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Analysis of Physiological and Ecological Characteristics of Rice Cultivated with Direct Seeding on Dry Paddy Field*

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Abstract : To understand the growth habit of rice plants under direct seedling cultivation on well-drained paddy fields, physiological and ecological characteristics were compared among directly seeded and transplanted rice cultivar "Whasungbyeo". Photosynthesis and respiration were lower in direct seeding cultivation (DSC) than in mechanical transplanting cultivation (MTC). Chlorophyll content and root activity were lower in DSC than in MTC from the tillering to heading stages, while they were higher 15 days after heading in DSC. The stomatal resistance of the upper leaves was higher in DSC than in MTC from the tillering to heading stages, however, it was higher in MTC than in DSC 15days after heading. The specific leaf area was higher in MTC than in DSC from the tillering stage to 15 days before heading, and was lower in MTC from the heading stage to 15 days after heading. The length of leaf blade and internode were longer in DSC than in MTC except the flag leaf and first internode. Partial dry weight was high in the upper part in MTC and lower part in DSC. CGR, RGR, NAF and LAI were higher in DSC than in MTC from the tillering to heading stages. The number of spikelets, yield and ripened grain ratio were higher in DSC than in MTC, while the number of panicles was higher in MTC.
Key words : Direct seeding cultivation, Mechanical transplanting cultivation, Photosynthesis, Rice.

乾田直播栽培稲の生理・生態的特性解析 : 許　煇・金　容基（韓国，忠北大学校農生物学科）
要　旨 : 乾田直播栽培におけるイネの生理生態的特性を究明するために，稲品種花成を乾田直播と機械移植栽培条件で栽培し，生育時期別にその生育および生理生態特性を比較調査した．乾田直播したイネの草丈は分げつ期までは移植水稲より短いが，分げつ期から出穂10日前までは乾田直播の方がまさる傾向となった．また分げつ期以後の茎数は乾田直播栽培で多かった．乾田直播稲の単葉の光合成能力と呼吸量は機械移植より低く推移し，出穂15日前にその差がもっとも大きかったが，出穂以後にはほとんど差がなかった．葉身の葉緑素含量と根の生理的活力は出穂以前までは乾田直播が機械移植よりやや低かったが出穂15日後にはかえってまさる傾向を示した．上位葉の気孔抵抗は分げつ期から出穂期までは乾田直播栽培が高かったが出穂後15日には機械移植で高くなる傾向がみられた．葉面積比率は分げつ期から出穂前15日までは機械移植で，出穂以後は乾田直播で高かった．収穫期の葉伸長および稈の節間長は止葉と上位部1節間を除いて乾田直播で機械移植栽培より長かった．収穫期の葉伸長および稈の節間長は止葉と上位部1節間を除いて乾田直播で機械移植栽培より長かった．地上部の生産構造をみると，乾田直播が機械移植栽培より同化部位が上位部に多く分布し，反面非同化部位は下位部で分布が少ない特性を示した．また乾田直播栽培では分げつ期から出穂期にかけてのCGR，RGR，NAR，LAIが高い値を示し，また1穂穎花数も多く，もみ収量，登熟歩合が高い特性を示した．
キーワード : イネ，乾田直播栽培，機械移植栽培，光合成能力．

The area of direct seeding cultivation (DSC) was approximately 3,200 ha in South Korea in the 1960's, but decreased to 1,800 ha in 1991[15]. However, it increased to 7,500 ha in 1993, and the area of DSC on dry paddy field was 3,500 ha[14]. It was reported that the area of suitable land for DSC on dry paddy field is 132,000 ha in the middle part (Kyungki and Chungcheng province) of Korea[6]. It is well known that DSC saves labor and costs in rice cultivation ; DSC saves 39% of total working time and 38% of total costs compared to MTC in Korea[8,9,10,20]. Also DSC on dry paddy field reduced the danger of lodging and satisfied ventilation and germination compared with other direct seeding cultivation[19]. Therefore, it is a suitable cultivation method for farm mechanization and streamlining production[7]. Although DSC was emphasized as a good cultural practice for stabilization of yield once in rice cultivation history in Korea, transplant cultivation has been developed and still, very little research has been done on DSC until now[9]. Previous research on DSC has mostly focused on the cultivation method, and little has been caried out on the physilogy and

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ecology of rice.

We carried out some experiments to find out the difference in the dry matter production, physiological and ecological characteristics of DSC and MTC in order to establish a system of DSC on dry paddy field. We hope that the results of our study presented in this paper can be used as a basis for the development of DSC on dry paddy field.

Materials and Methods

These experiments were carried out in Cheongju in 1994. A cultivar "Whasungbyeo", was used. For MTC, rice was seeded on April 20, and the seedlings were transplanted in the paddy field on May 25 at transplanting density 30×15 cm, 3 plants per hill. The total amount of chemical fertilizers applied on MTC was 11 kg N, 7 kg P, 8 kg K per 10a ; 5.5 kg N,7 kg P, and 5.6 kg K was applied as a basal dressing and 2.2 kg N at 12 days after transplanting and 3.3 kg N and 2.4 kg K at 20 days before heading were applied as a top dressing respectively. For DSC, rice was seeded directly on a dry paddy field on April 25 at seeding rates 5 kg/10 a. The chemical fertilizers 15 kg N, 7 kg P, and 8 kg K per 10 a were applied ; 6.0 kg N, 7 kg P, and 5.6 kg K as a basal dressing, and 3.3 kg N at the seedling stage, 3.0 kg N at tillering stage, 1.5 kg N and 2.4 kg K at 20 days before the heading stage, and 1.5 kg N at the heading stage as a top dressing were applied per 10 a respectively[11,12,16]. Plant length and the number of tillers was determined for 20 hills with three replications once in 5 days, 10 times from the tillering to the heading stage[1,2]. Photosynthesis in a single leaf was measured on compeletely expanded flag, 2nd, and 3rd leaf with three replications by a CO_2 gas analyzer (ADC 225-MK3, the analytical development Co. Ltd.)[21]. Measurement of photosynthesis was done under 30°C and 30, 000 lux in phytotron[3]. Respiration was measured with the same method of photosynthesis under dark conditions. The leaf area was determined by an automatic area meter (AAM-8, Hayashi Denko Ltd.) using completely expanded top 3 leaves at tillering, 15 days before heading, and 15 days after the heading stage, respectively. Generally, chlorophyll content, root activity and stomatal resistance affect photosynthesis activity[1,2]. Chlorophyll content was quoted from the ethyl alcohol extraction method (Osbone and McCalla method, 1961) using the same leaves as for the measurement of leaf area. Root activity was measured as oxidative ability by α-naphylamine (Yamada et al, 1961[22]). Stomatal resistance was measured on the completely expanded top 3 leaves at tillering, 15 days before heading, and 15 days after heading by Automatic Porometer (AP-4, Delta-T Devices Ltd.)[5,18]. Dry matter production was measured for 4 weeks from the tillering to the heading stage using the method of Hirao et al. and Saitoh[4,17]. Yield and yield components per 3.3 m^2 were determined by three replications and expressed as a dry weight of unhulled rice per m^2.

Results and Discussion

1. Atmospheric phenomena

Changes in atmospheric parameters during cultivation are shown in Table 1. Both the mean and highest temperature from May to August of 1994 were higher than those of an average year (1989～1993). Especially, the highest temperature of July was over 34°C. It was an abnormally high temperature compar-

Table 1. Changes in atmospheric parameters of an average year and 1994 in Cheongju.

		May		June		July		August		September	
		1994	AY[a]	1994	AY	1994	AY	1994	AY	1994	AY
Air Temp.	Mean	18.2	17.4	22.7	22.2	29.1	25.9	27.7	25.5	20.0	20.5
	Max.	24.2	23.7	28.6	27.7	34.5	30.6	32.5	30.4	26.3	26.5
	Min.	12.4	11.6	17.0	17.2	24.5	21.4	23.5	21.2	14.8	15.6
Precipitation	(mm)	108.3	100.3	140.5	133.8	85.5	220.5	318.5	26.5	48.1	171.5
Duration of Sunshine (hr)		220.2	234.4	234.6	196.8	247.1	177.1	232.5	171.1	231.0	187.5

[a] : Average year (1989—1993).

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ed to an average year.

In July, the precipitation decreased 145.0 mm as compared with an average year, while in increased 192.5 mm in August. The duration of sunshine during July and August was about 60～70 hours longer than that of an average year. This phenomena suggest that the abnormal climate conditions reasonably affect the results of these experiments.

2. Plant length and number of tillers

Before the tillering stage, plant length in DSC was shorter than that in MTC, but the reverse was true from the tillering stage to 10 days before heading. After the heading stage, it was longer in MTC again (Fig. 1). However, there was not a significant difference between DSC and MTC at each stage. This result showed the same tendency as seen in Lee's experiment[8]. The number of tillers in MTC was larger than that in DSC by the tillering stage, but after that, it increased remarkably in DSC (Fig 2). This report showed reasonable merit for the maintain of number of tillers and yield and yield components in MTC.

3. Physiological characteristics

Several parameters, such as chlorophyll content, root activity, and stomatal resistance, were measured to find the effects of photosynthesis. Photosynthesis reached its highest value at 15 days before heading, and thereafter gradually decreased in both cases. Photosynthesis was lower in DSC than in MTC throughout measurement. The difference of photosynthesis between two cultivations was 15.4 CO_2 mg $dm^{-2}h^{-1}$ on 15 days before heading, but no difference was found after the heading stage. There was no significant difference among leaf position on the stem in photosynthesis although it was slightly higher in DSC than MTC at heading and 15 days after

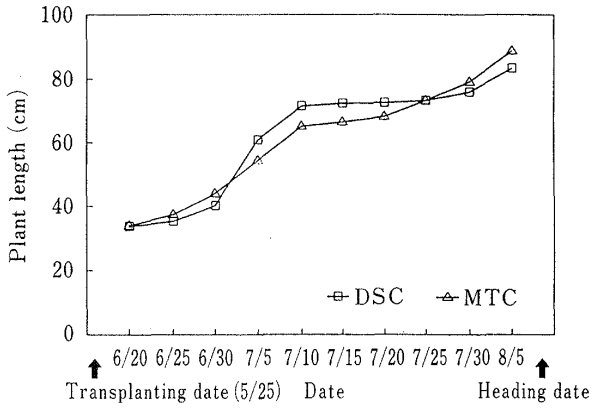


Fig. 1. Difference in plant length between DSC and MTC from the seedling to the heading stage.

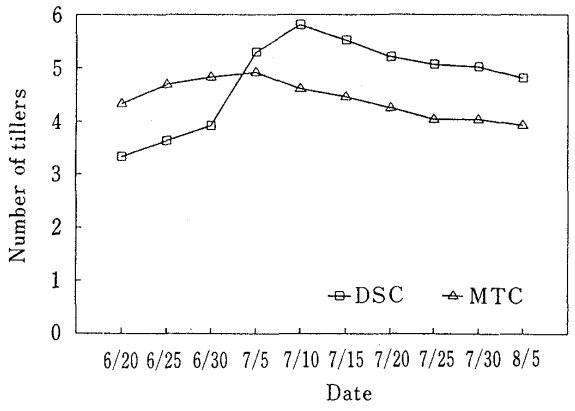


Fig. 2. Difference in the number of tillers between DSC and MTC from the seedling to the heading stage.

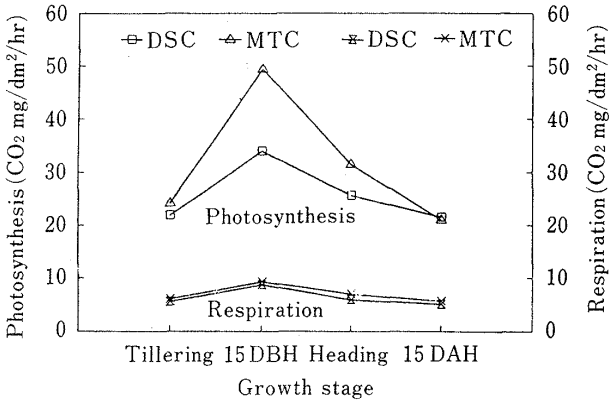


Fig. 3. Photosynthesis and respiration of top three leaves of rice in DSC and MTC. DBH : days before heading, DAH : day after heading.

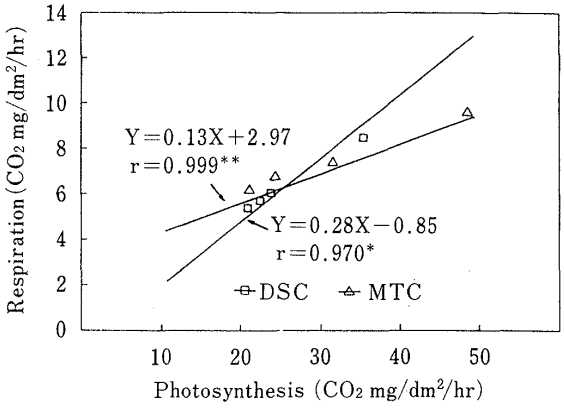


Fig. 4. Relationship between photosynthesis and respiration of the rice in DSC and MTC. * : significant at 5% level, ** : significant at 1% level.

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heading stage on the flag leaf. It is believed that photosynthesis was affected by irrigation time and fertilization method. DSC irrigate after the seedling stage and much more nitrogenous fertilizer is applied in DSC than MTC. Reduction of soil moisture content and mesophyll water content in DSC reduced photosynthesis. Therefore, chlorophyll content and root activity were decreased after 15 days before heading. Respiration was higher in MTC than in DSC. However that difference, 0.68 CO_2 mg $dm^{-2}h^{-1}$ was not significant (Fig. 3 and 4). Photosynthesis and respiration showed positive correlation coefficients (Fig. 4) ; Correlation coefficient between photosynthesis and respiration in DSC was significant, and highly significant in MTC.

Chlorophyll content of leaf decreases gradually with the lapse of time. It was higher in MTC from the tillering to the heading stage, while it was higher on 15 days after heading in DSC. The chlorophyll content declined significantly in MTC after the heading stage, but no significant decrease was found in DSC. From this result, the low chlorophyll content is considered to be affected by irrigation and other cultural practices between DSC and MTC from tillering stage to 15 days after heading stage (Fig. 5).

There was the difference in root activity between DSC and MTC. Root activity was the highest at the tillering stage, and then declined rapidly from 15 days before heading to the heading stage in both cases. The change of root activity seemed to be caused by an extreme high air temperature which resulted in water temperature increase. But this conditions did not affect photosynthesis directly as much as root activity. It is necessary to further study to conduct, the reason of the differential effect of high temperturature between photosynthesis and root activity. We believe that measurement of photosynthesis must be done not only on single leaf, but also on the whole plant (Fig. 6).

Stomatal resistance of upper leaves was measured to find the relationship between photosynthesis and stomatal resistance[5]. It was higher in DSC from the tillering to the heading stage than in MTC. But it was higher

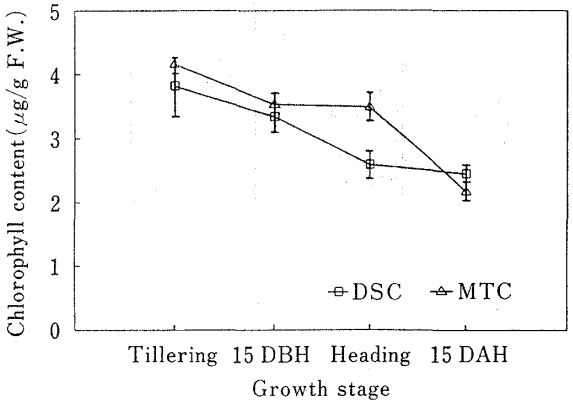


Fig. 5. Difference in the chlorophyll content of top three leaves of the rice between DSC and MSC. DBH : days before heading, DAH : days after heading.

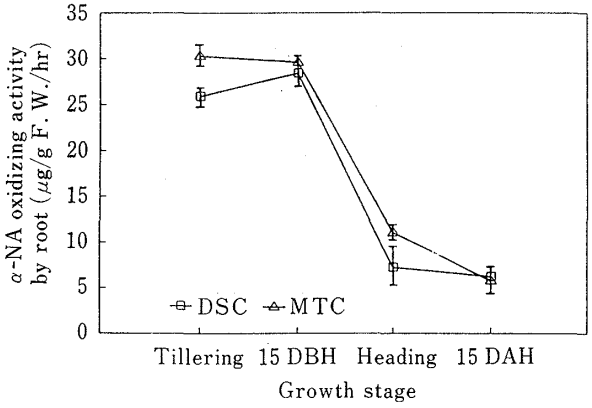


Fig. 6. Difference in the root activity of the rice between DSC and MTC. DBH : Days before heading, DAH : Days after heading.

Table 2. Difference of storatal resistance of the rice leaf blade between direct seeding (DSC) and mechanical transplanting cultivation (MTC) of the cultivar Whasung.

Cultivation	Stomatal resistance (sec/cm)			
	Tillering stage	15 days aefore heading stage	Heading stage	15 days after heading stage
DSC	1.96±0.36	2.42±0.70	0.67±0.18	0.48±0.08
MTC	1.66±0.71	2.17±0.81	0.48±0.11	0.60±0.14

± : standard deviation.

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in MTC on 15 days after heading. At the heading state, it declined rapidly, compared with 15 days before heading. The difference was thought to be caused by high temperature before heading, which was returened to normal temperature at heading stage. Also, we believe that the difference of stomatal resistance affects photosynthesis and respiration (Table 2).

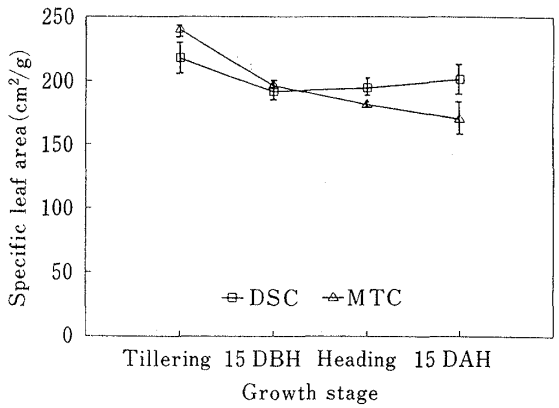


Fig. 7. Comparison of SLA of the rice between DSC and MTC. DBH : Days before Heading, DAH : Days after Heading.

4. Ecological characteristics

In order to find out the difference in ecological characteristics, specific leaf area, length of internode and leaf blade, partial dry weight, and growth analysis between two methods were investigated. Specific leaf area (SLA) was higher in MTC than in DSC from the tillering stage to 15 days before heading, but it was higher in DSC from the heading stage to 15 days after heading (Fig. 7). SLA in DSC was a litter higher at the tillering stage, and then it was not changed significantly. On the other hand, SLA in MTC was changed significantly. This result suggests that leaf in DSC became thicker, gradually.

Fig. 8 shows difference in the length of internode and leaf blade between DSC and

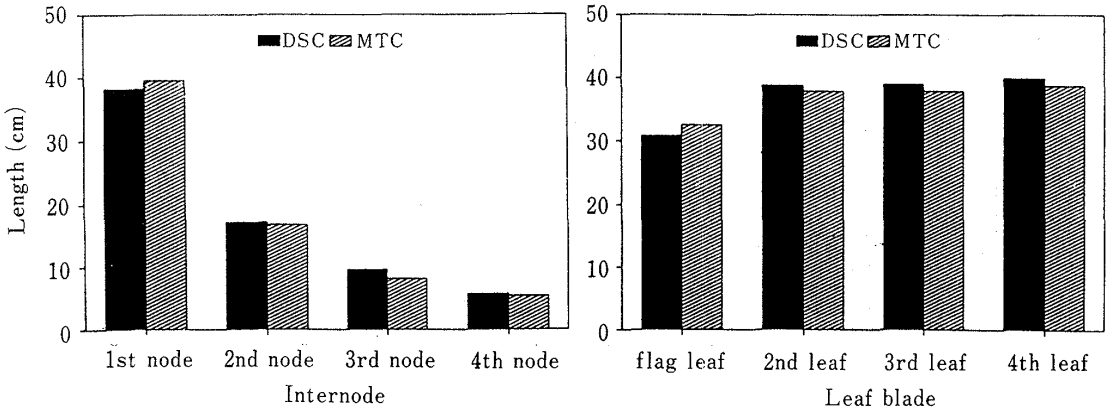


Fig. 8. Length of internode and leaf blade of the rice in DSC and MTC at the maturing stage.

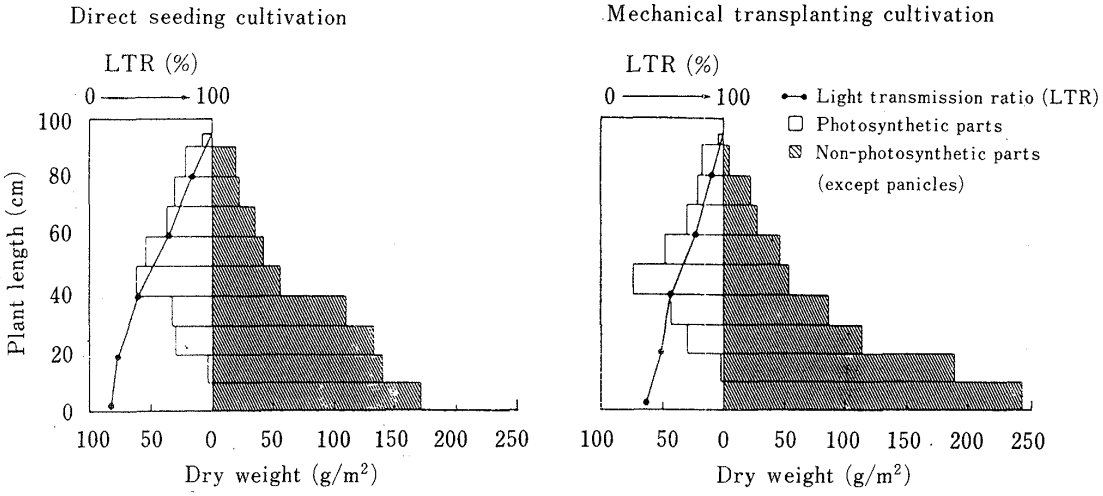


Fig. 9. Difference in the productive structure of rice between DSC and MTC at the maturing stage.

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Table 3. Changes of CGR, RGR, NAR and LAI between direct seeding (DSC) and mechanical transplanting cultivation (MTC) from the tillering to the heading stage (4 weeks) of the cultivar Whasung.

Cultivation	CGR ($g/m^2/day$)	RGR ($g/g/m^2$)	NAR ($g/m^2/day$)	LAI (m^2/m^2)
DSC	34.81	0.048	7.39	3.23
MTC	22.83	0.039	6.61	2.84

Table 4. Yield and yield components between direct seeding (DSC) and mechanical transplanting cultivation (MTC) of the cultivar Whasung.

Cultivation	Heading date day/mon.	Clum length (cm)	Panicle length (cm)	No. of panicles /m^2	No. of spikelets /panicle	Weight of 1,000 grains	Ripened grain ratio (%)	Yield[a] (g/m^2)
DSC	15. Aug.	70.86	19.37	405	96.9	23.45	88.3	717.0(112.7)[b]
MTC	6. Aug.	69.96	20.07	420	93.1	23.87	86.2	636.4(100.0)

a : Unhilled rice, b : Yield index.

MTC at the maturing stage. The first internode was shorter, and the second, third and fourth internode were longer in DSC than in MTC. The length of leaf blade was longer in DSC than in MTC, except in the flag leaf. This results show that not so much difference for the length of internode and leaf blade was detected in Tongil type rice compared to Japonica[1]. But we think the characteristics must be studied further for the DSC.

The distribution pattern of partial dry weight between two cultivations at the maturing stage is shown in Fig. 9. In DSC, photosynthetic parts with large dry weight were distributed toward upper layers, while heavy dry weight distribution appeared from 40 to 50 cm in MTC. Non-photosynthetic parts except panicles were distributed in much lower layers in MTC than in DSC. This production system was related to the light transmission ratio, which was lower in DSC than in MTC. All of these results suggest that photosynthetic parts grew very actively in DSC, while non-photosynthetic parts grew actively in MTC.

For growth analysis, CGR, RGR, NAR and LAI were calculated from the tillering to the heading stage. All were higher in DSC than in MTC. The difference of CGR between two cultivations was big ; It was 34.81 in DSC and 22.83 in MTC (Table 3).

5. Yield and Yield components

Panicle length, number of panicles, and weight of 1,000 grains were higher in MTC than in DSC. But there was no significant difference in the panicle length and number of panicles. Number of spikelets, ripened grain ratio, and yield were higher in DSC. This results was as same tendency as Lim's data[13]. Also, the difference of ripened grain ratio and yield were significant at the 5% level. Yield increase in DSC is due to the increase of dry weight ratio of above ground, CGR, RGR, NAR, and LAI, because rice plant in DSC grows very actively at the late stage (Table 4).

In this study, parameters on physiological characteristics, that is, photosynthesis, chlorophyll content, root activity, stomatal resistance were lower in DSC than MTC from 15 days before heading to the heading stage, but these gradually increased or equalized on 15 days after heading. For this reason, the final dry matter production and yield were high in DSC.

We carried out this study for obtaining basic information for DSC, and this is the first year result of our investigation. We believe it is necessary to do continuous experiments with different cultivars, fertilization, plant density and period of culture for better understanding of the physiological and ecological characteristics of rice in DSC.

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