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Теоретическое исследование взаиморасположения рабочих органов комбинированного агрегата

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Реферат. Показали, что органические удобрения, в отличие от минеральных, способны давать прибавку урожая в течение нескольких лет, они не наносят вреда окружающей среде и не загрязняют продукцию бахчевых культур нитратами. Уточнили, что их внесение – один из эффективных методов сохранения гумуса и повышения плодородия почвы, а значит получения более полновесных урожаев бахчевых культур с высокими показателями качества. Разработали комбинированный агрегат для локального внесения органических удобрений под бахчевые культуры. (*Цель исследования*) Теоретически обосновать взаиморасположение рабочих органов комбинированного агрегата для локального внесения органических удобрений. (*Материалы и методы*) Провели теоретические исследования с использованием методов аналитической геометрии и теоретической механики. Описали схему работы нового агрегата. (*Результаты и обсуждение*) Получили зависимости для определения поперечных расстояний между бороздорезами, осуществляющими нарезку борозд для внесения органических удобрений и для полива, а также продольных расстояний от ведущих задних колес трактора до бороздорезов, осуществляющих нарезку борозд для заделки органических удобрений, от бороздорезов для их внесения до разбрасывателя удобрений и от разбрасывателя удобрений до бороздореза для нарезки поливной борозды. Рассчитали оптимальные значения этих параметров. (*Выводы*) Установили, что поперечное расстояние между рабочими органами, осуществляющими нарезку борозд для внесения органических удобрений, должно составлять 0,9-1,3 м, а между рабочими органами для нарезки поливной борозды и борозды для внесения органических удобрений – 0,45-0,65 м. Определили оптимальные значения продольного расстояния: от ведущих задних колес трактора до рабочих органов нарезки борозд для внесения удобрений – не менее 0,21 м; от носка рабочих органов до разбрасывателя удобрений – не менее 1,5 м; от центра разбрасывателя до носка рабочего органа для нарезки поливной борозды – не менее 0,74 м.
Ключевые слова: локальное внесение органических удобрений, комбинированный агрегат, расположение рабочих органов, нарезка борозд для внесения удобрений и полива.

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Theoretical Study of Working Tool Placement in the Combined Unit

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Abstract. The author proves that organic fertilizers, unlike the mineral ones, are capable of increasing yields over several years; they do not harm the environment and do not pollute the melon crop fields with nitrates. It has been clarified that their introduction is one of the most effective methods of humus conservation and soil fertility enhancement, which means obtaining fuller yields of high-quality melons and gourds. The NIIMESH researchers have developed a combined unit for local application of organic fertilizers for melons and gourds. (*Research purpose*) Conducting theoretical studies on the substantiation of the configuration of the working tools of a combined unit for local application of organic fertilizers. (*Materials and methods*) The author has conducted theoretical studies using methods of analytical geometry and theoretical mechanics. (*Results and discussion*) Analytical dependences have been obtained to determine transverse distances between furrow shapers used for applying organic fertilizers and making an irrigation groove, as well as longitudinal distances between the tractor's rear wheels and the furrow shapers applying organic fertilizers, between the furrow shapers and the fertilizer spreader, and between the fertilizer spreader and the furrow shaper making an irrigation furrow. (*Conclusions*) It has been determined that transverse distance between the working tools that make furrows for applying organic fertilizers should range between 0.9 and 1.3 metre, transverse distance between the working tools making an irrigation furrow and a furrow for the application of organic fertilizers is 0.45-0.65 metre. The optimal values of longitudinal distances have been found as well: between the tractor's rear wheels and the working tools making furrows for applying fertilizers – no less than 0.21 metre, between the tip of working tools and the fertilizer spreader – no less than 1.5 metre, and between the fertilizer spreader center and the tip of working tools making an irrigation furrow – at least 0.74 metre.

Keywords: local application of organic fertilizers, combined unit, configuration of working tools, furrow shaping for fertilizer application and irrigation.

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The most effective way of increasing the output of melon cultivation is to increase the yield of melons and gourds by improving the agricultural technology of soil cultivating, developing new varieties, as well as improving soil fertility. Organic fertilizers, as contrasted to mineral fertilizers, are capable of giving a yield increase over several years; they do not harm the environment and do not pollute melon fields with nitrates [1, 2].

The application of organic fertilizers in a semi-fusty and rotted form is one of the most effective methods of preserving humus and increasing soil fertility, and, therefore, obtaining more comprehensive yields of high-quality melons and gourds.

Local application of organic fertilizers prevents the disadvantages typical for the spreading method.

Basing on the above-mentioned facts, our institute has developed a combined unit for local application of organic fertilizers for melons and gourds [3-5].

The research purpose is to theoretically determine the configuration of working tools of a combined unit for local application of organic fertilizers.

Materials and methods. The unit for local application of organic fertilizers includes frame *1*, hopper *2* mounted on it with a seed sowing unit in the form of paddle drums, support-driving wheels *3*, working tools *4* that make furrows for applying fertilizers, working tool *5* making irrigation furrows and fertilizer spreaders 6 (*Fig. 1*).

In the operating process, working tools *4* open up two furrows, into which fertilizers flow from hopper *2* through spreaders *6*. Working tool *5* makes an irrigation furrow between the furrows with introduced fertilizers. At the same time, the soil moved asides, encloses the fertilizers and forms ridges.

Results and discussion. The configuration of the working tools of a combined unit is determined by the following parameters (*Fig. 1*):

B_1 – transverse distance between the working tools (furrow shapers) making furrows for applying organic fertilizers, m;

B_2 – transverse distance between the working tools for making an irrigation furrow and furrows for applying organic fertilizers, m;

l_1 – longitudinal distance between the tractor's driving rear wheels and the working tools making furrows for applying organic fertilizers, m;

l_2 – longitudinal distance between the working tools making furrows for applying organic fertilizers and the fertilizer spreader, m;

l_3 – longitudinal distance between the fertilizer spreader and the working tools for making an irrigation furrow, m.

Lateral distance between the working tools making furrows for applying fertilizers can be determined with the following formula (*Fig. 2*):

$$B_1 = b + 2b_y, \quad (1)$$

where b is the distance between seed rows;

b_y is the distance between a seed row and the furrow for applying fertilizers.

According to the schemes (*Fig. 1 and 2*), transverse distance between the working tools making furrows for applying organic fertilizer and irrigation:

$$B_2 = B_1/2 = 0,5b + b_y. \quad (2)$$

Longitudinal distance between the tractor's rear drive wheels and the working tools making furrows for applying fertilizers should eliminate any possibility of soil clogging between them, because otherwise the technological process of the unit can be disturbed and energy costs for furrow making may increase.

To fulfill this condition, the propagation zone of soil deformation under the influence of the working

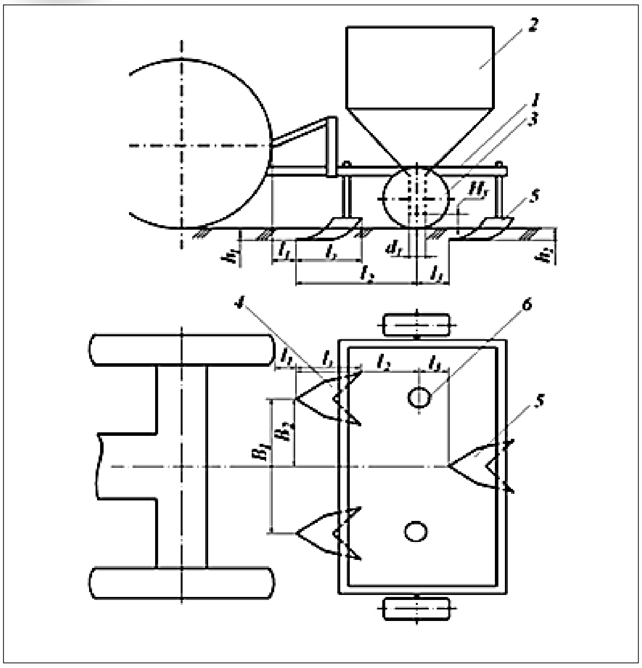

Fig. 1. Configuration parameters of the working tools of a combined unit

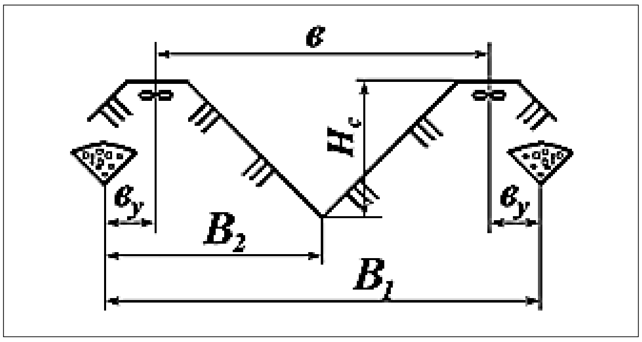

Fig. 2. Determination of transverse distance between working tools making furrows for applying fertilizers

tools should not reach the tractor's driving rear wheel, in other words:

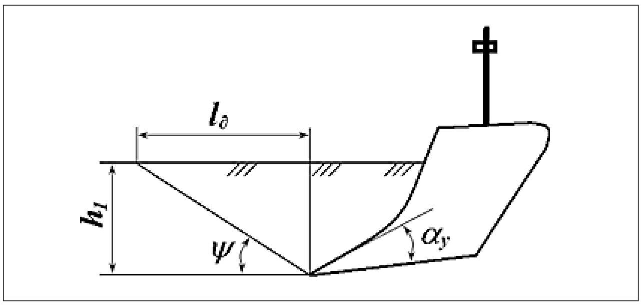

Fig. 3. Determination of longitudinal distance between the tractor's driving rear wheels and working tools making furrows for introducing fertilizers

$$l_1 > l_\partial, \qquad (3)$$

where l_∂ is longitudinal distance over which the soil deformation extends (*Fig. 3*):

$$l_\partial = h_1\, ctg\, \psi, \qquad (4)$$

where h_1 is the operating depth of the working tools making furrows for applying organic fertilizers;

ψ is the longitudinal splitting angle of the soil, which is equal to [6-8]:

$$\psi = \frac{\pi}{2} - \frac{\alpha_y + \varphi_1 + \varphi_2}{2}, \qquad (5)$$

where α_y is the soil penetration angle of the working tool tip;

φ_1, φ_2 – respectively, are angles of external and internal soil friction.

Operating depth h_1 of the working tools making furrows for applying organic fertilizers can be determined with the formula [9, 10]:

$$h_1 = \frac{\sqrt{2}H_c}{1+\sqrt{2}}, \qquad (6)$$

where H_c is the total depth of the furrow for applying organic fertilizers.

Taking into account equations (4)-(6), expression (3) can be presented as:

$$l_1 > \frac{\sqrt{2}H_c}{1+\sqrt{2}}\, tg\left(\frac{\alpha_y + \varphi_1 + \varphi_2}{2}\right). \qquad (7)$$

Longitudinal distance between the working tools making furrows for applying fertilizers and the fertilizer spreader is determined basing on the condition that organic fertilizers should be applied along the entire length of the furrows to the same depth.

To fulfill this condition, fertilizers should be applied to the bottom of the furrows after shedding lumps and soil particles from their slopes, which means that:

$$l_2 > l_э + V_a\, t + 0{,}5 d_T, \qquad (8)$$

where $l_э$ is the length of the working tool making furrows;

V_a is the operating speed of the unit;

t is the time spent on shedding lumps to the furrow bottom from its slopes;

d_T is the fertilizer spreader diameter.

In expression (8), the time spent on shedding lumps to the furrow bottom from its slopes is unknown. To determine it, we should make up a differential equation of motion for a lump falling from the furrow slope to its bottom (*Fig. 4*). It will look like this:

$$m\frac{d^2x}{dt^2} = G\sin\varepsilon - F, \qquad (9)$$

where m is the lump mass;

x is the reference axis directed along the furrow slope;

G is the lump weight;

ε is the inclination angle of the furrow slope to the horizon (the angle of natural shedding of the soil);

F is friction force.

Taking into account that $G = mg$ (where g is the acceleration of gravity) and $F = f_2 G cos\varepsilon = f_2 mg cos\varepsilon$

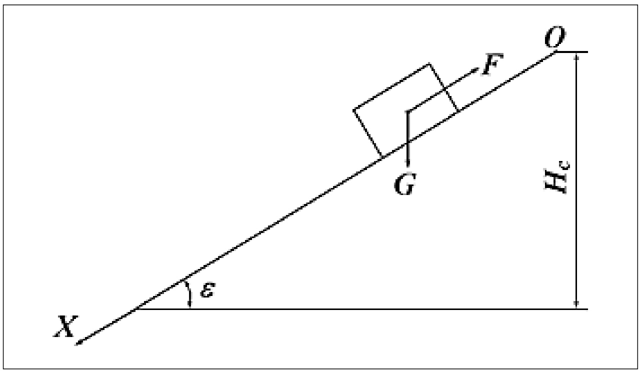

Fig. 4. Movement of soil lumps along the furrow slope

(where f_2 is the coefficient of internal friction of the soil), expression (9) can be represented as follows:

$$\frac{d^2X}{dt} = g(\sin\varepsilon - f_2\cos\varepsilon). \qquad (10)$$

Performing double integration of this equation taking into account the initial conditions

(at $t = 0$ ($dX/dt = 0$ and $x = 0$), we get:

$$X = \frac{gt^2}{2}(\sin\varepsilon - f_2\cos\varepsilon). \qquad (11)$$

This equation for a lump crumbling from the very top of the furrow slope has the following form:

$$\frac{H_c}{\sin\varepsilon} = \frac{gt^2}{2}(\sin\varepsilon - f_2\cos\varepsilon). \qquad (12)$$

Solving it with respect to t, we determine the time spent on lump shedding to the furrow bottom:

$$t = \sqrt{\frac{2H_c}{g(\sin\varepsilon - f_2\cos\varepsilon)\sin\varepsilon}}. \qquad (13)$$

Given this expression, equation (8) takes the form:

$$l_2 > l_{э} + V_a\sqrt{\frac{2H_c}{g(\sin\varepsilon - f_2\cos\varepsilon)\sin\varepsilon}} + 0{,}5d_T. \qquad (14)$$

Longitudinal distance between the fertilizer spreader and the working tool making an irrigation furrow is determined on the basis of the following condition:

$$l_3 > V_a\sqrt{\frac{2H_y}{g}} + \frac{\sqrt{2}H}{1+\sqrt{2}}tg\left(\frac{\alpha_c + \varphi_1 + \varphi_2}{2}\right), \qquad (15)$$

where H_y is the arrangement height of the fertilizer spreader relative to the furrow bottom for applying fertilizers;

H is the total depth of an irrigation furrow;

α_c is the soil penetration angle of the working tool making an irrigation furrow.

When condition (15) is fulfilled, the application of organic fertilizers by working tools making an irrigation furrow starts after the fertilizers are fully applied to the furrow bottom intended for fertilizer application. As a result, the fertilizers are introduced to the required depth.

Basing on agrotechnical requirements and reference sources, we will take [10, 11]: b = 0.9 m; b_y = 0-0.2 m; H_c = 0.3 m; α_y = 30°; φ_1 = 30°; φ_2 = 40°; $l_э$= 0.75 m; V_a= 2 m/s; H_y= 0,3 m; H =0,35 m; g = 9.81 mc^2, and also according to expressions (1), (2), (7), (14) and (15), we can find that transverse distance between the working tools making furrows for applying organic fertilizers should equal 0.9-1.3 m; transverse distance between the working tools making an irrigation furrow and a furrow for the application of organic fertilizers – 0.45-0.65 m; longitudinal distance between the tractor's driving rear wheels and the working tools making furrows for applying fertilizers – not less than 0.21 m; longitudinal distance between the tip of the working tools and the fertilizer spreader is at least 1.5 m; longitudinal distance between the fertilizer spreader center and the working tool tip making an irrigation furrow – at least 0.74 m

Conclusions. As a result of theoretical studies on the configuration of working tools of a combined unit for preparing fields for planting by making furrows for fertilizer application and irrigation furrows, as well as local fertilizer application, analytical dependences have been obtained taking account of the performance of a given process.

Using these dependencies, we have calculated that transverse distance between the working tools that make furrows for applying organic fertilizers should range between 0.9 and 1.3 m, transverse distance between the working tools making an irrigation furrow and a furrow for the application of organic fertilizers is 0.45- 0.65 m. The optimal values of longitudinal distances have been found as well: between the tractor's rear wheels and the working tools making furrows for applying fertilizers – no less than 0.21 m, between the tip of working tools and the fertilizer spreader – no less than 1.5 m, and between the fertilizer spreader center and the tip of working tools making an irrigation furrow – at least 0.74 m.

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