# Profit maximization using variable rate technology (VRT) in soybean (*Glycine max* (L.) Merr.) in the Sárrét Region, Hungary

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Abstract
Variable rate technology (VRT) in seeding (VRS) and variable rate application (VRA) of fertilizers aims to treat within-field differences occurring in agricultural lands. With the appropriate farm equipment, site-specific management can be carried out in order to define the most profitable treatment for various plants. The results of research on maize, winter wheat, and sunflower experiments are available regarding VRT in Hungary. However, results for soybean (*Glycine max* (L.) Merr.) experiments are still not widely available. The objective of our work and this paper was to investigate the effect of VRS and variable rate applications (VRA) of fertilizers on the profitability of soybean production in a 43.1-hectare trial field. Various trials were carried out, such as the effect of head fertilizer or bacteria starter treatment; however, in this paper only the profitability of the technological variations is reported. The trial is located in the Sárrét Region, Hungary. Management zones were determined according to earlier yield maps, satellite imagery, and earlier Topcon CropScan measurements. The applied treatments were: 1, varying only seed rates: 525-615 k-seed/ha; 2, varying nutrient rates: N: 32-54 kg in the form of Calcium ammonium nitrate (CAN 27%N), P: 84-116 kg in the form of Diammonium phosphate (DAP 18%N:46%$P_2O_5$), and K: 7-80 kg potassium (60%$K_2O$); and 3, varying seed and fertilizer rates as well. Base fertilizing was carried out on 27 March 2018. Seeding was carried out on 25 April 2018 using 15 cm row spacing. Top-dressing (FitoHorm Szója, 5 l/ha) and weed control (Corum herbicide, 1.9 l/ha) were carried out uniformly on 30 May 2018. For profit calculations all expenses were calculated (cultivation, soil sampling and analysis, seeding, top-dressing, herbicide treatment, nutrient replenishment, and yield mapping) as inputs and the yield actual selling price as income. The highest profit was reached by applying VRS and VRA at the same time. Untreated control resulted in a significantly lower profit. We state that the application of complex site-specific variable rate technology resulted in higher profit than individual VRS or VRA treatments using extra input materials. We also state that a reference site-specific technology for soybean treatment was also found, which can help advisors in the region in the future.
Keywords: VRA, VRS, soybean, profitability.

**Introduction**

Variable rate technology (VRT) in seeding (VRS) and the variable rate application (VRA) of fertilizers aims to treat within-field differences occurring in agricultural lands. With the appropriate farm equipment, site-specific management can be carried out in order to define the most profitable treatment for various plants. The results of research on maize, winter wheat, and sunflower experiments are available regarding VRT in Hungary; however, results for soybean (*Glycine max* (L.) Merr.) experiments are still not widely available. In order to apply variable rate seeding, there are four basic steps to be followed: first and foremost, management zones have to be identified. *Management zones* are well suited for locating benchmark soil-sampling sites. Small, spatially coherent areas within fields may also be useful in relating yield to soil and topographic parameters for crop-modelling evaluation. Stafford et al. (1998) used fuzzy clustering of combine harvester yield-monitor data to divide a field into potential management zones. Management zones are usually based on soil types or yield maps proceeding from several years of data (preferably from similar plants), or general knowledge of yield or any other within-field differences (Gili, 2017). Management zone analysis provides spatial information on within-field differences (Fridgen et al., 2003). The second step is that the *seed rate* has to be determined. A standard recommendation when VRS is introduced in a field is to decide on three to four seeding rates with a reasonable difference. Due to their ability to compensate for stand differences, soybean crops provide high yield over a range of seeding rates. Seeding rates over the economical limit, however, add unnecessary costs and can lead to problems with diseases and lodging, consequently lowering profit. Because of the potential differences in seed size, soybean seed should be planted based on seeds/ha, not kg/ha. The effects of row spacing and seed rate on soybeans in the US have been investigated by De Bruin and Pedersen (2008). They stated that adaption of narrow-row spacing and seeding rates in Iowa could be used to reduce production costs and increase yield and profitability. Once seeding rates are determined for each zone, a *prescription map* has to be created. As a final step, the prescription map has to be *uploaded into a variable-rate controller*. The controller has to be calibrated and set for the required parameters and finally has to be set to *record* as-planted information.

Row spacing of soybean has changed over time. In the past wide-row spacing (76 cm) was preferred by growers; nowadays, narrow-row spacing is used in practice.

Other than yield, the most important factor driving soybean row spacing practices is equipment and time management during the planting season. One of the key issues growers must consider is whether the economics of their farm justify having a machine dedicated specifically to planting soybeans. In practice, it is practical to share soybean with other crop-planter equipment such as wheat- or corn-planters (Jeschke and Lutt, 2018).

Yield increase for soybean row spacing was reported by Bertram and Pedersen (2004). They found a 5% yield increase in 0.19 vs. 0.76 m rows in southern Wisconsin, an 8.7% increase in central Wisconsin, and a 9.6% increase in northern Wisconsin in a 3-yr study.

Economic studies also reported advantages for narrower row spacing. Lambert and Lowenberg-DeBoer (2003) concluded that planting soybean in 0.19 m rows with a grain drill was more economical in annual corn–soybean rotation in the North-Central United States, based on a summary of studies

showing a 4.8% yield advantage for drilled (<0.25 m rows) compared with 0.38 m rows.
Soybean's high yields are possible only when the crop's nutritional requirements are met. Mismanagement of nitrogen or other fertilizer application prevents a grower from achieving yield potential. Variable rate technology (VRT) can be used to vary seed and fertilization rates within a field. Fertilizer variations have strong effects on yield production. Soybean grains have a nitrogen content of 40%, therefore adequate fertilization of nitrogen is required for achieving high-quality yields. According to McKenzie (2017) nitrogen (N) fertilizer is rarely recommended in Canada for soybean, even if the soil test N level is low and it is the first time soybean will be grown on virgin land. On the other hand, potassium and phosphorus variability highly affects production. Investigating phosphorus fertilization, Wittry and Mallarino (2004) reported better P fertilizer management applying VRA because it applied 12 to 41% less fertilizer compared with the traditional uniform rate fertilization method. On the other hand, McKenzie (2017) stated that recent research by the University of Manitoba has shown that phosphate ($P_2O_5$) fertilizer does not have a strong effect on soybean growth or yield.

## Materials and methods

Instrumentation

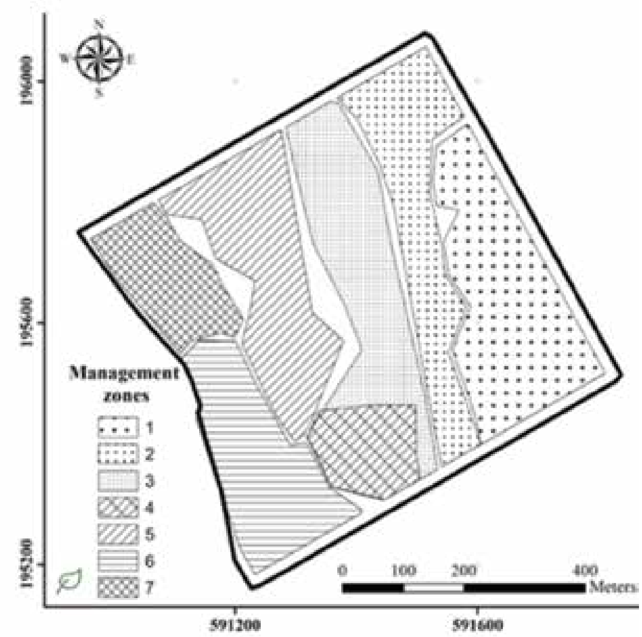
Cultivation was carried out using a Fendt 936 tractor and a Lemken diamant plough, the seedbed was prepared with the same tractor mounted with a Farmet kompaktomat 850. For fertilizing a Fendt 720 tractor and Amazone ZA-TS spreader were used. Seeding was carried out by a Fendt 720 tractor and a Horsch Pronto 6DC precision seeding machine. Top-dressing and weed control was carried out by a Fendt 716 tractor equipped with an Amazone UX fertilizer. For harvesting, a Claas Lexion 660 combine harvester was used equipped with a TopCon YieldTrakk yield monitoring system. For control and data collection, a TopCon X35 monitor was installed in the machines.

**Location**

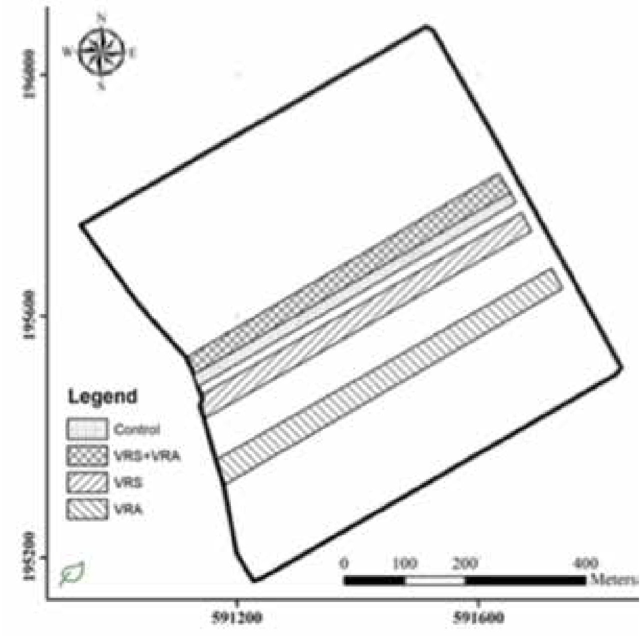
The trial is located in the Sárrét Region, Hungary. Management zones were determined according to earlier yield maps, satellite imagery, and earlier Topcon CropScan measurements. After autumn cultivation soil sampling and analysis were carried out in January 2018. Soil samples were collected from each management zone, defined by earlier experience and measurements (Fig. 1a.).

**Trials**

Various trials were carried out, such as the effect of top-dressing or bacteria starter treatment, however, in this paper focus is on the profitability of the technological variations of VRS and VRA. Applied treatments were: 1, varying only seed rates (VRS): 525-615 k-seed/ha; 2, varying




a)



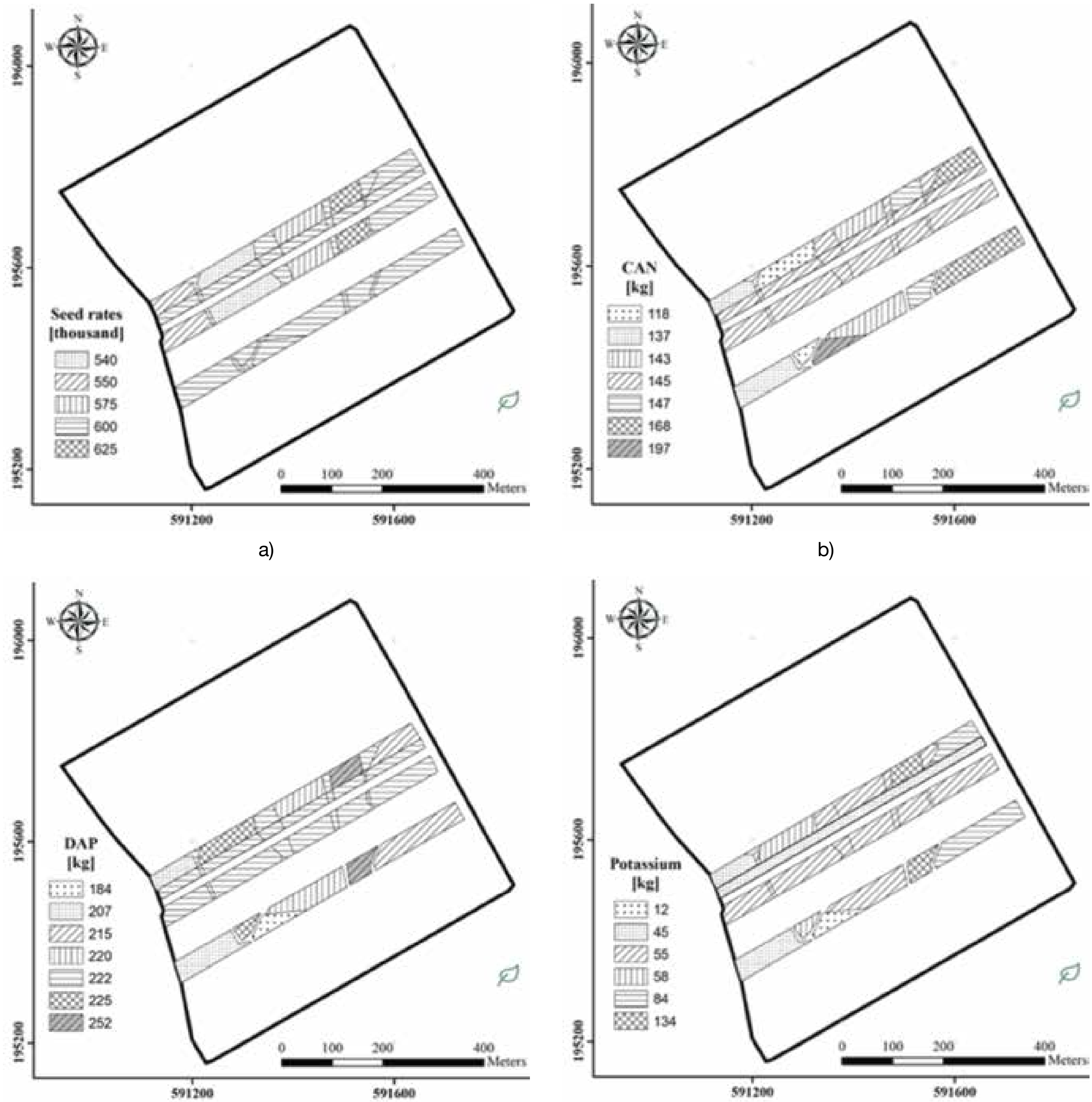

b)

Figure 1. Locations of the management zones (a) and the various treatments (b) within the trial field.

fertilizer rates (VRA): N: 32-54 kg in the form of Calcium ammonium nitrate (CAN 27%N), P: 84-116 kg in the form of Diammonium phosphate (DAP 18%N:46%$P_2O_5$), K: 7-80 kg potassium (60%$K_2O$); and 3, varying seed and fertilizer rates (VRS+VRA) as well (Fig 1b.).
Base fertilizers (DAP and Potassium) were applied on 27 March 2018 with the recommendation rates determined by soil sampling, laboratory analysis, and the "K-Prec" Ltd. advisory system. N application was carried out on 20 April using the same advisory method (Fig 2., Tab.1.). The seedbed was prepared on 23 April; seeding was carried out on 25 April. The row spacing was 15 cm.

Table 1. Fertilizer amounts applied in the experimental field

| Management zones | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
|---|---|---|---|---|---|---|---|
| Seed rate (thousands) | 600 | 625 | 575 | 575 | 540 | 550 | 550 |
| DAP (kg) | 215 | 252 | 220 | 184 | 225 | 207 | 222 |
| CAN (kg) | 168 | 147 | 143 | 197 | 118 | 137 | 152 |
| Potassium (kg) | 84 | 134 | 55 | 12 | 58 | 45 | 49 |




a) b)

a) b)

Figure 2. Amounts of variable rate applications in each experimental unit

Seeding rate (Fig 3.a), CAN (Fig 3.b) DAP (Fig. 3.c), and Potassium (Fig 3.d) treatments were applied according to the experimental setup.

Top-dressing (FitoHorm szója) was applied on 30 May in the amount of 5 l/ha. Weed control was carried out uniformly on the same date using Corum herbicide (1.9 l/ha). Expenses for each working task and input materials were calculated (Tab. 2.).

Fixed costs such as cultivation, soil sampling, and laboratory analysis, machinery for fertilizer application, top-dressing, weed control, harvesting, and costs for uniformly applied top-dressing material and weed control material were calculated for the whole field. Variable costs (fertilizers and seed) were calculated based on the size of the treatment units. All data was collected and uploaded into Topcon SGIS software. For income calculations yield was measured. Profit was calculated automatically by SGIS software for each management unit based on the collected and uploaded data. Moisture content was also registered, therefore the actual, comparable amount of dry yield for each unit was calculable. The actual market price for soybeans was EUR 322 /t.

**Results**

The differences in costs for control, only VRS, only VRA, and VRS+VRA were relatively low, EUR 659.35, EUR 663.44, EUR 667.29 and EUR 664.26/ha, respectively (Tab. 2.).

Table 2. Expenses of soybean production in EUR at the investigated farm (calculations are related to 1 ha).

| Expenses | Control | VRS | VRA | VRS+VRA |
|---|---|---|---|---|
| Soil sampling[1] | 10 | 10 | 10 | 10 |
| Cultivation+seed bed[2] | 143.75 | 143.75 | 143.75 | 143.75 |
| Machinery[3] | 65.63 | 65.63 | 65.63 | 65.63 |
| Top-dressing | 20.31 | 20.31 | 20.31 | 20.31 |
| Weed control | 65.63 | 65.63 | 65.63 | 65.63 |
| Harvesting | 68.75 | 68.75 | 68.75 | 68.75 |
| DAP[4] | 70 | 77.35 | 74.55 | 77 |
| CAN[4] | 23.4 | 23.24 | 24.54 | 22.59 |
| Potassium[4] | 15.19 | 15.19 | 17.44 | 18.56 |
| Seed[4] | 176.7 | 173.6 | 176.7 | 172.05 |
| Total | 659.35 | 663.44 | 667.29 | 664.26 |

[1]*Including laboratory analysis and advisory services*
[2]*Cost of labour (machinery, fuel, etc.)*
[3]*Cost of machinery for seeding, base fertilization, top-dressing and weed control*
[4]*Expenses are calculated for the treatment unit*

The maturation of soybean differed, therefore moisture content of the harvested areas differed as well. The control zone was harvested with 15.19% moisture content, whereas the VRS zone moisture content was 15.9%. The VRA zone was slightly less, at 15.2%, and the driest zone was the VRS+VRA application, at 13.4%. The differences in moisture content resulted in variations in yield as well. The total productivity of each investigated zone is shown in Tab 3. As production was the highest in the zone where VRS and VRA were applied (4.86 t/ha), this zone produced the highest income as well (EUR 1,564); consequently the highest profit (EUR 899.45) was realized here. Untreated control produced a significantly lower profit (EUR 704.83). Profit for the zones where only VRS or VRA was applied was even lower than the control zone's profit, EUR 598.86, and EUR 692.53, respectively.

Table 3. Calculation of the profit of soybean production in EUR at the investigated farm (calculations are related to 1 ha).

| | Control | VRS | VRA | VRS+VRA |
|---|---|---|---|---|
| Total Costs (EUR) | 659.35 | 663.44 | 667.29 | 664.26 |
| Moisture (%) | 15.3 | 15.9 | 15.2 | 13.4 |
| Yield* (kg) | 4,238.24 | 3,921.7 | 4,224.67 | 4,858.21 |
| Income (EUR) | 1,364.18 | 1,262.3 | 1,359.82 | 1,563.74 |
| Profit (EUR) | 704.83 | 598.86 | 692.53 | 899.47 |

**Corrected amount of yield for the treatment unit*

**Discussion**

Soybean is of high importance in Hungary as it is a valuable source of high-quality vegetable protein. Farmers practicing site-specific application are investigating ways to achieve best practices for soybean production. Research on variable rate technology and its adaptability in soybean production was carried out with the focus on profitability for variable rate seeding and variable rate fertilizer application. Calculations of profitability were carried out automatically with the help of Topcon SGIS software, which made it possible to easily collect the values for treatment units, even if there were more than 5 management zones within the area. Soybean planted in a 15-cm row produced a 3.9-4.8 t/ha yield, depending on the technology applied.

**Conclusions**

Applying variable rate technology to soybean production aimed to find the best technology and the most economical seed rate as well as fertilizer rates in the Sárrét Region, Hungary. The experiment was carried out by precision agriculture machinery; as-applied data collection was available for monitoring each piece of technology. The calculations clearly showed that applying variable rate seeding without variable rate fertilization or applying variable rate fertilization without variable rate seeding was even less profitable than the conventional (control) soybean production. We state that the application of site-specific variable rate technology as a complex solution results in significantly higher profit than the regular practice. We also state that a reference technology for soybean treatment was also found, which can be used in advisory systems in the future in the region.

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