Winter Cereal–Corn Double Crop Forage Production and Phosphorus Removal

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ABSTRACT

Maximizing P removal with cropping can increase regulated P-based manuring rates or reduce soil test P in manure-enriched soils. The potential for increased P removal with winter forage–corn silage double cropping was evaluated in a 3-yr study at Parma, ID. Winter barley (Hordeum vulgare L.), and both winter and spring genotypes of wheat (Triticum aestivum L.) and triticale (× Triticosecale Wittmack) were fall planted at three seeding rates (112, 168, or 224 kg ha\(^{-1}\)) and followed with silage corn (Zea mays L.). Corn alone and a noncropped treatment were included. Winter forages were harvested near boot stage. Seeding rates of 168 kg ha\(^{-1}\) were necessary for maximizing winter forage production but had little effect on P uptake. Winter forage production and P content were highly year dependent due largely to appreciable winterkill of spring wheat and winter barley in 1999. Winter forage P concentrations, unlike those for corn, decreased with successive harvests. Cumulative P uptake ranged as high as 65.7 kg ha\(^{-1}\) for winter triticale. Winter forages reduced corn yields in 2 of 3 yr and corn P uptake in 1 yr. Compared to corn alone, double cropping increased cumulative forage production from 8.4 to 15.9% and total P removal by 29.8 to 42.2%. Soil test P concentrations after 3 yr decreased more with double cropping than with corn alone. Half of the P decline was unrelated to P uptake and removal. Double cropping can increase total forage production, P removal, and hasten soil test P decline.

Surface water quality concerns have led to P-based limitations on manuring rates from confined animal feeding operations (CAFO). For P-based manuring, the primary limitation to higher manuring rates, other than manure P concentration, is the amount removed by the cropping system. Land resources with many CAFO are limited and more manure P is generated than can be removed with single annual crops. Increasing on-farm forage production and reducing purchased forages could improve the P balance for whole farms (Wang et al., 2000; Rotz et al., 2002). Increasing crop P uptake is important for improving the P balance in western dairies (Spears et al., 2003). Greater P removal with cropping would (i) slow or avoid soil P enrichment, (ii) enable herd size to be maintained or expanded to an economic scale, (iii) preclude the need for increased land resources or capital improvements to extend manure distribution systems, or (iv) hasten soil test P decline in previously P-enriched soil and reduce environmental risks of runoff P.

Phosphorus removal with double and triple crop forage systems for the southern USA was reviewed (Newton et al., 2003; Pant et al., 2004), but information is limited for areas with shorter growing seasons. Double crop (winter cereal–corn) forage systems for the intermountain western USA have potential for increasing crop P removal over that removed with corn alone, as well as increasing forages otherwise used in the CAFO enterprise. Ideally, fall planted winter cereals produce additional forage during the cooler part of the year without limiting the corn growing season and sacrificing corn production. Winter cereals harvested at or near the boot stage, rather than soft dough, are less productive, but the earlier harvest allows corn to be planted at near normal planting dates. Furthermore, winter cereal P accumulation precedes biomass production. For irrigated wheat, no postanthesis P uptake was reported (Manske et al., 2001) and others indicated that maximum P uptake occurred by heading (Miller, 1939; Boatwright and Haas, 1961). Thus, a boot stage harvest does not sacrifice P uptake and removal nearly as much as it does biomass.

Crop production practices may differ for maximizing boot stage winter cereal forage production and P removal from winter cereals grazed or produced for grain. The restrictions associated with double cropping can limit crop management options such as winter cereal planting dates. Whereas winter cereals produced in the U.S. Great Plains for grazing are planted earlier than normal to maximize fall forage (Lyon et al., 2001), late summer planted winter cereals may not be an option in a double cropping system where full season corn hybrids require late summer harvest dates to maximize their silage yield potential. Higher winter cereal seeding rates are used for fall grazing or early spring forage production than for grain (Hanaway et al., 1983; Watson et al., 1993; Holman et al., 2005). Information is needed on appropriate seeding rates for boot stage dry matter production and boot stage P uptake.

Winter cereals may differ in their potential for boot stage forage and P removal. Rye (Secale cereale L.) typically grows under cooler temperatures than winter wheat or winter barley, and can produce more vegetative biomass from late fall through early spring (Hanaway et al., 1983; Watson et al., 1993; Moyer and Coffey, 2000). The most common winter cereal currently used for boot stage forage in the intermountain western USA is triticale, the wheat × rye cross. There are few reports of winter cereals compared for both boot stage forage dry matter and P removal potential.

Spring cereal genotypes are fall planted in some areas where winters are mild enough that plants are not lost to low winter temperatures. We have observed fall planted spring genotypes that headed earlier than winter genotypes. Winter triticale genotypes required more growing degree days than spring genotypes to reach maximum main stem elongation and dry matter accumulation (Royo and Blanco, 1999). Earlier plant development and harvest

Abbreviations: CAFO, confined animal feeding operations; Olsen P, 0.5 M NaHCO3 extractable P; PRI, P removal index.
could result in higher early spring biomass production, if not more time for subsequent seedbed preparation or a longer growing season for corn silage.

The general objective of this study was to evaluate the winter cereal–silage corn double crop system for its potential to increase both forage production and P removal over that with corn alone as a single crop. The specific objectives were to compare fall planted winter and spring cereals for their boot stage forage and P removal potential, and evaluate seeding rates for their importance in both forage yield and P removal.

MATERIALS AND METHODS

A 3-yr, irrigated double-crop small grain boot stage harvest followed by silage corn) forage study was conducted at the University of Idaho Parma Research and Extension Center in a Greenleaf-Owyhee silt loam (fine-silty, mixed, superactive, mesic Xeric Calcargid). The double cropping involved three winter (barley, wheat, and triticale) and two spring (wheat and triticale) cereals all fall planted at three seeding rates (112, 168, or 224 kg ha

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in fall 1998 and fall 1999, but was not measured in fall 2000. Nitrogen fertilizer as urea was side-dressed 3 May 1999, 2000 and 21 May 2001. Corn was planted into the winter cereal stubble without tillage on 20 May the first year and year in the same plot so that cumulative treatment effects on soil test P after 3 yr could be determined. Treatments were arranged in a randomized complete block design with four replications. Individual plots were 1.5 by 9.1 m. The previous crop was alfalfa Medicago sativa L.

Soil samples were collected (0–30 cm depth) before establishment of the trial to characterize the site’s fertility. Initial surces included saturated paste pH of 7.3, 1.0 dS m

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RESULTS AND DISCUSSION

Winter Forages

Small grain winter forages differed in dry matter yield in some years (Tables 1 and 3). Winterkill reduced winter barley stands 23% and spring wheat stands 45% in 1999 (Tables 2 and 4) resulting in considerably less forage production than with spring and winter triticale or winter wheat. There was no winterkill observed in 2000 and 2001, and forage production did not differ as widely as in 1999. Forage yield for winter barley rebounded in the second year, in the absence of winterkill, yielding more than all other forages. Spring wheat forage yield also rebounded the second year and did not differ significantly from the two triticales and exceeded the yield for winter wheat. Rebounding spring wheat and winter barley yields in 2000 are possibly related to the poorer yields or stands in 1999. Spring genotypes in the absence of winterkill were as productive as winter genotypes of the same species. Winter wheat was consistently lower yielding than either winter or spring triticale ($P < 0.10$).

Triticale forage production, unaffected by winterkill, declined during the 3-yr study. All winter forage yields declined from 2000 to 2001 when production across all winter forages averaged only 80% as much as in 2000. Cumulative growing degree days (base 0°C) from planting to harvest were 14.2% fewer in 2001 than in 2000 (1255 vs. 1463), and the lowest of all years.

Three-year mean winter forage yields were 5.39, 5.86, and 5.97 Mg ha$^{-1}$ for the 112, 168, and 224 kg ha$^{-1}$ seeding rates, respectively. Seeding rates higher than 112 kg ha$^{-1}$ were required to maximize forage yield ($P < 0.01$). Forage yields from the lowest seeding rate ranged from 88 to 94% of those with 168 kg seed ha$^{-1}$. Forage yields for the two highest seeding rates did not differ. There were no significant interactions for yield involving seeding rates.

Mean winter forage P concentrations declined from the first year high of 3.91 g kg$^{-1}$ in 1999, to 3.15 g kg$^{-1}$ in 2000, and to 2.48 g kg$^{-1}$ in 2001 (Tables 1 and 3). Declining forage P concentrations were attributed to reduced available soil P with crop removal. Higher winter barley and spring wheat P concentrations in 1999 relative to 2000 may also be due to reduced plant populations and less competition for available P.

Forage P concentrations among forages differed in some years, but they were not consistent (Table 3). For example, spring triticale P concentrations were lower than those of winter barley in 1999, but higher than winter barley in 2000. Spring wheat was lower in P concentration than winter barley in 1999, lower than the triticales and winter wheat in 2000, but did not differ from other winter forages in 2001. Winter wheat tended to have higher P concentrations than spring wheat but differed significantly only in 2000. Lower P concentrations in spring genotypes relative to winter genotypes of the same species is consistent with more advanced plant development of spring genotypes at sampling. Seeding rates did not significantly affect winter forage P concentrations.

Phosphorus uptake differed among forages depending on the year, but mean winter forage P uptake over the 3 yr was greatest for winter triticale (Table 3). Winter forage P uptake by winter barley and especially the fall planted spring wheat was reduced in 1999 due to winterkill. With no winterkill, winter forages differed less in P uptake, and P uptake in 2001 did not differ among forages. Uptake of P in winter barley with no winterkill was comparable to triticale and as high or higher than winter wheat. Winter forage seeding rates did not affect P uptake.
Silage Corn

Previous winter forages affected corn silage yields more in some years than others ($P < 0.001$, Tables 1 and 5). Corn silage dry matter yields decreased in 1999 when corn was no-till planted into stubble of winter forages unaffected by winterkill (winter triticale, winter wheat, and spring triticale) where corn stands were reduced 25 to 32% (Table 4). Corn vigor also decreased in 1999 following winter forages (Table 4), in part due to regrowth of harvested forages. Consequently, corn silage dry matter yields were greater in 1999 following fall planted forages partially lost from winterkill. Corn yields were not affected by previous winter forages in 2000 but in 2001 corn yield was lower following all winter forages. Winter forage seeding rate did not affect corn yield in any year.

In contrast to winter forages, corn forage P concentrations and P uptake did not decline with successive harvests (Table 5). In fact, corn forage P concentrations and P uptake were greatest in 2001, the final year of the study. Winter forages did not affect corn forage P concentrations but higher silage yields caused greater P uptake ($P < 0.08$) for corn no-till planted in 1999 into winter forages with the least stubble.

Double crop (winter forage and silage corn) dry matter yield did not consistently differ in all years from corn alone (Tables 1 and 6), but over 3 yr was higher by 8.4 to 15.9% (Table 5). Double crop yield over 3 yr for spring wheat and corn was higher than for winter wheat and corn, but did not differ from other double crop combinations. Double cropped forages were appreciably more effective in P removal than corn alone, increasing P uptake by 29.8 to 42.2%. Double crop P uptake did not consistently differ among winter forage–corn combinations, but over 3 yr was higher for the winter triticale–corn combination than for spring wheat and corn, winter wheat and corn, and winter barley and corn.

Unlike corn alone, double cropping over 3 yr essentially removed as much P as was initially applied. To put these results in perspective for P removal based manuring, a difference in three year P uptake of 40 kg ha$^{-1}$ with double cropping, the minimum difference in this study, would enable $>26$ Mg ha$^{-1}$ higher dry manuring rates over the period, assuming a manure P content on a dry matter basis of 1.5 g P kg$^{-1}$. Manuring rates (or animal units the land resource would accommodate) in a P removal limited system could be increased from 30 to 42% with double cropping over that with corn alone depending on the winter forage used.

These double crop P removal estimates may be conservative for highly enriched soils with much higher initial Olsen P. For highly enriched soils, winter forage P concentrations would probably not decline as rapidly as they did in this study. Winter forage P concentrations would also likely be greater than those reported for the last year of this study, and possibly higher throughout the study. The mean National Research Council P concentration listed for heading stage triticale silage is 3.3 g kg$^{-1}$ (NRC, 2001).

Longer season silage corn hybrids might possibly be used as a single crop of corn silage, as they could be
planted earlier and harvested later by a few days. However, longer season hybrids, even if as productive as double cropping in total forage, would likely still lag in total P uptake due to lower forage P concentrations. Increasing corn silage yield using longer season hybrids in a double crop system would likely come at the expense of the winter forage contribution to total P uptake.

Double cropping would not involve additional equipment for most enterprises already producing swathed and chopped forages. Irrigation requirements would increase somewhat; for winter forage establishment possibly, but primarily to support spring vegetative growth. Winter forages in most dairies in the region are irrigated primarily to support spring vegetative growth. Winter forages in most dairies in the region are irrigated to support spring vegetative growth. Winter forages in most dairies in the region are irrigated to support spring vegetative growth.

**Soil Test Phosphorus**

Olsen P declined during the study in both cropped and noncropped treatments (Tables 1 and 6), and differed for noncropped, single, and double cropped treatments (< 0.0001). Olsen P after the last corn harvest was lower for all double cropped treatments than the Olsen P for corn alone, which was lower than the Olsen P for the noncropped treatment. Olsen P was unaffected by winter forage seeding rates and did not differ significantly among winter forage–corn combinations, ranging narrowly from 11.7 to 12.2 mg kg$^{-1}$.

The decline due specifically to cropping is the difference in Olsen P for the cropped and noncropped treatments. The Olsen P difference between double cropped and noncropped treatments in fall 2001 after the final harvest was about 10 mg P kg$^{-1}$. Considering that Olsen P in the noncropped treatment also declined about 10 mg kg$^{-1}$ over the same period, it appears from this study that crop P removal and natural sorption processes were equally responsible for the Olsen P decline in the double crop treatment. Olsen P decline from appreciably higher initial soil test concentrations than in this trial may exceed those reported here (Eghball et al., 2003). Conversely, we used an inorganic fertilizer P source in this study to raise initial available P, and the decline in soil test P may be greater with fertilizer P than with manure P sources (Laboski and Lamb, 2003).

The PRI for cropping system treatments differed significantly (< 0.0001). The PRI ranged narrowly from 18.1 to 19.5 for double crop combinations (averaged across seeding rates), all of which differed significantly (< 0.05) from the PRI for single crop corn (30.4). The reason for this difference is not clear. The PRI could differ for corn if more of the total P removed was from deeper than 30 cm relative to winter forages. Soil temperatures below 30 cm would certainly be cooler with root activity and P uptake more limited for winter forage than for corn. Planting configurations (narrow vs. wider row spacings) may also be involved. Olsen P was not measured beyond 30 cm in this study. The results suggest that winter forages, despite taking up less P than corn, play an inordinate role in lowering Olsen P from the first 30 cm and reducing the soil P most subject to runoff. This finding merits further study.

In summary, double cropping winter forages and silage corn increased total forage production in most years, appreciably increased P removal, and reduced Olsen P levels. The PRI for cropping system treatments differed significantly (< 0.0001). The PRI ranged narrowly from 18.1 to 19.5 for double crop combinations (averaged across seeding rates), all of which differed significantly (< 0.05) from the PRI for single crop corn (30.4). The reason for this difference is not clear. The PRI could differ for corn if more of the total P removed was from deeper than 30 cm relative to winter forages. Soil temperatures below 30 cm would certainly be cooler with root activity and P uptake more limited for winter forage than for corn. Planting configurations (narrow vs. wider row spacings) may also be involved. Olsen P was not measured beyond 30 cm in this study. The results suggest that winter forages, despite taking up less P than corn, play an important role in lowering Olsen P from the first 30 cm and reducing the soil P most subject to runoff. This finding merits further study. The PRI for cropping system treatments differed significantly (< 0.0001). The PRI ranged narrowly from 18.1 to 19.5 for double crop combinations (averaged across seeding rates), all of which differed significantly (< 0.05) from the PRI for single crop corn (30.4). The reason for this difference is not clear. The PRI could differ for corn if more of the total P removed was from deeper than 30 cm relative to winter forages. Soil temperatures below 30 cm would certainly be cooler with root activity and P uptake more limited for winter forage than for corn. Planting configurations (narrow vs. wider row spacings) may also be involved. Olsen P was not measured beyond 30 cm in this study. The results suggest that winter forages, despite taking up less P than corn, play an important role in lowering Olsen P from the first 30 cm and reducing the soil P most subject to runoff. This finding merits further study. The PRI for cropping system treatments differed significantly (< 0.0001). The PRI ranged narrowly from 18.1 to 19.5 for double crop combinations (averaged across seeding rates), all of which differed significantly (< 0.05) from the PRI for single crop corn (30.4). The reason for this difference is not clear. The PRI could differ for corn if more of the total P removed was from deeper than 30 cm relative to winter forages. Soil temperatures below 30 cm would certainly be cooler with root activity and P uptake more limited for winter forage than for corn. Planting configurations (narrow vs. wider row spacings) may also be involved. Olsen P was not measured beyond 30 cm in this study. The results suggest that winter forages, despite taking up less P than corn, play an important role in lowering Olsen P from the first 30 cm and reducing the soil P most subject to runoff. This finding merits further study.
in the first 30 cm over that with corn alone. Winter forage–corn combinations did not always differ in production or P uptake, but winter triticale and corn resulted in the greatest P uptake and removal over 3 yr. Seeding rates of 168 kg ha$^{-1}$ were frequently necessary for maximum boot stage forage production, but seeding rates did not appreciably affect P uptake.

REFERENCES


