The Benefit and Prospect of No-till and Cropland Mulch on Water Conservation of Loess Plateau in China

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Abstract: No-till and soil surface mulch are very important component of cropland tillage practice. Different soil management methods have different effects on soil erosion, soil water storage and crop yield. The objective of this study was, according to the water and calorific condition on loess plateau, combining with the research results obtained, to introduce no-till and soil surface mulch types used in production practice, their environmental and economical benefit and water conservation benefit in semi-arid ecosystem of loess plateau their application prospect of no-till and cropland mulch on loess plateau was discussed. It was put forward that no-till and biological mulch and straw or stubble mulch should be applied extensively on loess plateau. Straw mulch and plastic film mulch were recommended in flat regions, biological mulch was recommended in hilly and gully regions. This paper proposes that straw mulch could replace the soil mulch as special machines are developed.
Keywords: no-till, cropland mulch, water conservation, benefit and prospect, loess plateau

1 Introduction

The loess plateau in China was considered one of the important birthplaces of Chinese and World agriculture because agricultural production started 6,000 years ago in the region. Increasing population pressure from 500 B.C. and particularly during the past 500 years of almost exponential population growth, led to extensive clearance and cultivation of highly erodible slope land, and to the most serious soil erosion in the world (1). The landforms belong to a typical highland characterized by hills and gullies, and the climate is warm temperate on the loess plateau. There are arid, semiarid and semi-humid areas with aridity index 2.01—4.00, 1.51—2.00 and 1.00—1.50 respectively, production mainly depended on rainfall, hence rainfed farming is the typical agricultural practice in this region. The mean annual precipitation is 500mm—700mm. The soil is frequently subjected to moisture deficit in large area. Critical agricultural problems in the region are the shortage of cultivated area, serious losses of water and soil during rainfall events, frequent drought and low crop yield because of the non-uniform rainfall pattern and high yearly variability. Frost-free period are 90 days—230 days, which can meet the need of one cropping cycle in large areas, some places can harvest two crops per year. However, water shortage, short growth seasons, and accumulated temperature are main obstacles to crop production on loess plateau [1,2].

No-till and soil surface mulching has many advantages, e.g., regulation of temperature, soil and water conservation, improvement of soil physical characteristics, promotion of microbial activity, killing weeds in the field, preventing soil salinity and promotion of crop development. Hence, no-till and soil surface mulching could be an efficient measure for improvement of cropland ecosystem productivity on loess plateau on near-term and long-term.

There are several kinds of mulching methods used in production practices on loess plateau. Three main mulching methods are used extensively in the region: biological mulches, straw mulch or stubble mulch and plastic film mulch. This paper discussed these main mulch types and their benefits to the loess plateau cropland ecosystem.

2 Research methods

The study was conducted at different sites on loess plateau. Biological mulch method involves sowing plants so that the root system and stem could shade soil surface，avoiding wind and water erosion，and keep soil moist. Biological mulch experiment was conducted in the hilly and gully region of loess plateau. It involved planted tree/shrub/grass on sloped (>20°) farm land. The terraces and level land were put to crop production. Soil loss in small watershed and crop productivity was monitored in an 8.7km^2 area in the Zhifanggou small watershed in Ansai county in north Shanxi province from 1985 to 1998. A stubble or straw mulch experiment was conducted in highland region of loess plateau from 1991 to 2000. What straw (6,000kg/ha) was applied uniformly to soil surface during fallow period, or between rows of corn. Runoff, soil water content, crop yield, water flow speed, sandy content and runoff coefficient were investigated by means of small plot runoff amount and Time domain reflectometry (TDR). Plastic mulch experiments were conducted with winter wheat and spring corn in highland region. Plastic film (1m wide) was used to mulch the soil surface, and two sides of the film were held down with soil. Two rows of spring corn with 70cm row spacing and 40cm plant spacing, or 4 rows of winter wheat with 25cm row spacing and 10cm plant spacing were sown through the plastic film by special machine. Soil water content was measured with TDR, soil temperature (0cm—20cm depth) was measured in cold winter, crop growth period, grain yield, spring corn root number, root zone diameter, and root weight were investigated. All data were obtained with three replications. Average values were used to analysis. L.S.D method was used to test significant difference.

3 Research results

3.1 No-till

No-till is considered a very important conservation tillage. The benefits credited to no-till include soil and water conservation, lower production costs and greater production efficiency, arresting or reversing soil degradation processes and reducing nutrient and pesticide losses by reducing runoff volume (increased infiltration) and soil loss. The USA led the world in developing and using no-till technology. There is a coordinated national drive in the USA to increase the use of conservation tillage to 50% of the cropped area by 2002. Research results obtained in highland region of loess plateau from 1991 to 2000 shown that under no-till condition in winter wheat field, the consume of soil moisture was lower 28.6%—37.3% than conventional tillage treatment, and grain yield was higher 20.8%—25.4% in semiarid region.

3.2 Biological mulch

Maintaining vegetative cover soil by means of biological mulch is important in an erded soil region. Research has consistently shown the benefits of biological mulches in dramatically reducing water erosion and in improving the productivity of eroded soils. Soil losses decreased from over 10,000 t/(km^2 • yr) in 1985 to about 1,000 t/(km^2 • yr) in 1998 when forest and grass cover rate increased from 13.9% and 4.8% to 34.8% and 16.9% respectively. At the same time, spring corn productivity increased from 791.0kg/ha in 1985 to 5,408.3kg/ha in 1998 on hill and gully region of loess plateau.

3.3 Stubble or straw mulches

That is the use of plant straw, dry grass and crop-residue to cover soil surface. According to Soil Conservation Society (SCS) and the Conservation Technology Information Center, West Lafayette, IN, any tillage and planting system that leaves all or some portion of the previous crop’s residue on the soil surface is described as crop residue management. This kind mulch material can be decomposed to release nutrients, and provide other special effects. That are reduce tillage, avoid raindrop strike soil and hardpan, keep soil natural structure; reduce soil evaporation, conservation soil moisture; improve soil infiltration, promote soil microbe activity, increase soil organic content, increase soil aggregation formation; greatly reduce soil runoff，soils scours and wind erosion.

Crop residue management research involving soil and water conservation on loess plateau has been oriented toward increasing rainfall infiltration during the growth of warm-season crops. Crop residue mulch can obviously increase soil organic matter content and improve soil physical and chemical characteristics.

Field study results showed a positive relationship between organic matter content and crop residue mulch after the third year of experimentation.

The research results obtained in highland region of loess plateau showed that as the amount of straw mulch approaches 6,000kg/ha between spring corn rows, runoff was 45.30 m^3/ha in 1991，and 28.95 m^3/ha in 1992, but under conventional planting system runoff was 174.75m^3/ha and 116.17 m^3/ha respectively. The runoff reduction was 74% lower under straw mulch than conventional planting system. The amount of soil water storage in 1m-soil layer increased by about 41% in 1991 and 1992 respectively. Field simulation experiment results showed that under 15° slope and rainfall intensity of 1.78mm/min, The average water flower speed in straw mulch treatment was 16.80cm/s and 30.65cm/s in conventional planting. Water flower speed reduction was 13.85cm/s lower under straw mulch treatment than conventional planting system. The sandy content of runoff was 87.9kg/m^3 in straw mulch treatment and 173.5kg/m^3 in conventional planting system. The reduction sandy content was 49.34% under straw mulch treatment than conventional planting system. While the runoff coefficient was 0.38 in the treatment of straw mulch compared with 0.51 in conventional planting system. According to research results obtained in 1996—1999 in highland region of loess plateau, cropland water storage increased by 60.0mm—94.1mm, rainfall use efficiency increased by 24.5%—36.6% and wheat yield increased by 27.5%—31.3% under residue cover during fallow period after harvesting wheat. Corn experiment results showed that cropland water storage increased by 69.3mm—86.0mm, and corn grain yield increased by 23.2%—58.1% in the treatment with straw cover compared with conventional system.

3.4 Plastic film mulches

The plastic films are highly translucent and easily penetrable light by have less thermal conductivity and no-air-permeability. They improve soil temperature condition， promote crop growth and development，and increase yield. Since the 1980's, when plastic film mulch was extended to all part of the country, the area under plastic film mulch increased rapidly，and it has become an important measure for improving productivity of the soil and combat water erosion in the loess plateau of China.

Research results showed that soil moisture content was much high under plastic film mulch than under no plastic mulch (Fig. 1), especially in the soil layer above 140cm depth.

Table 1 showed that under cold condition, soil temperatures in 0cm—20cm layer were higher under plastic film mulch than under no-plastic film mulch. So plastic film mulch obviously increases soil temperature in certain periods during cold winter season.

Table 1 Soil temperature under plastic film mulch (℃)

	8:00			14:00			20:00		
	Tnp	Tp	Tp-Tnp	Tnp	Tp	Tp-Tnp	Tnp	Tp	Tp-Tnp
4Jan.,2000(clear)	–4.8	–3.2	1.6	12.3	10.5	–1.8	–2.0	–1.3	0.7
5Jan.,2000(cloud)	0.3	1.0	0.7	2.0	2.5	0.5	–2.0	–1.2	0.8
6Jan.,2000(clear)	–4.8	–4.0	0.8	11.7	11.4	–0.3	–4.8	–3.1	1.7

Notes: the data was obtained at Changwu Experiment demonstration zone in 2000. Measurement depth was 20cm.Tnp-Soil temperature with no-plastic mulch; Tp- Soil temperature with plastic mulch

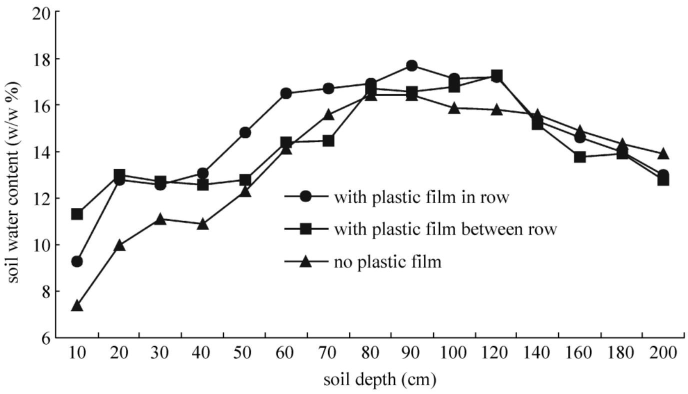

Fig.1 Soil moisture content under plastic film mulch (14Mar 1999) at Changwu Agroecological experiment station of CAS

Because plastic film mulch increased soil temperature during cold weather condition, and increased accumulated temperature, it enhanced corn growth and development, through early germination (corn seedlings emerged 5 days—8 days early and shortened growth duration 16 days—30 days). Table 2 showed that under condition of plastic film mulch or plastic film plus straw mulch, the root number, root zone diameter and root weight of spring corn were higher than under no-plastic or straw mulch. The root number, root zone diameter, root weight increased by 25.1%—39.3%, 24.5%—36.5%, 24.7%—39.1% in plastic film mulch treatments, and 36.3%—67.5%、40.4%—48.1%、39.7%—58.7% in plastic film mulch plus straw mulch treatments respectively. Hence, plastic film mulch promoted root system development. This is a good indicator of corn aboveground growth and high yield. Average spring corn yield increased by 66.0%—100.0% under plastic film mulch in high mountain region; and 26.0% in the plain and dam region (Table 3).

Table 2 Root system characteristics of corn under different mulching practices on loess plateau

	Shaanxi Heyang (21May 1996)			ShaanxiQianyang (17Jun.1996)			Shaanxi Changwu (7Jun.1996)		
	Root number	Root zone diameter (cm)	Root weight (g/plant)	Root number	Root zone diameter (cm)	Root weight (g/plant)	Root number	Root zone diameter (cm)	Root weight (g/plant)
Plastic film	9.0±0.6	7.1±0.4	0.43±0.03	22.7±1.4	23.4±0.5	6.45±0.3	31.4±1.1	21.7±0.8	9.1±0.7
Plastic+straw	11±0.7.	8.0±0.3	0.50±0.02	27.3±1.1	26.4±0.8	7.32±0.5	34.2±1.4	22.4±0.5	10.2±0.5
Corn straw	7.3±0.3	6.0±0.3	0.37±0.04	18.3±0.5	20.3±0.3	5.10±0.2	28.3±0.7	17.1±0.3	8.1±0.4
No-mulch	6.6±0.2	5.4±0.2	0.33±0.06	16.3±0.3	18.8±0.7	4.61±0.2	25.1±0.6	15.2±0.3	7.3±0.2
Mean	8.4	6.6	0.41	21.2	22.2	5.87	29.8	19.1	8.7
l.s.d. (*P*=0.05)	0.56	0.53	0.03	1.3	1.2	0.28	1.7	0.9	0.33
l.s.d. (*P*=0.01)	0.93	0.78	0.05	2.0	2.7	0.33	2.5	2.1	0.45

l.s.d.（*P*=0.05）means the minimum significant difference value at *p*=0.01;

l.s.d.（*P*=0.01）means the minimum significant difference value at *p*=0.05.

Table 3 Effects of plastic film mulch on Grain yield of winter wheat on loess plateau （kg/ha）

	Shanxi Changwu	Ningxia Guyuan	Shanxi Yongshou	Shanxi Huangnong	Shanxi Fangshan	Average
Plastic film	4,160±36	4,238±28	3,255±24	3,398±29	2,723±19	3,554±38
No-plastic film	3,557±20	3,293±16	2,265±21	2,265±23	2,168±15	2,709±27
Increase(%)	17±0.6	29±1.1	44±1.3	50±2.6	26±1.5	33±1.2
Mean	3,858	3,766	2,760	2,832	2,446	3,131
l.s.d.（*P*=0.05）	345	325	283	246	216	213
l.s.d.（*P*=0.01）	450	468	395	368	303	337

Note: the data at Shanxi Changwu were obtained in 1997-1999, and others in 1996.
l.s.d.（*P*=0.05）means the minimum significant difference value at p=0.01;
l.s.d.（*P*=0.01）means the minimum significant difference value at p=0.05.

4 Prospect for the development of cropland mulch on loess plateau

Straw mulch has the function of improving soil fertility, increasing soil organic matter accumulation and organic phosphorus content and improving soil physical properties following long term application in loess plateau. At present, it is used mainly in vegetable, flower, and tree seedling production. With the development of farm machine, it will become a major kind of mulch method in cropland system in north China, especially on loess plateau.

The use of plastic film mulch began during the late 1970's and early 1980's in northern China, and played very important roles in the production of corn, cotton, rice, peanuts, tobacco, potato, sweet potato, and vegetable production. The land area under plastic film is increasing. But, there are obviously differences in water conservation and yield among different mulch methods. There is still need to conduct more research on how to efficiently use plastic mulch for different crops in different regions of loess plateau. As the plastic industry developed, hyper-thin, high-intensity, low-cost plastic, and special plastic use machine and photolysis plastic film have appeared. Therefore, plastic film mulch will have expansive use prospect in flat cropland areas of loess plateau.

Biological mulch is a widely used mulching method to improve ecosystem, not only on loess plateau, but also in other regions. To rehabilitate the slope farmlands through tree/shrub/grass planting, the Chinese government is rebuilding nice plateau with green mountain and clears water, all using the functions of biological mulch. The next 10 years will be a critical period for land use change in the loess plateau. The Chinese Government has decided to launch the National Program for Development in the West, aiming at improving the degrading ecosystem and improving infrastructure. Loess plateau is one of the key areas for ecosystem improvement. There will be a very sharp policy implication on the land use pattern. The general policy for the ecosystem restoration is to encourage farmers to rehabilitate the slope farmlands through tree/shrub/grass planting. The strong political intervention and huge investment on the ecosystem restoration will have the biggest influence ever on the land use and land cover change in loess plateau area.

Soil mulch is a kind of traditional practice in semi-arid area of loess plateau. Because of its low input and easy operation, it is still used by farmers during fallow period in large area. In the semi-arid area of the loess plateau, farmers should, according to crop requirement and seasonal changes in soil moisture, adopt certain soil tillage method and soil mulch layer to store rainfall, reduce soil moisture evaporation and prevent runoff. As economic conditions improve and tillage machine's develops, crop residue mulch will replace soil mulch method.

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