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Quantitative sidedress nitrogen recommendations for potatoes based upon crop nutritional indices

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Abstract

The quantification of sidedress N rate from in-season information on crop N nutritional status is extremely important in order to use only the necessary amount of nutrient to achieve maximum yields without significant N losses from soil. During three consecutive years (1996, 1997 and 1998) field N fertilizer experiments with irrigated potato (*Solanum tuberosum* L., cv. Désirée) were conducted in Bragança (NE Portugal). Eight preplant treatments (0, 50, 100, 200 and 300 kg urea-N/ha and poultry manure, farmyard manure and municipal solid waste in rates equivalent to 100 kg organic-N/ha) were arranged as main plots and five sidedress N rates (0, 25, 50, 100 and 200 kg urea-N/ha) included as subplots. Petiole nitrate concentration, determined by a laboratory method (PNLab, g NO_3-N kg^{-1}, dry weight basis) and by the portable RQflex reflectometer (PNRQflex, mg NO_3 kg^{-1}, from fresh tissues), and leaf N content (LeafN, g kg^{-1}, dry weight basis) were used as N nutritional indices. From the five sidedress N rates applied over each of the preplant treatments, critical sidedress N rates were estimated for several different crop N nutritional status. This was achieved by establishing exponential asymptotic curves between sidedress N rates and tuber yields and solving the equations for 95% of maximum tuber yield. In a second step, multiple regression equations were established between the estimated critical sidedress N rates (SNrate, kg N/ha), as dependent variable, and each crop N nutritional indices (PNLab, PNRQflex or LeafN) and days after emergence (DAE). The equations obtained are:

$\text{SNrate} = 182.7 - 4.146 \times \text{PNLab} - 1.87 \times \text{DAE}$

$\text{SNrate} = 161.0 - 0.013 \times \text{PNRQflex} - 1.34 \times \text{DAE}$

$\text{SNrate} = 562.2 - 8.416 \times \text{LeafN} - 3.59 \times \text{DAE}$

These equations provide quantitative sidedress N rates for any level of crop N nutritional indices and sampling dates from 10 to 48 days after emergence.

Keywords: *Solanum tuberosum*; Crop N management; Decision support system; Plant analysis; Tissue testing

1. Introduction

Nitrogen is an important ecological factor. Its beneficial effects on crop growth are unquestionable, but if it

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is used in excess could lead to environmental contamination. Thus, the continuous improvement in fertiliser-N recommendation programs is recognized worldwide. The main limitation in several N recommendation systems all over the world is the estimation of soil contribution to N nutrition of crops. In fact, reliable laboratory methods of soil analysis of universal acceptance and widespread use, providing information concerning soil N availability, are not yet developed. The problem arises from the difficulty in preventing the time and rate of mineralization of soil organic substrates (Dahnke and Johnson, 1990).

The uncertainty of fertiliser-N recommendations performed from soil analysis, before the start of the growing season, and the high efficiency of N used at sidedress (Westermann et al., 1988), have given importance to fertilizer-N recommendation systems that include information taken during the growing season. Thus, an acceptable strategy for N management seems to be the application at preplant of a part of N expected to be needed with the necessary adjustments as sidedress (Ojala et al., 1990; Porter and Sisson, 1991). Plant analysis or tissue testing allow assessing the crop nutritional status and, consequently, can be used to make in-season N fertilization adjustments in order to better balance N rates with crop needs.

The results of plant analysis are often interpreted by critical levels or sufficiency ranges previously defined for a given crop and for specific growing stages. The critical level identifies the crop nutritional status, above which there is no need to add more N and vice versa, but not informs about the amount of nutrient to apply. Lemaire and Gastal (1997) developed the nitrogen nutrition index (NNI), which could diagnose the intensity of N deficiency, as well as situations of luxury consumption. The NNI can be determined, for any crop and at any time, as the ratio between the actual plant N% and the critical plant N% corresponding to adequate crop growth. Nitrogen nutrition index values close to 1 identify situations of non-limiting N supply. Values greater than 1 indicate luxury consumption. The closer the value is to 0, the greater the intensity of the N deficiency. However, in order to improve the accuracy of N recommendation programs, there is a pressing need for methodologies that truthfully quantify sidedress N rates from crop N nutritional indices or in-season soil tests. Attempts have already been made, namely by Baethgen and Alley (1989). Being one of the first and most interesting, this uses plant N concentration and crop N uptake as N nutritional indices in winter wheat. This, was followed by Singh (1993) in potato with petiole nitrate content and by Piekielek et al. (1995), Heckman et al. (1996) and most recently by Scharf (2001) on corn using, respectively, chlorophyll–SPAD readings, the pre-sidedress soil nitrate test and total N in whole plants and chlorophyll–SPAD readings. Their methodological basis consisted in establishing a relationship between the level of crop or soil N indicators and optimal sidedress N rates, for well-defined sampling dates.

The present study was conducted to quantify sidedress N rates for potato, based on two in-season crop N nutritional indices: the petiole nitrate concentration and leaf N. The main improvement from previous work is that quantified sidedress N recommendations are presented not for particular sampling dates, but continuously for the first part of the growing season, between 10 and 48 days after emergence, while N use efficiency is high.

2. Material and methods

2.1. Field experiments and laboratory analysis

The survey was conducted between 1996 and 1998 in North-eastern potato-growing region of Portugal (41 °N latitude and 6 °W longitude), with a Mediterranean-type climate, hot and dry during the summer growing season. Irrigation is a must for successful potato growing. The soil is a eutric Cambisol, loamy textured, with pH(H_2O) of 6.5 and organic matter content of 15 g kg^{-1}. Extractable P and K (ammonium lactate and acetic acid) ranged from 20 to 49 mg kg^{-1} and 84 to 149 mg kg^{-1}, respectively. Previous crops were corn for silage in summer followed by triticale for silage, grown as winter inter-crop.

The field experiments were arranged as a split-plot design. The main plots consisted on the following eight preplant N treatments: 0, 50, 100, 200 and 300 kg urea-N/ha and poultry manure, farmyard manure and a municipal solid waste, applied in variable rates corresponding to 100 kg organic-N/ha. The main plots were split into subplots to include five sidedress N rates (0, 25, 50, 100 and 200 kg urea-N/ha). In 1996 and 1997, the sidedress treatment of 200 kg N/ha was not applied