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RESEARCH ARTICLE

Determining N supplied sources and N use efficiency for peanut under applications of four forms of N fertilizers labeled by isotope ^{15}N

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Abstract

Rational application of different forms of nitrogen (N) fertilizer for peanut (*Arachis hypogaea* L.) requires tracking the N supplied sources which are commonly not available in the differences among the three sources: root nodule, soil and fertilizer. In this study, two kinds of peanut plants (nodulated variety (Huayu 22) and non-nodulated variety (NN-1)) were choosed and four kinds of N fertilizers: urea-N ($CONH_2$-N), ammonium-N (NH_4^+-N), nitrate-N (NO_3^--N) and NH_4^++NO_3^--N labeled by ^{15}N isotope were applied in the field barrel experiment in Chengyang Experimental Station, Shandong Province, China, to determine the N supplied sources and N use efficiency over peanut growing stages. The results showed that intensities and amounts of N supply from the three sources were all higher at middle growing stages (pegging phase and podding phase). The accumulated amounts of N supply from root nodule, soil and fertilizer over the growing stages were 8.3, 5.3 and 3.8 g m^{-2} in $CONH_2$-N treatment, which are all significantly higher than in the other three treatments. At seedling phase, soil supplied the most N for peanut growth, then root nodule controlled the N supply at pegging phase and podding phase, but soil mainly provided N again at the last stage (pod filling phase). For the whole growing stages, root nodule supplied the most N (47.8 and 43.0%) in $CONH_2$-N and NH_4^+-N treatments, whereas soil supplied the most N (41.7 and 40.9%) in NH_4^++NO_3^--N and NO_3^--N treatments. The N use efficiency was higher at pegging phase and podding phase, while accumulated N use efficiency over the growing stages was higher in $CONH_2$-N treatment (42.2%) than in other three treatments (30.4% in NH_4^+-N treatment, 29.4% in NO_3^--N treatment, 29.4% in NH_4^++NO_3^--N treatment). In peanut growing field, application of $CONH_2$-N is a better way to increase the supply of N from root nodule and improve the N use efficiency.

Keywords: urea-N, growing stage, N fixation, N use efficiency, root nodule

1. Introduction

Peanut (*Arachis hypogaea* L.) as an important food legume, is the main oilseed crop in China (30% of the total production for oilseed crop) (Xiong *et al.* 2013). The nitrogen (N) absorption for peanut is not only from N fertilizer and soil but also from the symbiotic N_2 fixation (about 90 Tg yr^{-1}) of root nodule (Uchida and Akiyama 2013; Divito and Sadras 2014; Zhang *et al.* 2014). The three N supplied sources are all important for peanut growth and yield formation (Wang

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and Wan 2011). Hence studies are necessary to know the intensity, amount or percentage among the three N supplied sources: root nodule, soil or fertilizer.

Obviously, there were interactions among the three N supplied sources. Many studies indicated that N fertilization could decrease the N supply percentage from soil, moreover restrain the development and N fixation efficiency of root nodule. The root growth and synthesis of flavonoids (signal materials for nodulation) was decreased by high N application, thereby the recognition and infection of rhizobia to legume, e.g., peanut and common bean (*Phaseolus vulgaris* L.) was inhibited (Rai 1992; Basu *et al.* 2008). And negative correlation was showed between N fixation by root nodule and N fertilization amount. As the N input amount increasing, the ratio of N fixation by root nodule to plant N amount was declined (Zahran 1999; Wan *et al.* 2000; Sun *et al.* 2010). In addition, the use of ^{15}N isotope further confirmed the change in N fixation and its negative relationship with N fertilizer (Liu *et al.* 2011). For peanut, Daimon and Yoshioka (2000) and Zhang *et al.* (2012) also confirmed that long-term or high N input inhibited the formation of nodule, which would further decrease the N supply form root nodule. Different from other legume, there was not root hair in peanut, and N fertilization affecting intercellular gap in cortical cells of lateral roots might restrain the infection of rhizobia to peanut. Hence, proper N fertilization was very important to stimulate the formation of root nodule and promote the N fixation.

Except N fertilization amount, rational forms of N fertilizer as the key improved the plant N absorption and N fixation by root nodule. The response of rhizobia to N changed under different forms of inorganic nitrogen, which further influenced the nodule development (Caballero-Mellado and Martinez-Romero 1999). Thus differentiating the effect of N forms on peanut growth is very important for rational N management. In agriculture practice, urea-N ($CONH_2$-N), ammonium-N (NH_4^+-N) and nitrate-N (NO_3^--N) are conventional N forms for peanut growth while they always exert different effects on N absorption (Bollman and Vessey 2006; Lü *et al.* 2013; Sulieman *et al.* 2014). So far as the different forms of N fertilizers, selecting one form as high N use efficiency (NUE) is necessary for economic benefits and friendly environment.

However, little researches focused on the effect of these N fertilizers on the changes among the three N supplied sources. Therefore, clarifying the effect of different N fertilizers on N supplied sources and NUE for peanut is the one of keys to choose rational N forms and manage N in agricultural practices.

In our study, four kinds of N fertilizers: $CONH_2$-N (sourced from urea), NH_4^+-N (sourced from ammonia sulfate), NO_3^--N (sourced from potassium nitrate), NH_4^++NO_3^--N (sourced fromammonium nitrate) labeled by ^{15}N isotope were applied in the field barrel experiment in Chengyang Experimental Station, Shandong Province, China, which were used to determine the N supplied sources and NUE over four peanut growing stages of seedling phase, pegging phase, podding phase and pod filling phase. The results from this study will lead the development of effective N management strategy for peanut growth and yield.

2. Results

2.1. Dry matter production of peanut under various N fertilization treatments

Total dry matter production of peanut among all the four treatments obviously increased with growing stages (Fig. 1-A1–A3). During the podding phase (PoP), the accumulation rate (7.2–9.4 g m^{-2} d^{-1}) and amount (352.4–467.9 g m^{-2}) of dry matter was both higher than in other growing stages of seedling phase (SP), pegging phase (PeP) and podfilling phase (PFP). $CONH_2$-N promoted significantly the dry matter production of peanut during the first three stages of SP, PeP and PoP, compared with the other three treatments (P<0.05). But the dry matter production was decreased significantly under $CONH_2$-N during the stage of PFP. The accumulated dry matter production of peanut over the four growing stages ranked as: $CONH_2$-N (685.4 g m^{-2})>NH_4^+-N (652.5 g m^{-2})>NH_4^++NO_3^--N (626.5 g m^{-2})> NO_3^--N (582.3 g m^{-2}).

2.2. Intensity and amount of N supply for peanut under various N fertilization treatments

N supply from root nodule Fig. 1-B1 indicated that intensity of N supply from root nodule was obviously higher at the pegging and podding phases and in $CONH_2$-N treatment among the four peanut growing stages and four treatments. There was 37.8–96.2 mg N m^{-2} d^{-1} supplied for peanut absorption during the pegging phase and podding phase at the four treatments, which was higher than during seedling phase and pod filling phase (3.3–36.0 mg N m^{-2} d^{-1}). Meanwhile, intensity of N supply among the four treatments was ranked as $CONH_2$-N>NH_4^+-N>NH_4^++NO_3^--N>NO_3^--N over all the four peanut growing stages (P<0.05).

Root nodule supplied more N amount for peanut at podding phase (Fig. 1-B2). The amount of N supply at podding phase was 4.8, 3.6, 1.9 and 2.5 g m^{-2}, respectively in $CONH_2$-N, NH_4^+-N, NO_3^--N, and NH_4^++NO_3^--N treatments. At the other three growing stages, amounts of N supply were 0.5–2.1, 0.2–1.5, 0.1–1.2, and 0.1–1.3 g m^{-2}, respectively in $CONH_2$-N, NH_4^+-N, NO_3^--N and NH_4^++NO_3^--N treatments, which was lower than at the podding phase. The accumulated amounts of N supply from root nodule were increasing as the growing of peanut in the four treatments (Fig. 1-B3).