BIOFUMIGANT NITROGEN RELEASE AND INFLUENCE ON SUBSEQUENT ONION AND WHEAT AS AFFECTED BY PHOSPHORUS

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ABSTRACT

Brassicae species have been proposed as biofumigants and green manures but the dynamics of their nitrogen (N) release is not well understood. Available phosphorus (P) can influence biofumigant biomass and N uptake but their influence on N release for onion production and subsequent wheat are lacking. Field studies were conducted in three years on a calcareous silt loam at Parma to measure the effects of available P on biomass P and N uptake of two brassica species (Idagold condiment mustard and Colonel oilseed radish) and their influence on N release for onion and wheat. Residual P from previous additions as well as from pre-plant applications were used as main plots in a split plot design with brassica species planted as subplots. Other subplots included non-planted subplots with and without late fall fumigation. Low P was more limiting to oilseed radish biomass and N uptake than it was to the condiment mustard. Biofumigant green manure potential was limited primarily to late winter/early spring as N release was rapid. Mineralized N in buried bags from biofumigants did not differ appreciably from nonbiofumigant treatments during the following growing season. The N mineralized from biofumigants during the season was minor relative to that occuring prior to planting onions or the N mineralized from other soil organic N sources during the season. Wheat production following onions was more affected by residual P than available N in fallowed non-fumigated soils, but by both residual P and N sidedressed for previous onions in other treatments.

INTRODUCTION

Mustard and oilseed radish cultivars are Brassicaes that have been suggested as biofumigant substitutes for commercial fumigants in controlling soil-borne pests and affecting the yield and/or quality of subsequent crops. They are also touted as nutrient scavengers and green manures. Biofumigant effectiveness as green manures may depend in part on the biomass produced. Biomass in turn depends on sufficient nutrient availability, including available P.

Phosphorus availability is sometimes marginal in calcareous soils. Brassica species also are non-hosts to mycorrhizae that facilitate P availability. Little has been reported on the response to P of Brassica species in southern Idaho or biofumigant N release for subsequent onion and wheat production. Therefore, as part of a Western SARE grant on the feasibility of biofumigants for onion production, one of the objectives of this study was to evaluate the N release dynamics from condiment mustard and oilseed radish grown with variable P and their effects on onion and wheat production.

METHODS

Previous P studies on a calcareous Greenleaf silt loam at Parma involved the application of variable amounts of P fertilizer to three different trials in different areas of the same field and initiated in fall 1997, 1998, and 1999. Experimental units receiving each P application served as main plots in a split plot design in subsequent years. The original P applications were later supplemented with additional P to maintain a range in available P. Several crops were rotated to the P treated plots including onions, wheat, barley, corn and beans. Mean residual P had decreased in the main plots, prior to planting the biofumigants, to levels that would be limiting to biomass production in many crops. Pre-plant main plot Olsen P ranged narrowly from only 5.6 to 6.8 ppm in 2001, from 5.9 to 6.9 ppm in 2002 and 5.4 to 6.7 ppm in 2003, for the lowest and highest previous P treatments, respectively. In two of the last three years additional P was applied immediately before initiating this trial.

Wheat or barley were previous crops and the stubble flailed and disked. A seedbed was firmed with a cultipacker prior to seeding Idagold mustard and Colonel oilseed radish as sub-plots within the main plots on August 15, 2001, August 20, 2002, and August 20, 2003 using seeding rates of 10 lb/A for Idagold and 25 lb/A for Colonel. Fertilizer N as urea was topdressed to the biofumigants at a rate of 100 lb N/A in all years and sprinkler irrigated to incorporate the N and irrigate the plots. Poast herbicide was applied to control the growth of grain volunteers. Other subplots were untreated (fallowed) until late fall when one of the two was fumigated with Metam Sodium. Additional main plot treatments for onions included N rates of 0 and 80 lb N/A as urea side-dressed on duplicate main plots of the lowest and highest residual P treatments.

Composite soil samples collected pre-plant in August from each year's trial area in the first foot indicated pH ranging from 8.0 to 8.2, OM from 0.9 to 1.2%, EC from 1.0 to 1.7 dsiemens/m, Olsen extractable K from 260 to 480, hot water extractable sulfate from 9.7 to 58, DTPA Zn from 0.6 to 1.8, and free lime from 10 to 12 %. Pre-plant available N in the first foot ranged from 70 to 100 lb/A.

Biofumigant biomass was sampled October 29, 2001, October 25, 2002, and October 28, 2003. Idagold mustard was at the late bloom stage at sampling in 2001 but closer to mid bloom in 2002 and 2003. Biofumigant biomass was flailed and rototilled Nov 1, Nov. 4, and Nov. 3.

Soil samples were collected from the first foot in early spring (March 29, 2002, March 6, 2003, and March 15, 2004) to determine biofumigant effects on available P, NO_3-N, and NH_4-N prior to planting onions. Buried bags were used to estimate mineralized N in the first foot during the onion growing season. Bags were removed and the change in NO_3-N from the initial value used to estimate mineralized N for each subplot treatment.

Onions were sampled near early bulbing and late bulbing to determine early season N uptake from treatments. Onion yields were measured after onions were lifted and the tops removed. Winter wheat was planted in October after the onion harvest. The wheat was not fertilized. Yield was measured at maturity with a small plot combine.

RESULTS AND DISCUSSION

Biofumigants grew rapidly after establishment in August. Harvested dry weights were lower in 2002 and 2003 than in 2001. The days from planting to sampling in 2002 and 2003 were 9 and 6 fewer than in 2001, respectively. Both brassica species accumulated appreciable N in their tops at the time of sampling, consistently exceeding preplant applied N. Radish N uptake increased with higher available P in two of three years. Idagold mustard N uptake was less affected by available P.

Soil NO_3-N in early spring in the first foot was consistently higher each year for the biofumigants than for the fallow or fumigated treatments (Fig. 1). Spring soil nitrates represent the combined effect of N applied preplant for biofumigants, and the overwinter net mineralization of N from incorporated biofumigants. The NO_3-N for the biofumigants averaged 23.2, 15.6, and 10.8 ppm higher than the nonbiofumigant treatments in 2002, 2003, and 2004, respectively. The mustard resulted in higher soil NO_3-N than the radish in two of three years. Higher available P effects on NO_3-N in early spring were inconsistent, increasing NO_3-N in 2002 but reducing NO_3-N in 2003. Soil test P in early spring was affected by previously applied P but was not appreciably affected by biofumigants.

Buried bag net N mineralization ranged from 148 to 172 lb N/A for the biofumigants over the three years, and 128 to 148 for the non-fumigated fallow treatments (Fig. 2). Buried bag net mineralized N from biofumigants during the

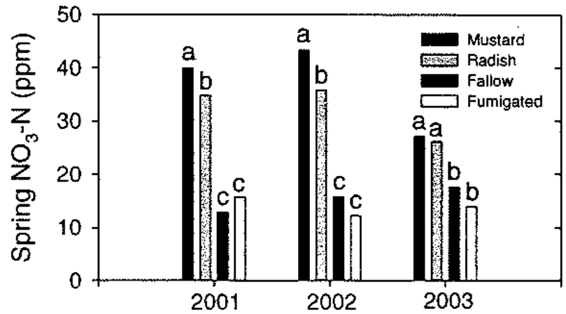

Figure 1. Early spring NO_3-N prior to planting onions as affected by fall treatments.

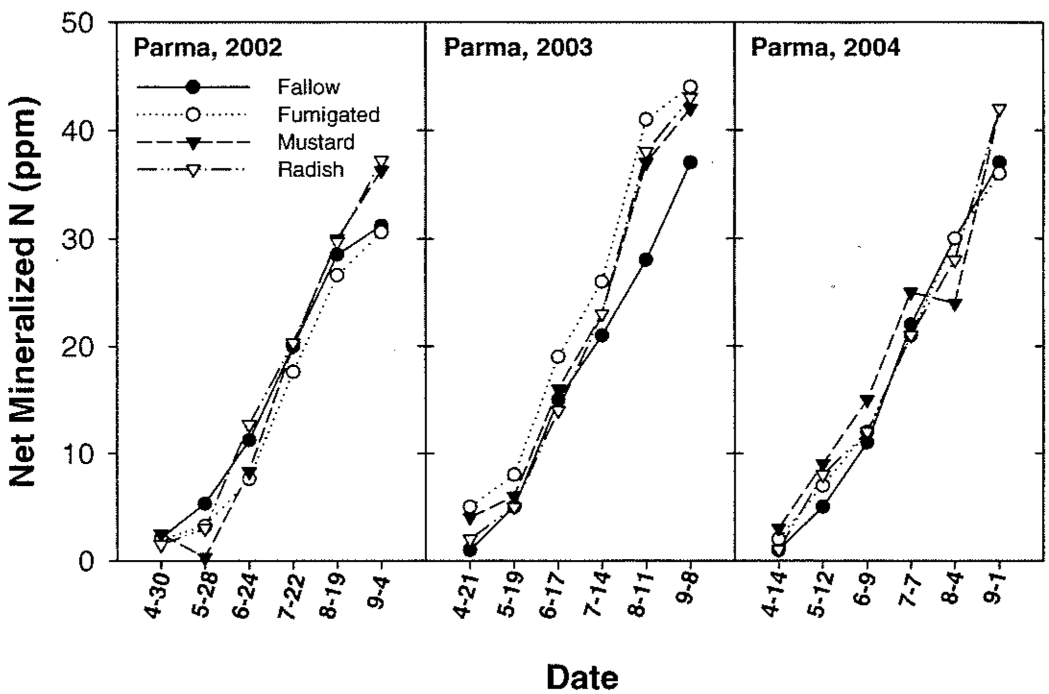

Figure 2. Net mineralization over time in each year from subplot biofumigant and non-biofumigant treatments as estimated from buried bags extracted periodically during the subsequent onion growing season. Sampling dates are equally spaced on the x axis but may not represent equal periods of time between samplings.

onion growing season did not differ consistently from fumigation but differed from the non-fumigated soil by only about 20 lb N/A. The net release of N from biofumigant residue appears to occur following incorporation in the fall and likely in late winter when temperatures increase. Consequently it may be subject to leaching from over winter precipitation or early season irrigation and may not offer significant slow N release advantages during the subsequent season. Fall fumigation in most years did not affect N mineralization during the onion growing season.

Onion N uptake at early bulbing was higher in soils with higher available P (Fig. 3). Uptake of N was lower in fumigated soils than in the fallow treatment in two of three years.

Biofumigants did not consistently increase N uptake over that in the non-fumigated fallow soil despite beginning the growing season with significantly greater NO_3-N. Onion N uptake at late bulbing did not differ consistently among treatments (data not shown).

Total onion yield was generally highest in fumigated soils with higher available P, but with low P, fumigation was detrimental. Fumigation in low P high lime soils frequently causes onion stunting, in part due to reduced beneficial mycorrhizal associations. Higher available P tended to increase yield in non-biofumigant treatments but the yield response to higher P was inconsistent following biofumigants. Side-dressed

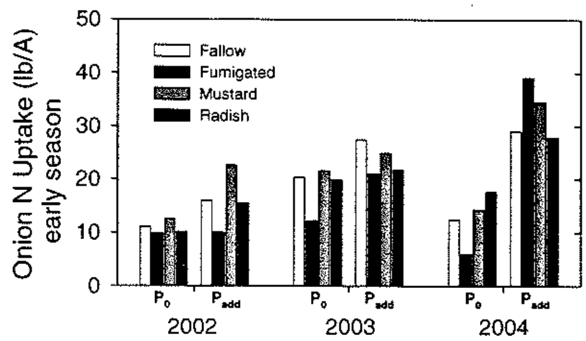

Figure 3. Onion N uptake at early bulbing as affected by the previous fall biofumigant and non-biofumigant treatments.

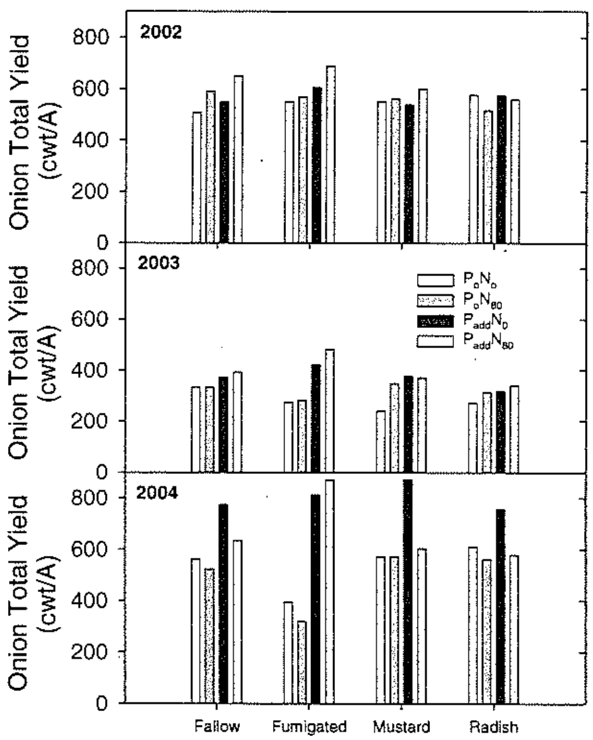

Figure 4. Onion total yield in each year as affected by biofumigant treatments and available P and N. The P_o is the lowest available P and P_{add} represents the highest available P for that year. The N_0 and N_{80} are N applied at 0 and 80 lb/A.

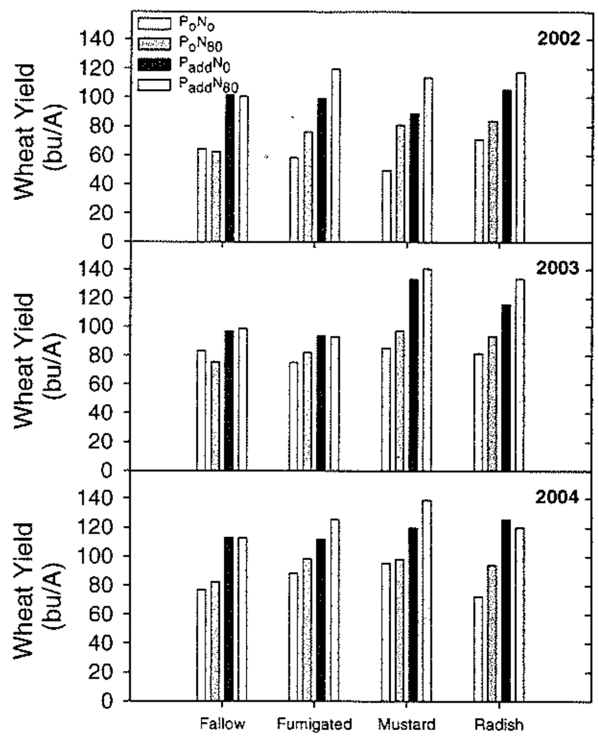

Figure 5. Wheat yield in each year following onions as affected by biofumigant treatments and available P and N.

N failed to increase onion yield in low P soil or where onions were preceded with biofumigants. Increased available N following biofumigants reduced the need for supplemental N. Yield decreased with sidedressed N in 2004 in some higher P treatments. With higher available P, onion yields decreased appreciably in 2004 with sidedressed N in all treatments except where the soil was fall fumigated. The yield loss occurred from reduced plant population.

Yield of wheat following onions increased with higher available P, particularly where N was applied to the previous onions. Wheat following onions grown after non-fumigated fallow did not increase in yield with N side-dressed to onions, regardless of available P. In contrast, yield of wheat following onions grown after other treatments frequently increased with the onion N sidedress. Occasionally, wheat yield was higher in previously fallowed/fumigated soils than soils only fallowed. The positive response to fumigation was possibly due to control of soil-borne wheat pathogens.

Wheat was more productive in two of three years when onions were grown after radish and mustard biofumigants rather than the non-fumigated or fumigated fallow treatments, The response to biofumigants was most likely due to higher available N. The results suggest that N fertilized biofumigants will have impact beyond the onion crop and into N sensitive second year crops. Onions are relatively inefficient in utilizing available N and frequently leave significant residual N for subsequent crops.

SUMMARY

Late summer planted biofumigants fertilized adequately with N can accumulate appreciable N, especially with adequate P. With early November incorporation, much of the biofumigant biomass N is released by spring and this readily available N contributes significantly to the following onion crop. Mineralization of N during the onion season increased with previous biofumigants but this N contribution was small relative to the combined contribution from residual N and biomass N release prior to onion planting. There may be advantages of biofumigants preceding other crops due to better control of significant pests, but the green manure (additional N or delayed N release) value of biofumigants is questionable following wheat. Given the minimal residual N following a wheat harvest and the N immobilization potential of incorporated wheat residue, biofumigants planted after wheat will require a significant fertilizer N investment and the biomass N accumulated will be largely available by spring rather than during the following growing season.