Effects of different tillage systems and amendments on root properties

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Abstract. The object of this study was to investigate the effect of different tillage systems and amendments on root properties. There were five treatments: maize continuous cropping, maize and peanuts rotation, peanuts continuous cropping, peanuts continuous cropping with low level of amendment and peanuts continuous cropping with high level of amendment. The results showed that maize continuous cropping increased total root length by 118.95\%, projected area by 204.86\%, projected area by 150.70\%, total root volume by 20.66\%, and average root diameter by 184.53\%. The amendments also improved root properties and the high level of amendment had much more better effect.

1. Introduction
The root is main organ to absorb nutrients and moisture for plants. The ability of crops absorbing mineral nutrient and moisture is about the development of roots [1]. The quality of root directly influences the growth of aerial part. The continuous cropping inhibits the crops growth and yield improvement [2]. Scientific and reasonable rotation is an effective measure to solve continuous cropping obstacle. Reasonable rotation with other crops can coordinate the relationship between the crop and soil, reduce the harmful microbes in the soil [3], improve soil ecological environment and promote high yield. Application of soil amendment is one of the important measures of restoration of degraded soil. Soil conditioner can effectively improve soil physical and chemical properties, soil nutrient status. It has a positive impact on soil microorganisms and productivity of degraded soil [4]. There were many researches about the effect of different tillage systems and amendments on root, such as Wang [5] set up five years of continuous monoculture sorghum as the control was compared to alfalfa and scallion planted in the fourth year. The results showed that incorporation of alfalfa and scallion into the rotation significantly improved sorghum shoot growth. Specifically, sorghum grain yield increased by 16.5\% in the alfalfa rotation plots compared to the CK. The rotations also increased sorghum root system growth, with alfalfa or scallion rotation increasing sorghum total root length by 0.3 and 0.4 times, total root surface area by 0.6 and 0.5 times, root volume by 1.2 and 0.6 times. Dong’s research results showed that treatments with amendments, except for lime, significantly increased the intensity of bleeding sap, root shoot ratio, biomass in bleeding sap.
As a result, this study was based on a six-year long-term experiment in order to investigate the effect of different tillage systems and amendments on root development and providing theoretical basis for solving peanut continuous cropping obstacle.

2. Materials and methods
The long-term experiment was located in Liaoning Province at the Shenyang Agricultural University Peanut Scientific Research Center (40°48'N, 123°33' E). The soil at the experimental site was a brown soil classified as an alfisol, with hydromica as a dominant clay mineral. This experiment began in 2011 and the basic physical and chemical properties are detailed in Table 1.

| Soil layer (cm) | Organic matter (g/kg) | Total N (g/kg) | Total P (g/kg) | Total K (g/kg) | Available N (mg/kg) | Available P (mg/kg) | Available K (mg/kg) | pH |
|----------------|-----------------------|----------------|----------------|----------------|--------------------|--------------------|--------------------|----|
| 0–20           | 13.1                  | 0.53           | 0.67           | 18.8           | 56.2               | 12.5               | 89.6               | 6.81|

The cultivars were Huayu 33 peanuts and Zhendan958 maize. There were five treatments: MC: maize continuous cropping, applied 487.4g carbamide +4441g (NH₄)H₂PO₄+405g K₂SO₄ every 27 m² plot. MPR: maize and peanuts rotation cropping and maize was cropped in 2016, applied 487.4g carbamide +4441g NH₄H₂PO₄+405g K₂SO₄ in every 27m². PC: peanuts continuous cropping, applied 162g carbamide +486g NH₄H₂PO₄+607.6g K₂SO₄ in every 27m² plot. PCCA: peanuts continuous cropping, applied 2024g amendment1+162g carbamide +486g(NH₄)H₂PO₄+607.6g K₂SO₄ in every 27 m² plot. PCBA: peanuts continuous cropping, applied 1619g amendment 2+162g carbamide +486g NH₄H₂PO₄+607.6g K₂SO₄ in every 27m² plot.

Microsoft Excel 2010 was used for the statistical analysis of the experimental data.

3. Results and discussion
3.1. The effect of different tillage systems on root

![Fig.1 total root length in different stage](image_url)
Fig. 2 projected area in different stages

Fig. 3 superficial in different stages

Fig. 4 total root volume in different stages
The figure 1 showed that total root length in each growth period with continuous cropping was higher than that with rotational cropping and it was 43.36 ~106.73 cm and 115.49~210.96 cm, respectively. The total root length reached a maximum of 210.96 cm in flowering and pegging stage and it increased by 118.95% compared with the same stage with continuous cropping.

The projected area of root was 3.67-15.11cm² and 17.34-28.53 cm² when continuous cropping and rotational cropping were used, respectively. In comparison with maize continuous cropping treatment, the projected area of root was higher than rotational cropping treatment in every stage and that averagely increased by 204.86%.

The superficial areas in each stage were 11.53-47.47cm² with continuous cropping and 34.51-77.40cm² with rotational cropping. The MPR treatment’s results were averagely higher 1.5times than MC treatment.

No matter continuous or rotational cropping, the total root volume was decreased. MC and MPR treatment decreased to 50.92% and 19.02%, respectively. Expect in pod-setting stage, the volume with rotational cropping decreased by 20.66% in comparison with continuous cropping. It was much higher than in any else stage.

From figure 5, in continuous cropping treatment, the average diameters were on the decline in all stages and decreased by 74.54%, except it increased from flowering and pegging stage to pod-setting stage and up to a maximum of 1.81 mm. In rotational cropping treatment, the average diameter increased from seeding stage to flowering and pegging stage and reached to 2.90mm. After that, it
decreased to 2.47mm in pod-setting stage and kept stable. Overall, the root average diameter with rotation cropping was greater than with continuous cropping and the average growth rate was 312.46%.

The root tips were 11-38 and 44-81 when continuous cropping and rotational cropping were used. In comparison with maize continuous cropping treatment, it was higher than rotational cropping treatment in every stage and that averagely increased by 184.53%.

In general, total length, projected area, superficial area and tips of root had the same change regulars. With continuous cropping, every index slowly growing from seeding stage to flowering and pegging stage, and reached the maximum in pod-setting stage. After that it declined gradually. In rotation cropping treatment, every index rapidly increased and up to the maximum in flowering and pegging stage. It gradually declined and had the minimum in mature stage.

The total volume and average diameter had similar regular. In continuous cropping treatments, the index declined from seeding stage. They increased rapidly from flowering and pegging stage to pod-setting stage. After that, it declined to the minimum in maturing stage. All index decreased when rotation cropping was used.

After long-term experiment for 6 years, rotation cropping treatments increased total length, project area, superficial area, average diameter and total tips of root in comparison with continuous cropping. Is same as the results of WANG’s [6]. Rotational cropping is a kind of effective measures to relieve the continuous cropping obstacle [7], promote crop growth and increase yield [8]. It will balance the relationship between crop and soil and lead to the changes of agricultural ecological environment by using reasonable rotation cropping. The reason of rotational cropping can increase root properties may be related to it can improved soil biological properties. Yue’s [9] study found that AWCD value of soybean and tobacco rotation cropping was obviously higher than that of tobacco continuous cropping. Rotational cropping increased the soil microbial carbon source and utilization ability. Roots are the main parts of the plants absorb the moisture and nutrient. Good root growth can increase crop yield, therefore, rotational cropping is conducive to solve obstacles of continuous cropping and promote the sustainable development of agriculture.

3.2. The effect of different amendment on root properties

![Fig.7 total root length in different stages](image)

PC
PCBA
PCCA

Fig.7 total root length in different stages
Fig. 8 projected area in different stage

Fig. 9 superficial areas in different stages

Fig. 10. total root volume in different stages
From figure 7, the different treatments of total length of root in every stage was 8.06-48.71cm, 6.51-29.32cm, 5.86-11.55cm, respectively and the sequence was PCCA>PABA>PC. In flowering and pegging stage, it reached the longest with PCBA and PCCA treatments and in comparison with PCBA treatment, PCCA treatment was longer 66.13%.

The projected area of root with amendment 2 applied was bigger than in application of amendment 1 in all stages and they were 0.35-2.24cm² and 0.3-1.2cm². In flowering and pegging stage, the total length reached the maximum and PCCA treatment increased by 86.67% compared with PCBA treatment. Expect in pod-setting stage, the projected area with amendment applied was bigger than without it. The projected area was the biggest in pod-setting stage and it was 1.14cm². In comparison with PCBA and PCCA treatment, it increased by 78.13% and 31.03%, respectively.

In figure 9, in application of amendment 2, the superficial areas in all stages were bigger than amendment 1 applied. They were reached the biggest in flowering and pegging stage, 3.90cm² and 3.77cm², respectively. The superficial area of PCCA treatment was increased by 3.45% compared with PCBA treatment. Except in pod-setting stage, superficial area in all stage obviously smaller than application of amendment in comparison with there was no amendment applied. In pod-setting stage, it bigger than PCBA and PCCA treatment 74.15% and 28.36% compared with PC treatment.

Overall, the total volume was the biggest with amendment 2 applied treatment and no amendment used treatment was the smallest. The volume reached the maximum in pod-setting stage whatever
which treatments and they were 0.94 cm$^2$, 0.69 cm$^2$, 0.58 cm$^2$, respectively. It increased to 36.23% and 62.07% when amendment 2 used in comparison with amendment 1 applied and no amendment used treatment.

In figure 11, the average diameter was the biggest in flowering and pegging stage in PCCA and PCBA treatment and they were 0.16 mm and 0.07 mm. In comparison with application of amendment 1, the diameter with amendment 2 applied was increased by 128.57%. In other stage, it in PC treatment was bigger than in PCBA treatment.

The total tips of root when amendment 2, amendment 1 and no amendment applied were 5-28, 2-10, 1-4 respectively. The tips were the most in seeding stage in PCCA and PCBA treatment and it in PCCA treatment was more than 180% compared with PCBA.

Relative to no amendment applied, amendment can obviously improve the total root length, the projection area, surficial area, total volume, average diameter and tips of root directly. The more content of amendment used, the better the effect was. Reason may be that the peanut continuous cropping decreased the soil quality and single crop continuous cropping consumed soil nutrient which cannot even replenished. The amendment added nutrients for the growth of peanuts [10].

4. Results

1) The rotation cropping can improve total length, projected area, projected area, total volume, average diameter and tips of root in comparison with continuous cropping.

2) The amendment was helpful to increase total length, projected area, projected area, total volume, average diameter and tips of root. The more amendment was applied, the effect was better

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