Effects of maize/peanut intercropping system on nodulation of peanut in northwest Liaoning

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Abstract. The maize/peanut intercropping system was considered as a technique, which can both reduce drought risk of sole maize and wind erosion of sole peanut in northwest Liaoning. To clarify the nodulation characteristic of peanut in maize/peanut intercropping system of semi-arid area in northwest Liaoning, a field experiment was conducted at National Agricultural Experimental Station for Agricultural Environment, in northwest Liaoning, China. Including three cropping system (M2P4, M4P4 and Sole peanut) and three densities of maize (2, 3, 4 plants m\(^{-2}\) for M2P4, 3, 4.5, 6 plants m\(^{-2}\) for M4P4) based on the configuration. The results showed that Intercropped with maize significantly promote the nodulation of peanut. The nodule number and nodule size of peanut in M4P4 was significantly more than that of intercrops M2P4 and monoculture. Increasing the proportion of maize in row promotes the nodulation of peanut in maize/peanut intercropping system. The middle density of maize (3 plants m\(^{-2}\)) is the best density for peanut nodulation in M2P4 intercropping system. 3 plants m\(^{-2}\) density of maize is better for nodulation of peanut in earlier stage of peanut growth in M4P4 system, while the high maize density (6 plants m\(^{-2}\)) is more suitable for peanut nodulation in middle and later periods.

1. Introduction
The northwest of Liaoning in northeast of China is a typical example of a semi-arid area. It is an important area for food production, meanwhile it is also vulnerable area in ecological environment. There is frequent drought in this region, and wind erosion and desertification are very serious. Since 1980s, to solve the regional drought, wind erosion and desertification problems, a lot of agricultural techniques were used, such as plastic film mulching techniques, return crop straw to the field, water saving tillage techniques and intercropping. Among them intercropping was considered as a technique which efficiently use natural resources, such as water and light, improve land productivity and
ecosystem services [1-3], building of soil organic matter and improved N cycling, and suppression of pests, weeds and diseases [4-6].

The maize/peanut intercropping was proposed in northwest Liaoning, because use this intercropping system can both reduce drought risk of sole maize and wind erosion of sole peanut. To date, there are studies showed that maize/peanut intercropping system improve the land equivalent ratio, water productivity, increase the root surface area density of crops and so on [7-9]. However, studies of maize/peanut intercropping in northwest Liaoning most focus on the configuration selection, regional wind erosion control, water and land productivity. The research on the effect of intercropping with maize on peanut nodule which related to the nitrogen fixation has not yet been reported. To clarify the effect on peanut nodulation in maize/peanut system is important for making high use of the symbiotic nitrogen fixation function of peanut, reducing the nitrogen fertilizer apply and improving the utilization efficiency of regional resources.

In this study, a field experiment was conducted at National Agricultural Experimental Station for Agricultural Environment, including the treatments of different planting patterns and densities, to clarify the nodulation characteristic of peanut in maize/peanut intercropping system of semi-arid area in northwest Liaoning.

2. Materials and Methods

2.1. Test site and materials

The field experiment was conducted in 2015 at the National Agricultural Experimental Station for Agricultural Environment, Fuxin city (42°09′02″N, 121°43′48″E), Liaoning, Northeast China. The region has cold dry winters and hot summers, and is classified as Dwa in the Köppen-Geiger classification. The average annual precipitation from 1965 to 2015 was 531 mm during the growing season (May to September) with a standard deviation of 134 mm.

The soil is an Aeolian sand with a bulk density of 1.45 g cm\(^{-3}\) averaged over 0-100 cm soil layer. The organic matter in the top 20 cm soil layer is 14.4 g kg\(^{-1}\), total nitrogen (N) 0.78 g kg\(^{-1}\), available N 45.2 mg kg\(^{-1}\), available phosphorus 17.4 mg kg\(^{-1}\), and available potassium 69.5 mg kg\(^{-1}\). We used the medium maturing maize (Zea mays L.) variety ZD958, early maturing peanut (Arachis hypogaea L.) variety BaiSha1016.

2.2. Field experiment design

In the field experiment we designed three cropping systems, in which there are sole peanut (SP) and two configurations for intercrops, which are M2P4 (two rows of maize and 4 rows of peanut) and M4P4 (four rows of maize and 4 rows of peanut), the row spacing (including the distance between maize strips, peanut strips, and the distance between maize and peanut rows) are all 0.5 m. The density treatments are based on the configuration, each configuration involved three densities of maize: for M2P4 is 2 (D1), 3 (D2), 4 (D3) plants m\(^{-2}\) of the maize/peanut system area. for M4P4 is 3 (D1), 4.5 (D2), 6 (D3) plants m\(^{-2}\) of the maize/peanut system area, corresponding to plant distances in the row of 33, 22 and 17 cm, respectively.

The plot area was 104 m\(^2\) (13 m length×8 m width). Maize and peanut were sown at the same time, on 18 May 2015. The final harvests were made on 23 September 2015. No irrigation was applied during the crop growing seasons, fertilizer was applied at a rate of 135kg ha\(^{-1}\) N and 59 kg ha\(^{-1}\) P.

2.3. Measurements

To determine the nodulation of peanut in different treatment, the plant samples were taken in different stages: Flowering stage, Pod setting stage and Maturity stage, and in different rows of peanut, including border row and middle row. The peanut roots were washed and then the nodules were picked from roots. Then we count the nodule number and got the nodule weights after air drying.
2.4. Data analysis
Data of nodule number and nodule weight in different system or densities were analyzed using the Univariate General Linear Models procedure of SPSS 20 (IBM, USA). Least significant differences (LSD) were used to separate treatment means at the 0.05 level.

3. Results and Discussion

3.1. The nodulation of peanut intercropped with maize in different configurations
The results shown in Table 1 that in florescence stage, the nodule number and nodule size of peanut were in the order of M4P4> M2P4>SP (Sole Peanut). In pod setting stage were M4P4>M2P4>SP for nodule number, and M4P4>SP>M2P4 for nodule size. In maturity stage were SP>M2P4>M4P4 for both nodule number and nodule size. Therefore, in the growth development period, the nodulation characteristic showed the best in M4P4, and then is the M2P4 configuration got more nodules than that of sole peanut. Nodule number and size of peanut in intercrops M4P4 was significantly more than that of intercrops M2P4 and monoculture. Therefore, increasing the proportion of maize in row promotes the nodulation of peanut in maize/peanut intercropping system.

Table 1 Nodule number and nodule size of peanut intercropped with maize in different configurations

| Cropping system | Florescence | Pod setting | Maturity |
|-----------------|-------------|-------------|----------|
|                 | Number plant\(^{-1}\) | Weight mg plant\(^{-1}\) | Number plant\(^{-1}\) | Weight mg plant\(^{-1}\) | Number plant\(^{-1}\) | Weight mg plant\(^{-1}\) |
| SP              | 8±5B        | 10.5±6.3B   | 13±7B    | 21.5±7.9B   | 45±7A        | 57.2±8.2A    |
| M2P4            | 16±3B       | 14.1±3.7B   | 16±4B    | 16.1±4.6B   | 26±4B        | 22.3±4.7B   |
| M4P4            | 28±3A       | 30.8±3.7A   | 46±4A    | 44.4±4.6A   | 19±4B        | 17.5±4.7B   |

\( ^{\text{§}} \) M2P4 indicates a intercropping system of 2 rows maize and 4 rows peanut, M4P4 is 4 rows maize and 4 rows peanut. The same capital letter compares the means of cropping systems.

3.2. The nodulation of peanut intercropped with maize in different densities
Table 2 showed the nodulation of peanut in different densities in each cropping system. In M2P4 system, the nodule number of peanuts in florescence, pod setting and maturity stages showed the trends as D2>D3>D1, D2>D1>D3 and D2>D3>D1, respectively. The nodule size of peanut in different stages are in the order of D2>D3>D1, D2>D1>D3 and D2>D1>D3, respectively. Which means the nodulation of peanut in D2 (3 plants m\(^{-2}\)) is significantly better than that of D1 and D3 in M2P4 cropping system. In M4P4 system, both nodule number and nodule size were in the order of D1>D3>D2 in florescence stage, D3>D1>D2 in pod setting stage and D3>D2>D1 in maturity stage. Therefore, the low maize density in M4P4 is better for nodulation of peanut in earlier stage of peanut growth, while the high maize density is suitable for peanut nodulation in middle and later periods.

Table 2 Nodule number and nodule size of peanut intercropped with maize in different densities

| Cropping system | Density | Florescence | Pod setting | Maturity |
|-----------------|---------|-------------|-------------|----------|
|                 | Number plant\(^{-1}\) | Weight mg plant\(^{-1}\) | Number plant\(^{-1}\) | Weight mg plant\(^{-1}\) | Number plant\(^{-1}\) | Weight mg plant\(^{-1}\) |
| M2P4            | D1      | 6±3b        | 4.17±1.9b   | 17±2ab    | 17.5±2.9ab  | 21±6a        | 22.8±9.6a    |
|                 | D2      | 30±4a       | 26.5±6.4a   | 23±8a     | 23.0±6.0a   | 32±9a        | 24.0±8.0a   |
|                 | D3      | 11±5b       | 11.7±5.3ab  | 8±1b      | 7.7±1.5b    | 26±6a        | 20.0±4.6a   |
| M4P4            | D1      | 40±6a       | 46.2±11.1a  | 41±8b     | 40.3±11.6ab | 16±4a        | 13.0±2.6a   |
|                 | D2      | 21±7b       | 22.0±6.7a   | 20±10b    | 20.0±8.5b   | 17±5a        | 14.3±4.6a   |
|                 | D3      | 23±5ab      | 24.3±5.1a   | 77±12a    | 72.8±12.9a  | 25±13a       | 25.2±14.3a  |

The same small letters indicates a no significant difference between plant density within a cropping system.
4. Conclusion
The nodulation of peanut can be promoted by intercropped with maize. The nodule number and nodule size of peanut in M4P4 was significantly more than that of intercrops M2P4 and monoculture. 3 plants m⁻² is the best density for peanut nodulation in M2P4 intercropping system, and it is also better for nodulation of peanut in earlier stage in M4P4 system.

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