The utilization of wheat straw as an energy source for biological nitrogen fixation

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In Australia, wheat straw residues have traditionally been burnt but the need for erosion control has led to an increasing trend towards straw retention. In some areas, straw retention and incorporation has coincided with a subsequent reduction in the need for nitrogenous fertilizers. This may be a result of nitrogen fixation by asymbiotic bacteria utilizing the products of straw breakdown as an energy source. There are probably 2 groups of microorganisms involved: 1) straw digesting organisms, 2) nitrogen-fixing bacteria utilizing the products of straw breakdown.

Methods

The acetylene reduction assay was used to estimate nitrogen fixation in soils containing wheat straw. In situ measurements in the field were made using open-ended cylinders which could be driven into the ground and enclosed to give a gas space into which acetylene (? 20%) and propylene (internal standard, 1-2%) could be introduced. Gas samples were analyzed using a gas chromatograph. In the laboratory, acetylene reduction assays were used to measure some constraints on nitrogen fixation such as temperature, moisture and the ability of soil microbial populations to use the products of straw breakdown.

Results and Discussion

An initial field assay, carried out in a black earth in the Gunnedah district, showed that when moisture was applied to the soil, acetylene reduction rates in plots where straw was incorporated increased over a seven-day period to 17.5 nmoles C_2H_4 $h^{-l}cm^{-2}$. In the burnt-straw plyts, initially there was a lower level of acetylene reduction (8.3 nmoles C_2H_4 h cm $_{2,}$ possibly due to unburnt residues) and this activity diminished to almost nothing by day 3. Acetylene-reducing activity was found to be best at or above field capacity, with a rapid decline as the soil dried. Moist conditions would favour the development of anaerobic or microaerobic microsites necessary for nitrogen fixation by many nitrogen-fixing bacteria.

In a later field assay in the same soil maintained at field capacity moisture it was shown that the acetylene reduction rate and duration increased with increasing levels of straw. A maximum acetylene reduction rate of 50 nmoles $C2H_4$ $h^{-l}cm\text{-}^{2}$ was measured after 12 days at the highest straw level of 4500 kg ha-1, and the duration of activity was more than 3 weeks. Acetylene-reducing activity was very sensitive to temperature, a significant drop in activity occurring when the daily maximum and minimum temperatures fell below 30?C and 20?C respectively.

Acetylene-reducing activity was found to be better in the black earth than in a more acid red earth from the Cowra district when equivalent amounts of straw were provided. The black earth was able to utilize a wider range of sugars representing products of straw breakdown, including sugar acids and sugar alcohols, than the red earth, which was unable to utilize sugar acids as an energy source for nitrogen fixation. This suggests that there may be a difference in populations of nitrogen-fixing bacteria and this may be attributed to the soil pH and clay content.

The results indicate that straw retention may result in an improved nitrogen status in the soil although this may vary according to soil type.