Research Perspective on Nitrogen BMP Development for Potato

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ABSTRACT

Nutrient best management practices (BMPs) are developed to optimize tuber yield and quality, and also to reduce environmental losses of nutrients. Nitrogen (N) management is important both in controlling potato growth and development and in minimizing the risks of groundwater contamination by nitrate and emissions of nitrous oxide, a greenhouse gas. Development of BMPs for N management must consider variation in the magnitude and timing of both N supply and crop N demand. Consequently, these BMPs must reflect differences among potato cultivars, soil properties, cropping systems, water management, and climatic conditions. Despite decades of research, selection of the appropriate rate and timing of fertilizer N application remains a challenging task. A greater understanding of soil N cycling, the development of test-based N recommendation systems, improvements in controlled-release fertilizer technology, and opportunities for spatially variable N management may provide new answers to the old question of “How much N do I apply to my potato crop, at what growth stage, and in what form?”

INTRODUCTION

Growers must produce commercial potato crops with high tuber quality in a cost-efficient manner to compete in global markets. Increasingly, growers are challenged to do so while minimizing the environmental impact of potato production. Nitrogen (N) and phosphorus (P) are the two nutrients of greatest economic and environmental significance. Because of the breadth of information available for N, this article will focus on recent developments in N management in potato production. Nitrogen management will be discussed both in terms of crop production, including crop growth, yield and quality, and in terms of environmental losses of N. This article will complement previous reviews of N or nutrient management of potato (Harris 1992; Haverkort and MacKerron 2000; Alva 2004; Munoz et al. 2005; Davenport et al. 2005) by focusing on existing and emerging best management practices (BMPs).
which may have the potential to improve the efficiency of N utilization in potato production, thereby reducing the risk of environmental losses of N. These BMPs are generally defined as economically sound, voluntary practices that are capable of optimizing production and minimizing nutrient contamination of surface and groundwater.

NITROGEN IN CROP PRODUCTION

Of all the essential elements, N is the one most often limiting for potato growth. Application of fertilizer N is usually necessary to ensure profitable potato production because most N in soil is present in organic form in soil organic matter and crop residues and is not readily available for plant uptake. This section will focus on the agronomic impacts of N utilization in potato production, thereby reducing the risk of which may have the potential to improve the efficiency of N utilization. Under conditions of adequate N supply, potato yield has been found to be influenced by other climatic variables, including temperature (Van Heemst 1986), while other studies have presented potato dry matter accumulation as a function of light interception, emphasizing the importance of canopy development for maximum light interception (Allen and Scott 1980). The relationship between radiation interception and dry matter accumulation has, however, been found to be influenced by other climatic variables, including temperature (Manrique et al. 1991). In more recent studies, Yuan and Bland (2005) reported that both temperature and incoming radiation were important factors affecting potato yield. Under conditions of adequate N supply, potato yield was found to be sensitive to temperature early in crop development and to photosynthetically active radiation during tuber bulking. Cool temperatures early in the season tend to delay vegetative growth and subsequent canopy development. Potatoes grown in climates with shorter growing seasons would be particularly sensitive to cool temperatures early in the season because the total season may not long enough for growth to reach full maturity. Once the canopy is developed, incoming radiation would then be the growth-limiting factor. Any factor that affects canopy development (e.g. moisture, nutrients, disease etc.) will also affect the ability of the leaves to intercept radiation.

Nitrogen supply plays a critical role in canopy development and dry matter accumulation. Plant growth is regulated by the relative internal supplies of C and N (Lemaire and Millard 1999). In addition, plants tend to optimize the N concentration per unit leaf area (Grindlay 1997). Nitrogen deficient plants partition N differently than N sufficient plants. A higher percentage of N is translocated to the tubers in N deficient plants compared with N sufficient plants (Millard et al. 1989). An adequate supply of N is required to achieve a canopy capable of intercepting high amounts of incoming radiation.

Potato tuber yield can be considered as a function of stem density per unit area, tuber number per stem, and mean tuber mass (De la Morena et al. 1994). Stem density and, to a lesser extent, tubers per stem are most affected by cultivar and physiological age of the seed (Allen and Scott 1992). Nitrogen fertilization was found primarily to increase tuber mass with little or no effect on stem density and inconsistent effects on tubers per stem (De la Morena et al. 1994). Almost all studies have shown positive effects of N application on marketable tuber yield; however, the rate of fertilizer N required to achieve optimum yield varies with site, growing conditions, disease incidence, and crop management (Bélanger et al. 2000a; Joern and Vitosh 1995a; Miller and Rosen 2005).

In addition to growth processes, the physiological process of tuberization itself is affected by numerous factors, the most important being light, temperature, and N supply (Jackson 1999). The grower has limited control over the light and temperature, but significant control over N supply. While specific effects of these factors are somewhat related to cultivar, it is not surprising that growth and ultimate yield can vary greatly depending on climatic conditions and N supply. It is therefore important that BMPs provide the necessary flexibility to modify fertilizer N management to respond to differences in crop growth among fields and years.

There is a strong link between plant N uptake and total dry matter accumulation (Vos 1995). Westernmann (1993) divided growth of the potato crop into five general stages, with each stage having a different N requirement. The length of each stage depends upon cultivar as well as climatic/environmental conditions. A generalized growth and N uptake pattern for a 'Russet Burbank' crop with an abundant fertilizer N supply under Midwest USA conditions is shown in Fig 1.

Stage I is the sprout development stage, and occurs within the first 30 days after planting. The seed tuber is the primary source of nutrients and energy for the developing shoot during this stage and soil N uptake is minimal. Growth stage II, occurring between 30 and 55 days after planting, is the vegetative