Optimizing seed quality and net returns through enhanced N management strategies for milling and general purpose winter wheat production in the Canadian prairies (N-release/placement/form/timing x Variety)

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BACKGROUND

The Canadian Wheat Board Select program requires a minimum standard protein content of 11.5% for Canada Western Red Winter Wheat (CWRW). Recent work at Lacombe and Lethbridge (Beres et al., 2010a; Beres et al., 2010b), and anecdotal reports from industry, indicate that this standard is difficult to meet. The Wheat Board has responded by lowering the minimum protein level to 11% in an effort to improve the consistent supply of winter wheat with this quality profile. The emergence of the ethanol feedstock market may negatively impact the select program if producers feel there is less risk and increased profitability in targeting starch production over protein production. Therefore, it is essential that a sustainable N management package is produced that optimizes protein performance using both novel and conventional forms of N fertilizer.

This project was designed to provide information that will increase the efficiency of nutrient management practices, which in turn improve the economic benefits to Canadian producers. Parallel treatments were evaluated in a number of sites to develop improved nutrient management practices suitable to specific agroecosystems, and to quantify interactions between management and environment. Nitrogen is the nutrient most commonly limiting to crop production in annual cropping systems, so the major focus of this study is on N management. The influence of N management on both milling and soft white varieties will be studied so that best management practices are developed for each class, which will allow for a balanced economic assessment of each production system. The objectives of this study are:

1) To determine the fertilizer management practices that improve protein content and increase the frequency of achieving Select grade of high yielding winter wheat.
2) Develop N management practices that optimize yield and starch characteristics in soft white winter wheat for use as an ethanol feedstock.
3) Apply a net return for each management practice and for starch vs. protein production so producers can fully assess which market best suits their farm business plan.

MATERIALS AND METHODS

Study Sites
Sites were established at Lethbridge and Lacombe, AB; Scott, Canora, and Swift Current, SK; and Brandon, MB. The work performed at Canora and Swift Current was contracted to the East Central Research Association and Wheatland Conservation Group. The Howden, MB site was abandoned as James Richardson International (Kelburn Farm Site) withdrew from the study indicating a lack of capacity to conduct agronomy work. Parallel treatments were established at each site and evaluated to develop improved nutrient management practices suitable to specific agroecosystems, and to quantify interactions between management and environment.

Study 1 (Test 291): Influence of Form and Placement on Protein and Starch Accumulation

<u>Experimental Design:</u>
Split Plot design (main plot = Variety (2); sub-plot = nitrogen form (14); total of 28 treatments)
Treatments

1. Two Varieties:
    a) AC Radiant (CWRW – milling quality Select variety)
    b) CDC Ptarmigan (General Purpose Soft white winter wheat – Ethanol feedstock)
2. Fourteen Nitrogen Management Treatments**:** (1X rated based on 80% soil test recommendation, sidebanded)
    a) Control: 0 N
    b) Urea[1] (uncoated): all sidebanded at time of seeding
    c) Urea (uncoated): all sidebanded at time of seeding
    d) Urea (uncoated): all broadcast in early spring
    e) Urea (uncoated): 1/2x sideband; 1/2x broadcast spring
    f) ESN[2]: all sidebanded at time of seeding
    g) ESN: all broadcast in early spring
    h) ESN: 1/2x sideband; 1/2x broadcast in spring
    i) SU[3]: all sidebanded at time of seeding
    j) SU: all broadcast in early spring
    k) SU: 1/2x sideband; 1/2x broadcast in spring
    l) Agrotain[4]: all sidebanded at time of seeding
    m) Agrotain: all broadcast in early spring
    n) Agrotain: 1/2x sideband; 1/2x broadcast spring

Urea[1]: 46-0-0
ESN[2]: polymer coated urea Environmentally Smart Nitrogen®
SU[3]: SuperU® - Super granulated urea with increased nitrogen stability ie. urease and nitrification inhibitor.
Agrotain[4]: Ammoniacal nitrogen stabilized with a urease inhibitor.
* An additional treatment of urea ammonium nitrate (28-0-0 UAN) was added at Lethbridge, Scott and Canora.

** All fertilizer was supplied by Agrium and Agrotain Itl.
*** Treatments 2 and 4-14 received 80% of the recommendation from Western Ag Labs PRS soil test system.
**** Treatment 1 received no N but levels of PKS will be applied based on the PRS soil test system.
***** Treatment 3 received 80% of the levels of NPKS based on the BodyCote soil test recommendation

Study 2 (Test 292): The influence of form and split application timing on protein accumulation.

<u>Experimental Design:</u>
Randomized Complete Block Design (16 N form and timing treatments; 4 replicates)
1. Sixteen Nitrogen Management Treatments**:** (1X rated based on 80% soil test recommendation, sidebanded)

a) Control: 0 N
b) Urea (uncoated): all sidebanded at time of seeding
c) Urea (uncoated):1/2x sideband; 1/2x b/c late fall
d) Urea (uncoated):1/2x sideband; 1/2x b/c early spring
e) Urea (uncoated):1/2x sideband; 1/2x b/c Early + 3wks
f) Urea (uncoated):1/2x sideband; 1/2x b/c Early + 6wks
g) ESN: all sidebanded at time of seeding
h) ESN:1/2x sideband; 1/2x b/c late fall
i) ESN: 1/2x sideband; 1/2x b/c in early spring
j) ESN: 1/2x sideband; 1/2x b/c Early +3wks
k) ESN: 1/2x sideband; 1/2x b/c Early + 6wks
l) SU: all sidebanded at time of seeding
m) SU:1/2x sideband; 1/2x b/c late fall
n) SU: 1/2x sideband; 1/2x b/c in early spring
o) SU: 1/2x sideband; 1/2x b/c Early + 3 wks
p) SU: 1/2x sideband; 1/2x b/c Early + 6 wks

Variety: Radiant (CWRW – milling quality select variety)

For All Experiments:

<u>Seeding operations:</u>
Fall Burnoff: Burnoff with glyphosate or Pre-Pass 24 to 48 hours prior to seeding at ½ litre/acre.

Seeding equipment:	9” ConservaPak
Seeding rate:	450 seeds/m^2 (Target density is 338 pl / m^2)
Seeding date:	Fall seeding should be done 1st week in September or earlier depending on environment.

<u>Fall Data Collection:</u>
1. Crop Emergence:

2. Soil Temperature: continuously measured with self logging buried sensors
3. Soil Moisture: at time of seeding

Spring & Summer Data Collection:
1. Plant Counts
2. Greenseeker Measurements: From Feekes 4 to fully emerged flag leaf (2-3 reading over the plots during that time frame).
3. Head Counts
4. Maturity Date
5. Crop Biomass
6. Grain Yield & % Moisture
7. Dockage
8. Kernel Weight
9. Grain Quality
10. Leaf Samples for Disease

Weed management:
Apply fall 2,4-D application when average leaf stage = 3 to 5; i.e., around mid-October. Apply spring in-crop Horizon™/Refine Extra™ for additional weed control.

Disease management:
Stratego™ was applied to control disease at sites where disease potential is high. Both varieties in Study 1 will be susceptible to leaf spot disease complex and rust. Therefore, monitor lower leaves and apply fungicides as required if degree of disease progression is such that leaf below flag appears vulnerable to infection.

Statistical Analysis:
Data were analyzed with the PROC MIXED procedure of SAS (Littell et al., 1996). The effects of replicate and site (location by year combinations) were considered random, and the effects of applied treatments were considered fixed. Contrasts were used to determine the statistical importance of certain comparisons among the applied treatments. A combination of variance estimates and P values were used to determine the importance of variance estimates for the random site by treatment interaction. Contrast statements were used to make comparisons. Treatment effects were declared significant at $P < 0.05$.

Information and code provided by Burgueno et al. (2001) was used to generate AMMI (additive main effects and multiplicative interaction) biplots for the host plant resistance and novel sources studies. Burgueno et al. (2001) also provided a framework to interpret information from AMMI biplots.

A grouping methodology, as previously described by Francis and Kannenberg (1978), was used to further explore treatment responses among sites. The mean and CV were estimated for each level of the treatment of interest across remaining treatments, sites, and replicates. Means were plotted against CV for each level of the treatment, and the overall mean of the treatments means and CVs was included in the plot to categorize the data biplot ordination area into four quadrants/categories: Group I: High mean, low variability (optimal); Group II:

High mean, high variability; Group III: Low mean, high variability (poor); and Group IV: Low mean, low variability. Additional descriptive tools will be employed after the final year is complete.

RESULTS AND DISCUSSION

For test 291, cultivar and N management main effect treatments significantly affected all variables, except for plant density/survival, and kernel wt. (Table 1). The interaction of cultivar and N treatment was not significant. CDC Ptarmigan yielded more, produced more heads per plant, and had lesser test wt. and protein conc. relative to AC Radiant (Table 2). Further exploration of the variety effect for grain yield indicated that variety means for each site were similar to overall variety means except at the 2007 sites (results not shown). For protein conc., by-site variety means were similar to variety means across all sites except the 2008 sites (results not shown). Despite, these apparent by-site varietal mean deviations from means averaged across sites, none of the aforementioned differences were statistically significant for the current analysis. For the effect of N treatment, the most prominent portion of this effect was the lesser response for the control relative to the other levels (Table 1 and Fig.1). Other significant N treatment differences were noted for yield and protein conc. Grain yield for spring broadcast levels or UAN levels of N treatment were less than for the other levels of N treatment. The UAN levels of N treatment resulted in less protein than for other levels of N treatment (Fig. 2).

For Test 292 (effect of timing, fertilizer form, and placement on Radiant), N management significantly affected, heads per plant, grain yield and protein conc. (Table 3). Like Test 291, the control resulted in lesser responses vs. other levels of N management (Figs. 3 and 4). Yield and protein conc. were less for fall-ESN treatments (Figs. 3 and 4). For both response variables, a couple of other N management levels (ESN-Sb and Urea-Sb+BC Fall for yield and SU-Sb+BC Fall for protein conc.) were part of the poor-response group.

Mean vs. CV biplots showed the treatment differences detected by the analysis of variance (Figs. 5 and 6). These biplots also revealed that the control was more variable for Test 291 yield and protein conc. (Fig. 5). Yield responses for UAN treatments were less variable for yield and more variable for protein conc. For Test 292, a split-application urea N treatment had similar yields to other top-yielding treatments, but varied less (an ‘optimal’ situation) (Fig. 6). Another trend that emerged from these biplots was that the ESN treatments often were less variable when compared with the SuperU treatments, especially for protein conc. In terms of both the mean and CV, ESN-sb and ESN-sb-bn treatments tended to separate from the main cluster of other treatments. The mean vs. CV biplots provided a unique view to assess of both the response level and risk of important winter wheat variables.

A few trends emerged for AMMI biplots derived from Test 291 grain yield and protein conc. data (Fig. 7). The most unique responses for the control were associated 2008 sites. The 2009 sites were more associated with distinct responses for SuperU and urea forms of the N treatment, and particularly urea-broadcast treatment. Yield responses for urea-REC tended to be unique at Brandon 2009. For protein conc., a group of sites (Scott 2009 most prominent) were associated with unique responses for the control. Protein conc. was particularly responsive for urea-Rec and SuperU-banded at Brandon 2008 and Lacombe 2009. AMMI biplots for Test 292 indicated unique grain yield responses occurred for two SuperU-sb treatments at Lethbridge 2007, Scott 2009, and Canora 2008 (Fig. 8). Not unlike Test 291, distinct control responses occurred for yield, but they occurred mainly at all Scott sites. Unique responses for protein conc. were most notable at Lethbridge, Scott, and 2008 sites. The control and ESN-sb treatments and one SuperU treatment were most discriminated at the aforementioned sites. The ANOVA did not indicate the site by treatment interactions were particularly notable. AMMI biplots, however, showed that winter wheat yield and protein conc. responded to select N treatments differently among sites.

Soil zones are one of the most distinguishable characteristics defining soil productivity across the Canadian Prairies. A preliminary assessment of average treatment responses for each soil zone indicated that varietal differences for Test 291 did not differ greatly with the exception of greater CDC Ptarmigan yields for the Black zone (Fig. 9). Protein conc. was clearly less for CDC Ptarmigan for all soil zones (Fig. 10). Also, UAN treatment yields and protein conc. often were equal to or greater than other treatments in the Black soil zone and lesser than other treatments in the Dark Brown soil zone (Figs. 9 and 10). For Test 292, most of the SuperU treatments often were equal to or greater than other treatments in the Dark Brown soil zone. The same advantage appeared not to occur in the other soil zones. Nothing clearly emerged for protein conc. treatment differences among soil zones. Future analysis hopefully will confirm these unique treatment effects among soil zones.

CONCLUSIONS

In terms of yield, the UAN form tended to be most inferior, and fall broadcasting of N seem to be an application method that should be avoided. Agrotain is showing that it may be the best N fertilizer form from a high-yield and consistency across environmental variation perspective. Also, split applications of N almost always provided maximum yields. It would appear that UAN form of N will provide consistently inferior protein conc. Moreover, UAN may not be able to meet the N demands for winter wheat growth and seed development in all but the Black soil zone; we have to remember that UAN treatments were not included at all sites. Future analysis will continue to explore the effect of environmental variability on treatment effects and investigate cause-effect models that utilize mid-season responses to predict yield outcomes when N management of winter wheat is varied.

ACKNOWLEDGEMENTS

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Table 1. ANOVA and non-orthogonal contrast results for Test 291 – Variety x N management.

Effect / Contrast	Spring density	Survival	Spikes plant^{-1}	Spikes m^{-2}	Yield	Kernel wt.	Test wt.	Protein
				(P value)				
Variety (V)	0.106	0.631	0.002	0.074	0.004	0.148	< 0.001	< 0.001
N treatment (N)	0.699	0.181	0.170	< 0.001	< 0.001	0.715	< 0.001	< 0.001
control vs. others	0.907	0.991	0.046	< 0.001	< 0.001	0.728	< 0.001	< 0.001
rec vs. others	0.780	0.003	0.217	0.203	0.078	0.580	0.568	0.009
rec vs. urea-sb	0.639	0.380	0.517	0.074	0.762	0.812	0.332	0.359
time/plac effect for esn	0.894	0.441	0.577	0.184	0.180	0.624	0.320	0.481
time/plac effect for nitrogain	0.271	0.446	0.214	0.337	0.842	0.995	0.360	0.997
time/plac effect for superu	0.323	0.561	0.369	0.235	0.965	0.995	0.761	0.266
time/plac effect for uan	0.163	0.708	0.087	< 0.001	0.402	0.965	0.638	0.839
time/plac effect for urea	0.885	0.008	0.265	0.196	0.386	0.971	0.336	0.261
urea vs. others effect for sb	0.509	0.456	0.157	0.285	0.034	1.000	0.415	0.052
urea vs. others for sb+sprbc	0.952	0.532	0.803	0.661	0.132	0.987	0.355	0.175
urea vs. others for sprbc	0.331	0.236	0.240	0.235	0.011	0.065	0.387	0.030
V x N	0.801	0.993	0.745	0.544	0.492	0.526	0.226	0.761
V x control vs. others	0.505	0.716	0.474	0.907	0.011	0.526	0.002	0.725
V x rec vs. others	0.374	0.121	0.151	0.290	0.768	0.872	0.680	0.605
V x rec vs. urea-sb	0.189	0.327	0.368	0.717	0.646	0.989	0.953	0.400
V x time/plac effect for esn	0.441	0.704	0.588	0.037	0.706	0.993	0.768	0.633
V x time/plac effect for nitrogain	0.741	0.787	0.842	0.805	0.445	0.960	0.768	0.472
V x time/plac effect for superu	0.176	0.837	0.180	0.281	0.518	0.958	0.361	0.877
V x time/plac effect for uan	0.527	0.973	0.323	0.770	0.872	0.990	0.792	0.989
V x time/plac effect for urea	0.332	0.225	0.355	0.666	0.790	0.996	0.643	0.694
V x urea vs. others effect for sb	0.434	0.991	0.304	0.051	0.243	0.998	0.480	0.210
V x urea vs. others for sb+sprbc	0.450	0.798	0.942	0.933	0.749	0.999	0.223	0.634
V x urea vs. others for sprbc	0.984	0.981	0.337	0.939	0.856	0.022	0.552	0.346
				(Variance estimate)				
Site (S)	4658	1786	0.949	21165	3461841	6.81	14.5	107
S x V (%)^{z}	13*	13	8	7*	4*	24	2*	17*
S x V x N (%)^{z}	2	7	8**	1	2**	12	1**	7**

^{z} Percentage of the variance associated with the random effect of site by variety or site by variety by N treatment divided by the sum of the total variance associated with the effect of site. The statistical significance of variance estimate is indicated immediately to the right of the percentage as follows: '*' = 0.05 ≥ P value ≥ 0.01; and '**' = P value < 0.01.

Table 2. Influence of variety on winter wheat responses for Test 291 – Variety x N management.

Variety	Spring density	Survival	Spikes $plant^{-1}$	Spikes m^{-2}	Yield	Kernel wt.	Test wt.	Protein
AC Radiant	223	111	2.13	458	4375	37.2	78.5	103
CDC Ptarmigan	204	115	2.70	494	4941	36.1	75.3	89
$LSD_{0.05}$	23	19	0.32	36	349	1.7	0.5	5

Table 3. ANOVA and non-orthogonal contrast results for Test 292 – N management: form/timing.

Effect / Contrast	Spring density	Survival	Spikes plant^{-1}	Spikes m^{-2}	Yield	Kernel wt.	Test wt.	Protein
				(P value)				
N treatment (N)	0.237	0.654	0.041	0.394	< 0.001	0.497	0.065	< 0.001
control vs. others	0.747	0.688	0.078	0.005	< 0.001	0.507	0.002	< 0.001
time app effect for esn	0.233	0.976	0.545	0.174	0.523	0.049	0.237	0.095
time app effect for su	0.445	0.729	0.063	0.971	0.415	0.723	0.304	0.077
time app effect for urea	0.101	0.097	0.086	0.990	0.599	0.957	0.439	0.091
urea vs. others for sb	0.539	0.471	0.092	0.782	0.675	0.954	0.512	0.212
urea vs. others for sb+bc espr	0.825	0.888	0.472	0.429	0.701	0.217	0.097	0.972
urea vs. others for sb+bc fall	0.791	0.952	0.937	0.305	0.723	0.771	0.759	0.877
urea vs. others for sb+bc lspr	0.665	0.727	0.591	0.735	0.155	0.358	0.672	0.259
urea vs. others for sb+bc mspr	0.417	0.075	0.176	0.785	0.374	0.673	0.990	0.972
				(Variance estimate)				
Site (S)	2298	3821	0.95	6160	1993535	11.5	6.01	273
S x N (%)[z]	5**	20**	7**	5**	3**	3**	1**	6**

[z] Percentage of the variance associated with the random effect of site by N treatment divided by the sum of the total variance associated with the effect of site. The statistical significance of variance estimate is indicated immediately to the right of the percentage as follows: '*' = 0.05 ≥ P value ≥ 0.01; and '**' = P value < 0.01.

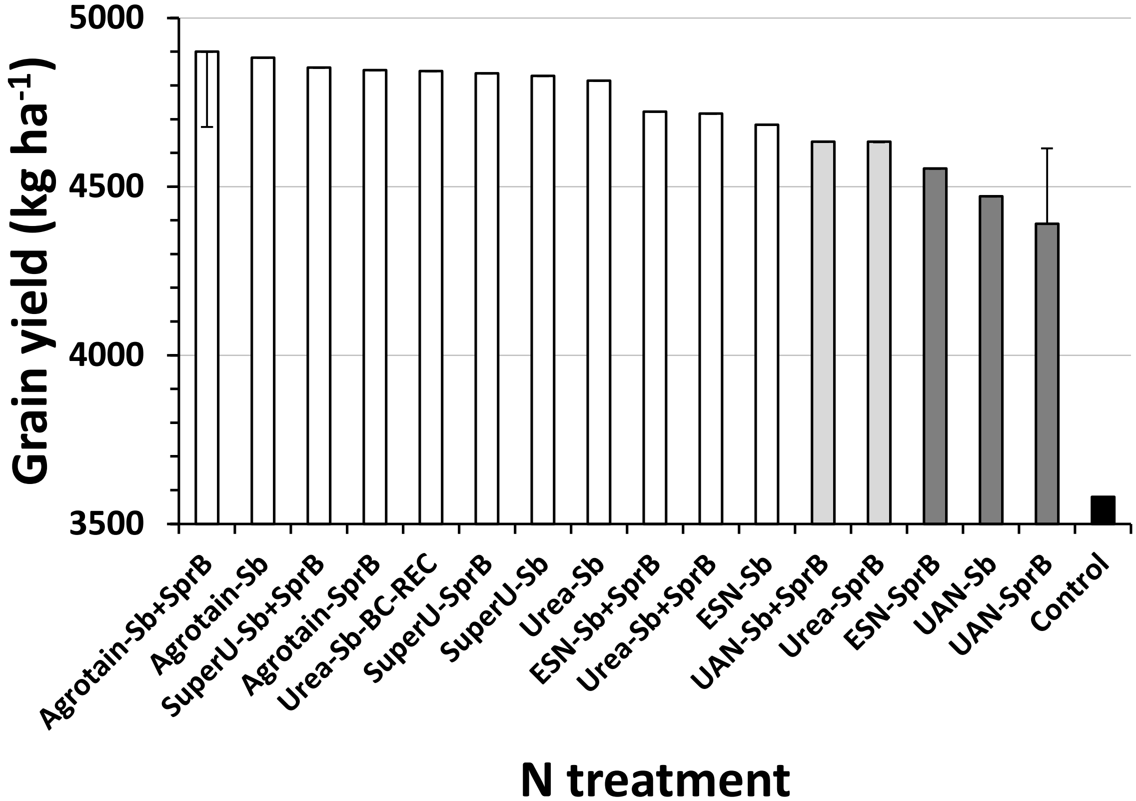


Fig. 1. Influence of fertilizer form, placement, and timing on winter wheat grain yield for Test 291 – Variety x N management. Means are in ranked order. Error bars represent $LSD_{0.05}$. Bar shading represents significantly different groups of means. Abbrev: ESN, polymer-coated urea; Agrotain, urease inhibitor; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast; REC, rate based on BodyCote labs recommendation.

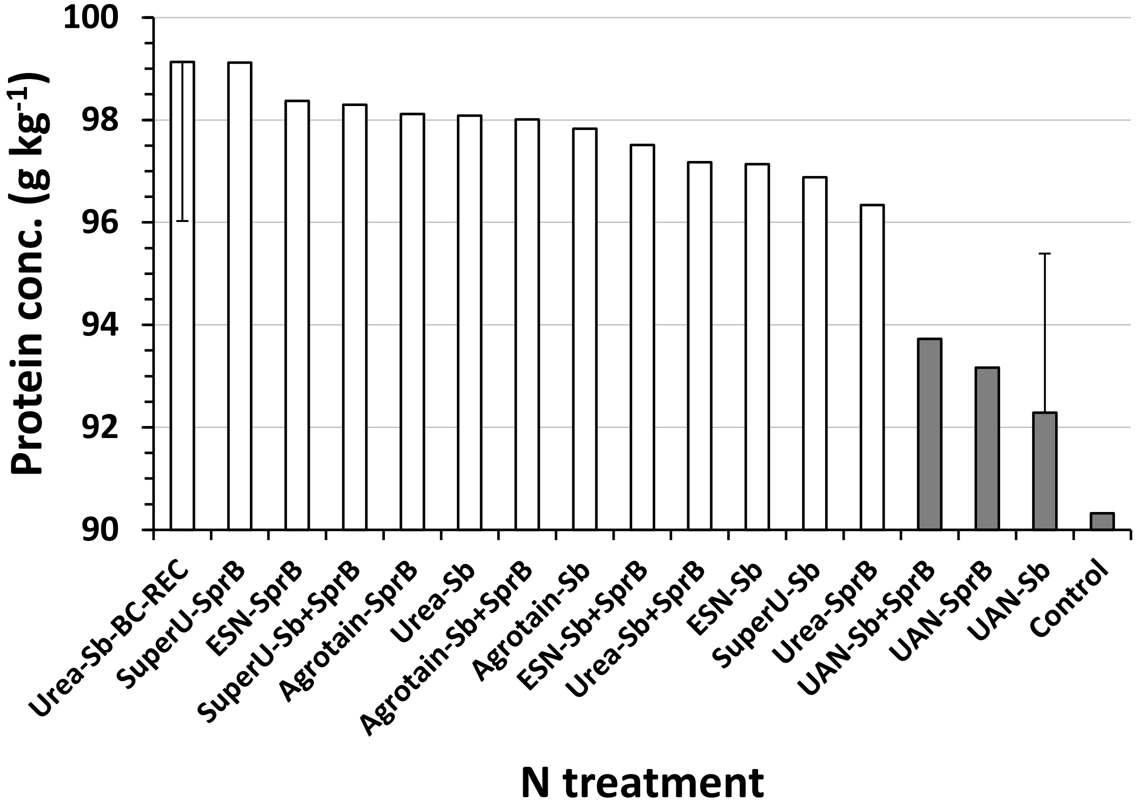


Fig. 2. Influence of fertilizer form, placement, and timing on winter wheat protein conc. for Test 291 – Variety x N management. Means are in ranked order. Error bars represent $LSD_{0.05}$. Bar shading represents significantly different groups of means. Abbrev: ESN, polymer-coated urea; Agrotain, urease inhibitor; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast; REC, rate based on BodyCote labs recommendation.

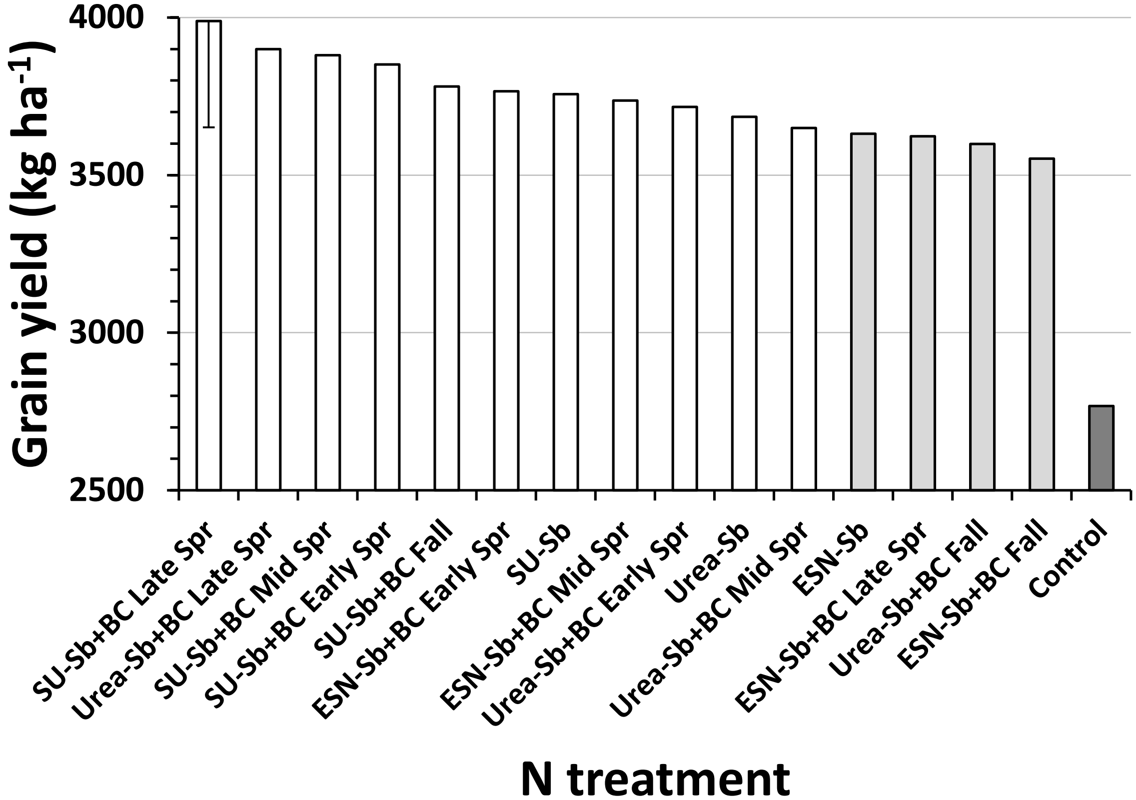


Fig. 3. Influence of fertilizer form, placement, and timing on winter wheat grain yield for Test 292 – N management: form/timing. Means are in ranked order. Error bars represent $LSD_{0.05}$. Bar shading represents significantly different groups of means. Abbrev: ESN, polymer-coated urea; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast.

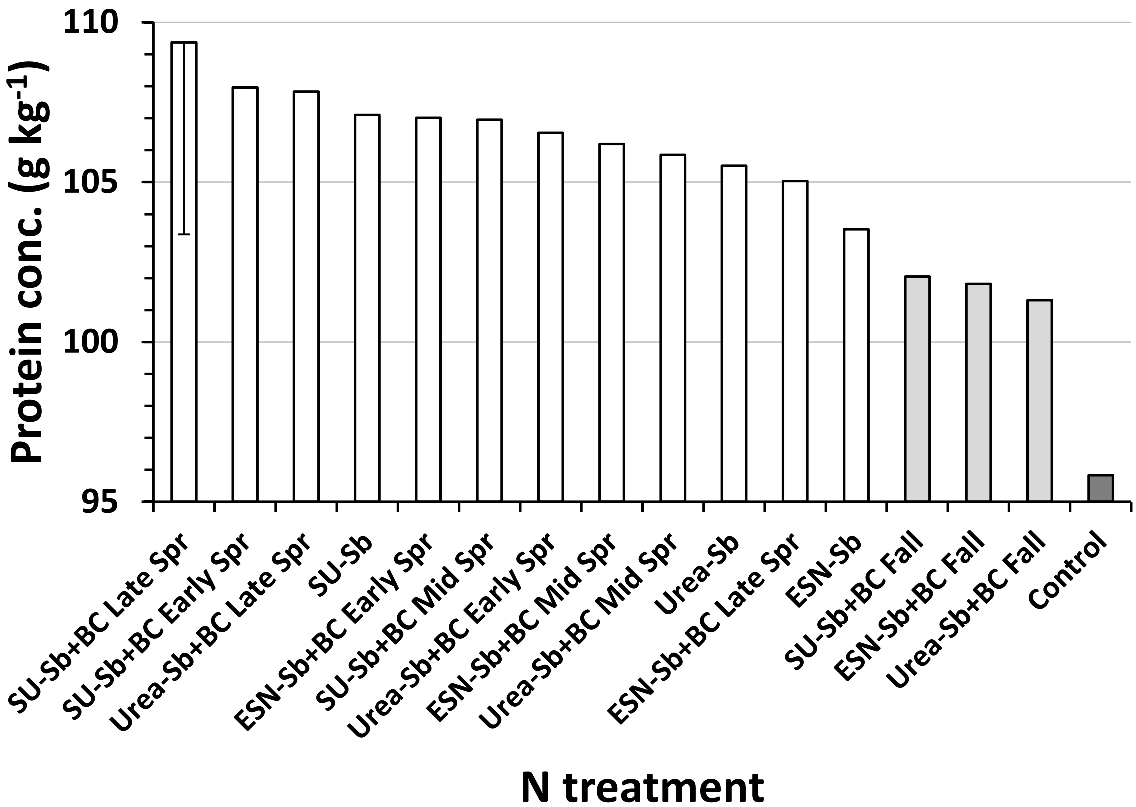


Fig. 4. Influence of fertilizer form, placement, and timing on winter wheat protein conc. for Test 292 –N management: form/timing. Means are in ranked order. Error bars represent $LSD_{0.05}$. Bar shading represents significantly different groups of means. Abbrev: ESN, polymer-coated urea; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast.

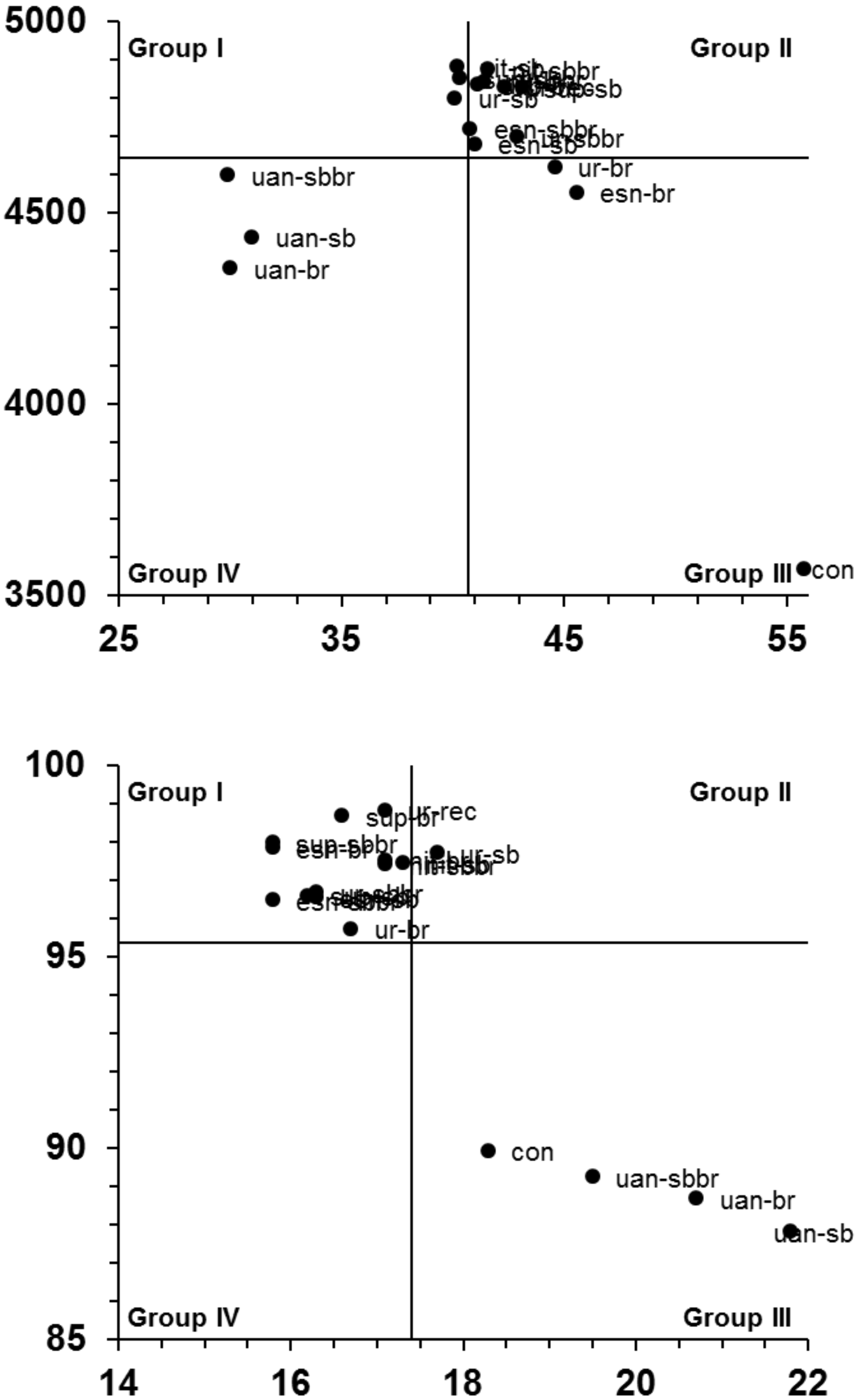


Fig. 5. Mean vs. CV biplot for winter wheat responses, Test 291 – Variety x N management. Yield (top biplot) units: kg ha^{-1} and protein conc. (bottom biplot) units: g kg^{-1}.

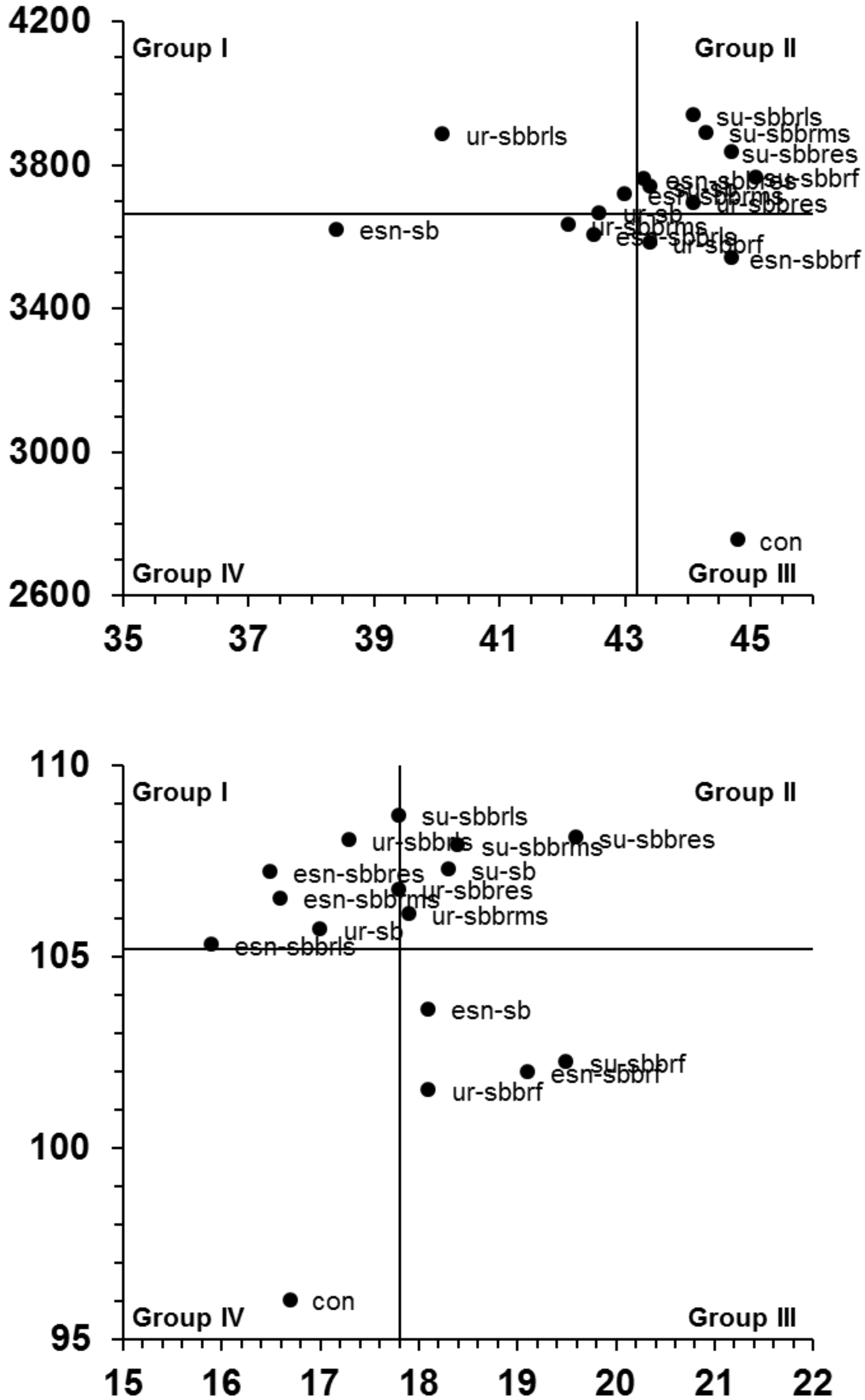


Fig. 6. Mean vs. CV biplot for winter wheat responses, Test 291 – N management: form/timing. Yield (top biplot) units: kg ha^{-1} and protein conc. (bottom biplot) units: g kg^{-1}.

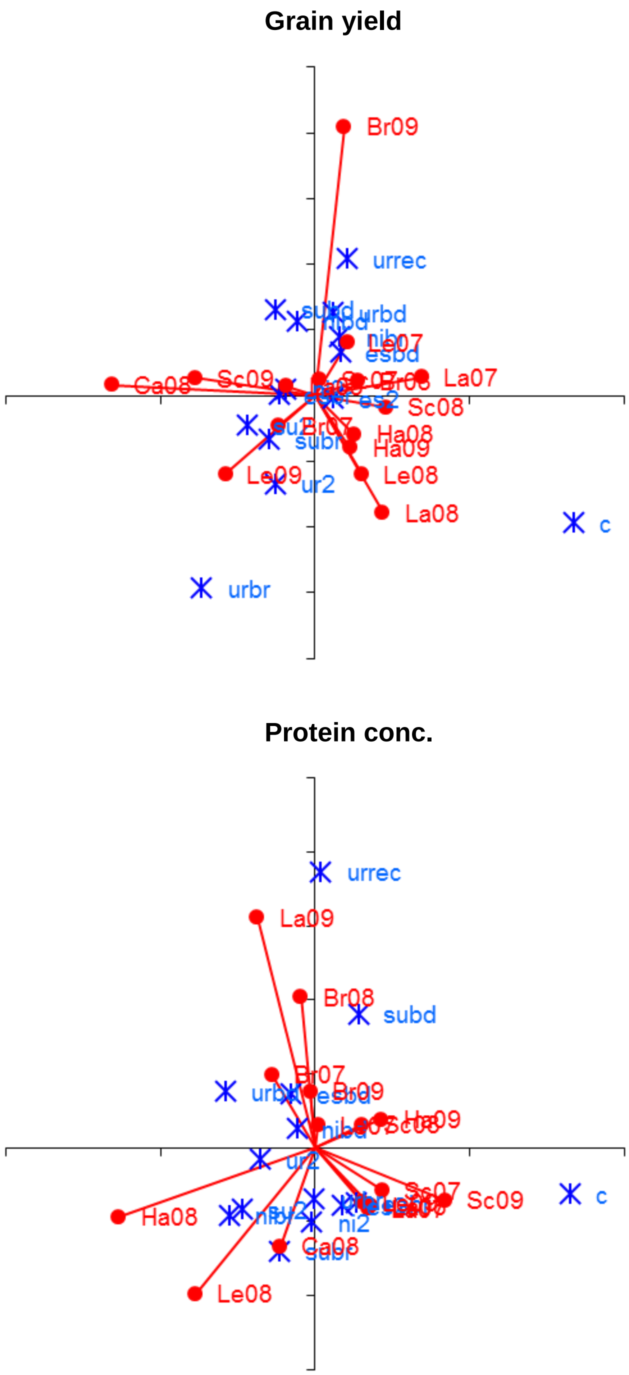
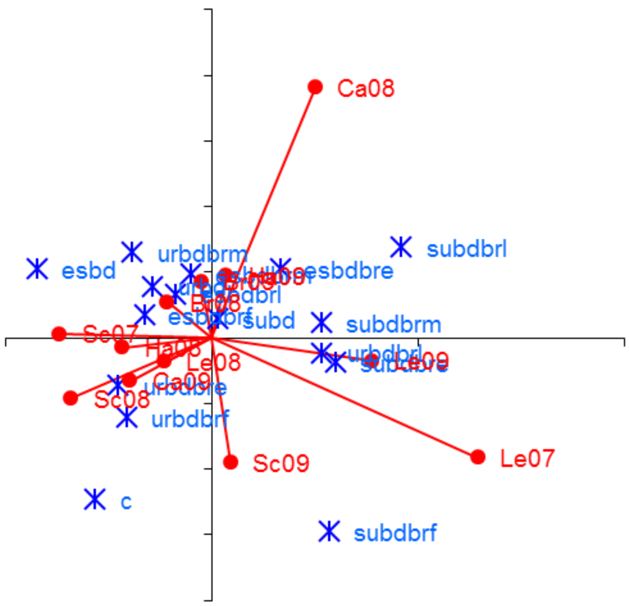


Fig. 7. AMMI biplot to describe variability of winter wheat treatment responses for Test 291 – Variety x N management.

Grain yield



Protein conc.

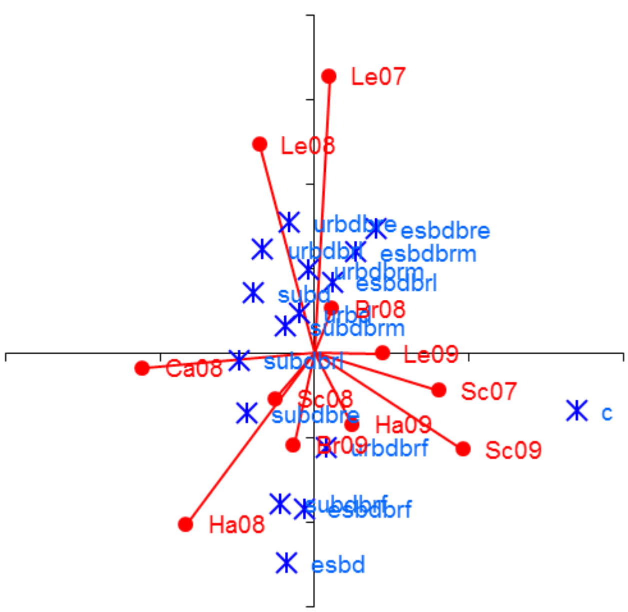


Fig. 8. AMMI biplot to describe variability of winter wheat treatment responses for Test 292 – N management: form/timing.

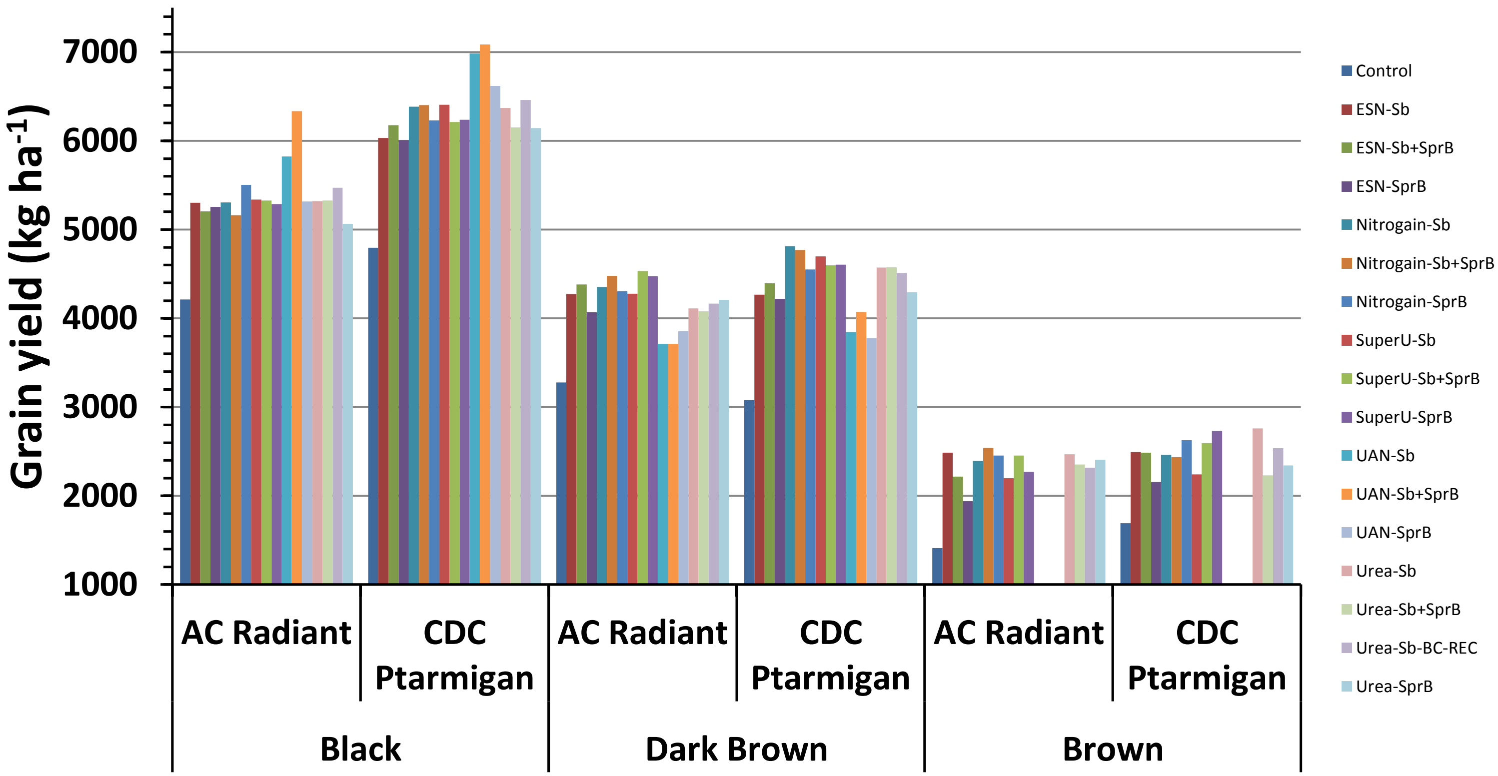


Fig. 9. Influence of fertilizer form, placement, and timing on winter wheat grain yield among soil zones for Test 291 – Variety x N management. Means are weighted estimates derived directly from raw data. Abbrev: ESN, polymer-coated urea; Agrotain, urease inhibitor; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast; REC, rate based on BodyCote labs recommendation.

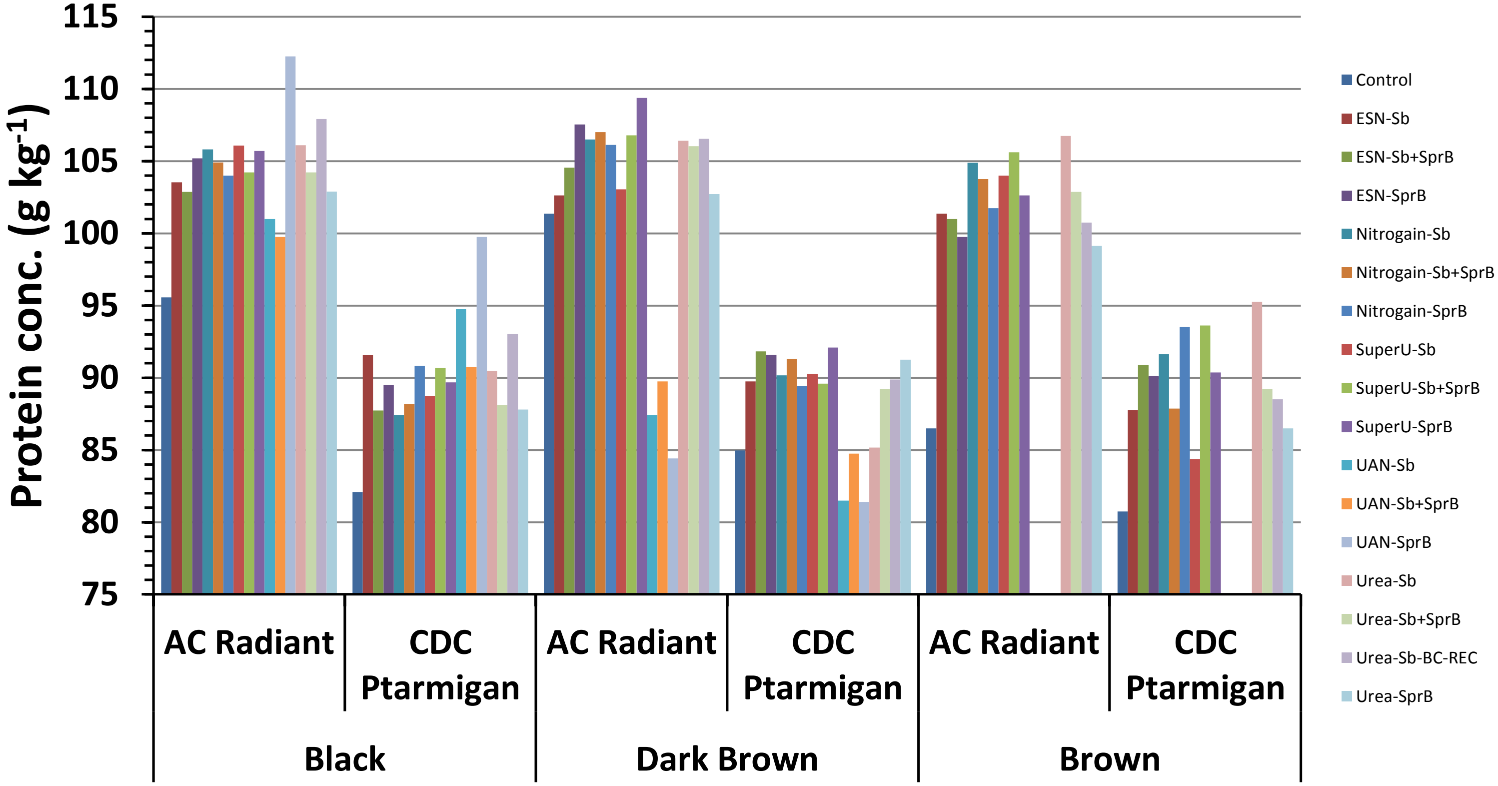


Fig. 10. Influence of fertilizer form, placement, and timing on winter wheat protein conc. among soil zones for Test 291 – Variety x N management. Means are weighted estimates derived directly from raw data. Abbrev: ESN, polymer-coated urea; Agrotain, urease inhibitor; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast; REC, rate based on BodyCote labs recommendation.

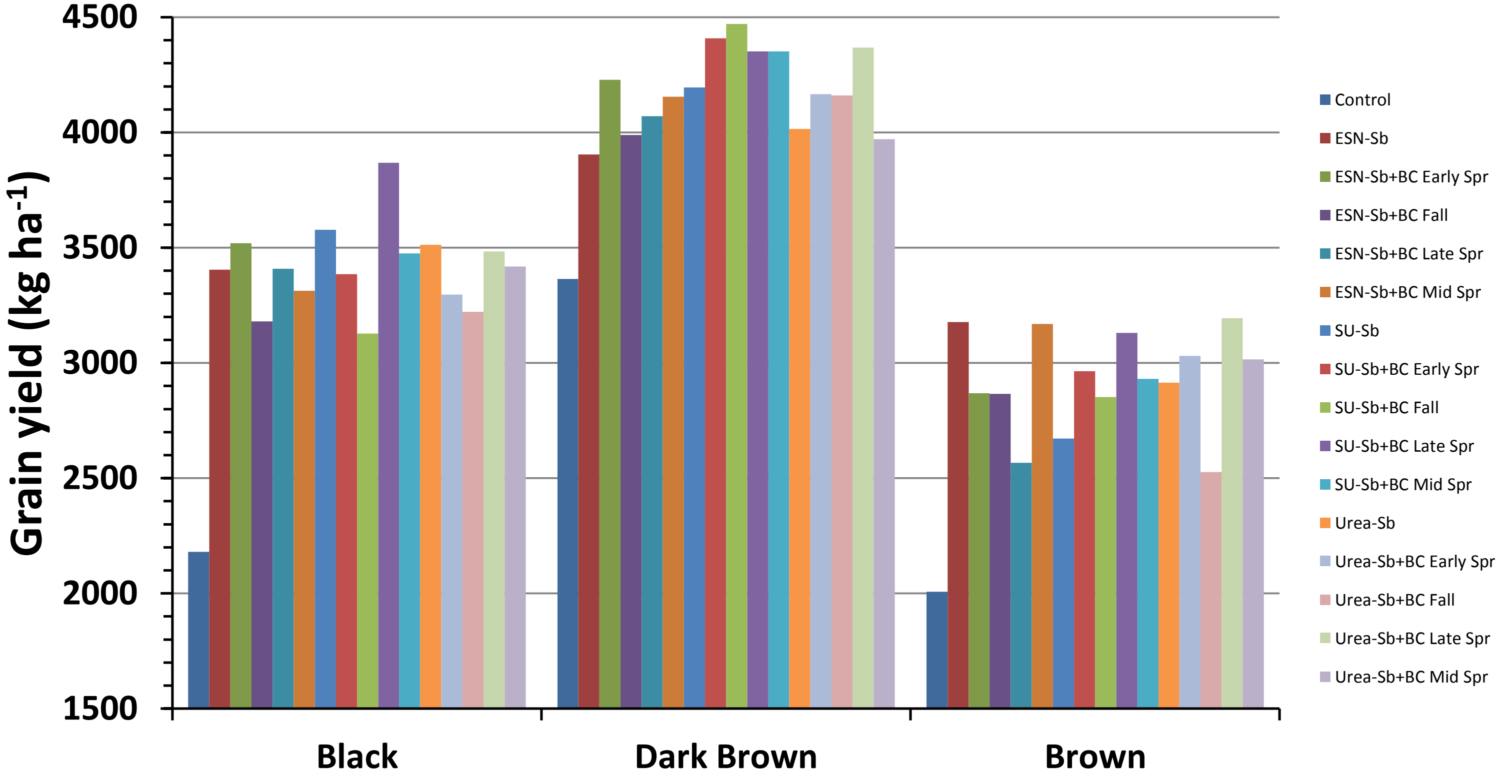


Fig. 11. Influence of fertilizer form, placement, and timing on winter wheat grain yield among soil zones for Test 292 – N management: form/timing. Means are weighted estimates derived directly from raw data. Abbrev: ESN, polymer-coated urea; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast.

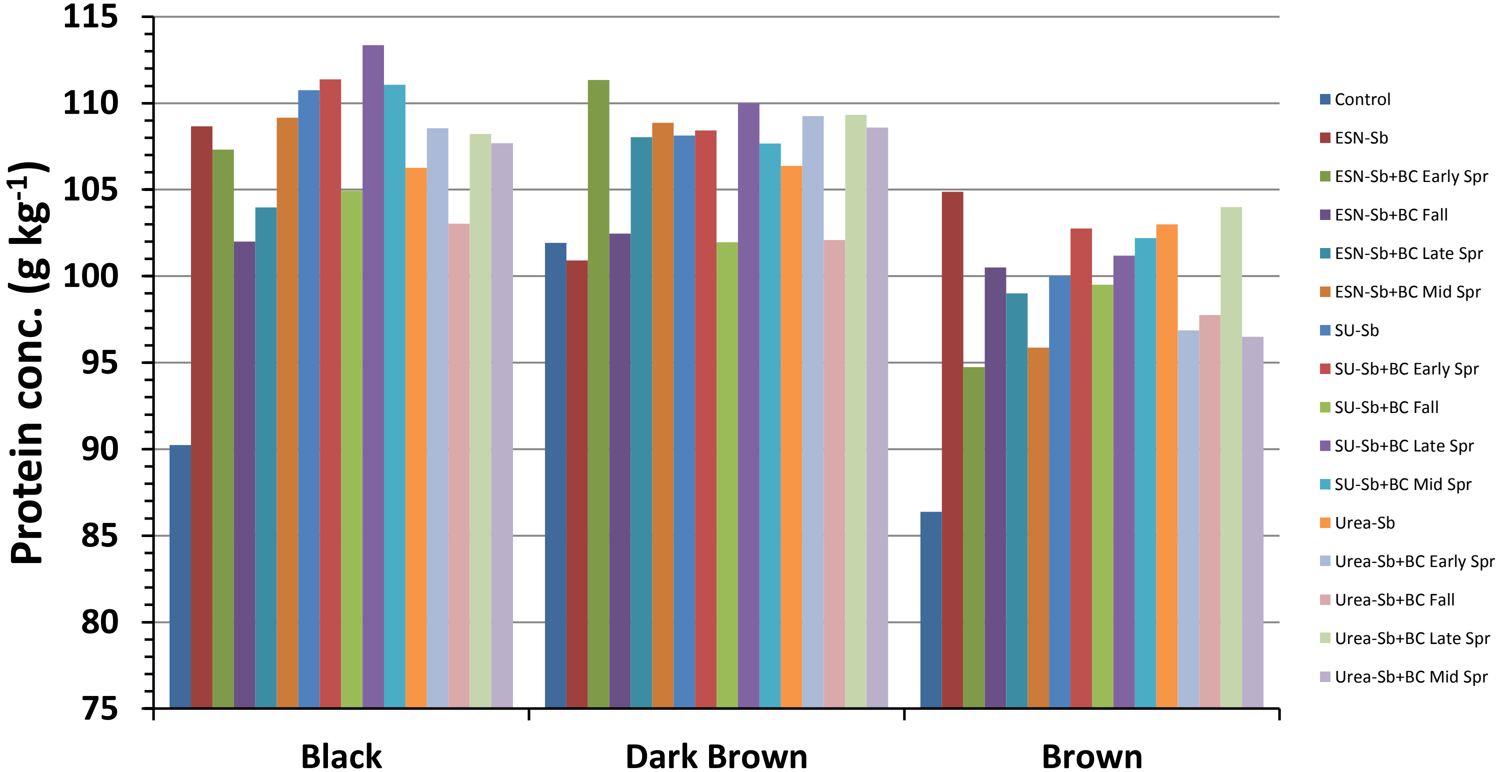


Fig. 12. Influence of fertilizer form, placement, and timing on winter wheat protein conc. among soil zones for Test 292 – N management: form/timing. Means are weighted estimates derived directly from raw data. Abbrev: ESN, polymer-coated urea; SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; Sb, sideband; SprB, spring broadcast.