動科論叢(13) : 59~73

Effects of Endophyte-infected and Endophyte-free Tall Fescue on Pasture Yield and Animal Performance

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1. Introduction

Orchardgrass, perennial ryegrass, tall fescue and ladino clover are the main forage species used on mixed pastures in Korea. The mixed pastures tend to be dominated by tall fescue, white clover or weeds in 4-5 years of use. Korean farmers have no interest in tall fescue because animals avoid it.

However, tall fescue is well adapted to wide range of on climatic and soil environment compare to most pasture species used in Korea. Because Korea is too cold in winter and too hot in summer, it is difficult to find forage species that can be used in such a climatic range. In particular, pasture soils in Korea are so poor that pastures tend to be devastated with domination of weeds without continuous application of fertilizer to pasture after establishment. But tall fescue is well adapted to such conditions. For this reason, it becomes important specie in a standard pasture mixture in Korea next to orchardgrass, importing 42 tons of its seeds in 1992, which is the second largest amount of forage species imported from foreign countries.

The fact that animals don't like to eat tall fescue on grazing pastures is associated with alkaloid contained in the plant because it is not only toxic to animals but also makes tall fescue not palatable. The alkaloid is excreted by an endophyte inhabiting tall fescue. The discovery of the association between the fungal endophyte, *Acremonium coenophialum*, in 1977 and the toxicity syndrome of livestock grazing tall fescue(*Festuca arundinacea*) shed light on the problem in grazing animals. A similar association between *Acremonium lolli* in perennial ryegrass(*Lolium perenne*) and the animal disorder, ryegrass staggers, was later identified in New Zealand. Most commonly observed symptoms of fescue toxicosis include poor heat tolerance, rough hair coat, elevated body temperature, and reduced weight gains in beef steers, particularly in summer during periods of high ambient temperature. Reduced milk production and reproductive problems associated with reduced serum prolactin levels are also evident

in animals grazing endophyte-infected tall fescue. Since the discovery of the *Acremonium/tall* fescue complex, it has been estimated that fescue toxicosis caused by alkaloids produced in endophyte-infected tall fescue is responsible for over $600 million in lost revenue to beef industry in the US alone.

The initial attempts to alliviate the endophyte problem resulted in the development of several new grass cultivars that do not contain the fungal endophyte. When these cultivars were used to replace existing stands of infected grass, they supported improved animal performance with none of the other potential disorders associated with endophyte-infected grass. However, it quickly became evident that the removal of the endophyte also affected plant growth. Endophyte-free stands were more susceptible to pests and environmental stresses than stands of endophyte-infected grass.

The *Acremonium/grass* association has been identified as a symbiotic mutualism with both the plant host and the endophyte benefitting from the relationship. The endophyte receives its nutrition from the host and also relies on the host for dissemination, while the host grass plant derives a number of competitive advantages from the presence of the endophyte. More in-depth studies of the physiological responses of plants to the presence of the endophyte have determined that phytohormone levels are enhanced by the growth of endophyte. These plant physiological responses have been associated with increased growth and tillering of endophyte-infected plants and improved drought tolerance.

Continued research in animal physiology and biochemistry has further elucidated the causel toxins of observed animal disorders. Evaluations of *Acremonium* collections have resulted in the discovery of strains that do not produce the mojor alkaloids identified as toxins.

Observations of insect and nematode feeding deterrence on endophyte-infected grasses have stimulated interest among entomologists and plant breeders in the possibility of conferring pest resistance to other economically important species. It has been determined that some of the biochemical agents involved in pest resistance differ from those involved in animal toxicoses. Taking advantage of these biochemical agents, it may be possible to reinsert them in endophyte-free tall fescue and perennial ryegrass to develop cultivars with improved pest resistance. These studies have actively been proceeding in advanced countries.

Simple researches have been carried out in Korea, such as endophyte distribution in tall fescue pasture, effect of endophyte-infected or free tall fescue on pasture production and its effect on animal performance. This paper is to review litereature on tall fescue endophyte and to help design future research on endophyte.

2. Effect on pasture production.

Endophyte infection in tall fescue is an important factor associated with pasture production. Read and Camp(1986) were the first to document that ungrazed endophyte-infected tall fescue plants exhibited more persistence under drought conditions when compared with tall fescue plants with a low infection level(Table 1). Their data reflect the variation in seed-sown populations as one of the endophyte-infected plantings within their replicated experiment showed only a 5% loss. Their results suggest that individuals within this first pasture have the genetic consistitution to survive without the endophyte.

Table 1. Loss of Kenhy tall fescue during a summer drought period.

Pasture No	Average infection level	
	94%	12%
1	0	5
2	11	74
3	1	84

Data from Read and Camp (1986)

The data in Table 2(Bacon,1993) indicate that there is an increased moisture requirement for infected seed. The increased moisture requirement might be purely physical, reflecting a need for leakage of inhibitory metabolities from endophyte-infected seed, rather than a genuine metabolic use.

Table 2. Seven day percentage germination of 'Kentucky 31' tall fescue seed on Polyethylene Glycol 20000 measured at 25°C and various osmotic potentials.

Osmoticpotential(-MPa)	%Germination	
	Infected	Uninfected
0	82	81
0.17	81	84
0.3	51	79
0.4	45	85
0.6	30	80
0.9	5	20
1.7	0	0

Data of Bacon(1993)

Arechavaleta et al.(1989, 1992) studied ergot alkaloid accumulation pattern along with nitrogen concentations under water-logged conditions in one endophyte-infected genotype and its fungus-free ramet grown under greenhouse conditions(Table 3). They concluded that after 90 days of being water-logged, endophyte-infected tall fescue continued to produce ergot alkaloids and produced more dry matter than the uninfected ramet(Arechavaleta et al., 1992)

Table 3. Endophyte-free(EF) and endophyte-infected(EI) tall fescue leaf blade width(LBW), thickness(LBT), and in vitro dry matter disappearance(IVDMD) as influenced by nitrogen(N) rate when flooded for 90 day.

Infection status	N rate (mg per pot)	LBW (mm)	LBT (mm)	IVDMD (g kg^{-1})
EF	11	10.98c	0.51a	660
	220	10.59c	0.46a	650
EI	11	9.18b	0.64b	630
	220	8.23a	0.57ab	660

Data od Arechavaleta et al(1989)

Values within columns, mean followed by same letter are significantly different at the 0.05 level by LSD.

The efficient utilization of low-level soil nitrogen provides evidence for direct effects on survival within the symbiosis, as Arechavaleta et al.(1989) has shown that efficient nitrogen utilization by one genotype of tall fescue (Table 4). The amounts of dry matter produced by endophyte-free grass at each of the three levels of nitrogen are not significantly different from the amount produced by endophyte-infected tall fescue receiving the low rate of nitrogen. There was a 50% increase in dry matter for endophyte-infected grasses receiving the medium-level nitrogen.

Table 4. Efficiency of nitrogen utilization, dry matter yield and 14 day regrowth height of endophyte-free(EF) and endophyte-infected(EI) tall fescue after a period 40-day exposure period to three soil moisture levels.

Infection status	N rate(mg per pot)			Prior soil moisture(MPa)		
	11	73	220	-0.03	-0.05	-0.5
	Dry herbage yield(g per pot)			Height(cm)		
EF	0.28a	0.4b	0.43b	11.2a	14.2b	10.8a
EI	0.39ab	0.82d	0.68c	16.3b	22.3c	22.8c

Data od Arechavaleta et al.(1989).

Means followed by the same letter are not significantly different at 0.05 level by LSD.

3. Effect on animal performance affected by endophyte-infected and free tall fescue

Cattle grazing tall fescue infected(E+) with the fungal endophyte or fed diets containing E+ hay and seed exhibit sign of toxicosis. Fescue toxicosis originally was referred to as 'summer syndrome' or 'summer slump' because signs were most pronounced during hot weather. However, Hoveland et al. (1984) showed a poor weight gain on endophyte-infected pastures throughout the grazing season(Table 5), being reduced almost as much during the cool-season months as during the warm-season months.

Table 5. Seasonal daily gains(kg) of steers grazing E+ and E- fescue(3 year average).

Months	Endophyte		ADG decrease
	〈 5%	〉 94%	
November, December, March	0.72	0.36	50%
April, May, June	0.78	0.32	59%

Hoveland et al.(1984)

Bond et al.(1984) reported that steers grazing a high-endophyte experimental fescue line spent less time grazing during the day and more time grazing at night(Table 6).

Table 6. Percentage of total daylight or dark hours steers spent in various activities.

Activity	Daylight		Dark	
	E- (%)	E+ (%)	E- (%)	E+ (%)
Grazing	52	34	8	22
Lying in field	14	2	81	50
In shade	15	51	0	3

Bond et al.(1984)

Osborn(1988) fed steers diets composed of E- or E+ hay and seed in controlled environments at 21℃(cool) and 32℃(hot)(Table 7). In general, the main effects of endophyte presence showed that feed intake was depressed,

rectal temperature and respiration rate were elivated, heart rate was reduced, and all measured peripheral temperatures were reduced; statistical significance varied between environment.

Table 7. Effect of consuming E- or E+ fescue seed and hay diets in a 21℃ Or 32℃ environment on certain physiological variables and peripheral temperatures.

Item	21℃		32℃	
	E-	E+	E-	E+
Feed intake(kg day-1)	6.7[a]	4.3[b]	5.4[a]	2.2[b]
Rectal temperature(℃)	39.0	39.0	39.9[a]	40.4[b]
Respiration rate(cpm)	46	45	78[a]	95[b]
Heart rate(cpm)	70[a]	53[b]	65[a]	49[b]
Ear canal(℃)	35.4[a]	34.1[b]	38.3	38.1
Ear tip(℃)	35.0	33.2[b]	37.8	36.4
Pastern(℃)	30.4	29.4	36.8	36.1
Coronary band(℃)	30.1	29.5	36.0[a]	35.2[b]
Tail tip(℃)	33.4[a]	32.1[b]	37.9[a]	37.2[b]

Osborn(1988).

Means with environment with different superscripts differ(P,0.05)

Danilson et al.(1986) assigned weaned beef heifers to pastures having low(0-20% infested), medium(25-60% infested), and high(80-99% infested) levels of infection(Table 8). The heifers were maintained on their respective E+ treatments for 2 years until they were re-bred following birth of their first calf. During winter, they received hay harvested from fields having E+ levels similar to their respective pasture treatments. Breeding was done during the spring. Heifer ADG while grazing decreased linearly with increasing infestation level; however, winter ADG while fed hay was just the opposite to the high-infestation group having the fastest gains. All heifers were observed in estrus prior to their first breeding; however, pregnancy rate decreased linearly as E+ level increased.

The effects of E+ fescue on mares and foals are more severe than on cattle or sheep. Pregnant mares that have grazed E+ fescue(Table 9) show several of the following signs : prolonged gestation lengths; failure to exhibit signs of approaching parturation including lack of mammary development, 'hollowing' of the paralumbar fossa and softening of the gluteal muscles; severe dystocia; retained and thickened placentas; abnormal presentation of foals during delivery; increased maternal mortality; agalactia and rebreeding problems(Monroe et al., 1988). In addition, the foals usually are stillborn or weak at birth and have

Table 8. Effect of endophyte-infected fescue on gains, pregnancy rates and milk yield of heifers[1].

Endophyte level(%)	Initial weight(kg)	Daily gains(kg day^{-1})			Pregnant (%)	Post-calving pregnant[2]	Milk produced[3] (kg per12h)
		Grazing	Winter	Total			
0-5	255	0.75	0.08	0.54	96	93	3.7
25-60	254	0.57	0.16	0.44	82	45	3.2
80-99	268	0.34	0.54	0.39	55	33	1.8

1 Danilson et al.(1986)
2. Schmid et al.(1986)
3. S.P. Schmidt et al.(1986)

Table 9. Effect of E+ fescue on gravid mares, foals, parturition and rebreeding.

	Endophyte	
	0%	94%
Gestation length	333[a]	360[b]
Foal weight(kg)	44.5	48.6
Rectal temp.(℃)	38.2	38.2
Placemtal weight(kg)	3.7	4.9
Stillborn foals	0/8	4/8
Retained placentas	1/8	5/8
Agalactic mares	1/8	7/8
Mares re-bred	6/8	3/7

Monroe et al.(1988)
a,b $p<0.01$

a high incidence of irrigular teeth eruption and overgrown hooves.

4. Study of tall fescue affected by endophyte in Korea.

In Kora, few studies have been done on tall fescue associated with endophyte. Korean climate is affected by monsoon, temperatur being high(25℃ or higher during the period of 60 days) between July and August, and low(-1℃ or lower during the period of 30 days of January). Most of the pasture species can not grow well under a wide range of climatic conditions, but tall fescue persists under this variable climate. If the relationship between endophyte and tall fescue is well identified under Korean climatic conditions, the species may

play a great role in extending the grazing period of pastures.

Lee(1995) investigated the rate of endophyte infection of tall fescue affected by tall fescue varieties and nitrogen application levels(Table 10). A significant difference was found among tall fescue cultivars. E-Ky31 tall fescue was not infected by endophyte, whereas E+Ky tall fescue showed a high rate of infection among 3 cultivars, with more infection in spring and fall than the other seasons.

Table 10. Endophyte infection affected by tall fescue varieties and nitrogen fertilizer levels.

Veriety	N fertizer level (kg/ha)	Percentage of infection(%)			
		Spring	Summer	Fall	Mean
Fawn	0	0	0	0	0
(E+)	140	0	0	0	0
	280	0	0	3.3	1.1
	420	3.3	0	3.3	2.2
	Mean	0.8	0	1.7	0.8
Ky 31	0	0	0	0	0
(E-)	140	0	0	0	0
	280	0	0	0	0
	420	0	0	0	0
	Mean	0	0	0	0
Ky 31	0	0	10.0	23.8	11.3
(E+)	140	0	53.3	38.2	30.5
	280	10.0	53.3	53.3	38.9
	420	3.3	16.7	60.0	26.7
	Mean	3.3	33.3	43.8	26.8
LSD(0.05)	V	NS	27.8	25.3	3.1
	N	NS	NS	NS	NS
	V×N	NS	NS	NS	NS

Lee (1995).
NS: not significance

Table 11 showed effect of weed occurrence as affected by tall fescue varieties and nitrogen application levels. The weed growth was not affected by tall fescue varieties(E- and E+), but was significantly decreased with increasing nitrogen levels. Hoveland et al.(1980) suggested that dallisgrass growth decreases under endophyte-infected tall fescue, with no occurence of weed. The result

of Lee(1995) was different from that of Hoveland et al. (1980).

Table 11. Weed percentage affected by tall fescue variety and nitragen fertilizer level in tall fescue pasture(%)

Variety	N fertilizer level (kg/ha)	Times of harvest				
		1st	2nd	3rd	4th	Mean
Fawn (E+)	0	5.3	9.0	14.0	28.3	14.2
	140	3.3	5.3	5.3	15.0	7.2
	280	2.7	5.3	3.0	14.0	6.3
	420	3.3	5.0	3.7	12.3	6.1
	Mean	3.7	6.2	6.5	17.4	8.5
Ky 31 (E-)	0	4.3	6.7	10.0	26.7	11.9
	140	5.7	5.7	6.3	25.0	10.7
	280	4.7	3.7	4.0	12.3	6.2
	420	3.3	4.8	5.8	17.8	8.3
Ky 31 (E+)	0	5.7	5.7	6.3	28.3	11.5
	140	6.7	3.7	3.0	20.0	8.4
	280	5.0	3.0	3.7	12.3	6.0
	420	3.3	3.0	3.0	9.0	4.6
	Mean	5.2	3.9	4.0	17.4	7.6
LSD(0.05)	V	NS	NS	NS	NS	NS
	N	1.3	1.5	2.2	6.4	1.8
	V×N	NS	NS	NS	NS	NS

Lee(1995)

Pasture production affected by pasture type and rate of endophyte infection was shown in Table 12. Endophyte-infected tall fescue harvested for the 2nd, 3rd and 5th time showed statistically higher dry matter yields than did endophyte-free tall fescue. De Battista et al.(1990) showed that the dry matter yield of endophyte-infected tall fescue was 24% more higher than that of E-free tall fescue, suggesting that the increase was associated with plant growth substances produced by plant itself.

Table 12. Dry matter yield of tall fescue as affected by pasture type and endophyte infection under grazing Unit : kg/ha

Pasture type	Endophyte status	Times of harvest						
		1st	2nd	3rd	4th	5th	6th	Mean
Mix	E+	1,643	1,320	567	985	1,269	1,048	6,832
	E-	1,585	894	418	877	1,151	1,227	6,152
	Mean	1,614	1,107	492	931	1,210	1,138	6,492
Mono	E+	3,333	1,587	495	1,395	1,515	1,456	9,781
	E-	3,329	1,519	399	1,430	984	1,059	8,720
	Mean	3,331	1,553	447	1,412	1,250	1,258	9,251
LSD(0.05)	P	137	NS	NS	NS	NS	NS	220
	E	NS	52	12	NS	59	NS	NS
	P×E	Ns	NS	NS	NS	NS	368	Ns

Lee (1995)

Rectal temperature of Korean cattle grazing on a tall fescue pasture did not show statistical difference between E+ and E- tall fescue(Table 13). Only rectal temperature of grazing cattle in September was significantly higher on a E+ tall fescue than on a E- tall fescue pasture. The result of this study did not agree with Read et al.(1984), suggesting that the rectal tempereture of animals grazing on E+ tall fescue is higher in comparison with that found on E- fescue.

Table 13. Recal temperature of Korean cattle as affected by pasture and endophyte infection under grazing Unit: ℃

Pasture type	Endophyte Status	Month of investigation					
		May	June	July	Aug.	Sept	Mean
Mix.	E+	38.7	38.9	39.2	38.8	38.0	38.7
	E-	38.8	38.7	39.2	38.6	38.3	38.7
	Mean	38.8	38.8	39.2	38.7	38.2	38.7
Mono	E+	39.1	38.8	38.8	38.8	37.9	38.7
	E-	38.9	38.7	38.8	38.9	38.4	38.7
	Mean	39.0	38.8	38.8	38.9	38.2	38.7
LSD(0.05)	P	NS	NS	NS	NS	NS	NS
	E	NS	NS	NS	NS	0.18	NS
	P×E	NS	NS	NS	NS	NS	NS

Lee(1995).

The experiment which compared Fawn endophyte tall fescue with Roa endophyte free tall fescue showed that during the whole grazing season the total mean dry matter yield of ungrazed pasture was significantly higher in Fawn tall fescue than in Roa padock(Table 13). This result is simailar to that of Read and Camp(1986), who showed a higher yield in endophyte variety grown in the field and of Marks and Clay(1990), who also found a better yield with E+ plant than with E- plant grown in glasshouse.

Table 14. Monthly changes of dry matter yields(kg/ha) as affected by the tall fescue varieties Fawn and Roa on mixed pasture.

Treat-	Dates investigated						
	Continuous grazing				Rotational grazing		
ment	March 22	April 8	May 17	June 21	July 21	Sept 6	Sept 21
T1*	1,116	1,568	3,405	2,531	2,152	670	388
T2**	1,361	1,103	1,104	1,745	1,931	402	249
P	0.246	0.004	0.000	0.001	0.579	0.003	0.046

Kim et al.(1998).
*T1 : Tall fescue Fawn + orchardgrass + perennial ryegrass + ladino clover
**T2 : Tall fescue Roa + ordhardgrass + perennial ryegrass + ladino clover

Our study showed that daily weight gain of grazing animals during the whole grazing period was 0.668 and 1.258kg/ha on Fawn(E+tall fescue) and Roa variety(E- tall fescue), respectively(Table 15). Significantly higher daily gain was found in calves grazed on Roa(E-) tall fescue than Fawn(E+) tall fescue pasture($P<0.01$). Comparing the low endophyte variety tall fescue with that of high endophyte variety(0.85kg/day) after grazing, When Schimidt et al.(1983) found a higher daily gain in cattle(1.16kg/day) grazing on low endophyte species, which is similar to our findings.

Table 15. Daily weight gain of Holstein cattle as affected by the difference of tall fescue varieties Fawn and Roa in grazing mixed pasture(kg).

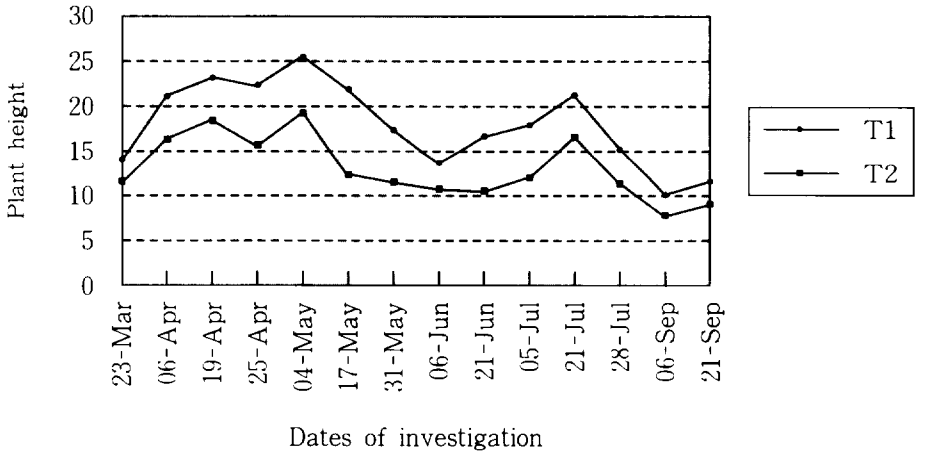
Treat- ment	Continuous grazing	Rorational grazing	Mean
T1	0.931	0.013	0.668
T2	1.709	0.130	1.258
P	0.010	0.131	0.005

Kim et al.(1998).

The effect of tall fescue variety Fawn(E+) and Roa(E-) on plant height after grazing was compared under continuous and rotional grazing(Fig1). The plant height of Fawn(E+)treated-paddock after grazing was significantly higher than that of Roa(E-), excluding the investigation of March. It is suggested that higher plant height of Fawn is associated with high alkaloid content, resulted in avoiding of grazing aniaml with low palatability.

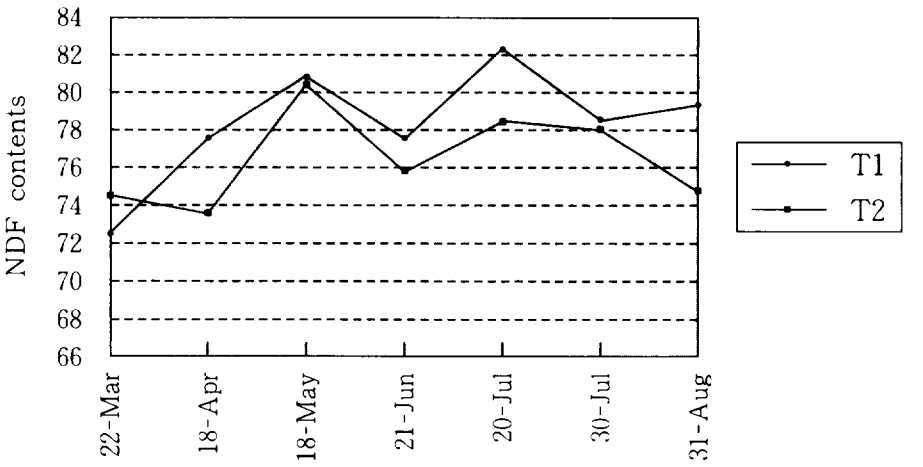
Fig 2 and Fig 3 compared tall fescue variety Fawn(E+) and Roa(E-) with

Fig 1. Plant heights affected by Fawn and Roa on mixed pasture



Kim etal(1998), T1 : Fawn tall fescue, T2:Roa Tall fescue

Fig 2. NDF contents affected by Fawn and Fawn on mixed pasture(%)

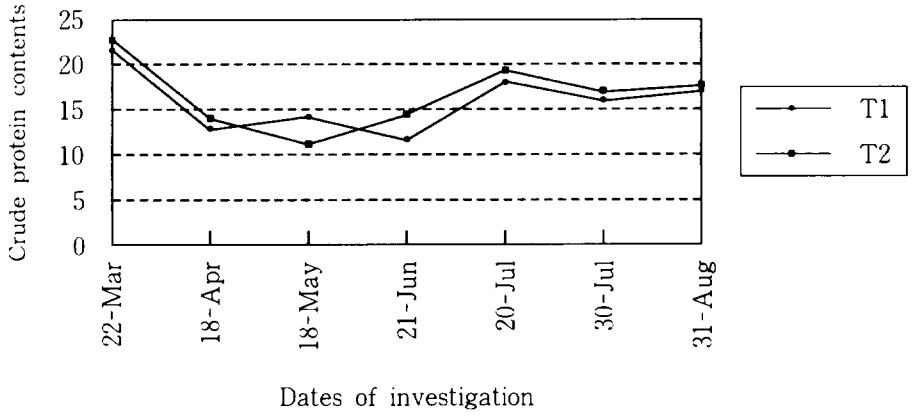


Kim etal(1998), T1 : Fawn tall fescue, T2:Roa Tall fescue

regard to NDF and crude protein contents of mixture of forages and weeds. Crude protein and NDF contents was not significantly different between Fawn and Roa variety pastures, except for NDF contents of the mixture harvested in August, when NDF content of Fawn(E+) was slightly higher than that of Roa(E-), whereas crude protein content was opposite.

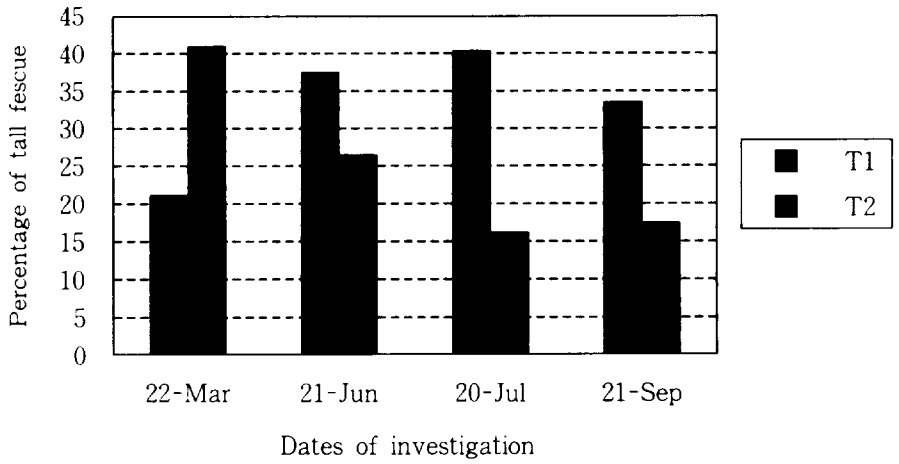
The percentage of tall fescue on grazing mixed pasture, as affected by the Fawn (E+) and Roa(E-) tall fescue variety was compared(Fig 4). The percentage of Fawn tall fescue was higher than that of Roa, ecept for the 1st harvest. This is attributed to its higher resistivity to Cheju climatic conditions in comparison with Roa.

Fig 3. Crude protein contents affected by Fawn and Roa on mixed pasture(%)



Kim etal(1998), T1 : Fawn tall fescue, T2:Roa Tall fescue

Fig 4. Percentage of tall fescue affected by Fawn and Roa on mixed pasture



Kim etal(1998), T1 : Fawn tall fescue, T2:Roa Tall fescue

5. Conclusion

Endophyte-infected tall fescue variety was found to be better under Korean climatic conditions, showing a higher dry matter yield, and higher density and height compared to E-tall fescue. However, daily weight gain of cattle grazing E- variety was higher than that found with E+ variety.

The percentage of E-tall fescue decreases with time because E-tall fescue is not tolerable to environment stresses, such as draught and overgrazing. Therfore we should work on new tall fescue cultivars that can persist those stresses without deterioration of its nutritional value.

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