Experience at Russian State Agrarian University – Moscow Timiryazev Agricultural Academy on introduction and integration of precision agriculture technology

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SUMMARY

Traditional and precision agriculture technologies are compared on the basis of the field experiment. Problems of soil and crop survey and mapping are discussed.

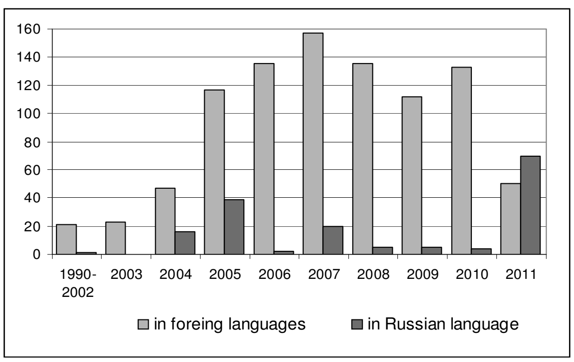
Keywords: *precision agriculture, autopilot, guess row spacing, N-sensor, inter-field variability, biomass mapping, yield mapping*

INTRODUCTION

Precision agriculture is a concept of sustainable farming management connected with stable economy, community and environment.

Precision agriculture bases on observing and responding to inter-field soil characteristics and crop variations. Three pillars of this concept are satellite imagery, information technologies, and geospatial tools with using satellite positioning system like GPS. The concept of precision agriculture at first was emerged in the UK and the United States in the 1990th. Before the end of the 1990th there was widely used only one aspect of precision agriculture – navigation satellite system. Now other components, such as N-sensor, crop-meter and so on, are expanding as well (Lowenberg-DeBoer, 2003). According to the Central Russian Agrarian Library (Net1) the number of articles on Precision Agriculture subjects in foreign languages increased during the 1990th–2007 *(Figure1)*. Later the number of publication decreased. Therefore, Precision Agriculture technologies in the world passed from development stage to well completed knowledge. There is another situation with articles in Russian. Today there are many publications about Precision Agriculture in Russian, Ukrainian and Kazakh languages. So, concept of Precision Agriculture came to the CIS countries.

Figure 1: **The number of articles about Precision Agriculture in world and Russian scientific press**



Precision Agriculture concept uncludes high technical level of information storage. All information about every field and crop can be displayed as maps: maps of soil properties, biomass, yield, weeds-patches and crop-diseases distribution. These maps are used for crop management (Schpaar et al., 2009). In Russia the concept of precision agriculture began to develop since the 2000th. The main centers of Precision Agriculture in Russia for the time being: AgroPhysics Soil Institute, St. Petersburg; ZAO "Eurotechnika", Samara; Russian State Agrarian University – Moscow Timiryazev Agricultural Academy, Moscow.

Scientific Center of Precision Agriculture (SCPA) was established in 2007. The Field experiment has been carrying out since 2008. This Center is the first academic centre of Precision Agriculture in Russia (Berezovskiy et al., 2009). The main functions of the Center are: studying, learning and introduction the technologies of precision agriculture, demonstration of new methods, carrying out the education process for students, post-graduates, farmers and all persons being interested in precision agriculture.

MATERIALS AND METHODS

Soil, Field and Crops Description

The experimental field is situated in Moscow at the arable area of Field Experiment Station of Russian State Agrarian University – MTAA. The squire of experimental field is about 6 ha. Soil characteristics (pH, content of humus, phosphorus and potassium) are inspected in all the areas of field experiment to create the soil fertility map. The soils of this area are faintly acid sod-podzol, loamy-sandy and sabulous-clayey underlaied by glacial clay. Plowing layer is about 22–24 cm. The content of humus in the plowing layer is 2.1–2.5%. Availability of nitrogen, phosphorus and potassium is high. Soil is well-suitable for cereal crops and potatoes planting.

There is the four-fields crop rotation: 1) green crop of vetch-oat mix, 2) winter wheat with break crop of mustard for green manure, 3) potatoes and 4) barley.

In the experiment such crops varieties are presented: winter wheat (Triticum aestivum, selection lines L-15 and L-1), barley (*Hordeum vulgare*, variety 'Mikhaylovskiy'), potatoes (*Solanum tuberosum*, varieties 'Nevskiy', 'Red Scarlett', 'Udacha' and others).

Technical device and equipment

The tractors are equipped with Navigation system (GPS; Trimble), Parallel guidance system (Autopilot), specific soil-tilling and seed-drilling device, fertilizers spreaders and pesticide sprayers with dosing device (AMAZONE).

For calculating experimental data, mapping and programming tractor's tasks the special program for precision agriculture SMS Advanced 9.0 (AG Leader, USA) is used.

Biomass of crops is observed and mapped several times during each vegetation season. Equipment for biomass mapping includes: N-sensor ALS® Yara and GreenSeeker® RT 200.

For estimation of Nitrogen content in the leaves of cereals during vegetation season N-tester® Yara is used.

Field experiment scheme

Two factors of crop planting are investigated in field experiment. Factor A is technologies of crop management, and factor B – soil tillage treatment.

Factor A. A1 is a traditional technology: using the marker disc for plowing, cultivation, sowing, crop-tending operations and fertilizing in equal dozes for all field areas. A2 is precision technology: using GPS-navigator and autopilot system for plowing, cultivation, sowing, crop-tending operations and fertilizing in different doses on-line according to N-sensors indicator for vegetating crops.

Factor B. B1 is moldboard plowing to the depth of 22–24 cm, B2 is reduced tillage, i.e. cultivation to the depth of 10 cm, B3 is no-till, direct seeding. Under the winter wheat planting moldboard plowing (spinner plow Euro Opal, seeder AMAZONE D-9-30) and no-till technology (Pneumatic sod seeder drills AMAZONE DMC-3001) are used and compared. Under barley planting moldboard plowing (spinner plow Euro Opal) and reduced tillage (cultivation to the depth of 10 cm with AMAZONE BBG Pegasus tractor mounted disc cultivator) are used and compared.

RESULTS AND DISCUSSION

The benefits of Autopilot system for Precision Agriculture

In the field experiment the infallibilities of different agrotechnological operations, conducting with or without GPS-navigator and autopilot system are compared. This system allows to escape overlap fail-place and blank spots in the field and to keep equal sowing distance. The results of three-year observations are presented in *Table 1*.

Autopilot system is more favorable for potatoes planting *(Table 2)*. Deviation of inter-row distance under traditional technology (marker) is about 7–13%, under precision technology (autopilot) is 3–5%. Location of potatoes plants exactly in the ridge center is requirement for correct potatoes planting. In traditional technology the deviation of plants from ridge central line was about 5–15 cm, in precision technology 2–4 cm *(Table 2–3, Figure 2)*. Potatoes are planted by tuber planter Grimmer GL-34T. Ridging is operated by ridge former Grimmer. Two technologies (autopilot and marker) for comparison the precision of these operations are used.

According to our observation, autopilot system is very useful from the point of view both quality and quantity of potatoes production (Berezovskiy et al., 2012).

Table 1.

Inter-row pass-way distance in the fields under different crops, operation sowing systems and seeders

Crop	Moldboard plowing, seeder AMAZONE D-9-30*		No-till technology, sod seeder AMAZONE DMC-3001*
	marker	autopilot	autopilot
	Inter-row pass-way distance (average ± deviation) (cm)		
	2008		
Barley	15,4 ± 3,4	13,5 ± 1,5	-
	2009		
Barley	14,0 ± 2,0	12,3 ± 0,3	17,3 ± 1,5
Vetch-oat mix	-	13,5 ± 1,5	18,1 ± 0,7
Winter wheat	16,3 ± 4,3	14,3 ± 2,3	17,3 ± 1,5
	2010		
Barley	15,2 ± 3,2	13,2 ± 1,2	18,1 ± 0,7
Vetch-oat mix	-	13,7 ± 1,7	19,1 ± 0,3
Winter wheat	17,0 ± 5,0	13,5 ± 1,5	20,2 ± 1,4

*Inter-row distance of seeder D-9-30 is: 12 cm, of sod seeder DMC-3001: 18.8 cm.

Table 2.

Inter-row pass-way distance in potatoes crops and significant deviation of plants from the ridge center regarding the autopilot and marker planting technologies

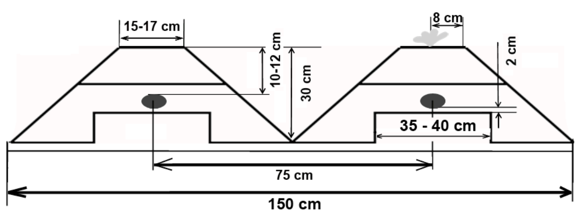
Year	Inter-row distance (cm)		Deviation of plants from the ridge center (cm)	
	marker	autopilot	marker	autopilot
2008	From 62 to 85	75 ± 3.5	± 10–13	± 3.5
2009	From 65 to 81	75 ± 2.8	± 6–10	± 2.8
2010	From 60 to 80	75 ± 3.3	± 5–15	± 3.3

Table 3.

Frequency (%) deviation of potatoes plants from the ridge center under different planting technologies

Deviation (cm)	Marker		Autopilot	
	Surface cultivation	Deep plowing	Surface cultivation	Deep plowing
0–2	14	17	40	41
3–5	35	20	48	37
6–8	25	24	10	15
9–11	17	25	2	6
12–14	7	14	-	1
>14	2	-	-	-

Figure 2: **Scheme of planting and furrow ridges at potatoes field**



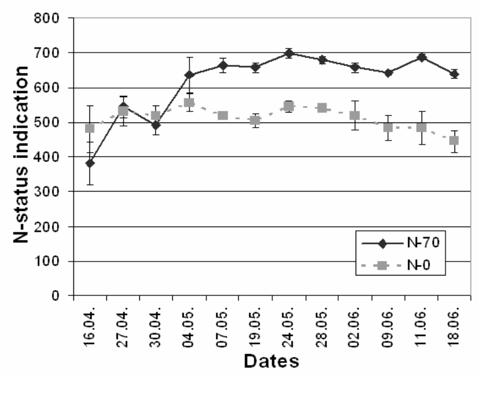
Using of Nitrogen-testers for estimate N-level in leaves of cereal plants

The using of leaf-nitrogen testers, biomass scanners and crop-meters is broadly adapted in precision agriculture (Lowenberg-DeBoer, 2003; Feiffer et al., 2007; Berezovskiy et al., 2009; and others). N-sensors are suitable for on-line application of fertilizers and pesticides (Berezovskiy et al., 2009; Schpaar et al., 2009). N-sensor measures NDVI (Normalized Difference Vegetation Index) that can be used as a reflection of crop density and health. Well-developed crop is described by high NDVI level. Low-level NDVI indicates depressed or diseased crop (Feiffer et al., 2007). According to NDVI-level the different doses of fertilizers and pesticides can be applied for the different spots of field (Lowenberg-DeBoer, 2003).

The measurement of leaf-N-status on winter wheat and barley with N-tester represents the "healthy status" of crops. This information is useful for application (if necessary) of different doses of nitrogen fertilizers and improving cereal grain quality.

The dynamic of nitrogen balance in wheat and barley leaves under various N doses is studied during three seasons under different weather conditions. The examples of wheat leaf N-dynamic tendencies are presented at *Figure 3.* Barley is not fertilized during vegetation season, but its N-status helps us to predict the further yield. Winter wheat is fertilized with ammonium nitrate twice a season: at the beginning of the spring vegetation (after winter, tillering stage) and at the beginning of earing stage. According to the scheme of the experiment various N doses are used: N=0 kg ha^{-1}, N=70 kg ha^{-1}, two times during the vegetation season (traditional agriculture) and N=60–80 kg ha^{-1}, two times during the vegetation season (precision agriculture; doses are calculated on-line by board computer according to actual wheat biomass).

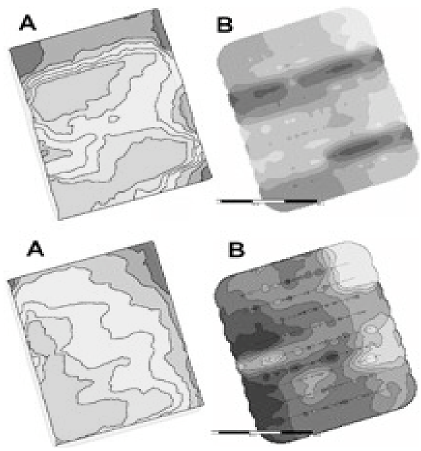
Figure 3: **Nitrogen balance in leaves of winter wheat under various N doses**



Biomass and yield mapping

For mapping of biomass two sensors: GreenSeeker and N-sensor are used. The aim of investigation was to estimate and compare calibration accuracy of these instruments. The search operating width of GreenSeeker is about 1 meter; the operation width of N-sensor is approximately 12–15 meters. These optical equipments for mapping biomass are used during the same periods of time. The GreenSeeker and N-sensor maps are similar on each observing date *(Figure 4)*. So these implemented devices are comparable.

Figure 4: **Two NDVI-measuring systems comparison**



Note: A – GreenSeeker, B – N-sensor, upper – 26–28 April, lower – 1–2 June.

Biomass maps are used to create prescription of N-application for crops according to their needs.

The algorithm of prescription is illustrated by *Figure 5*. Poor-biomass and over-biomass places at the field need lower dose of Nitrogen due to unprofitable using the fertilizers in high doses *(Figure 6)*.

Figure 5: **Prescription for N application at tillering stage of winter wheat (EC 30–36)**

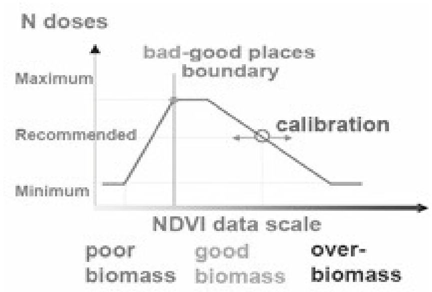
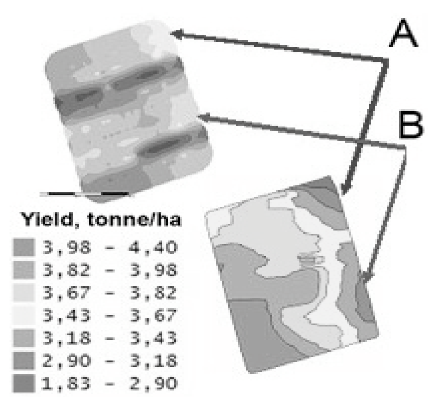


Figure 6: **Maps of winter wheat biomass and yield in 2010**



Comparison of different spots on the field: A – Poor biomass, low yield, application N 70 kg ha^{-1} two times during vegetation season; B – Poor biomass, low yield, application N<70 kg ha^{-1} two times during vegetation season.

Profitability of N application depends on spots on the field. If the conditions of the spots are unfavorable for wheat cultivation, it is no use to apply the high N doses. Profitability of N application at the problem spots of field is shown in *Table 4*.

Table 4.

Profitability of N application at the problem spots of field

Treatment	Yield (tonna ha^{-1})	Grain mass (kg) per every 1 kg of applied N	Profitability of N fertilizers use (%)
N= 0 kg ha^{-1}	2,40	-	-
Traditional agriculture N=70 kg ha^{-1}	2,73	4,7	-44
Precision agriculture N=65 kg ha^{-1}	3,11	10,9	+20

CONCLUSION

The researches of tree-year duration demonstrate the preference of precision agricultural technology in planting cereal crops and potatoes in the Central Region of Russia at loamy-sandy sod-podzol soils.

The following elements and methods of precision agriculture were examined: soil characteristics mapping, autopilot for sowing and crop-tending operations, green biomass mapping with N-sensors.

The using of optical N-sensors is effective for application of different doses of fertilizers and improving yield quality.

Autopilot system for sowing and crop-tending operations is much effective as it allows avoiding the over-sowing and gaps.

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