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Effects of nitrogen fertility and crop rotation on onion growth and yield, thrips densities, Iris yellow spot virus and soil properties

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ABSTRACT

Onion thrips and Iris yellow spot virus (IYSV) are two primary yield reducing factors in onion production worldwide. Current management practices rely on heavy use of insecticides and fertilizers, threatening the sustainability of onion systems. Little is known about how cultural practices such as reduced fertility, soil biostimulants, and crop rotation affect onion yield, thrips densities, soil properties, and IYSV incidence. In a replicated field experiment, reduced nitrogen (N) (134 kg N ha^{-1}, one-third the standard grower rate), slightly decreased yield and onion size. Adult thrips populations were 23 to 31% lower in the reduced as compared to standard N (402 kg N ha^{-1}) and biostimulant treatment, respectively. Growing onions following a one year cycle in corn rather than wheat reduced onion thrips in one of two years. The addition of a biostimulant had no effect on soil properties, but may have slightly increased yield, attracted adult thrips, and increased thrips populations. IYSV incidence was not influenced by fertilizer rate or crop rotation. Soil microbial biomass and readily mineralizable carbon were greater following wheat, while soil nitrate (NO_3^-) accumulation was greater in standard N treatments. Soil microbial activity, as measured by dehydrogenase enzyme potential, may have been adversely affected by high N rates. Results suggest that reduced N, without biostimulant, sustained onion yields, decreased onion thrips densities and potential for IYSV incidence, created a more favorable soil environment for microbial activity, and reduced the risk of NO_3^- leaching

1. Introduction

Allium cepa L., bulb onion, is a high value crop grown in the western United States and in many regions of the world. Farmland planted annually to onions in Utah exceeds 800 ha with a value between 4 and 10 million dollars (NASS, 2006). Due to the value of the crop, onions are intensively managed, frequently with short rotations, high fertilizer rates, and aggressive use of insecticides to suppress *Thrips tabaci* Lindeman, onion thrips (OT). Despite intensive management, yield loss due to thrips and diseases can be severe (Kendall and Capinera, 1987; Gent et al., 2006). Primary thrips control in the temperate U.S. is through almost weekly applications of several classes of insecticides, including pyrethroids, carbamates, spinosyns, and others from June through August (DeFrancesco, 2012). As a result, high input costs, removal of beneficial insects, and increased insecticide resistance are a growing concern (Larentzaki et al., 2007; MacIntyre Allen et al., 2005). In addition to economic losses associated with feeding damage, OT also vector Iris yellow spot virus (IYSV). IYSV causes lenticular shaped lesions on leaves that can lead to a substantial decline in photosynthesis and resulting bulb size, and has emerged as a serious threat to onion production worldwide (Pappu et al., 2009). Conservative estimates of 5–10% yield loss to IYSV have been reported in bulb production in Colorado (Gent et al., 2006). While some onion varieties appear less susceptible to the virus, no resistant variety is currently known (Gent et al., 2006; Shock et al., 2008). Excessive rates of fertilizers, increasing insecticide resistance, and continued crop loss from thrips and IYSV threaten the sustainability of onion production in the western United States.

To date, most research studies have focused on a single aspect of onion crop management at a time, such as improved methods of thrips control; however, an integrated or systems approach is necessary to examine the complex interactions between multiple farm components that affect production (Drinkwater, 2009; Doré et al., 2011). By examining the farm as a whole, the goal is to identify system-wide drivers of pest pressure, for example, and identify cultural practices that synergistically enhance production and ecosystem function for improved sustainability. As such, a whole farm approach should seek to optimize production by manipulating key components such as crop rotation, integrated pest management, and nutrient cycling.

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Altering cultural management practices such as crop rotation may be an effective method to suppress insect and disease pressure while maintaining yields. Modern agriculture favors shorter crop rotations for ease of management and perceived higher profits; however, this practice allows polyphagous pests such as OT to sustain populations between ideal hosts (Milne and Walter, 1998). Longer term, more diverse crop rotations have long been used effectively to prevent pests. Rotations that include fewer favorable hosts can interrupt resource requisites in time and/or space, such as oviposition sites or highly nutritious food sources, which may limit the success of insect populations as well as reduce virus incidence (Altieri, 1999; Zitter and Simons, 1980). Soils under longer crop rotations have also been shown to suppress soil borne pathogens, including fungi and nematodes (Peters et al., 2003). Successful management of a plant virus and its vector may require a broad approach with multiple changes in cultural practices, such as crop rotation and nutrient management (Zitter and Simons, 1980).

Nutrient management in onions is challenging due to the shallow root system of the crop. Nitrogen application rates as high as 450 kg ha^{-1} are common in order to increase bulb size and market value. However, high application rates of fertilizer may increase N in onion tissues and crop apparency to pests (White, 1984). Onions treated with a series of N applications showed highest OT populations at highest N application rates, 70% higher than in untreated control plots, with no increase in thrips populations at N application rates of 100 kg ha^{-1} or less (Malik et al., 2009). Moreover, fertilizer use efficiencies (FUE) in highly managed onions can be as low as 15% (Halvorson et al., 2002). Following an onion crop with highly efficient N users, such as corn to maximize nutrient recovery, may increase net nutrient capture to only 39% over two seasons (Halvorson et al., 2002). Nitrate contamination of ground and surface waters has been well documented as a by-product of intensive agricultural practices and associated with significant health risks and environmental impacts (Doran and Zeiss, 2000). Concern for excessive nitrate N ($NO_3{}^{-}N$) leaching in onion has prompted a re-evaluation of fertilizer application rates and timing. Reduced total inputs applied in slow release formulations have proven effective in maintaining high onion yields and large bulb size (Drost and Koenig, 2002).

There is also a growing interest in the concept of soil health as a means to reduce inputs and improve the sustainability of farming systems. Soil health can be described as “the capacity of soil to function as a vital living system to sustain biological productivity, promote environmental quality, and maintain plant and animal health” (Doran and Zeiss, 2000). The addition of organic amendments can greatly improve soil health through enhanced long-term fertility and physical properties of soils, as well as increasing microbial biomass and activity (Gunapala and Scow, 1998; Bulluck et al., 2002). The relative size and activity of the soil microbial biomass is an important indicator of the availability of labile C and N compounds, nutrient cycling potential, and the overall sustainability of management practices (Doran and Zeiss, 2000). Soil microbes can also serve important roles in disease suppression (Peters et al., 2003; Gil-Sotres et al., 2005; Larkin, 2008). High rates of N fertilizer have been shown to result in lower microbial biomass and activity (Gunapala and Scow, 1998) which in turn may exacerbate plant pests (Hines et al., 2006).

Growers seeking to improve the health of their soils for pest suppression and increased plant growth sometimes turn to biostimulant applications in lieu of organic matter additions and other inputs. Little is known about the impact of these amendments since the composition between products can vary widely; however, most biostimulants increase plant health and growth through improvements in nutrient availability as a result of soil microbial activity (Russo and Berlyn, 1990). Experimental results have been variable. Russo and Berlyn (1990) found improved root growth and better resistance to environmental stress with an organic biostimulant. Conversely, Chen et al. (2002) compared two commercially available formulations and concluded applications may reduce available N over time. As these products are increasingly marketed to growers as a low cost means of improving soil health and crop performance, it is important that these products are thoroughly evaluated.

Table 1
Fertilizer application rates and timing (rates are expressed as kg ha^{-1}, except biostimulant amendments which are in L ha^{-1}) for three fertilizer treatments in 2009 and 2010.

Time of year	Standard rate (*S*)	Reduced rate + biostimulant (*B*)	Reduced rate (*R*)
Fall	56.0 N[a]	28.0 N[a] 46.8[b]	28.0 N[a]
Spring Pre-plant	65.6 N[c] 222 P[c] 51.3 K[d]	13.1 N[c] 44.6 P[c] 10.5 K[d] 46.8[b]	13.1 N[c] 44.6 P[c] 10.3 K[Dd]
June	140 N[e]	79.6 N[e] 46.8[b]	79.6 N[e]
July	140 N[a]	13.1 N[c] 46.8[b]	13.1 N[c]
Total	401 N 222 P 51.3 K	137 N 44.8 P 12.3 K 140[b]	133 N 44.6 P 10.3 K

[a] Urea ammonium nitrate (UAN).
[b] More life.
[c] 10-34-0.
[d] 0-25-17S.
[e] Ammonium sulfate.

The goal of this study was to evaluate the effects of two N fertilizer rates, addition of a soil biostimulant, and two common crop rotation sequences on onion growth and yield, thrips populations, IYSV infection, soil health as measured by biological and biochemical indicators, and the potential for environmental risks from excess-N leaching. We hypothesized that applications of high N fertilizer rates will not consistently enhance onion growth and yield, but will, however, increase crop attractiveness to thrips and increase IYSV incidence levels while reducing soil health and increasing the potential for $NO_3{}^{-}$ N leaching.

2. Materials and methods

2.1. Field design

Two replicated trials were conducted from 2008 to 2010 at the Utah Agricultural Experiment Station in Kaysville, Utah. Each trial utilized a completely randomized design (CRD) and spanned two growing seasons. The treatment design included two factors: (1) crop rotation [wheat (W) or corn (C)] and (2) fertilizer [standard rate (*S*), reduced rate (*R*), or reduced rate plus biostimulant (*B*)]. The six treatment combinations were each replicated four times. The soil was a Kidman fine sandy loam (Soil Survey Staff, 2010) that had been fallow for several years prior to commencement of the trial. In the growing season prior to onion production, plots measuring 7.62 m by 15.24 m were planted to either field corn (*Zea mays* var. ‘Dahlco 2146’ in 2008 and ‘Pioneer 31G65’ in 2009) or wheat (*Triticum aestivum* var. ‘Jefferson’ in 2008 and 2009) with no addition of fertilizer or insecticide. The corn was removed as silage and the wheat harvested in late summer, and remaining residues incorporated into the soil followed by fall fertilizer application and bed preparation (Table 1). A spring application of fertilizer was applied on March 12, 2009 and March 29, 2010 prior to onion seeding (Table 1). *Allium cepa* var. ‘Vaquero’ (Nunhems Seeds, Parma, Idaho), bulb onion, was seeded in 90 cm beds with four rows per