TECHNICAL, ECONOMICAL AND ECOLOGICAL ESTIMATION OF MODERN COMBINE SOIL TILLAGE, FERTILISING AND SOWING MACHINES

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INTRODUCTION

One of the ways of raising labour efficiently and cutting production costs, as well as improving the ecological situation is introduction of combine machines and units (aggregates) performing simultaneously soil tillage, application of fertilisers and sowing field crops [2]. At the present time a long list of combine machines of various brands, complexity and prices is offered. Yet there are no objective criteria for their correct choice. There is a need in their systematisation, objective technical, technological, ecological and economical estimation.

The aim of the investigations is to carry out systematisation of up-to-date combine machines and aggregates performing simultaneously the operations of soil tillage, fertiliser application and sowing field crops, to find out the possibility, purposefulness and efficiency of their use on peasant farms under the Baltic conditions.

OBJECTS AND METHODS

The object of investigations is modern combine machines and units for soil tillage fertilising and sowing.

In our previous studies [1, 3] we have laid out basic principles and regulations concerning the possibility and purposefulness of combining technological operations, formation and application of combine machines. They are characterised by the following features:

– simultaneity terms of performed operations (pre-sowing soil preparation, sowing);

– limited terms of performed operations (sowing of winter crops after non-fallow crops);

– unstable weather conditions (the efficiency of separate operations is decreased);

– use of appropriate tractors for forming combine aggregates;

– suitability of operating parts for simultaneous work (loosening, sowing).

Possible combinations of operations are discussed for soil tillage, fertiliser application and sowing, the demand for machines, their maintenance costs. It has been considered that the most preferable machines for the Baltic conditions are tractor-mounted aggregates, including the wide-cut multi-sectional implements. Tractors having frontally mounted implements have preference [3]. These methods and developments are used for the classification and estimation of modern combine machines and units (aggregates).

RESULTS AND DISCUSSION

Characteristics of modern combine machines and aggregates performing simultaneously soil tillage, application of mineral fertilisers and sowin

Classification. Classification of combine machines and aggregates is carried out by their grouping according to the set of simultaneously performed technological operations, considering the following principal tasks:

– stubble loosening with additional tillage of the loosened surface;

– deep loosening with additional tillage of the upper soil layer;

– ploughing with additional soil tillage before and after the run of the plough;

– soil pre-sowing multi-operational tillage (loosening, levelling, rolling);

– soil pre-sowing preparation with fertiliser application;

– sowing with fertiliser application;

– soil pre-sowing preparation with sowing;

– soil pre-sowing preparation with fertiliser application and sowing;

– ploughing with additional soil tillage and sowing;

– direct sowing (into untilled soil) with fertiliser application.

Any of the types listed above may have variations depending on the task and conditions of work. The machinery for their implementation may be presented as special multi-operational machines or aggregates consisting of several simple single-operational or combine multi-operational machines (or their components), having several technological zones.

Combine machines for stubble loosening. Combine ploughs are used as looseners of the upper layer of soil with its turning. Besides that loosening is carried out by means of disk-shape or rotary knife-tooth harrows and duck-foot (goose-foot) cultivators with attachments (crushing rolls, rod-type harrows) for

additional crushing of soil. The most efficient cultivators are of the chisel type with spring-loaded stanchions (Kverneland Turbo, Vibro-Flex) equipped with a twisted or wing-type share plus a reversible pointed share (combine mouldboard feet) for better transfer of soil containing stubble remnants.

Combine deep looseners. Provision of the duck-foot deep looseners for overcompacted soils (the density of dried soil is higher than 1400 kgm^{-3}) by units (disk-shape or rotary knife-tooth sections, spring tines) for additional loosening of the upper layer of soil enable soil preparation during one pass for sowing (planting) of the cultivated crop.

Combine ploughing aggregates. Provision of ploughs (preferably reversible) with the units of operating parts for additional tillage of reversed layers: wedge-shaped ring packers (Kvernel and Packomat) optimising soil density, and rod harrows for fine loosening ensure simultaneous ploughing and soil preparation for sowing cultivated crop. Furrow bottom looseners (Kverneland ecoploughshares) allow to reduce ploughing depth and the consumption of fuel, respectively, but at full ploughing depth – to loosen the ploughing sub-layer (plough sole). The furrow widener of the last body creates conditions for better fitting of tractor wheels in the furrow.

Combine machines and aggregates for soil pre-sowing preparation are able to prepare good quality soil at one pass (on separate lots at two passes) for sowing or planting cultivated crops. Such are combined drag-harrows, cultivators, power-harrows (cyclotillers) and aggregates combined from the other parts. Combine home-made drag-harrows (working width 3-8 m) with adjusted implements: spring-tine harrows, rod rolls moving soil particles forward and aside thus well levelling the surface of the ploughed soil with lesser fuel consumption, creating a fine loose layer. Under favourable conditions, this is enough for the subsequent sowing of grain. For qualitative pre-sowing soil preparation, the combined cultivators have several (3-6) technological zones: surface levelling, loosening at required depth, clod crushing, density optimisation, final fine loosening-crushing and surface loosening.

In Latvia, home-made tractor-mounted KVU cultivators, of the working width of 2-14 m and frontally mounted spring-load levelling boards (drags), four rows of S-shape spring tines having a shallow (20-24°) share setting and a section of spring finger harrows arranged in four rows, or rod rolls, are the most commonly used. They ensure sufficient qualitative soil preparation for sowing grain. Kverneland Compact and Combinator cultivators are equipped in a similar manner, yet they have a wide range of accessories. For finer and more accurate soil tillage on sugar beet growing farms combine cultivators, equipped with arrow-type feet mounted on spring-loaded tines (stanchions) (Compactor of Lemken) or with thickened (5-6 rows), steeply arranged S-shape spring tines operating like harrows (Germinator), have gained popularity.

Vertical power-harrows (carousel harrows, or cyclotillers), provided with drags (spring-load levelling boards) and spur rolls (packers), are preferably used for the tillage of dry soils. For pre-sowing preparation of soil with simultaneous

deep loosening, power-harrows equipped with rigid stanchions (tines) of arrow-type (duck-foot) or combined shares (RAU Rototiller RVP), are used.

Aggregates for pre-sowing preparation of soil and fertiliser application are formed by mounting mineral fertiliser seeders (usually pneumatic) on combine cultivators.

Combine seeders used on farms have three variants: seeders that sow out seeds and fertilisers in a single furrow (Gaspardo, Accord); seeders that sow out and introduce fertilisers (to a full dose) separate from the seeds (Yuko, Tume, Simulta); seeders that sow out the basic dose separate from the seeds but the starting dose – together with the seeds (Väderstad). The latter ones are preferable.

Combine aggregates for soil pre-sowing preparation and sowing grain are formed by mounting together (integrating: Kverneland-Accord, RAU Combisem) or by hanging (hitching to the wide tools) on the combine soil tillage machines – cultivators (Kverneland Compact, KLB, KLX, KTB, KTC) or power-harrows (Kverneland Power Harrow PHB, RAU Rototiller), pneumatic (Accord) or mechanical (Amazone) sowing-machines of the corresponding working width. There are variants with the frontal mounting soil tillage part of the aggregate. During one pass they ensure quality pre-sowing soil preparation and sowing excluding the risk of unstable weather conditions.

Combine aggregates for soil pre-sowing tillage, fertiliser application and sowing find ever increasing application both abroad and in Latvia. There are aggregates on the basis of combine cultivators (Kverneland KLX), with the attachments (pneumatic sowing-machines) for separate sowing and introduction of mineral fertilisers and seeds, as well as on the basis of combine seeders (Vederstad Rapid F, Tume Agri Master), with additional operating parts for pre-sowing loosening of the soil surface.

Ploughing-sowing aggregates on the basis of combine reversible ploughs with the units of a pneumatic seeder (Kverneland Packomat-seeder). They carry out ploughing, pre-sowing preparation (optimisation of density, surface levelling and loosening) and sowing. They allow to perform simultaneous soil preparation and sowing at the shortest terms with minimum labour and finance consumption; however, the scale of their application is restricted to the agrotechnical terms of sowing.

Combine seeders for direct sowing (Väderstad Rapid Super) ensure grain sowing into the stubble without its preliminary tillage, separate introduction of the basic dose of mineral fertilisers, but the starting dose – together with the seeds and rolling.

The presented list and a short characteristics of up-to-date combined machines and aggregates bear witness of the ample possibilities for combining (simultaneously performing) the technological operations of soil tillage, fertiliser application and sowing in different soils considering the established crop rotation, conditions of work and the objectives to be attained.

Efficiency gained from the use of combined aggregates

Calculation of the application costs of machines for field crop growing is made by formula (1) which includes their yearly loading and the indices of crop sowing areas follows:

$$I_{ek} = B_1 a_1 T^{-1} W_{ek}^{-1} + B_m a_m L^{-1} + W_{ek}(S_t + N_e k q C_d), \quad (1)$$

$$T = \Sigma T_i, \qquad T_i = L_i W_i^{-1}, \quad (2; 3)$$

where:

W_{ek} – labour productivity in aggregate using, ha/h,
B_t, B_m – the price of tractor, farm machine, Ls or USD,
a_t, a_m – deductions coefficient for the renovation of a tractor, farm machine,
T – time of the tractor use per year, h,
L – crops sowing area, ha,
S_t – tractor operator's pay, Ls/h (USD/h),
N_e – the efficient power of the tractor engine, kW,
k – the coefficient of the tractor engine loading,
q – specific fuel consumption of the tractor engine, kg/kW h,
C_d – complex fuel price, Ls/kg or USD/kg (considering oil consumption, 7.5% of fuel consumption,
T_i – time to perform some i-mode of work, h,
L_i – amount of i-mode work, ha (t, km),
W_i – labour efficiency of i-mode work, ha/h (t/h, km/h),
n – number of work modes.

The investigations and the experience of work show that, in contrast to the use of single-operational machines, combination (simultaneous performing) of technological operations using combine machines (aggregates) cuts energy consumption, raises the efficiency and reduces total cost by 15-25%. In contrast to the conventional soil tillage technology and sowing with single-operational machines, combining cultivation and sowing cuts the costs by 15%, yet combined ploughing and sowing – by 25% (see Table 1). The use of machines with active operating parts (power-harrows) makes the technological process more costly (because of high prices of these machines).

Table 1. Soil tillage and grain sowing costs

Method	Technological operation	Index of costs
Conventional with single-operational machines	Ploughing + cultivation + sowing (3 passes of the aggregates)	100
Using a cultivator-seeder	Ploughing + cultivation with sowing (2 passes of the aggregates)	85
Using a power-harrow-seeder	Ploughing + cyclotilling with sowing (2 passes of the aggregates)	125
Using a ploughing-sowing aggregate (Packomat-seeder)	Ploughing with compaction and sowing (1 pass of the aggregate)	75

The use of combine aggregates performing several technological operations is purposeful in the ecological aspect as well. The reduced number of passes

minimises the undesired soil compaction, cuts the consumption of energy and fuel, decreases the amount of harmful exhaust gases.

CONCLUSIONS

1. The classification has been drawn up of the modern combine machines and aggregates (units) for simultaneous soil tillage, fertiliser application and sowing, grouping them together according to the set of simultaneously performed technological operation. Moreover, their technical, economical and ecological assessment is given.

2. A vast list of modern combine machines and aggregates opens ample opportunities for the combination (simultaneous performing) of technological operations of soil tillage, fertiliser application and sowing in different soils, considering the specificity of crop rotation, conditions of work and the objectives to be attained.

3. In contrast to the use of single-operational machines, the use of combine aggregates removes the weather risk, improves the quality of work, raises the efficiency, reduces the energy and fuel consumption (as a consequence, the amount of harmful exhaust gases) and the total cost by 15...25%. By their agrotechnical, energetic, economical and ecological criteria, these combine aggregates are highly efficient and therefore worth being introduced widely on peasant farms of Latvia. In order to use them intensely, it is purposeful for small farms to cooperate.

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SUMMARY

Comparative studies have been carried out to estimate the possibilities, purposefulness and efficiency of combine soil tillage, fertilising and sowing machines and units for field crops used on peasant farms under the Baltic conditions. It has been found out that the most widely used machines and units are aggregates combining pre-sowing tillage of soil (combine cultivators, or revolving power harrow), mineral fertiliser application (pneumatic distributors) and grain sowing (pneumatic, or mechanical sowing machines). As to the agrotechnical terms, ploughing-sowing aggregates may have a limited application. The most suitable are tractor-mounted machines. For combine aggregates, preference should be given to more powerful tractors having frontally mounted equipment as well. In contrast to single-operational machines, the use of combine aggregates removes the weather risk, improves the quality of work, raises their efficiency, reduces the consumption of energy and fuel (accordingly, the amount of harmful exhaust gases) and cuts the total costs by 15-25%.

For agrotechnical, energetic, economical and ecological considerations, the modern combine aggregates of soil tillage, fertiliser application and sowing are efficient and should be widely introduced on the farms of Latvia.