TECHNOLOGICAL OPERATIONAL ASSESSMENT OF ONE PASS COMBINED AGRICULTURAL MACHINERY FOR SEEDBED PREPARATION AND SEEDING

Oskars Valainis, Adolfs Rucins, Arvids Vilde
Latvia University of Agriculture
arucins@ltk.lv

Abstract. Analysis of traditional grain farming technologies have shown that in the majority of farms the preparing of the seedbed which involves weed combating, fertilizer and weed compost embedding, soil tillage, levelling of the soil and rolling is done step by step with simple agricultural implements. That results in many passes of the tractor to prepare the seedbed and seed. The number of passes is usually no less than five, but in several cases (e.g., extreme weather conditions) it can be much higher. This has a negative effect on the grain yields due to the compaction of the soil, especially at the ends of the field on the turning lanes of the tractor. The research has shown that compacted areas on the field could be up to 40 % from the field area and the grain yield decrease could be from 15 % to 20 %. To ensure optimal grain yields, rye, wheat, barley, oats available topsoil density should be no less than 1.3 $g \cdot cm^{-3}$. The depth of the subsoil should be at least 20-25 cm and the undersoil should be loose and at least 40-50 cm in depth. If the topsoil density is exceeded by 0.1 $g \cdot cm^{-3}$ the yields can decrease on average by 10 %. Because the seedbed preparation and seeding takes 43 % of the labor in grain production, the agricultural implements and machinery development is aimed at increasing the productivity and energy efficiency and decreasing the fuel consumption. Productivity is being increased by means of using high powered tractors and more sophisticated agricultural implements and machines which combine several agricultural work types into one machine, able to prepare the seedbed and seed in just one or few passes. This article analyses combined agricultural machinery technological choices for seedbed preparation and seeding. The operational costs of the use of the machinery and other significant indicators are given and explained.

Keywords: grain farming technology, combined seeders, operational costs.

Introduction

The main tasks of the soil preparation are to optimize the soil physical properties, provide the best conditions for the seed embedding, germination and growing, weed leftovers and fertilizer embedding, weed and insect combating.

Using simple conventional soil preparation technologies increases the amount of fuel needed to carry out the agricultural works required due to the compaction of soil that has an increased resistance because of higher density. The total fuel consumption is increasing with every extra pass a tractor has to make, especially in loose soil. On the other hand, working with low resistance aggregates, usually because of several factors, the working width of the aggregate is much lower than the optimal, so the tractor power is not being used at its full potential.

Soil preparation is a very important part of the grain production process as it is essential to maximize the possible yields. The mechanical soil preparation aids better water and air circulation and fertilizer dissolving in the ground, which can boost the grain yield. There are several ways to improve soil preparation agricultural machinery and the major ones are increasing their work efficiency, lowering machineries resistance and power needed to operate it thus reducing fuel consumption of the tractor and increasing and combining several machines into one and reducing the passes needed to prepare the seedbed.

Based on operations that can be carried out, the combined agricultural machinery can be divided into five groups (Fig. 1). And there are several combinations in almost each of the groups, e.g., in the first group there is agricultural combined machinery that is doing only the soil preparation: plowing and compacting, leveling and loosening, cultivating and loosening.

The most effective are the machines of the third group, which prepare the soil, fertilize it and carry out the seeding process in one pass.

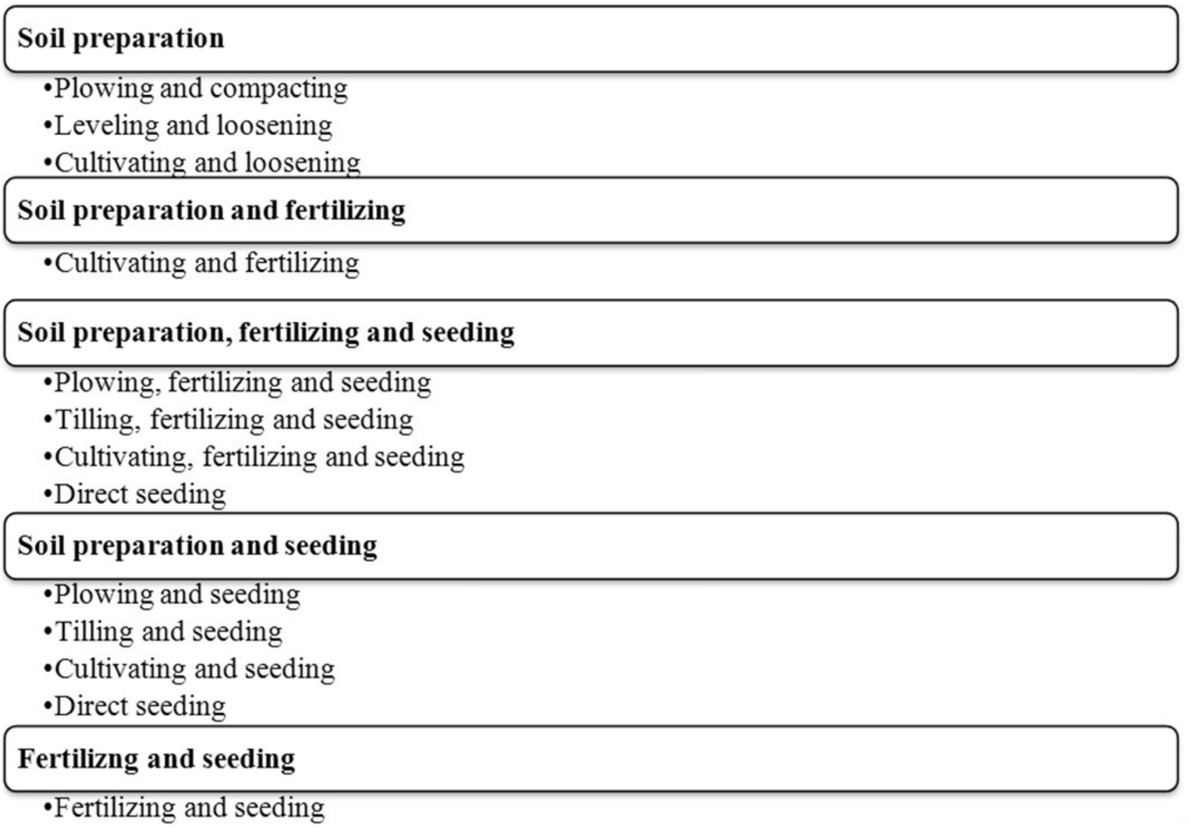

Fig. 1. **Combined agricultural machinery technological variants for soil preparation, fertilizing and seeding**

Materials and methods

To determine the total working costs an algorithm is used that accounts for different variables that are impacting the agricultural work: agricultural machinery and tractor depreciation, maintenance costs, fuel costs, labor costs, technical characteristics of the tractor and agricultural implement (such as engine power, working width, etc.), field area and an efficiency coefficient that determines how much of the total time can be accounted for actual working on the field.

$$TC = \frac{C_t}{Y_t \times h \times W} + \frac{C_a}{Y_a \times h \times W} + \frac{C_{mt}}{W} + \frac{C_{ma}}{W} + \frac{F \times C_f \times P \times ce}{W} + \frac{C_l}{W} \qquad (1)$$

where TC – total costs, EUR·ha^{-1};
C_t – purchase cost of the tractor, EUR;
C_a – purchase cost of the aggregate, EUR;
h – yearly workload of the tractor, h;
Y_t – tractor depreciation period, years;
Y_a – aggregate depreciation period, years;
C_{mt}, C_{ma} – maintenance costs of the tractor and aggregate, EUR·h^{-1};
F – fuel consumption of the tractor engine, kg·(kW·h)$^{-1}$;
W – working efficiency, ha·h^{-1};
C_f – fuel costs, EUR·kg^{-1};
P – tractor engine power, kW;
C_l – labor costs, EUR·h^{-1};
ce – engine efficiency coefficient.

Yearly workload of the tractor is determined by summing all the work the tractor is doing in one year. In this article the average workload of 1200 hours per year is used. The fuel consumption of the tractor engine is taken from the University of Nebraska – Lincoln, Nebraska Tractor Test Laboratory tractor test reports. All the taxes, which are deductible, are not taken into consideration in the calculation.

Using simple, one-pass agricultural aggregates can increase the tractor fuel consumption. With many agricultural machines there is the need to switch between them and also to carry each of them to the working field individually, so there is a lot of transport work between the operations, which increases the total fuel consumption, working hours of the tractors and in general the total production costs. Due to many passes that a tractor has made on the field, there will be places with high soil compaction degree and this soil shows much more resistance than normal soil and will increase the tractor fuel consumption when working in these areas.

Every agricultural work type is limited to several days (agro-terms) when it needs to be done and with a limited number of tractors available there is a risk that the agro-terms will not be met which can lead to yield decreases. The research has shown that, e.g., every day that has been retarded on agro-terms in seeding the grain yield per hectare is decreasing for 0.05 t.

Due to the fact that as much as one half of all labor-intensive processes in agriculture are connected with soil preparation and seeding, there is continuous agricultural aggregate development to reach higher productivity, decrease the power required to operate the aggregates and thus reduce the fuel consumption. The biggest increase in productivity can be achieved when using wider and more sophisticated agricultural aggregates that require more powerful tractors.

Results and discussion

There has been a research made in 1999 to 2001 regarding soil tillage and direct and combined seeding machinery technologies, but it has concentrated on the grain yield and quality parameters and the main conclusions were that at least the same grain yield can be achieved using combined seeding machinery as with traditional seeding methods and reducing the seeding costs at the same time. When the field conditions were considered as good, it did not affected the final grain yield very significantly [6].

There have been several studies in the recent years regarding the farm optimization and they have concentrated only on specific types of work or equipment. In 2010 Nikolajs Kopiks and Dainis Viesturs have published an article "Research into models of choice of tractor aggregates" where the main focus is on finding the most efficient tractor for a specific type of work [1]. The authors have developed an economic-mathematical model for choosing the most efficient aggregate and tractor combination. In other articles they have concentrated on the tractor fleet changes over the years (2000-2007) and how they meet the existing agricultural requirements.

In this research four types of combined machinery usage variants are compared to a traditional one-operation technology. The traditional one operation technology consists of ploughing, cultivating, seeding and levelling. The three different variants that the traditional technology is compared to include one combined aggregate and they are:

1. Reversible five body plough with a soil packer, mechanical seed drill and packer roller;
2. Reversible five body plough, mechanical seed drill with a cultivator and a packer roller;
3. Reversible five body plough, mechanical seed drill with a rotary tiller and a packer roller;
4. Combined direct seeding seed drill and a four body plough which is to be used every fourth year to increase the productivity of the land.

In all five variants an identical tractor with 105 kW engine power is used to make the comparison more precise. This specific tractor has been chosen because it can work efficiently with all the aggregates that are used in the calculation. The prices of the tractor and all the aggregates are for new machinery that is certified for use in the European Union. The depreciation period is 8 years. Average yearly use of the tractor is considered to be 1200 hours. The maintenance and repair costs for the tractor and aggregates are considered to be 4 % per year of the total value of the machinery. The percentage is so low due to the fact that this machinery is new and the first two years are covered by the factory guarantee in case of a breakdown.

The following table explains the characteristics and type of machinery that was used in the calculations.

Table 1

Machinery used in each technological variant

Technology	Tractor engine power, kW	Aggregates	Working width, m
I traditional	105	Reversible five body plough	2.5
		Cultivator	6.0
		Mechanical seed drill	4.0
		Packer roller	8.3
II combined	105	Reversible five body plough with soil packer	2.5
		Mechanical seed drill	4.0
		Packer roller	8.3
III combined	105	Reversible five body plough	2.5
		Mechanic seed drill with cultivator	4.0
		Packer roller	8.3
III-1 combined	105	Reversible five body plough	2.5
		Mechanic seed drill with rotary tiller	3.0
		Packer roller	8.3
IV direct	105	Combined direct seeding seed drill	4.0
		Reversible four body plough (used every 4th year)	2.0

The cost of buying all the machinery necessary for the I variant is 139500 EUR without taxes. If the I variant is considered as a reference, we can compare the costs to acquire the machinery necessary for each technology variant.

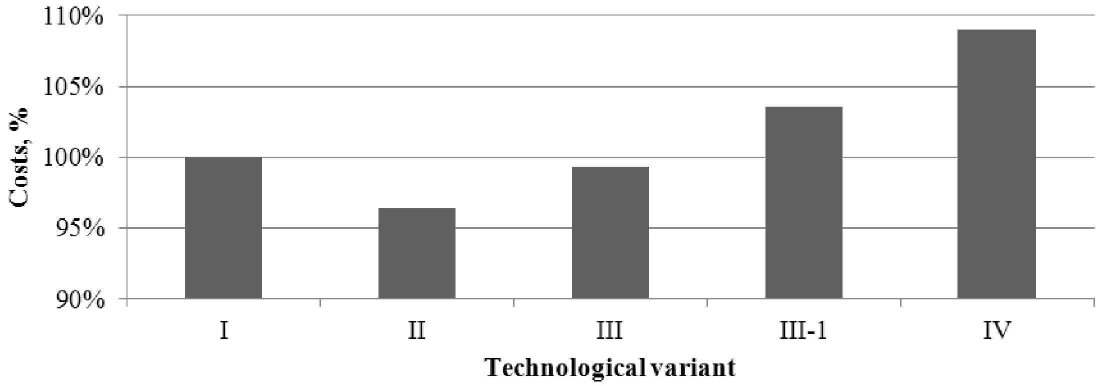

Fig. 2. **Machinery acquiring costs of each technological variant in relation to the I variant**

Compared to the I variant, the II technological variant has the lowest machinery acquiring costs, but they are only 4 % less, which is not considered a significant difference. The IV variant has the highest initial machinery buying costs, at 109 % of the total costs of the I variant. That can be explained by the high price of the direct seeding seed drill cost.

To compare all of the technological variants the algorithm was used to calculate the total costs of all five variants at different field areas. Up to 220 ha field area the most cost efficient variant was the II and after 220 ha it was the IV – using the direct seeding seed drill. At 300 ha of the land workable the usage costs per hectare of the IV variant are 8.3 % less than those of the I, 4.9 % less than those of the II, 7.4 % less than of the III and an impressive 12.5 % less than the costs of the III-1 variant. Figure 3 shows that the most expensive variant to use is the III-1 with the mechanical seed drill with a rotary tiller. That is due to the fact that a 105 kW tractor would only be able to work with a 3 meter wide mechanical seed drill with a rotary tiller because the rotary tiller demands high power input for it to work effectively. Also the working speed of this combined aggregate is lower than of the standard mechanical seed drill by 3-4 km·h^{-1}.

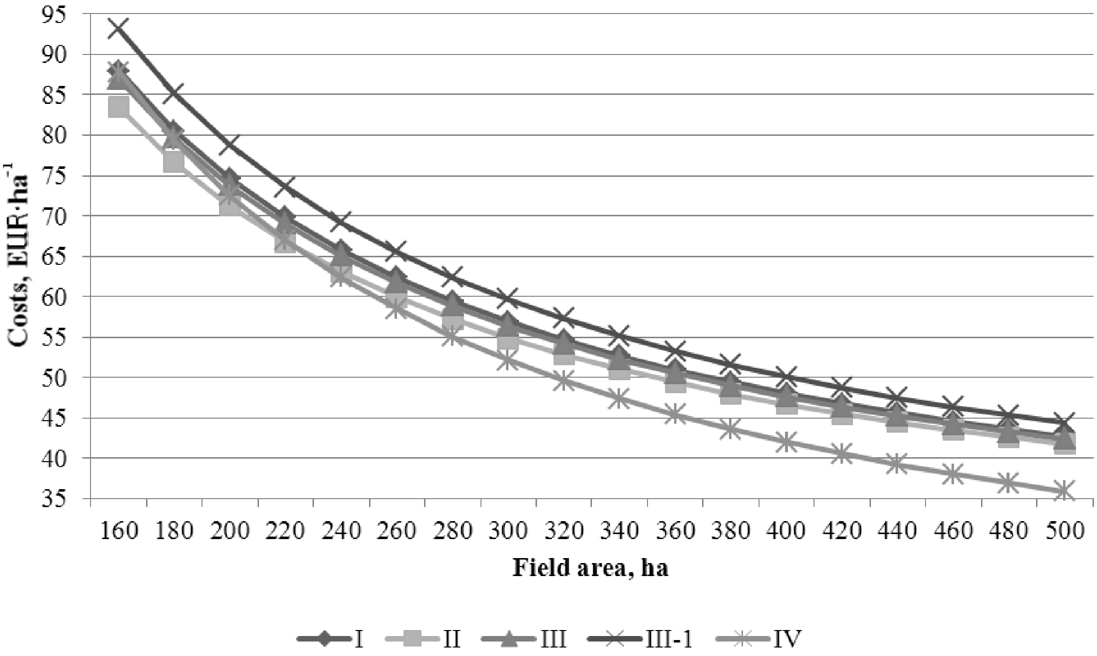

Fig. 3. **Total costs per hectare of all technological variants**

When the spring seeding time comes, it is essential to do every technological operation in time to increase the final yields of grain; therefore, it is necessary to compare also the time needed to complete the soil preparation and seeding for each individual technological variant.

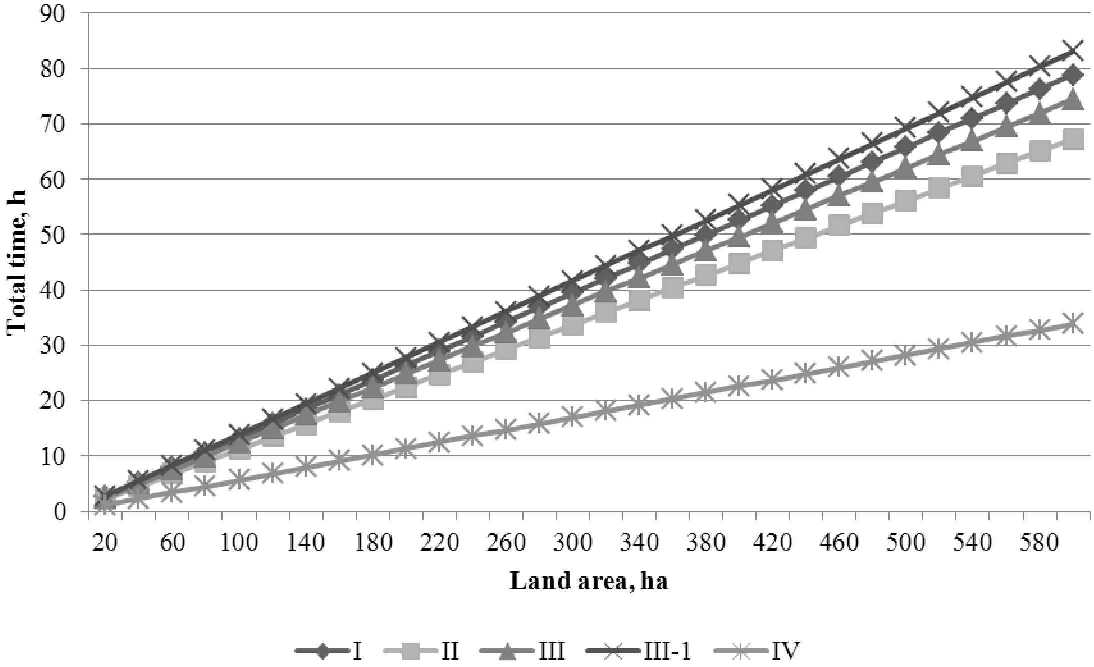

Fig. 4. **Total time required for soil preparation and seeding of all technological variants**

The total time required for soil preparation and seeding of each technological variant is shown in Figure 4 and the least time consuming variant is clearly noticeable. The technological variant with the most time required to prepare the soil for seeding and seed is the III-1 that utilizes a mechanical seed drill with a rotary tiller. The increase in the time required to seed is explained by a narrower working width compared to the other chosen variants that in the result decreases the productivity of hectare per hour. At 300 ha land area to be prepared for seeding and seed the technological variants chosen require the following amount of time to do the previously mentioned work: I – 39.4 h; II – 33.6 h; III – 37·2 h; III-1 – 41.5 h; 16.9 h; At this land area the usage of a direct seeding seed drill can save up to 25 hours of work and it is at least two times more efficient than any other technological variant chosen in this research.

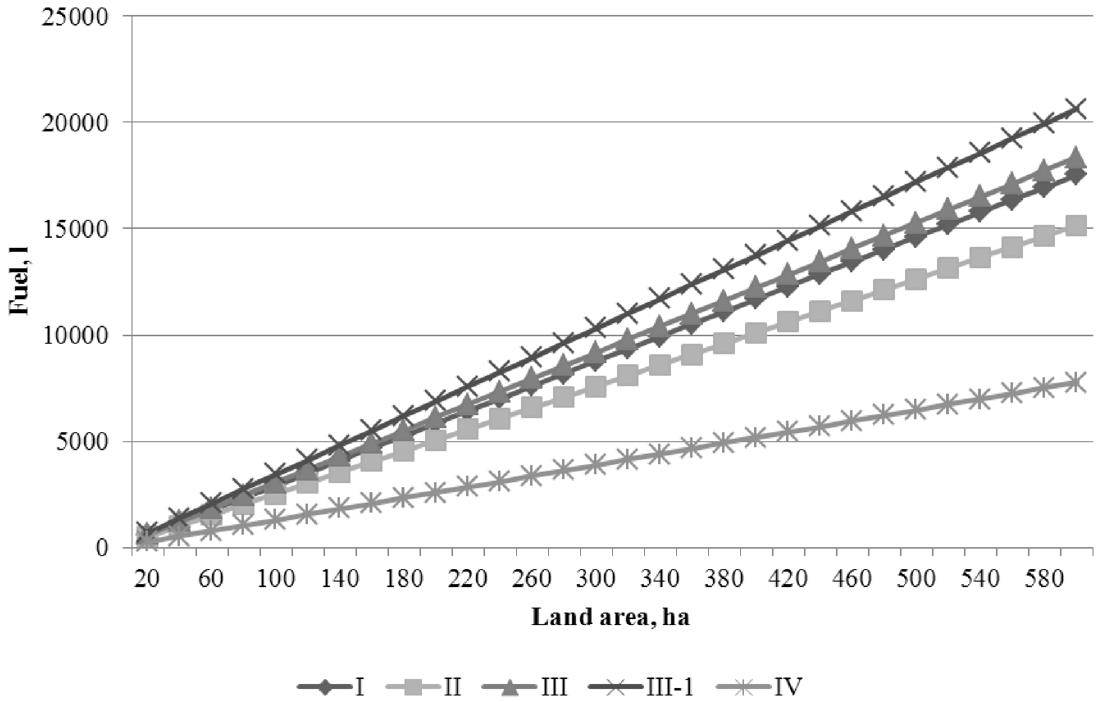

Fig. 5. **Total amount of fuel required for soil preparation and seeding of all technological variants**

Fuel consumption is another important factor when comparing the chosen technological variants. At 300 ha workable land area the corresponding fuel consumption of each variant (starting from the highest and ending with the lowest consumption) is as follows: III-1 –10319 l; III – 9178 l; I – 8768 l; II – 7580 l; IV – 3881 l; It is evident that the least fuel is required to operate the direct seeding seed drill, that is 1.95 to 2.65 more economical than any of the other four variants chosen.

Conclusions

1. The research results can be used as a guideline for choosing the optimal seedbed preparation and seeding technology.
2. Using one pass aggregates increases the time needed to prepare the seedbed and due to many passes a tractor has to make, the fuel consumption and costs are high.
3. Using a direct seeding seed drill is the most effective solution for seedbed preparation and seeding. The research results show that it has the lowest fuel consumption (up to 2.65 times less fuel is used comparing to other variants) and it needs the least time to complete the seedbed preparation and seeding works (up to 2.45 times less time required if compared to the other variants).
4. Using a reversible five body plough with a soil compactor is the most cost efficient choice when working in land areas up to 220 ha.
5. Using a direct seeding seed drill is the most cost efficient technological variant when working in land areas larger than 220 ha.

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