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ROLE OF UNMANNED AERIAL VEHICLES IN PRECISION FARMING

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Abstract

Purpose*: By 2050, world population will exceed 9 billion people. According to some projections to feed the world's population, the agricultural sector must increase production by 70%. The number of resources suitable for use in agriculture - land, water, energy - will decline. Here the farmers have to rely primarily on support of new technologies that not only increase production with limited resources, but also improve its effectiveness. Increased yields in crop production - a strategic task for Ukraine.* ***Discussion****: The object of research is the comparative analysis of the market of production and export of wheat in leading countries of the world is carried out. As well as advanced direction of crop capacity increasing in agriculture with help of Unmanned Aviation System is considered.* ***Results:*** *Practice shows that rural aircraft exceeds the performance processing ground equipment several times. It allows you to quickly carry out crops and their processing by pesticides, toxic chemicals, to make fertilizer, to monitor. The use of modern unmanned aerial vehicles will extend the benefits of small aircraft.*

Keywords: agriculture; airplane; crop protection; perspective; technologies; pest control; productivity; unmanned aerial vehicle; unmanned aircraft systems; wheat.

1. Introduction

Ukraine has been playing significant role on global agriculture arena for decades being among top 10 exporters of agriculture products with 32.5M hectares of arable land producing 90-100M tons of cereal every year. In addition, Ukraine has 30% of world “chernozem” or black soil, one of the most fertile soils worldwide. From economical perspective, every second hryvna in Ukrainian GDP comes from agriculture sector that employs around 20% of its population.

In 2015 World Bank predicted that the global population will increases to 9 billion people by 2050 mostly driven by emerging countries like Brazil, India, China and Africa. According to some projections, to feed the growing population, the agricultural sector must increase production by 70%. The key challenge is that the number of resources available for use in agriculture will be reduced. Areas of arable land are relatively stable and global warming puts significant restriction on use of water and energy to produce incremental crop.

This challenge puts a lot of responsibilities and pressure on Ukrainian agriculture sector. Increasing yields in crop production is a strategic task for Ukraine. The current methods of cultivation used in Ukraine and other countries limited to traditional technologies are inefficient and prevent from reaching the goal to address the problem. The current methods used for land cultivation that rely on land machines and traditional aircrafts have many shortfalls in productivity, efficiency and flexibility.

2. Previous research and publications

The solution to this problem is possible on the basis of the creation of new high-yield crop varieties and new technologies of their cultivation; introduction of advanced and high-performance equipment, new

forms of work organization in the agricultural sector. At the heart of the solution is precision agriculture concept that is a set knowledge intensive technologies, maximizing the use of agricultural resources, while reducing the cost of production to maximize performance and increase the profitability of land use. In mature agriculture countries precision agriculture is used for planning the workload, chartering of farmland, accounting field areas, monitoring of plant health condition and discriminatory application of fertilizers.

3. Research tasks

Various methods of information gathering, in particular from the aircraft, provide agronomic service relevant and reliable information on the field state: the problem areas, the development of plants, the effectiveness of fertilizers and herbicides use, efficiency and quality of agricultural machinery work, etc. Collected on a regular basis data form the basis for the solution of one of the most important tasks of agronomy that is forecasting yields.

4. Research results

Practice shows that agricultural aviation has advantages over ground equipment on the efficiency of field processing up to twelve times. It allows you to carry out aero seeding of some plants quickly, pesticides and other agriculture chemicals spraying, applying fertilizers, and carrying out monitoring. Furthermore, unlike conventional ground equipment, aircraft do not damage crops, and do not reserve the wheel track. This ensures additional harvest up to 6% and allows farmers to apply to spray crops when land machines cannot work in the field. For example, early spring or immediately after rainfalls, when soil is wet and wheeled vehicles simply cannot get in the field or late summer when crops are high (over 1 m) and tractors can damage the plants.

For timely sowing treatments needed either availability of technical equipment of farms with a large number of workers, or modern equipment with high-performance work. Timely processing of farmlands substantially limits the adverse weather conditions. In bad weather because of equipment downtime the best time for application of plant protection products is missed. So, it is extremely difficult to select herbicides which according to their mechanism of action do not relate to the dominant inhibitors in sowing of cereal crops for early spring application in a narrow temperature window.

Thus, in many cases, there is no alternative method to aviation. Its main advantage is high performance and efficiency of work, which allows optimal deadlines to process the field.

Currently the main air vehicle for crop spaying in Ukraine are airplanes An-2 and helicopters Mi-2. Most of the planes and helicopters of these models have long outlived their air worthiness, but even this equipment is in very short supply in domestic agriculture. The areas of farmland which need agricultural aviation spraying, account for about 30 722.2 thousand ha. One plane An-2 replaced the work of 5 – 10 tractor sprayers, processing 40 – 50 times more crops than a tractor sprayer per day. In addition, it saved 80 - 90% of labor costs. Agricultural aircraft operates in extremely difficult conditions. For better treatment of the plants in foreign practice may be used flights at a height of 1 – 2 meters from the ground and turns with banking angle up to 60°. It verges on the aerial acrobatics, exhausts a pilot and often leads to serious flight accidents. In the Soviet Union air spraying works were carried out without much damage to their quality at a height of 5 – 10 meters and followed by a climb and turn around maneuvers.

Advantages of the aircraft in the agricultural work are undeniable, if it flies over the flat field. Mountain slopes, broken ground, small fields require more maneuverable unmanned aerial vehicle (UAV). Its advantages are particularly valuable where it is impossible to arrange the runway, even for very light aircraft. Perfect landing characteristics of UAVs allow move the runway closely to the treated area. The advantages are obvious [1].

Efficiency of air assistants directly depends on the design features of the aircraft. One would think, does it matter what we use to spray fertilizers or chemicals? However, aircraft and high-performance chemicals made according to the latest requirements of farming, themselves do not provide economical and rapid processing of crops from the air. The chemical substance can be useful only if it is distributed evenly with a desired concentration on the treated surface. Meanwhile, the increase in the wing bearing capacity, or as they say in aerodynamics, increase the downwash flow, improves evenness of the chemical distribution on the surface to be treated. The lift in helicopter is created by dropping vertically down a large mass of air. Reflecting from the ground, such flow evenly covers both sides of the paper plant by pesticides, which is especially important in the processing of

gardens and vineyards: pests of fruit crops usually nest on the underside of the leaf. At the same time this effect is limited to the speed of up to 40 km/hour and when helicopter flies above that speed the spraying characteristics are similar to those of fixed wing aircrafts. [2]

UAVs are produced in many countries of the world: the United States, Israel, Germany, France, Japan, China are the leaders. The majority of the UAV are military ones, and a pioneer in use of UAVs for agricultural purposes is Japan. Purposes of UAV usage are various – scaring the birds, spraying of areas, theft protection, creation of fields' maps, monitoring the evenness of germination and analysis of all the necessary nutrients to plants availability over a large area. With the help of the UAV you can fix the spread of plant diseases on time, purposefully apply fertilizers or spray chemicals against pests.

Back in the 80s of the last century, Japanese scientists have found that the planes over fields of farmers are not the best solution. Their use is limited by difficult terrain, power lines, trees, populated localities. Researchers concluded that the most effective are not big vehicles, controlled by people on board, but small flying robots, in other words – UAVs. Since then, the Ministry of Agriculture of Japan has been actively promoting this idea. Several models of UAVs that are used to monitor crops are developed in Japan. Then, in 1990 an unmanned helicopter Yamaha RMAX was introduced as a modern means for spraying crops. A small, of the size of a motorcycle, remotely controlled helicopter equipped with a 2.4-liter two-stroke engine is capable of carrying a working load of up to 28 kg and spraying chemicals at a speed of 24 km/h [3-4].

Table 1 provides a comparison of the UAV and aircraft An-2.

According to constructive features the UAVs are divided into the following types: airplane, helicopter.

According to flight time UAVs are divided into: short-range (1-2 hours), average (6-12 hours), and long-range (24-48 hours).

According to take-off weights they are divided into: ultralight (up to 5 kg); light (up to 200 kg); medium (up to 1000 kg) and heavy (over 1000 kg);

According to altitude they are divided into: low-altitude – up to 1000 m, medium-altitude – up to 10,000 m, altitude – up to 20 000 m.

Typical UAV system is equipped with modern onboard and ground equipment:

• autopilot, which allows you to perform agricultural work in automatic mode with the help of satellite navigation system GPS both day and night;

• special sprayer with rotary nozzles, with adjustable optimum dispersion spraying of the working fluid (from monodisperse mist to atomizing rain);

• equipment for scanning of the cultivated area and transmission of information on the phytosanitary condition of crops to a personal computer or the Internet, which make it possible to specify and adjust the flight mode and work in the system of "precise deceleration."

UAVs do not need specially prepared permanent or temporary airfields. Takeoff and landing of the aircraft is possible on flat ground, not larger than 150x15m, which should have open approaches. Furthermore, they can take off from crops during germination development, particularly those which need to be processed. UAV is equipped with a radio-controlled braking and taxiway systems for its exact movements on the ground. Flight altitude on the field (from 5m during daytime to 10 – 20m at night) is regulated and controlled by 4 systems (barometric, GPS, ultrasonic and laser-guided), which guarantees high safety of flight and quality of the spray. The problem of rapid evaporation of the drops with ultralow spraying in hot weather conditions (30 degrees Celsius and above) is solved by dilution of preparations in anti-evaporation agents, for example, using aqueous solutions of nitrogen fertilizers (carbomide-ammonium mixture, etc.) or a fertilizer with a high content of amino acids (Megafol, Megafol protein, izabion). It should be also taken into account that density of some agents like carbomide-ammonium is 1.4 of density of water that can impact the amount of spray liquid that UAV can carry and spray[5]

For several years the domestic UAV flight tests took place and the vehicles are almost ready for the implementation of the integrated use of modern pesticides and agrochemicals permitted for aircraft use in Ukraine.

Almost all kinds of work in agriculture, previously recommended for aviation method, can be performed using the UAV but, so far, sieving of mineral fertilizers and ameliorants with high application rate.

Table 1

Advantages of application Airplane An-2 and UAVs in the agricultural sector

An-2	UAV
- Large airborne time; - High load capacity; - High resistance to sharp wind changes;	- The possibility of taking off in almost any terrain without the preparatory engineering work; - The ability to stay in the high readiness practically unlimited time; - Shorter and cheaper training of operators of the UAV ground control stations as compared with the preparation of the crews of manned aircraft; - Significantly lower cost (for one or two orders less, depending on the purpose and parameters of UAV) and opening times of mass production; - Possibility of providing information to consumers in near real time; - Ability to work under high radiation, chemical and bacteriological pollution of air and ground, as well as adverse weather conditions as well as night operations - UAVs do not need specially prepared permanent or temporary airfields; - There is no danger to lose the pilot; - A more accurate radius spraying; - Low cost of operation.

With their help it is possible to apply modern herbicides, insectoacaricides, fungicides, growth retardants, macro and micronutrient fertilizers for foliar application, and other growth-regulatory substances. Also it is possible to apply biological plant protection products, in particular sieving over crops of beneficial insects (Trichogramma etc.). As an example, it is to be recalled that the massive losses of cereal crops because of Fusarium and Septoria during long continuous rains in growing season in 2014, when tractors could not go in the field for weeks, managed to escape thanks to the aircraft. All of these types of work require the use of agrochemicals in reasonably short windows of time, in the proper physical phase, with high quality spraying at the minimum allowable expenses of expensive drugs and with high hygienic and environmental safety.

Having analyzed the market of unmanned aerial vehicles which can fertilize a relatively large planting acreage, we should conclude the average processing acreage by these devices. Unmanned ultralight aircraft weighing up to 40 kg with a load capacity from 20 to 35 kg are designed for low-volume spraying with the norm of the working fluid flow rate from 1 to 10 l/ha, instead of 50 – 400 l/ha in normal conventional spraying of land machines, with a working speed of 80 – 120 km/h, with a spray width of 15 – 25 m, and in some cases – up to 100 m with onboard fogging machines. UAV performance under low-volume spraying is high: 60 – 100 ha/h, 600 – 1000 ha/day, which is higher than that of off-market An-2.

It should also be said about the economic benefits of the treatments associated with a sharp fall in transportation of water (50 – 100 times), preparation and loading of working fluid in the sprayer tank, decrease in the number of auxiliary workers. But it is especially important to the reduction of energy consumption by using UAVs: for the treatment of 1 hectare of crops is enough from 10 to 200 ml of fuel. In such a case the cost of crops treatment is significantly lower than when using ground sprayers. They are able to introduce fertilizers and pollinate pests with small doses of chemicals that reduce the consumption of chemicals by about a third. Due to the greater maneuverability, some UAVs spray the crops almost without leaving the field. [8]

Other UAVs equipped with camera and weighing less than 700 grams can stay in the air for up to 45 minutes. During this period they are able to carry out aeroplane mapping (aerial photography, aerial mapping) of an area of size from 1.5 to 10 square kilometers. Cruising speed ranges from 36 to 57 km/h, radio contact with the operator can be kept at a distance of 3 km. UAV is able to withstand wind gusts of up to 12 m/s.

If we compare relatively low cost of UAV with enormous economic benefits that we get from the use of this miracle of technology, it becomes clear how popular will the UAVs be in the near future. This "robotics" of agriculture first of all will get interested the owners of large farms, where is difficult to keep track of how each leaf looks like, how is the growth of plants going, how is the color of the soil changing.[6-7]

Today, to manage a large farm is not easy. Because of the immensity of the fields, farmers may not know the condition of the land in each area and process all fields the same as required. For example, in June, all the fields are sprayed with the preparation fungicide against fungi, regardless of whether they appear in July or not. UAVs can solve this problem without big expenses, flying over farms and making high-quality images. [9]The navigation system of UAV accurately identifies and indicates the coordinates of the area on the captured images. Then, using this data, it is possible to collect the whole picture and get an idea about the state of the fields. UAVs also notice the farmer of early harvest loss. First signs of the disease in plants appear in a change of chlorophyll, the green pigment involved in photosynthesis. With the help of infrared images diseased plants can be noticed in time and prevent crop damage.

5. Conclusion

Precision agriculture is one of the "hottest" topics in agricultural and IT-specialists circles, as Forbes writes [10]. Since the fourth quarter of 2013, investments in clean technology increased significantly – writes Forbes, citing data from research company “Cleantech Group” [11].

According to the Ukrainian “IST Agro Service” Company (Chernihiv region, Varva), the use of innovative UAV technologies in agriculture can improve productivity, reduce costs, make better use of resources, automatize and control manufacturing processes. As a result we can save up to $150/ha.

AeroDrone startup develops, manufactures and operates UAV systems for crop protection. In 2016 2 UAV systems with payload of 20 and 50 kg (Fig. 1) started operations on the real fields spraying insecticides, herbicides for winter crops of wheat, corn and sunflower. The first results are confirming the key conclusions in this article regarding spray productivity, costs, infrastructure, and so on. The team also got a good learnings on the spray process, UAV refilling between flights, spraying strategy and ready to apply this knowledge, scale production and operations in 2017.

End-user is interested in the effectiveness of the product and price policy. What you need to consider, intending to buy an unmanned aircraft systems (UAS)? In any case it is necessary to take into account all the factors: the cost of the UAS components, the cost of one minute work of the complex, its reliability, etc., that affect the final result of a system operation. Another important factor should also be taken into account– technical staff for the system maintenance, which still needs to be appropriately trained. However, these costs will be paid back quickly by the results of work of the system and savings.

Fig. 1. Agricultural UAV “PAM-20”

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Роль безпілотних літальних апаратів під час виконання сільськогосподарських робіт

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Мета: До 2050 року населення Землі перевищить 9 мільярдів чоловік. За деякими прогнозами, щоб прогодувати населення планети, аграрному сектору доведеться збільшити виробництво на 70%. При цьому кількість ресурсів, придатних для використання в сільському господарстві - земля, вода, енергія, - буде скорочуватися. Тут аграрним виробникам доводиться сподіватися, перш за все, на допомогу нових технологій, що дозволяють не тільки збільшувати обсяги виробництва в умовах обмеженості ресурсів, а й підвищувати його ефективність. Підвищення врожайності культур в рослинництві - стратегічне завдання для України. **Результати:** Об'єктом дослідження виступає порівняльний аналіз ринку виробництва і експорту пшениці в провідних країнах світу, а також розглядаються перспективні напрямки підвищення врожайності зернових в сільському господарстві за допомогою безпілотних авіаційних комплексів. **Обговорення:** Практика показує, що сільгоспавіація перевищує по ефективності обробки наземну техніку в кілька разів. Вона дає можливість в короткі терміни проводити посів культур, їх обробку пестицидами, отрутохімікатами,

вносити добрива, вести моніторинг. Використання сучасних безпілотних літальних апаратів розширить переваги малої авіації.

Ключові слова: безпілотний літальний апарат; безпілотні авіаційні системи; боротьба зі шкідниками; засоби захисту рослин; літак; перспективні; технології; продуктивність; пшениця; сільське господарство.

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Роль беспилотных летательных аппаратов при выполнении сельскохозяйственных работ

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Цель: К 2050 году население Земли превысит 9 миллиардов человек. По некоторым прогнозам, чтобы прокормить население планеты, аграрному сектору придется увеличить производство на 70%. При этом количество ресурсов, пригодных для использования в сельском хозяйстве - земля, вода, энергия, - будет сокращаться. Здесь аграрным производителям приходится надеяться, прежде всего, на помощь новых технологий, позволяющих не только увеличивать объемы производства в условиях ограниченности ресурсов, но и повышать его эффективность. Повышение урожайности культур в растениеводстве - стратегическая задача для Украины. **Результаты:** Объектом исследования выступает сравнительный анализ рынка и экспорта пшеницы в ведущих странах мира, а также рассматриваются перспективные направления повышения урожайности зерновых в сельском хозяйстве с помощью беспилотных авиационных комплексов. **Обсуждение:** Практика показывает, что сельхозавиация превышает по эффективности обработки наземную технику в несколько раз. Она дает возможность в короткие сроки проводить посев культур, их обработку пестицидами, ядохимикатами, вносить удобрения, вести мониторинг. Использование современных беспилотных летательных аппаратов расширит преимущества малой авиации.

Ключевые слова: беспилотный летательный аппарат; беспилотные авиационные системы; борьба с вредителями; средства защиты растений; самолет; перспективные; технологии; производительность; пшеница; сельское хозяйство.

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