EFFECT OF MAP-BASED SITE-SPECIFIC SEEDING USING PROXIMAL SENSING DATA ON WHEAT YIELD PARAMETERS AND ECONOMY

Marius KAZLAUSKAS[1], Egidijus ŠARAUSKIS[1], Kęstutis ROMANECKAS[2], Vilma NAUJOKIENĖ[1], Indrė BRUČIENĖ[1], Sidona BURAGIENĖ[1], Dainius STEPONAVIČIUS[1], Algirdas JASINSKAS[1], Dovydas VAICEKAUSKAS[1], Abdul Mounem MOUAZEAN[1,3]

[1]*Department of Agricultural Engineering and Safety, Faculty of Engineering, Agricultural Academy, Vytautas Magnus University, Lithuania*
[2]*Department of Agroecosystems and soil Sciences, Faculty of Agronomy, Agricultural Academy, Vytautas Magnus University, Lithuania*
[3]*Department of Environment, Faculty of Bioscience Engineering, Ghent University, Belgium*

Abstract
Different areas of the field may support different numbers of winter wheat plants. It depends on the properties of the soil. The use of proximal sensor data for site-specific seeding can make better usage of the soil potential to increase yields and their quality parameters for greater cost-effectiveness. The aim of this work was to determine the influence of different soil granulometric composition based on electrical conductivity measurements on winter wheat yield by applying a variable seeding rate (VRS) in different soil management zones, derived from apparent electrical conductivity (ECa) maps. The results of the study showed that VRS resulted in average a 3.27% higher yield and a 3.95% higher relative profit than the control with a fixed seeding rate (FRS).

Key words: *variable rate seeding, soil management zones, winter wheat yield, soil electrical conductivity, grain protein, economic efficiency.*

INTRODUCTION

In order to optimize seed consumption and adapt to field variability, soil type, soil structure differences and to maintain the profitability of crop production, precision seeding or variable rate seeding (VRS) technologies are already being introduced in modern agriculture. Seed germination, crop development and yield potential can vary from field to field. Precision seeding is a way to link seed quantities to a specific site to increase plant yield and production efficiency (*Fulton, 2019; Šarauskis et al., 2022*). The variability of the precision seeding rate is usually determined by the apparent electrical conductivity (ECa) of the soil measurements, which are closely related to changes in soil moisture and the granulometric composition of the soil (*Grisso et al., 2009; Griffin et al., 2013*).
Winter wheat is most popular cereal crop grown in Lithuania (*Statistics Lithuania, 2022*), therefore the application of precision seeding technology to this crop in Lithuanian farms is very important. The aim of this work was to determine the influence of different soil granulometric composition based on ECa measurements on winter wheat yield by applying a VRS in different soil management zones.

MATERIALS AND METHODS

The research was carried out in 2020–2021 Panevėžys district, Naujamiestis on a commercial farm. The research field coordinates are 55.674734, 24.145607, the field area is 22.37 ha. At the beginning of the study on precision seeding technology, on 11th August 2020 the determination of the ECa of the soil was performed in the study field. The ECa of the soil was determined using an EM38-MK device by pulling it on the surface every 24 m between parallel neighboring tram lines. The soil ECa was scanned at a depth from 0 to 1.5 m. After measurement the ECa of the soil and determination the values of it, the whole study field was divided into 5 different soil management zones (MZ) from the highest to lowest accordingly the ECa (MZ1 – 28.6; MZ2 – 27.3; MZ3 – 25.7; MZ4 – 24.2; MZ5 – 22.6 $mS \cdot m^{-1}$).
On 16th September 2020 winter wheat was seeded in two variants: fixed seeding rate (control – FRS) and variable seeding rate (VRS) according to the seeding recommendation map in four repetitions. The width of one repetition was 36 m. Winter wheat (variety Skagen) was seeded, whose weight of 1000 grain was 44.8 g and a germination rate was 95%. In the control FRS technology, the seeding rate was 180 $kg \cdot ha^{-1}$. In the VRS, the seeding rate varied from 146 to 214 $kg \cdot ha^{-1}$ (MZ1 – 146; MZ2 – 153; MZ3

– 180; MZ4 – 197; MZ5 – 214 kg·ha^{-1}). In both treatments the same 6 m working width direct seeding using a drill Horsch Avatar 6.16SD (Germany) with coulter spacing of 16.7 cm and a seeding depth of 3 cm were used.
On 27th July 2021 plant samples were taken to determine yield. The samples were taken by cutting winter wheat plants with a knife from a 1.0 m long row. A total of 60 samples were taken, representing 5 replicates of each variant, depending on the EC zones of the soil. From the collected samples the mass of 1000 grains and the grain yield of wheat per hectare were determined.
The economic evaluation of the VRS technology was performed by determining the relative profit difference of this technology and it was compared to the control variant. The relative profit on seeding technology, excluding other costs, was calculated as follows: relative profit = income – (seed price + fertilization costs + plant protection products). The income of winter wheat yield was 240 EUR·t^{-1}. The price of winter wheat seed used for the research was 370 EUR·t^{-1}. Fertilizers and plant protection products were used at the same rates in both seeding treatment. Costs on fertilizers amounted to about 233 EUR·ha^{-1} and on plant protection products – 65 EUR·ha^{-1}. These calculations did not take into account farming equipment fuel consumption, operating costs, operator costs, etc.
Data from the experimental study were processed using the one-way ANOVA. Data were calculated using the smallest significance difference ($p < 0.05$) using the T-test. In Figures 2 and 3 the columns marked with the same letter do not differ significantly.

RESULTS AND DISCUSSION

After scanning the ECa of the soil map of the electrical conductivity of the soil was created and a map of the precision seeding of winter wheat with a variable seeding rate was prepared Fig. 1.

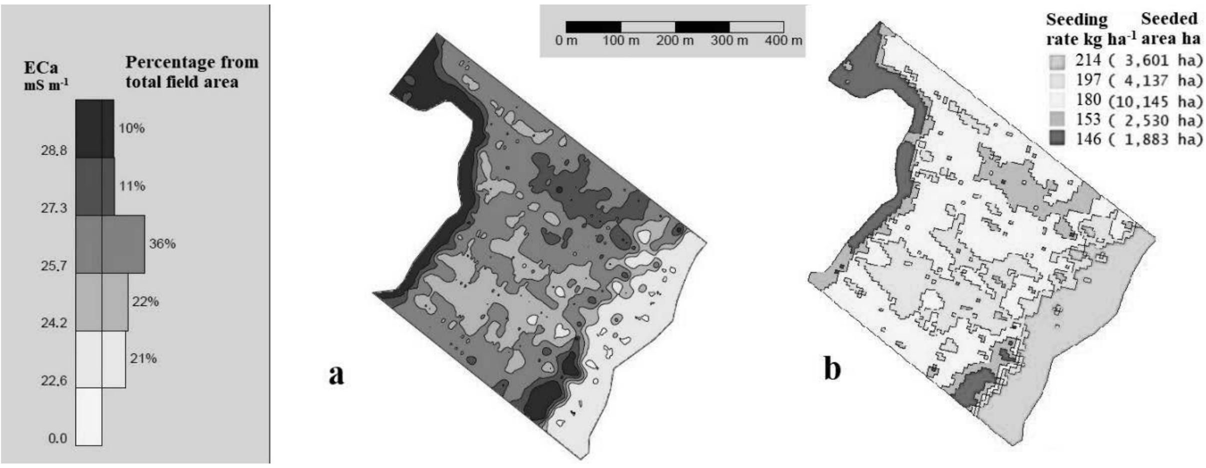

Fig. 1 Maps: a – soil electrical conductivity; b – variable rate seeding

The map of soil ECa distinguishes 5 different soil MZs,, which reflect 5 different seeding rates on the seeding map. The highest ECa of the soil indicates the maximum amount of clay particles corresponding to heavy soils, and these soils are able to retain moisture better (*Grisso et al., 2009*). In such soils, it is possible that the plants will have more tillers, which allow for a smaller amount of seeds to be sown, e.g. MZ1 – 146 kg·ha^{-1}. In the areas of the lowest ECa of the soil, low tillering of the plants and lower amount of developed ears are expected. Therefore, the highest seeding rate of 214 kg·ha^{-1} has been chosen in MZ5. In the control FRS treatment with a an average FRS of 180 kg·ha^{-1} was seeded.
The weight of 1000 grains of winter wheat was calculated and the obtained results are presented in Fig 2. Comparative calculations showed that a significant difference was found in the FRS of zone MZ5 compared to all other zones. The maximum weight of 1000 grains (37.44 g) was found in the VRS treatment in MZ4 zone and there was a significant difference in comparison with all other zones. Zones MZ1 and MZ2 of the VRS have significant differences with zones MZ3, MZ4 and MZ5. The VRS technology avoided significant areas of separation and the average weight of 1000 grains was about 35.1 g, while the average weight of 1000 grains in the FRS variant was about 34.0 g. The difference between the seeding variants was about 3.1%.

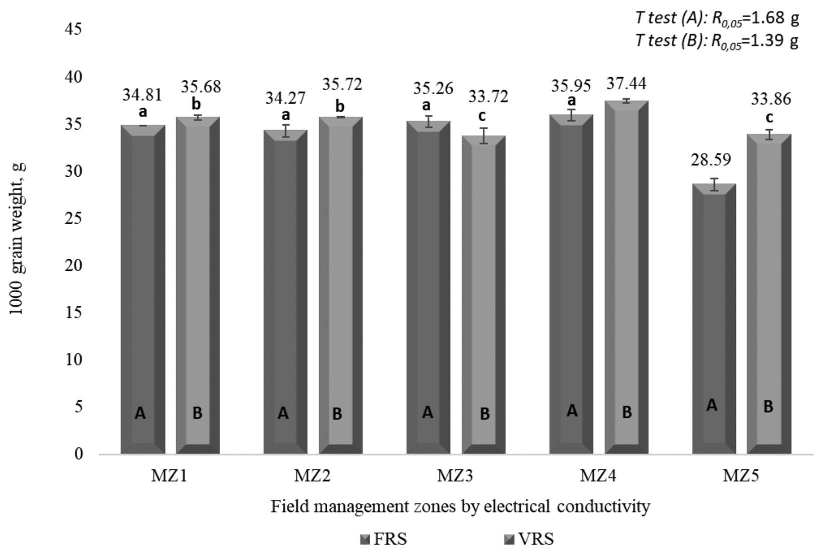

Fig. 2 Mass of 1000 grains (g) in different soil management zones: MZ1–MZ5 – soil management zones; FRS – fixed rate seeding; VRS – variable rate seeding

The biological yield of winter wheat was determined by laboratory tests. The obtained results are presented in Fig 3.

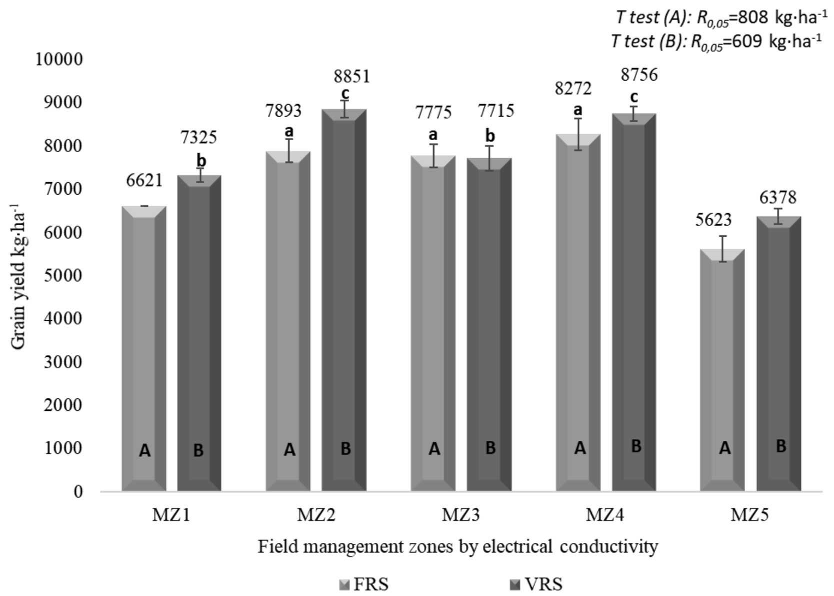

Fig. 3 Grain yield in different soil management zones: MZ1–MZ5 – soil management zones; FRS – fixed rate seeding; VRS – variable rate seeding

In the control treatment the significant differences of the yield were determined between zones MZ1 and MZ5 and these zones were compared to other zones. The lowest yield (5623 kg·ha^{-1}) was obtained in the MZ5 zone of the FRS variant. Although the seeding rate was the same (180 kg·ha^{-1}), lower grain yields were achieved in poorer sandy soils under the VRS. The VRS variant in the MZ5 zone had significantly lower yields in comparison to the other zones. Significantly the highest grain yields were achieved in MZ2 and MZ4 zones, where seeding rates were 153 and 197 kg·ha^{-1}. The yield of the VRS and the FRS variant in the MZ3 zone was very similar, because in this zone the seeding rate was the same – 180 kg·ha^{-1}. The average grain yield of the VRS, regardless of MZ, was 7782 kg·ha^{-1}, while in the FRS variant it was 7536 kg·ha^{-1} (246 kg·ha^{-1} less). Precision VRS technology resulted in average 3.27% increase in winter wheat yield. This study showed that many of the yield quality parameters were more homogeneous with VRS compared to FRS.

The economic indicators of traditional fixed rate and precision seeding technologies are presented in Tab. 1.

Tab. 1 Economic evaluation of different seeding technologies (FRS – fixed rate seeding; VRS – variable rate seeding)

Replications	Relative profit, FRS (Eur·ha^{-1})	Relative profit, VRS (Eur·ha^{-1})	Relative profit difference VRS to FRS %
1	1336.33	1382.05	3.42%
2	1303.76	1297.03	-0.52%
3	1604.43	1669.33	4.05%
4	1533.84	1658.12	8.10%
Average	1444.59	1501.63	3.95%

An economic evaluation of the traditional fixed rate and precision seeding technologies showed that the precision seeding technology resulted 3.95% higher relative profit per hectare in comparison to the traditional fixed rate technology. Economic profit can be a key for farmers interested in VRS (*Šarauskis et al., 2022*).

CONCLUSIONS

1. The weight of 1000 grains seeding winter wheat at a variable rate was 3.1% higher than seeding at a fixed rate.
2. The precision seeding technology has resulted in 3.27% increase in winter wheat yields over conventional seeding.
3. The precision seeding technology with a variable seeding rate has in average a 3.95% higher relative profit in comparison to traditional seeding technology at a fixed seeding rate.

ACKNOWLEDGMENT

This study was supported by European Regional Development Fund (project No. 01.2.2-LMT-K-718-03-0041) under a grant agreement with the Lithuanian Science Council (LMTLT)

REFERENCES

1. Fulton, J. (2019). Variable-rate seeding systems for precision agriculture. In Precision agriculture for sustainability. Stafford J., Ed.; Burleigh Dodds Science Publishing Limited, Silsoe Solutions, UK, 297p.
2. Griffin, S., Hollis, J. (2013). Using profile soil electrical conductivity survey data to predict wheat establishment rates in the United Kingdom. In Precision agriculture'13. Wageningen Academic Publishers, Wageningen. 491–497.
3. Grisso, R.B., Alley, M., Wysor, W.G., Holshouser, D., Thomason, W. (2009). Precision farming tools: Soil electrical conductivity. Virginia Cooperative Extension, 1–6.
4. Lietuvos statistikos departamentas. (2022). Žemės ūkio augalų pasėtas plotas. Prieigą per internetą: https://osp.stat.gov.lt/statistiniu-rodikliu-analize?hash=36784441-a07f-4c39-9946-774b5c062973#/
5. Šarauskis, E., Kazlauskas, M., Naujokienė, V., Bručienė, I., Steponavičius, D., Romaneckas, K., Jasinskas, A. (2022) Variable Rate Seeding in Precision Agriculture: Recent Advances and Future Perspectives. Agriculture, 2022, 12(2), 305, 1–24.

Corresponding author:
Ing. Marius Kazlauskas, Doctoral student, Department of Agricultural Engineering and Safety, Faculty of Engineering of Agriculture Academy, Vytautas Magnus University, Studentu 15A, LT-53362 Akademija, Kaunas Reg., Lithuania, phone: +370 612 40119, e-mail: marius.kazlauskas@vdu.lt