Effect of 2,4-D Amine on Top and Root Growth of Indonesian Rice Varieties with Special Reference to the Change of Root Development Behavior*

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Weed problems in newly opened paddy fields in Indonesia are becoming more serious as increasing amounts of fertilizers are applied. In thinly populated areas with a shortage of labour, a gradual increase in the usage of low-cost herbicides 2,4-D and MCPA is occurring, despite the fact that little information on the use of herbicides in tropical regions is available.

There have been previous investigations on the root system of rice plant such as those by SASAKI¹⁰⁾, IWATSUKI⁴⁾, CHO^{2,3)}, and OTA and LEE^{8,9)}. Few reports, however, have been published on changes in the root system caused by environmental factors except those by OGIHARA et al.⁷⁾ and KAWADA et al. using the Monoris method^{5,6)}. In these works only Japanese varieties were studied.

For these reasons this experiment using root boxes to clarify the root growth behavior of several Indonesian rice varieties affected by 2,4-D application was carried out in a greenhouse of Tokyo University of Agriculture in 1979.

Materials and Methods

Two indica (cereh) varieties (IR 36 and Citarum) and one japonica (bulu) variety (Sukanandi) were employed. Upland field subsoil was placed in root boxes into which two 26 days-old seedlings of each variety were transplanted on August 4. Control and 2,4-D plots were set up for each variety and 2,4-D amine was applied on August

20 (Fig. 1). The amount of fertilizer applied was 8 kg of ammonium sulphate, 15 kg of super phosphate and 4 kg of potassium chloride per 10a, and the amount of 2,4-D amine given was 60 g per 10a. Eleven and one-half ml of aqueous solution of 2,4-D amine (600 ppm) was sprayed in equal amounts on the basal portion of the plants and on the surface of soil (25×45 cm) of the root box.

All roots were copied on tracing paper with a pen through the glass of the root box on Sept. 10. Soil was carefully washed away by running water and root growth was investigated on Sept. 13.

Leaf diffusion resistance was measured on the abaxial surface of the second and third leaf blades from the upper-most leaf with a diffusive resistance porometer (Lambda Instrument Corp.) at about 11~12 a.m.

Results

Plant height (A), number of stems (B), (A×B) value, number of living leaves and dry weight of top and roots were decreased by the 2,4-D application. The degree of decrease in these values was in the following order: IR 36>Citarum>Sukanandi (Tables 1,2).

The longest root was observed in the Sukanandi control plot (Figs. 2,4). The average and total root length were decreased by 2,4-D application in the following order: Sukanandi<Citarum<IR 36 (Figs. 2,4). The total number of roots was also decreased by 2,4-D for Sukanandi and Citarum, however, it was increased for IR 36 (Fig. 2). That is, although extreme

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Fig. 1. Outline of "Root Box". (unit: cm)

Table 1. Top growth as affected by 2,4-D amine application.

Variety	2,4-D amine g/10a	Plant height (cm)			Number of stems			(A)×(B) %	No. of living leaves		
		Sept. 1	Sept. 10	Average % (A)	Sept. 1	Sept. 10	Average % (B)		Sept. 1	Sept. 10	Average %
Sukanandi	0	69.3	75.8	100.0	3.5	6.5	100.0	100.0	15.25	23.00	100.0
	60	63.3	72.3	93.4	2.5	2.5	50.0	46.7	13.22	14.09	71.4
IR 36	0	53.4	59.2	100.0	15.5	22.5	100.0	100.0	54.25	71.25	100.0
	60	43.8	52.8	85.8	7.0	8.0	39.5	33.9	30.50	32.25	50.0
Citarum	0	51.3	60.1	100.0	10.5	17.0	100.0	100.0	37.00	51.00	100.0
	60	40.8	47.7	79.5	6.0	7.0	47.1	37.5	25.90	31.50	65.2

Table 2. Dry weight of plants as affected by 2,4-D amine application.

Variety	2,4-D amine g/10 a	Dry weight			
		Top		Roots	
		g	%	g	%
Sukanandi	0	5.60	100.0	1.16	100.0
	60	3.50	62.5	0.63	54.3
IR 36	0	10.98	100.0	2.30	100.0
	60	6.33	57.7	1.13	49.1
Citarum	0	8.62	100.0	2.32	100.0
	60	5.29	61.4	1.21	52.2

inhibition in root elongation resulted from the herbicide, numerous roots shorter than 5 cm in length developed in a so-called

"octopus tentacle-like" root of the two indica varieties (Fig. 3). IR 36 especially realized an increase in total root number as a result of the many tiny 2,4-D-caused roots which appeared (Fig. 3). It was observed in the root map that roots elongated deeper into the soil for Sukanandi with long stalks and few tillers, while many short roots stretched mostly near the soil surface for IR 36 and Citarum, having short stalks and many tillers. Root development was inhibited by 2,4-D application to a greater extent in IR 36 and Citarum than in Sukanandi (Fig. 4).

Leaf diffusion resistance (R) was higher in the following order for the control plots: Sukanandi > Citarum > IR 36. It was in-

creased in the following order by 2,4-D application: IR 36>Citarum>Sukanandi (Table 3). This fact shows that transpiration per unit leaf area ($1/R$) was inhibited in the same order as above.

Discussion

It was found that the growth of top

and roots as well as the transpiration per unit of leaf area were inhibited by 2,4-D application in the following order: IR 36>Citarum>Sukanandi. This suggests that the absorption of water was inhibited by 2,4-D application through inhibition of the development and physiological activity of roots in the order: IR 36>Citarum>

Fig. 2. Development of root as affected by 2,4-D application.

Fig. 3. Differential effect of 2,4-D on the root development of rice cultivars.

Fig. 4. Roots distribution of rice varieties as affected by 2,4-D application.

Table 3. Leaf diffusion resistance as affected by 2,4-D amine application.

Variety	2,4-D amine g/10 a	August 22			August 24			September 3			Average of 3 determi- nations(%)	
		2nd leaf	3rd leaf	Average	2nd leaf	3rd leaf	Average	2nd leaf	3rd leaf	Average		
Sukanandi	0	4.69	4.62	4.66	5.09	5.46	5.28	3.82	4.18	4.00	4.65	100.0
	60	4.35	4.80	4.58	5.23	5.38	5.31	4.21	4.06	4.14	4.68	100.7
IR 36	0	4.36	4.50	4.43	5.39	4.93	5.16	3.45	3.54	3.50	4.36	100.0
	60	4.58	4.80	4.69	5.68	5.79	5.74	3.88	3.88	3.88	4.77	109.4
Citarum	0	4.39	4.46	4.43	5.31	5.39	5.35	3.89	4.13	4.01	4.60	100.0
	60	4.69	4.65	4.67	5.71	6.22	5.97	3.92	3.63	3.78	4.81	104.6

Note; The values in the table are average of four measurements.

Sukanandi.

Japanese breeders divide rice varieties into two growth types, panicle number type and panicle weight type¹⁾. Varieties belonging to the panicle number type have a large number of tillers and many small panicles, while varieties belonging to the panicle weight type have relatively few tillers and panicles, but their stalks and panicles are long.

OTA and LEE^{8,9)} observed the root distribution of many rice varieties within a soil block 20 cm in depth and found that the panicle number type varieties produced more numerous active upper nodal roots than the lower ones, which primarily spread near the soil surface. On the other hand, the panicle weight type varieties produced more active lower nodal roots, presumably reaching deeper into the soil.

TAKAI *et al.*¹²⁾ found that rice varieties with long and fewer panicles belonging to the panicle weight type, have many roots elongating deep in the soil, especially under a drought condition, consequently, they have higher adaptability to drought as compared with those belonging to the panicle number type which have shorter roots and more panicles.

In this experiment it was observed that the two indica varieties, IR 36 and Citarum, belonging to the panicle number type have numerous shorter nodal roots spreading mostly near the soil surface, while the japonica type, Sukanandi of the panicle weight group has long roots reaching deeper into the soil and fewer near the surface (Fig.

4). Therefore it is assumed that the two indica varieties have absorbed a larger amount of 2,4-D through their many shallow roots. The marked difference in 2,4-D injury, then, may be partly attributable to this varietal difference in root growth behavior.

SHIBAYAMA and NODA¹¹⁾ observed an excessive number of short and abnormal roots on MCPA treated rice plants. Root abnormalities similar to the so-called "octopus tentacle-like" roots were observed in the two indica varieties in this experiment. A tubular leaf which appears at lower temperatures was not found in this experiment, possibly due to the high temperature condition during the time 2,4-D was applied.

Summary

1) Fundamental research was conducted using root boxes to clarify the effect of 2,4-D amine application on root growth behavior of two indica (cereh) varieties of Indonesian rice, IR 36 and Citarum, and one japonica (bulu), Sukanandi.

2) In all varieties, plant height, number of stems, number of living leaves, length of longest root, average length of roots, total length of roots and dry weight of top and roots were decreased by 2,4-D application, whereas the number of roots shorter than 5 cm including many so-called "octopus tentacle-like" roots were increased, especially in two indica varieties (Tables 1, 2, Figs. 2~4).

3) Growth inhibition in top and roots and the appearance of abnormal roots

caused by 2,4-D application was remarkable in the following order: IR 36>Citarum>Sukanandi (Tables 1, 2, Figs. 2~4).

4) Leaf diffusion resistance was increased by the application in the following order: IR 36>Citarum>Sukanandi (Table 3).

5) With and without the 2,4-D application, roots elongated deeper into the soil in Sukanandi, panicle weight type, while they primarily elongated near the soil surface in IR 36 and Citarum, panicle number types (Fig. 4).

6) It was supposed that the higher susceptibility of the two indica varieties to 2,4-D injury may be partly attributable to their root growth behavior where many roots elongate near the soil surface.

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〔和 文 摘 要〕

2, 4-D アミンによるインドネシア稲品種の生育の差異,
ことにその根系の発達の変化

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1. インドネシアのインド型品種 (IR 36, Citarum) および日本型品種 (Sukanandi) について, 根箱を用いて 2, 4-D アミン施用がその地上部および地下部の生育に及ぼす影響, ことに根系の発達の変化について調査した.
2. 品種のいかんにかかわらず 2, 4-D アミン施用により草丈, 茎数, 生存葉数, 最長根長, 平均根長, 全根長および地上部, 地下部乾物重は減少した. しかしタコ足根を含む長さ 5 cm 以下の短い冠根の数はインド型品種で増加した (第 1, 2 表, 第 2 ~ 4 図).
3. 2, 4-D 施用による地上部, 地下部の生育阻害および異常根 (タコ足根) の発達は, IR 36 > Citarum > Sukanandi の順であった (第 1, 2 表, 第 2 ~ 4 図).
4. 葉の拡散圧抵抗値は 2, 4-D 施用により IR 36 > Citarum > Sukanandi の順に増大した (第 3 表).
5. 供試したインド型品種 (穂数型) が日本型品種 (穂重型) より 2, 4-D 感受性が大きいのは, 前者の品種が後者の品種にくらべて根が地表面近くに伸びる根系の特性に一部よると推測された (第 4 図).