COMPARATIVE ANALYSIS OF DIFFERENT APPROACHES TO VARIABLE RATE SEEDING

A.Melnitchouck, G.Donald, and T.Schmaltz

DynAgra Corp.
Beiseker, Alberta, Canada

ABSTRACT

The efficiency of variable rate seeding (VRS) was confirmed in various crops. It is proven that corn requires increasing seeding rates in high-yielding zones, whereas soybeans need lower rates. However, the data for wheat appeared to be controversial. The aim of our experiment was to determine the most efficient strategy for variable rate fertilization and seeding in spring wheat in the conditions of Canadian Prairies. Two approaches were tested: based on Normalize Difference Vegetation Index (NDVI), and on digital elevation model (DEM). The strategies for VRS included two types: seeding rate increased from 100 in the lowest yielding zone to 160 kg/ha^{-1} in the highest yielding area with the increments of 12 kg/ha^{-1}, and maximized to 160 kg/ha^{-1} in the lowest yielding area with a gradual reduction to 100 kg/ha^{-1} in the highest yielding zone. The constant seeding rate was 130 kg/ha^{-1}. The rates of carbamide varied from 93 to 284 kg/ha^{-1}, the constant rate was 252 kg/ha^{-1}.The experiment was laid out in four replications. Constant rate fertilization and seeding were used as control. The replications were placed within the field so that the average last year's NDVI values in each variant were equal. At the peak of the growing season, NDVI was calculated for comparison of green biomass development in each variant. On average, NDVI in the variants with variable rate fertilization and seeding exceeded the constant rate by 9.2%. The difference in grain yield between the same variants was 6.7%. Both values were significant at $P < .05$. Variable rate seeding with the reduced rates in high-yielding areas was more efficient that the variants with the higher rates; however, the difference was not statistically significant. Also, no significant difference at $P < .05$ was found between the variants based on NDVI and DEM.

Keywords: Precision agriculture, satellite imagery, variable rate technology, fertilizers, soil.

INTRODUCTION

Adjusting seeding rates depending on soil fertility and environmental conditions is an important component of crop production. Technologies of precision agriculture considerably facilitate this process, because seeding rates can be changed on-the-go. Traditionally, there are two main strategies for variable rate seeding (VRS). The first approach is to increase seeding rates in low-yielding areas and decrease in the high-yielding zones. This strategy is often recommended for many crops including wheat, barley, soybeans etc. The reason for this is that the plants require more space, when they are grown in favorable conditions. Tillering in cereals, or more intensive development of canopy in canola or soybeans lead to higher yield per plant, which gives an opportunity to save on seeds and increase total yield by optimizing crop density. The opposite point of view is to increase seeding rates in areas with higher yielding potential. This strategy is popular among corn growers. So far, there is no commonly accepted approach to variable rate seeding.

MATERIALS AND METHODS

Our experiment was carried out in a real farmer's field near Beiseker, AB, Canada. The total field area was 201.3 ha seeded to hard red spring wheat. To delineate management zones, we tested two methods: using Normalized Difference Vegetation Index (NDVI) and elevation data. Elevation data were collected using Light Derection and Ranging (LiDAR) before the growing season.

The main aim of our experiment was to answer the following questions:

1. Which method of delineation of management zones gives better results: based on topography or NDVI?
2. Should seeding rates for wheat be increased or decreased in high- and low-yielding zones?
3. How efficient are different models of variable rate technology in comparison to the constant fertilization/seeding?

We were not trying to determine the optimal seeding rates in this trial. To ensure the quality of the experiment, the replicates in the field were positioned so that the average NDVI values per replicate were identical (Table 1). The experiment was laid out in four replications (Fig. 1).

Table 1. Average NDVI values for different variants in the experiment.

Variant	NDVI 2007	NDVI 2008	Average
CF CS*	0.75315	0.553025	0.653088
VF1 VS1	0.77035	0.553425	0.661888
VF2 VS2	0.77305	0.556575	0.664813
VF1 VS2	0.77115	0.54965	0.6604
VF2 VS1	0.77075	0.557775	0.664263

*CF and CS – constant rate fertilization and constant rate seeding.
VF1 - VRT map is based on NDVI;
VF2 - VRT map is based on LiDAR data;
VS1 - Seeding rates are increased in high yielding zones and decreased in low-yielding zones;
VS2 - Seeding rates are decreased in high-yielding zones and increased in low-yielding zones.

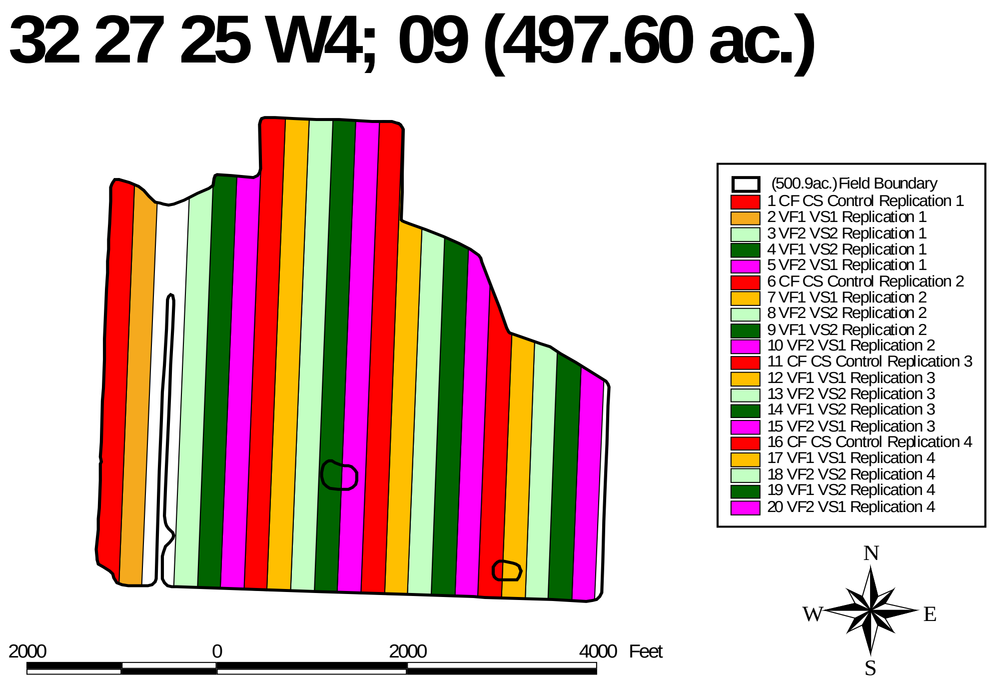

Fig. 1. Layout of the experiment.

To apply variable seeding rates, we created a prescription file (Fig. 2).

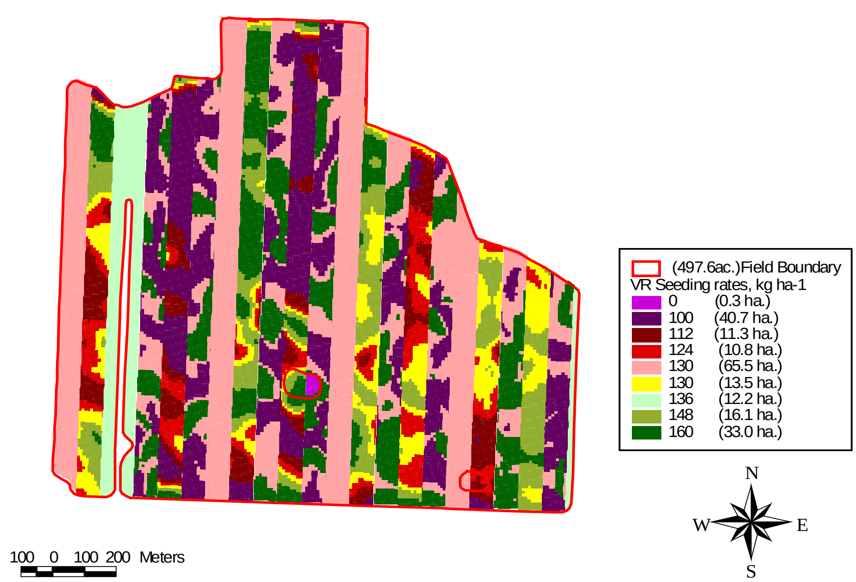

Fig. 2. Prescription map for variable rate seeding.

On July 12 and 21, 2009, two satellite images were collected for the field (Landsat 5TM). NDVI values were calculated for each pixel of the image; then two interpolated NDVI maps were created to visualize spatial variability of green biomass in the field (Fig. 2). At the end of the growing season, yield data were collected and analyzed using SSToolbox 3.8 (SST Development Group).

RESULTS AND DISCUSSION

Visual analysis of satellite imagery and yield data indicated obvious difference between the variants of the experiment (Fig. 3).

At the first stage, the following information was used for the analysis:

- Field boundary and 20 boundaries of replicates.
- NDVI data.

Analysis of NDVI values for each variant gave the results summarized in Table 2. Comparison of the VRF and VRS methods did not reveal significant difference between them at $P>.05$. However, topographical model of VRT performed better than NDVI with the probability of 84.1 %, and decrease of seeding rates in high-yielding zones worked better than increase of them with the probability 74.2%.

Table 2. The effects of variable rate fertilization and seeding on NDVI.

	Variant	NDVI
1 (control)	CF CS (Constant fertilization, constant seeding rates)	0.489
2	VF1 VS1 (Variable fertilization based on NDVI, variable seeding (seeding rates increased in high-yielding areas and decreased in low-yielding areas)	0.505
3	VF2 VS2 (Variable fertilization based on field topography, variable seeding (seeding rates increased in low-yielding areas and decreased in high-yielding areas)	0.532
4	VF1 VS2 (Variable fertilization based on NDVI, variable seeding (seeding rates increased in low-yielding areas and decreased in high-yielding areas)	0.522
5	VF2 VS1 (Variable fertilization based on topography, variable seeding (seeding rates increased in high-yielding areas and decreased in low-yielding areas)	0.528

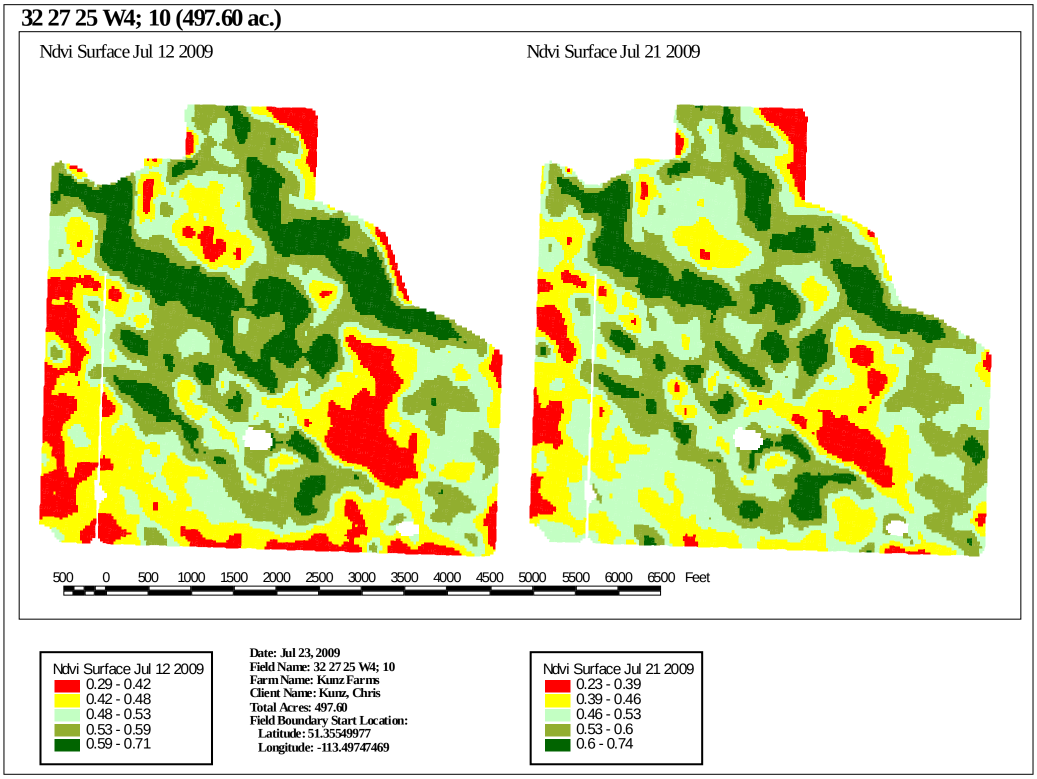

Fig. 3. Satellite image of the experimental field (Landsat 5TM, Jul 12 and 21, 2009).

The assessment of separate effects of variable rate fertilization and seeding indicated that the average NDVI values in the variants with VR fertilization and seeding was significantly higher than in the variants with the constant rate ($P> .05$, Table 3).

Table 3. Influence of variable rate technology on the amount of green biomass in the field.

Fertilization	NDVI Average
Variable Rate Technology	0.530
Constant Rate Application	0.489

At the next step, two-way ANOVA was applied to estimate the significance of difference between different models of VRT and VRS. The results indicated that the contribution of variable rate seeding was 25.7%, variable rate fertilization 65.7%, and 8.7 % was due to the interaction of the factors.
Yield map clearly shows the difference between the variants of the experiment; they are seen as vertical strips of different color (Fig.3). Analysis of yield data indicated that the variable rate technology performed better than the conventional approach (Table 4).

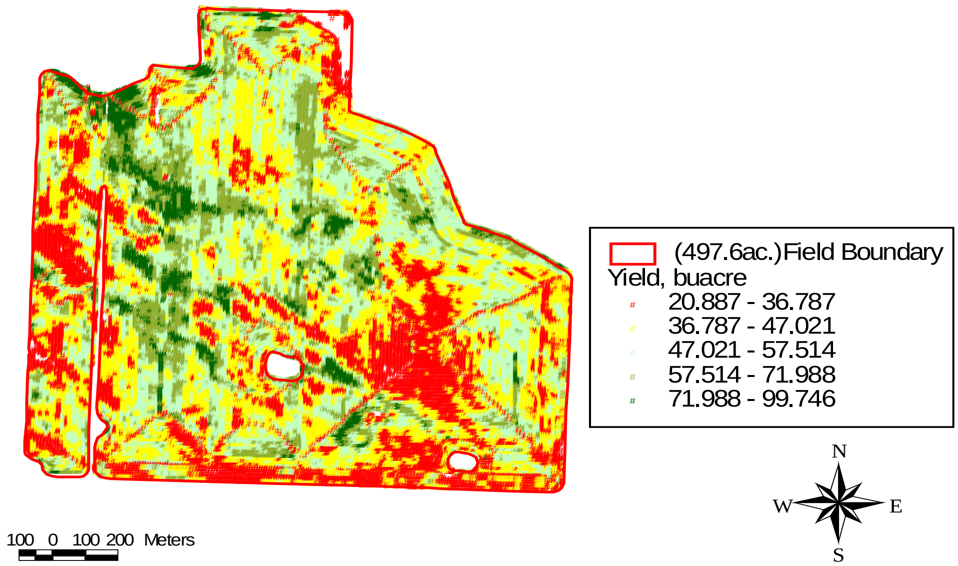

Fig. 4. Yield map (2009).

Table 4. The effect of different types of VR seeding and fertilization on grain yield.

Variant	Yield, bu/acre
CF CS	45.2125
VF1 VS1	47.065
VF2 VS2	49.195
VF1 VS2	47.9975
VF2 VS1	48.7675

On average, decreasing seeding rates in high-yielding zones performed better than increasing rates (Table 5). However, the difference was not significant at P> .05. The summer of 2009 was very dry, and apparently, it was the reason, why the yield data did not indicate the same difference between the variants.

Table 5. The effect of different types of VR seeding and fertilization on grain yield.

Variant	Yield, bu/acre
VS1 - Seeding rates are increased in high yielding zones and decreased in low-yielding zones	47.9
VS2 - Seeding rates are reduced in high-yielding zones and increased in low-yielding zones	48.6

CONCLUSION

Decreasing seeding rates in high-yielding areas and increasing them in low-producing zones is the best strategy for variable rate seeding in spring wheat. To make this technology economically efficient, variable rate seeding should be bundled with variable rate fertilization, which increased the efficiency of seeding rate adjustment.