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RESEARCH ARTICLE

Nitrogen Nutrition Index and Its Relationship with N Use Efficiency, Tuber Yield, Radiation Use Efficiency, and Leaf Parameters in Potatoes

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Abstract

Knowledge about crop growth processes in relation to N limitation is necessary to optimize N management in farming system. Plant-based diagnostic method, for instance nitrogen nutrition index (NNI) were used to determine the crop nitrogen status. This study determines the relationship of NNI with agronomic nitrogen use efficiency (AE_N), tuber yield, radiation use efficiency (RUE) and leaf parameters including leaf area index (LAI), areal leaf N content (N_{AL}) and leaf N concentration (N_L). Potatoes were grown in field at three N levels: no N (N1), 150 kg N ha^{-1} (N2), 300 kg N ha^{-1} (N3). N deficiency was quantified by NNI and RUE was generally calculated by estimating of the light absorbance on leaf area. NNI was used to evaluate the N effect on tuber yield, RUE, LAI, N_{AL}, and N_L. The results showed that NNI was negatively correlated with AE_N, N deficiencies (NNI<1) which occurred for N1 and N2 significantly reduced LAI, N_L and tuber yield; whereas the N deficiencies had a relative small effect on N_{AL} and RUE. To remove any effect other than N on these parameters, the actual ratio to maximum values were calculated for each developmental stage of potatoes. When the NNI ranged from 0.4 to 1, positive linear relationships were obtained between NNI and tuber yield, LAI, N_L, while a nonlinear regression fitted the response of RUE to NNI.

Key words: potato, nitrogen nutrition index, N use efficiency, tuber yield, radiation use efficiency, leaf parameters

INTRODUCTION

Potato (*Solanum tuberosum* L.) is important as food and vegetable in China. In a lot of farm frites, advanced irrigation and management practice are used to cultivate high quality potatoes. Nitrogen deficiency limits crop growth, whereas N excess is often lost to the environment and resulted in pollution. There is often a mismatch between N supply and demand in farming system (Haraldsen *et al.* 2000).

Plant-based diagnostic methods for determining N deficiency can be used to improve the efficiency of N utilization and reduce the risks of N losses to the environment. These diagnostic methods should be based on the definition of critical N concentration, which is the minimal N concentration required to achieve maximum crop growth (Lemaire *et al.* 2008).

In order to quantify crop responses to N deficiency, a nitrogen nutrition index (NNI) was proposed, defined as the ratio between the actual plant N concentration (%N) and the critical plant N concentration (%Nc)

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corresponding to the same biomass of the crop, where the critical crop N barely limited the growth rate of the crop (Lemaire *et al.* 2008). The critical crop N can be derived from the relationship between crop N uptake and dry matter production (Lemaire *et al.* 1989). NNI has been proposed on this basis to define the N status of the plant. Values of NNI⩾1.0 indicate that N supply to the crop is non-limiting or in excess, while values of NNI<1.0 indicate N deficiency (Lemaire *et al.* 2008). It was found that NNI was positively correlated with potato tuber yield and relative seed yield and negatively correlated with nitrogen use efficiency (NUE) and N uptake efficiency in linseed (Belanger *et al.* 2001; Christos 2011).

Optimization of N management requires the knowledge of the response of crop growth processes to N. Crop production is not only dependent on light interception, but also on radiation use efficiency (RUE), the ratio between the amount of radiation intercepted and gain in total plant dry weight during a particular time interval (Monteith 1972). When plant suffers N deficiency, N content in the plant is lower and carbon accumulation is negatively affected. The reduction in biomass production in response to N deficiency is associated with either a reduction in total radiation intercepted by the canopy, or by a decrease in the efficiency with which the intercepted radiation is used to produce dry matter, or a combination of both (Muchow and Davis 1988). Theoretical studies and experiments showed that leaf area index (LAI) of potato was very responsive to N supply, whereas RUE was found to be insensitive to N supply (Vos and Putten 1998). Some studies also found that RUE was significantly reduced by N deficiency, such as maize, rice, and winter oilseed rape (Vos and Putten 2005; Li *et al.* 2012). Nitrogen can affect RUE by an effect on average N_{AL} (Hammer and Wright 1994). The response of leaf parameters including LAI, N_L and N_{AL} to N deficiency varied in potato and maize (Vos and Putten 1998, 2005). Most of the previous studies on farming system N management focused on partly plant N nutrition diagnostic methods. There is rare information about NNI and RUE and also the relationship between NNI and growth components. The objectives of the present work are 1) to quantify NNI and RUE of different N treatments in whole growth stage of potato in farming system; 2) to establish relationships of NNI to agronomic nitrogen use efficiency (AE_N), tuber yield, RUE, and leaf parameters.

RESULTS

Nitrogen concentration and AE_N

Nitrogen concentration in whole plants, leaves and stems differed significantly in three N treatments in 56 and 98 DAE (days after emergence). Compared with the control (N1), the N_{TDM} of N1 and N2 which were affected by N fertilization were increased by an average of 11.1 and 63.6% at 56 DAE, respectively. And the values of 98 DAE were increased by 44.0 and 60.1%, respectively. The N_L, N_S and N_{TDM} decreased with the growth of potato plant. Compared with that of 56 DAE, the N_{TDM} of 98 DAE significantly decreased by an average of 43.3, 31.4 and 32.7% in N1, N2 and N3, respectively (Table 1). Even N_T have no difference among N1, N2 and N3, the N_T of N3 was higher than that of N1 in both sampling dates (Table 1). The AE_N of N2 was always higher than that of N3.

Tuber yield and yield components

There was a clear effect of N fertilization on tuber yield at 98 DAE (harvest), the yield of N2 and N3 were increased by an average of 30.5 and 54.0%, respectively compared with N1. However there was no significant difference between N2 and N3 at 56 DAE (Table 1). The tuber yield *vs*. thermal time is shown in Fig. 1-B. Cumulative absorbed photosynthetically active radiation (Cum. PARa) was increased with N fertilization, so it was the same with total dry matter (TDM), compared with N1, TDM of N2 and N3 increased by an average of 24.6 and 58.9%, respectively at 98 DAE. Harvest index was significantly decreased with the N fertilization increasing at 56 DAE, however there was no clear relationship between HI and N treatments at 98 DAE (Table 1). Table 2 lists the values of RUE from different sampling dates. The RUE significantly varied with the development stage and also with the N treatment, ranged between 1.29 and 2.81 g MJ^{-1}. At the beginning and the end of the growing period, the RUE of each treatment had a relative low value.

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