Soil-protecting Systems for Tillage and Mulching in Agricultural Land in Bulgaria

Hristo Beloev, Petar Dimitrov, Plamen Kangalov, Kaloyan Stoyanov, Evgeni Enchev

Abstract: *This paper discusses issues related to the description, methods of application and results obtained from the use of soil conservation tillage and mulching systems for growing crops on sloping land, demonstrating their effectiveness with reference to soil conservation and agricultural technology.*

Keywords: *surface and vertical mulching, minimum tillage, water erosion, soil compaction, loss of organic matter*

INTRODUCTION

Mulching or spreading a layer of different materials on the soil surface can be defined as a precautionary measure (practice) in the field of agriculture. This is done to: preserve soil moisture, prevent weed growth, increase soil fertility, and protect the soil surface from degradation processes - water and wind erosion, compaction, and reduction of soil organic matter.

Depending on the method of application and the type of technical means used, there are two types of mulching: surface mulching and vertical mulching.

One of the most important benefits of mulching is that it is part of the anti-erosion practices and is an agrotechnical measure to deal with soil water erosion in cropland. Its anti-erosion effect is demonstrated in several ways: soil is protected from the destructive effect of falling raindrops and especially hail, the volume of slope runoff is reduced and the absorption of rainwater into the soil is increased, the soil is protected from drying out and its moisture and humus content is preserved. Considering these guidelines and the fact that soil water erosion is closely linked to two other degradation processes, i.e., soil compaction and soil organic matter reduction, which are significantly dependent on it, we can conclude that mulching can also be of great importance in limiting them.

In Bulgaria, these three degradation processes constitute a problem of national importance because the losses they cause to our agriculture and especially to the sloping agricultural lands are considerable. For this reason, on these areas it is necessary to combine generally accepted technological operations with various methods of mulching aimed at limiting or completely preventing these processes, as well as improving the water-air regime of the soil and preserving soil fertility. The application of these two non-traditional practices (surface and vertical mulching) by using wheat straw crop residues, ready compost or manure as mulch, alone or in combination with other soil conservation measures, leads to a significant increase in their soil conservation and economic efficiency.

For this reason, advanced soil conservation technologies for minimum and non-traditional (vertical mulching) tillage in wheat and maize grain production on sloping land have been developed and researched by the Institute of Soil Science, Agrotechnologies and Plant Protection “Nikola Pushkarov” - Sofia, in collaboration with “Angel Kanchev” University of Ruse. They have been accepted and approved as a scientific product for implementation in practice by the Standing Committee on Innovations and Technologies at the Agricultural Academy - Sofia.

Along with these, similar soil conservation technologies combining surface mulching with contour farming (in which the main types of agricultural work are carried out across the slope or along the terrain horizontals) have been developed and studied by the same team and at the same time period, when producing the same crops on sloping land, with the same protective purpose.

The aim of this paper is to consider the issues related to the description, the methods of

application and the results obtained from the use of these soil conservation tillage and mulching systems, in the cultivation of agricultural crops on sloping land, as well as to present some results of the studies carried out with them, proving their effectiveness with reference to soil conservation and agricultural machinery.

MATERIAL AND METHODS

The research of the advanced technologies of minimum and non-traditional (mulching) tillage, as well as the soil conservation technologies for surface mulching with contour farming using different mulching materials (wheat straw, ready compost, or manure), in wheat and maize grain cultivation was conducted in the period 2012-2015, in the area of the village of. Trastenik, Ruse region, on sloping agricultural land, on carbonate black soil, with a slope of 5^{o} – 8,7%. Two field experiments were designed and conducted in four variants, in four replications, using a block design.

RESULTS AND DISCUSSION

In addition to the results obtained from the experiments conducted for popularising the proposed advanced technologies for minimum and non-traditional (mulching) tillage, the soil conservation technologies for surface mulching with contour farming using different mulching materials (wheat straw, ready compost or manure), in wheat and maize cultivation for grain, as agrotechnical soil conservation systems to limit or completely prevent water erosion, soil compaction and the reduction of soil organic matter it is necessary to provide detailed description of these technologies.. This can best be established once their nature and characteristics have been defined, i.e., the differences that exist between them and the traditional (conventional) technologies currently in use need to be specified. These differences need to be considered separately for each of them.

Improved soil conservation technology for minimum and non-traditional (mulch) tillage of wheat on sloping land

The differences of this technology with the traditionally (conventionally) applied one are as follows:

− applying the anti-erosion method of vertical mulching with ready compost or cattle manure;

− using direct sowing of the crop;

− carrying out all technological operations (treatments) across the slope.

Incorporating these soil conservation methods into the proposed improved technology for wheat cultivation on sloping terrain enables the reduction of surface water runoff and soil export during erosive rains. This also increases moisture retention and aeration, preserves the soil organic matter, and increase crop yields.

The advanced, soil- protecting technology for minimal and non-traditional (vertical mulching with ready compost or manure) soil tillage for growing wheat can be applied on soils with light and medium mechanical composition, namely soils rich in carbonate, typical and slightly leached chernozems, alluvial meadow soils, etc. For these types of soil, the technological process of this tillage system includes the following technological operations: vertical mulching with ready-made compost or manure, direct sowing, and plant protection operations to control weeds, pests, and diseases.

The pre-sowing anti-erosion measure of vertical mulching is applied with the machine shown in Fig. 1. Ready-mixed compost or manure is applied to the slots formed on the soil surface and to a depth of 0,40 m.

Direct sowing ensures quality sowing of the wheat seeds without additional pre-sowing treatments on the ground. This way of sowing preserves the soil structure, slows down the mineralisation of humus, improves the permeability of the subsoil and reduces erosion.

Fig. 1 General view of a modified breaker - dead furrower SHTN-2- 140 with a mulch bunker

To carry out the direct sowing in our case, the specialized planter cultivator SKS-2 (Fig. 2) is used, performing both soil tillage and sowing.

Fig. 2 General view of sowing tractor aggregate class 1,4 and planter cultivator SKS-2

In the uncultivated field, this machine simultaneously performs four technological operations: pre-sowing tillage, sowing, application of granular fertiliser and rolling of the sown rows.

The subsequent control of weeds, pests and plant diseases is done exclusively with the help of chemical methods using herbicides and preparations.

The application of this advanced soil conservation technology for minimum and non-traditional tillage in wheat cultivation on sloping land (at a slope gradient of 5^{o} – 8,7%) results in:

− - reduction of surface water runoff volume by 2.5 to 3.0 times
− - reduction of soil erosion by 6.2 to 6.5 times
− - reduction of organic carbon losses by an average of 5.5 times
− - increase in wheat grain yield by an average of 17.8% (783.7 kg/ha) and straw yield by 16.7% (570.4 kg/ha).

Improved soil conservation technology for minimum and non-traditional (mulch) soil tillage for growing maize for grain on sloping land.

This technology differs from traditional (conventional) technology in the following:

− Replacing the basic tillage operation of turning the soil with the no-till technological operation of ripping.

− Incorporating the anti-erosion method of vertical mulching with ready compost or cattle manure.

− Incorporating the anti-erosion method of soil-breaking with dead-farrowing in the seeding of maize in the shaped row spacings and in the hoeing the crop.

− Performing the combined anti-erosion method of soil-breaking with dead-farrowing in the row spacings simultaneously with the technological operation of ridging the maize.

− Performing all technological operations across the slope.

Incorporation of the above soil conservation methods in this improved technology leads, as in the previous improved technology for growing wheat on sloping land, to a reduction in surface water runoff and soil export, to an increase in moisture retention and aeration, to a conservation of soil organic matter and to an increase in maize yields. Furthermore, the condition that all soil tillage operations are carried out across the slope is one of the important ones for realising an additional anti-erosion effect.

This advanced technology for minimal and non-traditional tillage of maize for grain cultivation on sloping land includes the following soil conservation measures: soil ripping as main tillage; vertical mulching with ready-made compost or cattle manure; soil-breaking with dead-farrowing combined with seeding and hoeing; and soil-breaking with dead-farrowing combined with ridging. These operations are performed with the mounted chisel cultivator CP-7 (Fig. 3), specialised equipment for vertical mulching (Fig. 4), equipment for soil-breaking with dead-farrowing (Fig. 6) attached to the frame of the SPC-6 pneumatic precision seed drill (Fig. 5) and to the inter-row cultivator KRN-4,2 (Fig. 7), and combined device for furrowing, soil-breaking with dead-farrowing attached to the cultivator KRN-4,2 (Fig. 8).

To protect against water erosion the crops that require hoeing and ridging and that are sown on sloping land in the period immediately after seeding, when the soil and plants are least protected from erosive rainfall, and to reduce soil compaction, the technology includes soil-breaking with dead-furrowing performed simultaneously with seeding and anti-erosion treatment. For this purpose, pneumatic precision seed drills type SPC-6 with soil-breaking units are used (Fig. 5). They are attached to tractors with a nominal towing capacity of 14 kN.

Fig. 3 Chisel cultivator CP-7

Fig. 4 Device for applying organic matter or mulch to the soil

Fig. 5 Seeder SPC-6 with soil breaking units

Fig. 6 Soil-breaking units

Moving across the slope, the machine seeds the crop in rows, in this case grain maize, and at the same time its soil-breaking units, passing through the middle of each row, form a 0.25 m deep slit with small ridges on either side of the soil surface. At the bottom of each slit, the breaker-dead furrower create an underground passage (channel) parallel to the soil surface which, together with the slit, absorbs the surface water formed by erosive rains. This soil conservation tillage reduces surface water runoff and the amount of soil carried away by erosive rains falling after sowing. It also increases soil moisture, aeration and temperature, and limits soil compaction. Consequently, plant germination is accelerated, and further plant development is improved. In addition, the used soil-breaking units (Fig. 6) increase the transverse stability of the seed drill, thus avoiding the danger of lateral drift and improving the quality of sowing across the slope.

Fig. 7 General view of cultivator KPH-4,2 with a device for soil-breaking with dead-furrowing

The soil-breaking with dead-furrowing is also done with the first machine-done hoeing across the slope, in the row spacing at a distance of 1,4 m (across the row) and at a depth of 0,25 m using a device for inter-row anti-erosion treatment. This device is mounted on the cultivator KRN-4,2 after the hoeing units (Fig. 7).

In addition, the working units of the breaker – dead furrower reduce soil compaction and stabilise the machine laterally, as well as preventing lateral drift and plant cutting. This enables the crop rows to be orientated across the slope, which is appropriate for anti-erosion and agro-technical reasons.

Furrowing done by soil-breaking with dead-furrowing is carried out together with the second ridging. This combined anti-erosion treatment is performed across the slope and the technological operations of soil-breaking with dead-furrowing are done sequentially and simultaneously when cultivating these crops on sloping land. For this purpose, inter-row cultivators of the type KRN-4,2 or KOV-4,2 with devices for furrowing and soil-breaking with dead-furrowing are used (Fig. 8).

Fig. 8 General view of a device for furrowing, soil-breaking and dead-furrowing

This combined anti-erosion machine is aggregated with tractors with a nominal towing capacity of 14 kN. When operating across the slope, this machine-tractor aggregate carries out the simultaneous and sequential anti-erosion operations of furrowing, soil-breaking with dead-furrowing in the inter-rows of the crop (grain maize) in its 5-7 leaf phase. As a result, the plants in the rows are ridged while furrows are formed in the row spacing to a depth of 0.12-0.15 m and slits with underground furrows are formed in the middle of each even or odd row spacing to a depth of 0.25 m. These furrows, slits and underground passages act as a barrier to rainwater as it runs down the slope during the frequent erosive rainfalls at this time of year. This leads to a reduction in surface water runoff and in the amount of soil carried away. Another effect is the increase in soil moisture, preservation of soil fertility and crop yield.

The use of these technological operations of the advanced soil conservation technology for minimum and non-traditional tillage in the cultivation of corn for grain on sloping terrain (with a slope of 5^{o} – 8,7 %) results in:

- - reduction in surface water runoff volume by 5.2 to 5.4 times;
- - reduction in soil erosion of 21,5 to 24,3 times;
- - reduction in organic matter losses by an average of 17,4 times;
- - increase in maize grain yield by 16,4 % on average (1038,0 kg/ha).

Improved anti-erosion technology for contour and surface mulch tillage in wheat production on sloping land.

This technology differs from the traditionally (conventionally) applied one with respect to the following:

- it incorporates the anti-erosion method of surface mulching with wheat straw, ready-made compost, or cattle manure;
- all technological operations (treatments) are performed across the slope.

The anti-erosion advanced technology for contouring (carried out across the slope) and mulching (surface mulching with wheat straw, read-made compost, or manure) tillage for wheat production can be applied on soils with light and medium mechanical composition (soils rich in carbonates, typical and slightly leached chernozems, alluvial meadow soils, etc).

In this technology, soil tillage is an important link in agro-technical measures and is of great importance for obtaining high yields of wheat. In addition, because in this case it is carried out on sloping land and in order to create favourable conditions for protection against water erosion, compaction and loss of organic matter, it is necessary that these technological operations must also help both to perform the high-quality subsequent seeding and to limit the above-mentioned degradation processes. For this reason, within this tillage system, all the technological operations, which are not different from those ones traditionally carried out for this crop, must be carried out across the slope. In addition, the soil conservation measure of surface mulching with wheat straw, ready compost or rotted manure must be included.

In this case, surface mulching, as part of the improved anti-erosion contour-mulching technology, is a soil-conservation agrotechnical method in which the soil is covered with various organic residues: straw, compost, or rotted manure.

Fig. 9 Universal composting and mulching machine with hydraulic platform

In the application of this tillage system, surface mulching takes place after sowing, before wheat germination, across the slope. Depending on the type of organic mulch (wheat straw, compost, or rotted manure), it can be carried out in two different ways, with two different agricultural machines: the universal composting and mulching machine with a hydraulic platform for breaking and shredding round and parallelepiped bales (Fig. 9) and the fertiliser spreader trailer (Fig. 10).

Fig. 10 Fertilizer spreader trailer

The first machine was developed at Ruse University "Angel Kanchev" and is used for surface mulching with wheat straw. It is equipped with a hydraulic platform (Fig. 11), an auger breaking and shredding device and a deflector.

Fig. 11 Hydraulic platform for breaking and shredding round and parallelepiped bales

It is combined with tractors with a nominal towing capacity of 14 kN and engine power of 66,2 kW. The rear part of the frame of the hydraulic platform for breaking and shredding round and parallelepiped bales is attached to the rear three-point tractor hitch. When this machine works, the hydraulic platform takes the bale from a pile of bales at the end of the field or from a specialised front bale loader (Fig. 12) and feeds it to the breaking and shredding auger device. The bale can be shredded into pieces with different sizes. The shredded material is spread over the field surface or fed to a transport vehicle (fertiliser spreader trailer) by a deflector device.

Fig. 12 Front loader with device for round bales and parallelepiped bales

The second machine used for surface mulching is the fertiliser spreader trailer (Fig. 10). It is mainly used for mulching with rotted manure and compost. In rare occasions the mulch can be made from wheat straw. The fertiliser spreader trailer cab be either single-axle or double-axle with a load capacity of 3.5 to 16 tonnes. It is constructed in way that allows the operation to be performed in the following way: the mulch (organic solid fertiliser or compost) is loaded onto its bodywork by a front loader - Fadroma (Fig. 13). Then the mulch is fed by a chain plank conveyor located in the rear end to a fertiliser spreader. The fertiliser spreader is mounted at the rear end of the trailer. Its operating units are driven by the power take-off shaft

of the power units (tractors), and a reduction gear and a toothed clutch ensure the low-speed movement of the conveyor. The fertiliser spreader consists of two drums equipped with intake fingers and augers. In some trailers the drums can be positioned vertically or horizontally at the rear of the bodywork or along their length.

Fig. 13 Front loader-FADROMA

In the Republic of Bulgaria, the following types of fertiliser spreaders can be used for surface mulching with compost or rotted manure: spreaders 1PTU-6 (1PTU-3,5, PTU-14), ROU 6 and PPT-10 (PPT-16). They are aggregated with tractors with a nominal towing capacity of 14 kN to 50 kN.

In our case, the surface mulching of the soil with mulch (compost and rotted manure) is carried out with a fertilizer spreader trailer 1PTU-6, aggregated with a tractor "Belarus" MTZ - 952.

The application of this improved anti-erosion technology for contour-mulching soil cultivation in wheat growing on sloping land (at a slope gradient of 5º – 8,7%) results in:

− - reduction in surface water runoff volume by 1.3 to 1.5 times;

− - reduction in soil erosion of 1.8 to 1.9 times;

− - reduction in organic carbon losses by an average of 2.48 times;

− - increase in wheat grain yield by an average of 7.7% (338.0 kg/ha) and straw yield by 8.4% (284.7 kg/ha).

Improved anti-erosion technology for contour and mulch (surface mulch) tillage for growing grain maize on sloping land.

This technology differs from traditional (conventional) technology in the following:

− it incorporates the anti-erosion method of surface mulching with wheat straw, ready compost, or cattle manure;

− all technological operations are carried out across the slope.

Including the soil conservation method of surface mulching in the proposed improved contour and mulching technologies enables their application with the purpose of reducing surface water runoff and soil export during erosive rains, increasing moisture storage and aeration, retaining soil organic matter, and increasing yields of the respective crops.

In the anti-erosion technology under consideration, all technological operations included in the tillage must be carried out across the slope.

Immediately after wheat harvest, deep ploughing to a depth of 0.18-0.20 m is carried out on lighter soils and to a depth of 0.20-0.25 m on heavier soils. After alfalfa, hulling is carried out at 0.6-0.8 dm (to prune root necks) and 10-15 days after that, ploughing at a depth of 0.20-0.25m is performed. Irrigated areas are kept clean, depending on weed infestation, by disking and cultivation.

Pre-sowing preparation in spring is usually limited to 1-2 shallow treatments - harrowing

and cultivation. The last cultivation should be carried out with *Rau-combi* cultivators (Fig. 14). They have spring-cultivator and active rotary working parts providing levelled, fine-grained structure of the plough layer.

Fig. 14 Tillage with cultivator-combinator

Sowing is carried out in a dotted row with 6-8 row pneumatic seed drills type SPC-6, SPN-8 or Amazone ED-6, at an inter-row spacing of 0.70 m.

In the application of this advanced anti-erosion contour-mulching technology, as in the case of wheat production discussed above, the technological operation of surface mulching is carried out after sowing, before maize germination, and across the slope. Depending on the type of organic mulch used (wheat straw, compost, or rotted manure), surface mulching can also be done in the two methods already known to us, with the two agricultural machines already described above, i.e., the universal composting and mulching machine with a hydraulic platform for breaking and shredding round and parallelepiped bales (Fig. 11) and the fertiliser spreader trailer (Fig. 10). Again, the first machine is used for surface mulching with wheat straw. The second one, more precisely in this case the fertiliser spreader trailer 1PTU-6 (ROU-6) (Fig. 15), aggregated with a Belarus MTZ-952 tractor, is used for surface mulching of the soil with compost mulch or rotted manure.

Fig. 15 Spreader trailer ROU-6

In this anti-erosion technology, the care during vegetation includes measures to control weeds, diseases and pests related to maize and does not differ significantly from the one included in the advanced soil conservation technology for minimum and non-traditional (mulching) tillage in the production of maize for grain on sloping land and already described above. The only difference is that here, in the mechanical weed control, no agrotechnical methods are applied to protect the soil from water erosion together with the vegetation inter-row tillage. The latter, in the outlined advanced contour-mulch soil tillage technology for production of maize for grain on sloping land, are traditionally (conventionally) carried out with inter-row cultivators type KRN-4,2 or KOV-4,2 (Fig. 16), operating without soil-breaking and harrowing units.

Fig. 16 Cultivator for inter-row tillage

The application of these technological operations which are part of the improved anti-erosion contour-mulching technology in the growing of maize for grain on sloping terrain (with a slope 5º – 8,7 %) results in:

- - reduction in surface water runoff volume by 1.8 to 2.0 times;
- - reduction in soil erosion by 3,4 to 3,8 times;
- - reduction in organic matter loss by 2.23 times on average;
- - increase in maize grain yield by 9,8 % on average (619,0 kg/ha).

CONCLUSIONS

With reference to the provided descriptions and research findings, it can be concluded that the four soil conservation technologies for tillage and mulching, developed in Ruse University "Angel Kanchev" in cooperation with the Institute of Soil Science, Agro-technologies and Plant Protection "Nikola Pushkarov" in Sofia, and used in growing agricultural crops on sloping terrains, as well as the system of machines for their implementation are effective and comply with soil conservation and agrotechnical requirements.

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CONTACTS

Petar Dimitrov, Institute of Soil Science, Agricultural and plant protection "Nikola Poushkarov" Sofia, Experimental Station for Erosion Control, University of Ruse, 8, Studentska Str., 7017 Ruse, Bulgaria, e-mail: pddimitrov@dir.bg

Hristo Beloev, Department of Agricultural Machinery, Agrarian and Industrial Faculty, University of Ruse "Angel Kanchev", 8 Studentska str., 7017 Ruse, Bulgaria, e-mail: hbeloev@uni-ruse.bg

Plamen Kangalov, Department of Repair, Reliability, Mechanisms, Machines, Logistics and Chemical Technologies, Agrarian and Industrial Faculty, University of Ruse Angel Kanchev, 8, Studentska Str., 7017 Ruse, Bulgaria, e-mail: kangalov@uni-ruse.bg

Kaloyan Stoyanov, Department of Agricultural Machinery, Agrarian and Industrial Faculty, University of Ruse "Angel Kanchev", 8 Studentska str., 7017 Ruse, Bulgaria, e-mail: kes@uni-ruse.bg

Evgeni Enchev, Department of Agricultural Machinery, Agrarian and Industrial Faculty, University of Ruse "Angel Kanchev", 8 Studentska str., 7017 Ruse, Bulgaria, e-mail: eenchev@uni-ruse.bg