Influence of Transplantation in Different Stage on Growth and Yield of Spring Maize in Shanxi Early Mature Area

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Abstract In order to explore a new mulch-free maize planting mode and the best seedling age for maize transplantation in Shanxi early mature area, a field experiment was carried out using completely randomized block design. Taking mulch-based direct sowing as the control group, effects of transplantation in different stage on maize growing process, plant height, three-ear leaf area in mature period, and yield and composition factors of maize were studied. Results indicate that growing process of maize seedlings transplanted in every stage is slightly slower than the control group. Transplantation has effect of reducing plant height and three-ear leaf area in mature period. There was no significant difference between the yield of maize transplanted on May 1st and the control group, and the yield declined only by 7% compared with mulch-based direct sowing (CK). Damages to maize seedlings by the local late frost must be noticed when maize is planted by the method of mulch-free transplantation in early mature area. Transplanting the seedlings earlier after the late frost is deemed as an appropriate period in this area.

Key words Spring maize, Seedling transplantation, Transplantation period, Yield

1 Introduction

In Shanxi early mature area, drought and frost disasters are of frequent occurrence. Thus, maize production in this area can not do without plastic mulch. Plastic mulch can improve soil moisture and heat situation[1-2], increase water utilization efficiency[3-4], and coordinate the relation between soil nutrients and moisture. However, because PVC mulch film is difficult to degrade, accumulation of residual mulch film in soil has resulted in white pollution of soil and ecological environment[5-6]. In comparison, seedling transplantation is an effective agricultural technical measure for realizing drought resistance, low temperature resistance, and increasing per unit area yield of maize. This technology is widely applied in rice, fruit and melon cultivation, but there are very limited researches on application of maize production in low temperature and dryland areas[7]. In this situation, we studied mulch-free maize planting mode in Shanxi early mature area with the aid of this technology. Existing researches about maize transplantation period indicate that suitable transplantation period is a guarantee for high survival rate of transplantation and free from frost damage. Suitable transplantation is determined by cold resistance of seedlings and the time of getting warm after a cold spell. Through exploring the optimal transplantation period of maize cultivated by nutrition solution in Heilongjiang Province, Huo Zhaofa *et al.*[8] determined that the suitable maize transplantation period is the period when the lowest air temperature passes 0℃. When exploring the influence of different seedling transplantation period on maize yield in Bijie of Guizhou Province, Ruan Peijun found that[9] the optimal seedling period is from the middle of March to the middle of April, and during this period the earlier, the better. In the beginning of March, it is not safe because transplantation of seedlings is vulnerable to frost damage. Researches of Xie Dairong *et al.*[10] show that seedling and transplantation period not only concerns whether the transplantation can be successful and affect maize growth and yield, but also exerts great influence on maize quality. However, there is still no research report about equivalent ecological conditions for Shanxi early mature area. Therefore, we studied the optimal transplantation period according to climatic characteristics such as frost and drought of Shanxi early mature area, to promote consolidation and development of seedling breeding and transplantation technologies.

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2 Materials and methods

2.1 Experiment time and place The experiment was carried out in the Demonstration Base of Agricultural Integrated Water Conservation Research Supported by National Eleventh Five-Year Plan in Hecun Village, Yangqu County of Shanxi Province in 2013. This area is situated in central Shanxi Province and has typical semi-arid climate. Its geographical coordinate is 112.9°E, 38.0°N and has altitude of 1248.5 m. The average temperature in January is -10.3 ℃, and the average temperature in July is 20.2 ℃. Besides, its frost-free period is 143.9 days, and accumulated temperature ≥10 ℃ is 2840.6 ℃ (80% guarantee rate); annual precipitation is 459.0 mm, mainly concentrated in June to September (accounting for 73.7% of precipitation of the whole year), and the annual average evaporation is 1546.9 mm. Drought and insufficient accumulated temperature are major factors restricting agricultural production of this area. The soil in this area is light cinnamon soil and the nutrient content of 0 - 20 cm soil is 14.32 g/kg organic matter, 0.81 g/kg total nitrogen, 49.22mg/kg alkali-hydrolyzable nitrogen, 124.66 mg/kg rapidly available potassium, and 6.52 mg/kg rapidly available potassium phosphorus.

2.2 Experimental materials and design We took maize variety KWS3376 as the experiment crop. We took mulch-based direct sowing as the control group, set 3 outdoor seedling breeding stages

(April 25, May 1, and May 7) and repeated three times. Breeding of seedlings in every period were carried out in a paper drum (4 cm diameter and 6 cm height) in small greenhouse in advance. Seedlings were transplanted to field when they grew to two-leaf period. Breeding matrix adopted vegetable garden soil and biological organic fertilizer (number of living bacteria $\geqslant 0.2 \times 10^9$ and per gram organic matter $\geqslant 25\%$) mixed in 2∶1 ratio. The block area is 14.4 m^2 (4 m long and 3.6 m wide). The field planting density of 4 treatments is 60 cm for row spacing and 25 cm for plant spacing and water and fertilizer management and plant diseases and insect pests control are consistent with each other.

2.3 Survey and measurement items We observed and made a record of the whole seedling stage, heading stage, and silking stage, and measured the plant height on June 5 and July 20 separately. We employed the length/width coefficient method to measure the three-ear leaf area in mature period (length of leaf midvein × max width of leaf × 0.7). Before harvesting, we selected typical 10 maize ears with uniform growth, and measured ear length, thickness, bald ear length, and ear weight. Finally, we harvested each block separately and measured the actual yield.

2.4 Data analysis Experimental data were processed with the aid of Excel and SPSS software.

3 Results and analyses

Table 1 Influence of different transplantation periods on maize growing process

Experiment treatment	Sowing	Sprouting	Heading stage	Silking stage	Harvesting stage
Mulch-based direct sowing	5.01	5.10	7.06	7.11	10.10
Transplanted on April 25	4.03	4.10	7.08	7.13	10.10
Transplanted on May 1	4.10	4.16	7.11	7.15	10.10
Transplanted on May 7	4.16	4.22	7.13	7.18	10.10

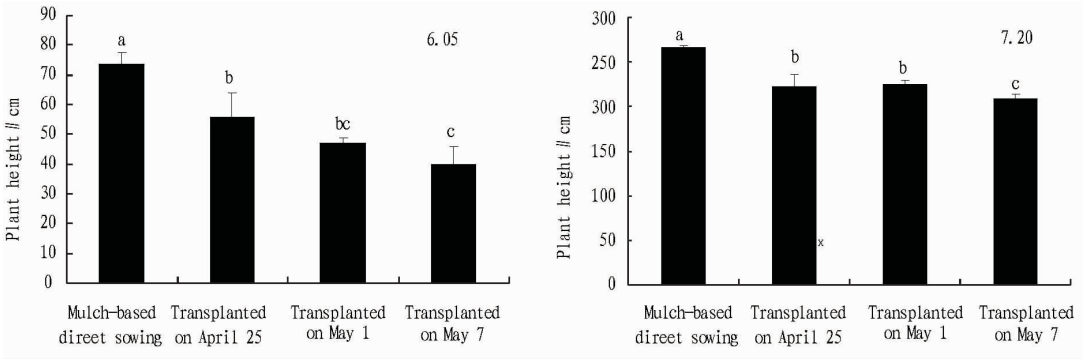

Fig. 1 Influence of different transplantation periods on maize plant height

3.1 Influence of different transplantation period on maize growing process Different transplantation period exerts direct influence on maize growing process (as shown in Table 1). Although the sprouting time of mulch-based direct sowing is obviously later than transplanted maize, the growing process is slightly faster than transplanted maize, and the time for entering heading stage and silking stage is 2 – 8 days ahead of transplanted maize. As for transplantation in different period, the growing process of maize seedling transplanted on April 25 is the fastest, followed by May 1, and the slowest is May 7. This indicates that earlier transplantation period brings faster growing process, possibly because when in earlier transplantation period, the root system suffers little damage, the symptom of recovery of seedlings becomes lighter, seedlings will adapt to new soil environment in a faster way and show faster growing and development process. Nevertheless, it should be noted that the earlier transplantation period does not necessarily bring better growing process. For example, in this experiment, maize seedlings transplanted in the earliest period (April 25) presented frost symptom in the next day after transplantation. Therefore, when determining optimal transplantation period, it is required to consider maize growth and yield, and also consider possible risks.

3.2 Influence of different transplantation period on maize plant height From Fig. 1, no matter in seedling period or heading and silking stage, the maize plant height is the highest in mulch-based direct sowing, followed by April 25 and May 1 (no significant difference), and the lowest is maize seedlings transplanted on May 7. With postponement of the transplantation period, the maize plant height in seedling stage and heading and silking stage gradually declines. This is possibly because postponement of transplantation period relatively shortens the recovery period of damaged root system, and the root system misses the optimal recovery period, leading to bad growth of aboveground parts. In sum, transplantation obviously reduces the maize plant height.

3.3 Influence of different transplantation period on the three-ear leaf area in mature period From measurement results of the three-ear leaf area in mature period (Fig. 2), it can be known that the three-ear leaf area of mulch-based direct sowing is significantly larger than those transplanted in every transplantation period. Besides, there is no significant difference in three-ear

leaf area in mature period of maize transplanted in different transplantation periods. The photosynthesis is the strongest in three-ear leaf. In the same time, the photosynthesis products will be the most and will be delivered to maize ears nearby, so the formation role of economic yield will be the largest. Therefore, the three-ear leaf plays a great role in promoting growth and yield formation of female ears. Significant reduction of three-ear leaf area due to transplantation may be one of reasons for decline in yield.

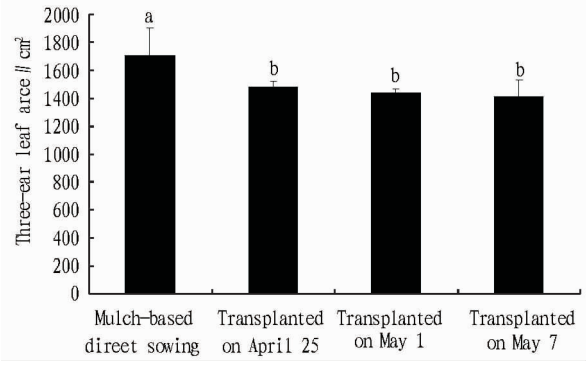

Fig. 2 Influence of different transplantation periods on the three-ear leaf area in mature period

3.4 Influence of different transplantation period on traits of maize ear From Table 2, it can be seen that the maize grain yield is highest in mulch-based direct sowing (CK), followed by maize transplanted on May 1 with yield reduction only 7% compared with the control group. The maize transplanted on May 7 has the lowest yield, reducing about 22.9% and 17.1% respectively, compared with the control group and maize transplanted on May 1. It indicates that transplantation period exerts significant influence on the maize yield. In terms of the yield components, there is no big difference between the total number of ears of maize transplanted in each transplantation period and its yield. The thickness of ears of transplanted maize is greatly lower than mulch-based direct sowing, while there is no significant difference between hundred grain weight and bald ear length among each treatment. This indicates that transplantation reduces the maize yield mainly through reducing number of ears. Results of the yield of maize transplanted in different period reflect that maize transplanted slightly earlier (on April 25) and later (on May 7) have yields lower than the maize transplanted on May 1. In Shanxi early mature area, from May 1, the temperature at 5cm topsoil can basically remain at 10℃. Transplantation in this period can prevent maize seedlings from frost damage, and it is favorable for recovery of injured root system. Thus, maize transplanted in this period has higher yield, and this period can be deemed as optimal transplantation period.

Table 2 Influence of transplantation period on the maize yield and the yield components

Experiment treatment	Ear length cm	Ear thickness cm	Bald ear length//cm	Number of ears	Hundred grain weight//g	Actual yield kg/ha
Mulch based direct sowing	16.9 ±0.2 ab	4.6 ±0.1 a	0.6 ±0.1 a	530 ±12 ab	33.7 ±1.3 a	11994.3 ±340.5 a
Transplanted on April 25	16.2 ±0.4 a	4.9 ±0.0 b	0.8 ±0.3 a	495 ±16 bc	32.6 ±1.2 a	9942.6 ±271.6 bc
Transplanted on May 1	17.2 ±0.5 b	4.5 ±0.1 c	0.7 ±0.2 a	537 ±26 a	33.5 ±2.6 a	11154.9 ±1019.1 ab
Transplanted on May 7	16.1 ±0.5 a	4.4 ±0.1 c	0.9 ±0.2 a	483 ±24 c	31.0 ±1.3 a	9250.1 ±753.7 c

4 Conclusions and discussions

In view of actual situations of drought, insufficient accumulated temperature and many maize varieties unsuitable for mulch-free planting in Shanxi early mature area, we explored the optimal transplantation period for mulch-free maize planting in this area. Through analyzing the difference in field traits and yield of maize transplanted in different periods, we found that maize transplanted slightly earlier (on April 25) and later (on May 7) have yields lower than the maize transplanted on May 1, with yield reducing only about 7% compared with mulch-based direct sowing (CK). Compared with mulch based direct sowing, transplanted maize can be sown in protected field in advance and realize sprouting in advance, but it is unavoidable to damage root system during transplantation, such as seedling lifting, transport, and soil burying[11]. Therefore, growing process, plant height, and yield of maize transplanted in every period in this study are not better than the mulch-based direct sowing, and there is varied difference because of different transplantation periods. Researches of Ruan Peijun *et al.*[9] indicate that the growing process of maize transplanted in different period is shortened with postponement of seedling period, and days of sprouting and heading increase with advances of seedling period. This reflects that earlier seedling transplantation in suitable period has certain role in increasing the maize yield. The experiment results show the maize yield gradually increases with advance of seedling period. In maize growth status, we also obtained results consistent with existing researches, but the results of yield are slightly different. With advance of the transplantation period, the field growth period of maize obviously extends. This is favorable for fully using the light and heat resources in Shanxi early mature area, to increase the light energy utilization efficiency. Nevertheless, it should be noted that the earlier transplantation period does not necessarily bring better growing process, and damages to maize seedlings by the local late frost must be noticed[12]. Therefore, suitable transplantation period should be as early as possible after the local frost. According to measurement results in recent 4 years, the temperature at 5cm topsoil can basically remain at 10℃ from May 1 in Shanxi early mature area. Transplantation at this time will greatly reduce the risk of frost damage. Besides, maize plant height after transplantation in different periods has slight reduction, which is consistent with findings of Zheng Wei *et al*[12] in sweet maize varieties. Transplanted maize presents reduction of three-ear leaf area in mature period. Since photosynthesis is the basis for yield formation, major position of photosynthesis happens in leaves, especially in the three-ear leaves[13]. Therefore, it is not difficult to understand why the yield of transplanted maize is lower than the control group. Although the yield of transplanted maize is slightly lower than mulch-based direct so-

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land, the terrace field changed from mountain slope has increasing soil nutrients on the whole with the length of farming. With the increase in the length of implementation of changing mountain slope into terrace field, the soil erosion intensity is reduced in the original sloping land, and meanwhile, successive years of farming and organic and inorganic fertilizer input has effectively promoted the accumulation of nutrients. The mean of various indicators about soil nutrients in the terrace field changed from mountain slope for 2 years is lower than in the sloping land, and there is the biggest difference in soil fertility, while the mean of various indicators about soil nutrients in the terrace field changed from mountain slope for 14 years shows a linear upward trend, and the difference in soil fertility decreases.

References

[1] ZHAO J, GUO HZ, CHEN JQ, *et al*. Type classification and countermeasure of soil and water loss of Three Gorges Reservoir Area[J]. Soil and Water Conservation in China,2010(1): 16 - 18. (in Chinese).

[2] LIU YS, FENG DX. Sustainable potential and models of land use in the Three Gorges Reservoir Area [J]. Geographical Research,2011(2):139 - 143. (in Chinese).

[3] FAN YF, LUO YJ, WEI CF. On level terrace engineering design of slope land in the hilly and mountainous, Southwestern China [J]. Journal of Mountain Research,2010,28(5):560 - 565. (in Chinese).

[4] WEI J, HE XB. Review of soil conservation practices on sloping farmlands in Three-Gorge Reservoir Area [J]. World Sci-tech R & D,2011, 33(1):41 - 45. (in Chinese).

[5] JIAO JY, WANG WZ. Analysis on the quality of level terrace in the Loess Plateau and the effect of soil and water conservation [J]. Transactions of the Chinese Society of Agricultural Engineering,1999,15(2):59 - 63. (in Chinese).

[6] WU FQ, ZHANG YB, SONG JL, *et al*. Current state and development trend of research on environmental effect of level terrace [J]. Journal of Soil and Water Conservation,2003,17(5):28 - 31. (in Chinese).

[7] ZHANG YT, WANG HG, LI ZY, *et al*. Soil and water conservation benefits of terracing on the slope [J]. Research of Soil and Water Conservation,2001,8(3):9 - 12. (in Chinese).

[8] XUE S, LIU GB, ZHANG C, *et al*. Effects of terracing slope cropland on soil quality in hilly region of Loess Plateau [J]. Transactions of the Chinese Society of Agricultural Engineering,2011,27(4): 310 - 316. (in Chinese).

[9] YANG M, CHEN GJ, WEI J, *et al*. Effects of different land use in terracing area on oil Nutrients: a case study of Wushan County in Chongqing [J]. Journal of Chongqing Normal University: Natural Science Edition, 2012,29(6):43 - 46. (in Chinese).

[10] LI PX, CHEN GJ, WEI J. Study on soil fertility evaluation of the typical terracing in Three Gorges Reservoir Area: a case study in Wushan County of Chongqing City [J]. Journal of Chongqing Normal University: Natural Science Edition,2013,30(6):55 - 62. (in Chinese).

[11] DONG HW, CHEN GJ, GUO Y, *et al*. Study on the evaluation of soil fertility quality of different slope years in the Three Gorges Reservoir Area [J]. Soil and Water Conservation in China,2014(6):35 - 38. (in Chinese).

[12] JIAO F, WEN ZM, CONG HJ, *et al*. Comprehensive evaluation of soil fertility abandoned cropland based on attribute recognition model [J]. Journal of Soil and Water Conservation,2010,24(5):204 - 207. (in Chinese).

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wing, this technology can realize mulch-free maize planting in Shanxi early mature area, to avoid accumulation of residual mulch films in soil, leading to white pollution of soil and ecological environment.

References

[1] WANG TH, LI YN. Effect of furrow planting winter wheat with plastic film mulching on water-use efficiency and soil temperature[J]. China Rural Water and Hydropower, 2011(1):46 - 49. (in Chinese).

[2] LI YS, WU LH, ZHAO LM, *et al*. Influence of continuous plastic film mulching on yield, water use efficiency and soil properties of rice fields under non - flooding condition[J]. Soil & Tillage Research, 2007, 93(2): 370 - 378.

[3] LI SZ, WANG Y, FAN TL, *et al*. Effects of different plastic film mulching modes on soil moisture, temperature and yield of dryland maize[J]. Scientia Agricultura Sinica, 2010, 43(5): 922 - 931. (in Chinese).

[4] BU LD, LIU JL, ZHU L, *et al*. The effects of mulching on maize growth, yield and water use in a semi - arid region[J]. Agricultural Water Management, 2013, 123: 71 - 78.

[5] HE WQ, YAN CR, LIU S, *et al*. The use of plastic mulch film in typical cotton planting regions and the associated environmental pollution[J]. Journal of Agro-Environment Science, 2009, 28(8): 1618 - 1622. (in Chinese).

[6] YANG YJ, HUANG ZB, YAN YM, *et al*. Effects on temperature and moisture of soil and seeding of maize to biodegradable film coverage[J]. Journal of Agro-Environment Science, 2010, 29(B03): 10 - 14. (in Chinese).

[7] GUO JP, WANG CY, MA SQ, *et al*. Experimental study on defending corn from cold injury and spring drought by growing and transplanting seedlings [J]. Journal of Natural Disasters,2003,12(1): 116 - 120. (in Chinese).

[8] HUO ZY, HE P, HU XH. On the variety selection of nutrient solution seedling transplantation maize and the determination of its transplanting time [J]. Journal of Maize Sciences,1996, 4(1):59 - 62. (in Chinese).

[9] RUAN PJ. The effect of different rearing periods and transplanting in different leaf ages on the yield of maize[J]. Tillage and Cultivation,1993(1):35 - 38. (in Chinese).

[10] XIE DR, LIANG XJ. Study on the influence of different transplanting period on hybrid maize[J]. Modern Agricultural Science and Technology,2010 (14):45 - 48. (in Chinese).

[11] YAN GB, WANG WC, LI YL. Study on seedling transplantation technology of maize paper pot Ⅱ[J]. Jilin Agricultural Sciences,2001, 26(1): 28 - 32. (in Chinese).

[12] WANG YQ. Study on transplanting date of mulched maize in the nonirrigated farmland in Xining area[J]. Agricultural Research in the Arid Areas, 2002,20(1): 22 - 25. (in Chinese).

[13] ZHENG W, YANG HS, WANG GJ, *et al*. Effects of plastic covering and cultivation by setting seedling on growth and yield of sweet corn[J]. Journal of Inner Mongolia University for the Nationalities(Natural Sciences), 2007,22(4):401 - 403. (in Chinese).

[14] CHEN L, CUI SP, SUN YB. Analysis on the gene effect of the ear traits of maize[J]. Acta Agriculturae Boreali - Sinica,1996,11(2):28 - 32. (in Chinese).