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Analysis of Productivity in Rice Plant (III) Dynamic Change of Canopy Structure

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벼의 생산력 분석

(Ⅲ) 군락구조의 동적변화

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요 약

새로 육종된 다수성 품종인 IR 667-수원 213과 진흥을 사용하여 출수후 군락구조의 동적변화를 질소영양과 관련하여 비교분석한 결과 다음과 같았다.

1. 군락구조 패턴 (출수기 건물중 수직분포)은 진흥에서는 수직형이고 IR 667 에서는 수평형이었다.
2. 엽면적 밀도 (또는 무게)의 수직분포 패턴이 IR 667 은 중앙부 우세형으로 진흥은 상부 우세형으로 분류되었다.
3. 군락구조 보존패턴과 엽면적 백분율 분포패턴은 엽면적밀도의수직분포패턴을 따랐다.
4. 군락보존력은 IR 667이 약하여 군락보존율이 낮으며 이는 엽의노화가 빠른것을 나타낸다.
5. 질소영양이 군락구조패턴에 거의 영향을 주지 않지만 질소의 느린공급(유황입힌요소)은 구조의 중앙부를 보존하여 상부우세형을 중앙부 우세형으로 변환 시키려는 경향을 보였으며 그것이 수량 증가의 원인이 된것같다.
6. 중앙부우세형과 상부우세형은 곡실생산에서의 상위엽의존형과 하위엽 의존형에 각기 잘 적합한것 같다.

Rice plant completes the construction of secondary productive structure at heading stage by its primary productivity and since then secondary productive structure begins to operate. Thus rice yield depends almost on canopy structure at heading. We proposed "canopy score" as criteria for the evaluation of canopy in a comparative analysis of canopy structure in relation to secondary productivity and found that newly bred IR 667 line has much higher score than commercial varieties (6). Three dimensional arrangement of productive structure and its change during ripening, however, could hardly be perceptible from canopy score. Spatial arrangement of structure has been investigated generally once at heading stage(2,7). The difference of about two weaks in ripening period between IR 8 or other tropical rice (30 days) (3) and Korean Varieties (45 days) suggests some differences in the change of canopy structure after heading. IR 667 line(IR8

×Taichung Native 1×Yukara) is expected to show a change different from commercial varieties since it showed faster destruction of productive organ though it has the same ripening duration as that of commercial varieties. The information on the change of spatial arrangement of structural components, thus, will give better interpretation of their productivity.

The way for the increase of rice plant productivity is bidrectional, i.e. either by breeding or by environmental improvement. The highest productivity must be promised when these two requirements are saticefied. A contemporary example is dwarf Mexican wheats in India which had limited acceptance until it was demonstrated clearly that proper planting depth along with addition of water and fertilizer produced mrakedly higher yields than could be obtained with native strains much less responsive to water and nitrogen (1). From this fact serious erosion of gene pool could occur depending on the environmental condition for the selection through breeding. It also indicates that the improvement of cultural practice could increase the yield of IR 667 even though it already exceed Jinhung by 32%. In the same way Jinhung could produce by a change of cultural method more than IR 667 could. The possibility of higher yield in Jinhung than in IR 667 appeared by the application of sulfur coated urea in a field experiment. Since rice yield in Korea depends predominantly on nitrogen nutrition (8) the effect of nitrogen nutrition to yield might be elucidated through analysis of its effect on canopy structure. In this study dynamic change of secondary productive structure was investigated in relation to nitrogen nutrition using IR 667 and Jinhung.

Materials and Methods

Jinhung and IR 667-Suwon 213(**Oryza satira L.**) in urea split atpplicaion plot (15kgN/10a, 40% as basal, 30% at 15 days after transplanting, and 30% at ear formation) and sulfur-coated urea plot (Tenesee Valley Authority, grade C) of a field experiment at Palkok-ri, Banwol-myon in 1971 were used. Double supperphosphate (17. 4kg), potassium murate (13.3kg) equivalent to 8kg/10a of phosphorus, or potassium, and 270kg/10a of wallastonite enough to give 130ppm of available silicate in soil were applied as basal dressing. Rice plants were transplanted on 1st, June with 30×15cm of spacing.

Vertical distribution of leaf area density: At one week before harvesting each 10 cm of layer of five hills in the part of medium growth were cut into plastic bags with water, separated into each part, and area of living leaves was measured as described previously(6). Leaf area density (leaf area cm^2/cm^3 space volume) was calculated by number of ear per m^2. Leaf area and area density at heading were estimated by dead leaf weight.

Vertical distribution of nonphotosynthetic organ: Separated organs of each layer as mentioned above were dried and weighed (g/m^2).

Canopy conservation ratio: It is designated as percent of leaf area at harvesting to that at heading. Vertical distribution of it was considered as pattern of canopy conservation(persistence).

Leaf area of various leaf position: Area of living leaves of five hills in medium growth was determined as described in the previous report (6) at harvesting stage. Leaf area and leaf area index at heading were calculated by dead leaf weight and number of ears.

Light transmission ratio: Using canopy light meter (Sansin kongyo model NS-II) light transmission ratio was measured as mean value of 4 shade spots at every 10 cm of canopy height.

Results and Discussion

Rice yield in Korea was primarily determined by nitrogen nutrition (8). The best nutritional environment of nitrogen for rice plant as well as for most other crops is "slow but enough" supply from rhizosphere. In the soil condition slow supply at low level of nitrogen could not afford enough amount while enough supply by such as fertilizer application could not avoid high concen-

Table 1. Effect of nitrogen fertilizers on grain and straw yield

	IR 667-Suwon 213		Jnhung	
	Urea	SCU	Urea	SCU
Grain (kg/10a)	713	777	617	809
Straw (kg/10a)	639	667	721	855
Grain/Straw	1.12	1.16	0.86	0.95
No. of tiller/m^2	275	275	218	207

SCU: Sulfur coated urea (Grade C from Tenesee Valley Authority)

tration of nitrogen that is harmful or even toxic to rice. Thus achieving of two contradictory but necessary conditions is the final goal being sought in the study of nitrogen application method. This ideal condition of nitrogen nutrition has been partially fullfilled mechanically by split application of nitrogen fertilizer, physically by deep placement or ball fertilizer, microbiologically by organic matter application, and chemically by silicate fertilizer or slow release nitrogen fertilizers. Slow release nitrogen fertilizer are the best ones of them but it is not so economical as for commercial use. Various slow release nitrogen fertilizers are still under test (3). Since sulfur coated urea(from Tenessee Valley Authority) seems to be economical by slight modification suitable to Korean paddy soil Mr. C. W. Hong, soil chemist is carring out field experiments. This investigation of canopy structure with a variable, nitrogen nutrition using two varieties was conducted on sulfur coated urea plot and urea split application plot in one of his field experiment.

Grain yields in two varieties were higher in sulfur coated urea (SCU) as shown in Table 1. Thus SCU effect in this case well agreed with the result of highest mean yield (3). IR 667 showed higher yield in urea split application but Jinhung showed higher yield in SCU indicating that productivity is changed depending on nitrogen nutrition between varieties. Secondary productivity (grain yield) did not follow primary productivity. It was greater in Jinhung than that of IR667 in both urea and SCU. Secondary productivity,however, was always higher where primary productivity is greater in the same variety. IR 667 had a grain-straw ratio greater than one while Jinhung had it less than one. IR 667 did not always have greater value than one (6) but it had always greater value than that of Jinhung when they were grown under the same condition. Primary productivity was also not always higher in IR 667 but depended on the growth condition (6). Smaller primary productivity of IR 667 than that of Jinhung may be attributed to unknown soil factors considering that IR 667. is likely to have greater primary productivity(6). Since primary productivity depends on growth condition grain-straw ratio could be a good index for the efficiency of secondary productive structure but it could not be a index of secondary productivity.

Effect of nitrogen nutrition to grain yield should be expressed primarily through productive structure. Figure 1 shows clearly the differences between varieties with two different nitrogen sources in productive structure one weeks before harvesting. The differences in spatial arrangement of productive structure appear clearly between varieties but little between nitrogen sources. It may be conconcluded that nitrogen sources hardly change productive structure which appears to be specific to each variety. Thus IR 667 had broad and low horizontal type while Jinhung had narrow and high vertical type. Such contrast between two varieties was showmn in tropical rice plants (2) and vertical type seems to be specific for tall variety while horizontal type seems to be specific for short culm variety. Such specific type appears to keep through ripening period without much

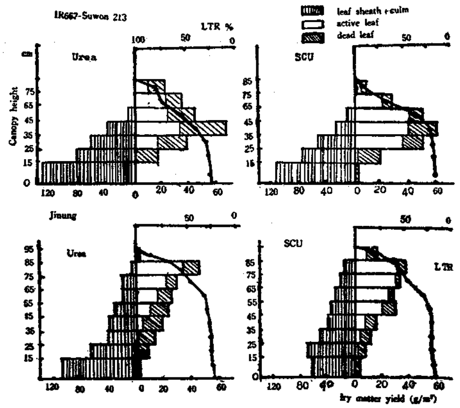

Figure 1. Canopy structure pattern of rice plant with different nitrogen nutrition at one week before harvesting.
Urea: urea split application, SCU: sulfur coated urea (Tenesee Valley Authority, grade C), LTR: light transmission ratio.

change from the distribution of dead leaves(Figure 1). The distribution of living leaves in each layer (clear part of Figure 1)was dominant in the central layers in IR 667 but predominated in the upper layers in Jinhung. These phenomenon were same at heading time (clear part and shade part in Figure 1). Therefore it was clear that the drying and death from leaf tips of upper leaves in IR 667 did not affect the type of canopy structure after heading. It only decreased living leaves, keeping the specific type. In the case of SCU, the leaves of upper part were conserved more and as the result there seems to be a trend that canopy type for IR 667 declines to that of Jinhung.

Light environment in canopy showed good relation to leaf weight distribution in each layer. Light transmission ratio(Figure 1)decreased rapidly in Jinhung having upper-dominant distribution while slowly in IR 667 having central dominant indicating that they follow well Bouger-Lambert's law (4). Light environment in canopy may be affected more by leaf area density (cm^2/leaf/cm^3 space volume) than by leaf weight distribution. The vertical distribution of leaf area density (Figure 2) showed similar to leaf weight distrib-

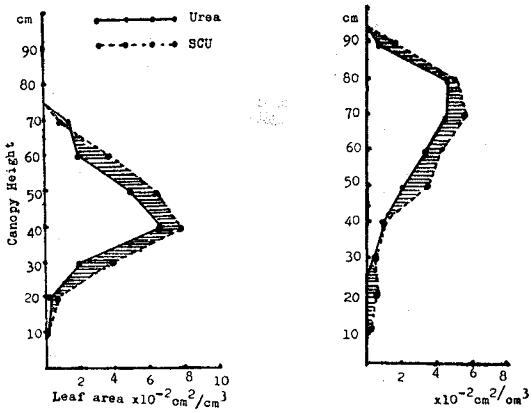

Figure 2. Pattern of vertical distribution of leaf area density.

Table 2. Effect of nitrogen fertilizers on percentage of active leaf at harvesting

leaf	IR 667-Suwon 213				Jinhung			
	Urea		SCU		Urea		SCU	
	cm^2/leaf	%AL	cm^2/leaf	%AL	cm^2/leaf	% AL	cm^2/leaf	% AL
1*	12.9	67.6	19.5	81.7	29.3	90.9	36.4	99.4
2	18.1	57.8	23.3	76.8	25.0	86.2	29.7	87.2
3	7.3	22.7	19.1	71.6	14.9	57.6	26.0	76.7

4	1.6	8.0	5.6	27.5	3.8	19.8	21.5	62.5
5	0	0	0	0	0	0	2.8	13.0
Total	39.9	33.1	67.5	52.1	73.0	53.8	116.4	75.1
LAI	1.00	(3.27)	1.85	(3.55)	1.59	(2.96)	2.40	(3.20)
Total**	70.3	52.6	82.7	66.0	72.3	55.9	107.0	73.0
LAI**	1.93	(3.66)	2.27	(3.44)	1.58	(2.83)	2.21	(3.02)

* : Counted from flag leaf downwards,
( ) : LAI at heading estimated by total percentage of active leaf,
SCU: Sulfur coated urea
** : Calculated from canopy layer analysis, one week before harvesting.

ution, thus IR 667 had central dominant type while Jinhung had apical (upper) dominant type. The shade part in Figure 1 indicates effect of nitrogen nutrition, that is, contribution of SCU in canopy persistence. Nigrogen nutrition keeps leaves from destruction by senescence but seems to be able to change distribution pattern of leaf area density.

The percent distribution of leaf area density in canopy profile (Figure 3) followed also leaf

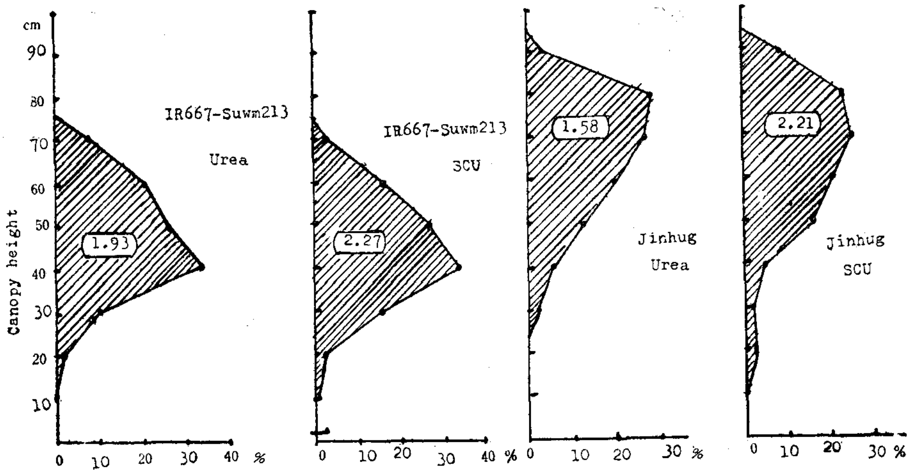

Figure 3. Percent distribution pattern of leaf area density.
Number indicates LAI

weight distribution or leaf area density distribution. But in this case a trend that SCU forced apical dominant type of Jinhung into central dom inant type was clearly shown. From leaf area of each leaf position (Table 2) it is well known that second leaf area is greatest in IR 667 and flag leaf area is greatest in Jinhung. If the upper part of canopy is consisted of upper leaves while the lower part of it is consisted of lower leaves, then specific type for each variety may be easily expected from the leaf area of various position. However canopy pattern seems to be quite different from leaf area in various leaf position since percent active leaf in Table 2 declined gradualy from top to bottom leaf but the conservation ratio in each layer of canopy (Figure 4) was different from the percent active leaf of positional leaf. The interesting fact is that canopy conservation pattern rather follows the distribution pattern of leaf area density. Thus in the case of central dominant of IR 667 canopy was persisted much more in certral part and destructed more in

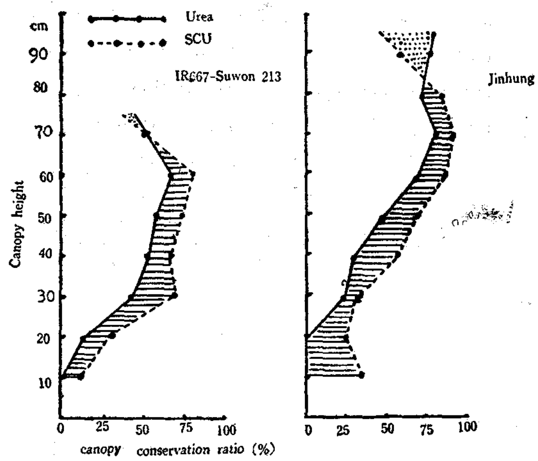

Figure 4. Canopy conservation pattern.

upper part while in the case of apical dominant of Jinhung canopy was perisisted much in upper part.

The dificulty in expectation of canopy pattern from leaf area of positional leaf was shown in the previous result(5) in which IR 667 had greater percentage of upper leaf area than in Jinhung at 20 days after heading. It was also clearly seen that SCU destructed more upper part in Jinhung and forced to have central dominant type (shade part in Figure 4). The effect of SCU is a retardation of leaf senescence. From Table 2 it is clear that SCU effect was smaller (14 % conservation) in IR 667 having rapid senescence while Jinhung having slow senescence was conserved 18 % of leaf area by SCU. The higher yield of Jinhung than IR 667 in SCU may be attributed to such greater persistence of productive organ. During a week before havesting decrease of leaf area index was considerable in IR 667 while no difference in Jinhung (Table 2) and this well agreed with the previous results (6).

It is well expected that the central dominant type should have better light transmission since it has more leaf in lower part than in the apical dominant type. For the better light transmission it must have small leaf openness, thus erect leaves, and a greater tiller openness, thus open tillers. IR 667 fullfilled those conditions (6).

Thus erect leaf follows the central dominant type while droopy leaf follows apical dominant type. It is difficult to answer which is the cause or result between the canopy pattern and leaf openess. They might be sinchronized into harmonious combination for each other through evolutionary processes. It is not also easy to conclude which type is more productive. It, however, could be said that the central dominant type is more productive since SCU in Jinhung showed higher yield by forcing the apical dominant form into the central dominant form. It is also well supported by the fact that IR 667 had a higher canopy score as well as higher yield (6). Thus the lesser effect of SCU in IR 667 than in Jinhung could be attributed to lesser contribution for the improvement of canopy structure since it has already better canopy structure. It is clear now that nitrogen nutrition increased yield partially through the improvement of canopy structure though the leaf quality is also affected by nitrogen nutrition.

In the preceding report (5) IR 667 was the upper leaf-depedend type while Jinhung was the lower leaf-dependend type for grain yield of positional leaves. Then it seems to be contradictory that the central dominant type of IR 667 has the upper leaf-dependent type while the apical dominant type of Jinhung has the lower leaf-dependent type. It may be interpreted by the difference in shade tolerance. A strong shade tolerant variety could have the apical dominant type since lower leaves can work more effectively under shade condition while a weak shade tolerant variety must have central dominant type for better light transmission. This assumption is strongly supported by the fact that SCU gave greater conservation of leaves and also greater yield in Jinhung since it is easily infered that shade tolerant variety will give greater yield at the same rate of conservation in productive organ and lower leaves will be persisted more in shade tolerant variety by the same conservation factors. The information on shade tolerancy that is unavailable at present will give the final answer. Shade tolerancy in rice plant appears to be important and interesting for analysis of productivity as well as for breeding and cultural practice in relation to weather.

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SUMMARY

Comparative study on dynamic change of canopy structure during ripening period were carried out by using newly bred high yield rice cultivar (IR 667-Suwon 213) and a commercial variety, Jinhung in relation to nitrogen nutrition. The results were as follows.

1. Canopy structure pattern (vertical distribution of dry matter density at heading) was vertical type for Jinhung and horizontal type for IR 667.
2. The vertical distribution pattern of leaf area density (or weight) in the canopy was central dominant type for IR 667 while apical dominant type for Jinhung.
3. Canopy conservation pattern and percent distribution pattern of leaf area density followed the vertical distribution pattern of leaf area density.
4. Canopy persistence was weaker in IR 667, thus they have smaller canopy conservation ratio indicating faster senescence.
5. Slow supply of nitrogen (sulfur coated urea) showed a trend to change the apical dominant pattern into the central dominant pattern by the conservation of central portion, and it resulted in higher yield though nitrogen nutrition did little affect canopy pattern.
6. The central and apical dominant pattern appeared to be well matched to the upper leaf-dependent type and the lower leaf-dependent type of grain yield, respectively.

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