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Nitrogen fertilizer and urease inhibitor effects on canola seed quality in a one-pass seeding and fertilizing system

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ABSTRACT

Field studies were conducted over three years on a clay loam (CL) and fine sandy loam (FSL) soil on the eastern Canadian prairies to evaluate the impact of urea and urea ammonium nitrate (UAN), with or without the urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT), placed near the seed-row in a one-pass seeding and fertilizing operation on seed protein, oil, chlorophyll and glucosinolate content of canola (*Brassica napus* L.). Application of N fertilizer as a side-band application at the time of seeding increased protein concentration and decreased oil concentration. Protein and oil yield increased with low to moderate N rates, but stabilized or fell with high N rates due to reductions in yield from seedling toxicity. Both chlorophyll and glucosinolate concentrations increased with increasing N rates. Use of UAN led to higher protein, chlorophyll and glucosinolate and lower oil concentration than urea on the CL soil. Use of the urease inhibitor NBPT generally increased oil concentration on both soils and reduced the chlorophyll and glucosinolate concentration on the CL soil. Observed difference may have been due to delayed maturity and reduced stand density caused by seedling damage and high N rates. High N rates applied as a side-band of urea or UAN near the canola seed row can negatively influence both seed yield and quality in canola and the negative effects may be reduced by the use of the urease inhibitor NBPT.

1. Introduction

Canola (*Brassica napus* L.) is a major oilseed crop throughout the world. Canola refers to cultivars of rapeseed that have been selected to contain low levels of erucic acid and glucosinolates. The seed contains about 40% oil and produces a meal containing about 38% protein that is used as a supplement in animal rations (Bell, 1984). Canola has a high demand for crop nutrients, including nitrogen (N) and N deficiencies commonly limit canola yield (Grant and Bailey, 1993). Therefore, proper N fertilization is important in optimizing canola yield and quality.

Oil and N content of canola seed are important quality characteristics, affecting oil yield and protein content of the meal. As the primary product from canola seed is the oil, high oil content is desirable. The meal is normally used as a protein supplement, therefore high protein content is also important. Nitrogen fertilizers frequently lead to both increased protein accumulation and concentration in canola seed (Asare and Scarisbrick, 1995; Grant et al., 2002; Lemke et al., 2009). However, oil and protein concentration tend to be inversely related, so increases in protein content due to N application normally result in a reduction in oil concentration (Asare and Scarisbrick, 1995; Rathke et al., 2005, 2006; Malhi and Gill, 2007; Brennan and Bolland, 2009; Gao et al., 2010).

High seed chlorophyll content in canola seed is of concern because chlorophyll in the seed is carried through the crushing process, giving an undesirable dark cast to the oil (Daun and Symons, 2000). In addition, chlorophyll pigments remaining in oil can increase oxidation rancidity and lead to difficulties in hydrogenation. Excess levels of chlorophyll in the seed can lead to downgrading or rejection of canola (Ward et al., 1992). Samples with more than 2.0% green seeds or over 22–24 mg chlorophyll kg^{-1} seed are assessed as sample seed, which may lead to a discounted price and difficulty in selling the crop (Daun and Symons, 2000). Factors that delay seed maturity may increase seed chlorophyll content (Ward et al., 1994; Grant et al., 2002).

Glucosinolate content is also of concern because hydrolysis of glucosinolates leads to the production of goitrogenic compounds and other potentially toxic products that reduce the feeding quality of the meal (Bell, 1984). Breeding of low glucosinolate canola cultivars markedly reduced the glucosinolate compounds as compared to traditional rapeseed cultivars. Canola cultivars must contain less than 30 μmol glucosinolates per gram seed (www.canolacouncil.org/uploads/Standards1-2.pdf, accessed August 25, 2010). Application of N fertilizer has been shown to increase the total glucosinolate concentration in canola (Zhao et al., 1993, 1994; Ahmad and Abdin, 2000), although the response varied

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with the specific type of glucosinolate and with the S supply (Zhao et al., 1994).

In-soil banding (injection) is an important management tool for improving N fertilizer use efficiency particularly under no-till systems where surface applications of N are not incorporated and thus are subject to volatilization losses and immobilization in surface residues (Malhi et al., 2001). Since placing the fertilizer in a concentrated band below the soil surface can reduce immobilization, volatilization, denitrification and leaching losses (Tomar and Soper, 1987) this practice has been widely adopted on the Canadian prairies. Banding N fertilizer during the seeding operation is very common (http://www.statcan.gc.ca/pub/21-021-m/2004002/t/4144648-eng.htm, accessed July 7, 2010) because seeding and fertilizing in a single operation reduces time, fuel and labour costs, and can help to decrease seedbed disturbance and retain soil moisture (Zentner et al., 2002). Equipment costs are lower if the seed and fertilizer can be placed in a single band, using only one opener, but this can lead to seedling damage at high N rates (Grant and Bailey, 1999; Malhi et al., 2003; Malhi and Gill, 2004; Grant et al., 2010).

Seedling damage can have a major impact on stand density, crop yield and maturity (Karamanos et al., 2004), which may have an influence on crop quality factors such as protein content, oil content and chlorophyll content. Canola is sensitive to seedling damage and the rates of N required to optimize crop yield are normally too high to be safely placed with the seed (Malhi and Gill, 2004). Producers on the northern Great Plains have increasingly adopted the use of openers that separate the seed and fertilizer in order to increase the amount of fertilizer that can safely be placed near the seed-row in a one-pass operation. However, sensitive crops such as canola may possibly be damaged by rates of N required to optimize seed yield, even when using seeding equipment currently in commercial use, thus influencing stand density, crop yield and maturity (Grant et al., 2010).

Urea ammonium nitrate (UAN), a liquid blend of urea and ammonium nitrate, and urea are both common forms of N fertilizer. Urea is not directly damaging to seedlings but after it hydrolyses in a reaction catalysed by the enzyme urease, the ammonia (NH_3) and ammonium (NH_4^+) produced can cause ammonia toxicity and osmotic damage (Bremner, 1995). Urea toxicity can be reduced by applying the urease inhibitor N-(n-butyl) thiophosphoric triamide (NBPT) to the fertilizer granule (Wang et al., 1995; Grant and Bailey, 1999; Malhi et al., 2003; Karamanos et al., 2004) or the UAN solution (Schlegel, 1991). The urease inhibitor (UI) slows the conversion of urea to ammonium, allowing more time for the intact urea molecule to move away from the seed-row and for rainfall to dilute the fertilizer, leading to a lower concentration of NH_4^+ and NH_3 near the seedling. While studies have evaluated the effect of urea or UAN with and without NBPT on canola yield and seeding damage (Schlegel, 1991; Wang et al., 1995; Grant and Bailey, 1999; Malhi et al., 2003; Karamanos et al., 2004; Grant et al., 2010), little information is available on the effects of urea or UAN, with and without NBPT on the resulting canola seed quality. Therefore, this study was designed to evaluate the effects of increasing rates of side-banded UAN and urea, with and without NBPT (UI) on canola oil, protein, chlorophyll and glucosinolate concentration, on two contrasting soil types.

2. Materials and methods

Field studies were conducted over a three-year period on a Newdale Clay Loam (CL) (Orthic Black Chernozem) (Ehrlich et al., 1957) and a Souris Fine Sandy Loam (FSL) (Orthic Black Chernozem) (Ehrlich et al., 1956) in Manitoba, Canada, near 49°50′ N 100°0′, for a total of six site-years. Both of these soils would be classified as Udic Borolls in the United States Department of Agriculture soil taxonomic system. Prior to the beginning of the study each year, soil samples were collected to a depth of 0–15, 15–30, 30–60 cm for pH, EC, N, and P. Soil EC and pH were determined with a soil:deionized water ratio of 1:2 (Carter and Gregorich, 2008). Nitrate-nitrogen and P were extracted with 0.5 M $NaHCO_3$ (Carter and Gregorich, 2008). Nitrate-N concentration in the extract was measured colorimetrically using a Technicon autoanalyser (Technicon Instruments Corp., Tarrytown, N.Y., 10591) and P was measured using an ARL 3410 ICP unit (Thermo Scientific, Mississauga, ON). Reliability of the analysis was assessed by including soil reference materials in each of the soil extracts. Measured concentrations matched the ranges in the standards. Soil characteristics are shown in Table 1. Temperature and rainfall were collected using automated weather stations located at the experimental sites through the growing season of

Table 1
Soil characteristics of test sites at the initiation of the study (Grant et al., 2010).

Depth (cm)	NO_3-N ($\mu g\,g^{-1}$)	P ($\mu g\,g^{-1}$)	K ($\mu g\,g^{-1}$)	SO_4-S ($\mu g\,g^{-1}$)	pH	EC (mS/cm)
Clay loam 1999						
0–15	4	18.5	228	3.8	7.8	0.32
15–30	2.9	nd[a]	nd	4.6	8.1	0.30
30–60	1.5	nd	nd	2.5	8.4	0.30
Clay loam 2000						
0–15	14.8	16.25	385	20	7.7	0.40
15–30	8.6	nd	nd	13.6	8.0	0.33
30–60	10	nd	nd	22.5	8.5	0.33
Clay loam 2001						
0–15	3.8	10.8	251	5.8	7.8	0.32
15–30	2.5	nd	nd	4.1	8.0	0.32
30–60	1.9	nd	nd	11.3	8.4	0.36
Fine sandy loam 1999						
0–15	5	5	130	4.2	7.5	0.20
15–30	2	nd	nd	7.1	7.9	0.23
30–60	1	nd	nd	3.3	8.1	0.22
Fine sandy loam 2000						
0–15	10.9	15	243	23.3	7.4	0.18
15–30	8.6	nd	nd	11.1	7.6	0.10
30–60	6.3	nd	nd	21.1	8.0	0.15
Fine sandy loam 2001						
0–15	15.6	17.4	448	69.8	7.0	0.56
15–30	4.8	nd	nd	89	7.5	0.49
30–60	4.1	nd	nd	284.4	8.0	0.73

[a] nd indicates not determined.