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Effect of Transplantation in Different Seedling Age 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 seedling age on maize growing process, plant height, yield and composition factors of maize were analyzed. Results indicate that growing process of maize seedlings transplanted in different seedling age is slightly slower than the control group. Transplantation has the effect of reducing plant height. Although the yield of transplanted maize in different seedling age is lower than the control group. Besides, with the growth of seedling age of transplantation, the gap is widening. However, it is expected to realize mulch-free maize planting by transplantation in Shanxi early mature area. The yield of maize transplanted in two-leaf seedling age is not significantly different from the control group, and the yield is only 9% lower than the mulch-based direct sowing (CK). In conclusion, two-leaf period is the best seedling transplantation age for maize in Shanxi early mature area in this experiment condition.

Key words Spring maize, Seedling age, Transplantation, Yield

1 Introduction

Drought and low temperature are the main agricultural meteorological disasters for dryland maize production in Shanxi early mature area. Maize production always uses plastic mulch in this area. In comparison, seedling transplantation technology is an effective agricultural technical measure for resisting drought and low temperature, and increasing per unit area yield. Such technology is common in rice, fruit and melon cultivation, but researches on application of maize production in cold and arid areas are very limitted[1]. Therefore, it is expected to realize mulch-free maize planting in Shanxi early mature area with the aid of this technology.

Researches on transplantation period indicated that plant height, yield and mature period of transplanted maize have direct relation with the maize seedling age. If the seedling age is younger, the survival rate will be higher. However, it may not reach the purpose of extending the growing period. If seedling age is older and leaves are too large, it will be difficult for seedlings to survive the transplantation, and too short period from transplantation period to ear differentiation period will significantly reduce the maize yield[2]. However, the best seedling age for maize transplantation is still to be determined. Yan Guangbin *et al.*[3] determined that the best transplantation period is conical period during their studies using paper pot breeding transplantation technology, and the transplantation should be not later than the one-leaf unfolding period. Ma Lin *et al.*[4] concluded that the best maize seedling transplantation period is two-leaf or three-leaf period. If transplantation is too early, the potential for yield increase will be little and the transplantation should be not later than four-leaf period; if leaf age is old, transplantation will lead to slow recovery of transplanted seedlings, small and old seedlings, empty stalk, and affect maize ear differentiation, accordingly reduce the yield. When exploring the effects of transplantation in different seedling age of maize on maize yield, Ruan Peijun[5] found the best period is two-leaf one-bud, followed by four-leaf one-bud, and the last is six-leaf one-bud. Although it has reached a common understanding that "the older sowing age for transplantation, the higher effect on maize ear differentiation, transplantation should be carried out in two to four leaves period"[2], suitable seedling age for transplantation is varied with difference of climate and maize varieties. At present, there is still no report about areas with equivalent ecological conditions of Shanxi early mature area. Therefore, we studied the best seedling age for transplantation according to climatic characteristics such as low temperature and drought of Shanxi early mature area, to promote consolidation and development of seedling breeding and transplantation technologies.

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. Situated in central Shanxi Province, this area (with geographical coordinate of 112.9°E, 38.0°N and altitude of 1248.5 m) belongs to typical semi-arid area. 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); an-

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nual 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 low accumulated temperature are major factors restricting agricultural production of this area. The soil in this area is light cinnamon soil and 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 Bingdan 16 as experimental crops. We took mulch based direct sowing as the control group, set 3 seedling breeding stages (April 5, April 11, and April 17) and 3 repetitions. Each breeding was carried out within a small greenhouse through paper tube (4 cm diameter and 6 cm height), breeding matrix adopted vegetable garden soil and biological organic fertilizer (number of living bacteria $\geqslant 0.2 \times 10^9$ and organic matter $\geqslant$250 g /kg) mixed in 2∶1 ratio, and transplanted in open field on May first. During transplantation, seedling age is four-leaf, three-leaf, and two-leaf. Mulch based direct sowing in field was carried out May 1st. The block area is 14.4 m^2 (4.0 m long and 3.6 m wide). Planting densities (60 cm for row spacing and 25 cm for plant spacing) and water and fertilizer management and plant diseases and insect pests control of the 4 treatments are consistent with each other.

2.3 Survey and measurement items We observed and recorded whole seedling stage, heading stage, and silking stage, and measured the plant height on June 5 and July 20 separately. At the mature stage, we measured the area of three ear-leaves of maize. Before harvesting, we continuously selected typical 10 maize ears with uniform growth, and measured ear length, thickness, bald ear length, and ear weight. When harvesting, we harvested each block separately and measured the actual yield.

2.4 Data statistics and analysis We made statistics and analysis of the experimental data with the aid of Excel and SPSS software.

3 Results and analyses

3.1 Effect of transplantation in different seedling age on maize growing process From Table 1, we can see that transplantation in different seedling age had direct effect on maize growing process. For maize planted in field in the same period, although the sprouting time of mulch based direct sowing was obviously later than transplanted maize, the growing process was slightly faster than transplanted maize, and the time for entering heading stage and silking stage was 2 – 7 days ahead of transplanted maize. For transplantation in different seedling age, two-leaf transplantation brought the rapid growing process, followed by the three-leaf, and the last was four-leaf transplantation. This indicated that younger seedling age brought faster growing process possibly because when transplantation in younger seedling age, the root system suffers little damage, the symptom of recovery of seedlings becomes lighter, seedlings will suit new soil environment in a faster way and show faster growth and development process.

Table 1 Effect of transplantation in different seedling age on maize growing process

Treatment	Sowing	Sprouting	Heading stage	Silking stage	Harvesting stage
Mulch based direct sowing	05 – 01	05 – 10	07 – 13	07 – 17	10 – 08
Two-leaf transplantation	04 – 17	04 – 23	07 – 15	07 – 20	10 – 08
Three-leaf transplantation	04 – 11	04 – 18	07 – 18	07 – 22	10 – 08
Four-leaf transplantation	04 – 05	04 – 12	07 – 20	07 – 24	10 – 08

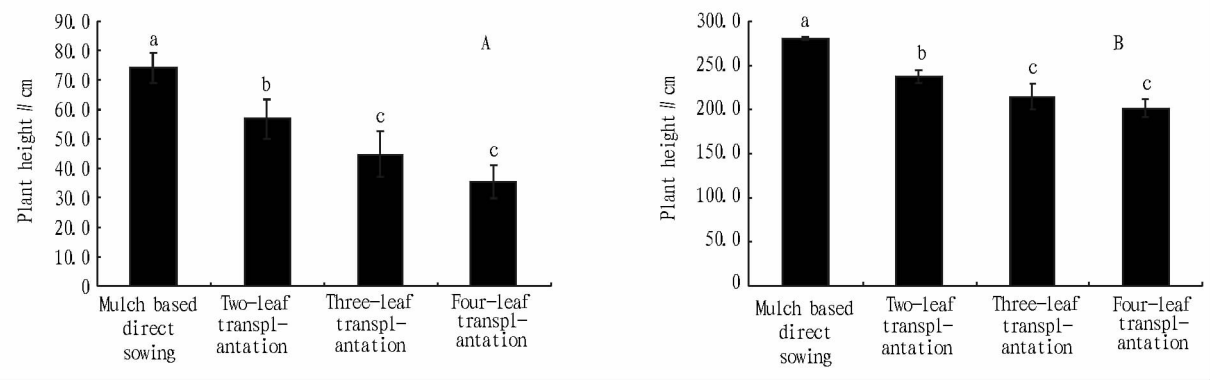
3.2 Effect of transplantation in different seedling age on maize plant height From Fig. 1, it can be seen that no matter at seedling stage, heading stage or silking stage, maize plant height of mulch based direct sowing was significantly higher than the height of transplanted maize plant, and with the rise of age of transplanted seedlings, the maize plant height at seedling stage and heading and silking stage took on decreasing trend. This indicated that if the seedling age was higher, the damage of seedlings during transplantation would be severer, which not only affects vegetative growth, but also impairs reproductive growth. In sum, maize plant height after transplantation declines greatly.

3.3 Effect of transplantation in different seedling age on traits of maize ears From Table 2, we can see that the maize yield was the highest from mulch based direct sowing, followed by two-leaf and three-leaf transplantation, reducing about 9% and 15% compared with mulch based direct sowing, the last was four-leaf transplantation, significantly lower than the mulch based direct sowing. In terms of yield composition factors, the difference between kernels per row and yield is consistent, while 100 grain weight and bald ear length were significantly lower than the mulch based direct sowing, and there was no significant difference in ear length, ear diameter and row of ear. This indicated that transplantation treatment reduced maize yield mainly through influencing kernels per row and 100 grain weight, and the effects were increasing with growing of transplanted seedling age.

4 Conclusions and discussions

In view of extreme weather such as unusual cold spell in early spring and maize-strangling drought possibly encountered by maize in Shanxi early mature area and actual situation that many maize varieties are difficult to become completely mature without covering film, it is necessary to use seedling transplantation technology to explore the best transplantation seedling age for mulch-free maize planting. Through analyzing traits and yield difference between transplanted maize and directly sowed maize, it can be found that with the growth of seedling age of transplantation, maize growth and yield take on decline trend. Especially, field traits and yield of maize transplanted in two-leaf seedling stage are relatively

ideal, with yield reduction only 9% compared with mulch based direct sowing (CK). Our study also indicates that transplantation will reduce maize plant height, which is consistent with research findings of Zheng Wei *et al.*[6] about sweet maize varieties.



Note: A: Seedling stage; B. Heading and silking stage. Different small letters in the same picture indicate significant difference ($P<0.05$).

Fig. 1 Effects of transplantation in different seedling age on maize plant height

Table 2 Effect of transplantation in different seedling age on maize yield and its component factors

Treatment	Ear length cm	Ear diameter cm	Bald ear length // cm	Row of ear	Kernels per row	100 grain weight // g	Actual yield kg/ha
Mulch based direct sowing	17.9 ± 0.1a	4.8 ± 0.0a	0.6 ± 0.2a	15.8 ± 0.3a	37.0 ± 0.7a	37.1 ± 1.1a	12 586 ± 54a
Two-leaf transplantation	17.4 ± 0.8a	4.8 ± 0.2a	1.1 ± 0.4b	15.9 ± 0.3a	34.7 ± 1.1ab	33.1 ± 2.8b	11 444 ± 1337ab
Three-leaf transplantation	17.2 ± 0.3a	4.7 ± 0.1a	1.2 ± 0.1b	15.6 ± 0.6a	34.9 ± 1.0ab	32.8 ± 0.4b	10 697 ± 616ab
Four-leaf transplantation	16.9 ± 1.0a	4.8 ± 0.0a	1.2 ± 0.2b	15.7 ± 0.4a	34.3 ± 2.0b	31.1 ± 0.4b	100 66 ± 705b

Note: different small letters in the same column denote significant difference ($P<0.05$).

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. Besides, with growing of seedling age, the number and length of roots penetrating the breeding container will increase accordingly. During transplantation, seedling lifting, transport, and soil burying will damage the root system of seedlings, leading to slow recovery of seedlings after transplantation[3]. In this study, growing process, plant height, and yield of transplanted maize seedlings are not better than mulch based direct sowing. With growing of transplanted seedling age, the gap is widening. Ruan Peijun *et al.*[5] found that seedling height, root number, total root length, and average length of each root are varied with transplanted seedling age, and they increase with increase of age of transplanted seedling leaves. Our study indicates that disturbance of transplantation to root system of seedlings is the least in two-leaf, followed by three-leaf, and the worst is four-leaf. Therefore, the best seedling age for transplantation in this experimental area is two-leaf period, not later than three-leaf period. The key of ensuring survival of transplantation is to protect root system, shorten or eliminate the recovery period, and increase the survival rate[7].

Although the yield of transplanted maize is slightly lower than mulch based direct sowing, 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[8-9]. If it is able to further optimize seedling transplantation technology, shorten the seedling recovery time, and ensure the yield close to mulch-based direct sowing, seedling transplantation will become an ideal maize planting method in Shanxi early mature area.

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