Managing Mixtures of Tall Fescue (*Festuca arundinacea* Schreb) and Zoysiagrass (*Zoysia japonica* Steud.) for Athletic Turf

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톨 페스큐와 한국들잔디로 혼합 조성된 운동장 잔디관리

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ABSTRACT

Managing a mixture of zoysiagrass with tall fescue has been proposed in transitional zone as a practical practice to combine the advantages of the two species and compensate the limitations. To manage the mixture is a challenge because two species are involved. The objective of this study was to determine if zoysiagrass/tall fescue mixture can be maintained with proper mowing and fertilization under simulated sport traffic at an acceptable quality level. Zoysiagrass was seeded in June and tall fescue was overseeded in August 1996. In November 1996, zoysiagrass coverage was 62.36, 29.88, and 30.02% for 0, 50, and 100 Kg ha^{-1} N rates, respectively. At the same time, zoysiagrass coverage was 23.53, 41.95, and 57.40% for the mowing heights of 6.5, 5.0, and 3.5 cm, respectively. Zoysiagrass and tall fescue coverage in July 1997 was showing the same trend as in the late season of 1996 although the differences were not as big. There were significant interactions between N fertilization rates and mowing heights. In November 1998, the zoysiagrass coverage was different among the two tall fescue variety mixtures, 21.68, and 32.25% in 'Arid' and 'Grasslands Garland', respectively. Zoysiagrass coverage was favored in lower mowing height, lower N rates,

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and lower traffic. Interaction effects on zoysiagrass were found between tall fescue variety and nitrogen rate, tall fescue variety and mowing height, and traffic and nitrogen rate. Zoysiagrass shoot density was 7.42, 25.47, and 58.95% for mowing heights of 6.5, 5, and 3.5 cm, respectively; and it was 47.27, 20.27, and 26.26% for N rates of 0, 50, and 100 Kg ha^{-1}, respectively in 1998. The effects on zoysiagrass shoot density from the interaction of N rate and tall fescue variety was significant in 1998. Shoot density responded to the N rate, mowing height, and traffic differently from the ground coverage, indicating that shoot and leaf growth have different adaptation strategies.

Key words: tall fescue, zoysiagrass, athletic turf, mixture, overseed, N fertilization, mowing height

INTRODUCTION

Zoysiagrass is used extensively in subtropical and transitional zones as lawn grass or on athletic fields because of its high stress tolerances and low maintenance requirements (Watson, 1989; Cockerham et al., 1994). Being a warm-season grass, zoysiagrass has certain limitations such as winter hardness and green period. In a transitional zone, where some cool-season and warm-season grasses meet their southern and northern limits of adaptations, respectively (Turgeon, 1985), tall fescue is also frequently used. Tall fescue can not tolerate extreme heat stresses and low mowing height although it is among the most heat resistant species in cool-season turf grasses. However, zoysiagrass and tall fescue has seasonal dynamics for their active growth and quality performances and compensates each other on these aspects. Common type zoysiagrass and turf type tall fescue also has similar leaf textures making the mixture of the two species rather uniform. Razmjoo (1995) attempted to extend the green period of manilagrass [*Zoysia matrella* (L.) Merr.] by overseeding with cool-season grasses without success. Overseeding zoysiagrass with perennial ryegrass (*Lolium perenne*), tall fescue, and Kentucky bluegrass (*Poa pratensis*) for better winter color had acceptable results (Longer, 1999; Zhang et al., 2008). Mixtures of zoysiagrass and tall fescue had been successfully maintained in the National Mall of Washington DC (Brede, 1991).

When used as a monostand, fertilization rate for zoysiagrass at 49 to 98 kg ha^{-1} provided acceptable turf quality (Weston and Dunn, 1985; McCrimmon, 1998). Fertilization time is also important for zoysiagrass and it is reported that fertilization in November with N could cause heavier winter injury and weed infestation (Dunn et al., 1993). Dunn et al. (1995) further reported that maintenance of zoysiagrass with only enough N to provide acceptable turfgrass density and color will give the best root development in nonsandy soils.

Research shows that tall fescue quality was better at mowing heights of 5 to 8.8 cm, than lower mowing height (Voigt et al., 2001; Dernoeden et al., 1993). Tall fescue does not tolerate very low mowing, but Ray et al. (2007) reported that overall quality of 15 varieties were better with 5-cm mowing height than 7.5-cm mowing height during the first year of establishment. Fertilization with N increased tall fescue coverage and compensated the detrimental effect of mowing for monostand (Hickey and Hume, 2003). A total N of 225 kg ha^{-1} yr^{-1} in one, two, three, or six applications did not show differences in tall fescue turf quality except that summer applications had higher weed infestation (Burns, 1981).

Managing a mixture of zoysiagrass with tall fescue is a challenge because two species are involved. Of the most important cultural practices that influence the population balance of the mixture are mowing and fertilization, especially for athletic turf use where the grasses are subjected to heavy traffic. A higher N rate is expected to favor the more aggressive grasses and make the content of mixed turf shift slowly (Engel, 1974). When zoysiagrass was mixed with Kentucky bluegrass, nitrogen favored cool-season grasses especially in fall season, and low mowing height favored higher percentage of zoysiagrass stand (Hawes, 1980). There have been many turf type tall fescue varieties released since 1950s (Buckner and Bush, 1979). Many of those varieties have different growth characteristics in terms of color, responses to N and mowing. At AgResearch of New Zealand, a turf type tall fescue cultivar 'Grasslands Garland' was released which has a dwarf growth habit, increased winter growth, fine leaves, and a dense sward for use in extremes of temperature and moisture (Rumball et *al.* 1991). Agronomic evaluations by the New Zealand Sports Turf Institute (Walmsley 1993) showed 'Grasslands Garland' has a low response to N and lighter green genetic color, and to be superior to many American cultivars at the time of testing. However, not enough research have been done to evaluate the effect of mowing height and N fertilizer combinations on zoysiagrass/tall fescue mixture under sports field conditions. The goal of present study was to determine if zoysiagrass/tall fescue mixture can be maintained with proper mowing and fertilization under simulated sport traffic at an acceptable quality level.

MATERIALS AND METHODS

Zoysiagrass 'Sunrise' (Jacklin Seed, ID USA) was planted from seeds at 150 Kg ha^{-1} in June 1996. Tall fescue 'Arid' (Jacklin Seed, ID USA) and 'Grasslands Garland' (Agresearch, New Zealand) was slit seeded into germinated zoysiagrass two months later in August 1996 at a rate of 300 Kg ha^{-1}.

The soil was a sandy loam with 3% soil organic matter on average. Starter fertilizer 10-30-10 was used at N rate of 25 Kg ha^{-1}. Fertilization treatment was applied in May, July, and September in during the three years of study at N rate of 0, 50, and 100 Kg ha^{-1} from urea (46-0-0). The turf was mowed weekly at mowing heights of 6.5, 5.0, and 3.5 cm. Irrigation was applied as needed to prevent water stress. Traffic treatment was applied from May to September of 1997 and 1998 at 10, 5, and 0 passes per week using a 70-Kg wear roller with football cleats mounded at 5 cm x 5 cm spacing. The roller has an oblong intersection shape, short radius of 20 cm and long radius of 40 cm, making the traffic a combination of impacting and shearing when pulled by two persons (Li and Hunt, 1997).

The percentage ground cover was assessed via point analysis using a set of 5 needles at 5-cm spacing. The needles were able to be moved freely up with spring loads after being pushed down. The ground cover identity was determined by the first touch during the downwards travel of the needles. One hundred points were measured in each plot. The shoot density of grasses was assessed by counting the shoots in sod plugs which were sampled from each plot with a 10-cm dia. cup cutter.

Experimental design was a split-split plot design with three replications. The traffic was designated as main plots, mowing as sub plots, and N levels as sub-sub plots. Statistics was conducted with general linear model using SAS 9.1 software.

RESULTS AND DISCUSSION

In September 1996 zoysiagrass coverage was 43.49% in no nitrogen treatment, significantly higher than that at higher nitrogen levels, while tall fescue coverage was the opposite, higher coverage in high N treatments. This indicated that N favors tall fescue growth at establishment stage. Two tall fescue varieties were not statistically different in coverage. However, 'Grasslands Garland' favors more zoysiagrass coverage with 41.41%, comparing to 36.39% coverage in 'Arid' (Table 1). Bare areas, as the third components of ground coverage, were not significantly different among different levels of treatments as a result of combined effect of zoysiagrass and tall fescue.

There were no significant interaction effects among variety, mowing height, and N level during the establishment stage (Table 1).

In October 1996, zoysiagrass coverage was sill higher in low N fertilization rates than in higher N rates with the coverage of 49.32, 38.99, and 36.86% for 0. 50, and 100 Kg ha^{-1} N rates, respectively (Table 2). Mowing height started to show significant effects on zoysiagrass coverage with low mowing heights favoring zoysiagrass growth in the mixture. The zoysiagrass coverage was 28.48, 40.56, and 55.41% for mowing heights of 6.5, 5.0, and 3.5 cm, respectively. The effects of mowing heights and N fertilization rates on two tall fescue varieties were opposite to zoysiagrass, i.e. higher N and mowing height favored tall fescue growth (Table 2).

Table 1. Ground cover of zoysiagrass (*Zoysia japonica* Steud.), tall fescue (*Fescuta arundinacea* Schreb), and bare areas as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in September 1996.

Factor	Level	n	Zoysiagrass Mean	Zoysiagrass Std Dev	Tall Fescue Mean	Tall Fescue Std Dev	Bare Mean	Bare Std Dev
						%		
Variety	Arid	27	36.39	8.96	50.08	9.72	15.29	11.78
	Grasslands Garland	27	41.41	7.57	47.96	7.36	12.79	4.95
Mowing Height	6.5 cm	18	38.91	8.83	49.02	8.80	14.04	9.22
	5 cm	18	38.91	8.83	49.02	8.80	14.04	9.22
	2.5 cm	18	38.91	8.83	49.02	8.80	14.04	9.22
Nitrogen	0 kg ha^{-1}	18	43.49	10.17	44.51	8.81	14.82	3.34
	50 kg ha^{-1}	18	35.18	5.66	50.62	8.45	16.10	10.48
	100 kg ha^{-1}	18	37.97	7.32	51.85	6.38	11.20	10.96

ANOVA of Zoysiagrass

Source	DF	SS	MS	F	P>F
Blocks	2	0.0398	0.0199	3.1800	0.0530
Variety	1	0.0401	0.0401	6.3900	0.0157
Mowing Height	2	0.0000	0.0000	0.0000	1.0000
Nitrogen	2	0.0764	0.0382	6.0900	0.0051
Variety * Mowing height	2	0.0000	0.0000	0.0000	1.0000
Variety * Nitrogen	2	0.0044	0.0022	0.3500	0.7061
Mowing Height * Nitrogen	4	0.0000	0.0000	0.0000	1.0000
Error	38	0.2382	0.0063		

ANOVA of Tall Fescue

Source	DF	SS	MS	F	P>F
Blocks	2	0.0678	0.0339	5.4400	0.0084
Variety	1	0.0080	0.0080	1.2900	0.2635
Mowing Height	2	0.0000	0.0000	0.0000	1.0000
Nitrogen	2	0.0724	0.0362	5.8000	0.0063
Variety * Mowing height	2	0.0000	0.0000	0.0000	1.0000
Variety * Nitrogen	2	0.0104	0.0052	0.8300	0.4435
Mowing Height * Nitrogen	4	0.0000	0.0000	0.0000	1.0000
Error	38	0.2370	0.0062		

Table 2. Ground cover of zoysiagrass (*Zoysia japonica* Steud.), tall fescue (*Fescuta arundinacea* Schreb), and bare areas as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in October 1996.

Factor	Level	n	Zoysiagrass Mean	Zoysiagrass Std Dev	Tall Fescue Mean	Tall Fescue Std Dev	Bare Mean	Bare Std Dev
					%			
Variety	Arid	27	40.73	17.20	54.23	17.75	6.54	8.52
	Grasslands Garland	27	42.86	16.53	53.49	19.73	5.28	3.22
Mowing Height	6.5 cm	18	28.48	10.35	67.39	16.25	5.14	5.73
	5 cm	18	40.56	10.75	54.84	10.39	5.10	4.75
	2.5 cm	18	55.41	13.57	37.69	7.34	7.50	8.30
Nitrogen	0 kg ha^{-1}	18	49.32	15.79	46.22	15.88	5.63	4.27
	50 kg ha^{-1}	18	38.99	15.85	55.61	19.09	6.93	7.94
	100 kg ha^{-1}	18	36.86	16.13	59.40	18.12	5.18	6.72

ANOVA of Zoysiagrass

Source	DF	SS	MS	F	P>F
Blocks	2	0.0700	0.0350	3.3200	0.0468
Variety	1	0.0074	0.0074	0.7000	0.4065
Mowing Height	2	0.8063	0.4032	38.2400	<.0001
Nitrogen	2	0.1974	0.0987	9.3600	0.0005
Variety * Mowing height	2	0.0043	0.0021	0.2000	0.8171
Variety * Nitrogen	2	0.0107	0.0054	0.5100	0.6051
Mowing Height * Nitrogen	4	0.0048	0.0012	0.1100	0.9773
Error	38	0.4006	0.0105		

ANOVA of Tall Fescue

Source	DF	SS	MS	F	P>F
Blocks	2	0.0016	0.0008	0.0700	0.9310
Variety	1	0.0010	0.0010	0.0900	0.7614
Mowing Height	2	1.1251	0.5625	51.4700	<.0001
Nitrogen	2	0.2296	0.1148	10.5000	0.0002
Variety * Mowing height	2	0.0062	0.0031	0.2800	0.7542
Variety * Nitrogen	2	0.0530	0.0265	2.4200	0.1023
Mowing Height * Nitrogen	4	0.0218	0.0054	0.5000	0.7376
Error	38	0.4153	0.0109		

The bare areas were not significant different among different treatments. There were no significant interaction effects on the coverage.

By November 1996, zoysiagrass coverage was 62.36, 29.88, and 30.02% for 0, 50, and 100 Kg ha^{-1} N rates, respectively (Table 3). At the same time, zoysiagrass coverage was 23.53, 41.95, and 57.40% for the mowing heights of 6.5, 5.0, and 3.5 cm, respectively (Table 3). Again, there were no significant interaction effects on the zoysiagrass coverage. In general, high N and low mowing height favor tall fescue growth at establishment stage during the fall of 1996.

Zoysiagrass and tall fescue coverage in July 1997 was showing the same trend as in the late season of 1996 although the differences were not as big (Table 4).

Table 3. Ground cover of zoysiagrass (*Zoysia japonica* Steud.), tall fescue (*Fescuta arundinacea* Schreb), and bare areas as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in November 1996.

			Zoysiagrass		Tall Fescue		Bare	
Factor	Level	n	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
					%			
Variety	Arid	27	40.54	23.26	61.86	27.70	1.12	2.09
	Grasslands Garland	27	42.33	29.75	62.93	34.40	0.53	0.85
Mowing Height	6.5 cm	18	23.53	20.05	79.71	28.74	0.36	0.77
	5 cm	18	41.95	26.77	61.40	27.35	0.40	0.67
	2.5 cm	18	57.40	18.86	42.39	15.02	1.72	2.40
Nitrogen	0 kg ha^{-1}	18	62.36	22.64	38.95	19.14	0.95	1.34
	50 kg ha^{-1}	18	29.88	18.44	72.20	27.05	1.01	2.02
	100 kg ha^{-1}	18	30.02	20.21	72.73	27.58	0.51	1.42

ANOVA of Zoysiagrass

Source	DF	SS	MS	F	*P*>F
Blocks	2	0.0978	0.0489	3.1300	0.0549
Variety	1	0.0052	0.0052	0.3400	0.5656
Mowing Height	2	1.2584	0.6292	40.3400	<.0001
Nitrogen	2	1.6359	0.8179	52.4400	<.0001
Variety * Mowing height	2	0.0589	0.0295	1.8900	0.1652
Variety * Nitrogen	2	0.0288	0.0144	0.9200	0.4054
Mowing Height * Nitrogen	4	0.1335	0.0334	2.1400	0.0948
Error	38	0.5927	0.0156		

ANOVA of Tall Fescue

Source	DF	SS	MS	F	*P*>F
Blocks	2	0.0974	0.0487	3.1400	0.0549
Variety	1	0.0025	0.0025	0.1600	0.6883
Mowing Height	2	2.1196	1.0598	68.2300	<.0001
Nitrogen	2	2.0221	1.0111	65.0900	<.0001
Variety * Mowing height	2	0.0673	0.0337	2.1700	0.1285
Variety * Nitrogen	2	0.0650	0.0325	2.0900	0.1374
Mowing Height * Nitrogen	4	0.2916	0.0729	4.6900	0.0035
Error	38	0.5902	0.0155		

There were significant interactions between N fertilization rates and mowing heights (Table 4). At low N rate, zoysiagrass coverage was higher in 'Grasslands Garland' mixture than in 'Arid' mixture, while at higher N rates, it was opposite (Fig. 1a). Weed coverage showed a different trend, in 'Grasslands Garland' mixture, weed coverage was the lowest in the 50, Kg ha^{-1} N rates while in 'Arid' mixture, weed coverage was the highest in the 50 Kg ha^{-1} N rates (Fig. 1b). The weed coverage might have been affected by the traffic treatment which was introduced in May, 1997. At medium level of traffic (5 passes $week^{-1}$), low nitrogen rate had the highest weed infestation, while at low or high traffic levels, high N had the highest weed infestation (Fig. 1c).

Table 4. Ground cover of zoysiagrass (*Zoysia japonica* Steud.), tall fescue (*Fescuta arundinacea* Schreb), weeds, and bare areas as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in July 1997.

Factor	Level	n	Zoysiagrass Mean	Zoysiagrass Std Dev	Tall Fescue Mean	Tall Fescue Std Dev	Weeds Mean	Weeds Std Dev	Bare Mean	Bare Std Dev
			%							
Variety	Arid	81	44.91	16.63	50.24	19.06	0.54	1.51	3.58	5.10
	Grasslands Garland	81	44.35	17.67	50.19	20.40	1.04	2.63	3.99	5.19
Mowing Height	6.5 cm	54	35.18	15.30	61.14	18.72	0.80	1.89	2.42	3.32
	5 cm	54	45.97	16.37	49.19	17.38	0.51	1.75	3.47	4.54
	3.5 cm	54	52.32	14.11	39.50	14.32	1.06	2.68	5.46	6.58
Nitrogen	0 kg ha^{-1}	54	41.80	17.32	54.03	19.81	0.67	1.91	3.69	5.10
	50 kg ha^{-1}	54	45.43	17.09	50.54	18.18	0.78	1.99	3.54	4.49
	100 kg ha^{-1}	54	46.63	16.66	45.96	20.14	0.92	2.51	4.12	5.77
Traffic	10 passes $week^{-1}$	54	42.81	17.74	50.50	20.78	0.81	2.04	5.12	5.83
	5 passes $week^{-1}$	54	45.63	17.72	49.48	21.01	0.93	2.36	3.55	4.94
	0 passes $week^{-1}$	54	45.44	15.82	50.66	17.23	0.63	2.04	2.68	4.27

ANOVA of Zoysiagrass

Source	DF	SS	MS	F	P>F
Blocks	2	0.1534	0.0767	3.4400	0.0330
Variety	1	0.0046	0.0046	0.2100	0.6485
Traffic	2	0.0995	0.0498	2.2300	0.1086
Mowing Height	2	3.0154	1.5077	67.5700	<.0001
Nitrogen	2	0.2547	0.1274	5.7100	0.0036
Variety * Mowing Height	2	0.0529	0.0264	1.1800	0.3069
Variety * Nitrogen	2	0.3337	0.1669	7.4800	0.0006
Mowing Height * Nitrogen	4	0.0516	0.0129	0.5800	0.6788
Traffic * Mowing Height	4	0.0352	0.0088	0.3900	0.8123
Traffic * Nitrogen	4	0.0472	0.0118	0.5300	0.7147
Traffic * Variety	2	0.1252	0.0626	2.8100	0.0615
Error	134	10.2190	0.0223		

ANOVA of Tall Fescue

Source	DF	SS	MS	F	P>F
Blocks	2	0.1780	0.0890	3.3400	0.0363
Variety	1	0.0000	0.0000	0.0000	0.9702
Traffic	2	0.0179	0.0089	0.3400	0.7154
Mowing Height	2	5.1719	2.5859	97.0800	<.0001
Nitrogen	2	0.7072	0.3536	13.2800	<.0001
Variety * Mowing Height	2	0.0791	0.0395	1.4800	0.2278
Variety * Nitrogen	2	0.3794	0.1897	7.1200	0.0009
Mowing Height * Nitrogen	4	0.0649	0.0162	0.6100	0.6562
Traffic * Mowing Height	4	0.0507	0.0127	0.4800	0.7537
Traffic * Nitrogen	4	0.1091	0.0273	1.0200	0.3944
Traffic * Variety	2	0.1574	0.0787	2.9500	0.0531
Error	134	12.1995	0.0266		

ANOVA of Weeds

Source	DF	SS	MS	F	P>F
Blocks	2	0.0108	0.0054	12.6600	<.0001
Variety	1	0.0030	0.0030	7.0800	0.0081
Traffic	2	0.0008	0.0004	0.8900	0.4126
Mowing Height	2	0.0025	0.0013	2.9700	0.0524
Nitrogen	2	0.0005	0.0003	0.6200	0.5409
Variety * Mowing Height	2	0.0006	0.0003	0.6700	0.5126
Variety * Nitrogen	2	0.0032	0.0016	3.7500	0.0243
Mowing Height * Nitrogen	4	0.0019	0.0005	1.1100	0.3519
Traffic * Mowing Height	4	0.0021	0.0005	1.2100	0.3042
Traffic * Nitrogen	4	0.0047	0.0012	2.7700	0.0268
Traffic * Variety	2	0.0006	0.0003	0.7000	0.4987
Error	134	0.1945	0.0004		

1a.

1b.

1c.

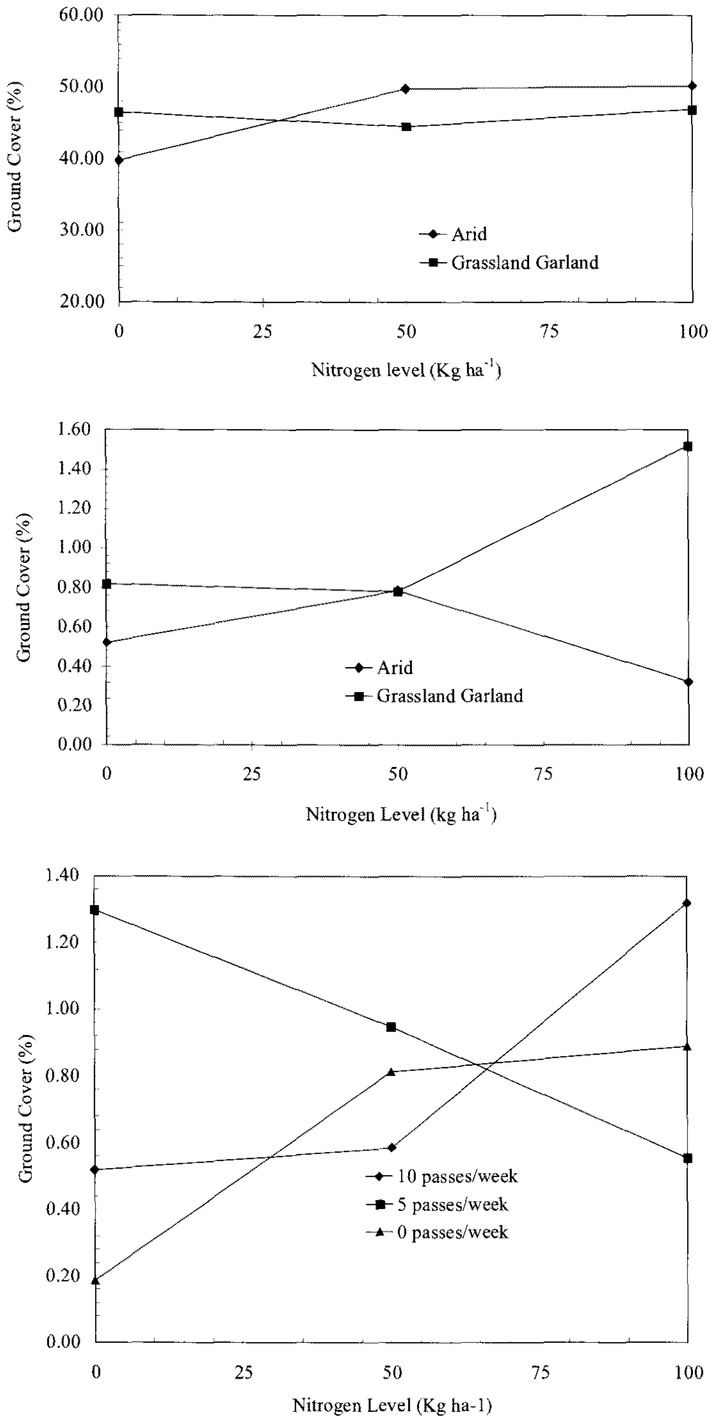


Figure 1. Ground cover in 1996 (a) zoysiagrass (*Zoysia japonica* Steud.) and (b) weeds as an effect of interactions between tall fescue (*Fescuta arundinacea* Schreb) variety and nitrogen fertilization rate, and (c) weeds as an effect of traffic and nitrogen fertilization rate.

Table 5. Ground cover of zoysiagrass (*Zoysia japonica* Steud.), tall fescue (*Fescuta arundinacea* Schreb), weeds, and bare areas as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in November 1997.

Factor	Level	n	Zoysiagrass Mean	Zoysiagrass Std Dev	Tall Fescue Mean	Tall Fescue Std Dev	Weeds Mean	Weeds Std Dev	Bare Mean	Bare Std Dev
						%				
Variety	Arid	81	50.01	24.46	51.00	25.69	0.19	0.88	2.06	3.65
	Grasslands Garland	81	49.52	25.87	51.75	27.98	0.35	1.96	2.15	3.97
Mowing Height	6.5 cm	54	36.38	22.85	65.35	26.57	0.11	0.46	1.45	3.34
	5 cm	54	52.54	24.50	48.84	24.01	0.14	0.60	1.49	2.90
	3.5 cm	54	59.50	20.69	38.59	19.82	0.56	2.51	3.36	4.66
Nitrogen	0 kg ha^{-1}	54	47.58	23.17	53.93	24.83	0.10	0.62	1.45	2.66
	50 kg ha^{-1}	54	52.10	27.37	49.94	27.74	0.20	0.93	1.73	3.05
	100 kg ha^{-1}	54	49.59	24.61	50.22	27.75	0.51	2.38	3.13	5.07
Traffic	10 passes $week^{-1}$	54	44.06	24.31	56.16	28.80	0.35	1.88	3.05	4.35
	5 passes $week^{-1}$	54	48.51	24.73	52.42	26.15	0.28	1.66	2.11	4.16
	0 passes $week^{-1}$	54	56.47	24.50	45.35	24.03	0.17	0.82	1.14	2.38

ANOVA of Zoysiagrass

Source	DF	SS	MS	F	*P*>F
Blocks	2	1.1650	0.5825	12.5600	<.0001
Variety	1	0.0038	0.0038	0.0800	0.7736
Traffic	2	1.7274	0.8637	18.6200	<.0001
Mowing Height	2	5.9398	2.9699	64.0200	<.0001
Nitrogen	2	0.2210	0.1105	2.3800	0.0935
Variety * Mowing Height	2	0.0074	0.0037	0.0800	0.9238
Variety * Nitrogen	2	0.5805	0.2902	6.2600	0.0021
Mowing Height * Nitrogen	4	0.0783	0.0196	0.4200	0.7928
Traffic * Mowing Height	4	0.1501	0.0375	0.8100	0.5200
Traffic * Nitrogen	4	0.1552	0.0388	0.8400	0.5027
Traffic * Variety	2	0.0822	0.0411	0.8900	0.4131
Error	134	21.2469	0.0464		

ANOVA of Tall Fescue

Source	DF	SS	MS	F	*P*>F
Blocks	2	1.4138	0.7069	14.0500	<.0001
Variety	1	0.0095	0.0095	0.1900	0.6647
Traffic	2	1.3147	0.6573	13.0600	<.0001
Mowing Height	2	8.2944	4.1472	82.4200	<.0001
Nitrogen	2	0.2199	0.1100	2.1900	0.1136
Variety * Mowing Height	2	0.0049	0.0024	0.0500	0.9527
Variety * Nitrogen	2	0.8028	0.4014	7.9800	0.0004
Mowing Height * Nitrogen	4	0.1394	0.0349	0.6900	0.5972
Traffic * Mowing Height	4	0.2377	0.0594	1.1800	0.3183
Traffic * Nitrogen	4	0.2808	0.0702	1.4000	0.2346
Traffic * Variety	2	0.0486	0.0243	0.4800	0.6170
Error	134	23.0449	0.0503		

ANOVA of Weeds

Source	DF	SS	MS	F	*P*>F
Blocks	2	0.0028	0.0014	6.4500	0.0017
Variety	1	0.0003	0.0003	1.3700	0.2418
Traffic	2	0.0003	0.0001	0.5700	0.5644
Mowing Height	2	0.0020	0.0010	4.6500	0.0101
Nitrogen	2	0.0015	0.0007	3.3700	0.0354
Variety * Mowing Height	2	0.0002	0.0001	0.4300	0.6506
Variety * Nitrogen	2	0.0027	0.0013	6.0600	0.0025
Mowing Height * Nitrogen	4	0.0006	0.0002	0.7000	0.5953
Traffic * Mowing Height	4	0.0007	0.0002	0.8300	0.5087
Traffic * Nitrogen	4	0.0005	0.0001	0.5500	0.6989
Traffic * Variety	2	0.0004	0.0002	0.9400	0.3932
Error	134	0.1005	0.0002		

The results of November 1997 were similar to that of July 1997 except the effect of interactions on weed infestation was not significant (Table 6, Fig. 2). In November 1998, the zoysiagrass coverage was different among the two tall fescue variety mixtures, 21.68, and 32.25% in 'Arid' and 'Grass Garland', respectively (Table 6). Zoysiagrass coverage was favored in lower mowing height, lower N rates, and lower traffic, while tall fescue favored by higher mowing height and medium level of N. Interaction effects on zoysiagrass were found between tall fescue variety and nitrogen rate (Fig. 3a), tall fescue variety and mowing height (Fig. 3b), and traffic and nitrogen rate (Fig. 3c).

The shoot density of zoysiagrass in the in November of 1996 was affected by tall fescue variety, mowing height, and N fertilization rate. Zoysiagrass shoot density was 10% higher in 'Arid' mixtures than in 'Grasslands Garland' mixtures (Table 7). Zoysiagrass shoot density was 43.03, 41.41, and 33.80% for mowing heights of 6.5, 5, and 3.5 cm, respectively; and it was 29.01, 43.05, and 45.93% for N rates of 0, 50, and 100 Kg ha^{-1}, respectively in 1996 (Table 7). The effect of N rates on the shoot density was opposite to the trend seen in zoysiagrass ground cover. The difference might have resulted from different N responses of leaf growth and tiller growth under mowed conditions. More defoliation stimulated N and carbohydrate movement to leaves and less for tiller and root growth. Zoysiagrass shoot density was also in a different trend for ground cover in two tall fescue mixtures, higher in 'Arid' and lower in 'Grasslands Garland' (Table 1 and 7). This might be because of the stronger tillering ability of 'Grasslands Garland' (Rumball et *al.* 1991). In November of 1997, however, zoysiagrass shoot density was higher for lower mowing height and lower N rates, contrary to the results from the year before (Table 8). The change of zoysiagrass shoot density in the second year into the study might be related to the maturity or introduction of traffic treatment. The shift of shoot population was further shown from the results of 1998 where zoysiagrass shoot density was higher in 'Grasslands Garland' mixture than in the 'Arid'. The relative shoot density in 1998 was reversed as affected by mowing height and N rate compared with the results of 1997 (Table 9). Zoysiagrass shoot density was 7.42, 25.47, and 58.95% for mowing heights of 6.5, 5, and 3.5 cm, respectively; and it was 47.27, 20.27, and 26.26% for N rates of 0, 50, and 100 Kg ha^{-1}, respectively in 1998 (Table 7). The effects on zoysiagrass shoot density from the interaction of N rate and tall fescue variety was significant in 1998 (Fig. 4). The interactions between mowing height and N rate, mowing height and traffic were not significant at 5% probability level, but would be at 8% probability level (Table 9). The results indicated that over time, the traffic, as well as N rate and mowing height would affect the population balance and the dynamic of shoot densities of zoysiagrass and tall fescue in the mixture.

Table 6. Ground cover of Zoysiagrass (*Zoysia japonica* Steud.), tall fescue (*Fescuta arundinacea* Schreb), weeds, dead tissues, and bare areas as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in November 1998.

Factor	Level	n	Zoysiagrass		Tall Fescue		Weeds		Dead Tissue		Bare	
			Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev
							%					
Variety	Arid	81	21.68	18.15	52.52	18.80	3.21	5.74	15.48	10.01	8.62	6.36
	Grasslands Garland	81	32.25	25.76	51.48	20.98	1.38	2.24	11.41	8.46	5.97	5.28
Mowing Height	6.5 cm	54	11.82	11.83	61.96	14.63	0.76	1.78	17.62	7.81	8.73	5.82
	5 cm	54	23.91	18.81	53.72	17.94	2.21	3.96	14.32	9.69	7.37	6.24
	3.5 cm	54	44.42	22.38	39.42	17.68	3.91	6.00	8.37	8.48	5.79	5.59
Nitrogen	0 kg ha^{-1}	54	39.77	27.36	47.95	19.86	0.94	1.69	7.90	6.74	6.06	6.37
	50 kg ha^{-1}	54	18.02	16.51	60.23	18.72	3.08	5.25	12.44	7.30	7.64	5.42
	100 kg ha^{-1}	54	22.81	16.74	47.42	17.50	2.85	5.17	19.95	9.83	8.20	6.01
Traffic	10 passes $week^{-1}$	54	23.93	21.53	51.24	18.68	2.30	4.06	13.34	9.47	10.90	7.47
	5 passes $week^{-1}$	54	25.65	22.58	53.46	19.97	2.14	4.03	13.54	10.48	7.21	3.87
	0 passes $week^{-1}$	54	31.39	24.17	51.28	21.14	2.44	5.21	13.46	8.52	3.78	3.42

ANOVA of Zoysiagrass

Source	DF	SS	MS	F	P>F
Blocks	2	0.5607	0.2803	21.8300	<.0001
Variety	1	0.4885	0.4885	38.0300	<.0001
Traffic	2	0.1785	0.0893	6.9500	0.0013
Mowing Height	2	3.2371	1.6186	126.0200	<.0001
Nitrogen	2	1.5530	0.7765	60.4600	<.0001
Variety * Mowing Height	2	0.0937	0.0468	3.6500	0.0287
Variety * Nitrogen	2	0.4755	0.2378	18.5100	<.0001
Mowing Height * Nitrogen	4	0.1121	0.0280	2.1800	0.0743
Traffic * Mowing Height	4	0.0079	0.0020	0.1500	0.9613
Traffic * Nitrogen	4	0.1260	0.0315	2.4500	0.0490
Traffic * Variety	2	0.0266	0.0133	1.0300	0.3585
Error	134	1.7210	0.0128		

ANOVA of Tall Fescue

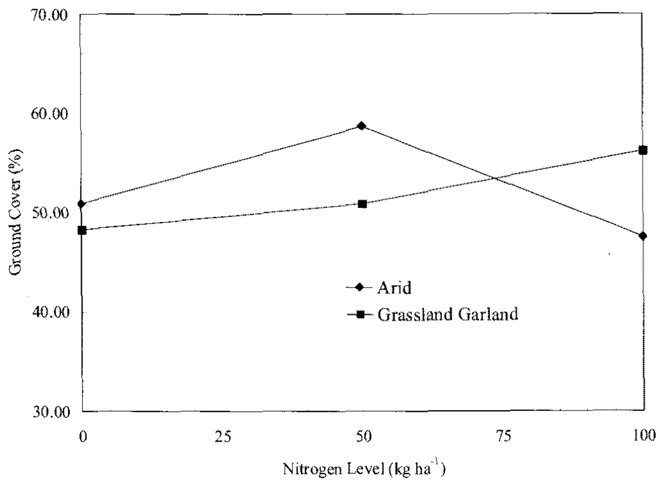
Source	DF	SS	MS	F	P>F
Blocks	2	0.3977	0.1988	9.5200	0.0001
Variety	1	0.0059	0.0059	0.2800	0.5944
Traffic	2	0.0241	0.0121	0.5800	0.5628
Mowing Height	2	1.9014	0.9507	45.5200	<.0001
Nitrogen	2	0.8033	0.4016	19.2300	<.0001
Variety * Mowing Height	2	0.0507	0.0253	1.2100	0.3005
Variety * Nitrogen	2	0.3275	0.1638	7.8400	0.0006
Mowing Height * Nitrogen	4	0.0590	0.0147	0.7100	0.5892
Traffic * Mowing Height	4	0.0213	0.0053	0.2600	0.9061
Traffic * Nitrogen	4	0.0427	0.0107	0.5100	0.7276
Traffic * Variety	2	0.0109	0.0054	0.2600	0.7716
Error	134	2.7984	0.0209		

ANOVA of Weeds

Source	DF	SS	MS	F	P>F
Blocks	2	0.0510	0.0255	17.4400	<.0001
Variety	1	0.0136	0.0136	9.2900	0.0028
Traffic	2	0.0002	0.0001	0.0800	0.9210
Mowing Height	2	0.0269	0.0134	9.1900	0.0002
Nitrogen	2	0.0149	0.0075	5.1000	0.0073
Variety * Mowing Height	2	0.0011	0.0005	0.3600	0.6961
Variety * Nitrogen	2	0.0035	0.0017	1.1800	0.3093
Mowing Height * Nitrogen	4	0.0049	0.0012	0.8300	0.5084
Traffic * Mowing Height	4	0.0045	0.0011	0.7800	0.5415
Traffic * Nitrogen	4	0.0011	0.0003	0.1800	0.9482
Traffic * Variety	2	0.0002	0.0001	0.0800	0.9264
Error	134	0.1959	0.0015		

ANOVA of Dead Tissue					
Source	DF	SS	MS	F	P>F
Blocks	2	0.0277	0.0139	3.1400	0.0463
Variety	1	0.0683	0.0683	15.4900	0.0001
Traffic	2	0.0001	0.0001	0.0100	0.9865
Mowing Height	2	0.2416	0.1208	27.3800	<.0001
Nitrogen	2	0.4088	0.2044	46.3300	<.0001
Variety * Mowing Height	2	0.0017	0.0008	0.1900	0.8258
Variety * Nitrogen	2	0.0079	0.0040	0.9000	0.4098
Mowing Height * Nitrogen	4	0.0247	0.0062	1.4000	0.2368
Traffic * Mowing Height	4	0.0117	0.0029	0.6600	0.6176
Traffic * Nitrogen	4	0.0453	0.0113	2.5700	0.0411
Traffic * Variety	2	0.0177	0.0088	2.0000	0.1388
Error	134	0.5911	0.0044		

2a



2.b

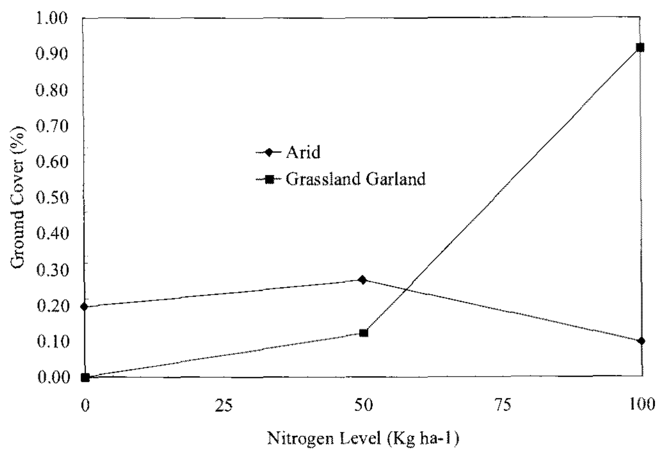
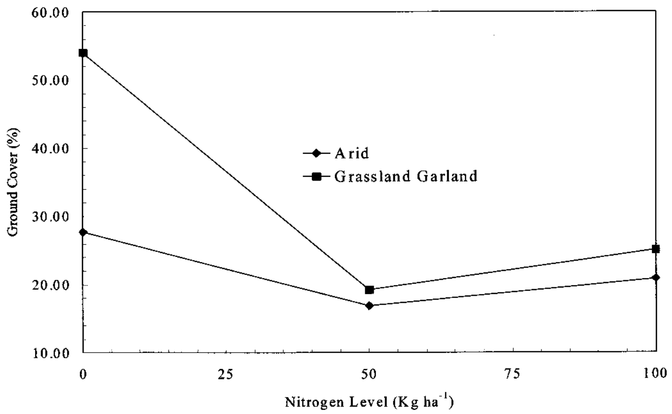


Figure 2. Ground cover in 1997 (a) zoysiagrass (*Zoysia japonica* Steud.) and (b) weeds, as an effect of interactions between tall fescue (*Fescuta arundinacea* Schreb) variety and nitrogen fertilization rate.

3a.



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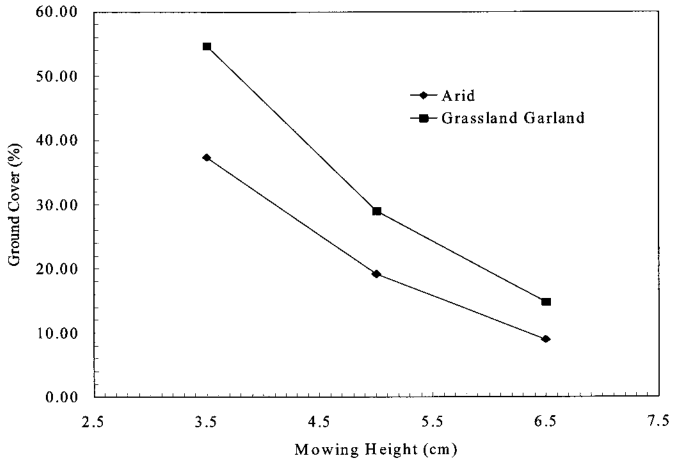

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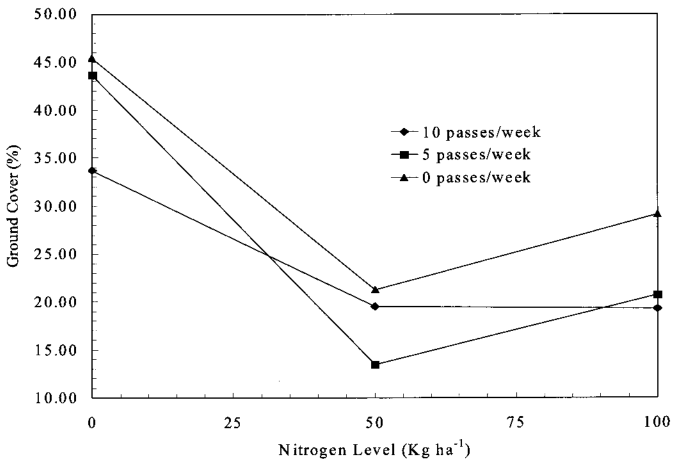

Figure 3. Ground cover in 1997 (a) zoysiagrass (*Zoysia japonica* Steud.) as an effect of interactions between tall fescue (*Fescuta arundinacea* Schreb) variety and nitrogen fertilization rate, and (b) zoysiagrass as affected by tall fescue variety and mowing height.

Table 7. Shoot density of zoysiagrass (*Zoysia japonica* Steud.) and tall fescue (*Fescuta arundinacea* Schreb) as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in November 1996.

Factor	Level	n	Zoysiagrass Mean	Zoysiagrass Std Dev	Tall Fescue Mean	Tall Fescue Std Dev
				%		
Variety	Arid	27	44.43	16.47	57.11	18.25
	Grasslands Garland	27	34.35	15.87	67.17	18.27
Mowing Height	6.5 cm	18	43.03	17.81	58.63	18.76
	5 cm	18	41.41	16.52	60.12	18.48
	2.5 cm	18	33.80	15.64	67.80	19.25
Nitrogen	0 kg ha^{-1}	18	29.01	10.10	71.74	13.36
	50 kg ha^{-1}	18	43.05	15.18	58.23	16.94
	100 kg ha^{-1}	18	45.93	19.03	56.03	20.58

ANOVA of Zoysiagrass

Source	DF	SS	MS	F	P>F
Block	2	0.0896	0.0448	2.41	0.1032
Variety	1	0.1626	0.1626	8.75	0.0053
Mowing Height	2	0.1025	0.0513	2.76	0.0761
Nitrogen	2	0.3431	0.1715	9.23	0.0005
Variety * Mowing Height	2	0.0249	0.0125	0.67	0.5176
Variety * Nitrogen	2	0.0476	0.0238	1.28	0.2897
Mowing Height * Nitrogen	4	0.0587	0.0147	0.79	0.5394
Error	38	0.7061	0.0186		

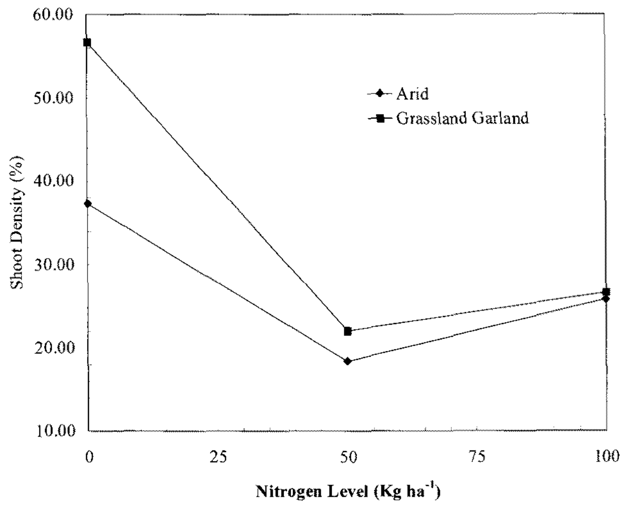

Figure 4. Shoot density in 1998 of zoysiagrass (*Zoysia japonica* Steud.) as an effect of interactions between tall fescue (*Fescuta arundinacea* Schreb) variety and nitrogen fertilization rate.

Table 8. Shoot density of zoysiagrass (*Zoysia japonica* Steud.) and tall fescue (*Fescuta arundinacea* Schreb) as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in November 1997.

Factor	Level	n	Zoysiagrass Mean	Zoysiagrass Std Dev	Tall Fescue Mean	Tall Fescue Std Dev
				%		
Variety	Arid	81	40.83	15.15	74.62	16.38
	Grasslands Garland	81	39.88	16.56	76.81	16.53
Mowing Height	6.5 cm	54	28.24	13.91	85.64	16.28
	5 cm	54	38.44	15.60	77.30	16.17
	3.5 cm	54	53.58	16.79	61.75	15.01
Nitrogen	0 kg ha^{-1}	54	49.63	17.17	68.18	17.09
	50 kg ha^{-1}	54	39.12	14.93	75.43	15.82
	100 kg ha^{-1}	54	31.93	14.85	82.63	15.77
Traffic	10 passes $week^{-1}$	54	38.27	15.97	79.16	17.17
	5 passes $week^{-1}$	54	44.24	16.36	72.09	16.26
	0 passes $week^{-1}$	54	38.51	15.24	75.70	15.80
ANOVA of Zoysiagrass						
Source		DF	SS	MS	F	*P*>F
Block		2	11.9404	5.9702	28.84	<.0001
Variety		1	0.0131	0.0131	0.06	0.8014
Traffic		2	0.4465	0.2233	1.08	0.3409
Mowing Height		2	6.4183	3.2091	15.5	<.0001
Nitrogen		2	3.1026	1.5513	7.49	0.0006
Variety * Mowing Height		2	0.3169	0.1584	0.77	0.4657
Variety * Nitrogen		2	0.1161	0.0581	0.28	0.7555
Mowing Height * Nitrogen		4	1.3669	0.3417	1.65	0.1604
Traffic * Mowing Height		4	0.2119	0.0530	0.26	0.906
Traffic * Nitrogen		4	0.4753	0.1188	0.57	0.6816
Traffic * Variety		2	0.0898	0.0449	0.22	0.8051
Error		134	94.8015	0.2070		

Table 9. Shoot density of zoysiagrass (*Zoysia japonica* Steud.) and tall fescue (*Fescuta arundinacea* Schreb) as affected by two varieties of tall fescue, mowing heights, and nitrogen levels in November 1998.

Factor	Level	n	Zoysiagrass Mean	Zoysiagrass Std Dev	Tall Fescue Mean	Tall Fescue Std Dev
				%		
Variety	Arid	81	27.29	11.93	85.26	15.89
	Grasslands Garland	81	35.69	12.65	78.35	16.91
Mowing Height	6.5 cm	54	7.42	4.84	97.52	10.63
	5 cm	54	25.47	9.09	84.63	15.14
	3.5 cm	54	58.95	13.56	50.15	11.97
Nitrogen	0 kg ha^{-1}	54	47.27	14.25	64.96	14.82
	50 kg ha^{-1}	54	20.27	9.62	90.62	15.33
	100 kg ha^{-1}	54	26.26	10.80	86.27	16.47
Traffic	10 passes $week^{-1}$	54	36.85	13.85	79.35	17.90
	5 passes $week^{-1}$	54	30.27	11.82	82.76	16.40
	0 passes $week^{-1}$	54	27.36	11.15	83.64	15.12

ANOVA of Zoysiagrass					
Source	DF	SS	MS	F	*P*>F
Block	2	2.1159	1.0580	18.65	<.0001
Variety	1	0.3178	0.3178	5.6	0.0194
Traffic	2	0.2854	0.1427	2.52	0.0846
Mowing Height	2	8.6749	4.3375	76.47	<.0001
Nitrogen	2	2.4876	1.2438	21.93	<.0001
Variety * Mowing Height	2	0.1722	0.0861	1.52	0.2229
Variety * Nitrogen	2	0.3546	0.1773	3.13	0.0471
Mowing Height * Nitrogen	4	0.4840	0.1210	2.13	0.0801
Traffic * Mowing Height	4	0.4950	0.1238	2.18	0.0744
Traffic * Nitrogen	4	0.1434	0.0359	0.63	0.6405
Traffic * Variety	2	0.0174	0.0087	0.15	0.8581
Error	134	7.6011	0.0567		

CONCLUSION

Mixing common zoysiagrass with tall fescue in the transitional zone is a practical practice to use the advantages of both species. Choosing a tall fescue variety is important for the initial mixture. Dwarf, denser, tall fescue varieties seemed to mix with zoysiagrass better than those with less and bigger tillers.

Low mowing height and N rates favors zoysiagrass coverage especially during the establishment stage. When sports traffics are involved, the coverage of zoysiagrass in the mixture with tall fescue was not only affected by N rates and mowing height, but also demonstrated interaction effects from tall fescue variety, N rate, mowing height, and traffic levels. Therefore, managing the N rates and mowing heights according to the varieties, traffic amount, and season is important.

Shoot density responded to the N rate, mowing height, and traffic differently from the ground coverage, indicating that shoot and leaf growth have different adaptation strategies. Thus turf managers have to asses not only the ground coverage but also the shoot density because those two parameters are interacting in a way that is not yet clear. More research is needed to study the photosynthesis, carbohydrates allocation, and other physiological mechanisms of zoysiagrass and tall fescue in a mixture and subjected to different management regimes.

국문 요약

톨 페스큐와 한국들잔디의 혼합 조성은 미국의 전이지역에서 두 종간의 장점을 취하고 각 종의 단점을 보완하는 실질적 관리기술로 제안되어 왔다. 이러한 두 종간의 초종 혼합은 관

리 상 어려움이 있다. 본 연구의 목적은 한국들잔디와 톨 페스큐의 혼합이 운동장 답압 하에서 예초와 시비에 의해 적절한 수준의 잔디 관리가 가능한지 실험하였다. 한국들잔디는 1996년 6월에 파종하였고 동년 8월에 톨 페스큐를 덧파종하였다. 1996년 11월에 한국들잔디의 피복율은 질소시비수준 0, 50, 100kg/ha에서 62.36, 29.88, 30.02%를 나타내었다. 예고 6.5, 5, 3.5cm에서 23.53, 41.95, 57.40%의 피복율을 보였다. 한국들잔디와 톨 페스큐의 혼합잔디는 1997년 7월에 1996년 늦가을과 큰 차이가 없는 피복율 수준을 보였다. 질소 시비율과 예고 간에는 유의한 수준의 교호작용이 있었다. 1998년 11월에는 한국들잔디의 피복율이 혼파 톨페스큐 두 품종간에 차이가 났는데, 'Arid'와 'Grassland Garland' 조성구에서 각각 21.68%와 32.25%의 피복율을 보였다. 한국들잔디 피복율은 낮은 예고, 낮은 질소수준과 저답압에서 높은 경향을 보였다. 한국들잔디에서는 톨 페스큐 품종간과 질소수준, 톨 페스큐 품종간과 예고, 답압정도와 질소수준에서 교호작용을 보였다. 한국들잔디의 줄기밀도는 1998년도 실험에서 예고 6.5, 5와 3.5cm에서 7.42, 25.47과 58.96%를 나타내었고, 질소수준 0, 50, 100Kg/ha 에서 47.25, 20.27, 26.26%의 밀도를 보였다. 한국들잔디의 밀도는 질소수준과 예고, 답압정도에서 영향을 받았는데 이것은 잔디 관리 방법에 따라 줄기밀도와 잎의 생장이 적응하는 방식이 다르다는 것을 의미한다.

REFERENCES

1. Brede, J. 1991. Zoysiagrass/Tall fescue: A winning combination. Seed World 129(6):33-38.
2. Buckner, R.C., and L.P. Bush. 1979. Tall fescue. M. Stelly (Ed.) Number 20 in the series Agronomy. Madison, Wisconsin USA.
3. Burns, R.E. 1981. Time of fertilizer application as it affects quality of tall fescue turf. Int. Turfgrass Soc. Res. J. 4:285-291.
4. Cockerham, S.T., V.A. Gibeault, and M. Borgonovo. 1994. Traffic effects on turfgrasses under restricted light. California Turfgrass Culture. 44:1-3.
5. Dernoeden, P.H., M.J. Carroll, and J.M. Krouse. 1993. Weed management and tall fescue quality as influenced by mowing, nitrogen, and herbicides. Crop Science 33:1055-1061.
6. Dunn, J.H., D.D. Minner, B.F. Fresenburg, and S.S. Bughrara. 1993. Fall fertilization of zoysiagrass. P.565-571. in R.N. Carrow, N.E. Christians, R.C. Shearman (eds). International Turfgrass Society Research Journal 7. Intertec Publishing Corp., Overland Park, Kansas.
7. Dunn, John H.; Minner, David D.; Fresenburg, Brad F.; Bughrara, S. S.; Hohnstrater, Chris H. 1995. Influence of core aerification, topdressing, and nitrogen on mat, roots, and quality of 'Meyer' zoysiagrass. Agron. J. 87:891-894.

8. Engel, R. E. 1974. Influence of nitrogen fertilization on species dominance in turfgrass mixtures. *Int. Turfgrass Soc. Res. J.* p. 104-111.
9. Hawes, D.T. 1980. Proceedings of the Third International Turfgrass Research Conference. P.65-74. Madison, WI 53711 USA.
10. Henry, M.J., V.A. Gibeault, M.K. Lleonard, and S. Cockerham. 1989. Response of zoysiagrass to nitrogen fertilization for winter color and general performance. Proceedings of the Sixth International Turfgrass Research Conference. P. 213-215.
11. Hickey, M.J., and D.E. Hume. 2003. Effects of mowing height and nitrogen on a turf tall fescue in comparison to perennial ryegrass and browntop bent sown alone or in mixtures 1. Establishment. Journal of Turfgrass and Sports Surface Science 79:23-32.
12. Li, D., and W.F. Hunt. 1997. Soccer wear simulation on sport turf mixture. Transactions of the CSAE. 13:164-168.
13. Longer, D.E. 1999. Low input overseeding of warm season lawns to enhance winter color. Annual Meeting Abstracts (ASA/CSSA/SSSA). Nov. 4, 1999. Salt Lake City, UT. 91:123.
14. McCrimmon, James N. 1998. Influence of nitrogen and potassium in three zoysiagrasses. HortScience. 33:516.
15. Ray, W.F., g.A. Picchioni, D.M. VanLeeuwen, and R.M. Goss. 2007. First-year response of turf-type tall fescue cultivars to different fertilization rates and mowing heights in semiarid conditions. HortTechnology 17:353-357.
16. Razmjoo, K., I. Takayuki, and K. Seiji. 1995. Overseeding manilagrass [Zoysia matrella (L.)Merr.] with cool-season turfgrasses. Journal of Turfgrass Management 143-52.
17. Rumball, W., R.B. Claydon, and M.B. Forde. 1991. 'Grasslands Garland' turf tall fescue *(Festuca arundinacea* Schreb.). N.Z J. Expt. Ag., 34:129-130.
18. SAS Institute. 2005. The SAS system for Windows. Release 9.1.3. SAS Inst., Cary, North Carolina.
19. Turgeon, A.J. 1985. Turfgrass Management. Revised Edition. Reston Publishing Co., Inc. Reston, Virginia. P45.
20. Voigt, T.B., T.W. Fermanian, and J.E. Haley. 2001. Influence of mowing and nitrogen fertility on tall fescue turf. Int. Turfgrass Soc. Res. J. 9(Part 2):953-956.
21. Walmsley, W. 1993. National turf variety trial report. N.Z.J. Turf Management 7:24-27.
22. Watson, J.R. 1989. The USGA Research Committee activities with particular reference to the utilization, problems and perspective of zoysiagrass in the USA. The 6^{th} International Turfgrass Research Conference, Tokyo, July 31-August 5, 1989. Pp. 437-440.

23. Weston, J.H, and J.H. Dunn. 1985. Thatch and quality of Meyer zoysia in response to mechanical cultivation and nitrogen fertilization. P. 449-458. in F. Lemaire (ed.) Proceedings Fifth International Turfgrass Research Conference, Institute Nationale de la Recherche Agronomique, Paris.
24. Zhang, J.M., J. Lou, K. Zhang, S.S. Lin, S.X. Mo, and L.J. Lu. 2008. Winter overseeding zoysiagrass sports turf with coolseason turfgrasses in southern China. Acta Horticulturae. 783:85-96.