Determination of an optimal nitrogen concentration threshold in the root zone for fresh-market spinach

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Full Title of the Summary
Determination of an optimal nitrogen concentration threshold in the root zone for fresh-market spinach

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Spinacia oleracea L., nitrogen, fertilization, crop sustainability

Summary
Introduction. Nitrogen (N) fertilization influences both yield and quality of spinach (*Spinacia oleracea* L.) as N availability in the root zone is positively correlated with biomass production, tissue concentration of minerals and antioxidants, and others commercial quality attributes such as leaf colour and wrinkledness. On the other hand, excessive N supply can lead to nitrate accumulation in edible plant organs, increased fertilization costs and environmental pollution due to nitrate leaching. In this work we analyzed the results of eight experiments conducted from 2007 to 2011 with spinach grown in open field under Mediterranean climate conditions. The main target of the work was to identify the optimal N concentration to be maintained in the root zone for sustaining crop yield and quality without N waste.
Materials and Methods. Eight experiments were carried out between September 2007 and April 2011: in each experiment two or more N doses (from 0 to 160 kg ha^{-1}) were applied. The different doses were established on the basis of pre-sowing and post-emergence analysis of soil samples taken in the 0-0.4 m soil profile according to standard protocols. Plant material was also collected during the cultivation and at harvest for the determination of biomass production, produce quality and tissue mineral content. Dry biomass production was plot against soil mineral N concentration (N_{min}) and fit with a segmented linear model. In this model, biomass production (Y) is assumed zero if N is ≤ to a minimum threshold (N_0). Above N_0, Y increases linearly with N_{min}: the optimal N concentration (N_{opt}) is the N_{min} above which Y does not increase significantly with respect to maximum Y.
Results and Conclusions.
During the whole experimental period climate variables mainly differed for cumulative radiation, photothermal units (PTU) and rainfall. Minor differences were found for mean daily air temperature and cumulative thermal time (GDD). The different climate conditions during the eight experiments influenced both crop yield and N_{min}. To minimize the effect of the climate on crop response to N_{min}, the yield was normalized on the basis of the photothermal units (Y_{PTU}). The hypothesis of a positive relationship between Y_{PTU} and N_{min} was verified by experimental data. Maximum Y_{PTU} was estimated through ANOVA (73.0 mg $°C^{-1}$ MJ^{-1}) as the average of those values that not differ significantly from the highest Y_{PTU} found. This quantity was finally used for the normalization of Y_{PTU} obtaining a coefficient (Y^*_{DW}) that represents the

yield as a proportion of the maximum yield (Fig. 1). Data were then fit with the segmented linear model, which explained 89% of measurement variability (Fig. 1). Using this model, N_{opt} was estimated to be 139.7 kg ha^{-1}, which corresponded to an average soil content of 24.1 mg kg^{-1} dry soil (in the 0-0.4 m profile), while N_0 was 37.0 kg ha^{-1} or 6.4 mg kg^{-1} dry soil. Suboptimal N_{min} reduced leaf colour (SPAD index), N and Mg tissue content, while increased leaf dry matter percentage at hatrvest (Table 1).
In conclusion, a value of N_{opt} was determined for spinach cultivation in the coastal area of Tuscany (Italy) under typical Mediterranean climate growing conditions. This value can be used to design N fertilization decision support systems for N fertilization consisting of simple factsheets to interactive computer programs.

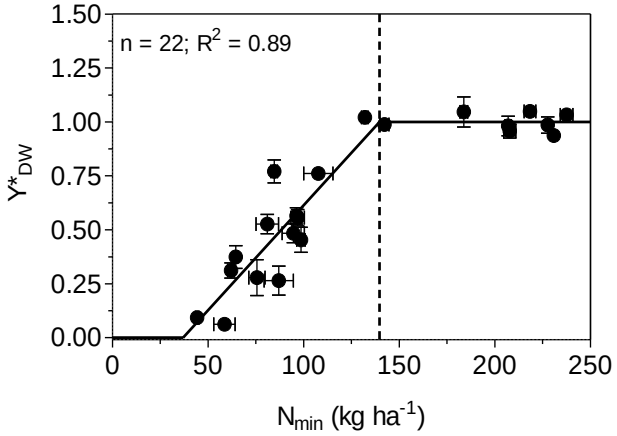

Fig. 1 Relationship between Y^*_{DW} and N_{min}. Measurements (mean of four replicates ±SE) are fit with a segmented linear model (line). Dotted line represents N_{opt}.

Parameter	N-	N+	ANOVA
SPAD	55.29±0.5	63.22±0.53	***
Nitrates	0.72±0.05	1.01±0.05	*
Dry matter	12.0±0.36	10.8±0.07	**
N	3.34±0.11	3.93±0.07	***
Ca	0.99±0.05	1.00±0.04	ns
Mg	0.63±0.04	0.82±0.03	***

Tab 1. Effect of $N_{min}<N_{opt}$ (N-) and $N \geq N_{opt}$ (N+) on leaf parameters of spinach. Units: SPAD, dimensionless; nitrates, g kg^{-1} FW; dry matter, %; N, Ca and Mg, g $100g^{-1}$ DW. ns, *, **, ***: non-significant, or significant at $P \leq 0.05$, 0.01 and 0.001, respectively.