The Role of Pulse Crops in Cropping Systems

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Research Summary

Pulse crops generally enhance grain yield when inserted into small grain cropping systems. The impact of pulses on cereal crop performance has been attributed to the ability of legumes to fix atmospheric nitrogen (N) biologically. Canadian research suggests that other factors may explain most of the yield enhancement that results when small grains are preceded by pulses. The impact of rotating small grains with pulse crops on cereal pathogens will be discussed in this paper. Crop scientists who have or are evaluating the impact of rotations that include pulses on disease severity in small grains in the prairie region of Canada and the northern USA will be identified.

Introduction

The benefit of rotating pulse crops with spring wheat (*Triticum* spp.) and other small grain crops on cereal yield has been documented. Yield increases of more than 20% have occurred when spring wheat or barley (*Hordeum vulgare* L.) followed peas (*Pisum sativum* L. subsp. *sativum*) rather than small grains in the prairie region of Canada (Wright, 1990; Stevenson and van Kessel, 1996a) and the northern USA (Meyer, 1987). More recently, yield increases ranging from 17 to 34% have resulted when spring wheat was rotated with peas rather than grown continuously in an ongoing study in southwestern North Dakota (data not presented). Assigning an economic value to the rotation benefit of peas has been elusive, in part because the reason[s] for the benefit is[are] not understood completely.

Gardner (1992) concluded from research in the early 1990s at Carrington, North Dakota, that the fertilizer replacement value of peas was equivalent to 45 kg N/ha (40 lb N/acre). Subsequently, Franzen and Goos (1997) concluded that N fixed biologically by peas was available to a subsequent spring wheat crop at a rate of 21 kg N/ha for every 1000 kg seed produced (1.25 lb N/acre per bushel) in North Dakota. However, Canadian research suggested that biological N-fixation failed to explain a majority of the rotation benefit to spring wheat and other cereal crops (Stevenson and van Kessel, 1996a, b). This is reflected in a biological N-credit for peas of only 5 to 10 kg N/ha for every 1000 kg seed produced (0.3 to 0.6 lb N/acre per bushel) in western Canada (Beckie and Brandt, 1997), or about 36% of the N-credit used in North Dakota. Preliminary results of an on-going study in southwestern North Dakota suggest that even a credit of 5 to 10 kg N/ha for every 1000 kg seed produced may be too high for peas grown in rotation with wheat (data not presented).

Several explanations for the non-N rotation benefit when peas are followed by spring wheat in crop rotations include: reduced incidence of disease (Cook, 1992; Turkington and Clayton, 2000); increased availability of phosphorus, potassium, and sulfur (Bullock, 1992); and the reduction of weed populations (Blackshaw et al., 1994). Stevenson and van Kessel (1996a) concluded that non-N benefits accounted for 92% of the yield increase when HRS wheat followed peas rather than spring wheat in western Canada. Stevenson and van Kessel (1996a) and others (Ashley et al., 1998; Bailey, 2000) have suggested that the impact of pulses on cereal disease pathogens may explain the non-N benefits in some environments.

Impact of Rotating Pulses with Wheat on Disease

The impact of tillage on foliar and root diseases of spring wheat was studied over 12 years at Indian Head, Saskatchewan (Bailey, 2000). Foliar disease severity was unaffected by tillage during both the first and second 4-yr cycles of the study (Bailey et al., 1992, 2002a). Foliar disease was more severe under no-till than conventional-till in only two of four years during the third 4-yr cycle (Bailey et al., 2002b). Similarly, root disease severity generally was unaffected by tillage during the study, although there were changes in composition of the root disease complex (Bailey et al., 1992, 2002a, 2002b). Wheat yield generally was unaffected by changing tillage practices (Bailey, 2000).

The role of rotation diversity in reducing wheat disease severity was assessed in the study summarized by Bailey (2000). Grain yield was enhanced when wheat was alternated every-other-year with a broadleaf crop (wheat-pea-wheat-flax [*Linum usitatissimum* L.]) rather than every third year (wheat-wheat-flax-wheat), or when grown in a fallow-wheat monoculture (fallow-wheat-wheat-wheat). The yield gain sometimes coincided with root disease suppression in wheat when grown in the diverse rotation (wheat-pea-wheat-flax) compared with the other two production systems. Bailey (2000) suggested that the elimination of tillage coupled with the insertion of broadleaf crops into rotations would reduce wheat disease severity. Peas (and not flax) were identified as a good choice for minimizing tan spot (*Pyrenophora tritici-repentis* (Died.) Drechs) infection in wheat, when preceding wheat in a crop sequence.

Disease severity was compared in wheat-pea and wheat-wheat sequences in two fields in Saskatchewan during the second year of a 3-yr study (Stevenson and van Kessel, 1996a). Leaf disease severity was unaffected by crop sequence at either location, but root rot severity was much greater (3.19 vs. 0.99 for wheat-pea and continuous wheat, 0 - 4 scale) in a field where "cereal-intensive" cropping occurred prior to establishment of the crop sequences. No differences in root disease occurred in a field fallowed prior to establishing crop sequences. Stevenson and van Kessel (1996a) speculated that the decline in disease inoculum during the fallow period eliminated any benefits that peas offered a subsequent wheat crop when root disease severity was assessed.

The impact of forage and grain legumes on wheat disease was evaluated in the Peace River region of Alberta. At Fort Vermilion, Alberta a crop management field trial was used to compare conventional versus zero tillage systems and legume-based crop rotations (Clayton et al. 1997). The trial was established in 1992. The crop rotations included: 1) field pea-wheat-canola (*Brassica* spp.)-wheat (FP/W1/C/W2), 2) red clover (*Trifolium pratense* L.)-wheat-canola-wheat (RC/W1/C/W2), 3) fallow-wheat-canola-wheat (F/W1/C/W2), and 4) wheat-wheat-wheat-wheat (W/W1/W/W2). Common root rot severity in the wheat was assessed in early August of 1994, 1995 and 1996. Overall, root rot severity was reduced under zero versus conventional tillage. Root rot severity also was reduced in rotations with field pea, red clover or canola as pre-crop treatments compared with continuous wheat. In addition, root rot severity was reduced in legume-based rotations compared with non-legume rotations. Wheat yields for rotations with field pea, red clover or fallow were similar, and were higher than those observed under continuous wheat (Clayton et al. 1997).

The impact of peas on wheat yield is being evaluated in an on-going study in southwestern North Dakota. Root disease severity is being quantified when wheat is rotated with peas and when wheat is grown continuously across contrasting tillage systems. Thus far, a causal relationship between wheat yield and root disease severity has not been established. For example, grain yield was enhanced by 17% when wheat followed peas compared with the continuous wheat monoculture in 2001, but there was no indication that root disease severity was affected by wheat production system (data not presented).

Ashley et al. (1998) established a causal relationship between rotation diversity and root disease severity in commercial wheat fields in western North Dakota. Wheat yields were up to 42% greater in fumigated compared with non-fumigated areas in fields where spring wheat was grown continuously or rotated with barley. No yield differences occurred between fumigated and non-fumigated areas in fields where there was a 2-yr break with non-host crops between successive wheat crops. This and subsequent research support current suggestions that a 1-yr break between successive wheat crops can increase yield up to 20%, and a 2-yr break up to 40%, compared with growing wheat continuously in southwestern North Dakota (R.O. Ashley, personal communication, 2001). Preliminary data from a crop-sequence study reported in this proceedings also indicate improved wheat production with a 1-yr and 2-yr break in successive wheat crops (Krupinsky et al., 2002b)

Peas and soybean (*Glycine max* L. Merr.) are two crops that have been used successfully to break cereal disease cycles when inserted into rotations dominated by barley and wheat (Ashley et al., 1998). There was a trend for infection by several pathogens to be reduced in spring wheat when preceded by peas compared with wheat (Bailey et al., 1992). Results of the studies by Ashley et al. (1998) and Bailey et al. (1992) demonstrate that pulses can reduce root disease severity in wheat if inserted into rotations dominated by wheat.

Other studies have demonstrated that rotating pulses with wheat can reduce cereal disease severity. For example, tan spot infection was reduced when spring wheat followed lentil (Lens culinaris Medik.) rather than wheat during years of high-disease pressure at Swift Current, Saskatchewan (Zentner et al., 2001). Incidence of leaf spotting by the septoria complex (*Phaeosphaeria nodorum* (Muller Hedja.), *Mycosphaerella graminicola* (Fuckel) Schroeter, and *Phaeosphaeria avenaria* (Weber) Eriksson f. sp. *Triticea* T. Johnson) was reduced when peas preceded wheat compared with a wheat monoculture (Pedersen and Hughes, 1992). Similarly, the incidence of fusarium head blight was reduced when wheat followed soybeans rather than corn (*Zea mays* L.) and wheat in a 3-yr study near Morris, Minnesota (Dill-Mackey and Jones, 2000). Results of these three studies indicate that the incidence of several cereal diseases was reduced when pulses preceded wheat in a crop sequence.

Pulse Diseases in Diverse Cropping Systems

Research on the impact of diverse rotations on pulse disease severity in the prairie region of Canada and the northern USA is limited. Canadian researchers have compared disease incidence of lentil and pea across contrasting tillage systems (Bailey et al., 1992, 2002a, 2002b; Zentner et al., 2001). However, design of the field studies prevented comparisons of different rotations on diseases of the pulses.

Scientists at the USDA-ARS Northern Great Plains Research Laboratory (NGPRL) at Mandan, North Dakota, began to address the impact of crop sequencing on pulse disease severity in 1999. Ten different crops were evaluated for yield in a matrix of all possible sequences over a 2-yr period. Severity of selected diseases in pulses and other crops was rated as part of the study. Development of the Crop Sequence Calculator was a result of this effort (Krupinsky et al., 2002b). The Crop Sequence Calculator version 2 is an interactive decision tool that assists growers in estimating the yield of pulses and other crops on the basis of the preceding crop. Free copies can be ordered electronically by accessing the NGPRL web page at: http://www.mandan.ars.usda.gov.

The benefits of incorporating pulses and other non-host crops into crop sequences on cereal disease management are summarized by Krupinsky et al. (2002a). These scientists warn that incorporating pulses and other broadleaf crops into rotations dominated by small grains increases the disease risk among pulses. This caveat supports research that determines the impact of diverse rotations on disease severity in pulses in emerging cropping systems in the prairie region.

Additional Sources of Information

There are several scientists who are knowledgeable about the impact of pulses on small grain diseases in the prairie region. Karen Bailey has published extensively on the subject of pulse and small grain diseases across contrasting tillage and crop production systems. Dr. Bailey is a scientist with Agriculture and Agri-Food Canada and is located at the Saskatoon Research Centre in Saskatoon. Joe Krupinsky also has published on the impact that pulses and other non-host crops have on disease severity in wheat. Dr. Krupinsky is a pathologist located at the USDA-ARS Northern Great Plains Research Laboratory at Mandan, North Dakota. Roger Ashley is a cropping systems specialist who continues to evaluate the impact of diverse rotations on root disease in commercial fields during the wheat phase. Mr. Ashley is with the Extension Service at North Dakota State University and is located at the Dickinson Research Extension Center. He works closely with Marcia McMullen, a plant pathologist with North Dakota State University and located in Fargo. Dr. Kelly Turkington is a plant pathologist at the AAFC Research Centre in Lacombe, Alberta and works on cereal and oilseed diseases as part of a collaborative research program investigating the impact and management of plant diseases in various cropping systems. Papers written by these scientists are excellent sources of information on how crop disease is affected by pulses and small grains in diverse cropping systems.

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