ジベレリン処理が水稲品種の初期生育に及ぼす影響について

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Effect of Exogenously Applied Gibberellic Acid (GA_3) on Initial Growth of Rice Cultivars*

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Abstract : The effects of exogenously applied GA_3 on rice seedling growth were analyzed by using 3 indica and 3 japonia varieties and the following results were obtained. (i) The increase of exogenously applied GA_3 concentration reduced leaf and root growth of most test cultivars. GA_3 increased the growth of sheath through enhanced partitioning of photosynthate to sheath. (ii) Increased NAR due to increased sink activity of sheath by the exogenous application of GA_3 was one of the major factor for promoting initial growth of rice by GA_3 treatment. (iii) Varietal difference in the initial growth in the control was positively related with leaf area developing ability. On the other hand, initial growth promotion by exogenous GA_3 was due to increased NAR and not to increased leaf area. Thus, the difference in endogenous GA_3 concentration might not be a major factor for controlling differential initial growth among rice varieties.
Key words : Gibberellic acid, Net assimilation rate, Rice varieties, Seedling growth, Water culture.

ジベレリン処理が水稲品種の初期生育に及ぼす影響について：片山勝之・秋田重誠（国際稲研究所）
要　旨：ジベレリン処理による水稲幼苗の葉面積展開と初期生育に及ぼす影響について検討した．日本稲3品種，印度稲3品種を水耕し，播種3日後，ジベレリン濃度を4処理(0.01, 0.1, 1及び10 ppm)し，その10日後調査した．結果は次のようであった．i)ジベレリン濃度を高めると，ほとんどの品種で葉と根の成長は減少したが，葉鞘への乾物分配が高まり葉鞘の成長は増大した．ii)ジベレリン処理は，葉鞘のシンクアクティビティを高め，さらには純同化率を高めた．このことが水稲の初期生育増加に及ぼす主要な原因の一つであった．iii)対照区の初期生育の品種間差は，葉面積展開能力に関係した．一方ジベレリン処理による初期生育は葉面積ではなく純同化率の増加によった．これらのことより，ジベレリンは初期生育の品種間差を支配する主要因とは必ずしも言えなかった．
キーワード：ジベレリン，純同化率，初期生育，水耕，水稲品種．

The significant advantage of higher initial growth is the primary factor for the extensive use of short duration varieties and F_1 hybrids. Faster initial growth is also considered an important characteristic for increased tolerance to adverse environment such as salinity[3]. The presence of wide variability in initial growth rate among rice varieties is well known. The seedling growth of a rice plant generally shows a closer relation with embryo weight and leaf area expansion rate[1].

However, little has been known on the physiological mechanism of differential leaf area developing ability among rice varieties. Information on the mechanism of the initial growth would give an essential clue not only in developing high yield rice varieties but also for improving tolerance of varieties to adverse environment.

Faster leaf area expansion rate may be related with several factors and growth regulators seem to be one of the possible factors. Gibberellic acid (GA_3), a phytohormone, has been known to affect elongation of leaf sheath[4),8)] and initial growth of plant. In maize, Rood et al[10,11,12)] suggested GAs played a role in the regulation of heterosis. Besides, GAs in embryo of seeds is known to regulate the synthesis of α-amylase which dehydrolyse starch of endosperm to be utilized for growth[6)].

In this report, the effect of exogenousely applied GA_3 on the leaf area developing ability and initial growth of rice plants was studied.

Meterials and Methods

Experiment 1

Three japonica (Tanginbozu, Nipponbare, Akihikari) and three indica (Guichao 2, IR64, Pokkali) varieties with different initial growth rate were used in the greenhouse. Seeds were sown on a seed bed made of styroform floated on nutrient solution in a 200 liter container

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after 1 day soaking and 1 day incubation at 30°C. Yoshida's culture solution was used where EDTA-Fe substituted for $FeCl_3$. Three days after seeding, GA_3 (provided by Kyowa Hakkou Co.) was added to the culture solution. The concentrations of GA_3 were 0.01, 0.1, 1 and 10 ppm. Each treatment was replicated four times. The pH of the solution was adjusted to 5. One hundred plants per variety were sampled after 10 days treatment. The leaf age of varieties was about 3.5. The leaves, stem and roots were separated and their dry weight was measured. Leaf blade area (leaf area) was measured with an automatic area meter (AAM-7, Hayashi-Denko). Nitrogen content was determined by the micro-Kjeldahl method. The specific absorption rate for total nitrogen (SAR) was calculated using the relationship described by Welbank[17];

$$SAR = (N_2 - N_1) \times (\ln W_{R2} - \ln W_{R1}) / (t_2 - t_1) / (W_{R2} - W_{R1})$$

where N is total nitrogen in the plant at t_2 and t_1, t is time in days and W_R is root dry weight at t_2 and t_1.

The sheath weight ration was calculated by the following formula;

Sheath weight ratio = Sheath dry weight/Total dry weight

Experiment 2

The materials in Exp. 1, with the addition of IR8 and Tetep were used. Procedures for raising materials and culture method were the same as in Exp. 1. The concentrations of GA_3 used were 0.01 and 0.1 ppm. One hundred plants per variety were harvested at 17 days after treatment. The leaf age of varieties was 5-5.5. Leaf blade length, leaf sheath length and plant length were measured.

Results

Experiment 1

The mean plant length of 6 varieties increased with the increase in concentration of exogenously applied GA_3 (Table 1). The dry weight of 6 varieties generally increased with the increase in GA_3 concentration up to 1 ppm except in Guichao 2 (Table 2). Dry weight of IR64 and Pokkali in 10 ppm GA_3 was lower than those of control. The initial growth of Tanginbozu, the most responsive variety, showed 32% increase in 10 ppm of GA_3 concentration. However, the dry weight of

Table 1. Mean plant length of six varieties tested with five concentrations of GA_3. T; Tanginbozu, N; Nipponbare, A; Akihikari, G; Guichao 2, I; IR64, P; Pokkali.

Var.	Plant length by GA_3 treatment (cm)				
	0 ppm	0.01 ppm	0.1 ppm	1 ppm	10 ppm
T	14.3 (100)	19.9 (139)	28.5 (199)	41.1 (287)	49.0 (343)
N	25.0 (100)	30.8 (123)	36.8 (147)	46.7 (187)	55.4 (222)
A	26.9 (100)	31.8 (118)	39.1 (145)	47.7 (177)	55.2 (205)
G	24.9 (100)	35.3 (142)	48.3 (194)	53.2 (214)	57.6 (231)
I	29.3 (100)	35.3 (120)	48.3 (165)	53.2 (182)	57.0 (194)
P	43.4 (100)	47.3 (109)	52.6 (121)	57.0 (131)	64.5 (149)

Note. Numerals in parentheses show the percentages to the 0 ppm-plot.

Table 2. Mean dry weight of six varieties tested with five concentrations of GA_3

GA_3 (ppm)	Variety (mg/plant)					
	T#	N	A	G	I	P
0	23.2b*	32.4b	34.0c	35.7c	47.2bc	52.5bc
0.01	29.9a	37.6a	39.9a	39.1a	51.6a	62.1a
0.1	29.5a	34.3ab	39.2ab	38.3b	48.8ab	62.0a
1	29.1a	35.2ab	39.5a	38.6b	49.7ab	57.4ab
10	30.6a	34.2ab	36.0bc	42.0a	44.2c	50.5c

Note. 1) # See Table 1.

2) *Any two means having a common letter are not significantly different by DMRT at the 5% level of significance.

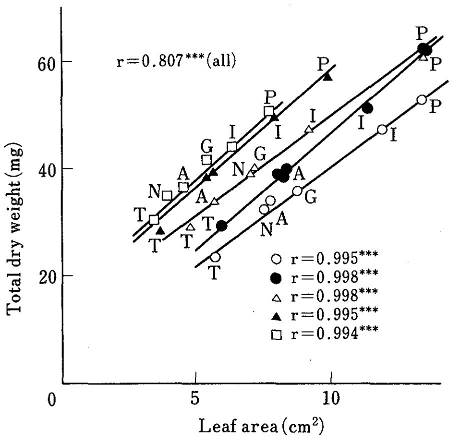

Fig.1. Relationship between leaf blade area and dry weight at 12 days after seeding with varying concentration of exogenously applied GA_3, control ; ○, 0.01 ppm ; ●, 0.1 ppm ; △, 1 ppm ; ▲, 10 ppm ; □. T ; Tanginbozu, N ; Nipponbare, A ; Akihikari, G ; Guichao 2, I ; IR 64, P ; Pokkali.

Tanginbozu in 10 ppm was less than those of the control of other varieties. Dry weight of each variety was positively related with leaf area in each GA_3 concentration (Fig.1). However, higher GA_3 concentration than 0.01 ppm often caused leaf area decrease (Fig. 2). When GA_3 concentration was higher than 0.1 ppm, leaf blade length increased while leaf width

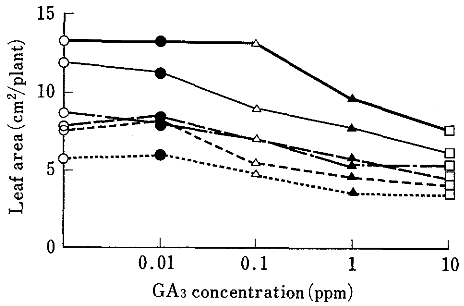

Fig.2. Effect of exogenously applied GA_3 on leaf blade area. Symbols are the same as those shown in Fig. 1.—— ; Pokkali, —— ; IR 64, — • — ; Guichao 2, ——— ; Akihikari, ------ ; Nipponbare, --------- ; Tanginbozu.

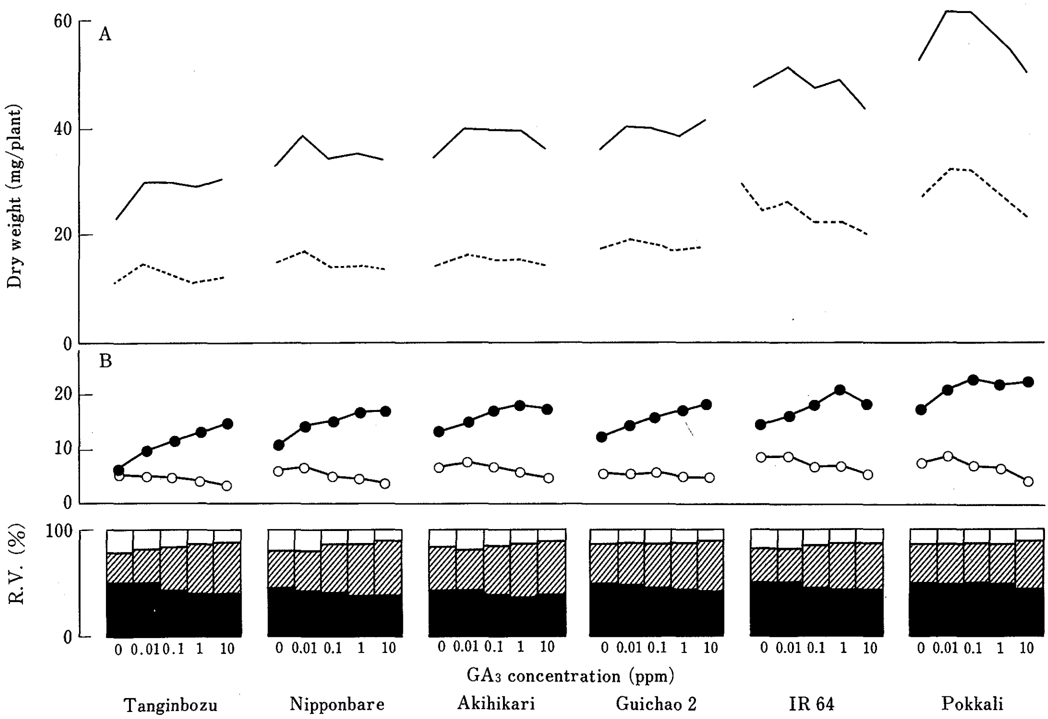

Fig.3. Effect of exogenously applied GA_3 concentration on partitioning of dry weight ; A)—— ; total weight, ------ ; leaf weight, B)—●— ; sheath weight, —○— ; root weight. Bar graphs at the bottm give relative values for leaf(■), sheath (▨), and root (□).

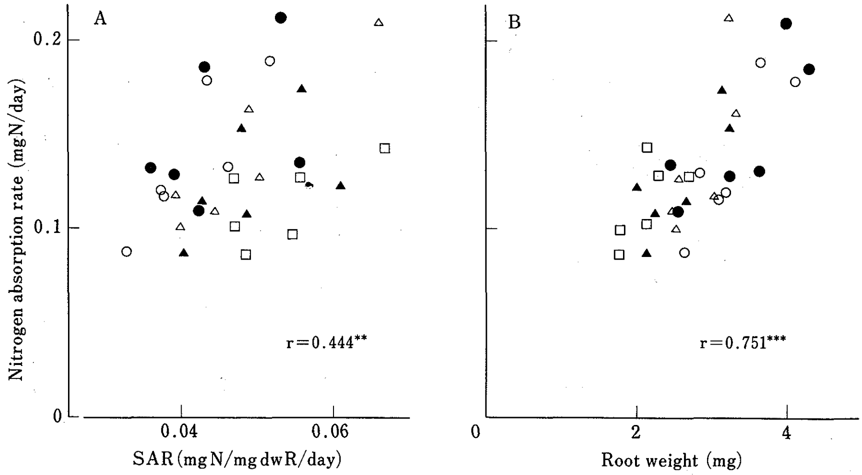

Fig.4. A) Relationship between specific absorption rate for nitrogen (SAR) and nitrogen absorption rate (NAR) and ; B) relationship between root weight and NAR with varying concentration of exogenously applied GA_3. Symbols are the same as those shown in Fig.1.

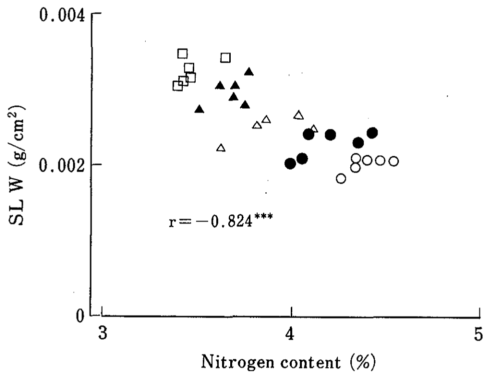

Fig.5. Relationship between nitrogen content and specific leaf weight (SLW) with varying concentration of exogenously applied GA_3. Symbols are the same as those shown in Fig.1.

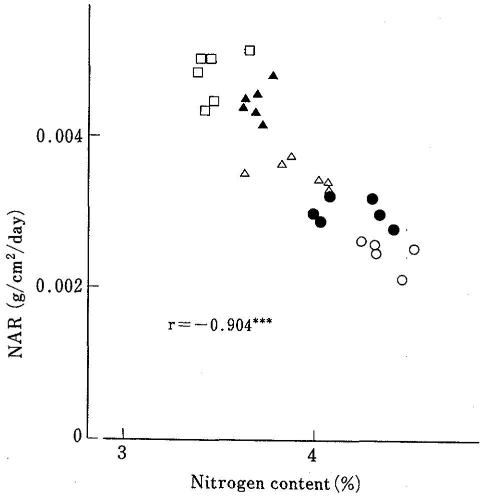

Fig.6. Relationship between nitrogen content of plant and net assimilation rate (NAR) with varying GA_3 concentration. Symbols are the same as those shown in Fig.1.

decrease. Since the leaf width decrease was greater, the total leaf area was reduced. The root weight of all varieties decreased with an increase of GA_3 concentration (Fig.3). On the other hand, sheath weight of all varieties increased remarkably with increase of GA_3 concentration. The nitrogen absorption rate was more positively related with root weight and less with SAR (Fig.4). Nitrogen content was reduced by GA_3. The amount of nitrogen absorbed was highly correlated with root weight. The color of the plant changed to light green with an increase in the GA_3 concentration. Specific leaf weight (SLW) also increased with the increase in GA_3 concentration and was negatively related with nitrogen content in the whole plant (Fig.5). Generally, net assimilation rate (NAR) is positively related with the leaf nitrogen content, however, in this experiment NAR was negatively related with nitrogen content with five concentrations of GA_3 (Fig.6). A high positive correlation was observed between sheath weight ratio and NAR (Fig.7).

Experiment 2

The leaf sheath length from the second and up to the fourth leaf increased with the increase of GA_3 concentration (Table 3). Plant length also increased with the increase in GA_3 concentration. The greatest response was from Tanginbozu, and least from Tetep and Pokkali (Table 3). Leaf blade length also increased with the increase of GA_3. Tanginbozu gave the best response in leaf blade length (Table 4). But the leaf blade length of the newest leaf in the control was superior to those of GA_3 treated plots. GA_3 delayed the leaf emergence of most varieties. The mean leaf area of the eight varieties tested with three concentrations of GA_3 decreased with the increase of GA_3 concentration (Table 5).

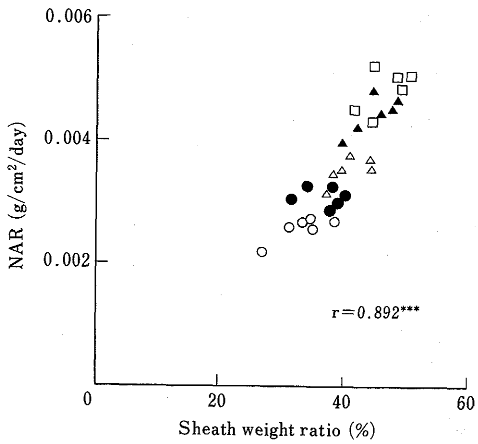

Fig.7. Relationship between sheath weight ratio and NAR with varying concentration of exogenously applied GA_3. Symbols are the same as those shown in Fig. 1.

Table 3. Effect of GA_3 on leaf sheath length (from the second to the fifth leaf) and plant length of eight varieties at 17 days after treatment.

Variety	GA_3 (ppm)	Leaf sheath length 2nd (cm)	(%)	3rd (cm)	(%)	4th (cm)	(%)	5th (cm)	(%)	Plant lengh (cm)	(%)
	0	2.0	(100)	4.4	(100)	6.3	(100)	7.5	(100)	20.9	(100)
Tanginbozu	0.01	2.7	(135)	6.0	(136)	7.4	(117)	7.9	(104)	24.5	(117)
	0.1	4.3	(215)	10.8	(245)	12.2	(194)	0	(0)	33.5	(160)
	0	3.8	(100)	9.1	(100)	11.1	(100)	11.4	(100)	34.5	(100)
Nipponbare	0.01	4.6	(121)	10.2	(112)	12.5	(113)	0	(0)	34.9	(101)
	0.1	5.9	(155)	12.5	(137)	14.5	(131)	0	(0)	40.2	(116)
	0	3.9	(100)	10.4	(100)	12.9	(100)	0		33.4	(100)
Akihikari	0.01	4.6	(118)	10.6	(102)	13.7	(106)	0		34.4	(103)
	0.1	6.4	(164)	14.0	(135)	16.6	(129)	0		39.9	(119)
	0	4.1	(100)	9.0	(100)	11.4	(100)	11.9	(100)	37.6	(100)
Guichao 2	0.01	5.0	(122)	9.9	(110)	12.4	(109)	12.7	(107)	38.0	(101)
	0.1	7.2	(176)	14.3	(159)	17.4	(153)	0	(0)	46.8	(124)
	0	5.0	(100)	9.9	(100)	11.4	(100)	14.4	(100)	39.3	(100)
IR8	0.01	5.4	(108)	10.4	(105)	12.6	(110)	12.4	(86)	39.7	(101)
	0.1	9.0	(180)	15.0	(152)	15.9	(140)	0	(0)	47.7	(121)
	0	4.8	(100)	9.0	(100)	12.4	(100)	12.1	(100)	39.7	(100)
IR64	0.01	5.2	(108)	9.0	(100)	11.2	(90)	11.5	(95)	40.1	(101)
	0.1	8.2	(171)	13.2	(147)	15.6	(126)	0	(0)	47.0	(118)
	0	5.8	(100)	12.0	(100)	16.7	(100)	0		42.9	(100)
Tetep	0.01	6.6	(114)	12.0	(100)	15.7	(94)	0		43.5	(101)
	0.1	7.8	(134)	13.8	(115)	19.0	(114)	0		48.3	(112)
	0	7.5	(100)	13.0	(100)	15.6	(100)	0		50.0	(100)
Pokkali	0.01	7.7	(103)	14.3	(110)	17.4	(112)	0		52.1	(104)
	0.1	9.2	(123)	17.1	(132)	19.5	(125)	0		56.6	(113)

Note. Numerals in parentheses show the percentages to the 0-plot.

Table 4. Effect of GA_3 on leaf blade length (from the second to the six leaf) of eight varieties at 17 days after treatment.

Variety	GA_3 (ppm)	Leaf blade length 2nd (cm) (%)	3rd (cm) (%)	4th (cm) (%)	5th (cm) (%)	6th (cm) (%)
Tanginbozu	0	1.2 (100)	4.8 (100)	9.1 (100)	12.2 (100)	7.4 (100)
	0.01	1.2 (100)	6.5 (135)	12.8 (141)	16.6 (136)	1.3 (18)
	0.1	1.4 (117)	11.1 (231)	21.2 (233)	16.9 (138)	0 (0)
Nipponbare	0	1.8 (100)	8.5 (100)	17.6 (100)	23.4 (100)	0
	0.01	2.1 (117)	10.4 (122)	20.6 (117)	22.5 (96)	0
	0.1	2.2 (122)	14.9 (175)	14.6 (83)	24.0 (102)	0
Akihikari	0	1.9 (100)	9.2 (100)	18.6 (100)	19.5 (100)	0
	0.01	1.8 (95)	10.1 (110)	18.9 (102)	19.5 (100)	0
	0.1	2.2 (116)	15.4 (167)	23.2 (125)	11.6 (59)	0
Guichao 2	0	2.7 (100)	10.8 (100)	17.7 (100)	23.8 (100)	3.3 (100)
	0.01	2.8 (104)	13.2 (122)	20.6 (116)	25.5 (107)	1.0 (30)
	0.1	3.2 (118)	18.3 (169)	25.5 (144)	29.4 (124)	0 (0)
IR8	0	3.5 (100)	14.2 (100)	22.0 (100)	27.9 (100)	7.6 (100)
	0.01	3.6 (103)	15.9 (112)	23.5 (107)	28.7 (103)	0.4 (5)
	0.1	4.8 (137)	23.5 (165)	21.5 (98)	30.8 (110)	0 (0)
IR64	0	4.2 (100)	13.8 (100)	19.8 (100)	25.4 (100)	5.4 (100)
	0.01	4.4 (105)	15.3 (111)	20.0 (101)	26.3 (104)	2.2 (41)
	0.1	5.4 (128)	23.1 (167)	25.6 (129)	31.2 (123)	0 (0)
Tetep	0	4.6 (100)	16.7 (100)	20.9 (100)	26.5 (100)	0
	0.01	4.9 (106)	18.8 (112)	22.3 (107)	27.9 (105)	0
	0.1	5.1 (111)	23.6 (141)	15.7 (75)	26.5 (100)	0
Pokkali	0	4.7 (100)	23.1 (100)	30.9 (100)	28.4 (100)	0
	0.01	4.9 (104)	22.2 (96)	34.5 (112)	22.8 (80)	0
	0.1	5.5 (117)	27.3 (118)	36.9 (119)	16.2 (57)	0

Note. Numerals in parentheses show the percentages to the 0-plot.

Table 5. Mean leaf blade area of eight varieties tested with three concentrations of GA_3 at 17 days after treatment.

Variety	Leaf blade area by GA_3 treatment (cm^2/plant) 0 ppm	0.01 ppm	0.1 ppm
Tanginbozu	12.5 (100)	12.9 (103)	12.5 (100)
Nipponbare	11.9 (100)	13.0 (109)	12.8 (108)
Akihikari	13.7 (100)	14.0 (102)	13.4 (98)
Guichao 2	19.6 (100)	19.0 (97)	13.0 (66)
IR8	22.8 (100)	19.7 (86)	19.1 (84)
IR64	19.4 (100)	20.6 (106)	15.4 (79)
Tetep	18.6 (100)	17.2 (92)	13.1 (70)
Pokkali	29.6 (100)	24.6 (83)	23.8 (80)

Note. Numerals in parentheses show the percentages to the 0 ppm-plot/

Discussion

According to Suge et al[13], the amount of gibberellin like substances present in Tanginbozu is negligible. This may explain the high response of Tanginbozu to exogenously applied GA_3. However, the dry weight of Tanginbozu even in the highest GA_3 concentration did not exceed that of the control in other varieties. Besides, leaf area of all varieties declined with GA_3 treatment. This change was due to a decrease in leaf blade width rather than leaf elongation. Takahashi et al[14] reported that the added GA_3 accelerated cell division in the longitudinal direction and repressed it in the transverse direction and the vascular bundle formation. Thus, increased the dry matter in GA_3 treated condition was chiefly attributed to the increased NAR. Increased the sheath weight might cause increased the surface area of sheath. However, the higher photosynthesis of the sheath might not bring about higher growth since the sheath photosynthesis has minimal effect on overall photosynthesis. Tsuno et al[16] showed that the photosynthesis of leaf sheath was less than one tenth of leaf blade photosynthesis. In addition, Togari et al[15] showed the nitrogen content of leaf sheath changed with that of leaf blade and the nitrogen content of leaf sheath was less than half that of leaf blade.

On the other hand, there was a positive correlation between sheath weight ratio and NAR. (Fig.7). This may indicate that GA_3 application enhanced sink strength in sheath. Exogenous application of GA_3 was effective for initial growth promotion, however, the lower or negative leaf area increase by GA_3 treatment clearly indicate that the differential initial growth among rice varieties may not directly be related with endogenous GA_3 metabolism. Increased NAR may partly be related to the increased SLW by GA_3 treatment. Alvin[2], Morgan[9], Lester et al[7] also reported GA_3 induced growth in kidney bean (*Phaseolus vulgaris* L.), *Festuca arundinacea* and *Pennisetum clandestinum* Hochst. These reports showed that GA_3 caused rapid translocation, improved plant structure, sustained photosynthesis due to delay in senescence of old leaves and increased sink strength. In our experiment, GA_3 delayed leaf emergence and possibly senescence of old leaves. Our experiment was conducted using seedlings, while older materials were used in the previous experiment. Therefore these factors pointed out by previous authors may hardly be involved. The marked increase in sheath weight by GA_3 application may indicate increased sink strength. Thus, increased sink activity in sheath would be the main factor for increased NAR (Fig.7).

This increased sink strength can be due to higher conversion of low molecular weight compounds into cell wall. This may be supported by previous work by Hayashi and Murakami[5] who observed increases in hemicellulose, cellulose and lignin in sheaths and decreases in total sugar, sucrose, starch, total nitrogen, protein nitrogen and non protein nitrogen under GA_3 treated condition.

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* In Japanese with English summary.
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