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Effects of Graded Seedling Transplanting on Growth, Yield and Medicinal Materials Quality of *Astragalus membranaceus* var. *Mongholicus*

Xiaojie Li[1,2], Yingtong Mu[1,2], Xiaoming Zhang[1,2], Junjie Wang[1,2]

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ABSTRACT

Background: Transplantation of *Astragalus Mongholicus* seedlings, compare the growth and development of astragalus and its yield and quality after graded transplantation, to provide the basis for improving the yield and quality of astragalus medicinal materials.

Methods: With the planting of *Astragalus Mongholicus* seedlings for one year as the material were divided into four grades according to different lengths and thicknesses and the indexes of plant height, thick stem, stem and leaf weight, root length, thick root, yield, Astragaloside IV and Calycosin7-O-β-D-Glucopyranoside content after different seedlings grades were determined.

Result: There is a close connection between the grade of *Astragalus Mongholicus* seedlings and the quality of the yield of medicinal materials. After graded transplantation, the yield of medicinal materials improves 38.52kg/667m^2 compared to the traditional transplantation method. The content of Astragaloside IV and Calycosin7-O-β-D-Glucopyranoside is also closely related to the seedling grade, the content of Astragaloside IV in the medicinal materials after transplanting the second and third grade seedlings was more than 0.02% higher than that of the first and fourth grades, after transplantationof the grade I seedlings, the content of Calycosin7-O-β-D-Glucopyranoside in the medicinal materials was more than 0.01% higher than that of the other three grades. The yield of astragalus medicinal materials is the highest after the seedlings are transplanted by grade and the content of the main active components of the medicinal materials is quite different after the different grades of seedlings are transplanted. Therefore, in actual production, the seedlings should be transplanted according to different specifications and grades to improve the yield and quality of astragalus.

Key words: *Astragalus membranaceus* var. *Mongholicus,* Growth and development, Medicinal material yield and quality, Seedling classification, Targeted metabolism.

INTRODUCTION

Astragalus membranaceus var. *Mongholicus* (*M. Astragalus*) is a perennial *Leguminosae* herb with a high market demand. The medicinal materials of astragalus are the dried roots of *M. astragalus* and *Astragalus membranaceus*. It is one of the typical medicinal and food homologous plants. Inner Mongolia is the authentic region of *M. astragalus* and the artificial cultivation range is expanding with the increase in the demand for *M. astragalus* in the Chinese herbal medicine market (Zhang *et al*., 2020). In recent years, the demand for raw materials of *M. Astragalus* has been increasing due to the international medical industry and the decreasing wild resources make cultivated *M. astragalus* herbs in short supply (Li *et al*., 2021).

The cultivation method of *M.Astragalus* is more traditional. The method of flat planting of mixed seedlings, the row spacing is not standardized and the method of placing seedlings when planting seedlings is also relatively random, lacks of reasonable cultivation techniques, resulting in uneven yield and quality of medicinal materials (Li *et al*., 2005; Guo *et al*., 2019; Cao *et al*., 2019; Xu *et al*., 2018). The quality of seedlings is an important factor affecting the yield and quality of plants (Pagare *et al*., 2023). However, there is a lack of systematic research on seedling quality, growth and development characteristics of different types of seedling after classification and transplantation and the status of the yield and quality of medicinal materials. In particular, there is no relevant research literature on the effect of seedling grad transplantation on the quality of medicinal materials (Zhao *et al*., 2014; Chen *et al*., 2016; Li *et al*.,

[1]Key Laboratory of Grassland Resources(Inner Mongolia Agricultural University), Ministry of Education, Hohhot, 010021, P.R. of China.

[2]Engineering Research Center for the Seed breeding of Chinese and Mongolian Medicinal Materials in Inner Mongolia, Inner Mongolia, 010011, China.

Corresponding Author: Junjie Wang, Engineering Research Center for the Seed breeding of Chinese and Mongolian Medicinal Materials in Inner Mongolia, Inner Mongolia, 010011, China. Email: jjw62@163.com

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2020; Cai *et al*., 2018). On-farm cultivation of *M. Astragalus* herbs are mostly done by seedling transplanting, proper adjustment of cultivation methods can improve and enhance the yield and medicinal quality of medicinal plants (Xu *et al*., 2020). In the cultivation of high-quality *M. Astragalus*, existing cultivation methods and techniques should be improved in terms of herbal yield, active ingredients and content (Sun *et al*., 2021).

M. astragalus has a wide range of applications in agriculture, animal husbandry and the medical industry (Seidu *et al*., 2018). Therefore, it is of great significance to conduct in-depth research on the yield and quality of medicinal materials after the classification and transplantation of the seedlings. The status of the content of two components Astragaloside IV (astragaloside) and Calycosin7-O-β-D-Glucopyranoside (C-7-O-β-D-G), which play a key pharmacological role in the finished medicinal material of *M. astragalus*, is the key to evaluating the quality of the medicinal material. After fully grasping the law of growth and development of seedlings after grading and transplanting and the yield and quality of medicinal materials, the field cultivation techniques of *M. astragalus* is an important means to improve the cultivation and management measures of *M. astragalus*.

Seedling quality is an important influencing factor in the growth and development of *M. astragalus* and the quality of herb yield and appropriate transplanting methods can effectively bring out individual potential and population advantages of the crop (Xi *et al*., 2012; Yan *et al*., 2018). In this study, based on the quality classification and transplantation of *M. Astragalus* seeds and seedlings in the research group at an early stage, combined with the phenotypic characteristics and the content of medicinal materials after transplantation, the growth and development status and the yield and quality of medicinal materials were further explored after the classification and transplantation of *M. astragalus* seedlings.

MATERIALS AND METHODS

Overview of test materials and test area

The *M. Astragalus* seedlings were taken from Chifeng City, which belongs to the northern temperate semi-arid continental monsoon climate. The altitude is 513 m, the annual average temperature is 6.9°C. The organic matter of the soil is 6.45 g kg^{-1} and the total nitrogen is 0.67 g kg^{-1}.

Experiment design

The experiment was conducted at the Research Farm of Inner Mongolia Agricultural University, Chifeng City, Inner Mongolia, China, seeded in April 2019 and transplanted in May-13, 2020. Before transplantation, the seedlings were divided into four quality grades according to length and thickness and the other seedlings were removed before transplantation. The specific division rules are shown in Table 1. After classification, they were planted horizontally according to the 17 cm row spacing and 48cm apart, the plant spacing was 20 cm. The random block design was repeated 3 times and the plot area was 4×20 m^2.

Dynamic monitoring of growth and development and yield and quality measurement of medicinal materials

After transplantation,the sampling was carried out 7 times on Jul-1, Aug-1, Sep-1, Oct-5, Oct-15, Oct-25 and Nov-5 and 10 plants were randomly sampled for each repetition. Weigh the fresh weight of the above-ground and underground parts, measure the length and the thickness of the main root, the height of the above-ground part and the thickness of the stem. The thickness of the main root and the diameter of the stem were measured with vernier calipers at 1 cm below the reed head and 1 cm above the ground, respectively and then the samples were dried at 65°C to constant weight and the dry mass was measured.

During the harvest period of medicinal materials on Nov-5, 2020, in each repeating block group, 1 m^2 aboveground plants were selected in each plot in turn to measure the fresh weight and dry weight of medicinal materials and the yield was measured after harvest. Subsequently, the content of each asteagaloside treatment and C-7-O-β-D-G was determined with reference to the quality detection method of the medicinal materials of astragalus stipulated.

Instruments

The composition content of medicinal materials was determined by ultra-high performance liquid chromatography (UltiMate 3000 Thermo USA), Thenmo-C18 (Hypersil GOLD, 100 mm × 2.1 mm, 1.9um) chromatography column detection. Astragaloside and C-7-O-β-D-G control products.

Statistical analysis

Data analysis was performed by SPSS26.0 of each index one-way ANOVA and image processing was processed using Sigama Piot 12.0.

RESULTS AND DISCUSSION

Effects of seedling quality on the growth dynamics of aboveground plants of *M. astragalus*

Plant height, stem thickness, fresh weight of stem and leaves, number of branches are important agronomic traits reflecting the growth and development of plants (Monika *et al*., 2023). July-August is the period of rapid growth of branch structure (Fig 1). The plant height of *M. Astragalus* increased

Table 1: Specification of graded transplanting seedlings.

Level	Main root length (cm)	Main root wide (mm)	The whole root fresh (g)
I	≥30.00	≥8.00	≥13.63
II	≥25.00	≥6.00	≥8.23
III	≥20.00	≥4.00	≥3.93
IV	18.00~20.00	≥4.00	≥2.43
Off-grade	<18.00	<4.00	<2.00

rapidly by more than 30.00 cm in 30 days. The height of the plant of seedlings of different grades reached its maximum of Sep-1, among which the height of the first grade seedlings was the highest, which was 112.00 cm and the growth rate of the fourth grade seedlings was lower than that of the other grades in the early stage. The overall growth rate of the first- and second-level stem diameters was the largest in the branching stage before August and then showed a slow growth state and stopped increasing in September when it entered the withered stage.

The number of rhizomes of first-class seedlings was the largest in different periods, around 2.0 per plant. The number of branches of the other three grades of seedlings was approximately 1.5 per plant. It shows that the seedling grade has a great influence on the number of first-level branches. The higher the grade, the more branches and the faster the withering rate of the above-ground branches.

Effects of seedling quality on growth dynamics of *M. Astragalus* root

The growth rate of root length of grade I, III and IV seedlings was slow during the period of withering and yellowing from Sep-1 to Oct-25, but during the harvest period from Oct-25 to Nov-5, the root length increased to an extreme value in a short period. The root length of grade II seedlings after transplantation maintained a uniform growth state throughout the growth period and there were no significant differences in the root lengths of all seedling grades after transplantation from Nov-5 to the end of the harvest period. After transplantation, the root thickness of grade I, II and III seedlings reached 14.89 mm, 12.03 mm and 10.58 mm in Sep-1, respectively and then reached a stagnant state, which lasted until the end of harvesting. However, there were significant differences between root thickness and the other three grades. The root thickness of grades II, III and IV was greater than 2.37mm after transplantation. However, grade IV seedlings maintained a uniform growth state after the rapid growth period of root thickness on Sep-1, indicated that the seedlings were still in a relatively active state after entering the withered and yellowing stage (Fig 2).

Effects of seedling quality on the dynamics of dry matter accumulation in aerial parts of *M. Astragalus*

In the process of plant growth, the relevant equations and parameters are obtained by fitting the biomass accumulation of *M. Astragalus* after transplanting seedlings at all levels are shown in Table 2. “t” is the post-emergence time (d) and “y” is the biomass accumulation value (g/plant). “t1” is the starting time of rapid accumulation of dry matter. “t2” is the end time of rapid biomass accumulation. “Δt” is the duration

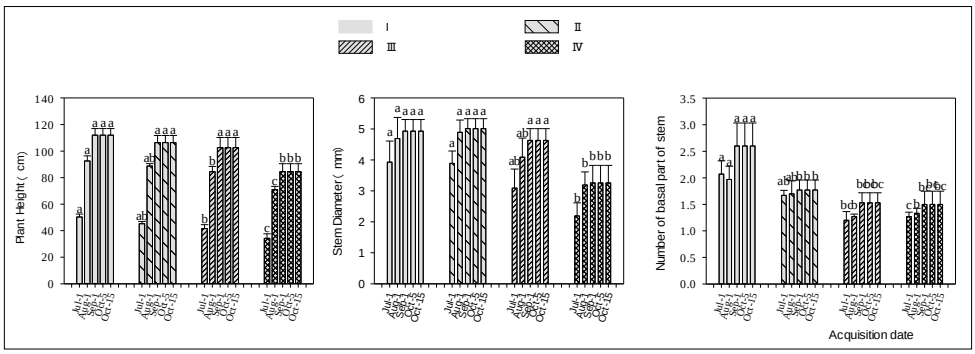

Fig 1: Growth dynamics of *M. astragalus* after seedling transplanting.

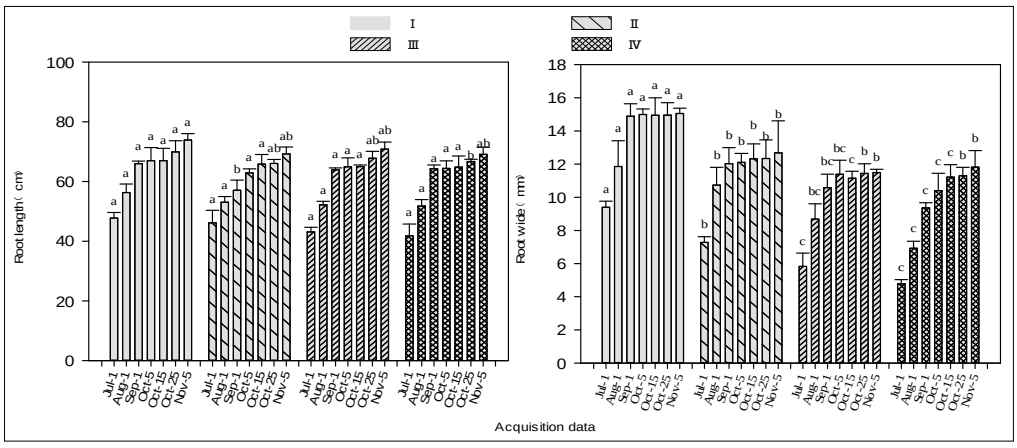

Fig 2: Growth dynamics of root phenotype characteristics after graded seedling transplanting.

of rapid accumulation of biomass . “Vmean” is the average growth rate [g/(strain • d)] during the period of rapid accumulation of biomass.

The correlation coefficients of each equation obtained by fitting have reached a significant level and are statistically significant. The dry matter accumulation process of the above-ground parts of grade I and grade II seedlings after graded transplantation of *M. astragalus* showed a nonlinear normal distribution curve and the grade III and grade IV seedlings showed a “S” curve growth state. The duration of dry matter accumulation (∆t) in the aerial part and the average growth rate (Vmean) during the dry matter rapid accumulation period jointly determined the amount of dry matter accumulation. The ∆t of the accumulation above-ground of the seedlings at all levels after transplantation was in the order II= III>IV>I. The ∆t of the grade II and grade III seedlings was 30 and 25 days longer than that of the grade I and grade IV seedlings, respectively. Under the same growth environment, the ∆t of the above-ground part of the grade I and grade IV seedlings after transplantation was the longest. The Vmean values of the seedlings at all levels were in the following order: I>II >IV >III and the Vmean values of the above-ground parts of the I seedlings were 0.16, 0.23 and 0.29 [g/(strain · d]. In the same growth environment, there were differences in the Vmean of the aboveground plants after transplanting the seedlings at all levels and the Vmean of the grade I seedlings was the largest.

After transplantation, the dry weight of stems and leaves increased rapidly from July to August after the seedlings of grades I,II and III were transplanted. The dry weight of the stems and leaves of grade III seedlings increased rapidly and approached the maximum growth value on Aug-1 and showing a slow increase subsequently. Grade IV seedlings still showed a rapid growth state during the period form Sep-1 to Oct-5 in the late stage of above-ground plant growth and the early stage of root dry matter accumulation. The accumulation of dry matter from shoots and leaves in the early and middle stages of growth from July to September in the aerial parts was grade I>II>III>IV. The fresh weight of the stem and leaves decreased rapidly in the above-ground part of the growth period starting from October, in which the rate of dry matter loss of above-ground stem and leaves was the fastest after transplanting of grade I seedlings and the dry matter weight of the grade III, IV and I seedlings was greater than 10.00 g. It can be seen that the aboveground biomass was still growing in the late growth stage after transplantation of small seedlings, while the aboveground part stopped growing in the late growth stage after transplantation of large seedlings and showed continuous wilting and the biomass accumulation was transferred from the aboveground stems and leaves to the roots. The growth of the above-ground parts slowed to stagnation rapidly from the maturity stage to the withering stage and the growth indices showed a fast and then slowly tredn throughout the growth and development period (Fig 3).

Table 2: Dynamic fitting equation for dry material accumulation of *M. astragalus* parts and its parameters.

Level	Equation	t1 (d)	t2 (d)	∆t (d)	Vmean	R^2	P
I	y=10.8363+438.6461·exp(-0.5((x-15.3424)/3.1536)^2)	49	79	30	0.42	0.951	<0.0001
II	y=29.5657+(891.0906/5.3756·sqrt(pi/2)))exp(-2((x-17.5846)/5.3756)^2)	49	109	60	0.26	0.944	<0.0001
III	y=29.8776+105.5089/(1+10^((10.532-x)29.8563))	49	109	60	0.13	0.881	<0.0001
IV	y=436.1620-424.9111/(1+(x/28.5205)^0.8804	109	144	35	0.19	0.968	<0.0001

Effect of seedling quality on the dynamics of dry matter accumulation in the roots of *M. astragalus*

The accumulation of dry matter in the roots of seedlings of each grade after transplantation was different from that in the aboveground part and the dynamics of dry matter growth in the roots of *M. Astragalus* was fitted and the related equations and parameters are shown in Table 3. The accumulation of dry matter from the roots after transplantation of seedlings of the four different grades showed a linear increase and the dry matter accumulation rate was III>IV>II>I. In the same growth environment, the ∆t values of root dry matter after transplanting of seedlings of all grades were I = III = IV > II and the ∆t values of the roots after transplantation of seedlings of grade II were 65 d lower than those of the other three grades. The accumulation of dry matter was was lower in the late growth stage and the Vmean values of the accumulation of dry matter in the root, after transplanting seedlings of all levels showed that II>I> IV>III. The Vmean values of the accumulation of dry matter from the roots after transplanting of grade a! seedlings were 0.048, 0.065 and 0.076 [g/(plant · d] higher than those of grade I, IV and III, respectively. In the early stage of growth, the dry matter from the underground root also accumulated rapidly to the maximum value, while the dry matter from the aboveground accumulated rapidly.

The increase in the weight of the accumulation of root dry matter was mainly concentrated in the two months of September and November. In the early and middle stages of root dry matter accumulation (July-August), the dry matter accumulation of roots of the four types of seedlings increased slowly after transplantation. In the late growth stage (Sep-1) and the yellowing stage (Oct-25), the accumulation of dry matter from the roots of the grade I, II and III seedlings stagnated after transplantation, while the accumulation of dry matter from the roots of IV still showed an increasing trend and the accumulation of dry matter exceeded that of III. It can be seen that although the base of all grade IV growth indexes was small at the time of transplantation, their later growth potential was greater and the accumulation of root dry matter was not significantly different from that of grade II and IIII seedlings after transplantation and the accumulation of root dry matter at the end of growth was I>II>IV>III (Fig 4).

Effect of graded transplantation of seedlings on the quality of *M. Astragalus* medicinal herb yield

The grade I seedlings yielded the highest after transplantation, which was 31.35%, 38.47%, 34.00% and 38.08%/667 m^2 higher than the grade II, III, IV and mixed seedlings. The yield of graded transplants was 31.82%/667 m^2 higher than that of mixed seedling transplants. It shows that seedling grade has a great influence on herb yield, in which grade III and IV have the greatest influence on herb yield after transplantation grade II and III have less influence on herb yield after transplantation and the yield after transplantation of mixed seedlings is extremely significantly lower than that after transplantation of graded seedlings, which indicates that graded seedling transplantation and elimination of out-of-grade seedlings transplantation are beneficial to increase herb yield (Fig 5).

Table 3: Dynamic fitting equation for dry material accumulation and its parameters.

Level	Equation	t1(d)	t2(d)	∆t(d)	Vmean	R^2	P
I	y=0.6468+8.6617x	49	174	125	0.109	0.942	<00.0001
II	y=3.7385+11.3486x	49	109	60	0.157	0.924	<00.0001
III	y=12.1038+13.3984x	49	174	125	0.081	0.956	<00.0001
IV	y=20.2836+12.9220x	49	174	125	0.092	0.970	<00.0001

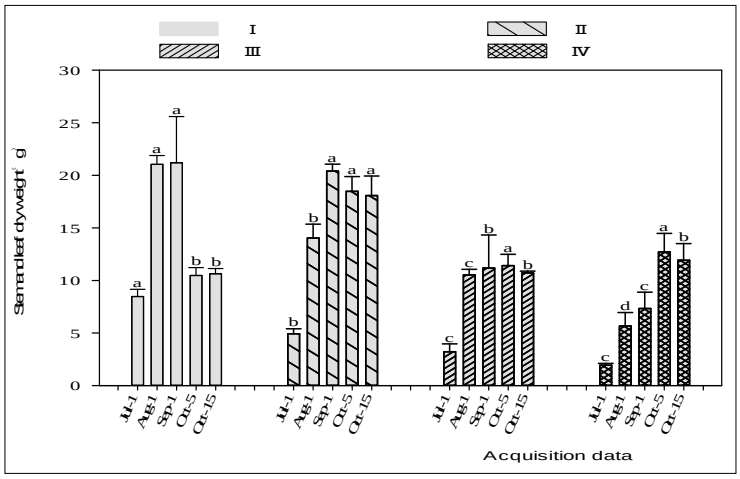

Fig 3: Accumulation of dry material after graded seedling transplanting.

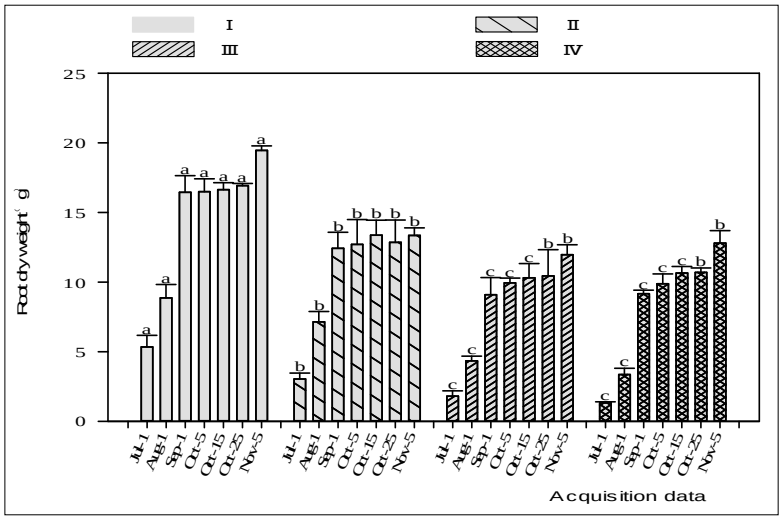

Fig 4: Dynamics of root dry material accumulation after seedling grade transplanting.

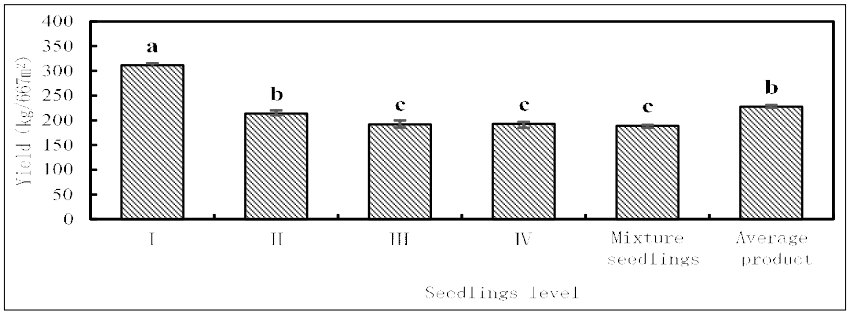

Fig 5: Production of medicinal materials after graded transplanting of seedlings.

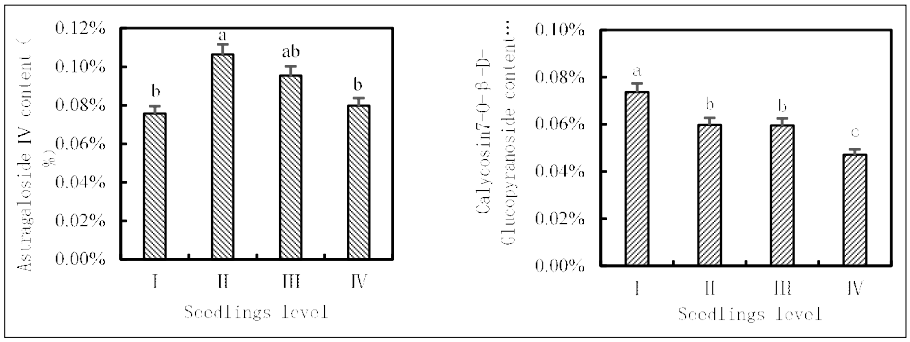

Fig 6: Effect of seedling quality on the content of Astragaloside IV and Calycosin7-O-β-D-Glucopyranoside in medicinal materials.

Grade II and III had the highest astragaloside content after transplantation, which was more than 0.2% higher than the astragaloside content I and IV. The content of C-7-O-β-D-G in herbs after transplantation of each grade was I>II>III> IV, with I having the highest content after transplantation, which was higher than the C-7-O-β-D-G content of C-7-O-β-D-G after transplantation of seedlings from the other three grades more than 0.01% (Fig 6).

CONCLUSION

Comprehensive analysis revealed that there was a close relationship between the grade of quality of *M. astragalus* seedlings and the quality of the herb yield. The graded transplant of seedlings had less effect on the root length of *M. astragalus* herb and more effect on root thickness and yield and the higher the grade of seedlings, the greater the root thickness, fresh weight and yield base after transplanting. In the traditional mixed seedling transplantation method, the quality of the herb yield was 188.96kg/667m^2 and after seedling graded transplantation, the herb yield was 227.48 kg/667m^2, which was 38.52 kg/667m^2 higher compared to the traditional transplantation method. The content of C-7-O-в-D-G and astragaloside was also closely related to the seedling grade, the coarser the

seedling, the higher the C-7-O-β-D-G content in the herb after transplantation. Thus, it is very important to according to different needs, specifications and unqualified seedlings should be removed at the time of transplantation to improve the cultivation technology of *M. astragalus*, to improve the yield and quality of *M. astragalus*.

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Conflict of interest: None.

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