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BROILER LITTER AS A COMPLETE NUTRIENT SOURCE FOR COTTON

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Abstract

The ability of poultry litter to support plant growth by supplying essential plant nutrients in the absence of other sources of the nutrients has not been studied thoroughly. The objective of this research was to determine the ability of broiler litter, as the sole nutrient source, in meeting the mineral nutrient needs of cotton and supporting plant growth. Under greenhouse conditions in an inert growing mix, broiler litter apparently supplied sufficient mineral nutrients and supported normal growth of cotton in the absence of other sources of nutrients. Tissue nutrient analysis during early boll development stage showed that the concentration of N, P, K, Mg, Fe, Cu, and Mn in the upper mainstem leaves was within published sufficiency ranges for cotton growth. The concentration of only Ca and Zn in the upper mainstem leaves fell below published sufficiency ranges. While a greater fraction of most mineral nutrients were partitioned to leaves, Fe and Cu were partitioned to in greater proportion to roots than to leaves, stems, or reproductive parts. Cotton extracted Mg and K with the greatest efficiency (up to 58%) and Cu and Zn with the least efficiency (as low as 1.7%) when litter was the only source of these nutrients. The extraction efficiency of N ranged between 21% at 120 g pot^{-1} litter and 27% at 30 g pot^{-1} litter. P was the most poorly extracted macronutrient with only 16% of the total applied P being extracted when 30 g pot^{-1} litter was applied and only 6% with the higher litter rates. The results of this research show that broiler litter can supply apparently all essential mineral nutrients to support normal cotton growth in the absence of any significant other nutrient sources. However, the extremely poor extraction efficiency of the micronutrients and that of P indicates that repeated application of broiler litter can lead to undesirable buildup of these nutrients in the soil.

Introduction

Poultry litter as a fertilizer is primarily used to meet the N needs and sometimes the P needs of crops. The vast majority of poultry litter research has also been focused on the management of litter as a source of N and on the dynamics of N and to some extent that of P in the soil. The performance of litter as a fertilizer is often measured by equating it to the performance of conventional N fertilizers (Mitchell et al., 1995; Negatu et al., 1996; Glover et al., 1998). This method of evaluation assumes that all yield benefits due to the use of litter arises from the N the litter supplies and ignores litter benefits due to the other components or beneficial characteristics of the litter.

Analytically, poultry litter is a complete plant food (Collins et al., 1999). However, its ability to support plant growth by supplying the different essential plant nutrients in the absence of other sources of the nutrients has not been studied thoroughly. The objective of this research was to determine the ability of broiler litter, as the sole nutrient source, in meeting the mineral nutrient needs of cotton and supporting plant growth.

Materials and Methods

This research was conducted under greenhouse conditions in plastic pots filled with 11 kg of a 2:1 (v/v) sand:vermiculite growing mix. The treatments included broiler litter rates of 0, 30, 60, 90, or 120 g pot^{-1} that received one of the following nutrient solutions: no supplemental nutrient solution, full Hoagland's nutrient solution, solution of macronutrients or solution of micronutrients. The 20 treatment combinations were tested using the randomized complete block design with three blocks. The broiler litter was thoroughly mixed with the growing medium, watered with enough water (~5.0 L) to thoroughly wet the entire growing mix on 16 December 2002, and allowed to stand for 21 d before planting to help reduce seedling damage due to initial surge of ammonia. The litter as applied to the growing mix contained 29.3 g total N kg^{-1}, 16.6 g P kg^{-1}, 27.6 g K kg^{-1}, 27.4 g Ca kg^{-1}, 5.78 g Mg kg^{-1}, 684 mg Fe kg^{-1}, 424 mg Zn kg^{-1}, 522 mg Mn kg^{-1}, 556 mg Cu kg^{-1}. Five cotton (cv. Stoneville 474) seeds were planted in each pot on 6 Jan. 2003 and thinned to 2 plants per pot after seedlings established. Adequate tap water was applied to each pot to meet water needs of plants throughout the growing period.

Plants were harvested 92 days after planting on 8 Apr. 2003 and the following measurements taken: mainstem nodes; plant height; dry (80^{o}C) weight of lower, middle, and upper mainstem leaves, branch leaves, stems (branch and mainstem), reproductive parts, and roots. Total N concentration in the different plant parts was determined by an automated dry combustion method using a ThermoQuest (CE Elantec Inc., Lakewood, NJ) C/N analyzer. Concentrations of P, K, Ca, Mg, Mn, Fe, Cu, and Zn in the plant parts were determined by Inductively Coupled Plasma (ICP) Emission Spectroscopy. Tissue concentrations of S, B, Cl, and Mo were not measured. Nutrient accumulation in each plant part was calculated as the product of concentration and dry weight of each plant part. Total nutrient extraction by plants in each pot was determined as the sum of nutrients accumulated in leaves, stems, roots, and reproductive parts. Total nutrient extraction as percent of total applied was considered as the efficiency by which cotton extracted these nutrients from the growing mix.

Results and Discussion

Plant Growth

Broiler litter supplied apparently adequate amounts of all essential nutrients and supported normal growth of cotton in the absence of any other source of nutrients. When no litter or supplemental nutrient solution was applied to the growing mix, plants did not show much growth after emergence and initial production of about one or two very small true leaves. These plants were highly chlorotic, formed only one or two mainstem nodes, and accumulated only 0.7 g pot^{-1} total dry matter 92 d after planting showing that the growing mix did not provide nutrients to support plant growth (Table 1). Applying 30 g pot^{-1} litter to the growing mix resulted in an obvious increase in chlorophyll index and plant growth. Additional litter beyond 30 g pot^{-1} increased dry matter of the different plant parts to varying extent. Supplementing litter with a solution of micronutrients did not result in additional growth, but supplementing it with the full Hoagland nutrients or just the macronutrients increased chlorophyll index, dry weight, and number of mainstem nodes when averaged across the litter rates (Table 1).

Tissue Nutrient Concentration

The concentration of P, K, and Mg in whole leaves from the upper one third nodes of plants that received litter as the sole nutrient source, regardless of the rate of litter, fell within published sufficiency ranges (Table 2). N concentration in the upper leaves also fell within the sufficiency range, but it was necessary to apply 120 g pot^{-1} litter. Ca concentration in the upper leaves was below the sufficiency range suggesting the plants did not receive adequate amounts of Ca from litter. Litter as a sole nutrient source also resulted in sufficient concentrations of Fe, Cu, and Mn (Table 3). It was necessary to apply 120 g pot^{-1} litter to bring the concentration of Fe to within the sufficiency range. Litter alone did not supply adequate Zn to bring Zn concentration in the upper leaves within published sufficiency range.

When averaged across litter rates, supplementing litter with a solution of macronutrients or the full Hoagland's solution increased concentrations of N, K, Ca, and Mg in the upper leaves, relative to litter that was not supplemented with the macronutrients. P concentration in the upper leaves was not affected by supplemental nutrient solution (Table 2). Supplementing litter with the full Hoagland's solution increased concentrations of Fe, Cu, and Zn in the upper leaves relative to the unsupplemented litter. Supplementing litter with a solution of micronutrients increased concentration of Zn and to some extent concentration of Fe and Cu. None of the supplemental nutrient solutions affected the concentration of Mn in the upper leaves. The lowest litter rate with no supplemental nutrient solution resulted in sufficient Mn concentration in the upper leaves.

Nutrient Partitioning

Regardless of whether litter was supplemented with nutrient solutions, a greater fraction of most mineral nutrients were partitioned to leaves than to any other plant part (Fig. 1). This pattern of partitioning was partly because of greater dry weight partitioning to leaves but also partly because of greater nutrient concentrations in leaves than in any other plant part. As much as 75% of absorbed Ca and as much as 66% of absorbed Mn were recovered in leaves. Partitioning of Mg to the different plant parts was similar to that of Ca with little effect of supplemental nutrient solution on partitioning of Mg. Unlike Mn or Ca, both Fe and Cu were partitioned in greater quantities to roots than to any other plant part (Fig. 1). Supplementing litter with a full Hoagland's nutrient solution seemed to increase the partitioning of Fe to roots and decrease the partitioning to leaves.

Nutrient Extraction

Cotton extracted Mg and K with greater efficiency than the other nutrients from litter. Plants that received 30 g pot^{-1} litter with no supplemental nutrient solution extracted 58% of the total applied Mg and 56% of the total applied K when harvested around the early boll growing stage. This efficiency dropped to 28% for Mg and 27% for K when applied litter was increased to 120 g pot^{-1}. Extraction efficiency of Ca decreased form a high of 32% at 30 g pot^{-1} applied litter to 13% at 120 g pot^{-1} litter. The extraction efficiency of N ranged between 21% at the highest rate of litter application and 27% at the lowest rate of litter. P was the most poorly extracted macronutrient with only 16% of the total applied P being extracted when 30 g pot^{-1} litter was applied and was as low as 6% with higher litter rates. Among the four micronutrients, cotton extracted Fe and Mn with better efficiency than Cu or Zn. When no supplemental nutrient solution was applied, cotton extracted as much as 9.1% of Fe and 7.2% of Mn supplied by 30 g pot^{-1} litter. The corresponding extraction efficiency of Cu was only 1.7% and that of Zn 1.9%.

These results show that the benefits of using litter as a fertilizer and soil amendment is not limited to supplying N alone. Broiler litter can supply the other mineral nutrients in sufficient amounts to support normal cotton growth in soils deficient in any or all of the macronutrients. However, the extremely poor extraction efficiency of the micronutrients and that of P indicates that repeated application of broiler litter with the same nutrient composition as in this study could lead to the buildup of these nutrients in the soil.

References

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Table 1. Chlorophyll index and growth of cotton supplied with broiler litter as a nutrient source supplemented with nutrient solutions that contained micronutrients, macronutrients, or the full Hoagland's nutrients.

Applied Broiler Litter g/pot	**Supplemental Nutrient Solution**			
	None	**Macronutrients**	**Micronutrients**	**Full**
		Chlorophyll Index		
0	26.6	29.7	27.6	44.0
30	38.0	48.2	37.7	50.3
60	47.7	48.2	46.1	49.6
90	49.4	49.8	46.9	48.5
120	46.3	49.6	47.9	47.9
		Plant Height, *cm*		
0	0.9	35.3	1.3	44.2
30	38.7	51.7	39.2	42.5
60	48.0	42.2	36.8	39.3
90	42.0	41.8	43.2	42.2
120	38.7	39.5	38.3	41.0
		Mainstem Nodes, *no.*		
0	1.2	10.0	1.7	10.5
30	9.2	11.2	10.0	11.8
60	12.0	12.0	11.2	11.7
90	12.2	12.3	12.2	12.5
120	11.3	11.5	12.0	12.0
		Dry Weight, *g/pot*		
0	0.7	12.3	0.9	27.6
30	25.6	38.1	27.2	35.2
60	32.9	31.9	34.4	36.8
90	35.5	35.0	32.2	33.5
120	34.9	34.0	35.2	34.4

Table 2. Concentration of macronutrients in upper mainstem leaves of cotton grown with broiler litter supplemented with nutrient solutions that contained micronutrients, macronutrients, or the full Hoagland's nutrients.

Applied Broiler Litter g/pot	Supplemental Nutrient Solution – None	Macronutrients	Micronutrients	Full
	Nutrient Concentration, *g/kg*			
Nitrogen				
0	-----	49.9	-----	41.3
30	12.4	38.6	13.4	41.3
60	21.8	42.1	20.8	40.6
90	26.6	40.6	30.7	42.3
120	33.2	42.8	31.8	46.4
Phosphorus				
0	-----	5.6	-----	3.6
30	4.0	4.2	2.6	3.4
60	4.2	4.7	3.5	3.2
90	4.5	4.4	3.2	3.9
120	4.9	5.0	3.4	4.5
Potassium				
0	-----	34.9	-----	29.1
30	12.3	25.9	14.0	31.7
60	18.1	32.0	22.6	32.9
90	20.5	32.5	25.5	32.6
120	25.3	33.3	25.4	34.5
Calcium				
0	-----	25.1	-----	18.9
30	12.4	17.2	11.5	18.0
60	11.8	20.1	13.4	21.7
90	11.4	20.4	14.2	19.2
120	13.3	18.5	12.9	22.9
Magnesium				
0	-----	8.4	-----	6.5
30	4.1	6.3	3.9	6.4
60	4.4	7.5	5.1	6.8
90	4.6	7.7	5.7	6.9
120	5.5	7.3	5.6	7.8

Table 3. Concentration of micronutrients in upper mainstem leaves of cotton grown with broiler litter supplemented with nutrient solutions that contained micronutrients, macronutrients, or the full Hoagland's nutrients.

	Supplemental Nutrient Solution			
Applied Broiler Litter	**None**	**Macronutrients**	**Micronutrients**	**Full**
g/pot	**Nutrient Concentration, *mg/kg***			
Iron				
0	-----	198.9	-----	81.7
30	36.0	62.1	41.3	61.7
60	45.8	67.2	60.6	60.4
90	47.1	62.4	54.4	64.6
120	51.8	59.3	50.1	71.3
Copper				
0	-----	5.3	-----	8.8
30	3.9	8.6	6.4	11.7
60	5.3	8.6	8.7	13.4
90	6.3	7.1	11.0	13.8
120	7.7	7.1	10.0	13.4
Manganese				
0	-----	228.0	-----	75.3
30	64.8	51.7	56.8	51.6
60	55.2	62.3	50.0	53.4
90	49.4	58.3	54.8	49.8
120	59.7	62.1	52.8	69.9
Zinc				
0	-----	9.4	-----	25.4
30	16.6	17.6	18.6	34.2
60	12.3	11.8	17.4	44.4
90	12.5	10.7	27.4	39.2
120	16.0	18.7	29.6	40.4

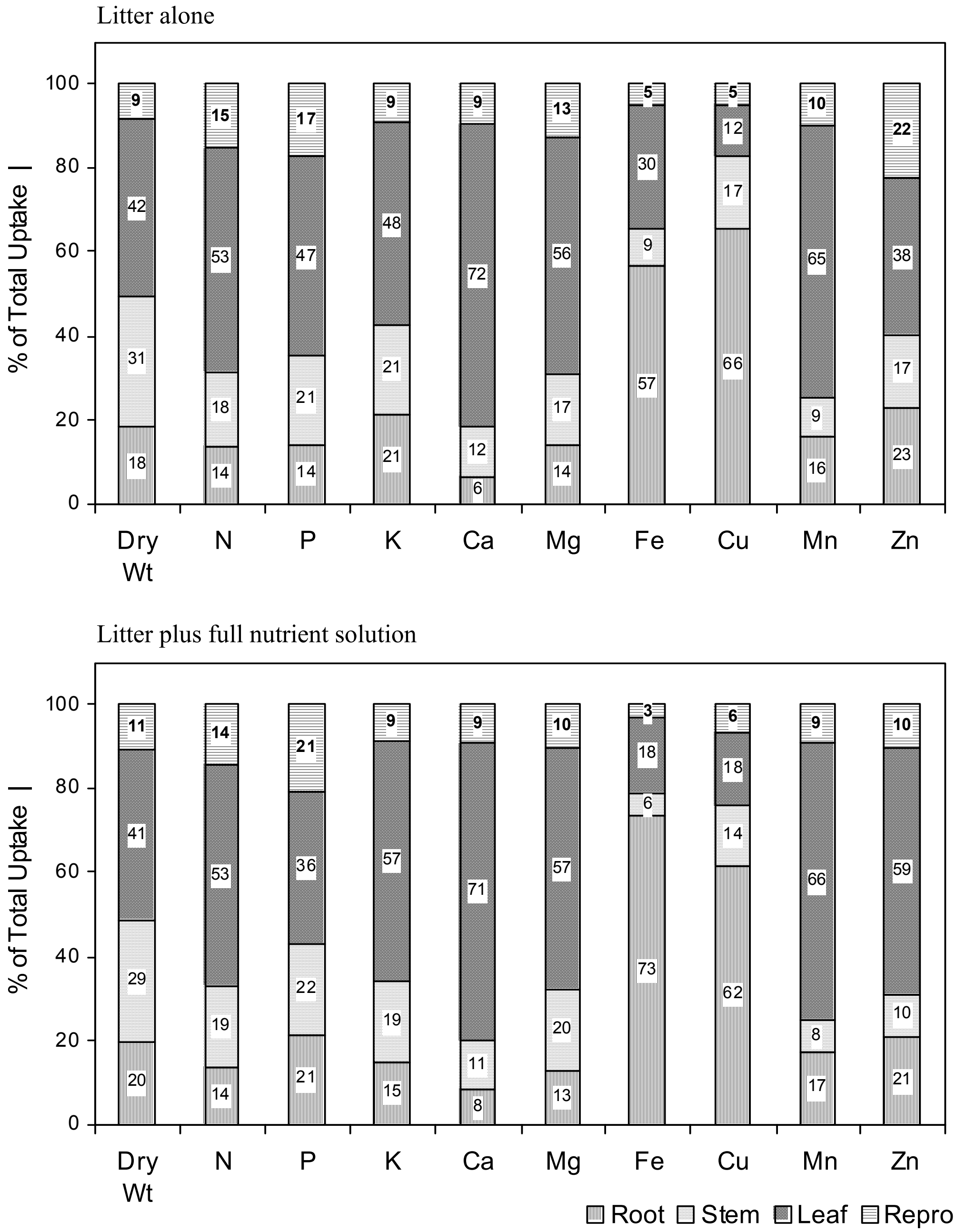

Figure 1. Partitioning of mineral nutrients to roots, stems, leaves, and reproductive parts of cotton grown with broiler litter as the sole nutrient source or litter plus supplemental Hoagland's nutrient solution. Each value is an average across the four litter rates (30, 60, 90, and 120 g/pot).