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Construction Method for Mulching System in Plant Production

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Abstract: Based on the establishment of demands for a mulching system in plant production, the function of a soil cover for affecting soil physical properties was analyzed. And 5 construction principles for soil cover with agricultural waste materials, inorganic materials, transparent and nontransparent plastic film and low plant for living mulch were suggested. Through technological evaluation of solution variants according to 10 established evaluating criteria system, the reasonable solution variant with a higher grade of approach towards a imagined ideal solution variant was found out. A fundamental condition for mulching system was composed. Finally the effects of selected mulch material on soil physical properties were examined through a field experiment.

Key words: mulching system; soil physical property; plant cultivation; construction method

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1 Introduction

The cover of soil surface with mulch materials is a widely used agricultural technique for improving soil and plant productivity[1]. The goal of a soil cover determines the selection of mulch materials, the duration and the grade of cover. At the same time the subsystems in plant growth environment (atmosphere, mulching zone and soil) must be in correspondence. Design method for mulching system under restrictions of field production factors should be found out for an optimal usage of soil cover under consideration of material exchange in the system, technological possibility and economic benefit in plant cultivation[2].

Construction method of a mulching system is a process of demand and realization for soil cover. The mulch zone created by the cover modifies soil properties in accordance with needs of plant growth. Design of mulching system is also a procedure of optimization of partly conflict parameters by plant cultivation[3]. The effects of soil cover on soil physical properties are important for modifying soil condition so that the goal of design of mulching system is concentrated on the influence of soil cover on temperature, moisture content and porosity of a soil with a special consideration of soil physics and plant cultivation.

2 Demands for Mulching System

The goal and technological conditions of mulching system must be first put out clearly in form of demands. There are demands which must be fulfilled, otherwise the considered goal can not be achieved, for example, a definite effect of a cover on soil temperature and moisture content, these demands are given priority 1 (shortly P1). Certain lowest and highest demands for mulching system such as minimal and maximal increase of soil temperature and moisture content could also be included within P1 through appropriate formulation.

The demands which should be considered under certain permissible conditions are given priority 2 (shortly P2), for example, weed control and erosion control by soil cover. There are also other demands for mulching system which should be certainly considered but its fulfillment is not

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necessary such as improvement of soil microorganism and increase of soil fertilization, these demands may be taken into consideration with priority 3 (shortly P3).

The distinction and the classification of the demands are necessary because the fulfillment of the goal by mulching system could only be evaluated through examination of possible cover variants For influence of a soil cover on soil physical properties and plant growth, the demands for a mulching system can be established. They can be classified as follows:

1) Functional demands

increment/decrement of soil temperature	P1
increment of soil moisture content	P1
preservation of soil structure	P1
improvement of plant growth	P1
possibility of weed control	P2
control of water erosion	P2
possibility of early harvest	P2
possibility of organic manuring	P3

2) Intersection demands

safe cover on soil surface	P1
adaptability to climatic condition	P1
changeable duration of cover	P1
possibility of mechanization	P2
control of cover effects	P2
no damage to soil microorganism	P1
no hindrance to seed emergence	P1
no damage to plant growth	P1

3) Operation and technique demands

simple operation and handling	P1
same time spreading with seed	P2
no recovery of mulch materials	P2
little time expense by operation	P2
low energy consumption for operation	P2
low consumption of mulch materials	P3

3 Functional Examination and Solution Principle

From complete task of a soil cover, the complicated total function can be divided into subfunctions with lower complicity for better understanding. The functional mechanism of a soil cover for affecting soil physical properties and plant growth environment consists in 5 subfunctions (shortly F_i):

increase/decrease of soil temperature F1;

increase/decrease of soil moisture content F2;

increase/decrease of soil porosity F3;

protection of soil structure F4;

prevention of soil erosion F5.

From integration of above subfunctions, the conclusion is that the total function is based on physical properties of mulch material, which forms a mulch layer between soil surface and atmosphere. Subfunctions solutions must be found out and be jointed together into a solution principle which contains physical effect for fulfillment of functions of a mulching system. The required subfunctions should be insured only through proper selection of mulch material with special physical properties Different subfunctions of a soil cover must be realized through a definite mulch cover. The physical effect of subfunction F1 for modifying soil temperature, F2 for improving soil moisture regime and F3 to F5 for protecting soil porosity, structure and preventing soil erosion could be represented in solution variants as follows:

1) cover with organic waste materials such as compost, straw and tree trashes;

2) cover with nontransparent synthetic materials such as black paper and black granular;

3) cover with transparent synthetic materials such as plastic film and light colored film;

4) cover with inorganic materials such as sand, gravel and aluminum film;

5) cover with lower living plant such as leguminous and grass

The solutions variants above concern predominantly physical solution principles which guarantee the safe function of soil cover and fulfill the demands with P1. The main problem by combination of subfunctions is recognition of physical availability for achievement of a disturbance free exchange of materials and energy (water, air and light) between atmosphere and soil and inside of mulch layer.

4 Technological Evaluation of Solution Variants

In order to obtain an objective decision for mulching system, the solution variants must be examined through evaluation, in which "value", "benefit" or "strength" should be given to a solution variant according to its functions for the purpose set up previously. The process of evaluation through comparison of the solution variants or with a imagined ideal variant let to a "valence" indicating the approach grade of solution variant towards the ideal variant. The method of analysis of benefit value is an important and suitable procedure for this process[2].

4.1 Establishment of Evaluation Criterion

Evaluation of solution variants takes place by introduction of goals of a mulching system, with which the criteria of evaluation could be established and the solution variants could be judged. By selection of the criteria, the consideration should be concentrated on a balance of important demands with P1. And other demands with less importance could not be taken into account firstly, such as demands with P3. The following criteria are selected according to the demands for mulching system. The solution variants were evatuated for affecting soil physical properties.

1) increase of minimal soil temperature;
2) decrease of maximal soil temperature;
3) preservation of soil moisture content;
4) conservation of soil structure;
5) convenience by soil cover operation;
6) resolution of mulch material after cover;
7) insurance of cover function;
8) possibility of plant manuring;
9) lower consumption by cover operation;
10) possibility of weed control.

The examination of solution variants would be carried out through awarding value to variants in accordance with its functional strength. The evaluation criteria towards desired effect by evaluator. According to guideline VDI 2225, a value scale from 0 to 4 (Tab. 1) could be used for analysis of solution variants[2].

Tab 1 Value scale for evaluation

Value	Meaning
0	Unsatisfactory solution
1	Acceptable solution
2	Sufficient solution
3	Good solution
4	Ideal solution

4.2 Evaluation of Solution Variants

According to above evaluation criteria, a part value (PV_i) should be given to each solution variant. Then a whole value (WV) can be calculated as follows:

$$WV = \sum_{i=1}^{n} PV_i$$

In comparison with the ideal solution, the whole value of a solution variant should be changed into a relative valence (RV) indicating the approach grade towards the imagined ideal solution which has a maximal whole value (WV_{max}). The relative valence of a solution variant is calculated as follows:

$$RV[\%] = \frac{WV}{WV_{max}} \times 100$$

The results of technological evaluation for suggested solution variants are shown in Tab. 2. Under consideration of higher whole value and value profile among evaluation criteria, the solution variant 1 and 2 should be taken for the purpose to affect soil physical properties. The solution variant 3 has a higher whole value but can not meet the demand for decrement of maximal soil temperature by criterion 2, so that this variant is basically used for increase of soil temperature in cool region.

The solution variant 1, soil cover with organic waste materials of agricultural products, consists of many materials. Compost is one of those materials with manifold favorable applications in field production. So the use of compost as mulch material is a new experiment which should be carried out for a better recycling of organic waste materials in agricultural production system.

Tab 2 Evaluation tabular for solution variants

Evaluation criterion	Solution variants				
	1	2	3	4	5
1	2	2	4	1	0
2	4	1	0	2	2
3	3	4	4	2	1
4	4	4	4	3	3
5	3	3	3	3	3
6	4	1	1	2	3
7	2	4	4	2	3
8	3	1	1	1	3
9	4	2	2	4	2
10	3	3	1	2	1
WV	32	25	26	23	21
RV = (*WV*ö40) × 100	80.0	62.5	65.0	57.5	52.5

The solution variant 2, soil cover with nontransparent synthetic materials, consists of black plastic film and black paper in the practice. Because the black plastic films are already used very often by field production, the function of black paper for affecting soil physical properties should be examined for its better usage in mulching system.

Through technological evaluation of solution variants, the important prerequisite for mulching system was established with proper selection of mulch materials. Experiment should be carried out to examine the functions of soil cover affecting soil conditions for plant growth in field production. The definite functions of soil cover with compost and black paper were determined by field experiment. The possible construction method for mulching system was verified by experiment[4~6].

5 Conclusions

1) Through establishment of demands for mulching system, the goal and conditions of a soil cover and its required effects on soil physical properties are clearly presented. The demands with higher importance had higher priority and must be fulfilled in comparison with those which should be considered but not definitely be realized in mulching system.

2) The functional demands, intersection demands and operational and technological demands together with the present total necessities to reach the purpose of a soil cover.

3) Analysis of solution principles and functional examination provide a method to investigate the functions of a mulching system and furthermore to establish the solution variants in accordance with the possibilities of soil cover.

4) The technological evaluation led to a comparison of solution variants with an imagined ideal variant. A reasonable solution variant was found out according to the evaluation criteria for better fulfillment of the tasks for mulching system.

5) The effects of selected mulch materials on soil physical properties were examined through field experiment. A proper construction method for mulching system was verified.

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地表覆盖种植技术工艺的构建方法研究

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摘　要: 以机械设计方法学为理论基础, 探讨了以改善作物生长的土壤物理条件为目标的地表覆盖种植技术工艺在种植业生产上的应用特点, 进而阐述了自然环境2地表覆盖层2土壤2作物系统中构建地表覆盖种植工艺的功能要求、交互作用要求、技术要求和操作要求, 并根据各种要求的重要程度建立了满足要求的地表覆盖技术工艺的三级优先原则。以此为基础, 研究了地表覆盖的部分功能以及部分功能的组合总体功能, 并对其功能进行了检验分析。在列举可能作为地表覆盖材料的前提下, 提出构建地表覆盖种植工艺的 5 种方案: 农业生产废弃物覆盖地表, 如碎秸秆、谷物颖壳和碎草等; 不透光合成材料覆盖地表, 如黑色沥青涂层纸和黑色塑料薄膜; 透光合成材料覆盖地表, 如各种无色塑料薄膜; 无机地表覆盖材料, 如细沙、砾石等; 低矮活体植物生长条件下的地表覆盖, 如苜蓿草和各种其它草类。根据覆盖方案的技术评价方法, 建立了 10 项指标的评价体系, 并以 5 级指标值为评价准则, 对 5 种覆盖方案进行了技术总值和相对价值的计算。在检验各种覆盖方案相对评价指标体系的部分值分布均衡性以及相对有效值大小的基础上, 确定了农业有机废弃物覆盖地表的相对价值为 80% , 是满足对作物生长土壤物理因素改善的较佳覆盖方案。研究过程所遵循的原则和地表覆盖种植工艺的构建原理和方法对于地表覆盖种植技术的正确应用以充分发挥其功能具有重要的实际意义。

关键词: 地表覆盖; 土壤; 物理因素; 作物栽培; 构建方法

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