agronomy

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Hot Foam and Nitrogen Application to Promote Spring Transition of “Diamond” Zoysiagrass (*Zoysia matrella* (L.) Merr.) Overseeded with Perennial Ryegrass (*Lolium perenne* L.)

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Citation: Caturegli, L.; Sportelli, M.; Pirchio, M.; Sciusco, G.; Volterrani, M.; Tucci, M.; Magni, S.; Minelli, A.; Fontanelli, M.; Frasconi, C.; et al. Hot Foam and Nitrogen Application to Promote Spring Transition of “Diamond” Zoysiagrass (*Zoysia matrella* (L.) Merr.) Overseeded with Perennial Ryegrass (*Lolium perenne* L.). *Agronomy* **2022**, *12*, 1049. https://doi.org/10.3390/agronomy12051049

Academic Editors: Massimiliano Probo and Jiafa Luo

Received: 21 February 2022
Accepted: 25 April 2022
Published: 27 April 2022

Abstract: In transition areas, cool season turfgrasses are overseeded in autumn to maintain the high quality of dormant warm season turfgrasses, while in spring several agronomic methods (scalping, coring, topdressing, verticutting, irrigation, and targeted fertilization) or chemical desiccation are adopted to remove the cool season turfgrasses from the stand. To reduce chemical applications, several methods of “thermal weeding” have been experimented with, but little is known about these methods in zoysiagrass (*Zoysia spp.* Willd) spring transition. A study was conducted at the University of Pisa, Italy, on Manila grass (*Zoysia matrella* (L.) Merr., cv “Diamond”) (Zm) overseeded with perennial ryegrass (*Lolium perenne* L.) (Lp) with the aim of comparing different methods of cool season grass suppression (scalping and hot foam) and different application rates of nitrogen. To assess treatment effect, green cover, turf quality, turf color, shoot density, and some vegetation indices (GLI, DGCI and NDVI) were determined. An average green cover of at least 90% was obtained on all plots seven weeks after the treatments. While scalping had minor effects on turf appearance and on polystand composition, hot foam had a stronger effect on turf color, green cover, and turf quality in the weeks following application. Once it had recovered from the hot foam treatments, the turf had a greater number of Zm shoots and a relevant reduction of Lp shoots. The hot foam was very effective in suppressing Lp while maintaining Zm recovery capacity.

Keywords: overseeding; turfgrass; warmseason; coolseason; thermal weeding

1. Introduction

The use of warm season turfgrass species in the Mediterranean area is justified by their low water requirement and high tolerance to heat, drought, and wear [1,2]. In recent years, fine textured dwarf varieties adapted to low cutting heights have been released for applications in tee/green conditions [3,4]. The use of zoysiagrasses (*Zoysia spp.* Willd) on golf courses in the United States is quite recent [5] and their use for putting greens, tees, and fairways is spreading [6–8]. In previous studies, carried out in central and northern Italy, zoysiagrass has shown good adaptation, being the slowest to enter winter dormancy and the fastest in spring green-up [9–11]. In transition areas, overseeding with cool season species is often considered a necessary practice to maintain high quality and aesthetic standards of warm season turfgrasses [12,13]. Perennial ryegrass (*Lolium perenne* L.) (Lp) is the most popular cool season turfgrass species used to obtain a green live turfgrass on a dormant warm season stand [4]. However, overseeding zoysiagrass may not be as successful as bermudagrass (*Cynodon spp.* (L.) Pers.) and seashore paspalum (*Paspalum vaginatum* Sw.). Due to its canopy architecture and slow growth rate, zoysiagrass does not tolerate spring competition from the overseeded species, thus showing poor spring transition and summer recovery [14,15]. Autumn overseeding often causes a decline in warm season turfgrass spring green-up, mostly attributed to destruction of the canopy when overseeding and competition for light and nutrients [16].

In this case, due to cool and wet conditions, Lp becomes a weed species since it may remain present when it is no longer required, thus delaying the transition to warm season species [17]. Despite a complete removal of competition from Lp, poor warm season turfgrass recovery has been observed and attributed to allelopathic chemical release during cool season plant death [18]. Hence, turf managers need to adopt suitable strategies to obtain a quick and complete removal of Lp, while sustaining fast warm season turfgrass growth.

Common agronomic methods adopted to remove cool season turfgrass species are scalping, coring, topdressing, verticutting, irrigation, and targeted fertilization [17,19]. As to scalping, this practice has had varying results in expediting spring transition on overseeded warm season turfgrass putting greens [17]. This is in accordance with Fontanier et al. [14], who reported that *Zoysia* and *Lolium* have a similar response to low mowing heights, thus justifying the hypothesis that the overseeded species might not be very susceptible to the suppressive action of scalping in fairway conditions.

Chemical desiccation of the overseeded turfgrass is a very effective method to selectively remove the unwanted species while preserving the warm season turfgrass. Several products are routinely applied in the USA with this aim. In particular, several sulfonylurea herbicides have been introduced into the turf market to control cool season turfgrasses during spring transition [20,21]. However, this practice is not allowed due to a European directive and country legislation that specifically ban the use of herbicides on sports surfaces [22]. As a substitute for chemical desiccation of weeds, several methods relying on heat transfer to plants, referred to as "thermal weeding", have been subject to experimentation by various authors in numerous contexts and play an important role in organic agriculture [23–26]. Thermal weed control may be performed through several methods [27] whose effects are comparable to non-selective chemical treatments. Turfgrass applications have been reported for steaming, flaming, and hot foam. Fontanelli et al. [28] report a desiccation of Lp in which applying glufosinate-ammonium at a rate of 0.75 kg ha^{-1} was comparable with that achieved by steaming with at least 4000 kg ha^{-1} of steam or flaming with at least 140 kg ha^{-1} of liquified petroleum gas (LPG). Hot foam effect on tall fescue (*Schedonorus arundinaceus* (Schreb.) Dumort.) has been documented by Martelloni et al. [24], who found that the application of 3.33 L m^{-2} was the least effective rate for complete devitalization. When applied to warm season turfgrasses, flaming has been reported to be tolerated by "Salam" seashore paspalum and "Patriot" hybrid bermudagrass. Martelloni et al. [29,30] observed an almost unchanged vitality of underground organs when thermal treatments with up to 100 or 157 kg ha^{-1} LPG were applied during the spring season green-up to Patriot and Salam, respectively. Both warm season turfgrasses showed a full ground cover recovery within 3 weeks from treatment applications.

For surface management, it is expected for spring transition to progress quickly in order to reduce the suspension period [31]. Nitrogen fertilization is certainly the maintenance tool that may stimulate growth and recovery after damage or stress more than others [8,32,33]. However, while the application of soluble N from ammonium nitrate increases the density of the stems in bermudagrass [17], zoysiagrass is the warm season turfgrass with the least evident response to nitrogen fertilization [34,35]. Among soluble forms of N, ammonium sulfate application in the spring period has been reported to increase the degree of coverage in zoysiagrass without increasing the risk of brown patch infection [32].

The objective of this study was to compare different methods of Lp suppression (scalping and hot foam) and different application rates of nitrogen as tools to promote spring transition of "Diamond" zoysiagrass overseeded with Lp.

2. Materials and Methods

The trial was carried out in the experimental station of the Centre for Research on Turfgrass for Environment and Sports (CeRTES), Department of Agriculture, Food and Environment, University of Pisa, located at S. Piero a Grado, Pisa (43°40′ N, 10°18′ E, 6 m asl), Italy, from October 2020 to June 2021. On 19 October 19, 2020, a mature stand of Manila grass (*Zoysia matrella* (L.) Merr.) (Zm) cv "Diamond", established on a silty loam soil (Calcaric Fluvisol, 28% sand, 55% silt, and 17% clay) with a pH of 7.8 and 18 g kg^{-1} organic matter and a turf height of 18 mm was scalped and aerated with a verticutter. A 3 mm silica-sand top-dressing was carried out afterwards. Overseeding was carried out on the same day with a blend of Lp with 50% cv "Neruda I" and 50% cv "Tetragreen". Lp was broadcast-seeded at a rate of 100 g m^{-2}. To improve seed germination, the trial area was covered with geotextile (30 g m^{-2} specific weight) for 20 days after seeding and irrigated when necessary. At sowing date, 50 kg ha^{-1} of N, 92 kg ha^{-1} of P, and 100 kg ha^{-1} of K were distributed. From November 2020 to March 2021, monthly fertilization with 50 kg ha^{-1} $month^{-1}$ of N was applied.

During the trial, mowing was carried out with an autonomous mower (Husqvarna mod. Automower 310; Husqvarna; Stockholm, Sweden) custom-modified to set the mowing height at 18 mm. Irrigation was applied as necessary to maintain a healthy turfgrass. No weed or pest control was necessary during the trial.

A split-plot experimental field layout with three replications was adopted. The methods of Lp suppression consisted of: (a) scalping and (b) hot foam. The two Lp suppression methods were compared with non-treated control plots. Four levels of N fertilization (0, 50, 100, and 200 kg N ha^{-1}) were considered as a secondary treatment. The main plots had an extension of 10 m^2 (5 × 2 m) while subplots had a size of 2.5 m^2 (1.25 × 2 m).

On 12 April 2021, with the increase in average daily temperatures (Figure 1), treatments intended for Lp suppression were carried out. Scalping was carried out with a reel mower (McLane mod. 20-3.5 RP-7; McLane; Paramount, CA, USA) set at its lowest cutting height in order to obtain a final turf height of 11 mm. Clippings were removed. The thermal treatment was performed with hot foam application using a specific machine (Foamstream® MW Series; Weedingtech Ltd., London, UK) (Figure 2). A detailed description of the machine used in the trial is provided in Martelloni et al. [24]. The machine basically uses water and a biodegradable foam agent to generate a flux of 0.2 L s^{-1} of hot foam which is delivered to the plot surface with a handheld lance that has a shield at the end that applies the hot foam in a 0.3 m wide stripe. In this trial, the hot foam was applied at a constant speed of 0.1 m s^{-1}, maintaining the shield rim at 5 mm from the ground. The foam dose applied on the plots was 6.7 L m^{-2} and the foam temperature was 88.5 °C [24].

On 13 April 2021, the four levels of nitrogen (N) from ammonium sulfate (21-0-0) were distributed in order to promote zoysiagrass growth.

From 20 April to 1 June 2021, the following parameters were assessed (using visual rating scales) with the aim of monitoring spring transition: green cover (0% = no green vegetation, 100% = green vegetation), turf quality (1 = poor, 6 = acceptable, and 9 = best), and turf color (1 = straw brown, 6 = light green, and 9 = dark green) [36]. Green cover was also determined through digital image analysis by the measurement of green leaf index (GLI). GLI values range from −1 to +1 (−1 = bare soil; +1 = full green cover) [37,38] and were determined through the acquisition of Red Green Blue (RGB) photos using an unmanned aerial vehicle (UAV) (Mavic Mini quadcopter, DJI, Shenzhen, China). Details on image acquisition and processing are reported ahead in this section.

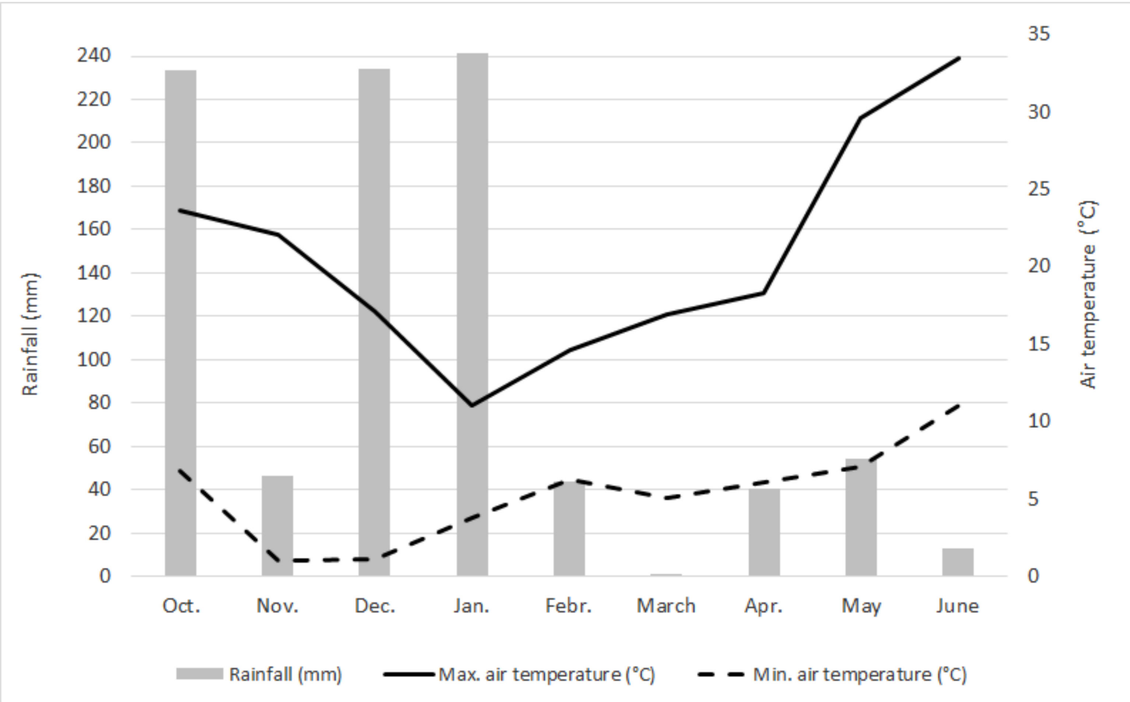

Figure 1. Monthly mean maximum and minimum air temperatures and monthly rainfall of the study period (October 2020–June 2021) at the experimental station of the Centre for Research on Turfgrass for Environment and Sports (CeRTES), Department of Agriculture, Food and Environment, University of Pisa, located at S. Piero a Grado, Pisa, Italy (43°40′ N, 10°18′ E, 6 m asl).

Figure 2. (**a**) Hot foam machine; (**b**) hot foam distribution with a handheld lance.

On 1 June 2021, when all the plots treated with cool season turfgrass suppression methods had recovered at least 90% of their green cover, plant stress was determined by the measurement of normalized difference vegetation index (NDVI) and dark green color index (DGCI). NDVI readings were collected with a handheld crop sensor (GreenSeeker Model HSC-100, Trimble Navigation Unlimited, Sunnyvale, CA). DGCI and GLI were determined from remote imaging acquired by flying a UAV over the plots. In order to refer the data acquired to uniform light conditions, the UAV was flown 11 m above the experimental area so as to include all plots in a single image. The UAV is equipped with a 1/2.3-inch CMOS image sensor which can shoot 12-megapixel RGB photos. Images were taken between 11.30 am and 1.30 pm (local time), in complete absence of clouds. Images were downloaded and analyzed with the open-source GIMP 2.10 software (www.gimp.org (accessed on 1 June 2021) to extract the mean RGB values of the sampled areas. RGB values were then converted into hue saturation brightness (HSB) values, using the method suggested by Karcher and Richardson [39] to finally calculate the dark green color index (DGCI). DGCI value is expressed on a scale from 0 (very yellow) to 1 (dark green) [40]. In order to evaluate the actual Lp suppression during spring transition and the density of the polystand, on 1 June 2021, two 50 cm^2 core samples per plot were collected and shoot density was determined by direct counting. Data are reported as number of shoots cm^{-2} separately for Zm and Lp and as the total of the mixed stand.

Statistical analysis was carried out with the statistical software COSTAT 6.400 (CoHort Software, Monterey, CA, USA) and R (R Foundation for Statistical Computing, Vienna, Austria). For the four dependent variables repeated over time (green cover, GLI, turf color, turf quality) a full model of ANOVA with repeated measures was adopted, including time, treatment method, and N rate as factors. According to the results of this first model, the effect of the treatment methods was then analyzed separately date by date (significant method x time interaction). Concerning the effect of the N rate, data were pooled over time (not significant N rate × time interaction). All the dependent variables not repeated over time (NDVI, DGCI, shoot density) were analyzed by two-way ANOVA. Means were separated with Fisher's protected least significant difference at 0.05 probability level.

3. Results

The results of the full model ANOVA with repeated measures are shown in Table 1. The results of the two-way ANOVA on dependent variables not repeated over time are shown in Table 2.

Table 1. Full model ANOVA of the effect of different suppression methods of *Lolium perenne* (Lp) (control, scalping, and foaming) and nitrogen applications (0, 50, 100, and 200 kg N ha^{-1} application rate) on dependent variables repeated over time (green cover, green leaf index (GLI), turf color, turf quality).

Factors and Interactions	Green Cover	GLI	Turf Color	Turf Quality
Method (M)	***	***	***	***
N rate (N)	*	ns	***	***
M × N	**	**	***	*
M × Time	***	***	***	***
N × Time	ns	ns	ns	ns
M × N × Time	ns	ns	ns	ns

Significant F test at $p \leq 0.05$ (*), $p \leq 0.01$ (**), $p \leq 0.001$ (***); ns, not significant.

Table 2. Results of analysis of variance testing the effects of method (M) of *Lolium perenne* suppression (control, scalping and foaming), nitrogen application (0, 50, 100 and 200 kg N ha^{-1} application rate) and their interactions on Normalized Difference Vegetation Index (NDVI), Dark Green Color Index (DGCI), and shoot density (no.cm^{-2}) of *Zoysia matrella* (Zm), *Lolium perenne* (Lp) and their mixed stand (total). NDVI, DCGI and shoot density were determined 1 June 2021, only.

Treatments	NDVI	DGCI	Shoot Density (no.cm^{-2})		
			Zm	Lp	Tot.
Method (M)	*	ns	*	*	*
N rate (N)	ns	ns	ns	ns	ns
M × N	ns	ns	ns	ns	ns

* Significant F test at the 0.05 level of probability; ns, not significant.

3.1. Effect of the Suppression Methods

From 20 April to 25 May 2021, the methods of Lp suppression adopted in the trial (scalping and foaming) affected green cover percentage (Table 3). The treatment with hot foam considerably reduced the percentage of green cover (2.5% residual green cover) (Table 3). Scalping, on the other hand, did not significantly reduce the percentage of green cover compared to the untreated control plots. During the observation period, 7 weeks after completion of the experimental treatments, plots that received hot foam progressively recovered the percentage of green cover up to 90%. In fact, no statistically significant differences between treatments were observed on June 1.

Table 3. Green cover (%): mean effect of *Lolium perenne* suppression method.

Suppression Method	Date of Observation						
	April 20	**April 27**	**May 4**	**May 11**	**May 18**	**May 25**	**June 1**
Hot foam	2.5 c	6.6 c	24.8 b	38.9 b	51.4 b	68.8 b	91.3
Scalping	94 b	96 b	100 a	100 a	100 a	100 a	100
Control	100 a	100 a	100 a	100 a	100 a	100 a	100
LSD ($p \leq 0.05$)	*1.1*	*5.8*	*15.9*	*24.2*	*28.9*	*19.3*	*ns*

Means are significantly different at the 0.05 level of probability as determined by Fisher's protected LSD. Means followed by the same letter do not differ significantly.

The GLI index appeared to be a successful measurement tool to identify induced differences in the green cover percentage caused by different Lp suppression treatments. GLI values obtained with treatments carried out from 20 April to 25 May were significantly lower using hot foam rather than scalping (Table 4). In fact, no significant differences were observed between scalping and the untreated control. On 1 June, no significant differences were observed between the untreated control and both hot foam and scalping, as in the visually estimated coverage percentage (Table 4).

Table 4. Green Leaf Index (GLI): mean effect of *Lolium perenne* suppression method.

Suppression Method	Date of Observation						
	April 20	**April 27**	**May 4**	**May 11**	**May 18**	**May 25**	**June 1**
Hot foam	−0.01 b	0.01 b	0.03 b	0.05 b	0.06 b	0.10 b	0.11
Scalping	0.13 a	0.13 a	0.14 a	0.16 a	0.13 a	0.13 a	0.12
Control	0.12 a	0.13 a	0.11 a	0.14 a	0.11 a	0.12 ab	0.13
LSD ($p \leq 0.05$)	*0.02*	*0.01*	*0.04*	*0.04*	*0.03*	*0.02*	*ns*

Means are significantly different at the 0.05 level of probability as determined by Fisher's protected LSD. Means followed by the same letter do not differ significantly.

In the first two surveys of the test period (20 April and 27 April), color was significantly affected by the Lp suppression methods (Table 5). In particular, the hot foam treatment showed an almost total devitalizing effect on plant green tissues, resulting in brown coloration. During these surveys, the turf was still not able to recover sufficiently to change the color in an appreciable way, so the obtained data are equal to 1.0.

Table 5. Turf color (1–9): mean effect of *Lolium perenne* suppression method.

Suppression Method	Date of Observation						
	April 20	**April 27**	**May 4**	**May 11**	**May 18**	**May 25**	**June 1**
Hot foam	1.0 c	1.0 b	2.8 b	3.7 b	4.5 b	4.9 b	4.9 b
Scalping	7.5 b	7.6 a	7.5 a	7.4 a	7.1 a	7.0 a	7.0 a
Control	8.1 a	8.1 a	7.4 a	7.2 a	7.0 a	6.9 a	6.8 a
LSD ($p \leq 0.05$)	*0.3*	*0.5*	*1.4*	*1.9*	*1.4*	*1.3*	*1.3*

Means are significantly different at the 0.05 level of probability as determined by Fisher's protected LSD. Means followed by the same letter do not differ significantly.

Scalping produced a slight but significant change in color compared to the untreated control on 20 April (Table 5). The mean effect of the hot foam suppression method also showed an unacceptable turf color on 4 May (2.8 using a 1–9 scale where 1 is straw brown, 6 light green, and 9 dark green) and on 1 June (4.9). Conversely, during the same period, scalping did not significantly reduce turf color values compared to the untreated control. Turf color mean values over the period ranged from 6.9 to 7.5 (Table 5).

Turf quality showed a trend similar to that observed for turf color (Table 6).

Table 6. Turf quality (1–9): mean effect of *Lolium perenne* suppression method.

Suppression Method	Date of Observation						
	April 20	**April 27**	**May 4**	**May 11**	**May 18**	**May 25**	**June 1**
Hot foam	1.0 b	1.2 b	1.3 b	2.3 b	3.4 b	4.4 b	5.7
Scalping	7.6 a	7.8 a	7.8 a	7.4 a	7.3 a	7.1 a	7.1
Control	7.6 a	7.8 a	7.8 a	7.6 a	7.3 a	7.2 a	7.3
LSD ($p \leq 0.05$)	*0.4*	*0.4*	*0.9*	*1.4*	*1.8*	*2.1*	*ns*

Means are significantly different at the 0.05 level of probability as determined by Fisher's protected LSD. Means followed by the same letter do not differ significantly.

The mean effect of the hot foam suppression method showed unacceptable turf quality during the entire trial. Conversely, during the trial period, scalping did not significantly reduce turf quality values compared to the untreated control. On 1 June, at the end of the trial, the effect of the *Lolium perenne* suppression method was no longer statistically different because the turf quality on the plots treated with hot foam improved.

3.2. Effect of the Nitrogen Application

The interaction between N application and time was not significant, while the interaction between the suppression methods and the N application was always significant for the dependent variables repeated over time. Data showing the interaction between the two main factors are then presented pooled over time (Table 7). All the dependent variables showed lower values for hot-foam-treated plots while scalped and control plots gave similar results. Concerning the effect of nitrogen application, improvement due to the increasing rate is more evident in the scalped plots and in the control plots. In these cases, as expected, a significant positive trend follows the higher rates. The effect of the hot foam treatment, on the other hand, seemed less influenced by the fertilization, as the lowest and the highest doses usually do not give significant differences (Table 7).

Table 7. Effect of the suppression method x N application pooled over time.

Method	N Rate (kg ha^{-1})	Green Cover (%)	GLI	Turf Color (1–9)	Turf Quality (1–9)
Hot foam	0	40 c	0.06 d	3.1 fg	2.7 g
	50	37 c	0.04 e	2.8 g	2.4 g
	100	51 b	0.05 de	4.0 e	3.3 f
	200	35 c	0.05 de	3.3 f	2.8 g
Scalping	0	98 a	0.12 c	6.5 d	6.9 e
	50	99 a	0.14 ab	7.0 c	7.4 bcd
	100	99 a	0.14 ab	7.6 b	7.7 abc
	200	99 a	0.14 a	8.3 a	8.1 a
Control	0	100 a	0.12 c	6.8 cd	7.1 de
	50	100 a	0.13 bc	6.8 cd	7.3 cde
	100	100 a	0.12 c	7.8 ab	7.9 ab
	200	100 a	0.13 abc	8.1 a	8.0 a
LSD ($p \leq 0.05$)		*6.3*	*0.02*	*0.5*	*0.5*

Means are significantly different at the 0.05 level of probability as determined by Fisher's protected LSD. Means followed by the same letter do not differ significantly.

3.3. Normalized Difference Vegetation Index (NDVI) and Dark Green Color Index (DGCI)

At the end of the trial, on 1 June, 2021, among the studied indices, NDVI was proven to be able to differentiate in a statistically significant way among the two suppression methods of Lp. Specifically, as shown in Table 8, NDVI allowed one to statistically ($p \leq 0.05$) distinguish hot foam (0.67) from scalping (0.75) and control (0.73). No significant differences were observed between scalping and control. NDVI values obtained with GreenSeeker consisted of the average values for each plot and were consequently affected by green cover (%). Foam-treated plots showed a percentage of green cover of 91.3%, compared to 100% in the scalped plots and in the untreated control. NDVI can perceive a change in turf color, since it is a plant stress index that, in this case, analyzes the color of the entire hot-foam-treated plots. At the end of the trial, the average turf color value was 4.9 (Table 5), with the green coverage of the plots close to 90 % (Table 3), and an average NDVI value of 0.67 (Table 8).

Table 8. Normalized Difference Vegetation Index (NDVI) and Dark Green Color Index (DGCI): mean effect of *Lolium perenne* suppression method on 1 June 2021.

Suppression Method	NDVI	DGCI
Hot foam	0.67 b	0.42
Scalping	0.75 a	0.45
Control	0.73 a	0.43
LSD ($p \leq 0.05$)	*0.05*	*ns*

Means are significantly different at the 0.05 level of probability as determined by Fisher's protected LSD. Means followed by the same letter do not differ significantly.

On the other hand, DGCI, measured at the end of the trial, was not statistically significant in differentiating between different Lp suppression treatments, or between different doses of nitrogen fertilization distributed on the area (Table 8).

3.4. Shoot Density

Shoot density showed no statistical difference between plant numbers of plots treated with scalping and control for both Zm and Lp (Table 9). In contrast, hot foam treatments showed a significant reduction of Lp plant numbers that were replaced by a significantly higher number of Zm plants (6.1 no.cm^{-2}) compared to what was observed in plots treated with scalping or control.

Table 9. Mean shoot density (no.cm^{-2}) for *Zoysia matrella* (Zm), *Lolium perenne* (Lp) and mean total shoot density for the association (Zm + Lp) as influenced by suppression method on 1 June 2021.

	Zoysia matrella	*Lolium perenne*	Total (Zm + Lp)
Hot foam	6.1 b	0.5 b	6.6 b
Scalping	4.5 a	8.0 a	12.5 a
Control	3.9 a	8.3 a	12.2 a
LSD ($p \leq 0.05$)	*1.5*	*0.8*	*1.7*

Means are significantly different at the 0.05 level of probability as determined by Fisher's protected LSD. Means followed by the same letter do not differ significantly.

It should be noted that green cover percentage of hot-foam-treated plots was lower throughout the test (ranging from 2.5 to 91.3% for hot foam, 100% in each survey of both control and scalping) (Table 3). A lower green cover (%) in hot-foam-treated plots was also confirmed by the values of total shoot density of the association (Zm + Lp). Hot foam shoot density was statistically lower than shoot density obtained with scalping and control (6.6 hot foam, 12.5 scalping, and 12.2 control) (Table 9).

4. Discussion

In agreement with the available literature, Zm maintained at 18 mm did not show susceptibility to scalping, and the Lp-Zm association showed similar ecological adaptation to cutting as Zm [14,15]. Compared to control plots, green cover percentage, turf shoot density, and composition did not change significantly after scalping, so this method was not an advantageous method for Lp suppression in the spring transition. In contrast, the Lp suppression performed by hot foam application was very effective in reducing the presence of Lp plants, which are considered weeds during this period. Hot foam was also effective in increasing the number of Zm shoots; however, a slight delay in Zm recovery was observed after the hot foam treatment. The different effect observed on turf color when comparing hot foam and scalping can be explained since hot foam is a very effective method designed for the non-selective control of spontaneous flora, and in this study, differentiated foam doses were not tested. Despite a slight reduction in total density and a lower percentage of green cover, for the reasons discussed above, the authors can state that during spring transition, the hot foam treatment allowed one to significantly reduce Lp without compromising Zm recovery capacity. Nitrogen fertilization, even performed with high doses, was shown to have little effect on reducing the effects of the hot foam treatment. Since Zm is a slow-growing species [9,14], treatments performed with hot foam must be performed considering Zm slow recovery times, especially in the case of sports field applications [5,12]. However, additional factors must be considered when evaluating the undesirable effects of hot foam suppression. While hot foam achieves Lp control comparable to that of chemical treatments [17], alternative agronomic methods generally provide partial control of the overseeded species [14,17]. When the total suppression of the cool season turfgrass species is not ensured, the two species coexist during the summer period and this in turn generates two main undesirable effects. First, the warm season turfgrass species fails to cover evenly the ground and secondly, summer turfgrass management must take into account the thermal, water, and pest management needs of the cool season species to preserve density, color, green cover, and turf quality. In fact, when both cool season and warm season species coexist during summer, if the cool season species dies in summer drought, the warm season turf will show an uneven ground cover. The use of ground-based vegetation indices such as NDVI measured with GreenSeeker or DGCI and GLI [39–41] measured by drone can help to determine the differences in turf color and green cover percentage. GLI was indeed in agreement with visually estimated green cover percentages, as also verified by Louhaichi et al. [37] and Barbosa et al. [38]. Since NDVI and DGCI are plant stress indices [42], the values acquired in this trial may have been influenced by the percentage of green cover of the hot-foam-treated plots that reached 90% green cover at the end of the trial. Compared to NDVI, DGCI was less effective in determining differences between different methods of cool season suppression during the spring transition, likely due to the distance of image acquisition performed by drone compared to NDVI acquisition, which was instead performed on the ground [42]. On the actual ability of the NDVI acquired with GreenSeeker to distinguish between different transition methods, we can therefore state that statistically significant differences were shown between the hot foam treatment and the other two treatments (scalping and control). From this point of view, the study of diversified doses of hot foam treatments is very important for future tests. Moreover, the implementation of new technologies has made the most recent models of the hot foam machine much more versatile in the regulation of the treatment itself, not only concerning the dose of hot foam delivered, but also for the possibility to easily adjust foam temperature and its layer thickness. The use of these differentiated methods of application of Foamstream® may also optimize this type of treatment for selective applications, leading to the right compromise between suppression of Lp and warm season species recovery. Similar experiments have been carried out for the selective control of weed species using flaming treatments on various warm season turf species [29,30]. As part of future experiments, considering the high effectiveness of hot foam on Lp, the efficacy of the method could be investigated as part of a turfgrass conversion from cool season to warm season species with plugs transplant, as already performed by Fontanelli et al. [28] with flaming and steaming.

5. Conclusions

Hot foam was shown to be a very efficient method for Lp suppression and a great alternative to the use of chemical herbicides. Hot foam treatment allowed to remove Lp and at the same time permitted Zm to return, dominating the association. Scalping was shown not to be as effective as hot foam for Lp suppression, so it is not a valid alternative. The slight undesirable effects associated with the use of hot foam are compensated considering that, without effective alternative systems, failure to remove Lp may induce similar effects in the short term and progressive thinning of Zm in the long term. Finally, in these trials, DGCI was not able to detect significant differences in the case of less evident nitrogen effects. Future research on both warm season species choice and different hot foam doses may help to define how to optimally perform hot foam treatments for turf transition from the association Lp + Zm to pure Zm. Moreover, considering the efficiency of hot foam in suppressing Lp, future research may be carried out to test hot foam as a conversion method for sports turfs, shifting from Lp turfs to Zm turfs.

Author Contributions: Conceptualization, S.M., L.C., M.T., G.S. and M.F.; methodology, L.C., S.M., M.T., G.S., M.F. and M.V.; validation, M.T., G.S., L.C. and S.M.; formal analysis, L.C., S.M., investigation, G.S., S.M., M.T., L.C.; data curation, L.C., S.M., and M.T.; writing—original draft preparation, L.C., S.M., G.S., M.T.; writing—review and editing: M.S., M.F., M.P. and A.P.; visualization, C.F., M.R., M.S., A.M., M.P.; supervision, M.V., M.F.; project administration, M.V., M.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors would like to thank the company Weedingtech, for providing the machine used in this test. Furthermore, the authors would like to thank Lorenzo Greci and Romano Zurrida from the Department of Agriculture, Food and Environment (DAFE) of University of Pisa for their technical support. The use of Foamstream® technology in this research was possible according to the trial contract stipulated by the DAFE of the University of Pisa with Weedingtech Technologies Limited, London (UK) that provided for the hot foam machine used in this trial.

Conflicts of Interest: The authors declare no conflict of interest.

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