Carbon Requirements of Leguminous Plants Receiving Different Nitrogen Nutrition

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There are different opinions concerning the carbon requirements of legumes at symbiotic dinitrogen fixation in comparison to mineral nutrition. Besides information on equal C-demands /HARDY and HAVELKA, 1975/ results were published about higher energy requirements of air dinitrogen binding by legume-Rhizobium symbioses /SILSBURY, 1977/. In the present paper the carbon consumption of N_2 fixation and nitrate assimilation is compared taking white lupin /Lupinus albus L./ as an example in experiments carried out at the University of Halle.

Materials and methods

White lupins /var. kievskij mutant/ were cultivated in Mitscherlich vessels containing soil as substrate until they had 8-10 leaves each /MERBACH, 1982/. After this the plants were kept for several days under the conditions of 12 h light /40 klx/ and 12 h dark in order to obtain a steady state balance. According to MCCREE and SILSBURY /1978/ in this case the following equation is valid:

$$D_o = \Delta TS + N_W + N_E$$

where: D_o = apparent CO_2 assimilation in light /mg CO_2 influx per light period of 12 h/;
ΔTS = dry matter increase per day in CO_2 equivalents;
N_E = maintenance respiration /mg CO_2 efflux per dark period of 12 h after prolonged darkness of > 24 h and consequently after consumption of short time assimilate reserves/ and
N_W = growth respiration /use for biosynthesis processes/.

From these components D_o, N_E and ΔTS were determined experimentally, N_W was calculated after $N_W = D_o - (N_E - \Delta TS)$. The estimation of D_o and N_E was carried out by means of CO_2 gas exchange analysis /IRGA method, open system/. Root respiration /N_{Wu}/, too, was measured. ΔTS was obtained as the difference between the plant dry matter yield at the termination and beginning of the experiment /preharvest as starting point/. In order to convert

ΔTS into CO_2 equivalents the carbon content of dry matter was determined using the method described by JACKSON /1958/. The carbon content of the lupin dry matter amounted to 39.1% and consequently, the conversion factor from dry matter to CO_2 was 1.43.

Results

As it is evident from Table 1, the N_2 fixing plants showed a significantly higher apparent CO_2 assimilation /D_o/, growth respiration /N_W/, and

Table 1

Apparent CO_2 assimilation /D_o/, maintenance respiration /N_E/, growth respiration /N_W/, root respiration /N_{Wu}/, and C-demands of the N-assimilation at different nitrogen nutrition /mean values from 6 replications/

Components	NO_3^- nutrition /0.4 g N as $NaNO_3$ per pot/	N_2 fixation without N, inoculation with Rhizobium lupini	/N_2-NO_3^-/
D_o mg CO_2/12h/$^{-1}$.g^{-1}ΔTS	2135 /100/	2365 /111/^{x}	230
N_E mg CO_2/12h/$^{-1}$.g^{-1}ΔTS	230 /100/	232 /101/	2
N_W mg CO_2/12h/$^{-1}$.g^{-1}ΔTS	312 /100/	527 /169/^{x}	215
N_{Wu} mg CO_2/12h/$^{-1}$.g^{-1}ΔTS	236 /100/	461 /195/^{x}	225
g C per g N	3.6 /100/	7.0 /194/^{x}	3.4

x = vs. NO_3^- variant with $\alpha = 0.05$ significant /variance analysis, t-test, single calculation/

root respiration /N_{Wu}/ than the nitrate assimilating plants while synthesizing 1 g dry matter. In contrast, the values of maintenance respiration /N_E/ did not differ between the two variants. It is interesting to note that the increases /N_2 - NO_3^-/ in D_o, N_W and N_{Wu} /Table 1/ were nearly equal.

The C demand per g of fixed N_2 /7 g/ was much higher than the C requirement per g of assimilated nitrate-N /3.6 g/. Similar information is given by other investigators /PATE et al., 1979; MINCHIN et al., 1980/. Consequently, the actually assayed carbon requirement for symbiotic N_2 fixation was higher than the theoretic values calculated to 2.57 until 4 g C /PHILLIPS, 1980; HARDY and HAVELKA, 1975; SHANMUGAN et al., 1978/. This is caused mainly by the energy demands, necessary for nodule formation and maintenance /MERBACH, 1982/. The dinitrogen fixing plant needs consequently more energy /carbon/ than the nitrate assimilating plant to synthesize the same amount of substance although NO_3^- nutrition demands relatively much energy. Therefore effective N_2 fixation requires essentially sufficient assimilate providing. This fact has to be considered at the development and selection of more productive Rhizobium-plant-symbioses.

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