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, and anecdotal reports from industry, indicates 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 will provide information that will increase the efficiency of nutrient management practices to improve the economic benefits to Canadian producers. Parallel treatments will be 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

Experimental Design

Sites will be established at Lethbridge and Lacombe, AB; Scott, Canora, and Swift Current, SK; and Brandon, MB. The work performed at Canora and Swift Current will be contracted to the local Agri-Arm East Central Research Association. Parallel treatments will be 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

Split Plot design (main plot = Variety (2); sub-plot = nitrogen form(14); total 28 treatments)
Treatments

1. Two Varieties:
   a) 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) will be added at Lethbridge, Scott and Canora.

All fertilizer will be supplied by Agrium and Agrotain Itl.

*** Treatments 2 and 4-14 will receive 80% of the recommendation from Western Ag Labs PRS soil test system.
**** Treatment 1 receives no N but levels of PKS will be applied based on the PRS soil test system.
***** Treatment 3 will receive 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.

Experimental Design:

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:
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.

Fall Data Collection:
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 ie. around mid-October. Apply spring in-crop Horizon™/Refine Extra™ for additional weed control.

Disease management:

Stratego™ to be 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. Site-specific BLUPs (best linear unbiased predictors) were used to estimate and compare variety and N treatment effects among sites in different soil zones (Brown, Dark Brown, and Black) sites (Littell et al. 2002). Contrast and estimate statements were used to make the aforementioned comparisons and estimate BLUPs for the different combinations applied treatments for each soil zone. Treatment effects were declared significant at $P < 0.05$.

An extension of the mixed model described in the preceding paragraph was implemented to assess important site interactions with variety and N treatment (Littell et al. 2002). For the analysis, a covariable was created from the precipitation and temperature data for each site. Interactions between the covariable and combinations of variety/N treatment with were tested to determine if precipitation and temperature variability across sites explained the site by variety/N treatments interactions. Statistically significant ($P < 0.05$) covariable interactions and a notable reduction for the site by variety/N treatment interaction variance estimates were considered to be prerequisites to further examine mean responses at different levels of precipitation and temperature. The treatment means were estimated at a low, average, and high level of the covariable to examine how treatment effects varied among sites.

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

Data was successfully captured at all locations in 2008 and 2009 with the exception of Test 292 at Brandon in 2008. The Howden, MB site was abandoned as Jame Richardson International (Kelburn Farm Site) withdrew from the study indicating a lack of capacity to conduct agronomy work.

In test 291, cultivar and N management main effect treatments significantly influenced grain yield, test weight and protein concentration (Table 1). Cultivar selection did not influence spikes per m^2, but there was a difference between cultivars in spikes per plant, which was also weakly effected by N management. In Test 292 (effect of timing, fertilizer form, and placement on Radiant), grain yield and protein concentration were significantly influenced by N management (Table 2).

Grain yield results to date for test 291 are summarized in Fig. 1. The values averaged over cultivar generally fall within similar statistical significance; and further exploratory analysis in Fig.2ab indicates that the UAN provided more consistency with respect to grain yield, however, yield potential was also consistently lower. Timing and placement effects indicate a similar pattern of reduced yield when all fertilizer was applied in spring, with the exception of SuperU. Generally, the split application vs. all fertilizer banded at seeding produced similar grain yield. In test 292, a split application involving a fall application had lower yield in most forms except urea (Fig. 3), and produced unstable protein levels below the 11% minimum standard for Select CWRW (Fig. 4 and Fig. 5).

CONCLUSIONS

Results are preliminary and patterns could change after the third and final year is completed. Most forms have produced similar outcomes but the UAN form requires more research, particularly treatments incorporating stabilizers as the market share of 1/3 liquid indicates a desire by producers to use liquid N. Fall applications of N should be avoided, particularly if higher protein is desirable. Future analyses will explore relationships between environmental patterns and crop response to nutrient managements.

ACKNOWLEDGEMENTS

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Table 1. ANOVA and non-orthogonal contrast results for Test 291 - Cultivar x N mgmt.

Effect	Contrast	Spring emerg plants m^{-2}	Survival	Grain Yld	Spikes $plant^{-1}$	Spikes m^{-2}	kwt g 1000^{-1}	twt kg hL^{-1}	Protein %
					P value				
Variety		0.144	0.563	**0.035**	**0.014**	0.207	0.191	**< 0.001**	**< 0.001**
N Treatment		0.787	0.348	**< 0.001**	0.089	**< 0.001**	0.782	**0.006**	**< 0.001**
Variety*trt		0.784	0.978	0.619	0.698	0.179	0.594	0.683	0.813
	Control	0.363	0.743	0.260	0.042	0.149	0.314	**< 0.001**	**0.001**
	ESN-Sb	**0.024**	0.524	0.202	0.037	0.260	0.423	**< 0.001**	**0.002**
	ESN-Sb+SprB	0.330	0.751	**0.059**	0.105	0.157	0.310	**< 0.001**	**0.002**
	ESN-SprB	0.173	0.945	0.198	0.006	0.679	0.440	**< 0.001**	**< 0.001**
	Nitrogain-Sb	0.545	0.773	**0.018**	0.305	0.156	0.342	**< 0.001**	**< 0.001**
	Nitrogain-Sb+SprB	0.167	0.392	**0.019**	0.063	0.161	0.527	**< 0.001**	**< 0.001**
	Nitrogain-SprB	0.102	0.811	0.233	0.172	0.711	0.465	**< 0.001**	**< 0.001**
	SuperU-Sb	0.434	0.599	**0.041**	0.050	0.156	0.593	**< 0.001**	**< 0.001**
	SuperU-Sb+SprB	0.124	0.927	0.096	0.224	0.083	0.423	**< 0.001**	**< 0.001**
	SuperU-SprB	0.559	0.918	0.134	0.281	0.902	0.504	**< 0.001**	**< 0.001**
	UAN-Sb	0.356	0.871	**0.059**	0.613	0.479	0.574	**< 0.001**	**0.044**
	UAN-Sb+SprB	0.807	0.795	**0.026**	0.499	0.609	0.585	**< 0.001**	**0.041**
	UAN-SprB	0.206	0.960	0.095	0.004	0.809	0.629	**< 0.001**	**0.022**
	Urea-Sb	0.820	0.340	**0.008**	0.187	0.089	0.364	**< 0.001**	**< 0.001**
	Urea-Sb+SprB	0.345	0.503	0.075	0.009	0.764	0.426	**< 0.001**	**< 0.001**
	Urea-Sb-BC-REC	0.083	0.066	**0.037**	0.373	0.028	0.394	**< 0.001**	**< 0.001**
	Urea-SprB	0.164	0.653	**0.048**	0.006	0.143	0.006	**< 0.001**	**0.001**
	AC Radiant	0.766	1.000	**< 0.001**	0.749	**0.019**	1.000	0.460	**< 0.001**
	CDC Ptarmigan	0.804	0.155	**< 0.001**	0.075	**< 0.001**	0.085	**0.014**	**0.003**
	control vs. others	0.817	0.975	**< 0.001**	0.177	**< 0.001**	0.940	**< 0.001**	**< 0.001**
	rec vs. others	0.631	**0.006**	0.111	0.699	0.129	0.714	0.259	0.106
	urea vs. others - sb	0.786	0.731	0.126	0.740	0.129	1.000	0.595	0.129
	urea vs. others - sb+sprbc	0.745	0.484	0.617	0.808	0.474	0.997	0.574	0.344
	urea vs. others - sprbc	0.577	0.516	0.143	0.215	0.130	0.064	0.640	0.132
	time app - urea	0.905	0.138	0.535	0.278	0.508	**0.015**	0.611	0.584
	time app - uan	0.721	0.960	0.594	0.382	**0.017**	0.979	0.443	**0.015**
	time app - superu	0.801	0.899	0.372	0.430	0.227	0.994	0.279	0.025
	time app - nitrogain	0.629	0.545	0.829	0.554	0.635	0.993	0.981	0.561
	time app - esn	0.556	0.568	**0.041**	0.772	0.308	0.993	0.935	0.982
	var x control vs. others	0.718	0.976	0.119	0.781	0.489	0.673	**0.025**	0.742
	var x rec vs. others	0.391	0.080	0.814	0.268	**0.058**	0.780	0.220	0.427
	var x urea vs. others - sb	0.131	0.988	0.333	0.823	**0.031**	0.998	0.533	0.209
	var x urea vs. others - sb+sprbc	0.913	0.798	0.741	0.740	0.632	0.999	0.695	0.505
	var x urea vs. others - sprbc	0.547	0.865	0.831	0.523	0.992	**0.024**	0.489	0.428
	var x time app - urea	0.237	0.385	0.367	0.382	0.313	**0.007**	0.919	0.502
	var x time app - uan	0.693	0.988	0.867	0.119	0.928	0.998	0.723	0.963
	var x time app - superu	0.580	0.885	0.735	0.711	0.224	0.980	0.335	0.942
	var x time app - nitrogain	0.538	0.865	0.173	0.770	0.479	0.970	0.642	0.695
	var x time app - esn	0.367	0.753	0.632	0.609	**0.037**	0.980	0.935	0.614
	rec vs. urea-sb	0.690	0.295	0.528	0.619	**0.052**	0.994	0.428	0.681
	var x rec vs. urea-sb	**0.045**	0.480	0.366	0.716	0.590	0.966	0.556	0.689
					Variance estimate				
	Intercept	4214	1862	4511279	0.391	25387	6.40	9.19	81.0
	Variety	937	356	197602	0.113	2219	3.19	0.27	35.2
	Variety*trt	186	0	48697	0.074	0	1.94	0.13	10.5
	site*variety (% of total)	18*	16	4*	20*	8*	28	3*	28*
	site*variety*trt (% of total)	3*	—	1**	13**	—	17	1**	8**

Comparison of varieties for each trt.
Overall comparison of trt for each varieties.
Specific contrasts.
Percentage of the variance associated with the random effect of site*variety or site*variety*trt divided by the sum of the total variance associated with the effect of site. The statistical significance of variance estimates is indicated immediately to the right of the percentage as follows: "*" = 0.05 ≥ P value ≥ 0.01; and "**" = P value < 0.01.

Table 2. ANOVA and non-orthogonal contrast results for Test 292 - Effect of timing, form, and placment on Radiant winter wheat.

Effect	Contrast	Spring emerg plants m^{-2}	Survival	Grain Yld	Spikes $plant^{-1}$	Spikes m^{-2}	kwt g 1000^{-1}	twt kg hL^{-1}	Protein %
N mgmt		0.485	0.542	**< 0.001**	0.066	0.357	0.630	0.436	**< 0.001**
	control vs. others	0.927	0.747	**< 0.001**	0.340	**0.012**	0.471	**0.015**	**< 0.001**
	urea vs. others - sb	0.387	0.449	0.910	**0.012**	0.501	0.993	0.774	0.211
	place comp - urea	0.292	0.067	0.488	0.100	0.927	0.878	0.363	0.134
	place comp - esn	0.395	0.979	0.818	0.608	0.086	0.095	0.732	0.190
	urea vs. others - sb+bc espr	0.574	0.863	0.281	0.191	0.356	0.588	0.182	0.932
	urea vs. others - sb+bc fall	0.797	0.953	0.903	0.939	0.312	0.656	0.586	0.828
	urea vs. others - sb+bc lspr	0.881	0.656	0.265	0.767	0.664	0.895	0.742	0.359
	urea vs. others - sb+bc mspr	0.538	**0.046**	0.472	0.170	0.878	0.921	0.673	0.912
	place comp - su	0.552	0.688	0.651	0.096	0.948	0.627	0.700	0.155
					Variance estimate				
	site	1331	5122	1247396	0.899	7170	5.80	4.01	224.42
	site*trt	220	1430	38909	0.034	263	0.47	0.01	19.47
	site*trt (% of total)	**14***	**22***	3*	4	4*	7**	0	8**

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

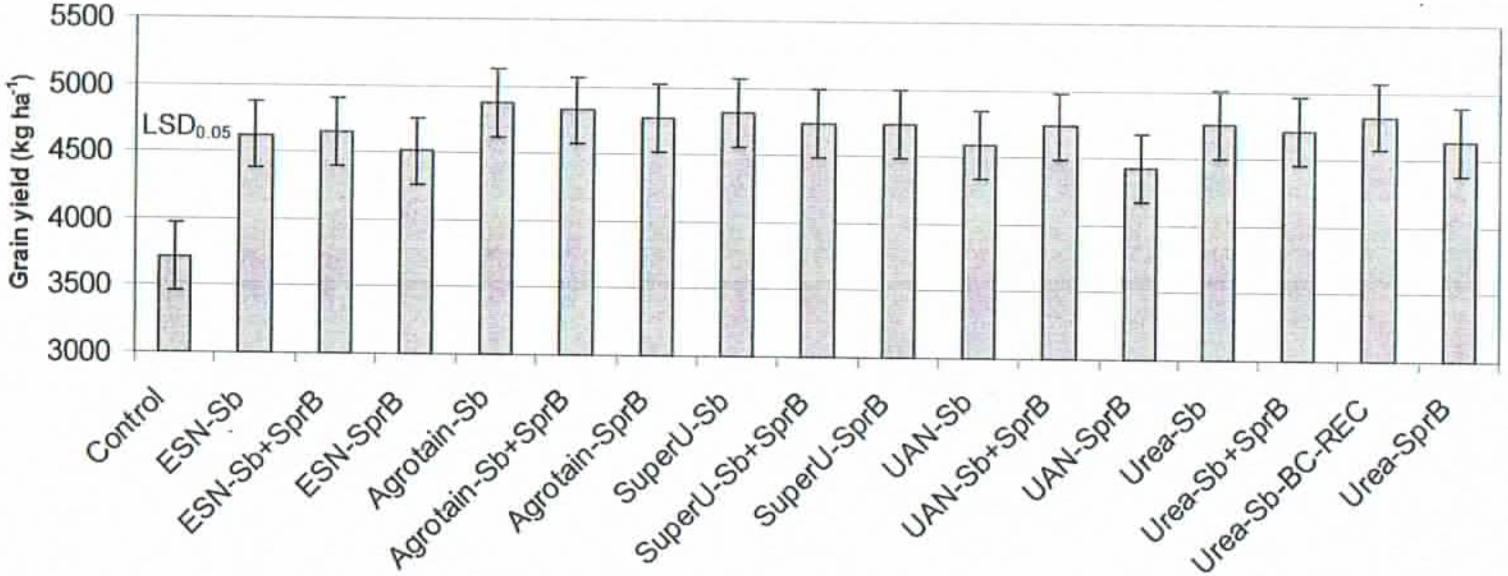


Fig. 1. **Influence of fertilizer form, placement, and timing on winter wheat. Abbrev: ESN, polymer-coated urea; Agrotain, urease inhibitor, SU, SuperU, urease/nitrification inhibitor; UAN, urea ammonium nitrate; sb, sideband; SprB, spring broadcast.**

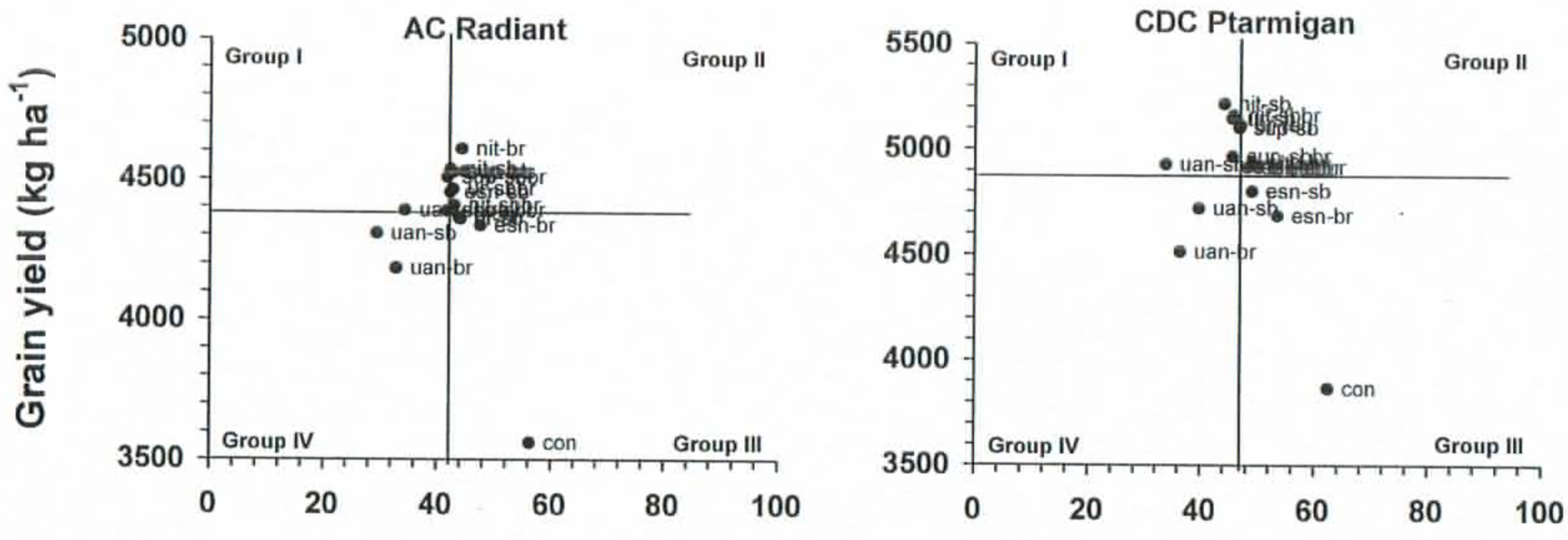


Fig. 2 ab. Grain yield response of AC Radiant and CDC Ptarmigan to fertilizer form, placement, and timing

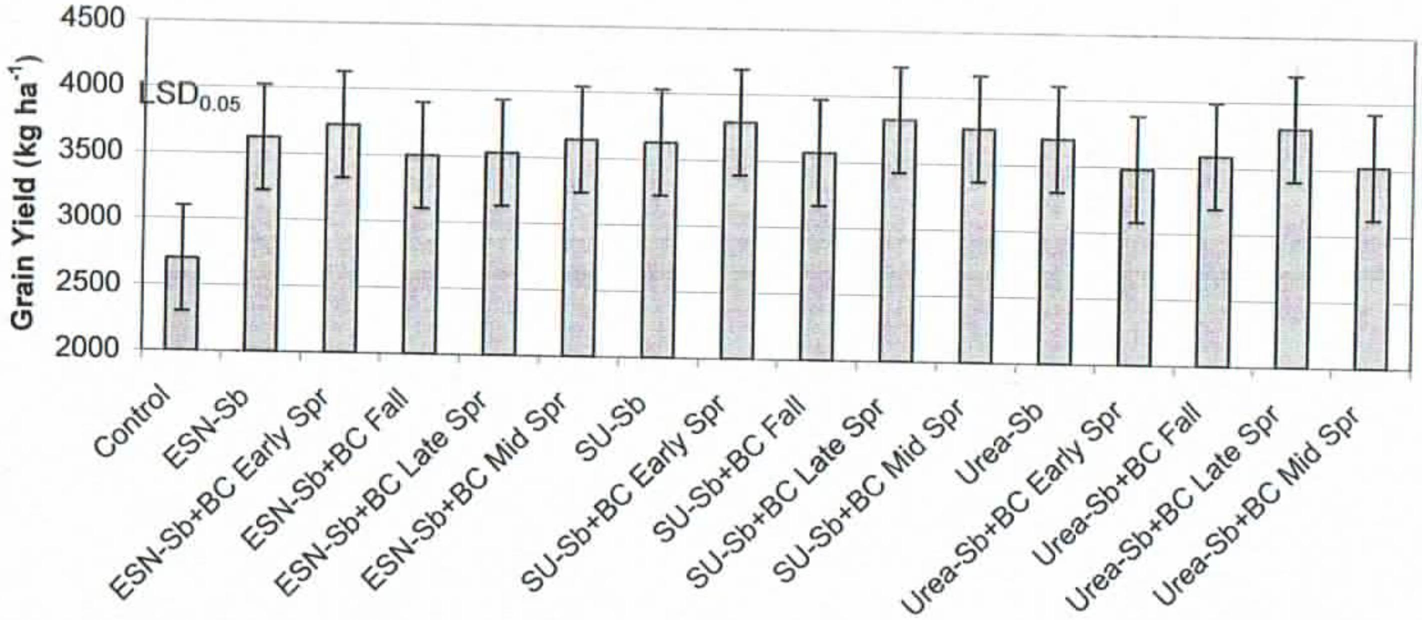


Fig. 3. Influence of fertilizer form, timing, and placement on Radiant winter wheat. Bars represent the protected $LSD_{0.05}$ value. Abbreviations: ESN, polymer-coated urea; SU, SuperU, urease and nitrification inhibitor; sb, sideband; BC, broadcast.

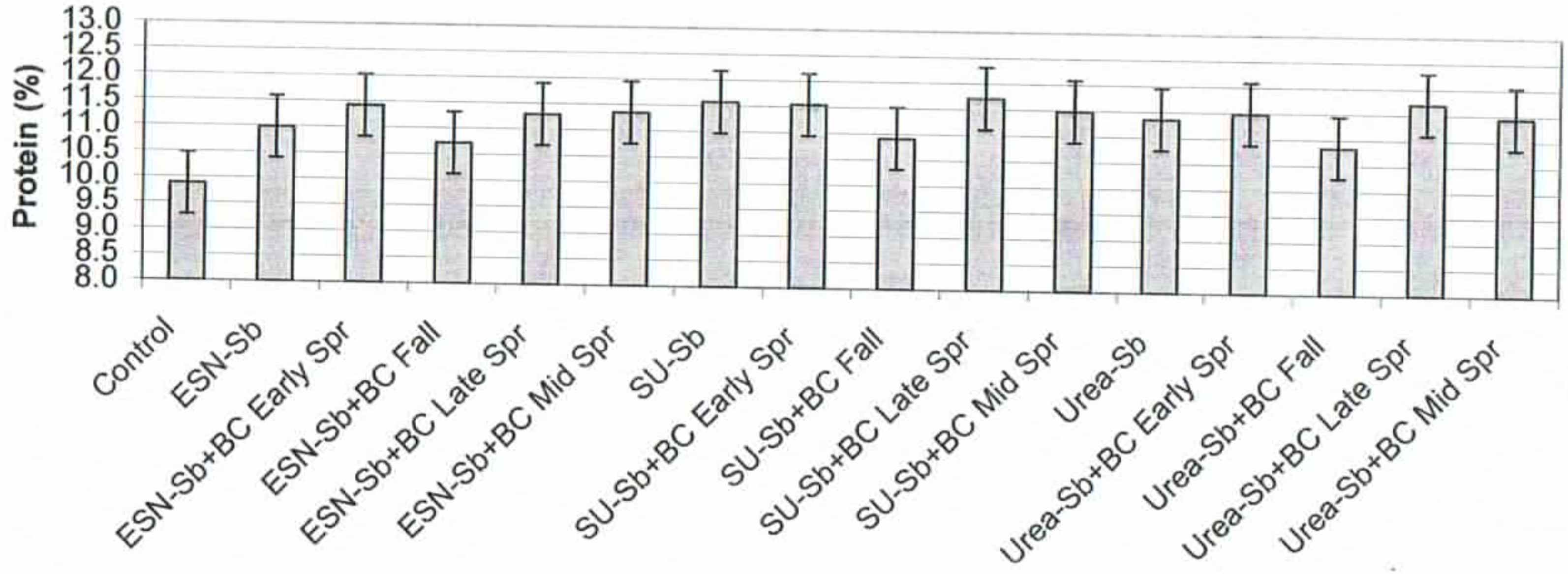
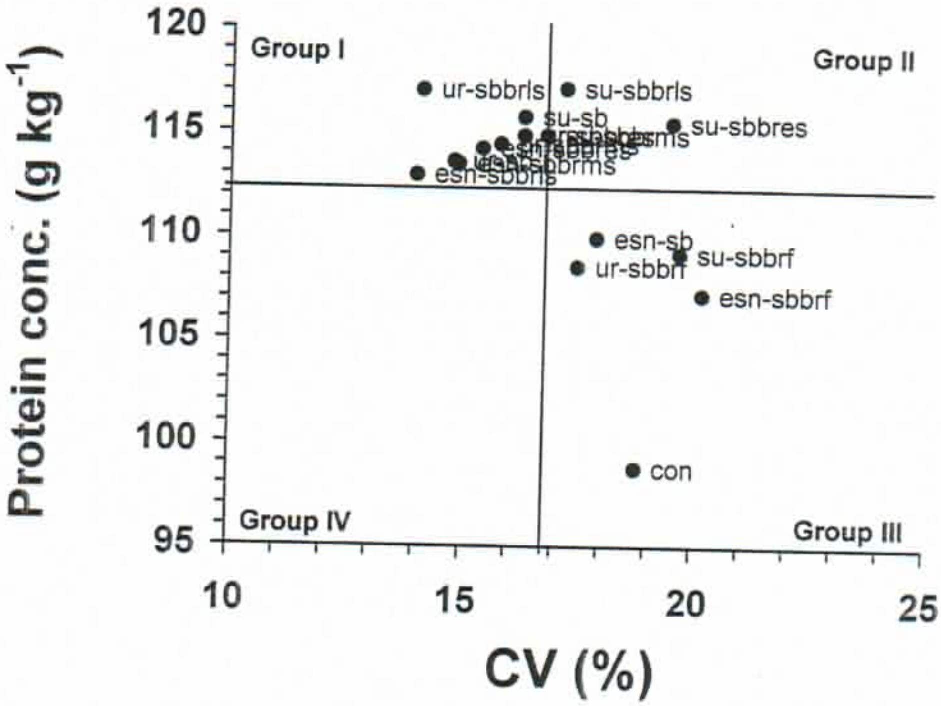


Fig. 4. Influence of fertilizer form, timing, and placement on Radiant winter wheat. Abbreviations: ESN, polymer-coated urea; SU, SuperU, urease and nitrification inhibitor; sb, sideband; BC, broadcast.



Group I: High mean, low variability (optimal)
Group II: High mean, high variability
Group III: Low mean, high variability (poor)
Group IV: Low mean, low variability

Fig. 5. Biplot of treatment grain protein vs. variability of treatment..