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Influence Of Automatic And Parallel Driving Systems On The Efficiency Of Using Machine-Tractor Units In The Northern Region Of The Republic Of Kazakhstan

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Abstract.

Precision farming systems are being intensively introduced into the agricultural production of the Republic of Kazakhstan. According to developers and dealerships, precision farming can reduce the cost of fertilizers, seeds, PPA, fuel, and lubricant mate-rials by an average of 20%. At the same time, the possibilities of obtaining efficiency from the use of precision farming systems in certain conditions of their use have not been fully studied. The aim of this work was to assess the influence of parallel and automatic driving systems on the technical, operational, and economic indicators of units for sowing, chemical processing, harvesting, and deep autumn tillage in comparative tests in the northern region of the Republic of Kazakhstan. To achieve this purpose, comparative tests of a seeder for sowing wheat, self-propelled sprayer for chemical weeding of wheat and flax, combine harvester for harvesting wheat, and al-so the unit for deep, subsurface tillage in Northern Kazakhstan were conducted. In the course of conducting comparative tests, the influence of GPS navigation systems, automatic and parallel control systems, as well as seeding control systems on agricultural, energy, operational, technological, and economic performance of units was determined.

KeyWords: comparative tests, precision farming, parallel driving, automatic driving, unit.

Introduction. In the early 90-ies of the 20th century, a new concept appeared in the world of agricultural science, known as precision farming. The origination of precision farming was due to the emergence of the possibility of using a global positioning system (GPS, GLONASS). The use of precision farming technologies will lead to the transformation of agriculture. This conclusion is based on the obtained economic effects in the field of profitability, productivity, crop quality, and environmental protection (V. V. Yakushev 2016). Precision Livestock Farming (PLF) will contribute to the shift of commercial aquaculture or agriculture from conventional experience to a knowledge-based development regime by adapting some core concepts from the PLF and accounting for the boundary conditions and possibilities that are unique to agricultural operations. Only by the expanded use of new technologies and automated systems can this be accomplished. In order to provide solutions to the aquaculture/ agriculture industry, the Precision Farmings project is aimed at combining cutting-edge research in sensing technologies, lasers, and artificial intelligence with practical applied research.

Precision farming allows reducing the cost of fertilizers, seeds, plant protection agents (hereinafter PPA), fuel, and lubricant materials by an average of 20% (Hallett 2017; Colezea et al 2018; Gikunda & Jouandeau 2019; Quiroz & Alférez 2020; Vecchio et al 2020). In addition to reducing energy costs, resources and increasing productivity, precision farming allows the physical and agrochemical properties of the soil, the field gets the right shape, convenient for agricultural operations (Garcia et al 2016; Kelc et al 2019). Application of precision farming systems with a maximum profit provided that agricultural production, economic and natural resources are optimized. This opens up real opportunities for producing high-quality products and preserving the environment (Keskin et al 1999; V. P. Yakushev & Yakushev 2007). Precision farming systems are well established and successfully applied in the United States, Canada, Brazil, and Europe (Keskin et al 1999; Barocco & Lee 2017; Fulton et al 2018; Gusev et al 2019; P. O. Skobelev et al 2019; P. Skobelev et al 2019; Shchutskaya et al 2020). Currently, the market of Kazakhstan offers various precision farming systems such as parallel and automatic driving systems, seeding control, crop mapping, differentiated application of mineral fertilizers, and PPA. Many of these systems are already used in agricultural production. They can be purchased and installed on existing farm equipment, or buy a new tractor, seeding complex, or self-propelled sprayer on which the manufacturer has already installed this equipment. At the same time, the possibilities of obtaining efficiency from the use of precision farming systems in certain conditions of their use have not been fully studied.

Materials and Methods. In the Kostanay branch of “Scientific and Production Center of Agricultural Engineering” LLP, in 2019, works were carried out to determine the influence of GPS systems, navigation of automatic control “GreenStar 3-2630” and seeding control (on wheat sowing), GPS navigation and automatic control system “GreenStar 2-2600” (on chemical processing of crops), GPS navigation and parallel driving system with a course indicator of the company “Raven” (on wheat harvesting) and GPS navigation and parallel driving system Trimble EZ-Pilot with a display CFX-750 (on deep subsurface tillage) on agrotechnical, energy, operational, technological, and economic indicators of the unit.

Comparative tests were conducted to determine the influence of automatic and parallel driving systems on the unit's performance. During the tests, the agrotechnical, energy and operational and technological indicators (Enache et al 2011) of units consisting of a seeding complex

"John Deere 1890" with a seed hopper "John Deere 1910" in a unit with a tractor "John Deere 9410R" on wheat sowing equipped with GPS navigation systems, automatic control "GreenStar 3" and seeding control, a self-propelled sprayer "John Deere 4730" on a chemical weeding using GPS navigation and automatic control systems "GreenStar 2", combine harvester "ACROS-530" and chopper Power Stream 9 with GPS navigation and parallel driving systems (course indicator) of the company "Raven", deep-ripper SPT-7 and tractor K-744R3 equipped with GPS navigation and parallel driving Trimble EZ-Pilot with a display CFX-750 and without seed control systems, automatic and parallel driving (systems were disabled).

The tests were conducted in the North Kazakhstan region, the Republic of Kazakhstan. The method of conducting comparative tests was based on the requirements of regulatory documentation. The test conditions were determined in accordance with the requirements of GOST 20915-2011 (Mehta et al 1995). Assessment of agrotechnical indicators on seeding according to GOST 31345, on chemical weeding according to GOST R 53053-2008, on tillage according to GOST 33736-2016, on harvesting according to GOST R 28301-2015 (GOST 2009; IL & Dubrovina 2013; Boyko et al 2018; Zubko et al 2018; Lariushin et al 2019; Rzaliyev et al 2020; Selivanov et al 2020). Assessment of energy indicators - according to GOST 52777-2007. Operational and technological assessment - according to GOST 24055-2016 (GOST 2007). The data obtained were processed using mathematical statistics using the computer program Excel (Dospekhov 1985). The assessment of economic efficiency of units was determined according to ST RK GOST R (GOST n.d.; Sorokin & Tabashnikov 2015).

Results and Discussion. Comparative tests of the seeding complex "John Deere1890" in the unit with the tractor "John Deere 9410R" equipped with the GPS navigation and automatic driving system "GreenStar 3", AutoTrac (automatic control) and seeding control from the "John Deere" company and without the system were conducted from May 16 to 22, 2019. The GPS navigation and automatic driving system "GreenStar 3" provides an accuracy of ± 20 cm from the passageway to the passageway. Setting up and preparing the seeding unit for operation, shown in Figure 1, was carried out by specialists of the farm.

Figure 1. Seeder "John Deere1890" + trailed pneumatic hopper "John Deere 1910" in the unit with the tractor "John Deere 9410R» in operation (front side view)

The conditions of comparative tests on wheat crops were typical for the zone. Average values of indicators at a depth of up to 15 cm: soil moisture - 22.3 %; soil volume mass - 1.08 g/cm3; soil hardness - 1.1 MPa. Humidity - 42 %, air temperature - 20.5oC, seed purity - 98.2 %, seed moisture - 14.2 %, bulk density of wheat seeds - 773 kg/m3. Prior tillage – dust mulching (weeder harrow), application of fertilizers to a depth of 15-16 cm (seeder SGS-2,1).

The results of comparative tests of the seeder "John Deere 1890" (without the GPS navigation system, automatic driving, and seeding control) on wheat sowing show that at a speed of 11.3 km/h and operating width of 12.4 m, productivity per hour the main time is 14.1 ha, shift and operational time - 10.4 ha. Coefficients of use of shift and operating time - 0.74. During the operational and technological assessment of technical failures were not recorded. Therefore, the utilization rates of shift and operating time are equal. Power consumption for moving the unit across the field - 202.4 kW, specific fuel consumption - 5.3 kg/ha. The specific energy consumption per hour of main time is 50.2 MJ/ha. Actual seed consumption was 71.5 kg/ha.

The use of GPS navigation and an automatic driving system for sowing provides an increase in the working width of the seeder to 12.8 m. At a speed of 11.3 km / h, the unit capacity in one hour of the main time reached 14.5 hectares, shift and operating time - 11.0 ha. The use of a seeding control system contributed to an increase in the utilization rate of shift and operating time. Coefficients of use of shift and operating time - 0.75. Specific fuel consumption - 5.1 kg/ha. The specific energy consumption per hour of main time is 49.2 MJ/ha. Actual seed consumption - 70.0 kg/ha.

It was found that the use of GPS navigation systems, automatic driving, and control of seeding on wheat crops provided an increase in the operating width by 0.4 m or 3.2 %. At the same time, the capacity of the unit for one hour of the shift and operating time increased by 0.6 ha, which is 5.7 %. The use of GPS navigation, automatic driving, and seeding control in wheat crops results in a

2% reduction in specific energy consumption. Specific fuel consumption is reduced by 0.2 kg/ha, and seed consumption by 1.5 kg/ha or 4.0 and 2.0 %, respectively (Figure 2).

It is established that the unit consistently and efficiently performs the technological process regardless of the availability of GPS navigation, automatic driving, and seeding control systems.

The calculation of economic efficiency showed that the use of GPS navigation systems, automatic driving, and seeding control leads to a reduction in total cash costs by 8.2 %, while the annual savings in total cash costs is 1465 thousand tenges (3.6 thousand US dollars) compared to the seeding unit without systems.

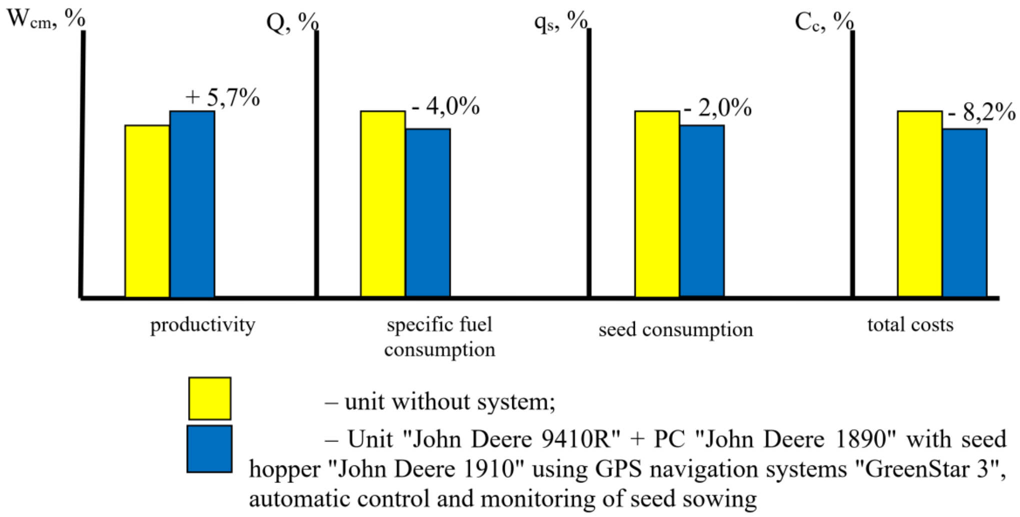

Figure 2. Influence of GPS navigation system, automatic driving "GreenStar 3" and seeding control on technical and economic indicators of the unit on sowing wheat

In the period from 19 to 26 June 2019, comparative tests were conducted on the sprayer of a self-propelled "John Deere 4730" equipped with GPS navigation and automatic driving systems (AutoTrac) with a display "GreenStar 2" and without an automatic driving system. The type of sprayer in operation is shown in Figure 3.

Figure 3. Sprayer “John Deere 4730” in operation (rear side view)

Comparative tests of a self-propelled sprayer were carried out on the chemical processing of cereals and oilseeds. The work was carried out from 8 p.m. until 10 a.m. the next day due to the high wind speed and high ambient temperature in the daytime. During the day, the air temperature reached 25-30°C, and the wind speed was eight m/s. Adjustment and preparation of the sprayer for work was carried out by specialists of the farm.

The conditions of comparative tests on the chemical processing of cereals (wheat) and oilseeds (flax) were typical of the zone. Average values of indicators at a depth of 10 cm: soil moisture - 26.4%, soil volume mass - 1.1 g/cm3, soil hardness - 1.5 MPa. Humidity is 38%, air temperature is 16.2°C, wind speed is 0.8 m/s, plant height is 11.2 cm, working fluid temperature is 15°C, row spacing for flax is 25.2 cm, for wheat - 15.3 cm, the number of weeds - 229 pcs/m2. Test conditions are typical of the zone when carrying out chemical processing of cereals and oilseeds.

The results of comparative tests show that the use of self-propelled sprayer "John Deere 4730" (without a GPS navigation system and automatic control) on the chemical weeding of cereals and oilseeds at a speed of 26.2 km/h and a working width of 27.8 m ensures productivity for the main hour of 72.8 ha, shift and operational time - 38.6 ha. Coefficients of use of shift and operating time - 0.53. The power consumption for moving the sprayer across the field is 94.9 kW, specific fuel consumption is 0.78 kg/ha. The specific energy consumption per hour of main time is 5.4 MJ/ha. The preset flow rate of the working fluid is 55.0 l/ha; the actual one is 59.6 l/ha.

It was found that the use of GPS navigation and an automatic driving system led to an increase in the working width to 30.4 m. The unit's productivity, at a speed of 26.2 km/h, in one hour of the main time reached 79.6 ha, shift and operating time - 45.2 ha. Coefficients of use of shift and operating time - 0.57. The specific energy consumption per hour of main time is 5.0 MJ/ha, and the specific fuel consumption is 0.66 kg/ha. The preset flow rate of the working fluid is 55.0 l/ha; the actual one is 52.0 l/ha.

The use of the GPS navigation system, automatic driving on the chemical weeding of cereals and oilseeds provided an increase in the working width by 2.6 m or 8.4%. Sprayer productivity in one hour of the shift and operating time increased by 6.6 ha, which is 14.6%. Specific fuel consumption is reduced by 0.12 kg/ha, specific fluid consumption by 7.6 l/ha or 17 and 14.5%, respectively.

It was found that the unit stably and efficiently performs the process regardless of the availability of GPS navigation, automatic control.

Based on the obtained data, the economic efficiency of using the self-propelled sprayer "John Deere 4730" equipped with GPS navigation and automatic control system and without a system was calculated.

An analysis of the results of comparative tests showed that the use of a self-propelled sprayer “John Deere 4730” equipped with a GPS navigation and automatic control system provides annual savings in the total cost of money in the chemical weeding of grain and oilseeds in the amount of 6 562.6 thousand tenges (16.4 thousand $ US). Total cash costs are reduced by 9%, specific fuel and herbicide consumption by 17 and 14.5%, respectively. Figure 3 shows a diagram of the influence of the automatic driving system on the technical and economic indicators of the self-propelled sprayer "John Deere 4730" during chemical weeding of cereals.

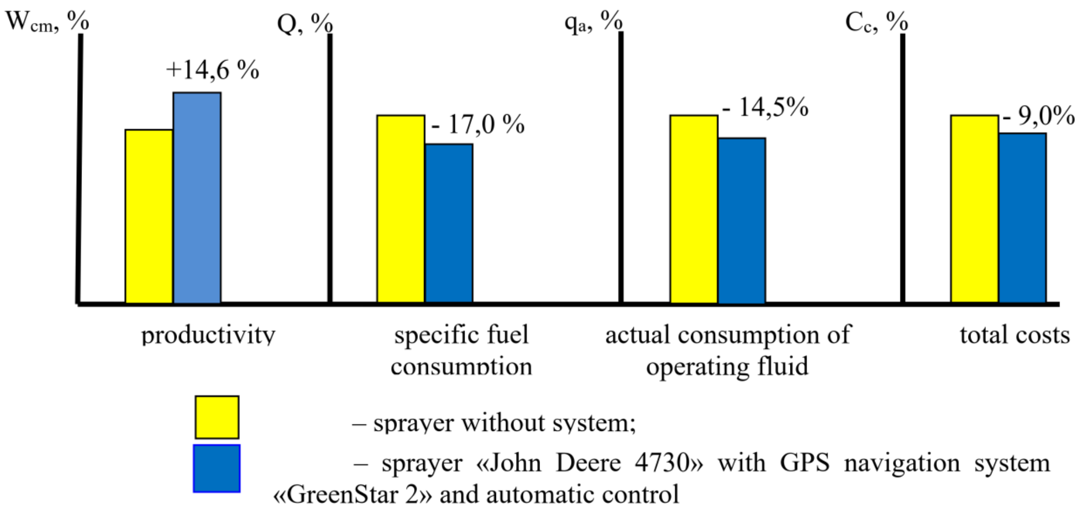

Figure 3. The influence of the automatic driving system on the technical and economic indicators of the self-propelled sprayer "John Deere 4730" during chemical weeding of cereals

In the period from September 12 to September 15, 2019, comparative tests of the combine harvester “ACROS-530” with a header Power Stream 9 equipped with a parallel driving system (GPS navigation with direction indicator) by “Raven” (USA) and without using a parallel driving system were conducted. Combine harvester “ACROS-530” with a header Power Stream 9 is shown in Figure 4.

During testing, the average values of indicators at a depth of 10 cm: soil moisture - 19.7%, soil hardness - 1.2 MPa. Wheat grain yield - 20.2 kg/ha, 1000 grain weight - 43 g, grain moisture - 18%, straw moisture - 16.2%, plant height - 0.6 m, plant density - 379 pcs/m2, no weediness. The conditions of comparative tests of the combine harvester “ACROS-530” with a header Power Stream 9 during agrotechnical, energy, and operational-technological assessments were typical for the zone during the period of work.

The results of comparative tests of the combine harvester “ACROS-530” (without a GPS navigation system and parallel driving) on cereals harvesting (Table 3) show that at a speed of 7.8 km/h and a working width of 8.6 m, productivity per hour main time is 6.7 ha, shift and operational time - 4.7 ha. Coefficients of use of shift and operating time - 0.7. Specific fuel consumption - 7.1 kg/ha. The specific energy consumption per hour of main time is 76.9 MJ/ha.

Figure 4. Combine harvester RSM-142 "ACROS-530" with a header Power Stream 9, in operation

It was found that the working width of the header, thanks to the GPS navigation system and parallel driving, increased to 8.7 m. Unit productivity at a speed of 7.8 km/h in one hour of main time reached 6.8 ha, shift and operating time – 4.8 ha. Coefficients of use of shift and operating time - 0.7. Specific fuel consumption - 7.0 kg/ha. The specific energy consumption per hour of main time is 75.8 MJ/ha.

The GPS navigation and parallel driving system, when harvesting cereals, increases the working width by 0.1 m or 1.2%. At the same time, the productivity of the combine harvester for one hour of the shift and operating time increased by 0.1 ha, which is 2.1%. Using the system allows to reduce specific energy consumption by 1.1 MJ/ha or 1.4%, and specific fuel consumption by 0.1 kg/ha or 1.4% compared to a combine harvester without a system.

It was established that the combine harvester “ACROS-530” with a header Power Stream 9 steadily and efficiently performs the process regardless of the availability of GPS navigation and parallel control.

The cost-effectiveness of using the combine harvester “ACROS-530” equipped with a GPS navigation system and parallel control and without system was calculated. During the calculations, the data obtained during comparative tests were used.

Based on the results of the economic assessment, it was established that the use of the combine harvester “ACROS-530” with the parallel driving system (GPS navigation with direction indicator) of the Raven company allows reducing the total cash costs by 3%, labor costs and specific fuel consumption by 1% compared to the combine harvester “ACROS-530” without a parallel driving system. The use of the combine harvester “ACROS-530” with a header Power Stream 9 equipped with a parallel driving system for harvesting wheat provides annual savings in total cash costs of

233.4 thousand tenges ($ 585 US). Figure 5 shows a diagram of the influence of the parallel driving system on the technical and economic indicators of the combine harvester “ACROS-530” with a header Power Stream 9 on wheat harvesting.

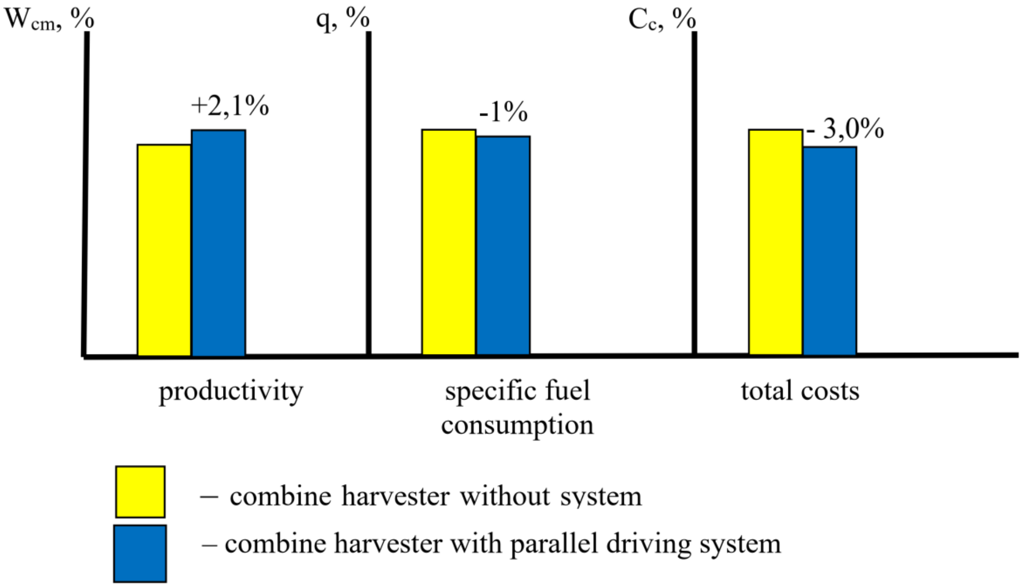

Figure 5. Influence of the parallel driving system on the technical and economic indicators of the combine harvester "ACROS-530" with a header Power Stream 9 on wheat harvesting

According to the results of comparative tests of the combine harvester "ACROS-530" with a header Power Stream 9 on wheat harvesting equipped with a parallel driving system, it was found that the use of the system requires increased stress and attention, which leads to rapid fatigue of the machine operator.

In the period from September 16 to 19, 2019, comparative tests of the deep-ripper SPT-7 in unit with a tractor K-744 P3 equipped with a parallel driving system Trimble EZ-Pilot (auto-steering) with a display CFX-750 manufactured by “Trimble” (USA) and without using the system were conducted. Figure 6 shows the unit in operation.

The tests were carried out on the processing of a steam field in the North Kazakhstan region. The Trimble EZ-Pilot parallel driving system with a display CFX-750 was operated using a free satellite signal (GPS) with an accuracy of up to 100 cm. Setting up and preparing the equipment for the operation was performed by specialists of the farm and Navistar Asia Kazakhstan LLP.

Test conditions for deep tillage were typical for the area. Average values of indicators at a depth of up to 30 cm: soil moisture - 24.9 %, soil volume mass - 1.2 g/cm3, soil hardness - 2.7 MPa. Humidity - 28 %, air temperature - 21.40C, and wind speed - 4.5 m/s. Prior tillage – cultivation to a depth of 12 cm.

Figure 6. Deep-ripper SPT-7 in unit with tractor K-744 P3, in operation

Comparative tests of the deep-ripper SPT-7 in unit with the tractor K-744 P3 equipped with the parallel driving system EZ-Pilot were carried out at a speed of 7.8 km/h, the path depth of the plow working bodies was 22.0 cm, and the standard deviation was within 2.4 cm. The working width of the deep-ripper using the parallel driving system and without using the system was 7.3 m.

It has been established that the use of the parallel driving system EZ-Pilot using a free signal (GPS) from a satellite with an accuracy of 100 cm does not provide technical and technological advantages for unit consisting of a tractor K-744 R3 and a deep-ripper SPT-7 for primary tillage.

Based on the obtained data, the economic efficiency of using the unit consisting of the deep-ripper SPT-7 and the tractor K-744 P3 equipped with the parallel driving system EZ-Pilot with and without the display CFX-750 was calculated.

The analysis of the results of the economic assessment showed that the operation of the unit consisting of the tractor K-744 P3 equipped with the parallel driving system EZ-pilot and the display CFX-750 and the deep-ripper PGP-7 as compared to the unit consisting of the tractor K-744 P3 and deep-ripper STP-7 without a system leads to an increase in total cash costs of $ 174 tenge/ha ($ 0.4 US) and cost overruns of 160.6 thousand tenge ($ 402) or 3% per year. Figure 7 shows a diagram of the influence of the parallel driving system on the technical and economic indicators of the combine harvester “ACROS-530” with a header Power Stream 9 for wheat harvesting.

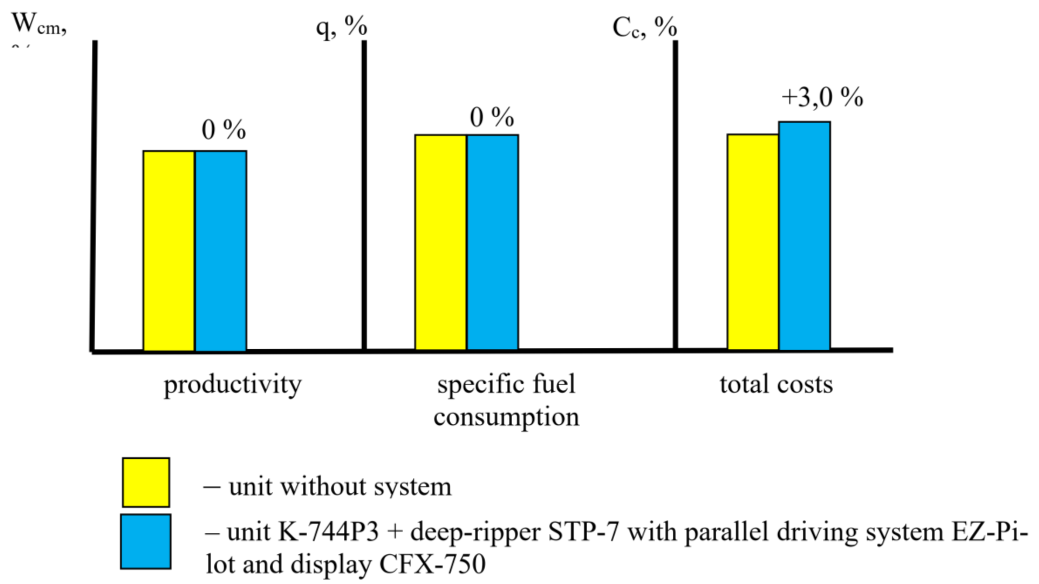

Figure 7. Influence of parallel driving system EZ-pilot and display CFX-750 on technical and economic indicators during deep steam processing

Conclusion

1) The use of GPS navigation system, automatic driving "GreenStar 3" in wheat sowing provided an increase in the productivity of the unit in one hour of shift time by 5.7%, reduction of labor costs by 5%, specific fuel consumption by 4.0%, and seed consumption by 2.0% The annual savings of the total cost of money from the operation of the sowing unit are 1,465 thousand tenges ($ 3.6 thousand US).

2) Using the GPS navigation and automatic control system "GreenStar 2" on the chemical weeding of cereals and oilseeds contributes to an increase in shift productivity by 14.6%, a reduction in specific energy consumption by 8%, fuel consumption by 17.0%, and working fluid consumption by 14.5%. At the same time, total cash costs are reduced by 9%, the annual saving of total cash costs is 6562.6 thousand tenges ($16.4 thousand US).

3) The use of a parallel driving system (GPS navigation with a direction indicator) on wheat harvesting leads to an increase in productivity by 2.1%, a decrease in total cash costs by 3%, labor costs and specific fuel consumption by 1.4%, while annual savings in total cash costs are 233.4 thousand tenges ($ 585 US).

The use of a parallel driving system for harvesting cereals requires increased stress and attention, which leads to an increase in the fatigue of the machine operator. To increase the efficiency of using a combine harvester, it must be equipped with an automatic driving system.

4) The use of the parallel driving system EZ-Pilot and the display CFX-750 using a free GPS signal from a satellite in the North Kazakhstan region is not economically feasible on the tillage. This leads to an increase in total cash costs in the amount of 174 tenges/ha (0.4) and costs overruns by 160.6 thousand tenges ($ 402 US) per year.

To ensure the efficiency of the use of units equipped with the parallel driving system Trimble EZ-Pilot and the display CFX-750 on deep tillage in the northern region of the Republic of Kazakhstan, it is necessary to use a paid GPS signal from the satellite providing an accuracy of 15-20 cm.

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