Using ^{15}N to measure N fertiliser efficiency in fertigated and drip irrigated pepper and melon crops

Martínez-Gaitán[1] C., Thompson[1] R.B., Gallardo[1] M., Granados[2] M.R., Fernández[2] M.D., Giménez[3] C.

[1]*Dept. Crop Production, University of Almeria, 04120 La Cañada, Almeria, Spain*
[2]*Research Station of the Cajamar Foundation, P.O. Box 250, 04080 El Ejido, Almeria, Spain*
[3]*Dept. Agronomy, University of Cordoba, 14080 Cordoba, Spain*
email: cmgaitan@ual.es

Abstract

^{15}N was used in field experiments to measure N fertiliser efficiency of sweet pepper and melon crops receiving N fertiliser through fertigation and drip irrigation. Two combined irrigations and N fertilisation managements were evaluated, being conventional local management and improved management. Nutrient solution containing ^{15}N-labelled $Ca(NO_3)_2$ was applied at two growth stages (rapid vegetative growth and late fruit production), using inverted polyethylene bottles fitted with intravenous drippers. ^{15}N uptake was determined in above-ground biomass from plants directly receiving ^{15}N-labelled nutrient solution and from each adjacent plant on either within the same crop row. ^{15}N recoveries varied between 44 and 82%. Notable amounts of ^{15}N were recovered in the two adjacent plants indicating lateral movement within the same crop row. Appreciable redistribution of ^{15}N absorbed from vegetative growth to fruit occurred.

Background and objectives

The greenhouse-based vegetable production system of south-eastern Spain has 27,000 ha of simple plastic greenhouses in the province of Almeria and an estimated additional 10,000 ha in adjoining coastal provinces (Castilla and Hernández, 2005). Eighty percent of cropping occurs in soil, the rest in “open” hydroponic systems. This industry is associated with considerable nitrate (NO_3^-) contamination of underlying aquifers. In this system, N management is based on experience, and NO_3^- is the most commonly-used form of fertiliser N applied (Thompson *et al.*, 2007). The combined use of drip irrigation, fertigation and computer-controlled programmers provides the technical capacity for precise N management, which would reduce NO_3^- leaching loss. Simulation models are being used to estimate the daily N fertiliser requirements based on N uptake (Granados *et al.*, 2007). These approaches require N fertiliser efficiency values, which are currently not available for this system.

The objective of this work was to develop the appropriate procedures and to use ^{15}N to assess the N fertiliser efficiency of sweet pepper and melon crops receiving N fertiliser through fertigation and drip irrigation.

Materials and methods

The field experiments were conducted in two identical plastic greenhouses in a clay soil in Almeria, SE Spain (36º48´N, 2º43´W). Pepper (*Capsicum annum*, L. convar. ´Vergasa´) and melon (*Cucumis melo*, L. convar. ´Deneb´) crops were grown during, respectively, 21 July–14 December 2005 and 14 February–22 May 2006, following transplanting as 6-week old seedlings. Above-ground drip irrigation was used, with one dripper immediately adjacent to each plant. Plants were grown in rows, with 0.5 and 1.0 m spacings within and between rows, respectively. Complete nutrient solutions were applied in all irrigations, with approximately 90% of N as $Ca(NO_3)_2$, the rest as $NH_4H_2PO_4$, as is local practice.

Two combined irrigation and N fertilisation management systems were used for pepper, one each in each greenhouse, being conventional management (CM-P) and improved management (IM-P). CM-P was based completely on local practices. For IM-P, irrigation management was based on estimated ET_c and maintenance of soil matric potential within -40 to -10 kPa; the applied NO_3^- concentration was 40% less than in CM (average applied NO_3^- concentrations were 7 m*M* in IM-P vs. 11 m*M* in CM-P). Improved management was used with melon; irrigation management was as in IM-P, and N fertiliser management was based on a locally-developed model of crop N uptake (Granados *et al*., 2007), the average NO_3^- concentration in applied nutrient solution being 11 m*M*.

For each management system, four replicate individual plants directly received nutrient solution containing ^{15}N-labelled $Ca(NO_3)_2$ (18 and 16 atom % excess ^{15}N in pepper and melon crops, respectively) for three consecutive days. In pepper, ^{15}N was applied 27–29 September 2005 during rapid vegetative growth. In melon, ^{15}N was applied, to crops receiving improved management, at two different growth stages: (i) 4–6 April 2006 during the rapid vegetative growth phase (RVG-M) and (ii) 25-27 April 2006 during the late fruit production phase (LFP-M). ^{15}N-labelled nutrient solution was applied using inverted 1.5 L polyethylene bottles fitted with intra-venous drippers. Applied volumes and nutrient concentrations were identical to those being applied to the crops being grown throughout each greenhouse. A 1 m long x 22 cm high sheet metal plate was inserted into the soil midway between adjacent rows of plants/drippers to 20 cm depth, to prevent uptake by plants in adjacent rows. After final harvest, all plant material from the plants directly receiving ^{15}N-labelled nutrient solutions (DLP) and from each plant immediately adjacent on both sides within the same crop row (AP) was assessed for N content and ^{15}N enrichment.

Table 1. Volume of ^{15}N-labelled nutrient solution applied (V) and the amount of ^{15}N-labelled N applied (LNA) at each labelling, and the total amount of mineral N applied throughout the entire crop for the pepper and melon crops being studied.

Pepper crop				Melon crop			
Manage-ment	V (mm)	LNA (kg N ha^{-1})	TNA (kg N ha^{-1})	Applic-ation	V (mm)	LNA (kg N ha^{-1})	TNA (kg N ha^{-1})
CM-P	11	3.4	461	RVG-M	11	2.7	310
IM-P	11	2.3	266	LFP-M	14	6.6	310

Results and discussion

The mean combined recovery of ^{15}N in above-ground biomass of the directly-labelled and two immediately adjacent pepper plants was, respectively, 82 and 66% for the IM-P and CM-P treatments (Table 2). In the IM-P treatment, 70 and 12% of the crop-recovered ^{15}N were, respectively, in the directly-labelled and two adjacent plants. The respective percentages for the CM-P treatment were 51 and 15%. These data demonstrated that improved management practices appreciably increased the recovery of ^{15}N, and that notable lateral movement of applied N occurred. They suggested that approximately one third of applied NO_3^--N with conventional management is not recovered by pepper crops.

The mean recovery of ^{15}N in above-ground biomass of the directly-labelled and two immediately adjacent melon plants was, respectively, 63 and 44% for the RVG-M and LFP-M applications (Table 2). In the RVG-M application, 54 and 9% of the crop-recovered ^{15}N was, respectively, in the directly-labelled and two adjacent plants. The respective percentages for the LFP-M application were 31 and 14%. These data indicate that the crop recovery of ^{15}N-NO_3^- was lower during fruit production than during vegetative growth, and that notable lateral movement of applied NO_3^--N occurred. With the RVG-M application, there was a higher ^{15}N recovery and less lateral movement than with the LFP-M application.

Table 2. Percentage of crop-recovered ^{15}N from ^{15}N-labelled nutrient solution applied to pepper and melon crops. The values presented are the average of four replications.

Pepper crop						Melon crop					
CM-P			IM-P			RVG-M			LFP-M		
DLP	AP	TOTAL	DLP	AP	TOTAL	DLP	AP	TOTAL	DLP	AP	TOTAL
51	15	66	70	12	82	54	9	63	31	14	44

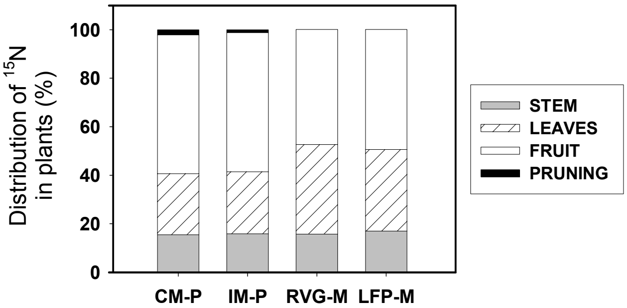

Figure 1.Distribution of crop-recovered ^{15}N in pepper (P) and melon (M) crops.

There was a considerable redistribution of absorbed ^{15}N to fruit, from all applications (Figure 1). This occurred even from applications during rapid vegetative growth and despite that the amounts of ^{15}N-labelled N applied were only 0.7–2.1% of total applied N.

Conclusions

Recoveries of ^{15}N from ^{15}N-labelled $Ca(NO_3)_2$ varied appreciably between 44 and 82%. Higher recoveries were associated with: (i) improved compared to conventional management practices, and (ii) applications during rapid vegetative growth compared to during late fruit production. Notable lateral movement of applied ^{15}N occurred which was higher with conventional management practices. There was a considerable redistribution of absorbed ^{15}N during vegetative growth to fruit.

Acknowledgements

This work was funded by the Spanish Ministerio de Educación y Ciencia, Project No. AGL2004-07399.

References

Castilla N., Hernández J., 2005. The plastic greenhouse industry of Spain. Chronica Horticulturae, 45(3), 15-20.

Granados M.R., Thompson R., Fernández M.D., Martínez-Gaitán C., Gallardo M., Giménez C., 2007. Reducing nitrate leaching with a simple model for nitrogen and irrigation management of fertigated vegetable crops. In: Proceedings of 15th N Workshop. University of Lerida Foundation. Llerida, Spain. 28-30 May 2007.

Thompson R.B., Martínez-Gaitán C., Gallardo M., Giménez C., Fernández M.D., 2007. Identification of irrigation and N management practices that contribute to nitrate leaching loss from an intensive vegetable production system by use of a comprehensive survey. Agricultural Water Management, 89, 261-274.