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Response of Four Rice Varieties To Three Regimes of Soil Moisture Tension Under Two Levels of Fertilization

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Summary

Four rice varieties, including an old and a new Korean, were grown on controlled soil moisture conditions of pF 1.8, pF 2.5 and flooding, and the heading time, plant height, tiller numbers, top dry weight, relative development of root to top, and the nitrogen and chlorophyll content of leaf were observed.

Among the four varieties, an upland rice variety Sensho showed the highest resistance to drought in terms of the stabilities of the plant traits observed. This variety grew fairly well under a dry condition of pF 2.5. The growth at pF 1.8 was rather better than the growth under the flooding. Reduction of the root development under flooding was remarkable in this variety.

A new Korean variety Yushin was susceptible to drought as compared with an old Korean variety Pungok. Yushin was especially susceptible to drought when grown with less fertilization. Taichung Native 1, an indica variety involved in the parentage of Yushin, was very susceptible to drought. When grown under a dry condition of pF 2.5, Taichung Native 1 and Yushin sharply reduced in total dry matter production, the relative development of root to top, and the nitrogen and chlorophyll content of leaf.

In Korea remarkable progress has been made in rice breeding using indica-japonica crosses. New Korean rice varieties have a good plant type suited to higher levels of fertilization resembling their semi-dwarf indica parents. With these new varieties production of rice in Korea has increased rapidly. However, one of the significant features of rice production in Korea is a considerable annual fluctuation depending upon the weather conditions. Stability of yield can be increased by improving the methods of cultivation. Varietal differences in response to environmental stresses are also important in this respect.

Drought is a factor responsible to the annual fluctuation of rice production. In this paper, we report the response of four rice varieties to three regimes of soil moisture tension under two levels of fertilization.

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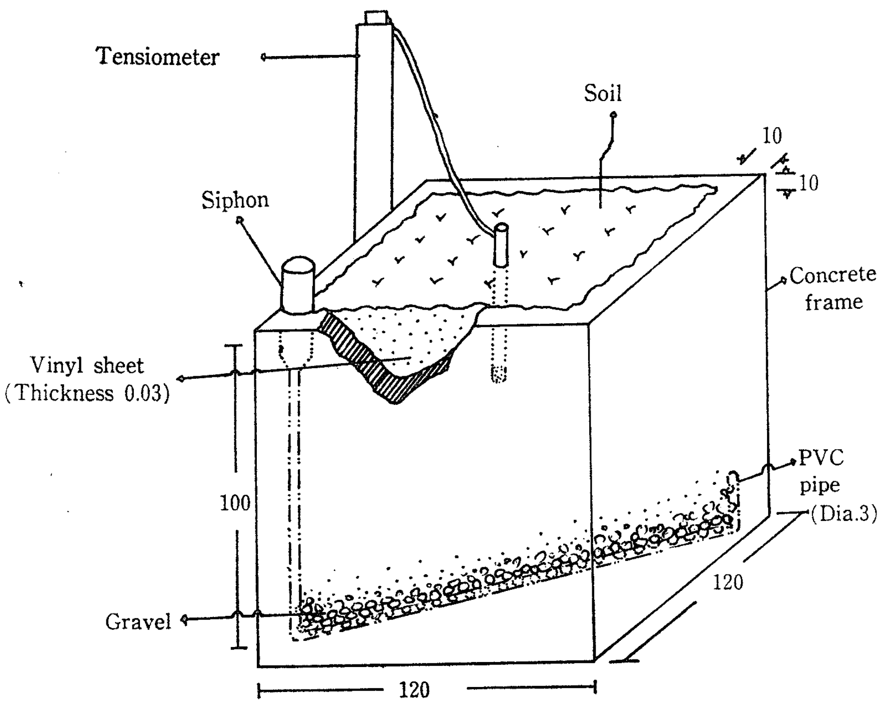
Materials and Methods

Varieties: Four varieties; Taichung Native 1, Yushin, Pungok, and Sensho, were selected. Taichung Native 1 is a semi-dwarf indica variety released in Taiwan. Yushin is a semi-dwarf indica-japonica hybrid progeny selected in Korea. Taichung Native 1 is involved in the parentage of Yushin, the coefficient of their relationship being one forth. Semi-dwarfness of both varieties is due to a dwarf gene originally introduced from an indica variety, Dee-geo-woo-gen. Pungok is a japonica variety selected in Korea from the cross Nakate-Ginbozu×Kairyo-Aikoku. Sensho is a Japanese upland variety presumably introduced from Taiwan or Korea (1). Sensho belongs to japonica in its broad sense, although it may belong to jawanica in Matsuo's classification (2).

Treatments: Dr. Yuuki Iwanami, the Institute for Agricultural Research, Tohoku University (Present: National Forestry Research Institute) had constructed a series of concreate frames incorporating an irrigation-system illustrated in Fig. 1. By courtesy of Dr. Iwanami, we grew our materials in these frames. Six frames filled with Kawatabi andosoil (1m×1m×1m) were used for obtaining three regimes of soil moisture tension under two levels of fertilization. Plants sown from seed on 17 May 1976 were transplanted in the frames on 3 June. Four hills of each variety, total 16 hills were grown in each frame. The arrangment of the hills was completely randomized in the frame. The distance between hills was 25 cm, and each hill



All dimensions in centimeters

Fig. 1 Irrigation system

consisted of two plants. Two weeks after transplanting, control of soil moisture was started. The water level of the flooding plot was kept 5 cm above the surface of the soil. The soil moisture tension of the other plots was adjusted to pF 1.8±0.15 or pF 2.5±0.15 at a depth of 20 cm of the center of the plot every morning (9–10 am) with a tensiometer and the irrigation-system illustrated in Fig. 1. All the frames were placed under a transparent vinyl tunnel to avoid the rain. Half the plots were fertilized at the rate of 12 g N, 12 g P, and 12 g K per m^2 (per frame), and the other half at the rate of 3 g N, 3 g P, and 3 g K per m^2 (per frame). A commercial compound fertilizer containing 8% N, 8% P, and 8% K was used. For all the plots, half the amount was dressed on 3 June prior to transplanting, a quarter on 20 July, and another quarter on 25 August.

Measurements: Growth characteristics observed were: first heading time and full heading time; plant height and number of tillers (6 July, 1 Aug., 23 Aug., 15 Sept., 20 Oct.); chlorophyll content per unit leaf area (flag leaf, 3–5 Oct.); dry weight and nitrogen content of leaves and stems together with leaf area (20 Oct.) and stratifical distribution of roots (20 Oct.). Chlorophyll content was measured by the method of Arnon (3). Nitrogen content by the semi-micro Kjeldhal method. Roots were sampled by an ameliorated Monolish's apparatus (30 cm width, 45 cm depth, and 6 cm thickness), and washed for photo, and then dry weight of roots sampled from every 10 cm depth layer (from the surface of the soil upto 40 cm) was measured.

Except for root observation, all the data were taken for each hill (16 hills per plot). Then, the mean value for each variety was calculated with the estimation of standard deviation of the mean. Root observation was carried out only on two representative hills of Yushin and Sensho (4 hills per plot).

Results

Heading time: Table 1 shows the number of days from transplanting to first heading and full heading. In Sensho and Pungok number of days to heading was relatively stable under differing levels of soil moisture and fertilization. In Sensho the earliest heading was observed under light fertilization with pF 1.8. In Taichung Native 1 and Yushin, the heading time was markedly delayed under dry soil conditions. Light fertilization also delayed the heading in these varieties, especially in Yushin.

Plant height: Table 2 shows the plant height observed on 20th October. Sensho exhibited the highest stature among the varieties observed, while Taichung Native 1 and Yushin showed low statures, throughout the whole plots. Decrease in plant height with dry condition was remarkable in Taichung Native 1 and Yushin. The ratio of the plant height under pF 2.5 to that under flooding, in average of two levels of fertilization, was 0.74 in Taichung Native 1 and 0.72 in

TABLE 1. *Days to First Heading and Full Heading from Transplanting*

Variety	Heavy fertilization			Light fertilization		
	Flooding	pF 1.8	pF 2.5	Flooding	pF 1.8	pF 2.5
Taichung N. 1	98-103	104-112	120- *	97-101	111-117	*-*
Yushin	98-107	101-112	117- *	105-112	113-123	*-*
Pungok	90- 94	94- 98	97-102	91- 93	89- 94	92-98
Sensho	87- 89	90- 96	93- 96	87- 90	83- 87	85-89

* First heading or full heading was not observed at 139 days after transplanting

TABLE 2. *Plant Height (cm, 20 Oct.)*

Variety	Heavy fertilization			Light fertilization		
	Flooding	pF 1.8	pF 2.5	Flooding	pF 1.8	pF 2.5
Taichung N. 1	89±4.5	72±2.5	61±1.8	72±2.5	72±1.5	57±4.8
Yushin	74±3.5	65±4.0	57±2.5	75±0.8	64±0.5	50±2.1
Pungok	105±4.3	94±3.5	83±6.4	97±2.5	93±2.0	78±3.4
Sensho	122±4.1	123±1.1	112±5.5	103±4.0	116±4.0	108±2.6

Yushin, while it was 0.80 in Pungok and 0.98 in Sensho. Beside, Sensho grew tallest under pF 1.8, while other varieties under flooding.

Number of tillers: Table 3 shows the number of tillers observed on 20 October. Coefficients of error variation are generally too high to draw out conclusions. However, we can at least point out that Sensho was less-tillering than other varieties and that Yushin sharply decreased the number of tillers when grown under dry condition combined with less fertilization.

TABLE 3. *Number of Tillers (20 Oct.)*

Variety	Heavy fertilization			Light fertilization		
	Flooding	pF 1.8	pF 2.5	Flooding	pF 1.8	pF 2.5
Taichung N. 1	31.4±3.2	30.8±2.1	24.5±4.5	17.0±2.5	28.3±4.1	17.8±5.7
Yushin	20.0±1.5	17.5±3.5	19.0±1.0	18.0±2.0	14.3±1.7	10.5±2.0
Pungok	21.5±1.1	13.3±1.8	12.3±1.7	12.3±0.8	14.8±1.7	10.8±0.7
Sensho	9.3±0.8	11.3±3.0	9.5±2.7	7.0±1.0	8.8±1.4	7.5±1.0

Chlorophyll content: Table 4 shows the chlorophyll content of the flag leaf observed on leaf area basis. In Pungok the content was relatively stable under three regimes of irrigation. In Sensho the content was higher under pF 1.8 and 2.5 than under flooding. The highest content in Sensho was observed under pF 2.5 combined with less fertilization. In Taichung Native 1 the content was markedly decreased under dry soil condition, and the lowest content was observed under pF 2.5 combined with less fertilization. In Yushin decrease in the content with dry condition was not so marked when the plants were grown under heavy fertilization, while the decrease was obvious under light fertilization.

TABLE 4. *Chlorophyll Content per Unit Leaf Area of Flag Leaf* (mg/dm^2)

Vairety	Heavy fertilization			Light fertilization		
	Flooding	pF 1.8	pF 2.5	Flooding	pF 1.8	pF 2.5
Taichung N. 1	4.6±0.5	3.3±0.2	3.3±0.4	4.4±0.3	3.4±0.4	2.7±0.5
Yushin	4.4±0.2	4.7±0.7	4.0±0.2	4.3±0.3	2.9±0.5	3.2±0.4
Pungok	4.3±0.4	4.5±0.1	4.4±0.1	3.9±0.1	3.7±0.4	3.8±0.3
Sensho	4.4±0.5	5.1±0.2	4.7±0.4	4.0±0.4	4.4±0.1	5.6±0.4

Nitrogen content: Table 5 shows the nitrogen content of the living leaves observed on 20 October. Under flooding heavily fertilized condition Taichung Native 1 exhibited the highest content per unit leaf area followed by Yushin and Sensho, and Pungok showed the lowest content. Taichung Native 1 sharply decreased the nitrogen content when grown under dry condition. Decrease in the content due to less fertilization was also marked under flooding or at pF 1.8. In case of Yushin decrease in the nitrogen content due to less fertilization was predominant at all three regimes of irrigation. Dry condition (pF 2.5) also decreased the content under heavy fertilization. In Pungok the content was relatively stable under changing levels of fertilization and soil moisture tension. In Sensho dry condition (pF 2.5) rather increased the nitrogen content.

TABLE 5. *Nitrogen Content Per Unit Leaf Area* (mg/dm^2 *average of living leaves, 20 Oct.*)

Variety	Heavy fertilization			Light fertilization		
	Flooding	pF 1.8	pF 2.5	Flooding	pF 1.8	pF 2.5
Taichung N. 1	10.1±1.7	8.5±0.3	6.5±0.2	7.0±0.2	6.9±0.1	6.5±0.3
Yushin	8.4±0.2	8.7±0.1	7.3±0.2	5.6±0.2	5.8±0.2	6.4±0.3
Pungok	6.8±0.1	7.4±0.1	7.0±0.2	6.9±0.2	6.5±0,4	6.4±0.2
Sensho	8.2±0.2	8.2±0.1	9.6±0.2	7.3±0,1	7.1±0.1	10.7±0.3

Top dry weight: Table 6 shows the top dry weight observed on 20th October. The environmental influences on the top dry weight of the hills were considerable. However, we can point out that Yushin tended to decrease the top dry weight sharply when grown under dry condition (pF 2.5), while Sensho tended to maintain a fairly high top dry weight even under a dry condition of pF 2.5.

Root development: Table 7 shows the relative development of roots to the top. Under flooding conditions Yushin showed a higher root top ratio than Sensho, while under dry conditions Sensho showed a higher ratio than Yushin. This varietal difference was especially remarkable when the plants were grown under light fertilization. Varietal differences in the stratifical distribution of roots (shallowness or deepness of the root-system) were not clear.

TABLE 6. *Top Dry Weight (g per hill, 20 Oct.)*

Variety	Heavy fertilization			Light fertilization		
	Flooding	pF 1.8	pF 2.5	Flooding	pF 1.8	pF 2.5
Taichung N. 1*	54.6±10.3	45.7± 6.5	22.6± 4.8	27.9±3.8	38.6±6.6	19.5±8.8
Yushin*	35.6± 1.4	26.1±11.1	14.5± 5.8	29.6±6.6	19.6±8.0	9.1±2.1
Pungok**	63.0±10.2	38.3±10.3	25.9± 7.7	37.9±4.5	40.3±4.2	25.9±4.5
Sensho**	45.1± 8.9	74.4±29.8	52.0±24.0	28.7±8.6	47.8±8.8	38.1±8.7

* leaf and stem, ** leaf, stem and ear

TABLE 7. *Root* Top** Dry Weight Ratio* (%)

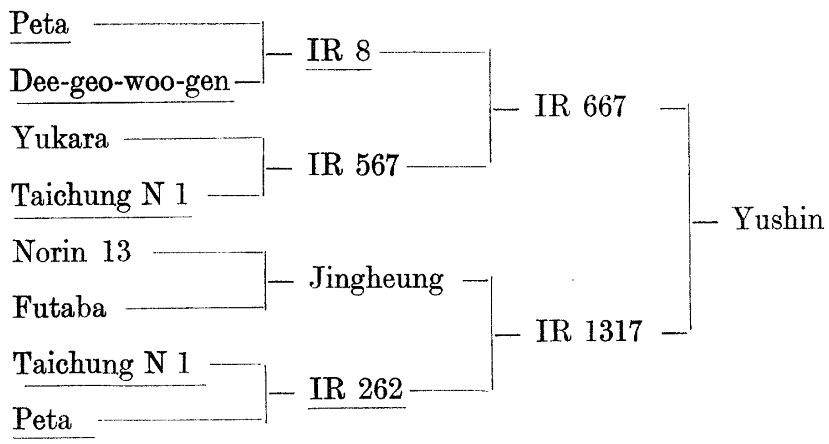
Variety	Heavy fertilization			Light fertilization		
	Flooding	pF 1.8	pF 2.5	Flooding	pF 1.7	pF 2.5
Yushin	10.6	13.1	8.5	6.1	6.0	4.5
Sensho	7.3	15.4	11.2	3.2	13.5	8.5

Average of 2 hills. * Partial roots recovered from the soil of 6×30×40 cm depth by an ameliorated Monolish's apparatus. ** Total top.

Discussion

A new Korean leading variety Yushin was more susceptible to drought than was an old Korean variety Pungok. Yushin was especially susceptible to drought when grown with less fertilization. These results suggest the importance of a proper irrigation-system and a sufficient fertilization to support the healthy growth of this new leading variety.

Yushin is a variety derived from the indica-japonica crosses described below. Underlined are the indica varieties.



Taichung N 1, an indica variety involved in the parentage of Yushin, was found to be very susceptible to drought in the present experiment. Beside, Singh and Tsunoda (4) observed that IR 8, an indica variety involved in the parentage of Yushin, was highly susceptible to dry conditions of the soil and the air with regard to the rate of CO_2 uptake of single leaves. These results indicate a possibility that the high susceptivity of Yushin to drought was derived from the indica varieties involved in the parentage.

When grown under a dry condition of pF 2.5, Taichung N 1 and Yushin reduced the total matter production, relative development of root to top, and the nitrogen and chlorophyll content of leaf. A reduction in the carbon assimilation may bring about a poor root development. In turn, a poor development may bring about an insufficient supply of mineral and water to the top which results in a reduction in the carbon assimilation. This argument is somewhat similar to the story of the chicken and the egg. Further investigation is needed to draw out the varietal traits which are primarily responsible for the high susceptivity to drought of these varieties. Varietal differences in the gas exchange resistance including the cuticular resistance (5) may be one of the trait should be investigated further. Rice generally exhibits a lower gas exchange resistance as compared with other summer crops. Some indica varieties grown in the rainy season of the tropical Asia especially loose the gas exchange resistance under a wet warm condition, but sharply increase the resistance by the environmental stress such as chilling (6) and drought (4). Development of the vascular system, especially of the vessel (water supplying tube) relative to the leaf area (evaporating surface) may be another point to be investigated (7).

Among the four varieties observed, an upland rice variety Sensho showed the highest resistance to drought. This variety grew fairly well even under a dry condition of pF 2.5. It is interesting that the growth of this variety at pF 1.8 was better than growth under flooding. Reduction of the root development under flooding was remarkable in particular in this variety. Factors involved should be investigated further.

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