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Effects of Mowing and TIBA(Triiodobenzoic acid) on Dry Matter Production of Cultivated *Zoysia japonica* Community

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잔디깍기와 TIBA 處理가 잔디 人工群落의 物質生産에 미치는 影響

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ABSTRACT

An experiment was made in order to analyze the growth characteristics and productivity of *Zoysia japonica* under control, mowing and TIBA treatment conditions at the experimental farm of Kyung Hee University.

The field was planned by the split plot design method and each treatment was given to two plots (40×40 and 100×100 mm) and was replicated three times. Each plot was 9 m^2 for *Zoysia japonica*. The sampling of each plot was taken once a week after sowing. In order to know the dry matter of total standing crops, each organ of plants was kept at 90°C and weighed. Total leaf area of a plant was measured by drawing method. The author adopted the growth analysis of English School. Holocellulose analysis by sodium chlorite method was made.

The increasing rate of LAI was high in all plots between 10th and 12th week after sowing and high growth rate of assimilatory organ was observed in low density area of TIBA plot. Between 10th and 12th week after sowing all the experimental plots showed high increasing rate of standing crop and in the process of growth each density area of TIBA plot recorded high increasing rate. In all the plots F/C ratio and RGR were high when the growth rate of assimilatory organ was increasing cosiderably, and the higher the planting density was, the higher F/C ratio was recorded. In all the plots NAR recorded maximum rate before the growth period to show a high increase of RGR. In the process of the growth TIBA plot showed high increasing rate of NAR. CGR showed high value in high density areas of all the plots and reached its maximum in the 13th week after sowing. Compared to the other experimental areas the low planting density areas of control plot and TIBA plot showed considerable earlier lignification indicating low Holocellulose content in the growth process.

INTRODUCTION

Since Watson(1947), Blackman and Wilson(1951) established quantitative growth analysis of the productivity of plant population, there have been active studies of physiological ecology on the relationship between plant functions and environments (Monsi and Saeki, 1953; Iwaki, 1959; Donald, 1961; Hiroi and Monsi, 1966), the competition-density effect of plant community (Hozumi, *et al.*, 1956; Yoda *et al.*, 1963). Michell (1953) and Younger(1972) investigated the interrelationship between growth characteristics and temperature and light intensity.

Thaine(1954), Mckee *et al.*(1967) and others found out the defoliation effect of the dry matter production of grasses. And Ackerson and Chilcote(1978) found out the TIBA effect which increased the dry matter productivity of Kentucky bluegrass.

However, a few attempt have been made to investigate the relationship between the primary production related to the growth process of grass (*Zoysia* spp.) environment, and to find out the density effect of its community from the point view of the economy of plant.

The object of this research is to analyze the dry matter productivity of grasses, the competition-density effect of plant function and environments, in order to find out the characteristics of physiological ecology for improvement of the cultivation methods of grasses.

MATERIALS AND METHODS

The present experiments on the grasses (*Zoysia japonica*) were performed at the experimental field of Suwon Campus, Kyung Hee University. The seeds of grass for the experiments were treated for seedling acceleration and supplied by Chung Ang Nursury in Seoul and screened by hydrometrical selection. The installation of experimental plots were split into control plot, mowing plot and TIBA (Triiodobenzoic acid) plot by split plot design and each plot's area was 9 m^2.

Before sowing, the field was plowed as deeply as about 200mm, soil was sieved with sieve of 4 mm wide mesh to seperate gravels, and leveled smooth with board for accurate measuring of sowing distance. The results of soil analysis of experimental field areas follows; pH(1:5H_2O), T-N, P_2O_5, O. M, K and Ca were 5.5, 0.15%., 226 ppm, 1.6%, 0.38 mg/100 g, and 4.8 mg/100 g respectively. The soil acidity was adjusted to pH 6.0-6.5 by supplying lime fertilizer.

On May 26, 1985 the grass seeds were planted on the seeding bed. Each sowing spot of 400 mm^2 area got exactly 3 seeds and the soil mixed with fine sands were covered as thick as about 1mm on the seeding bed. After germination, they were thinned to one seeding per spot. On July 23 the seedlings were transplanted in each experimental plot divided into two plots, 40 ×40 mm and 100×100 mm planting density. After the transplant 30 plants were sampled from each plot at random every week. Considering the edge effect, the plants from their edge to the third line were excluded from sampling.

During the experiments, weeding, irrigation and other cares at each plot were executed at the same time by the same methods. After every sampling the grasses in mowing plot were clipped to keep the height of 50-60 mm and for TIBA treatment, 1500 ppm TIBA liquid was sprayed on the leaves of grass in TIBA plot.

Each sampled grasses was divided into leaves, stems and roots, and dried in a drying oven at 90°C until it had constant weight, and weighed.

For leaf area drawing method was employed. Blackman's method was followed for the analysis of Relative Growth Rate, Net Assimilation Rate and Crop Growth Rate. And for the consideration of weather conditions, meteorological data of the Central Meteorological Office, Suwon Station, were used. Lignin quantity measuring by Klason method and holocellulose analysis by Sodium chlorite method (Wise) were executed from June 20, to for the analysis of the data.

RESULTS AND DISCUSSION

I. Dry Matter Production

Leaf Area and Leaf Area Index(LAI). The analyses of leaf area and LAI in the growth process of each plot's grasses are shown in Tables 1, 2, 3. Every plot exhibited high growth rate of leaf area during the first 12 weeks after sowing, indicating that the assimilatory organ area of each grass increased during the period and the ratio to absorb the solar energy which is necessary for assimilation products. As shown in Table 3 every plot had the tendency of high average Leaf Area Index (Ave-LAI) in the areas of the planting density of one plant of 40× 40 mm and the increasing rate of LAI in all the plots was considerably higher during the period of middle and end of August. LAI in 12 weeks after sowing was relatively high in the TIVA plot while low in the mowing plot. During the period to show high increasing rate of LAI, the increasing rate of dry matter production was also considerably high, thus, it could be presumed that LAI had a positive relationship to dry matter production. As a major factor to influence the matter production of plants, Watson(1962) and others gave more emphasis on LAI than degree of photosythesis ability of each plant.

Donald(1961) also argued that optimal leaf area is the major factor accumulating the organic matter to the maximum in a plant community.

Standing Crop. The seasonal changes of standing crop in different density and different conditions are shown in Tables 1, 2. Between 11th and 12th week after sowing the increase rate of standing crop was considerably high in all the plots showing that assimilatory organs were developing during the period. The increase rate of standing crop was relatively higher in TIBA plot.

Grasses of every plot showed considerably high growth rate of each organ's dry matter during the first 12 weeks after sowing. In the area of low planting density (one plant, 40× 40 mm) of control plot and mowing plot, the dry weight of leaves was decreased from 15th week after sowing.

On the other hand in the areas of high planting density of all plots the dry weight of stems was increased more than that of leaves from 13th week after sowing.

All the areas of TIBA plot showed high increase rate of standing crop and lower planting density areas showed considerably higher increase rate proving that TIBA is effective in increasing that dry matter productivity of grasses. In their research on the effect of TIBA on

Table 1. The growth change in dry weight and leaf area under different treatmen in 40 × 40 mm density.

		Leaf(g)	Stem(g)	Root(g)	Total			Leaf Area	
					Mean(g)	SD	g/m²	Mean(mm²)	SD
Jul. 30	C	0.016	0.013	0.009	0.03	0.005	18.75	221	0.702
	M	0.020	0.016	0.008	0.04	0.005	25.00	222	0.773
	T	0.017	0.013	0.007	0.03	0.004	18.75	223	0.571
Aug. 6	C	0.035	0.025	0.010	0.07	0.013	43.75	340	1.176
	M	0.035	0.024	0.014	0.07	0.019	43.75	345	1.274
	T	0.038	0.020	0.012	0.07	0.012	43.75	316	0.964
Aug. 13	C	0.067	0.040	0.032	0.14	0.025	87.50	910	2.590
	M	0.068	0.033	0.033	0.14	0.020	87.50	898	1.890
	T	0.070	0.044	0.034	0.14	0.022	87.51	1057	1.984
Aug. 20	C	0.145	0.099	0.066	0.31	0?055	193.75	2533	5.370
	M	0.133	0.116	0.064	0.31	0.055	193.75	2327	4.965
	T	0.177	0.091	0.073	0.34	0.032	212.50	3487	4.684
Aug. 27	C	0.214	0.175	0.082	0.47	0.072	293.75	4629	7.790
	M	0.212	0.183	0.077	0.47	0.464	293.75	4528	5.248
	T	0.253	0.228	0.077	0.55	0.101	343.75	6815	18.012
Sep. 3	C	0.301	0.260	0.132	0.69	0.119	431.25	7585	17.263
	M	0.288	0.302	0.101	0.69	0.604	431.25	6137	10.328
	T	0.335	0.334	0.139	0.80	0.103	500.00	9288	13.746
Sep. 10	C	0.337	0.318	0.145	0.80	0.112	500.00	9223	19.183
	M	0.310	0.329	0.132	0.77	0.095	481.25	7756	14.789
	T	0.388	0.370	0.154	0,91	0.046	568.75	11219	12.467
Sep. 17	C	0.371	0.374	0.151	0.89	0.098	556.25	10228	15.385
	M	0.352	0.361	0.136	0.84	0.071	525.00	9216	15.172
	T	0.440	0.396	0.190	1.02	0.109	637.50	13586	18.049
Sep. 24	C	0.440	0.393	0.159	0.99	0.064	618.75	11321	15.874
	M	0.397	0.386	0.150	0.93	0.073	581.25	10692	17.879
	T	0.492	0.458	0.193	1.14	0.104	712.50	15708	18.070
Oct. 1	C	0.460	0.452	0.163	1.07	0.074	668.75	10924	12.316
	M	0.388	0.452	0.162	1.00	0.059	625.00	9968	15.781
	T	0.487	0.555	0.151	1.23	0.093	768.75	14897	15.265

C:control plot, M:mowing plot, T:TIBA treated plot.

the tillering and dry matter of Kentucky bluegrass, Ackerson and Chilcote(1978) reported that in TIBA treated plots, tillering was accelerated markedly and dry weight of the part exhibited above ground increased considerably. The result of our research also showed a similar tendency.

Though TIBA treatment increases the productivity especially that of leaves, more researches on the genetic mechanism related to the tillering control are required. As shown in Table 4,

Table 2. The growth change in dry weight and leaf area under different treatmen in 100×100 mm density

		Leaf(g)	Stem(g)	Root(g)	Total			Leaf area	
					Mean(g)	SD	g/m²	Mean(mm²)	SD
Jul. 30	C	0.019	0.017	0.009	0.04	0.003	4.50	220	0.273
	M	0.019	0.018	0.008	0.04	0.001	4.50	222	0.178
	T	0.019	0.018	0.008	0.04	0.001	4.40	225	0.505
Aug. 6	C	0.042	0.030	0.016	0.08	0.012	8.80	341	1.094
	M	0.048	0.028	0.019	0.09	0.024	9.00	320	1.054
	T	0.044	0.032	0.017	0.09	0.014	9.30	336	0.706
Aug. 13	C	0.085	0.067	0.039	0.19	0.030	19.10	1034	2.314
	M	0.090	0.066	0.033	0.18	0.027	18.90	923	1.728
	T	0.103	0.070	0.045	0.21	0.048	21.80	1051	2.614
Aug. 20	C	0.918	0.191	0.109	0.48	0.113	48.80	3369	12.510
	M	0.188	0.183	0.102	0.47	0.079	47.30	2819	5.890
	T	0.236	0.206	0.114	0.55	0.085	55.60	3536	5.585
Aug. 27	C	0.392	0.408	0.222	1.02	0.117	102.20	6752	13.041
	M	0.317	0.331	0.164	0.81	0.133	81.20	5714	12.849
	T	0.420	0.510	0.230	1.16	0.066	116.00	7209	9.050
Sep. 3	C	0.803	0.882	0.209	1.89	0.339	189.40	9901	19.140
	M	0.552	0.634	0.188	1.34	0.104	137.40	8081	9.468
	T	0.909	1.038	0.256	2.20	0.453	220.30	11475	26.999
Sep. 10	C	1.100	1.300	0.290	2.69	0.309	269.00	13472	18.841
	M	0.881	0.946	0.206	2.03	0.144	203.30	11061	21.051
	T	1.324	1.477	0.311	3.11	0.103	311.20	16388	10.164
Sep. 17	C	1.598	1.747	0.341	3.68	0.384	368.60	17832	22.626
	M	1.223	1.380	0.269	2.87	0.169	287.20	14069	21.430
	T	1.733	1.987	0.381	4.10	0.679	410.10	21656	44.679
Sep. 24	C	1.940	2.062	0.512	4.51	0.554	451.40	23447	32.967
	M	1.406	1.775	0.361	3.54	0.254	354.20	18600	12.179
	T	2.115	2.335	0.404	4.85	0.290	485.40	27400	27.378
Oct. 1	C	1.982	2.296	0.537	4.81	0.379	481.50	22784	24.914
	M	1.440	1.870	0.408	3.71	0.397	371.80	17639	25.459
	T	2.285	2.493	0.562	5.34	0.497	534.00	27141	30.248

C:control plot, M:mowing rlot, T:TIBA treated plot.

Table 3. Average LAI of *Zoysia japonica* in each plot. (m²/m²)

Plot	Jul. 30 -Aug. 6	Aug. 7 -Aug. 13	Aug. 14 -Aug. 20	Aug. 21 -Aug. 27	Aug. 28 -Sep. 3	Sep. 4 -Sep. 10	Sep. 11 -Sep. 17	Sep. 18 -Sep. 24	Sep. 25 -Oct. 1
	0.17	0.39	1.24	3.04	5.14	7.25	9.27	12.82	14.46
	0.17	0.36	1.06	2.56	4.72	5.93	7.82	10.14	11.32
	0.17	0.36	1.28	3.22	5.74	8.62	11.81	15.26	17.04
	0.03	0.06	0.15	0.35	0.60	0.84	0.97	1.07	1.11
	0.03	0.06	0.15	0.33	0.55	0.69	0.95	0.99	1.03
	0.03	0.06	0.20	0.50	0.80	1.02	1.24	1.46	1.03

Note. Ave · LAI $=(L_2-L_1)/\log(L_2-\log L_1)$

Table 4. Linear regression and correlation coefficient between dry weight leaf area in 40×40 ㎜ and 100×100 ㎜ density

	40×40 ㎜			100×100 ㎜		
	Dry wt. equation		Dry wt. vs. LA	Dry wt. equation		Dry wt. vs. LA
	a	b	r	a	b	r
Cortrol	0.074	0.008	0.984**	-0.101	-0.020	0.989**
Mowed	0.008	0.009	0.980**	-0/006	0.020	0.986**
TIBA treated	0.068	0.007	0.990**	-0.008	0.020	0.998**

**: Significant at 1% level

r : Regression coefficients for the linear regression

+ : Dry weight=a+b(leaf area)

there exists positive relationship between standing crop and LAI. In mowing plot, the estimated relationship between standing crop and leaf area by linear regression in low planting density area(40×40 mm/one plant) and in high planting density area(100×100 mm/one plant) respectively showed that:

$$Y=0.008+0.009X,\ r=0.980 \text{ and } Y=-0.006+0.020X,\ r=0.986$$

Here r is a coefficient of correlation.

Compared to the other plots, the change of leaf area is a very influential variable on dry matter production according to the estimated regression model, which thus should be considered when mowing grasses. Ackerson and Chilcote (1978) also reported that the grasses were clipped the closer to the ground, the more decrease of tillers, the less effect of TIBA treatment, and the lower dry matter and concentration of water soluble carbohydrate were observed. Thus, it is important to keep optimal leaf area when mowing. As shown in Tables 5, 6, there existes high significance among control, mowing, and TIBA plot considering both of low and high planting density area.

Table 5. Aanalysis of variance for drymatter in *Zoysia japonica* under deffrent treatment

40×40 ㎜				100×100 ㎜			
DF	SS	MS	F	DF	SS	MS	F
2	0.89	0.45	3.28[1]	2	21.83	10.64	3.50[2]
350	47.75	0.14		317	964.99	3.04	

1) $P(F>F_{0.05})=0.0389$ 2) $P(F>F_{0.05})=0.0315$

Table 6. Duncan test for drymatter in *Zoysia japonica* under different treatment

40×40 ㎜			100×100 ㎜		
T	M	C	T	M	C
0.628	0.517	0.515	2.164	1.884	1.514

T: TIBA treated, M: mowed, C: control.

F/C ratio. The ratio of photosynthesis organ versus nonphotosynthesis organ, F/C, was high during 10th through 11th week after sowing in all experimental plots, and indicated lower tendency after then as show in Table 7. And low tendency was shown in mowing plot rather than the others.

Table 7. F/Coratio of *Zoysia japonica* in each plot(g/g)

Plot	Jul.30	Aug.6	Aug.13	Aug.20	Aug.27	Sep.3	Sep.10	Sep.17	Sep.24	Oct.1
40×40 mm										
control	0.73	1.00	0.93	0.88	0.83	0.77	0.73	0.71	0.80	0.75
mowed	0.83	0.97	1.03	0.74	0.82	0.71	0.67	0.71	0.55	0.63
TIBA treated	0.85	1.19	0.90	1.08	0.83	0.71	0.74	0.75	0.76	0.65
100×100 mm										
coutrol	0.73	0.91	0.80	0.68	0.62	0.73	0.69	0.77	0.75	0.70
Mowing	0.73	0.91	0.90	0.66	0.64	0.67	0.76	0.74	0.66	0.63
TIBA treated	0.73	0.90	0.90	0.74	0.57	0.70	0.74	0.73	0.77	0.74

Ⅱ. Growth Analysis

Relative Growth Rate(RGR). As shown in the Tables 8,9, until the 12th week after sowing relative growth rate increased in the growth process and reached to the maximum around the middle of August and decreased markedly after the peak. All the plots showed the tendency that during the period of high LAI the increase rate of RGR and F/C ratio weie also high. In the high planting density areas of all plots RGR were higher than that in the low planting density areas. And the growth rate in TIBA plot was higher than that in the other plots.

Net Assimilation Rate(NAR). Since the growth of green plants depends mainly on photosynthesis, and the ratio of leaf area to an unit of planting area gives a major factor to the plant growth, the relationship between the speed of growth and an unit of leaf area could be a criterion of the efficiency of photosynthesis.

This idea which comes from Gregory(1928) is an important concept which constitutes the basis of British growth analysis along with the Blackman compounded interest law. As shown in the Tables 8,9, all the experimental plots show considerably high increase rate of NAR between the 10th and the 11th week after sowing and the rate decreases after that. All the plots showed the tendency that until the last 10 days in August NAR was higher in high planting density areas of each plot, but from the 15th week after sowing all the plots showed relatively similar NAR values. Therefore, it can be presumed that the areas of planting density of one plant to 40×40 mm of each plot were under high competition-density effect in the process of growth. As shown in the Table 10, there exist negative relationship between NAR and LAI.

Table 8. Growth elememts of *Zoysia japonica* in 40×40 mm density plots

PLOT	DATE	R.G.R (g/g/week)	N.A.R (g/m²/week)	C.G.R (g/m²/week)	L.A.R (mm²/g/week)
Control	Jul.30-Aug. 06	0.59	0.70	0.12	58.51
	Aug.07-Aug.13	0.69	0.81	0.32	57.33
	Aug.14-Aug.20	0.80	0.77	0.95	74.13
	Aug.21-Aug.27	0.42	0.29	0.88	90.42
	Aug.28-Sep. 3	0.39	0.23	1.18	104.47
	Sep.04-Sep.10	0.14	0.08	0.58	112.65
	Sep.11-Sep.17	0.11	0.06	0.58	115.10
	Sep.18-Sep.24	0.10	0.06	0.77	114.68
	Sep.25-Oct.01	0.08	0.05	0.72	108.03
Mowed	Jul.30-Aug.06	0.53	0.69	0.12	52.04
	Aug.07-Aug.13	0.65	0.75	0.27	57.24
	Aug.14-Aug.20	0.78	0.71	0.75	70.17
	Aug.21-Aug.27	0.41	0.30	0.77	86.00
	Aug.28-Sep.03	0.38	0.26	1.11	92.36
	Sep.04-Sep.10	0.11	0.07	0.42	94.82
	Sep.11-Sep.17	0.10	0.06	0.47	105.22
	Sep.18-Sep.24	0.09	0.05	0.51	112.36
	Sep.25-Oct.01	0.07	0.04	0.45	107.05
TIBA treated	Jul.30-Aug.06	0.61	0.75	0.13	56.52
	Aug.07-Aug.13	0.75	0.79	0.33	60.77
	Aug.14-Aug.20	0.84	0.59	0.76	90.32
	Aug.21-Aug.27	0.49	0.27	0.87	113.75
	Aug.28-Sep.03	0.37	0.25	1.15	119.72
	Sep.04-Sep.10	0.12	0.06	0.52	119.73
	Sep.11-Sep.17	0.12	0.06	0.71	128.27
	Sep.18-Sep.24	0.11	0.05	0.76	135.52
	Sep.25-Oct.01	0.08	0.04	0.68	129.16

In particular, as LAI increased NAR decreases linearly. The lower the density of grasses, the more sensitive NAR to the change of LAI was. As shown in Table 12, in all the experimental plots of each planting density areas, there existed positive relationship between NAR and mean temperature and between NAR and amount of solar radiation with high significance.

Especially, in the low planting density areas of control plot and TIBA plot, mean temperature was the influential variable to the change of NAR. Solar radiation had also positive relationship with NAR with significance.

Table 9. Growth elements of *Zoysia japonica* in 100×100 mm density plots

Plot	Date	RGR (g/g/week)	NAR (g/m²/week)	CCR (g/m²/week)	LAR (cm²/g/week)
Control	Jul.30-Aug. 6	0.67	0.16	0.01	47.84
	Aug. 7-Aug.13	0.78	0.16	0.01	49.13
	Aug.14-Aug.20	0.94	0.15	0.02	63.17
	Aug.21-Aug.27	0.74	0.11	0.04	67.92
	Aug.28-Sep. 3	0.62	0.11	0.07	58.32
	Sep. 4-Sep.10	0.35	0.07	0.06	51.16
	Sep.11-Sep.17	0.31	0.06	0.06	51.16
	Sep.18-Sep.24	0.20	0.04	0.04	50.26
	Sep.25-Oct. 1	0.06	0.01	0.01	49.62
Mowed	Jul.30-Aug. 6	0.69	0.16	0.01	43.47
	Aug. 7-Aug.13	0.74	0.17	0.01	43.84
	Aug.14-Aug.20	0.92	0.17	0.03	56.20
	Aug.21-Aug.27	0.54	0.08	0.03	65.60
	Aug.28-Sep. 3	0.53	0.08	0.04	64.09
	Sep. 4-Sep.10	0.39	0.07	0.05	56.56
	Sep.11-Sep.17	0.35	0.07	0.06	51.55
	Sep.18-Sep.24	0.21	0.04	0.04	50.82
	Sep.25-Oct. 1	0.05	0.01	0.01	49.98
TIBA treated	Jul.30-Aug. 6	0.73	0.16	0.01	44.89
	Aug. 7-Aug.13	0.85	0.19	0.01	44.27
	Aug.14-Aug.20	0.94	0.17	0.03	58.00
	Aug.21-Aug.27	0.74	0.12	0.06	63.08
	Aug.28-Sep. 3	0.64	0.11	0.09	56.48
	Sep. 4-Sep.10	0.34	0.07	0.07	52.44
	Sep.11-Sep.7	0.28	0.05	0.06	52.76
	Sep.18-Sep.24	0.17	0.03	0.04	54.69
	Sep.25-Oct. 1	0.10	0.02	0.03	53.56

Table 10. Linear regression and correlation cofficient between NAR and LAI in 40×40 mm and 100×100 mm density plots

Plot	40×40 mm			100×100 mm		
	NAR equation⁺		NAR vs. LAI	NAR Equqtion⁺		NAR vs. LAI
	a	b	r	a	b	r
Control	0.659	-0.053	-0.871**	0.167	-9.121	-0.976**
Mowed	0.645	-0.066	-0.900**	0.167	-0.139	-0.937**
TIBA treated	0.608	-0.042	-0.864**	0.182	-0.105	-0.986**

** : Significant at 1% level

+ : Regression coefficients for the linear regression NAR, r=a+b(LAI)

Table 11. An analysis of the meteological date observed at Suwon branch office of Central Meteological Office

Date	T.m.	T.max	T.mir	E	R	D	S
Jul.24-Jul.30	27.0	32.7	23.3	6.4	11.5	6.8	2026
Jul.31-Aug. 6	26.4	29.8	23.5	4.1	106.4	3.4	1120
Aug. 7-Aug.13	25.8	30.2	21.9	4.2	74.9	5.9	1460
Aug.14-Aug.20	26.3	30.6	22.4	4.2	74.9	5.9	1434
Aug.21-Aug.27	27.5	32.1	23.7	4.6	7.0	7.9	1645
Aug.28-Aug.27	25.3	29.1	22.3	3.2	36.4	4.4	1087
Sep. 4-Sep.10	23.6	27.5	20.9	3.1	58.6	4.4	1201
Sep.11-Sep.17	20.3	23.6	17.6	1.9	57.4	1.5	7.39
Sep.18-Sep.24	18.3	22.1	14.9	2.1	14.3	2.0	829
Sep.25-Oct. 1	15.7	21.4	10.6	3.1	6.3	6.8	442

T.m. : Mean temperature, ℃, T.max : Maximum temperature ℃

T.min : Minmum temperature ℃, E : Evaporation mm/day

R : Rainfall mm/week, D : Sunshine hour hr/day, S : Solar radiation cal/mm^2/day

Table 12. Linear regression and correlation coefficient between NAR and meteological elements in each plot

plot		NAR equation(A)		NAR vs. M. temp.	NAR equation(B)		NAR vs.M.temp
		a	b	r	a	b	r
40×40 mm	Control	20.277	8.755	0.690*	8.554	7.406	0.630
	Mowed	20.082	0.715	0.720**	8.455	8.011	0.641*
	TIBA treated	20.430	9.013	0.677*	8.795	7.264	0.590
100×100 mm	Control	18.047	55.036	0.775**	6.836	44.758	0.681*
	Mowed	16.534	68.389	0.901**	5.751	54.958	0.782**
	TIBA treated	17.369	57.474	0.871**	6.098	48.575	0.795*

** : Significant at 1% level

(A): Regression coefficients for the linear regresssion
NAR=a+b(mean temperature)

(B): Regresssion cofficients for the linear regression
NAR=a+b(solar radiation)

Leaf Area Ratio(LAR). NAR, which is the value of leaf area necessary for one gram of plant production, means structural distribution rate of assimilatory organ and has important characteristics in energy regeneration. In the high planting density area (one plant, per 40×40 mm) of all the plots. LAR Value was high and mowing plot showed relatively lower values.

From around the middle of August every plot showed relatively high values, especially, in the high planting density areas the increase rate of LAR was considerably higher. Higher LAR value in higher density areas might be due to high F/C ratio and low photosynthesis because of receiving less amount of sunlight. In my research paper "Study on the Competition-Density Effect of Some Higher Plant" (Jin, 1972), I explained the high LAR in high density areas by the two factor analysis such as the ratios of leaf area/leaf weight and leaf weight/plant weight.

Nomoto *et al.*(1961), in their experiment using green beans, showed that under the condition of receiving low amount of sunlight, LAR and leaf area increased and the ratio of leaf weight to plant weight decreased.

Crop Growth Rate(CGR). CGR means the speed of crop growth per unit of time. In particular, it shows how many grams of production are made during an unit of time (week) in an unit of square area(cm^2), which can be also shown as NAR × LAI.

As shown in Tables 8, 9, in all the plots and each plant density areas, the CGR was increasing until the 13th week after sowing and was decreasing after that.

During the experimental period the CGR values were high in the areas of high planting density (one plant, 40×40 mm) of all the plots and the peak was recorded around the end of August as 1.18 g/m^2/week in the high planting density areas of control plot. In each density arears the CGR of mowing plot was low, whereas, in low density areas of control plot In each density arears TIBA plot recorded high value.

It shows that NAR and CGR tend to decrease after leaf area reaches to some point. Based on the fact, optimal leaf area index (LAI opt.) could be inferred as an optimal level of LAI maximizing CGR.

$$NAR = a - b\,(LAI)$$
$$CGR = NAR \times LAI = a(LAI) - b(LAI)^2$$
$$\frac{d(CGR)}{d(LAI)} = a - 2b(LAI)^{set} = 0$$
then $a = 2b(LAI)$, LAI opt. $= a/2b$

According to the formula of above LAI opt.'s in the low density areas of control plot, mowing plot and TIBA plot were 0.69, 0.60, and 0.87 respectively. And those were 6.22, 4.84 and 7.24 in higher density. Since these LAI opt.'s were derived from the grasses cultivated during this experiment, thus, it should not be generalized to all grasses. However, the above results suggest the possibility of applying growth analysis method to the growth analysis of grasses.

The amount of plant crop could be increased, by improving environments and changing sowing season to match the peak of seasonal change curve of CGR, on the other hand, by keeping high level of LAI(Watson, 1947). The estimated multiple linear regression among CGR and LAI, RGR, Mean Temperature and Average Solar Radiation shown in Table 13. Among them LAI was a very influential variable to CGR. Therefore, it is very important to improve the cultivating method to keep the optimal leaf area index. Of course, other variables than the ones considered in this research might interact with each other complicatedly affecting CGR, thus, muti-variable regression analysis which could take into account all the variables at the same are required.

Table 13. Multiple linear regression and correlation coefficient among CGR, LAI,, RGR and meteological elements in earch plot

plot		CGR	equation+		CGR vs. All var.		Prob.
	a	b	c	d	e	R^2	P(F>F.05)
40×40 mm Control	-9.626	0.353	2.664	0.333	-0.048	0.952	0.006
Mowed	-7.906	0.245	2.106	0.290	-0.063	0.931	0.013
TIBA treated	-10.055	0.297	2.301	0.371	-0.081	0.877	0.041
100×100 mm Control	-0.284	0.120	0.042	0.011	-0.003	0.934	0.012
Mowed	-0.213	0.127	0.085	0.006	-0.001	0.843	0.066
TIBA treated	-0.368	0.119	0.062	0.014	-0.004	0.971	0.003

+ : Regression coefficients for the multiple linear regression

CGR=a+b(LAI)+c(RGR)+d(mean temperature)+e(solar radiatoin)

Ⅲ. The Analysis of Holocellulose Content of Leaves

Table 14 shows the results of holocellulose content analysis of the leaves which were taken from grasses in different planting density and different conditions. The result of the analysis by employing Klason Method to find out the changing rate of holocellulose and lignin contents

Tabel 14. Contents of holocellulose of *Zoysia japonica* in each plot

Plot		Aug.20	Aug.27	Sep.3	Sep.10	Sep.17	Sep.24	Oct.1
40 × 40 mm Control	X1	6.52	5.35	5.77	6.31	7.25	7.37	7.54
	X2	0.66	0.66	0.68	0.67	0.65	0.64	0.64
	X3	71.2	70.1	73.1	71.6	70.3	67.3	69.6
Mowed	X1	6.78	6.95	5.23	6.56	7.41	6.80	7.23
	X2	0.68	0.63	0.65	0.65	0.66	0.61	0.63
	X3	73.1	70.7	63.9	70.2	71.7	65.6	68.0
TIBA treated	X1	7.39	6.55	5.60	6.70	7.44	5.81	6.93
	X2	0.67	0.64	5.60	6.70	7.44	5.81	6.93
	X3	73.2	69.0	70.5	71.0	70.6	68.6	68.6
100×100 mm Control	X1	5.49	7.76	5.31	6.51	7.28	7.39	9.10
	X2	0.64	0.66	0.65	0.64	0.63	0.62	0.61
	X3	68.0	71.2	69.3	68.2	68.7	67.4	67.6
Mowed	X1	5.85	4.97	5.22	6.72	6.75	6.65	5.71
	X2	0.70	0.75	0.64	0.65	0.67	0.63	0.61
	X3	74.7	79.5	68.1	70.0	71.5	68.0	64.5
TIBA treated	X1	6.80	5.79	5.78	6.53	6.51	8.46	7.56
	X2	0.64	0.61	0.65	0.65	0.64	0.62	0.63
	X3	68.8	65.4	69.7	67.8	68.7	68.1	68.7

X1: Contained water(%)

X2: Residue(g)

X3: Contents of Holocellulose(%)

showed the relative increase of a lignin content in the growth process of grasses. Based on that results, the holocellulose content of grasses was analyzed by applying Wise Method during the period from the second ten days of August to the first ten days of October. While high value of holocellulose content was recorded in the high density area of all the plot, the low density areas (one plant, per 100×100 mm) of control plot and TIBA plot showed considerable lignification already from around the middle of August recording the low level of holocellulose content, however, mowing plot showed similar results as the high density areas of each plot because every week's mowing increased the ratio of new leaves in the sampled grasses for analysis. Nakasawa(1968) reported that comparing the tissue of spring wood with that of autumn wood, the latter showed the more considerable lignification and low value of holocellulose content in the experiment on chemical use of timber of Japanese Larch.

By analyzing the Dry Matter Production and Growth Characteristics of the grasses cultivated on the experimental field of Kyung Hee University under the conditions of different treatments and plant densities, the following results were obtained.

1. Between the 10th and 12th week after sowing all the control, mowing and TIBA plots recorded high growth rate of LAI and in the low density area of TIBA plot high growth rate of assimilatory oragan was observed, and showed high increase rate of standing crop and in the process of growth each density area of TIBA plot recorded high increase rate.
2. There existed positive relationship between standing crop and leaf area with high significance. And in mowing plot leaf area was an influential variable to dry matter production.
3. In all the plots F/C ratio was high when the growth rate of assimilatary organs was increasing considerably, and the higher the planting density was, the higher F/C ratio was recorded. And the increase rate of RGR was high during the growth period when the growth rate of assimilatory organs was increasing and F/C ratio was high.
4. In all the plots NAR recorded maximum increase rate before the growth period of high increase rate of RGR. In the process of growth TIBA plot showed high increase rate of NAR.

When LAI increased, NAR decreased linearly and it had positive relationship with mean temperature and mean solar radiation with high significance.

5. CGR showed high value in the high density area of all the plots and reached its maximum in the 13th week after sowing. The optimum leaf area indices for the maximum level of CGR in the high density of contol plot, mowing plot and TIBA plot were presumed to be 6.22, 4.89 and 7.24 respectively and 0.69, 0.60 and 0.87 in the low density areas of respective plots.
6. The result of multiple linear regression analysis showed that LAI was an important variables influencing CGR. And suggested the importance of improvement of the cultivating method to keep optimal leaf area index.
7. Compared to the other experimental areas the low planting density areas of control plot and TIBA plot showed considerably earlier lignification indicating low holocellulose content in the growth process.