EXPERIENCES IN THE CANADIAN PRAIRIES WITH ENHANCED EFFICIENCY N FERTLIZERS FOR WINTER AND SPRING WHEAT PRODUCTION SYSTEMS

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ABSTRACT

This presentation summarizes several studies all designed to address knowledge gaps around enhanced efficiency urea fertilizer (EEF) efficacy for nitrogen (N) management in western Canadian winter and spring wheat production systems. Polymer-coated urea was first studied to determine how handling effects can alter the coating integrity of environmentally smart nitrogen (ESN®). While N release rates increased from retail or farm-handling such as transferring product through equipment containing scaly deposits, header-manifold systems with high air fan speeds, or with air boom applicators, the crop compensated to any injury sustained and grain yield was usually unaffected or could be mitigated through proper equipment maintenance and settings. Additional research conducted confirmed the substitution of urea with ESN allows 3x rates of seed-placed N provided N release was ≤ 40%, which is readily achieved through proper handling. Studies exploring winter wheat crop responses to urea type (urea, urea+urease inhibitor - Agrotain®; urea+urease and nitrification inhibitor – SuperU®, polymer-coated urea – ESN®; urea impregnated with a nitrification inhibitor - ENtrench®; and urea ammonium nitrate – UAN) when all applied at planting were compared to split-applications were conducted at study sites across the Canadian prairies representing the main soil zones. The results suggest split applications of N might be most efficient for yield and protein optimization when combined with an enhanced efficiency urea product, particularly with urease or urease+nitrification inhibitors, and if the majority of N is applied in spring. Aside from seed-placed applications, ESN® appears to release too slowly in the northern Great Plains. For example, results from unpublished work report yield results in the following order: SuperU® ≥ ENtrench® ≥ urea ≥ ESN®; the yield response to SuperU® was significantly higher than ESN®. However, proportions of ESN® in side-banded (1:1 ratios with urea) systems improved yield in certain conditions. New studies have been initiated for spring wheat to determine the efficacy of other placement, timing, and rate practices for EEFs in spring wheat.

INTRODUCTION

Aside from water, nitrogen is the major yield-limiting factor in wheat production systems in the Canadian Prairies, and the costliest when considering wheat generally utilizes roughly one-half, or less, of the nitrogen applied. As growers strive for higher yields through intensified practices and new genetics, the knowledge gap around N management systems remains far from closed. One question that arises is the role of enhanced efficiency N fertilizers (EEFs), with respect to greater nitrogen use efficiency through reduced losses and higher overall returns to offset associated input costs. Nitrogen fertilizer management is also complicated by the registration of new extremely high-yielding Canadian Western Red Spring (CWRS) wheat cultivars, with field yields of +100 bu/ac reported by some growers. Moreover, the yield potential for Canadian Western Red Winter generally exceeds CWRS by 20%. For both classes of wheat, however, the trade-off for high yield in some cultivars is a reduction in grain protein concentration. Growers must achieve a minimum protein content of 13% and 11%, respectively for CWRS and CWRS, to avoid price discounts. Some recently registered, high-yielding wheat cultivars struggle to meet these minimum requirements unless nitrogen (N) fertilizer management is focused on simultaneously achieving protein targets. Given the innovations around the introduction of EEFs and significantly higher attainable yield benefits with the latest genetics, a review of N management systems is needed to fully exploit this new Genetics x Environment x Management (GxExM) synergy.

MATERIALS AND METHODS

Handling effects on polymer-coated urea

Separate experiments were conducted for the simulated abrasion and handling studies at each site near Lethbridge, Alberta, Canada. The simulated abrasion experiment (Experiment 1) consisted of 10 kg ESN® lots that were rolled in a cement mixer drum with 2 kg of crushed landscape rocks to create abrasion severity calibrated by increasing the time durations in the drum to achieve lots that differed by 10% in total N release when immersed in water at 23°C for 7d (Table 1). A detailed description of nitrogen release methodology is reported by Zhang et al. (2000). The nine treatments were arranged in a randomized complete block design with three blocks (Table 1). The handling study (Experiment 2) involved three factors that were perceived to potentially affect the integrity of the polymer coating: 1) Retail point handling, which consisted of two loading methods: a) loading the product using a blender that was scaled with fertilizer deposits, or b) loading product after the blender first loaded 10 tonnes of potash for the purpose of de-scaling the blender to minimize abrasion; 2) Farm handling, which consisted of two loading methods: a) loading product into tote or 'mini-bulk' bag (Trimeg holdings LTD, Calgary, AB, Canada) using a 15 cm diameter, steel-flighted auger (Brandt Manufacturing, Regina, SK, Canada), or b) no auger employed – material poured directly into tote bag at retailer and emptied through spout on the bottom of the tote; and 3) Method of application, which consisted of a) control – not handled, b) ConservaPak air drill (Model CP 129A, Vale Farms, Indian Head, SK, Canada) set to high fan speed, c) ConservaPak air drill set to medium fan speed, d) Flexi-Coil delivery system with Easy Flow Header manifold (CNH, Saskatoon, SK, Canada) and John Deere MaxEmerg opener (Moline, IL), e) Flexi-Coil delivery system with product metered to calibration tube, not through manifold, f) 'Barber' drop spreader (Barber Engineering Company, Spokane, WA) set at high rate or wide opening, g) 'Barber' drop spreader set at medium rate or opening, h) Valmar air boom applicator (Model 245, Valmar Airflo Inc., Elie, MB, Canada) set to high fan speed, and i) Valmar air boom applicator set to low fan speed. For implements with more than one exit point, a sample of product was collected by combining equal quantities from each exit point into a composite sample. The three factors (retail handling, farm handling and method of application) were combined into a 36 treatment, factorial randomized complete block design with 3 blocks (Table 1).

To determine crop responses to the variations in abrasion levels and corresponding rates of N release for both experiments, samples were seed-placed with canola (*Brassica napus* L. cv. 'Invigor 5020'), winter wheat (*Triticum aestivum* L. cv 'AC Radiant'), spring wheat (*Triticum* *aestivum* L. cv 'CDC Go'), winter triticale (X *Triticosecale* Wittmack cv 'Bobcat'), and spring triticale (X *Triticosecale* Wittmack cv. 'Pronghorn'). Triticale was not included in the handling study (Experiment 2). The canola and cereal plots were sown at rates of 150 seeds m^{-2} and 300 seeds m^{-2}, respectively. Seed-placed ESN® rates for canola and cereals were 45 kg N ha^{-1} and 90 kg N ha^{-1}, respectively, which would be 3x the safe rate of seed-placed uncoated urea. Plots consisted of 4 rows spaced 23 cm apart with an overall size of 0.92 m wide by 3 m long, and sown in early-spring or late-summer using a self-propelled plot seeder equipped with a cone splitter and zero-tillage double disc openers. The seed bed utilization for this seeder configuration is narrow and would be approximately 10%.

A follow-up study was conducted to determine how upper limits of seed safety using seed-placed ESN® in cereals and canola change with increased N rates and alterations to the coating integrity of ESN®. Alterations to the coating integrity of ESN® were created in the laboratory (consistent within an incremental range of 20 to 80% N release after 7 d immersion in 23°C water) and then arranged in a factorial combination with five rates (30, 45, 60, 75, and 90 kg N ha^{-1}) of the seed-placed ESN lots and urea (100% N release). The same crop responses and varieties used and described above were adopted for this experiment.

Enhanced efficiency N fertilizer management

Although several studies are presented, the following methodology is the general experimental approach that we have designed and followed. Study locations varied but were chosen to represent that major soil zones of the Canadian prairies ie. Lethbridge, Lacombe, Falher, Alberta; Scott, Indian Head, Canora, Saskatchewan; and Brandon, Hallonquist, Manitoba. The N management treatments included the following urea types: 1) uncoated urea (46-0-0), 2) Ammoniacal N stabilized with a urease inhibitor NBPT (Agrotain®), 3) Super-granulated urea with increased N stability derived from urease and nitrification inhibitor (SuperU®), 4) polymer-coated urea – Environmentally Smart Nitrogen® (ESN®), and 5) urea ammonium nitrate (UAN; 28-0-0). We have also recently explored responses with ammoniacal N impregnated with a nitrification inhibitor (ENtrench®). All fertilizer was supplied by Nutiren, Corteva and Koch Agronomic Services. If N rates were not a factor in the treatment structure, rates for all treatments were usually based on 80% soil test recommendation from Western Ag Labs Plant Root Simulator® (PRS; Saskatoon, SK, Canada). Each urea type was applied using the following timing/placement methods: 1) all N side-banded at time of seeding, 2) all N broadcasted in early spring at approximately Zadoks growth stage 30, and 3) half N side-banded and half N broadcasted in spring. The experimental designs were full factorial randomized complete block or designs that utilized a split-plot arrangement, always with four replications. Main effects studies were cultivars and subplots N management treatment combinations. Experimental unit dimensions varied but were usually based on 3.7 m wide by 15.2 m long dimensions. Additional N management treatments have included urea type and various split application time/placement possibilities. For example, 1) all N side-banded at time of seeding, 2) half of N side-banded and the other half was broadcast late fall (i.e., first week of November), 3) half of N side-banded and the other half was broadcast early-spring (Zadoks 30), 4) half of N side-banded and the other half was broadcast mid-spring (Zadoks 40), and 5) half of N side-banded and the other half was broadcast late-spring (Zadoks 45-50). We have also compared split applications of the following to all N side-banded at planting: 1) 30% N side-banded at planting and 70% broadcast in late fall (i.e., first week of

November), and 2) 30% N side-banded at planting and 70% broadcast in early spring at approximately Feekes growth stage 4 at the beginning of stem elongation.

Seeding Operations and Pest Management

For both tests, glyphosate or Pre-Pass® (florasulamSC - 4.95 g ai/ha; glyphosate - 445 g a.e. ha-1) (Dow AgroSciences Calgary, AB, Canada) was applied across the entirety of each site 24 to 48 h prior to seeding using a motorized sprayer calibrated to deliver a carrier volume of 45 L ha-1 at 275 kPa pressure. Seeding was conducted with a ConservaPak™ air drill configured with knife openers spaced 23 cm apart. Winter wheat was sown at a rate of 450 seeds m-2, with a target plant density of 338 plants m-2. Seeding dates for each site in both experiments are summarized in Table 1. All plots, including the control, received blanket applications of other macronutrients based on Western Ag Labs PRS® soil test system.
Weed control was achieved with an application of 2,4-Dichlorophenoxyacetic acid (2,4-D LV ester - 560 g a.e. ha-1; 2,4-D Ester LV 600, Nufarm Americas Inc., Burr Ridge, IL, USA) when average growth was the 3 to 5 leaf stage around mid-October. If necessary, a tax mix of thifensulfuron/tribenuron (15 g a.i. ha-1 - Refine Extra®, Dupont Canada Agricultural Products, Mississauga, ON, Canada) and clodinafop (56 g a.i. ha-1; Horizon® 240 EC, Syngenta Crop Protection Canada, Guelph, ON, Canada) Horizon™ plus Refine Extra™ was applied in the spring for additional weed control. All post-emergent herbicide applications were made using a motorized sprayer calibrated to deliver a carrier volume of 45 L ha-1 at 275 kPa pressure.

RESULTS AND DISCUSSION

Handling effects on polymer-coated urea

There was an inverse relationship observed between most crop response variables and increased nitrogen release treatments (abrasion). Winter wheat compensated through increased tillering and maintained high grain yield regardless of abrasion severity. Acceptable plant populations were maintained up to the 60% release level and crop canopy differences were not as apparent in the latter stages of the vegetative crop phase. With respect to retail and on-farm handling, the most serious abrasion occurred when transferring product in equipment containing scaly deposits; topdress applications with an air boom applicator, or with seeders configured with header-manifold systems operating at high air fan speeds. In most cases, the crop compensated to any injury sustained and grain yield was usually unaffected or could be mitigated through proper equipment maintenance and settings.

The highest and most stable yield for canola and wheat was achieved with 60 to 90 kg N ha-1 with ESN® that had 20 to 40% N release. Triticale appeared to tolerate even greater release rates of N (80%) at the highest N rate. Results from this study confirm the substitution of urea with ESN allows at least 3x rates of seed-placed N provided N release $\leq$ 40%, which is easily achieved through proper handling. Substitution of uncoated urea with ESN will allow producers to seed-place N in a single-pass with rates that achieve N sufficiency.

Enhanced efficiency N fertilizer management

The wide range of environmental conditions resulted in a fairly diverse set of site-years that was representative of growing conditions for winter wheat in western Canada. Moreover, the range of growing conditions encountered in this study provided an adequate estimate of how N treatments as designed in the two experiments would affect winter wheat responses in western Canada. Of all the factors tested, varietal differences were most variable among sites, suggesting merit for future development of variety specific N management. Also, the control and the most inferior N form, UAN, appeared to be most sensitive to environment variation among sites. With regards to the remaining N treatments, where variety effects, and treatment nor variety by treatment interactions were noted to be deviant at select sites, these deviations were neither frequent nor consistent enough to indicate that average differences among N fertilizer forms and placement/timing would vary among sites. Furthermore, the sites where treatment deviations were detected were not the same sites noted as 'unique' sites from partial least squares analysis (all Lacombe). Productivity levels can vary considerably among soil zone and potentially affect responses to applied treatments. Yields among soils for both tests in this study were as follows: Brown = 2.6 Mg ha-1, Dark Brown = 4.2 Mg ha-1, and Black = 4.5 Mg ha-1. Based on our results, no conclusive evidence suggests that N management with respect to urea type and its placement or timing will differ among soil zones regardless of whether you consider productivity, quality, efficiency, or profitability of winter wheat. Therefore, we can conclude that Agrotain® and SuperU® may be applied during seeding operations and/or broadcast in-crop the next spring with reasonably low risk that there would be any yield-related penalty relative to a more typical urea side-banded at the time of seeding regardless of the winter wheat variety.

Similar results have been observed in unpublished work where yield results were in the order of SuperU® ≥ ENtrench® ≥ urea ≥ ESN®; the yield response to SuperU® was significantly higher than ESN®. For timing and placement, superior yields were observed when N was all-banded and least with a 30% banded/70% late fall in-crop application. A split application of N in-crop at Feekes 4 produced similar yields to all banded. Moreover, Agrotain Ultra® was superior to all other N sources with regards to wheat grain yield and agronomic efficiency.

Aside from seed-placed applications, which is where ESN**®** provided substantial improvements to seed safety, ESN**®** appears to release too slowly in the northern Great Plains. This is somewhat expected given that the specification of the polymer-coating are designed to be optimized for corn production in the Central Plains. However, proportions of it in side-banded (1:1 ratios with urea) systems improved yield in certain conditions.

Protein management for winter and spring wheat remains a concern for the industry. An aspect that warrants further investigation is how the influence of daily minimum temperatures identified by our PLS analysis may be used as a management tool to optimize grain protein concentration.

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