CHEMICAL CHANGES IN CEREAL STRAW UNDER TWO FALLOW SYSTEMS AND ITS RELATIONSHIP TO NUTRIENT AVAILABILITY

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Abstract

In recent years, conventional mechanical fallow has been partly replaced by herbicide-fallow on the prairies. With the chemical system of weed control, the straw is not mixed with the soil until seeding the following spring; meanwhile the nutrient status of the straw may change during the fallow period. To determine how the nutrient status of the straw may be changing, a site was chosen and divided into a chemical fallow (chem) and mechanical fallow (conv) system. The standing residue was sampled from the chem side and surface trash from the conv side at six week intervals starting in April of 1994. The site was located in the Brown soil zone near Central Butte. The straw being sampled was from a previous wheat crop. The straw on the conv site exhibited increases in nitrogen and phosphorus content while carbon content decreased due to loss of C as CO_2 during decomposition. Significant losses of water soluble P occurred from the standing straw over the fallow period.

To help understand how straw weathering affects nutrient availability in a subsequent crop, a growth chamber experiment was conducted in which three different straw treatments were applied to the soil in pots and wheat was grown in the soil. Anion exchange membranes were buried for two hours once a week in each pot to monitor changes in the nutrient status of the soil. Wheat plants were grown for 45 days and then harvested. Dry matter yields and nitrogen and phosphorus uptake by the plants was determined. Yields were reduced when straw was applied to the soil. Nitrogen uptake was reduced with the addition of straw to the soil due to immobilization by both fresh and weathered straw. However, the phosphorus concentration in the plant tissue and also the P uptake was significantly enhanced with straw additions, indicating that leaching of soluble P contained in cereal straw may be an important contributor to P available to a subsequent crop.

Introduction

In recent years there has been a shift from mechanical-fallow (conventional-tillage) to herbicide-fallow (them-fallow). There are several reasons for this change including: reduced chemical costs, reduced time in the field, reduced potential for wind and water erosion and reduced evaporation due to the continual straw cover. With a them-fallow system there is no incorporation of straw until seeding time the following year. During the fallow period, nutrients may be leached from the standing residue which may affect availability of soil nutrients upon incorporation.

Our study was undertaken to observe changes in carbon, nitrogen, and phosphorus content in straw residue on a them-fallow and a conventional-fallow site over the fallow year and to determine the effects on nutrient availability to a subsequent crop.

Materials and Methods

In the spring of 1994, a field experiment was set up near Central Butte, Saskatchewan in the Brown Soil zone. A 4 acre site (Ardill association), with an undulating landscape, was divided into two equal areas to compare the effects of mechanical tillage and chemical-fallow on standing wheat straw residue composition. Samples were taken every six weeks and ground before analysis. Total carbon, nitrogen and phosphorus content of the wheat residue was determined.

In the winter of 1994, a growth chamber study was set up to determine the potential of weathered cereal straw incorporated into the soil to mineralize/immobilize soil nutrients. Wheat plants were grown in a replicated experiment in soil with 1) fresh straw, 2) year-old them-fallow straw, and 3) no straw treatments. Anion exchange membranes (Schoenau et al., 1993) were used to monitor the soil available nitrogen status on a weekly basis during the experiment. The plants were harvested at heading and analyzed for yield and total N and P uptake to determine the net influence of the straw treatments on nutrient availability.

Results and Discussion

A. Changes in straw nutrient composition

After sampling from the Central Butte site for over seven months the total carbon content in the straw from the them-fallow site varied from 43.4 to 45.4% (Figure 1).

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Figure 1. Total carbon (TC) content of straw in fallow at Central Butte study site.

Meanwhile, the conventional-fallow site straw carbon remained unchanged during the first three months, but decreased rapidly once the straw was incorporated during tillage operations. The decrease in carbon is likely due to microbial decomposition of the straw carbon to CO2 as induced by residue incorporation (Reinertsen et al., 1984).

Wheat straw nitrogen content can vary greatly with reported values ranging from 0.22% to 1.25% (Smith and Peckenpaugh, 1986). The total nitrogen content of the straw from this site was very low, with both sites below 0.3% nitrogen. From April to mid October total nitrogen content of the straw from the chem site showed only minor fluctuations while the conv site residue more than doubled its initial nitrogen concentration (Figure 2). By October, the incorporated straw had undergone some breakdown, and the increases in nitrogen concentration were likely due to loss of carbon as CO2 during decomposition.

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Figure 2. Total nitrogen (TN) content of straw in fallow at Central Butte study site.

Phosphorus content in the standing residue from the chem site showed a slight decrease over the sampling period (Figure 3), while the conv site exhibited an increase in phosphorus content. Wheat straw can immobilize soil P if straw P content is below 0.2% (Black and Reitz, 1972), and since the P content of the straw is less than 0.1% immobilization of soil P is likely with incorporation of the residue in the conventional site.

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Figure 3. Total phosphorus (TP) content of straw in fallow at Central Butte study site.

The C:N ratio of the straw on the chem site showed a slight decrease over the sampling period while the ratio of the straw on the conv site dropped by a significant amount (Figure 40, reflecting greater decomposition and loss of C as CO2 when straw is incorporated.

The C:P ratios depicted in Figure 5. are much larger than the C:N ratios, reflecting the lower phosphorus content in the straw compared with nitrogen. Hannapel et al., 1964, suggested that if C:P ratios exceeded 200: 1 then immobilization of soil P would occur. In the chem site, the trends in C:P are opposite to the C:N with an expanding ratio exhibited over the sampling period. This expansion in C:P ratio is due to loss of water soluble phosphorus constituents from leaching in the standing straw. Reductions in water soluble P content in standing straw were shown to be related to rainfall events during the fallow season (Gares and Schoenau, 1994). Water soluble phosphorus makes up a large proportion of the total straw content and is largely inorganic in nature. On the conv site, decreases in C:P ratio were observed similar to the decreases in C:N ratio.

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Figure 4. The ratio of carbon to nitrogen (C:N) in straw in two fallow systems at Central Butte.

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Figure 5. The ratio of carbon to phosphorus (C:P) in straw in two fallow systems at Central Butte.

B. Effect of straw on nutrient availability to wheat

Wheat plants were grown in pots until heading stage (appoximately 45 days), and then harvested. There were significant differences in dry matter yield between the treatment where no straw was applied compared with treatments where straw had been added (Figure 6). Yields were over 35% greater when no straw was added to the system. although there was a slight difference between the two straw-applied treatments, it was not significant.

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Figure 6. Dry matter yield of wheat grown with three straw application treatments.

Through the use of anion exchange membranes (AEM), soil available nitrogen was monitored over the growing period of the wheat plants. The bars in the graph (Figure 7) represent nitrate sorbed by an anion exchange resin strip buried for 2 hours every two weeks in pots containing plants with the various straw treatments applied. The lines represent changes in resin sorbed nitrate in pots with straw added, but no plants grown. Initially, soil nitrate is very low, but slowly increases as the mineralization process takes place. The soil nitrogen content in the treatment with no straw added remains high until the plants use up most of the available nitrate and then declines. In treatments where straw was added, the available nitrate is much less than the no straw treatment. Initially, mineralization increases the amount of available nitrate, but decomposition of the nutrient poor straw quickly immobilizes the nitrate and after only 4 weeks, most of the available nitrate is utilized. By the seventh week, immobilization appears to be subsiding and mineralization takes place increasing available N.

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Figure 7. Changes in the soil nitrate content during a nine week period

Figure 8. shows the relationship between yield and treatment and nitrogen uptake and treatment. When no straw is applied, the yield is highest because nitrate availability is the highest. As straw is added to the soil, immobilization reduces N availability to the plant and yield suffers. The nitrogen uptake mimics the yield curve.

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Figure 8. Nitrogen uptake and yield response to straw application

As seen in Figure 9, the trends for phosphorus uptake are opposite to nitrogen, with P uptake highest in treatments where straw was added and yield reduced by N immobilization. Phosphorus uptake is lowest when yield is highest. The extra available P may be coming from the added straw. Schreiber and McDowell (1985) stated that wheat residue may be an important source of nutrients in runoff from croplands, especially phosphorus. Leaching of soluble P compounds from cereal residues may be an important source of available P for subsequent crops.

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Figure 9. Phosphorus uptake and yield response to straw application

Conclusion

Carbon and nitrogen content of the straw in the them-fallow system showed no change in nutrient status over the 6 month fallow period. On the tillage fallow site, decreases in carbon and increases in nitrogen content of the straw were observed which were attributed to CO_2 evolution during residue breakdown induced by mixing during tillage. The total phosphorus concentration in straw decreased slightly in the them-fallow site, while large increases in P concentration occurred in the tillage site. Losses in P in the them-fallow straw were associated with loss from the water soluble fraction which makes up to 50% of total straw content.

Addition of both weathered and fresh straw immobilized plant available nitrogen from the soil and reduced yield. Soluble P constituents leached from the straw may have contributed to the plant available soil pool and enhanced P availability to the subsequent crop.

Acknowledgements

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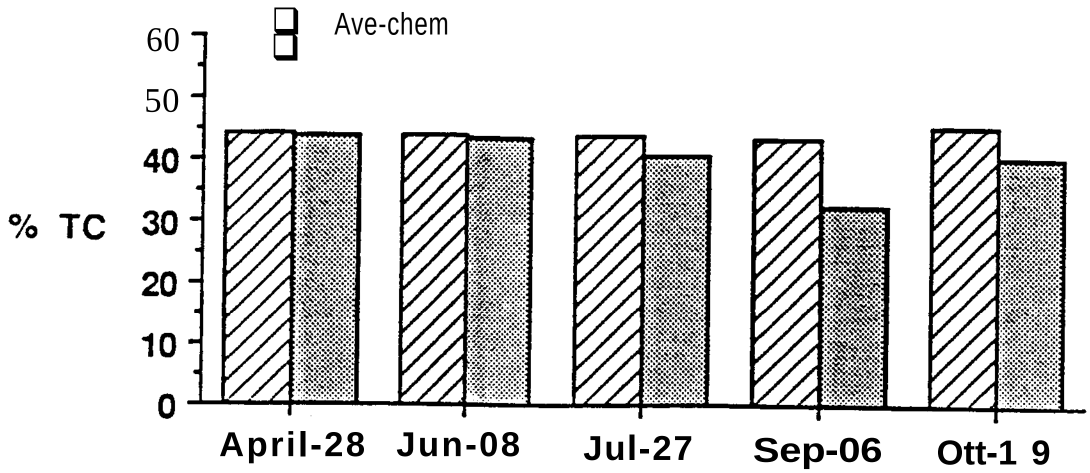


Figure 11. Total carbon (TC) content of straw in fallow at Central Butte study site.

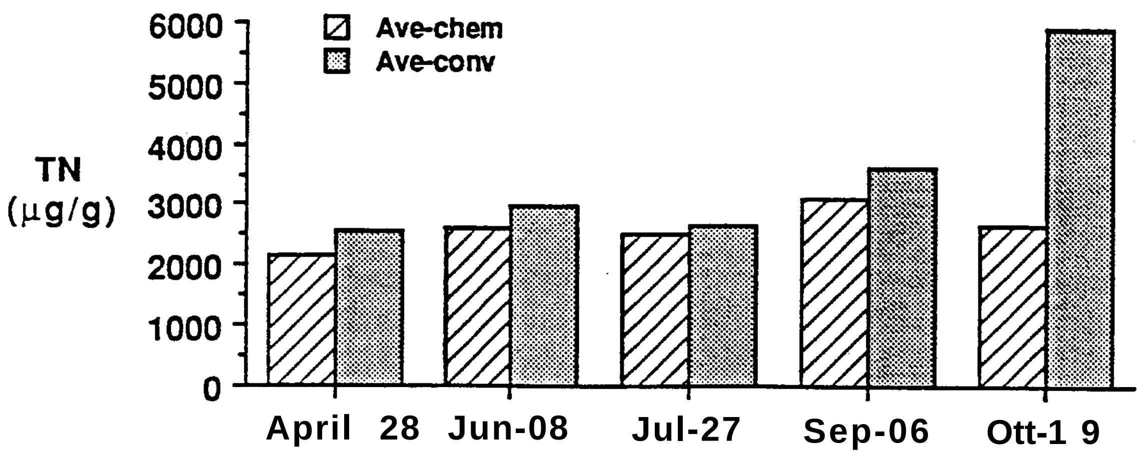
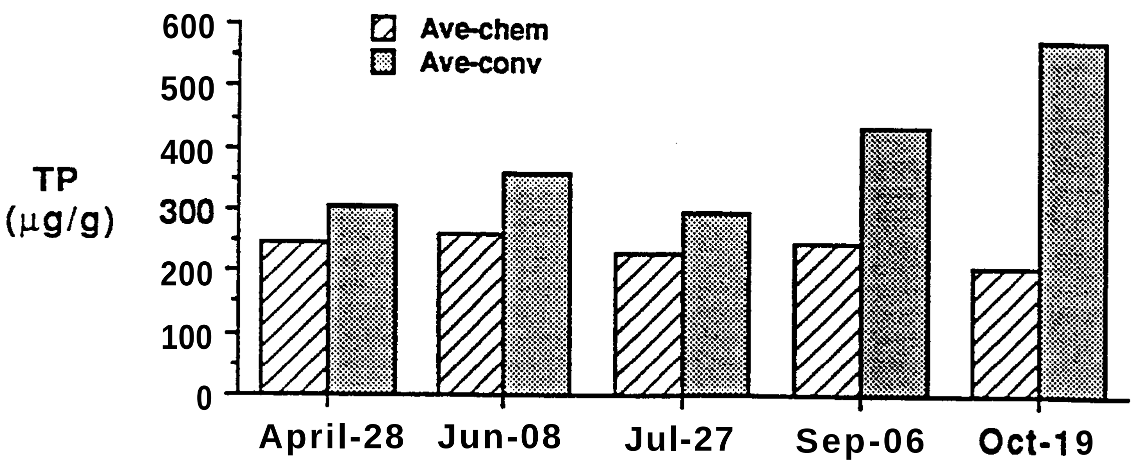


Figure 2. Total nitrogen (TN) content of straw in fallow at Central Butte study site.



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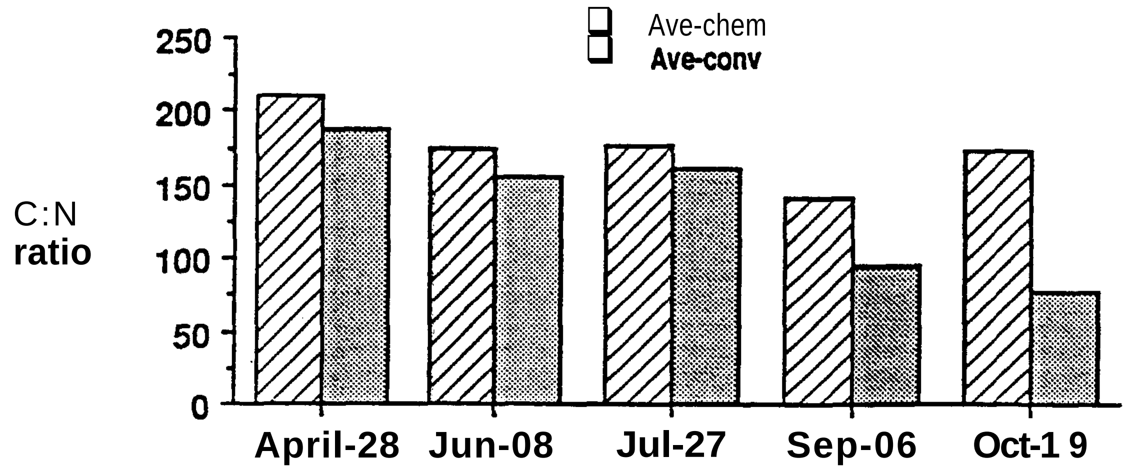

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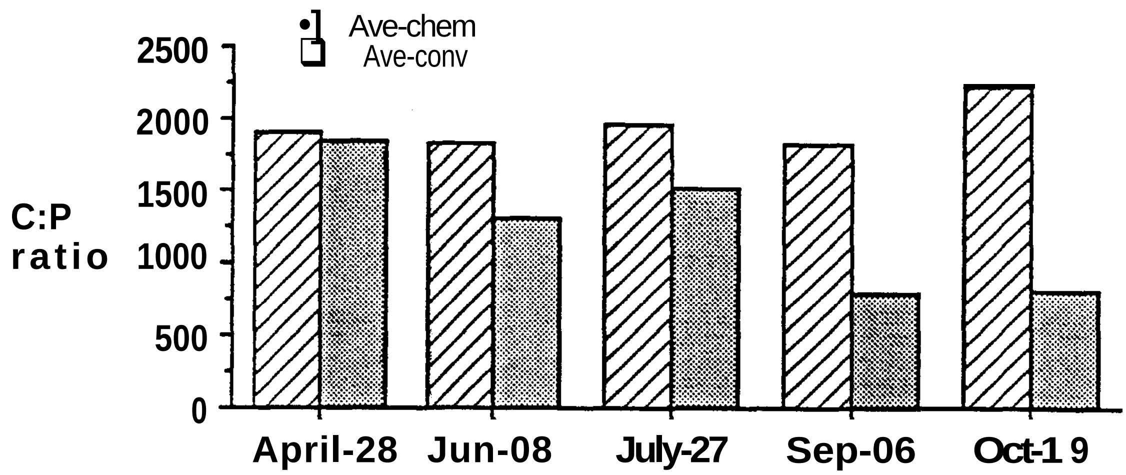

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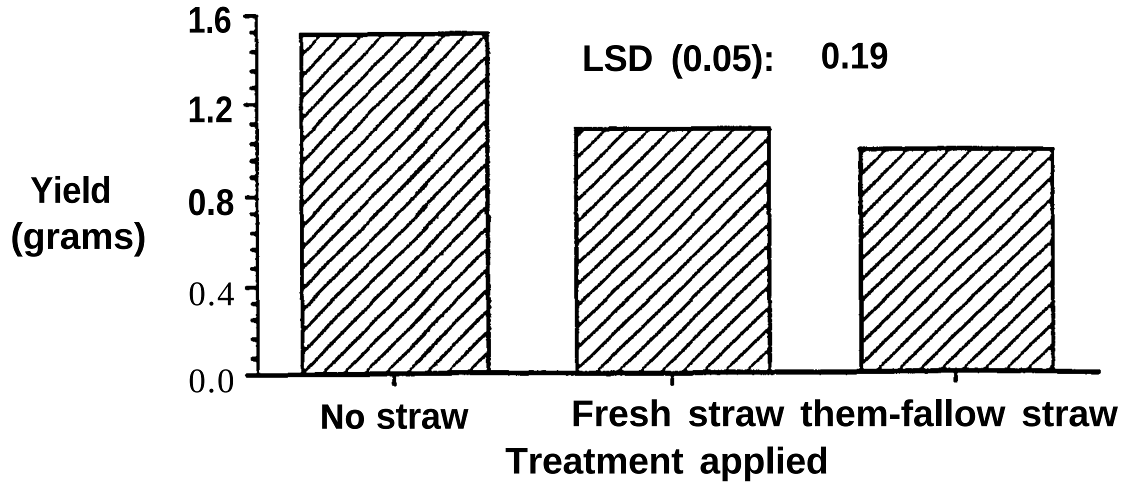
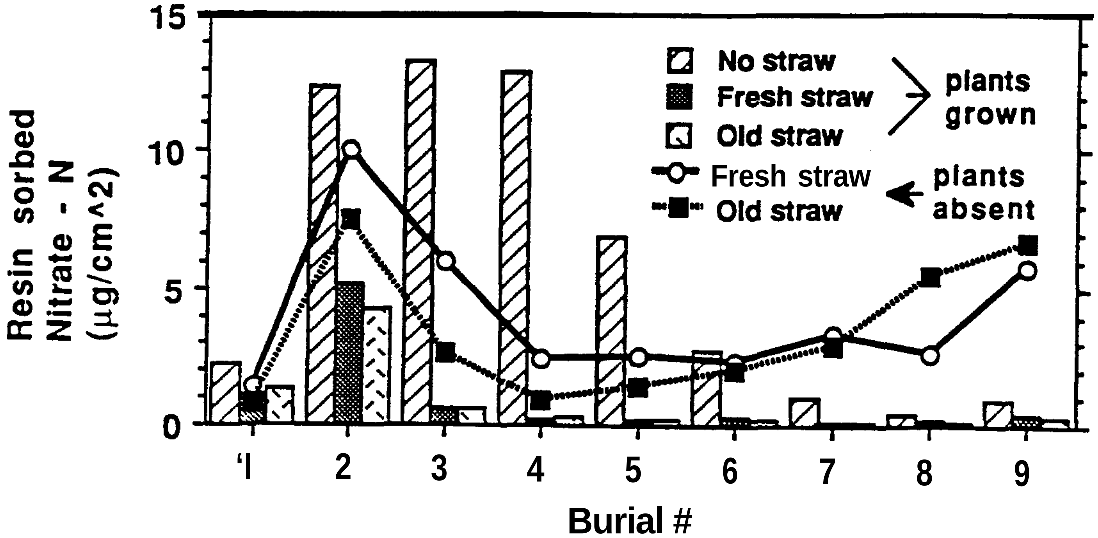


Figure 6. Dry matter yield of wheat grown with three straw application treatments.



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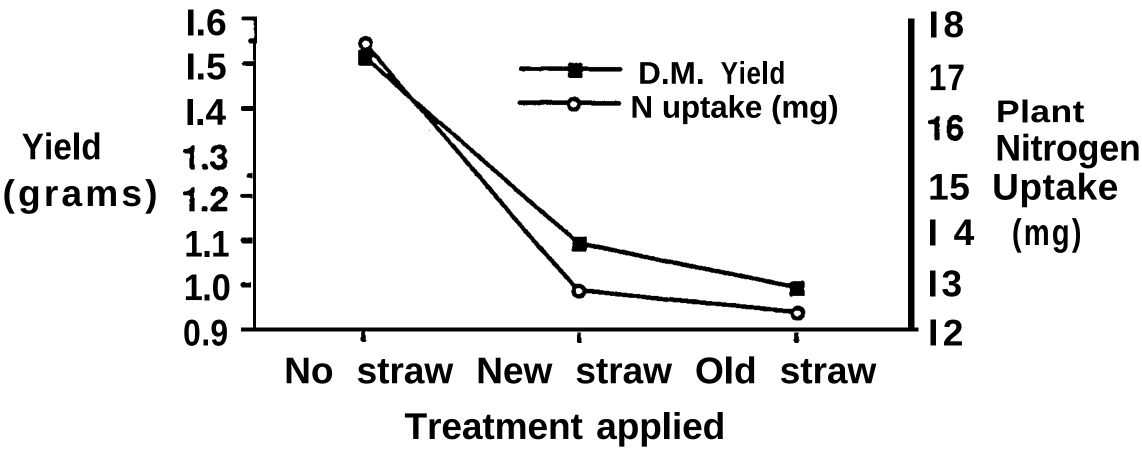

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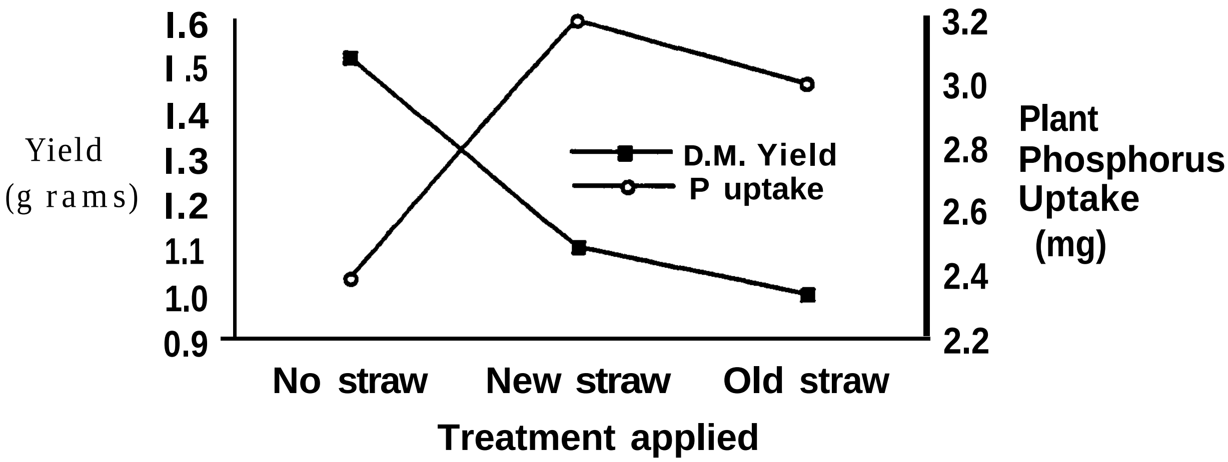

Figure 9. Phosphorus uptake and yield response to straw application