Effect of Silicon Application on *Lolium perenne* Development and *Fusarium* Control

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Keywords: Fusarium patch disease, *Microdochium nivale*, *Lolium perenne*, silicon, disease incidence, sward development

Abstract

Fusarium patch disease caused by *Microdochium nivale* is one of the most troublesome diseases on sporting surfaces in the Northern Hemisphere. It can occur all year round under favourable environmental conditions. Control of the disease is difficult to attain with some strains reported to show resistance to a number of commercial agrochemicals. Silicon is an element deemed unnecessary for plant development but it has been suggested that its application could enhance disease resistance through the deposition of a physical protection barrier on the leaf tissue. This research aimed to investigate the effects of silicon applied as potassium metasilicate at 1200 ppm to *Lolium perenne* turf on plant development and Fusarium patch disease control. It was found that the application of potassium metasilicate to *L. perenne* significantly increased root length, density, and root colour. The turf sward also showed significantly reduced disease symptoms following three applications.

INTRODUCTION

It is generally accepted that plants need 14 essential nutrient elements (both macro and micro) to develop, but in reality they need many more such as silicon (Turner and Hummell, 1992). It is thought that silicon benefits plant growth indirectly since it hardens the leaf tissue thus creating a physical barrier limiting pathogen infection, promoting vertical leaf growth to enhance light interception and penetration and increasing plant vigour (Shama, 2006; Nolla et al., 2006). Fusarium patch disease caused by *Microdochium nivale* remains one of the most common and troublesome diseases of turf in the Northern Hemisphere particularly in the United States of America, Canada, the United Kingdom, Ireland, and northern Europe (Vargas Jr., 2005). Most groundsmen and greenkeepers encounter the occurrence of the disease on both sports turf and fine turf annually. The climate in Western Europe favours its spread and development at any time throughout the year (Mann, 2002; Smith et al., 1989). Most cultivars of perennial rye grass (*Lolium perenne*) are considered to be moderately resistant to the disease (Smith et al., 1989). However, with the more general use of partially or fully enclosed sports stadia, an artificial environment is produced. This has created a new niche for this disease resulting in the fact that Fusarium patch disease is now considered to be a disease of *L. perenne*. The first symptoms of the disease appear as circular but occasionally asymmetrically shaped patches of dead/decaying matted grass on the surface of the pitch or green, ranging in size from 50 to 500 mm in diameter. A possible preventative measure is the application of silicon to the turf to physically harden the leaf structure and indirectly restrict disease development. However, there are no literature reports concerning its use for disease prevention, development, or control.

An experiment was conducted to establish if potassium metasilicate, applied as a spray or a drench (at a concentration of 1200 ppm), influenced the growth and development of *L. perenne* using root density, colour, length, and number of root laterals as parameters of measurement. The effect of the product on controlling the incidence of Fusarium patch disease on perennial rye grass was also examined.

MATERIALS AND METHODS

On 23 February 2007, *L. perenne* seed, comprising three cultivars; 35% 'Bareuro', 35% 'Greenfair', and 30% 'Action', was sown in 2-L nursery containers which were filled to the top with Shamrock™ potting compost at an equivalent seeding rate of 18 g m^{-1}. The pots (150) were placed in a glasshouse maintained at 18°C for seed germination and plant development at Thornfield Glasshouse Unit. The grass was irrigated as required and cut to a height of 25 mm. When it was adequately established treatments commenced in late May. Two different experiments were carried out. The first was to establish the effect of potassium metasilicate on *L. perenne* development and growth, and the second to determine its effects on Fusarium patch disease development.

Silicon

Silicon is commercially available as potassium metasilicate (K_2O 30.6%, S_1O_2, 19.4%). In this form, it has a very high pH (>14) and requires diluting with glass distilled water to give a concentration of 1200 ppm silicon followed by neutralization with 10% nitric acid prior to its application. The neutralized potassium metasilicate (pH 7.0) was applied to the containerized *L. perenne* turf at 8.0 ml/container, either as a drench using a syringe or as a spray using a hand held sprayer, at biweekly intervals commencing on 25 June 2007 to determine its effects on turf growth. Harvesting of the grass was carried out at biweekly intervals commencing one week after the application of silicon, i.e., on 2, 16 and 30 July 2007. The grass was cut back to a height of 25 mm and the clippings immediately put into paper bags and placed in a cold store at 4°C (to avoid moisture loss) prior to weighing. Samples of tissue (6 g fresh weight) were placed in an oven heated to 75°C for 48 h to dry. The dried samples were placed in a desiccator before being sent to a commercial laboratory (Lancrop Laboratories) in England for tissue silicon determination.

The following three treatments were established: 1. no silicon applied (control); 2. silicon applied by spray at three biweekly intervals; 3. silicon applied by drench at three biweekly intervals.

The experiment was carried out in a glasshouse maintained by thermostatically controlled fans at 20±2°C. Twelve replications within each treatment were established and the treatments were laid out in a completely randomized design.

Fusarium

On 1 May 2007, five core samples, 12 cm in diameter and 4 cm in depth, were removed using a soil auger from part of a USGA specification golf green at Rosemount Horticulture Field Station that had suffered a severe outbreak of Fusarium patch disease the previous autumn. The grass had been appropriately treated with a range of Agrochemicals (Amistar, Bolt, Chipco green, and Fusanil Snare) during this period to overcome the severe outbreaks. Despite this, pockets of infection remained. Infected leaf blades were plated on to potato dextrose agar gel in petri dishes. The dishes (50) were sealed and incubated on a shelf fitted with ultra violet lighting in the laboratory and maintained under a 16 h photoperiod for ten days at room temperature. On 10 May 2007, the cultures were examined for the characteristic red and yellow colour symptoms of *Fusarium* growth and the identity of the pathogen determined. After a further two weeks (24 May 2007) a third subculture was certified to be a pure culture of *M. nivale*.

Method of *Fusarium* Application

The *Fusarium* suspension was prepared by adding a small amount (1-2 ml) of unsterilized water to each petri dish. The water was used to float the cultured spores from the dishes with the aid of a glass slide into 25 ml conical flasks. The spore suspension was filtered through a new "J" cloth to remove agar segments; the filtrate was collected and made up to 40 ml with water. After adding a few drops of a wetting agent (Tween 20), the suspension was mixed using a magnetic stirrer and a 1.0 ml sample taken, using a Pasteur pipette, to count the number of spores present in the suspension on a Mod-Fuchs

Rosenthal haemocytometer under a compound microscope. A mean number of seven spores in each square of the haemocytometer represented a concentration of 5×10^5 spores/L, or the target concentration necessary to cause disease infection on the grass. The spore suspension was poured into a hand held sprayer and immediately applied to the grass growing in the containers. Spore suspension applications commenced on 2 July 2007. Immediately, the grass was covered with translucent polythene sheeting to increase relative humidity levels and hence encourage disease establishment and development. After one week, leaf samples were cultured on potato dextrose agar gel and within a further two days fungal growth was visible on the agar plates, confirming *Fusarium* infection. The first visible disease symptoms on the grass were apparent within two weeks of inoculation. The first spray and drench applications of potassium metasilicate were made seven days later with subsequent applications at biweekly intervals. Harvesting was carried out one week after the respective silicon applications, namely 30 July 2007, 13 August 2007, and 27 August 2007. The grass was weighed, dried, and analyzed as described above.

The following three treatments were established:

1. No silicon was applied to *Fusarium* inoculated grass (control).
2. Silicon applied by spray at three biweekly intervals on *Fusarium* inoculated grass.
3. Silicon applied by drench at three biweekly intervals on *Fusarium* inoculated grass.

The experiment was carried out in a glasshouse as described above.

The base silicon content in the grass was established by analyzing tissue harvested on 18 June 2007 prior to the commencement of the experiments. Root density was evaluated using a scale of one to five where a value of one was transparent whilst a value of five was very dense. Root colour was evaluated using a scale of one to three, where a value of one equalled white and a value of three indicated yellow with two being intermediate. Root length was measured in cm whilst the number of lateral roots produced was counted. The incidence of Fusarium patch disease was scored using a scale of one to five where one indicated no disease present and five indicated complete grass infection. Total yield data were subjected to Analysis of Variance (ANOVA). The Tukey-Kramer multiple comparison test was used to compare least square means of treatments. The general linear model was used in SAS statistical software for all procedures using Statistical Analysis Systems (SAS) (SAS Institute, 2001).

RESULTS

Effect of Potassium Metasilicate on *Lolium perenne* Development

The analysis of variance for the data showed that there were significant differences between the treatments in root density, colour, and length but not on lateral root count (Table 1). Root density was significantly greater (in excess of 50%) in the turf tissue following a drench application of potassium metasilicate in comparison to a spray application (Table 2). Root density was also significantly greater than in the control treatment. There was no significant difference in mean root density between the spray treated and the control plants. The colour of the grass roots was also significantly influenced by the application method. When the potassium metasilicate was applied as a drench, the roots were found to be significantly whiter in colour, whereas when the grass was sprayed they remained yellow with no significant difference between them and the control. Root length was significantly longer (9%) than in the control treatment or those treated by spray (6%) application or drench application. There was no significant difference between the spray application and the control plants (Table 2). The mean values for silicon uptake by *L. perenne* ranged from 169 to 296 ppm (Table 3). When the product was sprayed onto the plants, silicon uptake tended to be reduced. Uptake values were higher for the drench applications compared to both the control and the spray applications, with uptake from the spray applications being the lowest (Table 3).

Effect of Potassium Metasilicate on *Fusarium* Incidence

The analysis of variance for the data on the effect of potassium metasilicate on Fusarium patch disease incidence showed significant differences between the treatments (Table 4). The application of potassium metasilicate significantly reduced disease incidence compared to the control irrespective of the method of application (Table 5). As a drench, it reduced disease incidence 18% and, as a spray, it reduced the disease incidence by approximately 40% compared to the control. Thus the spray applications were approximately one third more effective (Table 4). The mean values for silicon uptake by the *Fusarium* inoculated plants ranged from 169 to 311 ppm (Table 6) with greater plant uptake occurring when the product was applied as a drench.

DISCUSSION

Development of *Lolium perenne*

The application of potassium metasilicate at a concentration of 1200 ppm by means of either a spray or a drench had no undesirable effect on root growth and development of *L. perenne*. In agreement with Ma et al. (2001) the turf plant can accumulate high concentrations of silicon (296 ppm) without exhibiting any adverse effects. For example, root density, colour, and length were significantly more intensive, healthier, and more invasive in comparison with the control treatment. This result is similar to the findings reported by Gillman and Zlesak (2000) and Nelwamondo and Dakora (1999) working with legumes. It is clear that the potassium metasilicate was selectively absorbed by the root system in preference to the shoots thereby increasing its efficacy. It is probable that its uptake is maximized during periods of transpiration confirming the early hypothesis of Jones and Handreck (1967). On the contrary, the application of potassium metasilicate as a spray treatment for plant development was ineffective. Thus, its application may have caused temporary stomata closure, or it may have simply evaporated. There was no uptake pattern detected in silicon following drenching or spraying and this concurs with the findings of Mitani and Ma (2005). It also supports the work of Ma et al. (2001) who suggested differential silicon uptake by the roots led to this phenomenon. Suggestions of Russell (1980) are also supported since repeated applications aided root development even though silicon is not essential for development. The results demonstrate that the application of potassium metasilicate as a drench to turf stimulated root activity and resulted in the production of white roots with increased density and length. This suggests that silicon application may prevent or reduce Localized Dry Patch condition. Furthermore, given that the drench promoted the development of denser rooting systems it also suggests that drenching selected areas of a pitch that are subjected to intense wear during the playing season should enhance wear tolerance and provide for the preservation of greater grass cover on the pitches especially towards the end of the playing season. This finding may also have a major significance in football stadia where the installation and use of supplementary illumination is too expensive. On the contrary, if used in association with supplementary illumination, it is possible that the photoperiod as currently suggested by the trade could be amended. Enhancing the root system by the drench application of silicon is an interesting concept and one that requires further investigation.

Fusarium* Control in *Lolium perenne

Significant differences in *Fusarium* control were established. The application of a silicon drench to *Fusarium* infected grass resulted in a significant reduction in disease levels. In this work, when the product was applied as a spray at known levels to infected grass, a further significant improvement in disease control occurred. This difference in disease incidence for grass treated with potassium metasilicate was highly visible. In fact, its application prevented the coalescence of the infected patches. This finding concurs with the work of O'Donnell (unpublished) which showed that the application of potassium metasilicate as a drench reduced the incidence of downy mildew on Hebe.

Although, the disease was not eradicated by the application of potassium metasilicate, either by drench or spray, a significant reduction in disease incidence was found. It is possible that the silicon physically restricted the development of the disease. However, the mechanism is unknown at this time and requires elucidation. This finding has not previously been reported in the scientific literature. As silicon is the most abundant element in soils (Epstein, 1999) and, unlike other nutrients, it does not damage the plant when it accumulates in excess (Ma et al., 2001), the potential for applying silicon as a cultural control method for Fusarium patch disease on sporting surfaces presents exciting possibilities. As a spray it was significantly more effective in reducing disease incidence.

CONCLUSIONS

The application of potassium metasilicate at 1200 ppm by spray or drench to *L. perenne* does not adversely affect sward development. Its application significantly increased root length, root density, and promoted a healthier root system. It may have application in controlling physiological disorders such as Localized Dry Patch by encouraging deep root development. Drench application of the potassium metasilicate encouraged greater plant development in comparison to spray application. On the contrary, the application of potassium metasilicate by spray application significantly reduced the incidence of Fusarium patch disease on *L. perenne* and has potential as a non-agrochemical method of disease control.

ACKNOWLEDGEMENTS

Thanks to Ray O'Haire, Kevin Kenny for assistance with experimental work, and to Philip Moreau, Glenbrook Nurseries, Co. Clare, Ireland, for the provision of the potassium metasilicate. This research was funded by the University College Dublin.

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Tables

Table 1. ANOVA analysis of the effect of silicon application on root density, colour, length, and root lateral production.

Source of variation	Df	F value	Pr>F
Root density	2	10.87	***
Root colour	2	10.40	***
Root length	2	4.21	*
Root laterals	2	1.61	NS

***, **, * and NS indicate significance at P=0.001, 0.01, 0.05 and not significant at P=0.05.

Table 2. The effect of potassium metasilicate application by two methods on root density, colour, and root length.

Method of application	Root density	§Root colour	Root length
Drench	3.83a	1.17b	15.14a
Spray	2.50b	2.50a	14.04b
No silicon applied	2.16b	2.17a	13.67b
SED	0.376	0.303	0.302

Means followed by the same letter within a column are not significantly different according to Tukey Kramer multiple comparison test at P=0.01. § A value of 1=white; 3=yellow.

Table 3. Mean silicon uptake (ppm) in *Lolium perenne.*

Treatment	2nd July	16th July	30th July
Control	229a	229b	229b
Spray	227a	169a	186a
Drench	221a	266c	296c

Means followed by the same letter within a column are not significantly different according to Tukey Kramer multiple comparison test at P=0.01

Table 4. ANOVA of the score of incidence of disease.

Source of variation	Degrees of freedom	F value	Pr>F
Model	2	15.18	***
Residual error	33		

*** indicates significance at P=0.001.

Table 5. The effect of potassium metasilicate application by two methods on the incidence of *Fusarium*.

Method of application	Score for incidence of *Fusarium*
Spray	2.42a
Drench	3.50b
No silicon applied (control)	4.25c
SED	0.34

Means followed by the same letter are not significantly different according to Tukey Kramer multiple comparison test at P=0.05.

Table 6. Mean silicon uptake (ppm) in *Fusarium* inoculated *Lolium perenne*.

Treatment	30th July	13th August	27th August
Control	229b	229b	229b
Spray	169a	214a	277a
Drench	292c	240c	311c

Means followed by the same letter within a column are not significantly different according to Tukey Kramer multiple comparison test at P=0.01.