Effects of Different Tillage Practices on Photosynthetic Characteristics of Crops in the Loess Plateau

Ruiqing Zhang¹,², *, Mingde Hao², *

¹ShaanXi Land Construction Group, Shaanxi construction land engineering institute of technology, Key Laboratory of Degraded and Unused Land Consolidation Engineering, the Ministry of natural Resources of China, Shaanxi Provincial Land Consolidation Engineering Technology Research Center, Xi'an 710075, China
²Institute of Resources and Environment, Northwest A&F University, Yangling 712100, China

*Corresponding author e-mail: mdhao@ms.iswc.ac.cn, *78666975@qq.com

Abstract. This thesis bases on traditional farming and no-till covering different measures as the research object, analyzes on crop photosynthetic physiological indexes, the results are as follows: With the period of growth, leaf net photosynthetic rate of each process has a rising trend from high to low. Tasseling stage has the most obvious the phenomenon. Under the traditional tillage condition, plastic film mulching with the straw mulching has the highest net photosynthetic rate. The straw mulching is the lowest. Under no-till conditions, the highest net photosynthetic rate of plastic film mulching on average is 33.81 (including mol/(m², s). It is 3.7% higher than no cover. Under different tillage coverage measures condition, the leaf transpiration rate shows that tasseling stage is higher than jointing stage of ratooning buds. Jointing stage of ratooning buds is higher than huge bellbottom period. Huge bellbottom period is higher than seedling. Seedling is higher than mature period. In seedling stage, spring maize stomatal conductance is lower. Tasseling stage to achieve the highest. Under traditional tillage condition, the mulch with straw mulching maintains a higher average stomatal conductance 260.63 parts per million. It is 46.0% higher on average than uncovered; under no-till conditions, plastic film mulching has the highest transpiration rate of, and straw mulching is the lowest.

1. Introduction

The Loess Plateau is the most important dry farming area in China. It is a typical rain-fed area with serious soil erosion. It is an important factor causing low and unstable crop yields. Covering tillage technology is an effective means to protect and manage soil in arid, semi-arid and semi-humid drought-prone areas, and it is also a change of traditional farming system. This technology can regulate the "water, fertilizer, gas and heat" of farmland soil, change the physical and chemical properties and environmental quality of soil in arid areas, and achieve stable and high yield through different tillage and mulching measures [1-3]. Therefore, the implementation of this technology in the Dryland of the Loess Plateau is of vital importance to the sustainable development of agriculture in the region.
Implementing different tillage and mulching measures in this area is conducive to improving water use efficiency and crop yield. More than 90% of crop yield comes from photosynthesis, especially in late growth stage, the contribution of photosynthetic products from functional leaves to grains can reach more than 80%. Therefore, people attach great importance to improving the photosynthetic physiological process of crops and regulating the photosynthetic efficiency of leaves [4]. Straw mulching can increase soil nutrients, improve soil structure and physical properties, and long-term straw returning can increase the content of soil humus, enhance soil water storage and moisture conservation, and regulate soil temperature [5]. As no-tillage mulching and subsoiling mulching improved soil water storage and storage capacity, the net photosynthetic rates of no-tillage mulching and subsoiling mulching were 14.7% and 28.6% higher than that of traditional tillage in the middle and later stages of grouting respectively [6]. In Longkou, Shandong Province, four tillage methods were adopted for wheat, namely, traditional tillage straw returning, rotary tillage straw returning, notched disc raking and no-tillage straw covering. The results showed that the photosynthetic rate (Pn) of flag leaf in traditional tillage mode after anthesis was higher than that in rotary tillage mode and narrow tillage mode, but the senescence of flag leaf in the two modes was later than that in conventional tillage mode, and the higher chlorophyll content, actual photochemistry efficiency, maximum photochemistry efficiency, photochemistry quenching coefficient, effective photosynthetic time and photosynthetic time of leaves were maintained at the end of grain filling. Photosynthetic function lasted for a long time, which was more conducive to grain filling. Li Yongping [7] et al. (2009) conducted experiments in Ningxia with five treatments: ridging and mulching, ridging and non-mulching, straw mulching, ridge-free mulching and conventional tillage. The results showed that the net photosynthetic rate, transpiration rate and chlorophyll content of leaves planted on ridging and film-mulching side were 9.77%, 16.21% and 16.95% higher than those of the control (conventional tillage), respectively.

This experiment studied the effects of different mulching tillage measures on Photosynthetic Characteristics of Spring Maize in order to provide theoretical basis for water and fertilizer regulation and efficient utilization of precipitation resources in this area.

2. Materials and Methods

2.1. General situation of test area
The experimental area is located in Changwu Agroecology Test Station at the junction of Shaanxi and Gansu, with an elevation of 1200 meters. The soil is black loess and the parent material is deep loam Malan loess. It belongs to the Loess Plateau area. The climate in this area belongs to the warm temperate zone semi-humid continental monsoon climate. The accumulated temperature is 3 029°C (≥ 10°C), frost-free period is 171 days, annual average precipitation is 580 m, average temperature is 9.1°C, groundwater level is 50-80 m, light, and temperature and heat are abundant. It belongs to the typical Rain-fed Agricultural area. The distribution of rainfall is uneven, mostly concentrated in July-September. The precipitation during spring sowing is very little, and the growth of crops. Water demand during growth period is not consistent, spring drought often occurs, which has a great impact on crop yield (Yang Xiao 2009).

2.2. Experimental design
Crops are mainly wheat and maize which are ripe once a year. The long-term positioning experiment started in 2004 with 10 treatments. In 2011, the rainfall during maize growth period was 484 mm. The sowing time was April 20, 2011. The plot area was 7m*5m=35 m². The plot was designed by random block design. Three times of repetition, wide row planting 60 cm wide row planting and 30 cm narrow row planting. The tested maize varieties were “Jinsai 6850”. The pure N 150 kg/hm² and P₂O₅ 90 kg/hm² were applied uniformly. Nitrogen fertilizer uses urea, containing 46% nitrogen, phosphorus fertilizer uses calcium superphosphate, containing 16% P₂O₅. Sprinkle into the soil before planting (Wang Bianjun 2011). The experimental design is shown in Table 2-1.
Table 1. The design of experiment of spring maize with different coverage under conservational

| Treatment                      | Design of experiment                                                                 |
|--------------------------------|---------------------------------------------------------------------------------------|
| Traditional tillage (CT)       | During the whole growth period, no mulching was carried out, tillage was carried out before Spring Maize sowing, and after tillage, the tillage depth was 20 cm |
| Traditional tillage+plastic film mulching (CP) | Before sowing, plough the soil, cover it with plastic film according to certain size, drill holes in the film and sow it, without straw mulching during the whole growth period |
| Traditional tillage+straw mulching (CS) | After corn harvest, straw was evenly placed between ridges and covered during the winter fallow. When spring corn was sown, straw was taken out and evenly covered in the closure after sowing |
| Traditional tillage+plastic film mulching + straw mulching (CPS) | Before sowing, plough the soil, lay plastic film, drill holes on the film and sow. After sowing, lay the last year's straw among the rows, covering the whole period |
| No-till (NT)                   | No tillage before sowing, sowing with no-tillage seeder, no covering after sowing      |
| No-till+ plastic film mulching (NTP) | Before sowing, no tillage, direct mulching, drilling holes in the film planting        |
| No-till+ straw mulching (NTS)  | No tillage before sowing, sowing with no-tillage seeder, and covering straw in the middle of ridges at the end of planting |
| No-till+ straw mulching+ plastic film mulching (NTPS) | Before sowing, no tillage was carried out, mulching the plastic film directly, drilling and sowing on the film, and evenly laying straw + straw between the film and the film after sowing |

2.3. Analytical determination method
The photosynthetic parameters and physiological indexes of functional leaves were measured at different growth stages of three leaves treated with different treatments. The net photosynthetic parameters of corn cob clover were measured by CID-340 portable photosynthetic analyzer. The main measuring periods were seedling stage, jointing stage, trumpet mouth stage, heading stage, milk maturity stage and maturity stage. The representative maize plants with uniform growth were selected and listed. The photosynthetic rate of maize functional leaves was measured from 9:00 to 11:00 in the morning. The main physiological indicators were net photosynthetic rate $P_n$ (μmol·m$^{-2}$·s$^{-1}$), stomatal conductance $G_s$ (ppm) and transpiration rate $T_r$ (mmol·m$^{-2}$·s$^{-1}$) of corn cob clover.

3. Results and analysis
Maize is a light-loving C4 crop. The light saturation point is much higher than other crops. Light is the source driving photosynthesis. CO$_2$ is the raw material. Photosynthesis of leaves is the basis of yield formation. Under different tillage and mulching measures, photosynthesis of maize varies significantly. With the development of growth period, photosynthesis rate fluctuates.

3.1. Effects of Different Tillage and Covering Measures on Net Photosynthetic Rate ($P_n$) of Spring Maize Leaves
With the development of growth period, the net photosynthetic rate of spring maize leaves under different tillage and mulching measures showed a trend of first rising and then falling (Fig. 2-1), and there were two peaks at jointing stage and heading stage, respectively, while the maturity stage was the lowest.

Under traditional tillage conditions, the net photosynthetic rate of all mulching treatments was the highest at heading stage, ranging from 35.30μmol/(m$^2$·s)-44.26μmol/(m$^2$·s), while that of Mulching with plastic film and straw was between 14.20μmol/(m$^2$·s)-44.26μmol/(m$^2$·s), which was 14.5%-20.7%, 6.8%-14.5% and 14.3%-22.5% higher than that of no mulching, plastic film mulching and straw mulching, respectively. The net photosynthetic rate of straw mulching was the lowest in all growth stages. From seedling stage to maturity stage, net photosynthetic rate of different mulching
measures fluctuated and increased, the first wave peak appeared at jointing stage, the second wave peak appeared at heading stage, and the ripening stage reached the trough. This may be due to the fact that maize at jointing stage and heading stage is the key period of maize growth, and its physiological functions are relatively active, preparing for maize reproductive growth, so it has a higher net. Photosynthetic rate. At maturity stage, the leaves of maize show senescence, which leads to lower net photosynthetic rate.

Under no-tillage conditions, the net photosynthetic rate of Maize under different mulching measures was basically the same as that under traditional tillage. The net photosynthetic rate fluctuated with the postponement of growth period, the maximum at heading stage, the second at jointing stage and the smallest at maturity stage. The net photosynthetic rate of plastic film mulching was 1.6%-9.8%, 8.9%-13.5% and 4.9%-13.3% higher than that of no mulching, straw mulching and plastic film plus straw mulching, respectively.

Under the same mulching measure, the net photosynthetic rate of leaves under no-mulching tillage was 7.3%-12.7% higher than that under traditional tillage; under plastic film mulching measure, the net photosynthetic rate of leaves under no-tillage was 3.7%-12.5% higher than that under traditional tillage; under straw mulching measure, the net photosynthetic rate of leaves under no-tillage was 2.6%-10.6% higher than that under traditional tillage; under plastic film plus straw mulching measure, the net photosynthetic rate of leaves under no-tillage was 8.0%-15.3% lower than that under traditional tillage. The net photosynthetic rate of leaves under straw mulching is relatively low, which may be due to less rain and lower temperature in spring. Straw mulching makes the ground temperature rise slower, which affects the growth of maize and reduces net photosynthetic rate.

Figure 1. Different cultivation and mulching measures the impact of the different growth stages of spring maize leaf net photosynthetic rate

3.2. Effects of different tillage and Mulching Measures on leaf transpiration rate (Tr) of Spring Maize

From Figure 2-2, it can be seen that the leaf transpiration rate of spring maize under different tillage and mulching measures showed a fluctuating trend of first rising and then falling with the development of growth period, similar to the overall change trend of net photosynthetic rate, there were two peaks, peaking at heading stage and lowest at maturity stage.

Under traditional tillage conditions, the transpiration rates of leaves in different growth stages of mulching treatments were as follows: male-drawing stage > jointing stage > big trumpet mouth stage>milk ripening stage>seedling stage>mature stage. The transpiration rates of Mulching with plastic film and straw were 4.5%-20.7%, 6.8%-14.5% and 14.3%-22.5% higher than those of other treatments during the whole growth period, respectively. The transpiration rates of maize leaves in stage I and stage II were 6.54, 5.80 and 7.64 mmol/(m²*s), respectively. The transpiration rates of all mulching measures were as follows: plastic film plus straw>plastic film>no mulching>straw mulching, which was consistent with the conclusion of net photosynthetic rate of maize.
Under no-tillage conditions, the transpiration rates of leaves in different growth stages of mulching treatments were as follows: heading stage > jointing stage > big trumpet mouth stage > milk ripening stage > seedling stage > mature stage. During the whole growth period, the transpiration rates of plastic film mulching were superior to those of other treatments, which were 0.9%-33.2%, 618.3%-55.9% and 20.1%-56.1% higher than that of no-mulching, straw mulching and plastic film plus straw mulching, respectively. The transpiration rates of maize leaves at heading stage were 6.06, 3.83 and 6.62 mmol/(m²•s), respectively. The transpiration rates of all mulching modes were as follows: plastic film > no mulching > Plastic Film plus straw > straw mulching, which was consistent with the conclusion of net photosynthetic rate of maize.

Figure 2. Different cultivation and mulching measures the impact of the different growth stages of spring maize leaf transpiration rate

3.3. Effects of different tillage and Mulching Measures on stomatal conductance (Gs) of spring maize leaves

Leaf stomatal conductance is related to plant photosynthesis and transpiration, and is an important factor determining plant photosynthetic and water transpiration intensity (Warren and Dreyer 2008). Its size is related to net photosynthetic rate and CO₂ concentration (Bernacchi et al. 2007; Warren 2008; Buck-ley 2008). The stomatal conductance of spring maize leaves under different tillage and mulching measures was lower at seedling stage, then increased gradually, reached the highest at heading stage, and then decreased gradually (Fig. 2-3).

Under traditional tillage conditions, the stomatal conductance of leaves covered with plastic film and straw was the highest at different growth stages, and the difference between them was not significant at jointing stage. The bell mouth stage was the second stage, and the maturity stage was the lowest. During the whole growth period, the stomatal conductance of leaves covered with plastic film and straw was superior to that of other treatments, and maintained a higher stomatal conductance, 39.1% to 54.1% higher than that of leaves covered with no mulch, plastic film mulch and straw mulch, respectively. 8%, 10.3% - 40.6% and 41.6% - 57.2%. The stomatal conductance of maize leaves at jointing stage, bell mouth stage and heading stage were 320.62, 246.72 and 390.01 ppm, respectively. The stomatal conductance of each covering mode was as follows: plastic film plus straw > plastic film > no mulching > straw mulching.

Under no-tillage conditions, the stomatal conductance of leaves covered with plastic film was the highest in different growth stages, and there was no significant difference between them at jointing stage and heading stage. The stomatal conductance of leaves covered with plastic film was the lowest in maturity stage. During the whole growth period, the stomatal conductance of leaves covered with plastic film was superior to that of other treatments and maintained a better stomatal conductance, which was 1.1%-11.4%, 21% higher than that of no-mulching, straw mulching and plastic film plus straw mulching, respectively. 2%-33.0% and 9.3%-26.2%. The stomatal conductance of maize leaves at jointing stage, bell mouth stage and heading stage were 313.59, 217.27 and 388.92 ppm,
respectively. The stomatal conductance of maize leaves under different mulching modes was as follows: plastic film > no mulching > Plastic Film plus straw > straw mulching, which was consistent with the conclusion of net photosynthetic rate and transpiration rate of maize.

![Figure 3. Different cultivation and mulching measures the impact of the different growth stages of spring maize leaf stomatal conductance](image)

4. Conclusion

(1) The net photosynthetic rate of leaves of all treatments increased first and then decreased with the growth period. It was the largest at the heading stage. Under traditional tillage conditions, the net photosynthetic rate of plastic film plus straw mulch was the highest, and the net photosynthetic rate of straw mulch was the lowest. Under no-tillage conditions, the maximum net photosynthetic rate of plastic film mulch was 33.81µmol/(m²•s), which was 3.7% higher than that of no-mulch.

(2) Under different tillage and mulching measures, the transpiration rate of leaves was at the stage of tasseling > jointing > trumpet mouth > milky stage > seedling stage > mature stage.

(3) The stomatal conductance of spring maize was lower at seedling stage and highest at heading stage. Under traditional tillage conditions, the stomatal conductance of spring maize under plastic film and straw mulching was 260.63 ppm on average, 46.0% higher than that without mulching. Under no-tillage conditions, the stomatal conductance of plastic film mulching was the highest, while that of straw mulching was the lowest.

References

[1] Li Wuqiang, Wen Xiaoxia, Gao Maosheng, Xiong Xiaorui. 2008. Study on Water and Physiological Effects of Ridge-ridging, Film-mulching and Ditch-sowing Wheat in Semi-humid Area. Journal of Northwest Agriculture, 17 (5): 146-151.

[2] Zhang Dong Mei. 2007. Effects of mulching tillage on soil environment and maize growth. [M]. Taiyuan: Shanxi University.

[3] Zhang Baolin, Chen Fu. 2005. Study on Soil Water Availability of Mulched Farmland in Dry Plateau of Western Shanxi Province. acta agriculturae boreali-sinica, 20 (3): 57-61.

[4] Hu Tingji, Yang Yongguang, Ma Yuanxi. 1986. Wheat ecology and production technology. Zhengzhou: Henan Science and Technology Publishing House: 19-23.

[5] Shen Yuhu, Huang Xiangguo, Wang Haiqing. 1998. The farmland effect of straw mulching. Agricultural research in arid areas, 16 (1): 45-50.

[6] Li Youjun, Wu Jinzhi, Huang Ming, Yao Yuqing, Zhang Canjun, Cai Dianxiong, Jinke. 2006. Effects of different tillage methods on Photosynthetic Characteristics and water use efficiency of wheat flag leaves. Journal of Agricultural Engineering, 22 (12): 44-48.

[7] Li Yongping, Yang Jianhe, Feng Yongzhong, Kang Jianhong and Wu Hongliang. 2009. Effect of ridging and mulching on water harvesting of Maize in wind erosion area of Loess Plateau. Journal of Agricultural Engineering, 25 (4): 66-69.