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OPTIMIZATION OF FERTILIZER APPLICATION UNIFORMITY IN CAPACITY OF CULTIVATED SOIL BY COMBINED PLOWS

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Abstract
In today's stages of agriculture, they widely use combined cultivating units, while the main cultivation – combined ploughsharing – racked working bodies with additional working bodies, systems, devices. At the Podilskyi State Agricultural and Technical University construction of combined plow is proposed which provides simultaneous fulfilment of deep plowing with ploughsharing – racked working bodies, active layer crumbling and mineral fertilizing of active core, topsoil milling and mineral fertilizing. The purpose of research is the choice of the basic technological parameters – rotor radius R, the rotation frequency ω and influence of their values on the quality of soil crushing and preparation of plant residues and fertilizers. In the work we used the method of mathematical modeling of the process of fertilizers movement, soil cutting with the rotor knives that spins with regard to the vertical axis, limits of coil sowing device rotation in order to ensure minimum and maximum standards of a fertilizers applying, fertilizers supplying from coils and distribution of feed on the horizon, we considered analytical value between parameters of ray blades knife holder – width, radius, angle setting to the horizon.

Key words:
optimization, fertilizer, application, cultivated soil, combined plow.

Introduction

Mechanical soil cultivation is an important technological process in agriculture and is carried out with the aim of creating a loose upper layer, mixing the soil with previously applied fertilizers, and grinding and harvesting plant and root precursor residues. The researches of many scientists have proved the economic and biological efficiency of combining these operations into a single technological process through the development and use of combined machines, in particular combined plows.

Formulation of problem

Scientific works of Salo V.M., Panova I.M., Shmonina V.A., Belousov S.V., Mari I.A., Panasyuk A.N., are devoted to scientific substantiation, experimental verification of work of combined plows (Salo *et al.* 2016; Subrata, 2014; Vetohyn *et al.* 2009; Belousov *et al.* 2015; Mari *et al.* 2014; Panasyuk *et al.* 2011).

The research has established the main technological parameters and operating modes of the main elements of plows – geometrical sizes of rotors, their location, frequency of rotation, peculiarities of work on soils of different type and state (weediness, humidity).

The question of the local application of mineral fertilizers during the main cultivation of soil is devoted to the scientific search of Koval' V. I. (Koval' *et al.* 2000; Mushtai, 2001; Mushtai, 2005.)

The research was based on the technological idea of deep soil loosening and layering of mineral fertilizers, the technological parameters of the

process were determined and the agronomic efficiency of the association was proved (Mushtai, 2005; Bendera *et al.* 2017).

However, there are no scientific studies on the effectiveness of combining the plowing operations by the blade plow, the grinding of the arable layer by the active working body – the vertical rotor and simultaneously input into the zone of crushing mineral loose fertilizers.

Purpose of research

Proceeding from the peculiarities of the basic preparation of the soil for sowing of agricultural crops as an object and the necessity of the scientific and technological substantiation of the process of plowing, the input of mineral fertilizers, the grinding of the arable layer and the processing of roots and plants residues as a subject, the purpose of the research is analytical modeling of the interaction process rotor of a combined plow with a layer at the same time input mineral fertilizers through its internal cavity.

According to the object, subject and goal, the following research tasks are defined:

- to substantiate the technological scheme of the work of the combined plow;
- to determine the limits of regulation of the speed of the coil for optimal, minimum and maximum fertilizer;
- calculate fertilizer application horizontally;
- determine the technological parameters of the blades - width, radius, angle of installation.

In the course of research, methods of analysis and mathematical modeling were used.

Research results and discussion

During the choosing the type of technological scheme, the main requirement was taken into account – the rational placement of the plow elements from the viewpoint of ensuring the ultimate goal – the getting of a crushed arable layer with uniformly distributed mineral fertilizers along the width and height of the section and in the longitudinal direction.

Taking into account the technological possibility of fertilizers in layers of blades, we predict the greatest efficiency, and therefore the quality of mixing of soil and fertilizers in option 3.

Then the general technological scheme of the combined plow will have the following form.

During the moving of plow 1, cuts the layer and submit it to the truncated shelf 2. At the time of the ascent of the formation from the shelf, a vertical rotor with knives 8, grinds the layer.

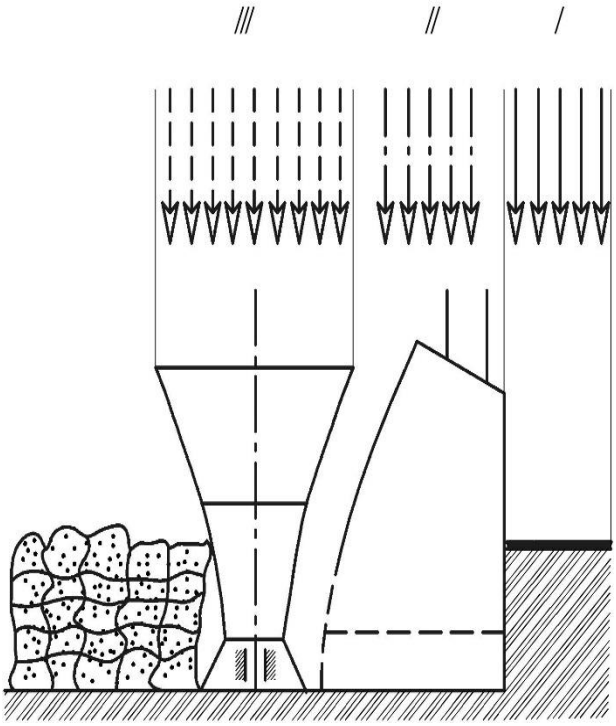

Figure 1. Variants of inputing mineral fertilizers: Option I: Delivery of fertilizers in front of the plow case; Option II: Inputing the fertilizer between the rotor and edged of the shelves; Option III: Inputing of fertilizers to the working zone of interaction between knives of the rotor and the stratum.

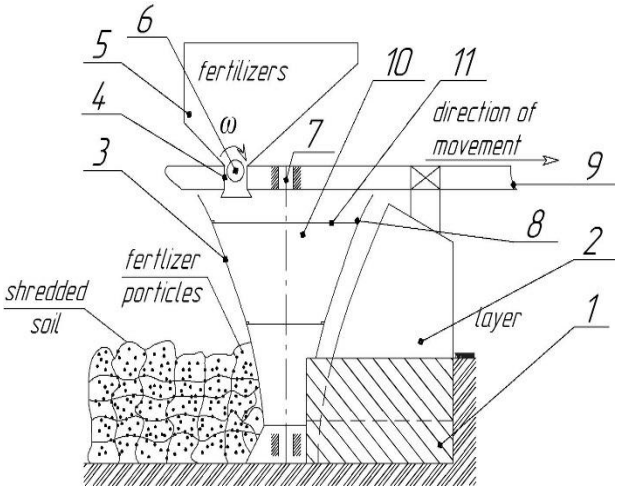

Figure 2. Technological scheme of the combined plow**:** 1. the plow case; 2. shortened shelf; 3. Conical vertical rotor; 4. tubular; 5. Tow Box; 6. seeding machine; 7. Hydraulic motor; 8. knives; 9. Frame; 10. feeding area of fertilizers; 11. rays of knives.

Drive rotor from an energy source (for example, hydro engines 7). Mineral fertilizers (mixtures of

mineral fertilizers) from the tow box 5, seeding machines 6, are inputing by the tubes 4 to the cavity of the rotor 10. During the flight of fertilizers from the fertilizer tube into the cavity of the rotor rays of knives, centrifugal force sends them to the zone of interaction of knives with soil.

According to the technological scheme, the seeding system consists of a tow box and seeding machines. Considering that the classical sowing machines of the reel type, which have good characteristics, regarding the uniformity of seeding. Here are their main technological parameters and operating modes.

Necessary technological innings of the seeding machine, based on the input of normative hectare, N the width of the capture of the plow B_l, the translational velocity V_{lin}, and the number of fertilizer tube (devices) z is equal.

$$g_t = NB_l \cdot V_{lin} \cdot \frac{1}{z} \quad (1)$$

Supplying of material is calculated through the technological parameters of the seeding machine - the working volume V_k, the rotational speed and the working length of the coil l_p within the structural $l_к$ is equal

$$g_k = V_k \cdot n \cdot \frac{l_p}{l_k} \quad (2)$$

Equating the formulas (1) and (2) determine the rotational speed of the coil

$$n = \frac{NB_l V_{lin} l_k}{V_k l_p z} \quad (3)$$

Given that the meaning of the size of the norm, depending on the agronomically given, can vary from N_{min} to N_{max} it is necessary to provide for the possibility of changing the speed of rotation, that is, to set the reduction of the drive. Within the full speed of rotation n_i the norm is governed by a smooth change in the working length of the coil l_p.

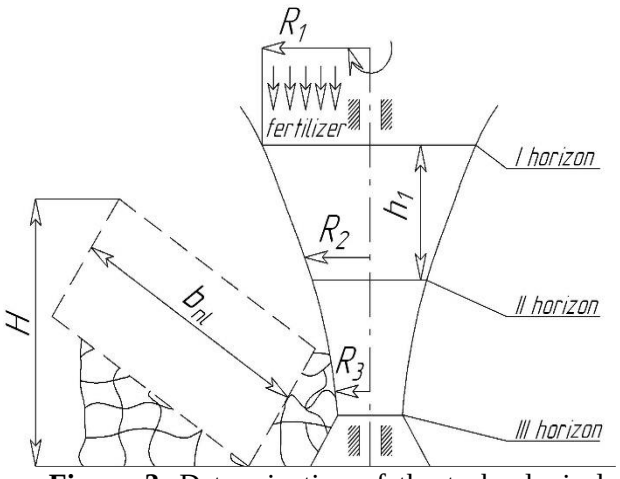

Figure 3. Determination of the technological parameters of the rotors

The performance of the coil machine is the start (base) for further substantiation of the operating mode of the constituent parts of the fertilizer application system of the fertilizer tube, rotor, (as an element of fertilizer application).

The maximum angular speed of the coil is checked for the technological capability according to the criterion of fertilizer filling of the coils of the coil under its own weight G at the available centrifugal force F_{crf} acting on the particles.

Filling condition. $G > F_{crf}$, $g \geq m\omega^2 R$ from here

$$\omega \leq \sqrt{\frac{g}{R}} \text{ or } n \leq \frac{30\sqrt{\frac{g}{p}}}{\pi}. \quad (4)$$

Considering the rays for which the knives are fastened, as blades of fertilizer spreaders, it is possible to determine the throughput through the ratio of the areas of transverse (horizontal) projections of each horizon (h_i).

$$F_i = z \cdot R_i \cdot b_l \cos\alpha \quad (5)$$

where R_i – radius of the ray;

b_l – width of the blades;

α – angle of inclination of the blade in a vertical plane.

Accordingly, for the first horizon, the amount of fertilizers that are input into the active zone.

$$g_1 = \frac{\pi R_1^2 g_k}{z R_1 b_l \cos\alpha} = \frac{\pi R_1 g_k}{z b_l \cos\alpha} \quad (6)$$

For the 2nd

$$g_2 = \frac{\pi R_2 g_1}{z b_l \cos\alpha} \quad (7)$$

For the 3rd

$$g_3 = \frac{\pi R_3 g_2}{z b_l \cos\alpha} \quad (8)$$

For discharges of fertilizers of the wort-type (in our case, the rays) the inputing is determined by the formula.

$$g_l = B_l \cdot R_l \cdot V_{crl}\gamma \quad (9)$$

where V_{crl} – circular speed of blade ($V_{crl} = \omega R$);

γ – density of fertilizer.

Comparing the real feed and constructive we determine the required width of the blade.

$$B_l = \sqrt{\frac{\pi g_i}{\sin\alpha \cdot \cos\alpha \cdot \omega R \gamma}} \quad (10)$$

where g_i – inputing on i – horizon.

We predict the probability of inputing fertilizers on the bottom of the furrow. The size of the inputing should be considered as the balance Δg.

$$\Delta g = g_l - g_1 - g_2 - g_3. \quad (11)$$

Conclusions

As a result of scientific analytical studies of the process of fertilizer movement from the tow box to the zone of active crushing of the stratum defined:

- technological scheme of the combined plow, which combines three agricultural operations - deep

plowing, active milling of the formation and layering of mineral fertilizers (blends) through the rotors;

- the limits of the frequency of rotation of the coils of the end-of-pipe apparatus are determined for ensuring the minimum and maximum norm of fertilization rate;

- analytically calculated the inputting of fertilizers to the horizons according to the criteria of the throughput of the rays of fastening of knives and the base productivity of the coil;

- the width of the blade (beam) and the installation angles relative to the horizon are determined at a fixed speed and radius.

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