Investigations on soil conservation and precision of tillage with tractor and gantry units

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Abstract: Investigations on soil conservation and precision of tillage with tractor and gantry units. The compressed soils can be loosened more intensively with the use of the rotary cultivators. It is suggested to separate stones and clods in the stony soils and the bigger stones should be removed from the growing zone of potatoes. The horizontal cultivators are more universal, they can be used to loosen and to mulch the soil. It is purposeful to use the technology of the harrowing and the multiple hilling. Thus, the space between rows is compacted by the wheels of the tractors. The number of passes is minimized during the potato growing. The new generation of the tractors with front and rear linking systems makes more perfect combined aggregates, when some of them are mounted on the front of the tractor and others on the rear of the tractor. Gantry agriculture has great influence on the soil structure. It enables to investigate theoretically possibilities of minimization of the interaction between the chassis and the soil compacting by different types of circular and shuttle gantry modules. It is possible to investigate the influence of the uneven fields on curvature of chassis paths and to select the chassis types.

Key words: soil compacting, aggregates, gantry modules, chassis, precision, technology, mulch.

INTRODUCTION

The trends of higher operational speed and labour productivity are related with an increase in the used capacities and enlargement of aggregates, therefore, they contradict the principles of soil conservation [Bareisis, Šniauka 2000, Powalka 2007, Skrebelis 2007].

The problem of soil degradation has resulted from the impact of agricultural machinery chassis and application of chemicals. Slowing down a further deterioration of soil is a difficult, long-term problem, as the soil has to be not only conserved but also improved in order to meet the needs of future generations. A soil conservation issue is especially urgent due to high energy costs in potato growing [Viselga, Kamiński 2006].

A fertile soil is formed as a result of thorough work and substantial energy costs. It is important not to underestimate this result, i.e. not to damage the soil, its humus, microclimate and energy reserves accumulated in the soil.

The gantry agriculture has great influence to the soil conservation. If the cultivation of the deeper soil surface, combined aggregates and other tested means decrease the negative results on the interaction between the chassis and the soil, the gantry agriculture repeals the reasons to brake the soil structure by the chassis.

The use of gantry systems is the shortest way to increase the yield, to minimize energy consumption and pollution of the surroundings, and to improve the working conditions of the staff [Viselga 2006].
EXPERIMENTAL OBJECTIVE

The experimental objective is to group, analyse and generalise the key trends and needs of field crop and potato production modernisation, and to determine the relationship between them.

To investigate the processes of soil deep loosening, furrow loosening by rotary implements separating and crushing the clods, and mulching when growing potatoes with permanent tramlines and on enlarged furrows, as well as to determine possibilities for the reduction of soil packing energy costs per unit of production and for potato lifting improvement.

To evaluate the possibilities of the simplest circular energetic modulus (Fig. 1) of the gantry agriculture, the conditions for the operation of the main working parts in the circular trajectory and to use the best results to make the perspective simplification trends of the technological schemes of the power modulus of the reciprocal movement type.

EXPERIMENTAL METHODS

The following composite parts of combined aggregates testing stands were formed: rotary cultivator – mulching equipment, tramlining equipment with deep loosening chisel shares, clod and stone separator, special spur-type roller. These implements can be aggregated with 14 kN class MTZ-82 tractors autonomously or fitted in combined aggregates.

Tramlining equipment is designed to form tramlines and to loosen the soil between them while planting potatoes, as well as for localisation of soil rich in humus or green manure while preparing the soil for potatoes. It consists of an universal frame, two tramline hillers, two support depth control wheels, and three chisel shares. Tramline hillers are placed in front of tractor wheels.

For the determination of soil hardness we used an electronic self-writing penetrometer CP20 (England) with a standard 12.5 mm diameter cone-shaped tip. Soil resistance to this tip pressing

FIGURE 1. The scheme of the power modulus of the circular gantry system
is recorded in the memory of this apparatus every 15 mm from the surface to the set depth. For measuring of soil hardness distribution in the width of the whole interrow and for the measuring of furrow profile, besides hardness metering equipment, we used 1.5 m long horizontal plank with legs stuck in the soil, in which 1.4 m length on both sides every 10 mm (with 5 mm sliding) holes of 15 mm diameter were drilled.

We investigated the circular (Fig. 1) and shuttle gantry aggregates. The circular carriage driven by the electric motor rotates the cantilever beam around the support centre. The implement mounting cart moves across the beam. Different working implements can be mounted on this cart and they would acquire the spiral movement or that of concentric circles. The shuttle units were investigated by laser measurement implements.

EXPERIMENTAL RESULTS

Major engineering soil conservation means in field crop and potato production, besides tillage of soil with adequate moisture regime at optimum terms, education of agricultural producers, control of environmental aspects, can be grouped into three main parts: means related to machinery improvement, advancement of technologies and reduction of chemical pollution.

Firstly, an important and considerable part is devoted to the reduction of chassis pressure on the soil. One can find traditionally used means among them such as: doubling of wheels, special low-pressure tyres, caterpillar and semi-caterpillar chassis. Regardless high energy costs, on stony soils it is necessary to remove small stones over 3 cm in size. Our long-term experiments suggest that from energy and soil conservation point of view it is most efficient to remove stones in one time from the whole arable layer, while preparing the soil for potatoes by combined complex aggregates. Arable layer is sifted, stones are separated into fractions: small stones up to 6–8 cm are crushed and spread in the soil, bigger stones are removed from the field in a hopper. Up to 40% of fuel is economised, potato yield is increased about 10% and anti-erosive effect is created.

An important role is played by advancement of machinery design – evenly operating ploughs, mouldboard less implements and ploughs ploughing with mounted rotary soil loosening or clod crushing implements. Optimum operation regime is of special importance for actively operating working parts.

When preparing the soil by conventional cultivators with passive working parts the soil and interrows are passed several times during the spring soil preparation. Soil hardness increases with every pass (Fig. 2).

Mulching of green manure crops oil radish and white mustard in the surface 10 cm soil layer reduces soil hardness (Fig. 3), weed incidence on the fields (Fig. 4), increases productivity, nutrient content and the amount of earth-worms in the soil as much as 10 times. It is an undoubtedly valuable soil improvement means. No increase in the amount of earth-worms was found after spraying potatoes with pesticides.
FIGURE 2. The relationship between soil hardness in the middle of an interrow and the number of passes of tractor’s MTZ-82 earthing-up and planting aggregates.

FIGURE 3. Effect of mulching on soil hardness in potato furrows before potato lifting.

FIGURE 4. Effect of soil loosening (a), mulching and cultivation methods (b) on weed incidence.
When loosening by a combined aggregate and planting separately, the amount of clods over 30 mm in diameter collected during potato lifting was 28.5% lower and on average 18.4% lower in all the experimental treatments than in the control.

While setting modernisation trends of field crop production a special attention should be drawn to the reduction of energy costs. It is equal to the reduction of production costs and enhancement of profitability. It goes without saying that on cultivated, not compacted soils energy costs are always lower. Therefore, all the three mentioned trends are interrelated.

Replacement of organic fertilisers by mulching of green manure crops and growing of ecological production are also ways to save energy costs, as these means result in lower energy consumption, lower soil compaction and better suppression of weeds. Technologies of precision and gantry agriculture are completely new. Experimental results of circle and shuttle gantry systems [Viselga 1998] have shown that wheel skidding is as low as 1%, and soil loosening energy costs can be reduced as much as 20%. Installed power according to the results of our tests makes up only 3–5 kW, and for ploughing and cultivation only about 240 kWh/ha is used. In gantry agriculture the amount of production per area unit is increased, as it is possible to narrow interrows and protection zones of some crops and not to pack the soil. It is a technology of the future.

The operation width of the gantry system implements when perpendicular mounted on the beam depends on their distance up to the revolution centre $R_p$ and the beam $l$. The smallest divergence of the operation width from the design one that is equal to 0.18 m (Fig. 5) will be when the implements are under the beam, i.e. $l = 0$. But in some cases it is difficult to do $l = 0$ in practice, then the implements should be turned by the radius angle $\alpha = \frac{\pi}{2} - \arctg \frac{R_p}{l}$ depending on the turn. At that time the operation width of the plough will can be calculated according to equation:

$$b = \sqrt{\frac{3b_p^2 + a_n^2}{4} + R_p^2 + l^2 + 2\sqrt{\frac{3b_p^2 + a_n^2}{4}(R_p^2 + l^2)}} \sin \left(\arctg \frac{2b_p}{\sqrt{a_n^2 - b_p^2}}\right) +$$

$$- \sqrt{R_p^2 + l^2 + \frac{a_n^2 - b_p^2}{4}}$$

where: $a_n$ – the length of the ploughshare blade, $b_p$ – the design width of the plough.

When the turn radius of gantry implements is (3–6) m, one side of the profile of the potato furrow, closer to the rotation centre, has the smaller area than the other side of the profile (Fig. 6). When the implements move away from the centre, on the contrary, the area of the peripheral side of the furrow profile is smaller than the area of the other side of the furrow profile: when the turn radius is (9–12) m, the furrow asymmetry is 13%, and when it is (15–18) m, the
furrow asymmetry is 1%. The furrow asymmetry is insignificant, when the hiller is at \((6–12)\) m distance from the rotation centre.

Experimental tests showed that the operation speed has the greatest influence to the work quality of the hilling bodies, if compared with all the other tested implements. The operation speed should be not smaller than 0.55 m per second because only at this speed the symmetrical row profiles may be formed (Fig. 6).

From the shuttle modules the simplest are the positional beam with two chassis and longitudinally mounted mowing implements. The field area is unlimited, the motor power is 3–4 kW.

The wheels of positional shuttle modules precisely copy unevenness of field and the beam has more deviations of straight movement (Fig. 7). Walking chassis with length support decreases this deviations and quantity of positional corrections. The gantry modules and especially positional shuttle modules in comparison of the tractors decrease motor power and deviations from straight movement and width of rows.
CONCLUSIONS

- Tractors with a front suspension rod and a front power shaft, evenly ploughing ploughs with mounted loosening implements, mouldboard less aggregates, mulching implements, gantry systems, complex and combined implements are the means of field crop production modernisation which should be used as widely as possible.
- By one pass of a combined soil tillage aggregate and experimental potato growing technology involving narrow-wheeled tractors it is feasible to reduce soil hardness in the zone of tracks 1.5 times and to increase the depth of friable soil to 22 cm.
- Rotary cultivators loosen the soil more intensively than mouldboard ploughs or passive shares of cultivators. The soil loosened by these implements as well as mulched soil is packed less before potato planting, the clod content is lower in them, the weed incidence is 2.5 times lower and the tubers are 18–28 cleaner.
- Soil friability, reduction of harmful effect of soil compaction by wheels and mulching of green manure crops increased potato yield 40.3% and reduced dirt content.
- Very important is the indicator of incorporation fullness of green manure crops, as mineralisation of green manure in the soil surface is low.
- The angle of the deviation of the plough body and other implements from the design position if directly proportional to the body distance from the bar the gantry circular module and width is smaller than the design one not more than 10%. The ploughing depth at the centre is smaller by 32 mm than in the peripheral part.
- To avoid the furrow asymmetry at the centre, the hillers should be as close as possible to the circular module bar and their operation speed should be increased, at least, up to 0.55 m/s.

FIGURE 7. The influence of shuttle module chassis type to quantity of positional correction
REFERENCES


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