphasized using cell shading).

Year	Treatment	Macronutrients (lb/bu)						Micronutrients (lb/100 bu)			
		N	P_2O_5	K_2O	Ca	Mg	S	B	Cu	Mn	Zn
2020	NC	3.44	0.81	1.28	0.18	0.16	0.17	0.14	0.07	0.17	0.20
	MC	3.45	0.82	1.27	0.18	0.15	0.17	0.13	0.07	0.18	0.18
	MNC	3.50	0.82	1.24	0.17	0.15	0.17	0.13	0.07	0.20	0.18
	1 ton/ac	3.47	0.79	1.24	0.17	0.16	0.17	0.15	0.07	0.18	0.20
	2 ton/ac	3.38	0.79	1.22	0.17	0.16	0.17	0.15	0.07	0.17	0.19
	3 ton/ac	3.45	0.79	1.22	0.17	0.16	0.17	0.15	0.07	0.18	0.19
2021	NC	3.36	0.81	1.18	0.18	0.15	0.16	0.16	0.07	0.19	0.20
	MC	3.17	0.81	1.21	0.20	0.16	0.16	0.15	0.06	0.19	0.19
	MNC	3.32	0.82	1.23	0.18	0.16	0.17	0.14	0.07	0.20	0.19
	1 ton/ac	3.15	0.77	1.18	0.21	0.16	0.16	0.16	0.07	0.21	0.20
	2 ton/ac	3.30	0.82	1.23	0.18	0.16	0.17	0.15	0.07	0.19	0.20
	3 ton/ac	3.33	0.84	1.26	0.17	0.16	0.17	0.17	0.07	0.21	0.21
2022	NC	3.34 a	0.74	1.24	0.19	0.14	0.17 b	0.19	0.07	0.21	0.22
	MC	3.25 ab	0.75	1.31	0.19	0.14	0.19 a	0.18	0.08	0.21	0.21
	MNC	3.24 b	0.79	1.28	0.18	0.14	0.19 a	0.16	0.07	0.20	0.21
	1 ton/ac	3.32 ab	0.77	1.26	0.19	0.14	0.18 a	0.18	0.08	0.20	0.22
	2 ton/ac	3.30 ab	0.79	1.30	0.19	0.14	0.18 ab	0.18	0.09	0.21	0.22
	3 ton/ac	3.27 ab	0.79	1.30	0.18	0.14	0.19 a	0.18	0.08	0.22	0.22

HOW FAR AHEAD OF SOYBEAN PLANTING SHOULD I APPLY LITTER?

Yield & Seed Mineral Nutrient Profile with Litter Applied Six Weeks Before Planting

A study conducted in Tennessee compared two soybean fertilizers (3 ton-litter/ac vs. 0-60-60 commercial fertilizer) applied May 1 across soybean planting events that occurred May 1 or two, four and six weeks later. Soils in the field were medium testing for both P and K, indicating that both P and K were required to achieve 100 percent yield potential (Table 1). Yield declined as the time between fertilizer application and planting increased (Figure 6) because of the shortened growing season with the increasing delay in planting. Taken in aggregate across all planting timing treatments, the mean yield was significantly higher for litter (79 bu/ac) than for the commercial fertilizer treatment (70 bu/ac). The improved yield using litter may be attributable to the litter providing nitrogen. However, nodule counts, as well as plant height and node and pod counts, did not vary significantly between fertilizer types (Figure 7). Seed from the soybean plants fertilized with litter did tend to have slightly higher mean boron concentration than for the seed from plants fertilized with the P and K mineral fertilizers (Figure 8).

Applying Litter to a Winter Cover Crop Preceding Soybean

A long-term study (10 year) was completed in 2001 in Alabama comparing soybean yield when a preceding wheat cover crop was fertilized with litter (100 lb-total N/ac; = 50-lb-available N/ac; = 2 ton/ac) or mineral fertilizer (100 lb-N/ac as ammonium nitrate) [12]. Each of the cover crop fertilization methods received fall applications of lime and K based on soil tests. Phosphorus also was fall applied based on soil test but only to the commercial fertilizer treatment. In this study, fall applied litter significantly increased soybean yield. Applying litter to the preceding cover crop had a more consistent and positive effect on soybean yield than crop rotation (continuous soybean, soybean in rotation with corn) and the tillage method (no-till, strip tillage and conventional tillage). This study suggests that litter may perform well when applied to a preceding wheat or cover crop. The explanation provided in the study publication was that litter may have provided soil micronutrients that were deficient.

An Environmental Best Management Practice Is to Apply Litter at Planting

The studies summarized above indicate that it is possible to apply litter well ahead of soybean planting, even in the prior fall. Particularly for mineral nutrients, there should be no effect on availability to a subsequent soybean crop. In the case of double crop wheat, litter nitrogen would be used more efficiently. Fall applications to fallow ground should be avoided because this creates a risk for surface and groundwater pollution due to nitrogen losses in the absence of plant N demand.

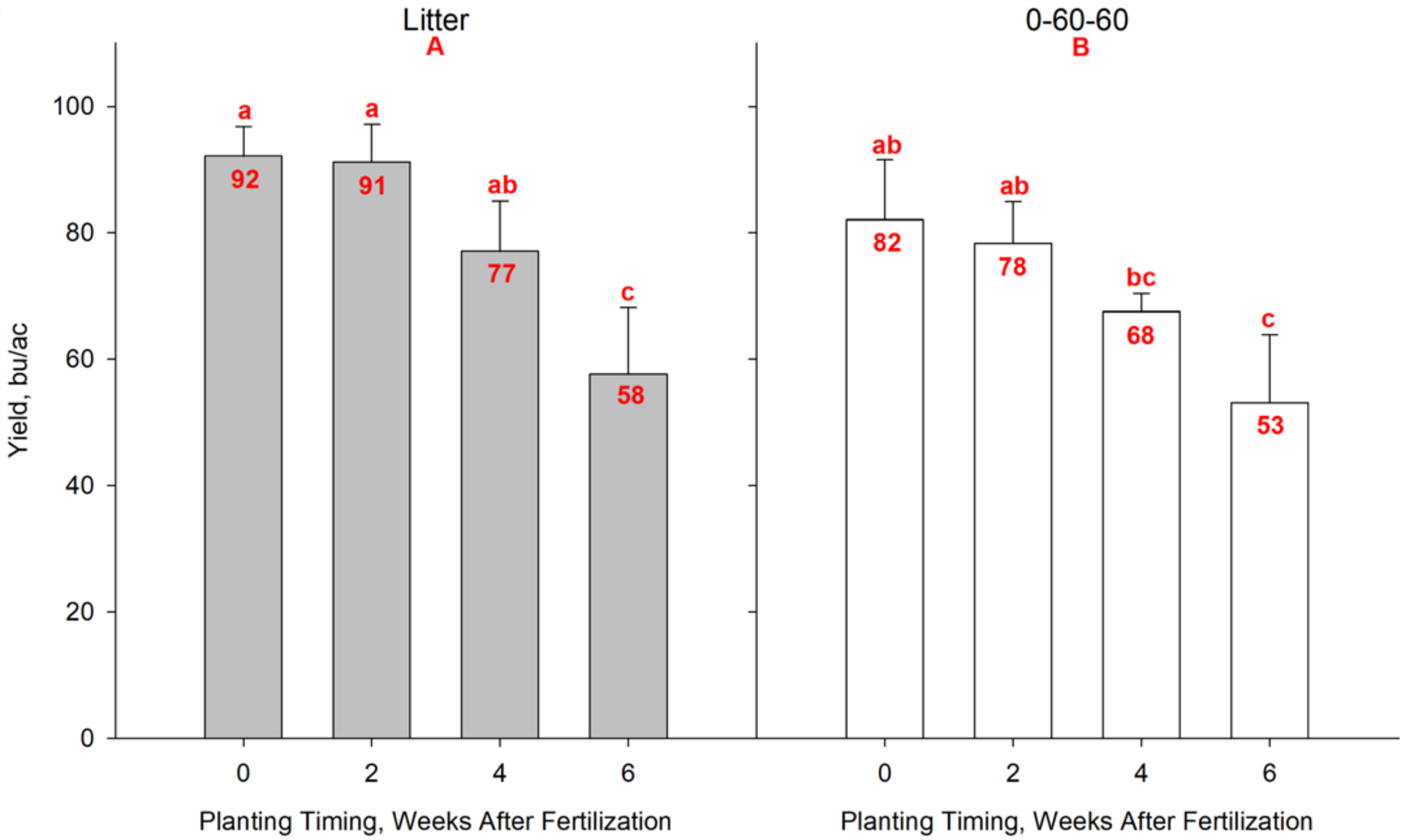

Figure 6. *A comparison of grain yield for soybean fertilized with litter (3 ton-litter/ac) versus mineral fertilizer (0-60-60) on May 1 for planting events that occurred May 1 or two, four or six weeks after fertilization. Planting timing events that do not share a common lowercase letter are significantly different. Aggregate soybean yield across all the planting timing treatments was higher with litter (uppercase A) versus mineral fertilizer (uppercase B).*

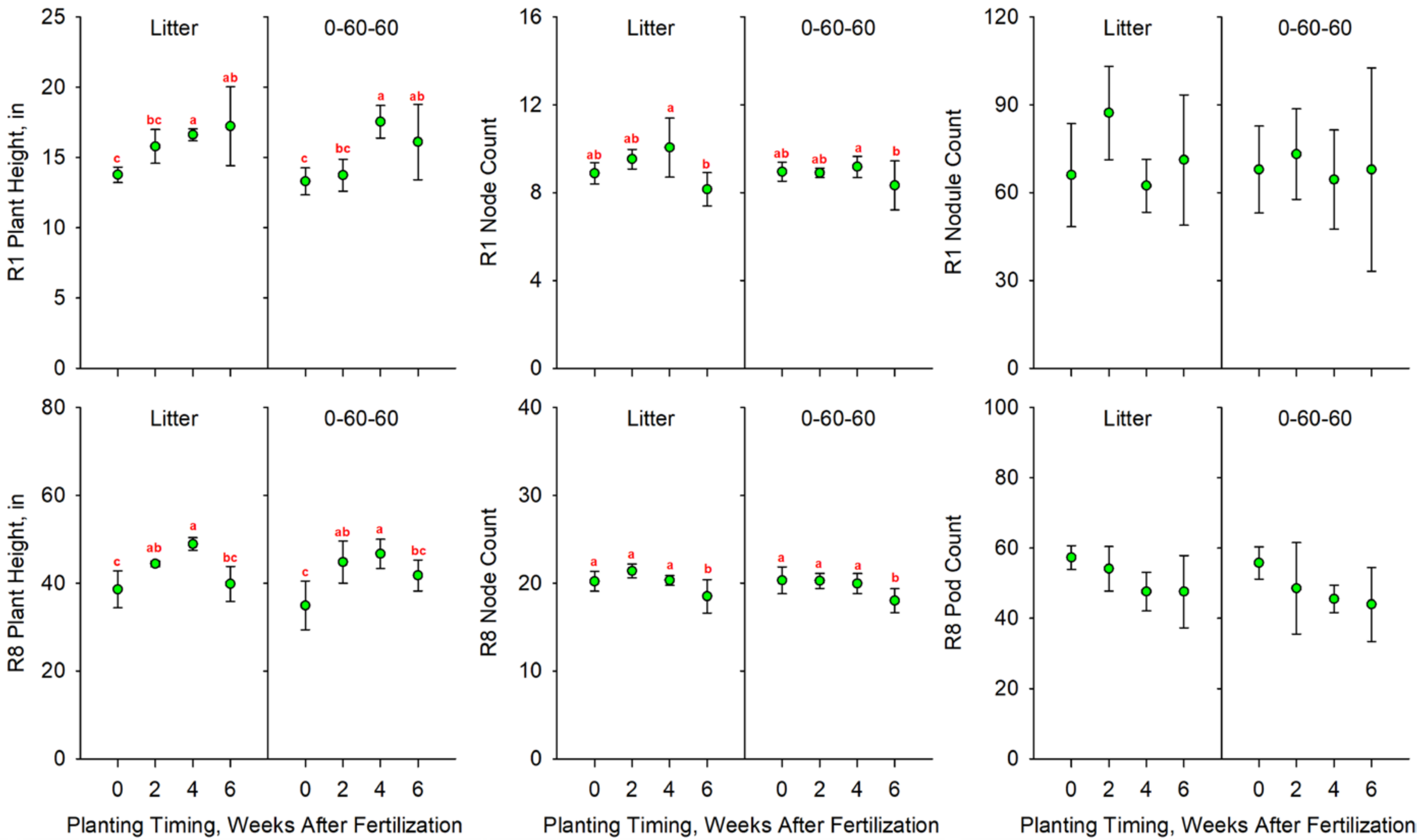

Figure 7. *Soybean R1 plant height, node count and nodule count (top) and R8 plant height, node count and pod count (bottom) in plots fertilized with either litter or mineral fertilizers (0-60-60) on May 1, with planting occurring the same day as fertilization or two, four or six weeks later. Plant metrics that do not share a common lower-case letter are significantly different. Plant metrics did not vary significantly by fertilization method.*

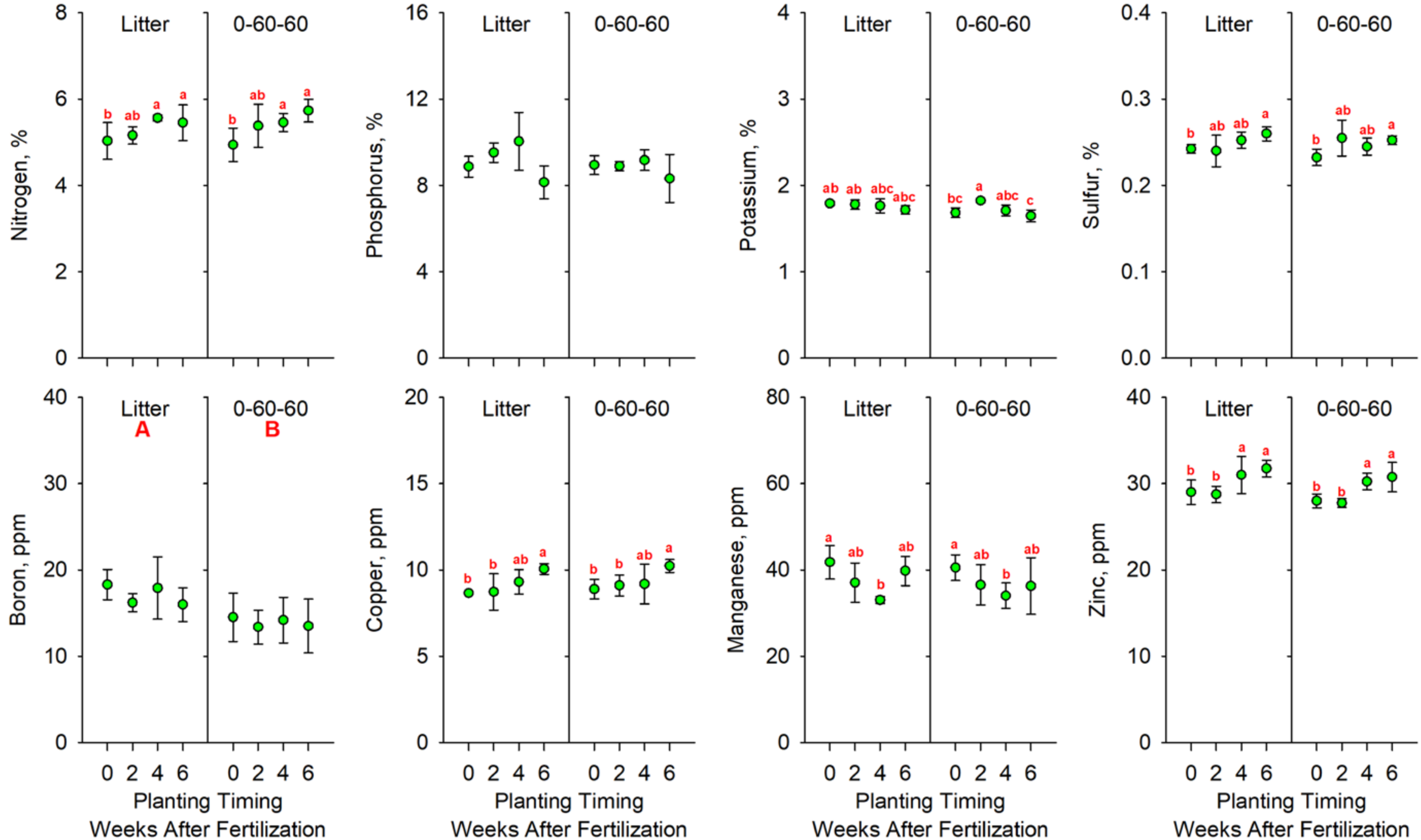

Figure 8. *Soybean seed nitrogen and mineral nutrient concentrations at harvest following the application of two different fertilizers on May 1 with planting occurring on May 1 or two, four and six weeks after fertilization. Nutrient concentrations for the different planting timing treatments that do not share a common lower-case letter are significantly different. Fertilizer treatments that do share a common uppercase letter are significantly different.*

SUMMARY

The value of litter for soybean production is maximized for fields that require both P and K to reach full yield potential. Fertilizing with litter will often result in taller soybean plants with more above ground biomass without significantly improving yield. Improved yields will sometimes occur if the litter provides mineral micronutrients that are deficient in the soil and may some years be in part a result of litter providing N. The take home message for soybean producers is to regularly soil test and prioritize litter to fields that are deficient in P and/or K.

The research conducted in Tennessee and surrounding states indicates that it is safe for soybean producers to assume that the P and K contained in litter is plant available in season to address soil deficiencies, even when applied at planting. Both trifoliate leaf and seed concentrations of N and macro- and micro-nutrients indicate that litter can serve as a superior source of not just P and K but boron and sulfur and likely other mineral micronutrients.

Finally, be aware that applying litter to soybean can be perceived as a poor agronomic practice because most research indicates that nitrogen applications to soybean will not improve agronomic returns. When litter is applied to soybean at planting, this risk is minimal because soybean will utilize the litter nitrogen early season instead of relying entirely on nitrogen fixation. Fall application of litter to wheat or a cover crop would promote more efficient use of the litter nitrogen. However, fall application to fallow ground for a subsequent soybean crop should be avoided because at the time of application there is no crop present to utilize the applied nitrogen – this substantially increases the risk for N losses to the environment which can degrade surface and groundwater quality.

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