Chapter 4: Influence of percolation pattern on growth and yields of rice plants with stratified polluted paddy field using soil dressing models.

4.1 Introduction

In case of polluted field, soil dressing is popular, effective and cheaper technology for agriculture sector. In Japan, there are about 87.2% (7327 ha) of the total polluted land were remedied by applying uncontaminated soil or replacing the soil (MOE, 2006). This study was conducted to understand the influence of a percolation pattern on growth and yields of rice plants using stratified polluted paddy field model with soil dressing. The experiment was conducted with 12.5, 15 and 20 cm with soil dressing system in a stratified polluted paddy field. The stratified paddy field was subjected two kinds that were open and closed system percolation. The effect of percolation was observed on growth and yields of rice plants with various soils dressing from a Cd polluted paddy fields.

In case of growth of rice plants, the plant length, number of stem, number of leaves, weight of dried root of each soil layer, soil plant analyzer development (SPAD), the heading time of panicle and yellowish part of leaf were measured from planting to harvesting period. On the other hand, in the yields section, measured the panicle length, number of panicle, weight of panicle, weight and number of paddy, number and weight of rice grain, percentage of fill up rice grain, dry weight of straw and weight of 1000 kernels. In this section, the main objective was the influence of percolation pattern on growth and yields of rice plant with soil dressing.

4.2 Plant length

The plant length was measured from transplanting to harvesting period. In 2009, the average plant length of the models M-1, M-2, M-3, M-4, M-5 and M-6 were 104.1 cm, 105.7 cm, 103.2 cm, 108.2 cm, 109.0 cm and 111.5 cm as shown in Fig.62. The average plant length in open system percolation was lower than the closed system percolation in 2009. In 2010, the average plant length M-7, M-8, M-9 and M-10 were 110.7 cm, 108.6 cm, 114.30 cm and 112.1 cm as shown in Fig. 63. In both percolation system, the rice plants grows up to 65 days from transplanting period as shown in Fig. 62 and 63. In 2010, the average plant length in closed system percolation was higher than the open system percolation. In closed system percolation, plant length was higher comparatively to open system percolation by applied to 15 cm soil dressing and same case occurred with 20 cm soil dressing open and closed system percolation models. Finally, percolation pattern effect on the plant length. In open system percolation, plant uptake more Cd than the closed system percolation model which has affect the rice plants growth. According to Nguyen *et al.*, (2005); restricted growth process of rice plants and decrease the length due to Cd concentration in soil above 20 mg/kg which was supported to open system percolation.

4.3 Number of stem

The average number of stem of M-1, M-2, M-3, M-4, M-5 and M-6 were 13.3, 14.1, 13.5, 14.9, 14.5 and 15.7, respectively as shown in Fig. 64. On the other hand, the models of M-7, M-8, M-9 and M-10 were 15.5, 15.5, 16.9 and 14.9, respectively as shown in Fig. 65. In 2009 experiment, the average number of stem was higher in closed system percolation than the open system percolation models due to reduction status of soil layers. But in 2010 experiment, the number of stem has no significant difference between the open and closed system percolation models by applied to 15 cm soil dressing. On the other hand, the stem number of rice plants in closed system percolation was higher than the open system percolation by applied to 20 cm soil dressing; that might be effect of soil oxidation-reduction status.

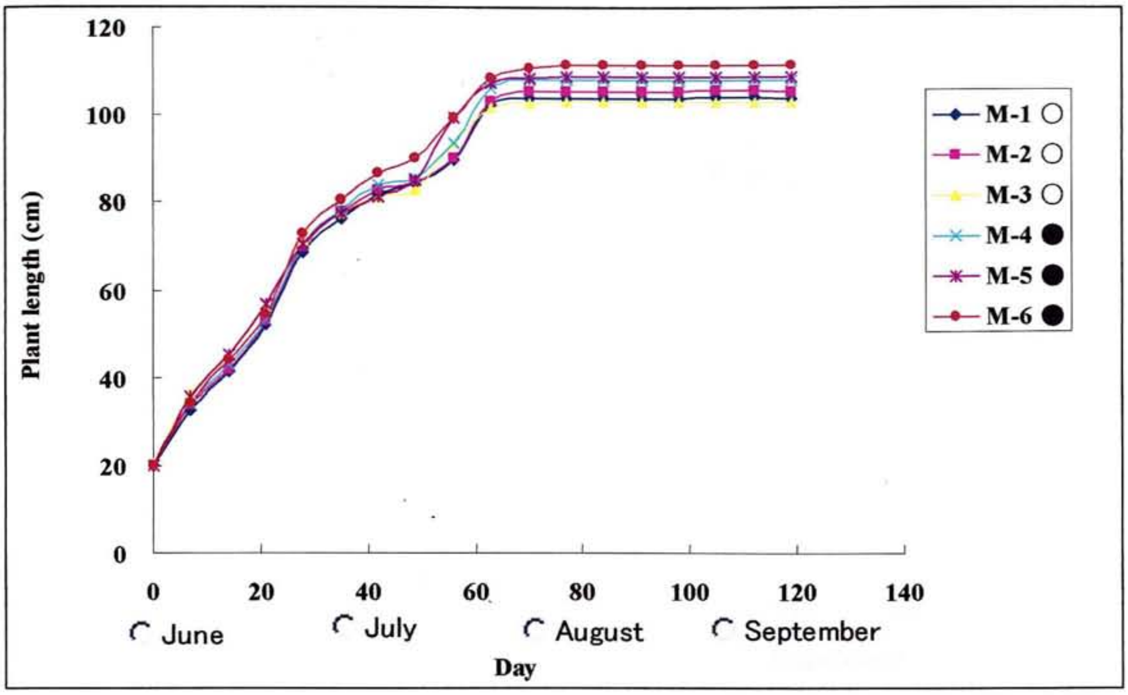

Fig.62: The plant length of rice plant in 2009

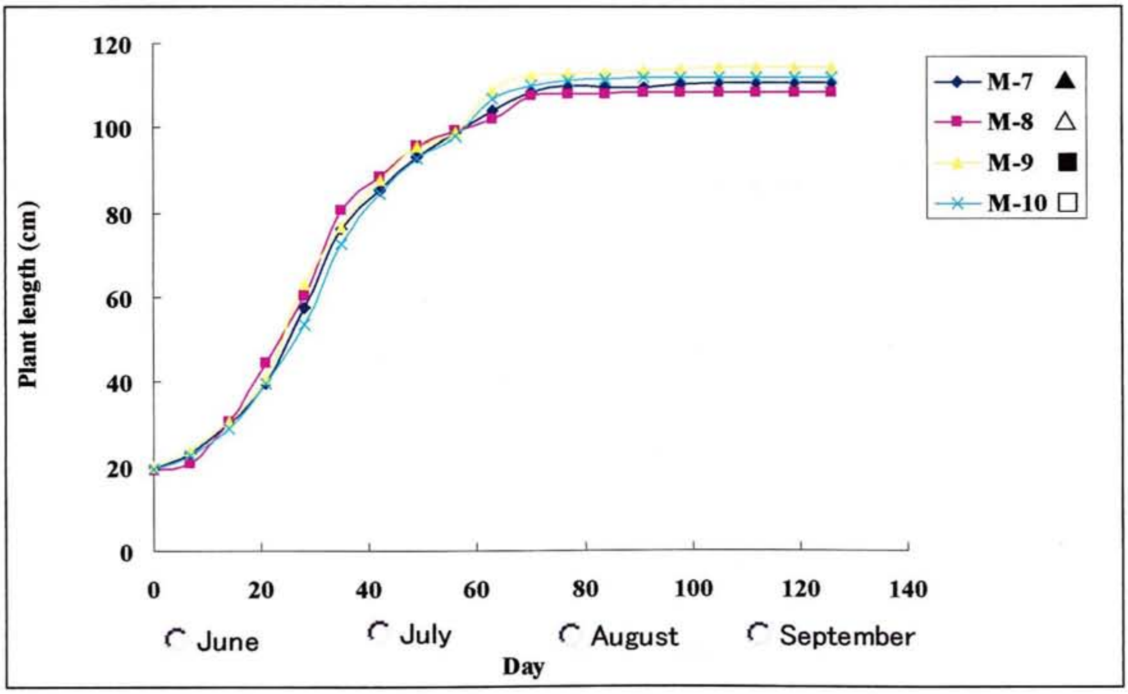

Fig.63: The plant length of rice plant in 2010

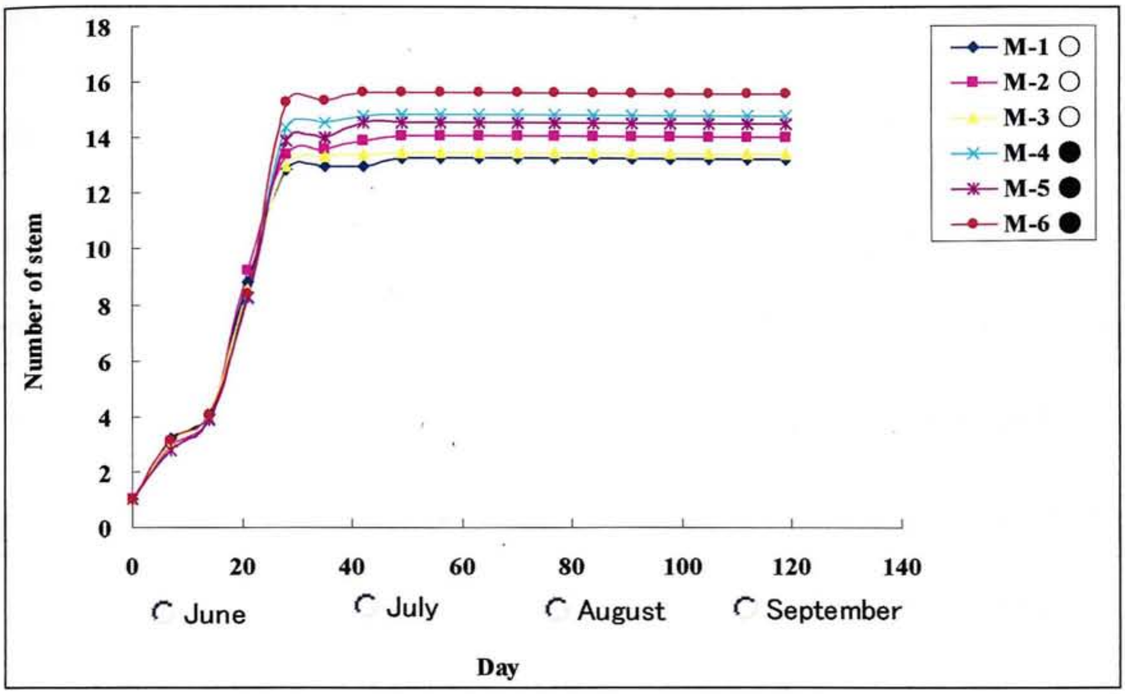

Fig. 64: The stem number of rice plants in different percolation models in 2009

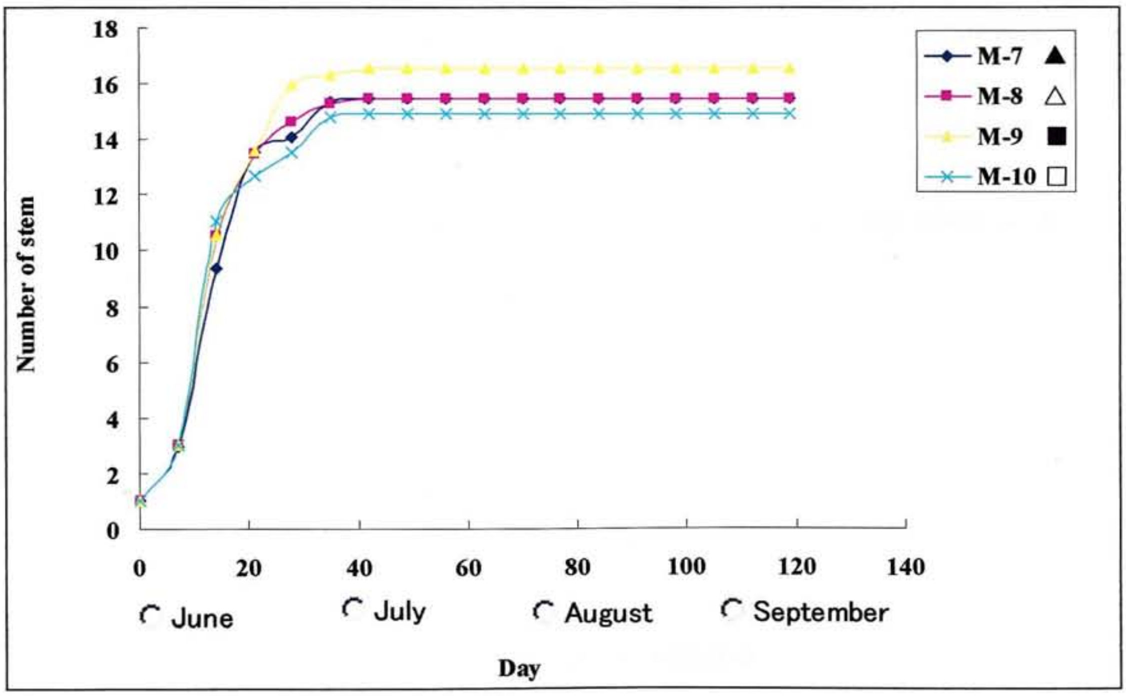

Fig. 65: The stem number of rice plants in different percolation models in 2010

4.4 Number of leaf

High number of leaves per plant could serve as measures of good plant vigor and high (good) weed competitiveness, which would be very desirable to the resource –poor farmers. The number of leaf of rice plant was measured in all of percolation models. Actually in 2009, the average leaf number in M-1 to M-6 models with open and closed system percolation were almost same and number was 15 as shown in Fig. 66. The models of M-7 and M-8 were as closed and open system percolation with 15 cm soil dressing. On the other hand, M-9 and M-10 were as closed and open system percolation with 20 cm soil dressing. In 2010, the average number of leaf in the models of M-7, M-8, M-9 and M-10 were 14.5, 14.0, 14.9 and 14.2, respectively. In that results, the number of leaf were higher in closed system percolation than the open system percolation as shown in Fig. 67. These results can be attributed to the effect of different percolation patterns presents in Cd-contaminated soils.

4.5 SPAD (Soil plant analyzer development)

The chlorophyll meter provides a simple, quick, portable, and non-destructive method for estimating leaf chlorophyll content. The decrease of chlorophyll amount in rice blade was measured using soil plant analyzer development (Type of No. SPAD-502) during plant growth stage to harvesting period. The highest SPAD value was measured from planting to early blooming stage in both percolation of 2009 and 2010 due to growth stage of rice plants. The average SPAD value was about 43 in early blooming stage of open and closed system percolation models but that value was gradually decreased with the increasing cultivation period. In 2009, the average SPAD value in M-1, M-2, M-3, M-4, M-5 and M-6 were 26.2, 25.8, 26.5, 28.2, 28.4 and 29.0, respectively. The SPAD value of M-7, M-8, M-9 and M-10 models were 33.2, 32.2, 34.6 and 33.5, respectively. The higher SPAD value observe in 2010, this cause might be soil dressing and comparatively average higher temperature was recorded. The average amount of chlorophyll in open system percolation decrease faster than in closed system percolation shown in Fig. 68 and 69. The chlorophyll content in leaf depend on such factor such as Cd content in soil, nitrogen level in soil, water availability, redox potential of soil , soil temperature, air temperature and so on. Many Scientist have been reported that , the photosynthesis of leaf have been affected by cadmium (Santa *et al.*,1999) and the SPAD value increased with the increase of N levels, and decreased with the increase of Cd contents in solution (Qin *et al.*, 2009). In open system percolation, formation of soluble Cd ions due to oxidation status of soil. Therefore, availability of soluble Cd in soil affect the rice plants SPAD which was supported to the open system percolation.

4.6 The heading period and number of panicle

The heading period and number of panicles were measured of each open and closed system percolation. The heading period of rice plants in both percolations of each model were nearly equal. In 2009 and 2010, heading period of rice plants was started at 62^{th} and 58^{th} day from transplanting due to fluctuate of air temperature. The average number of panicle of M-1, M-2, M-3, M-4, M-5, M-6, M-7, M-8, M-9 and M-10 models were 9.4, 8.3, 6.6, 8.7, 8.5, 9.4, 12.8, 10.7, 12.6 and 12.5. In this result, the average number of panicle showed in closed system percolation was higher than the open system percolation.

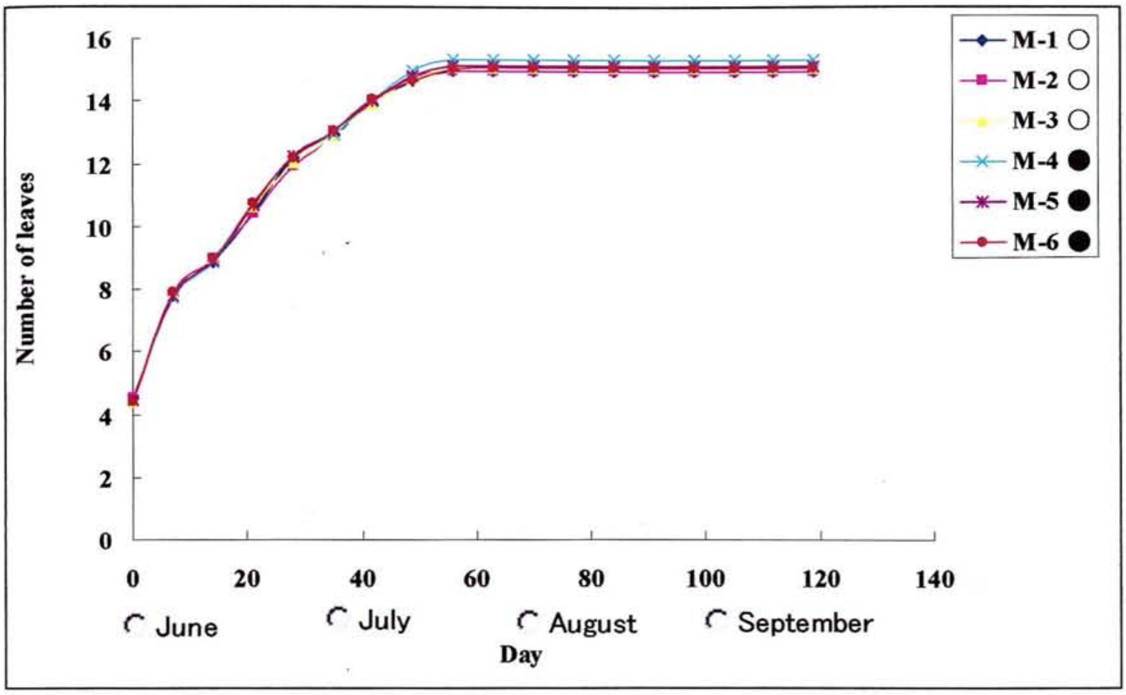

Fig. 66: Number of leaves in different percolation system in 2009

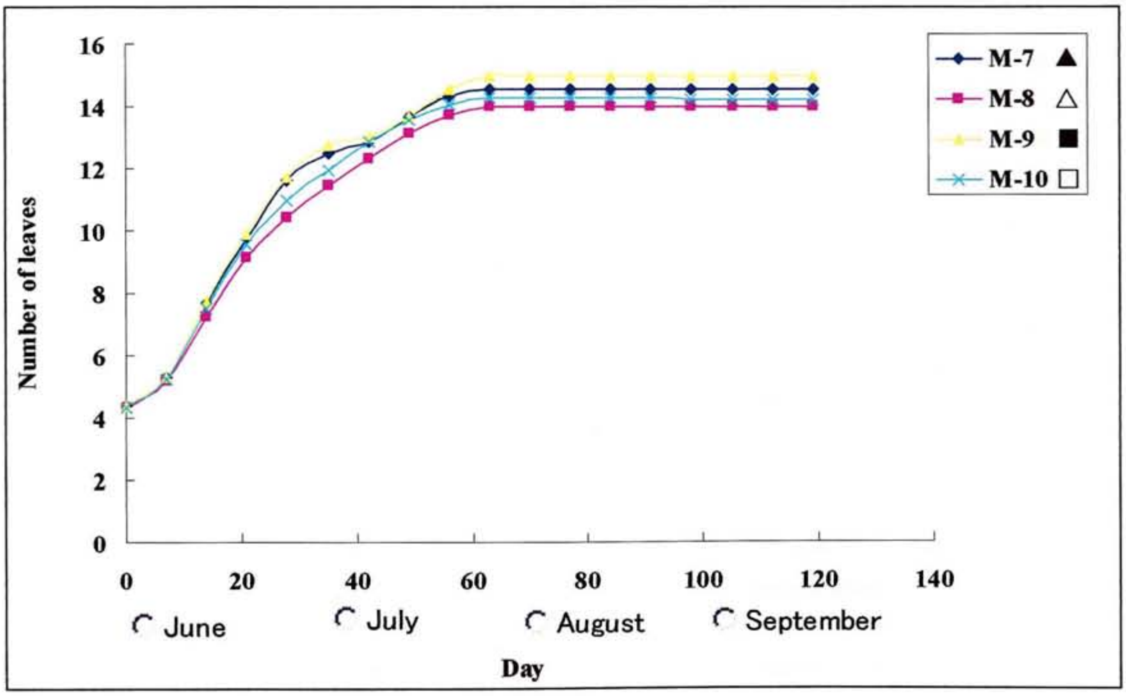

Fig. 67: Number of leaves in different percolation system in 2010

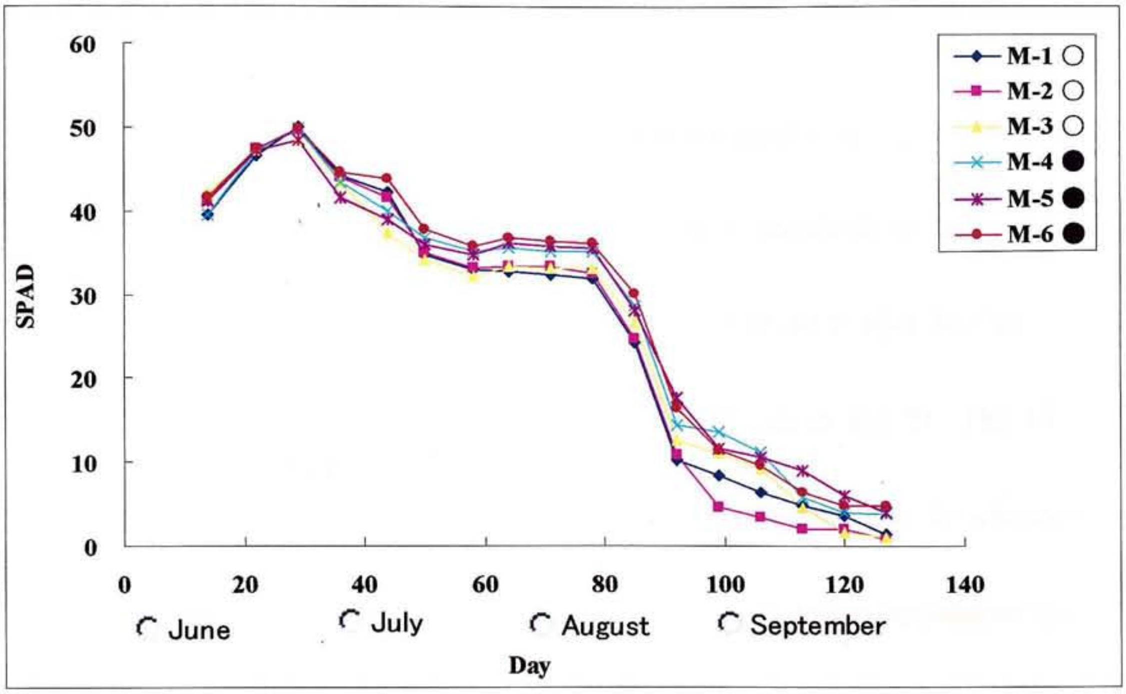

Fig. 68: SPAD value of rice plants in the experiment of 2009

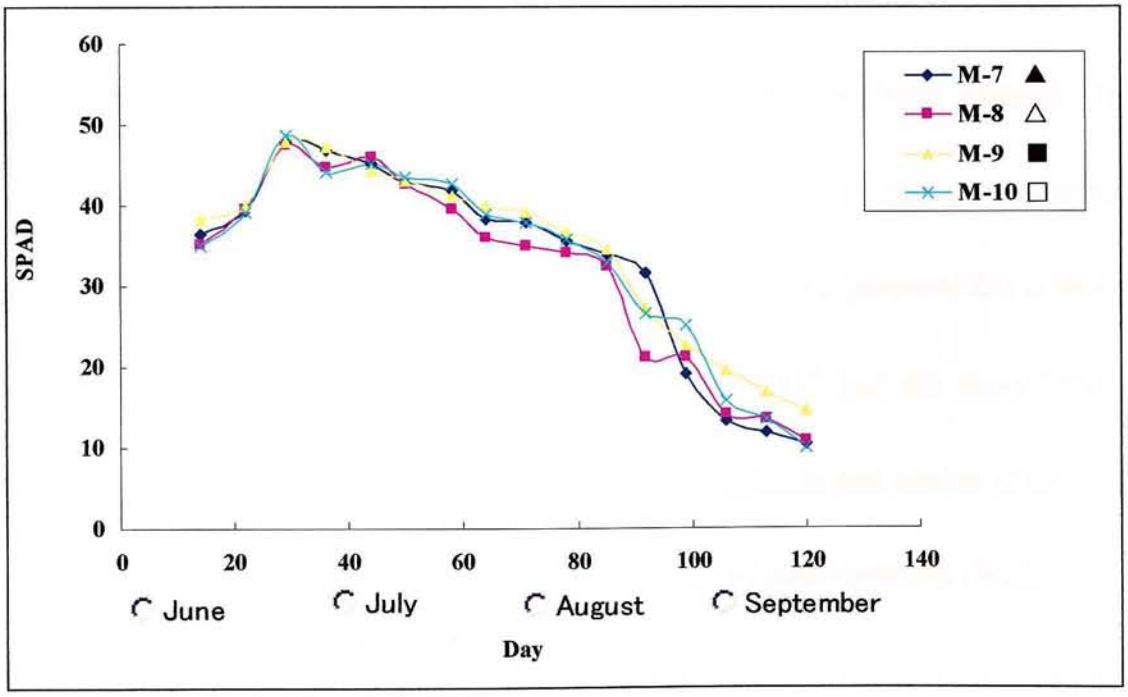

Fig. 69: SPAD value of rice plants in the experiment of 2010

4.7 Height of the 14th leaf

The total height of 14th leaf was measured of both percolation systems. In 2009 models, the average 14th leaf lengths were 32.8 cm and 37.3 cm, respectively in both percolation systems as shown in Fig. 69. In 2010, the length of 14th leaf (M-7, M-8, M-9 and M-10) were 45.0, 41.3, 45.9 and 43.6 cm, respectively as shown in Fig 71. The 14th leaf heights of 2009 models were lower than the 2010 models due to environment temperature. Moreover, the leaf height was higher in closed system percolation than the open system percolation models with the same soil dressing models.

4.8 Yellowish part of rice plant

The yellowish part of rice plants were measured in both percolation systems. The percentage of yellowish part of 14th leaf was firstly dried in the closed system percolation than the open system percolation in 2009 and 2010 experiment that is shown in Fig. 72 and 73. In the harvesting period, observed of 14th leaf dry about 78% in closed system percolation but 43% in open system percolation and similar results was found in 2010. The results indicated that the difference of photosynthesis ability of rice plants in two systems during ripening time.

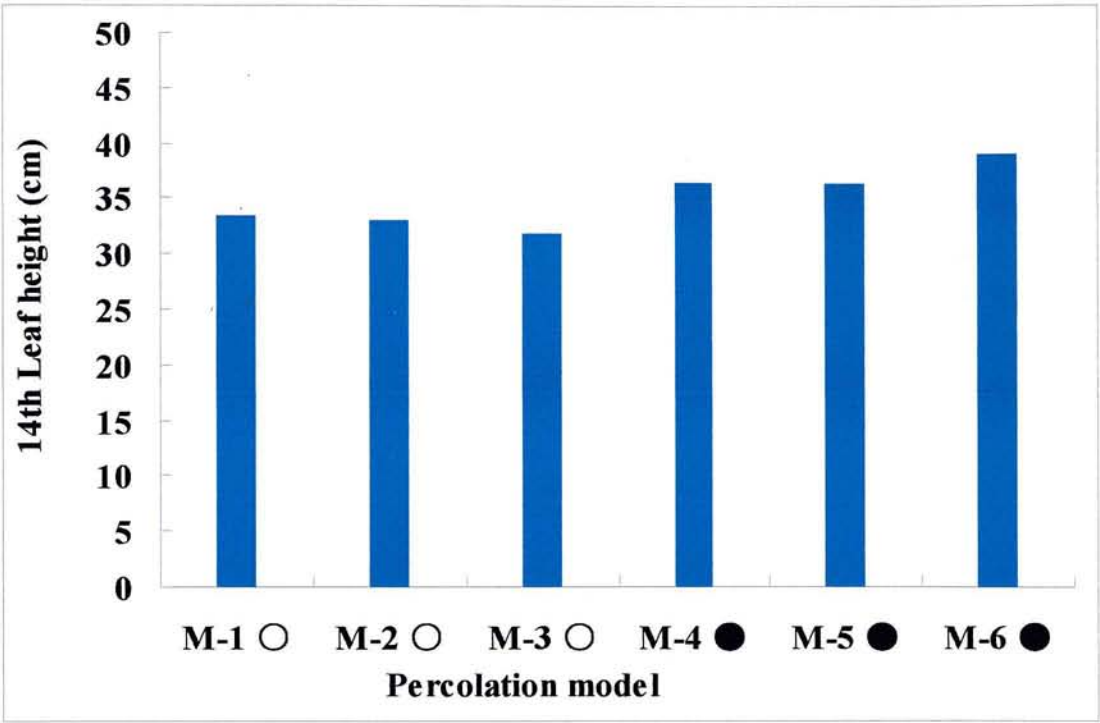

Fig. 70: Height of 14th leaf in open and closed system percolation model in 2009

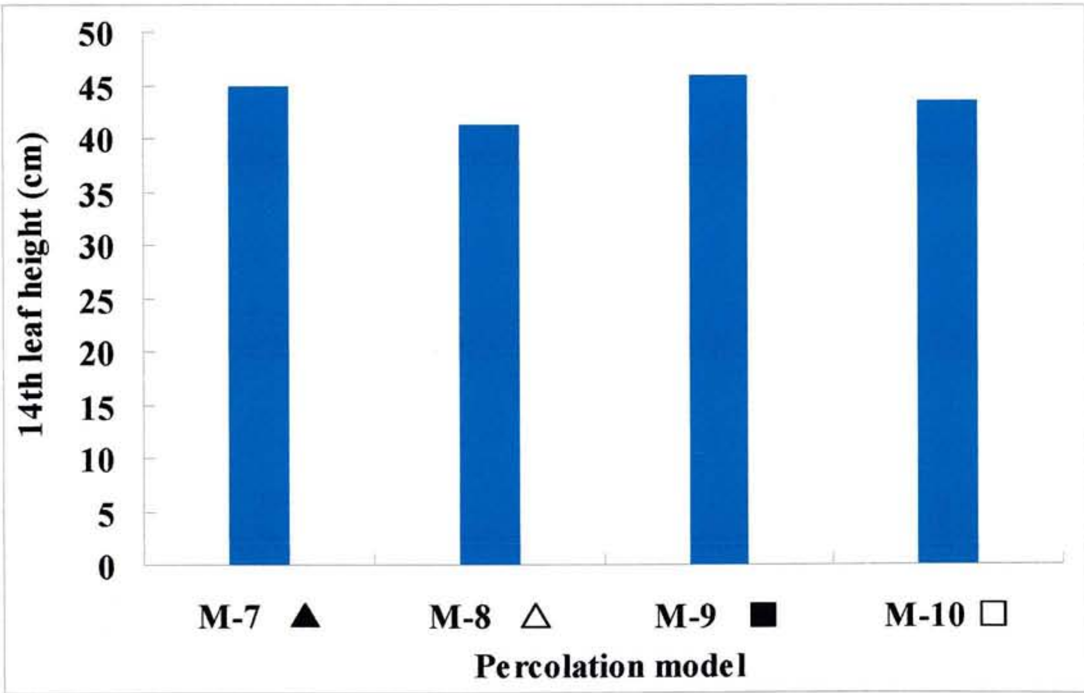

Fig. 71: Height of 14th leaf in open and closed system percolation in 2010.

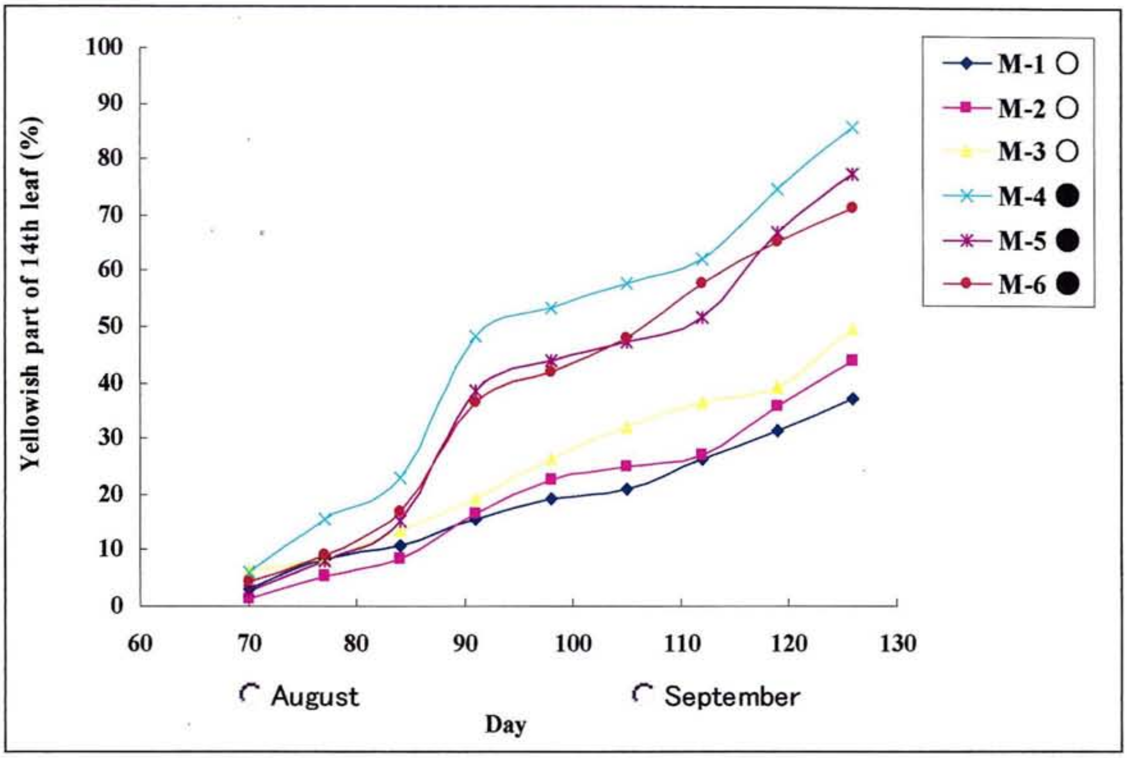

Fig. 72: Yellowish part of 14th leaf in open and closed system percolation in 2009.

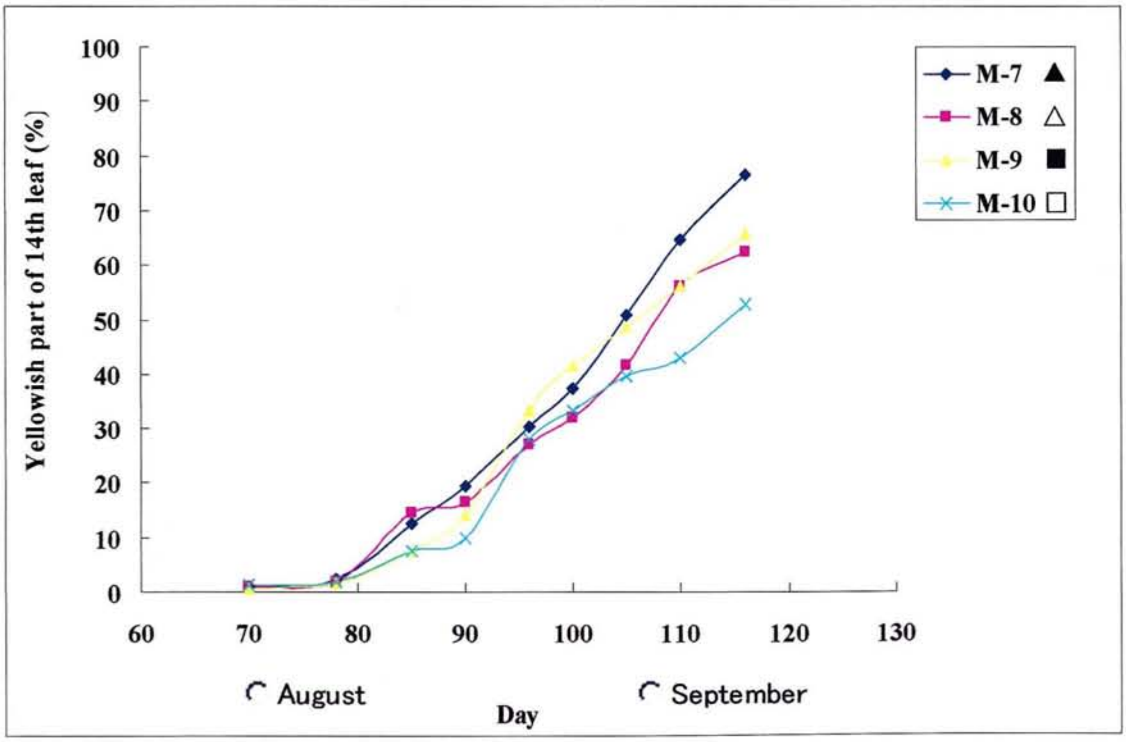

Fig. 73: Yellowish part of 14th leaf in open and closed system percolation in 2010.

4.9 Weight of dry roots

The vegetative root growths of each soil layer were weighted in closed and open system percolation models of 2009 and 2010. Rhizosphere is an important environmental interface connecting plant roots and soil. Roots excrete some organic substances to rhizosphere during the growth rhizosphere controls the entrance of nutrients, water and other chemicals, beneficial or harmful, to plants. About 78 percent rice plant's root growth in plow layer (I layer) of both open and closed system percolation. Both closed and open system percolation, the average dried weight of root's in plow layer (174 g / column) was almost similar in 2009 and 2010 models. In 2009, the average dried weight of roots in II layer and III layer (33.0 and 6.3 g/column) in open system percolation were higher than closed system percolation (16.0 and 2.5 g/ column), respectively due to oxidizing condition of plowsole and subsoil in open system percolation as shown in Fig. 74. But in 2010, the models of M-7, M-8, M-9 and M-10; the dried root weight were in layer I (167.6, 182.5, 180.3 and 190.4 g/column), layer II (32.2, 45.6, 21.4 and 35.4 g/column) and layer III (6.8, 9.1, 5.7 and 6.6 g/column) as shown in Fig. 75. The root grows of rice plants were higher in plowsole under oxidation condition of soil with 12.5, 15 and 20 cm soil dressing models. In this study, showed that the root growth was higher in soil oxidation condition but MARDI (2002), stated that in sterile and non-sterile hydroponics conditions, exudates of rice plants roots stressed with Pb and Cd.

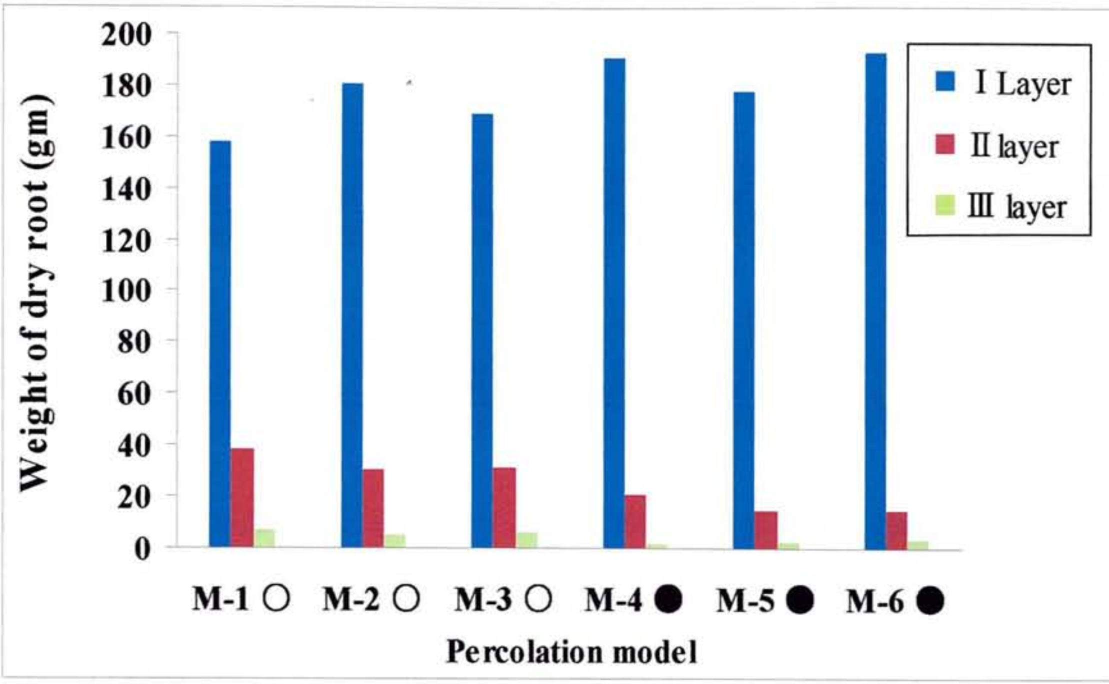

Fig. 74: Weight of dry root in different soil layer in 2009

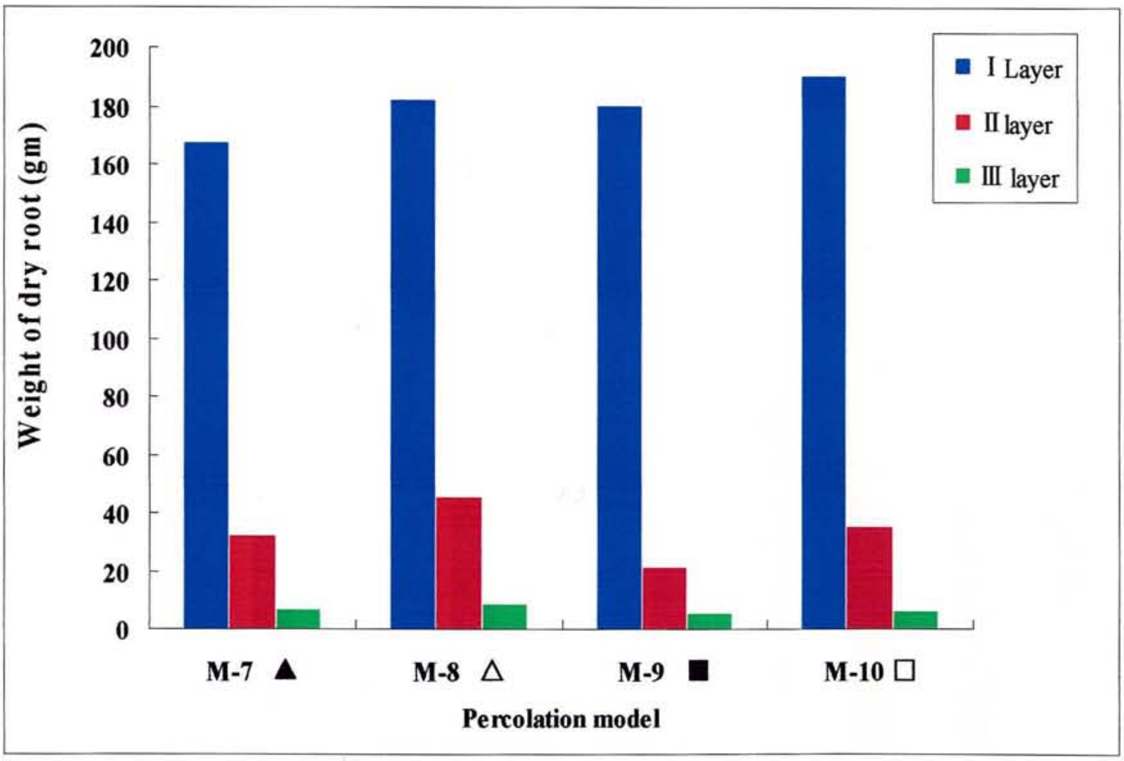

Fig. 75: Weight of dry root in different soil layer in 2010

4.10 Yields of rice plants

4.10.1 Dry weight of straw

Vegetative growth of rice plants related to straw weight. The average weight of straw in M-1, M-2, M-3, M-4, M-5, M-6, M-7, M-8, M-9 and M-10 were 10.7, 13.8, 11.9, 14.2, 14.1, 15.1, 15.5, 10.8, 14.6 and 13.2 g/ hill as shown in Fig. 76. The above results showed that average straw weight of closed system was higher than that the open system percolation within the same soil dressing model. So percolation pattern influence the straw weight of rice plants. According to Ishikuro *et al.*, (1997), vegetative growth and production of rice plants under submerged condition. This statement can be explained by the closed system percolation model due to a high ground water level was maintained.

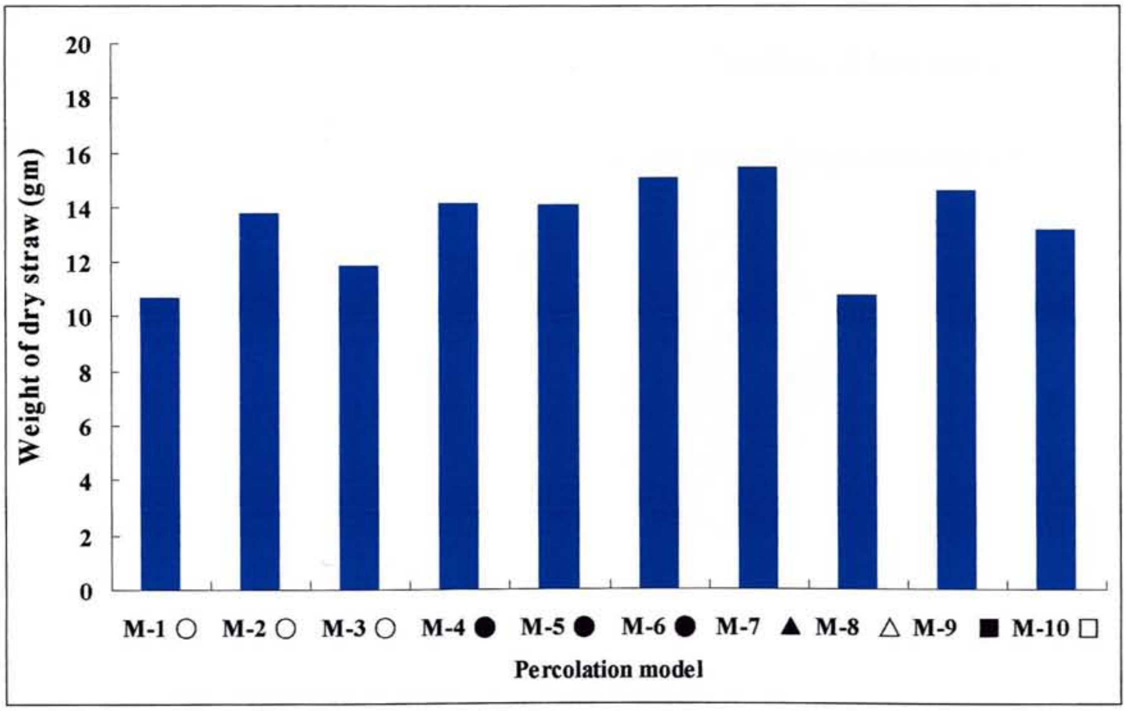

Fig. 76: Weight of dry straw in open and closed system percolation model.

4.10.2 Length, Number and Weight of panicle

The average length of panicle of each hill in M-1, M-2, M-3, M-4, M-5, M-6, M-7, M-8, M-9 and M-10 were 16.9, 16.6, 17.1, 17.5, 18.9, 17.9, 23.0, 26.5, 19.5 and 18.9 cm, respectively as shown in Table 6. The average number of panicle with the treatment of 12.5, 15 and 20 cm soil dressing in open system percolation (6.9, 10.7 and 11.0)) were lower than the closed system percolation (8.8, 11.7 and 12.8). Moreover, the weight of panicle in closed system percolation (20.5, 26.1, 27g/hill) were higher than the open system percolation (15.4, 21.1 and 24.7 g/hill). On the other hand, the number and weight of imperfect of panicle was higher in open system percolation than the closed system percolation models. Moreover, soil oxidation-reduction status controlled by percolation pattern. The length, number and weight of panicle were measured higher in 20 cm and 15 cm closed system soil dressing model. Therefore, it was concluded that percolation effect on panicle length and weight of rice plants which was depends on the condition of soil oxidation-reduction status.

Table 6: Panicle length, number and weight of rice plants in experimental models.

Year	Percolation system	Model	Panicle				
			Length (cm) *	No. of Panicles/hill *		Weight of panicles/hill (gm) *	
				Perfect	Imperfect	Perfect	Imperfect
2009	Open	M-1	$16.9^{b} \pm 1.4$	$7.7^{b} \pm 1.6$	0	$16.9^{ab} \pm 3.1$	0
	Open	M-2	$16.6^{b} \pm 1.2$	$6.1^{b} \pm 1.5$	0	$14.3^{b} \pm 2.8$	0
	Open	M-3	$17.1^{ab} \pm 1.5$	$6.9^{b} \pm 1.2$	1	$15.1^{b} \pm 2.7$	0.7
	Closed	M-4	$17.5^{a} \pm 1.0$	$8.8^{ab} \pm 2.0$	0	$20.9^{ab} \pm 5.5$	0
	Closed	M-5	$18.9^{a} \pm 0.8$	$8.2^{a} \pm 2.7$	0	$19.9^{a} \pm 6.3$	0
	Closed	M-6	$17.9^{a} \pm 0.9$	$9.5^{a} \pm 2.0$	0	$20.8^{a} \pm 5.5$	0
2010	Closed	M-7	$23.0^{a} \pm 4.7$	$11.7^{a} \pm 3.0$	1	$26.1^{a} \pm 7.4$	0.3
	Open	M-8	$26.5^{ab} \pm 3.3$	$10.7^{b} \pm 2.7$	3.6	$21.1^{b} \pm 5.3$	1.4
	Closed	M-9	$19.5^{a} \pm 1.7$	$12.8^{a} \pm 2.4$	0.7	$27.0^{a} \pm 7.2$	0.2
	Open	M-10	$18.9^{b} \pm 1.2$	$11.0^{ab} \pm 2.4$	2.5	$24.7^{ab} \pm 7.7$	1.1

Note: Means within the same row followed by the * letter are not significantly different to each other at $p>0.05$ by DMRT.

4.10.3 Number and weight of Paddy and rice grain

In this section, weight and number of paddy were measured and rice grain with different soil dressing and compare with open and closed system percolation as shown in Table 7. The average number of paddy with 12.5cm, 15 cm and 20 cm soil dressing in open percolation system were (659, 868 and 1024) lower than closed system percolation (748, 1120 and 1024), respectively. In this case, models M-1, M-3, M-8 has significant differ ($p>0.05$) from that models M-4, M-5, M-6, M-7 and M-9 but M-2 and M-10 did not differ significantly from other models.

The weight of paddy with 12.5, 15 and 20 cm soil dressing in open system percolation were (16.2, 18.9 and 22.3 g) lower than closed system percolation (17.7, 23.7 and 24.7 g), respectively. The models of M-1, M-3 and M-8 has significant difference ($p>0.05$) from that models of M-4, M-5, M-6 and M-7 but model M-2, M-9 and M-10 has not significantly differ with other models. The paddy weights of rice plants were higher with increasing the soil dressing models.

In 2009, the number of rice grain in open system (573) were lower than closed system percolation (695) but in 2010 models, the number of rice grains in open system were (781 and 963) lower than closed system percolation (973 and 988). The number of rice grains in models M-1, M-2, M-3 and M-8 was significantly different (p>0.05) from that the models of M-4, M-6, M-7 and M-9 but model M-5 and M-10 was not significantly different from the others models. The number of rice grain was found higher in 20 cm soil dressing model comparatively to 12.5 and 15 cm soil dressing models.

In 2009, the total weight (12.5 g) of perfect rice grains per hill in the open system percolation model was lower than that (15.1 g) in the closed system percolation model. But in 2010 models, the weight of grains in models of M-7 and M-9 (18.4 and 19.6 g) were higher than the models of M-8 and M-10 (14.6 and 18.0 g). In the case of rice grain weight, models M-4 , M-6 and M-7 has differ significantly (p>0.05) from that of models M-1, M-2 , M-3 and M-8 and M-5, M-9 and M-10 model showed no significant difference with the other models. The total weight of rice plants per hill was higher in 20 cm soil dressing models with closed system percolation than the 12.5 and 15 cm soil dressing models. So the production of rice plants depends on soil dressing methods with closed system percolation.

In 2009 models, the grain fill up in open system percolation was 93.5 % and 94.4% in closed system percolation. In 2010 models, the grain fill up in open system percolation was about 92.2% and closed system was 87.8%, respectively. The models of M-3 and

M-9 has significant differ with the model of M-7 but model M-1, M-2, M-4, M-5, M-6, M-8 and M-10 were not significantly differ with each other.

In 2009 models, the water content in rice grain was about 6% in both percolation systems but 8.5% in 2010 models. The water content in rice grain was higher in 2010; this cause due to the thickness of soil dressing and percolation system. The model of M-1, M-3 and M-9 was significantly different with the models of M-6 and M-7. On the other hand, the models of M-2, M-4, M-5, M-8 and M-10 has not significant difference with other models.

In 2009 experiment, the 1000 kernels weight was about 24.2 g in both percolation systems but in 2010, the weight was lower in open system (22.5 g) than the closed system percolation (23.2 g). The models of M-1, M-2 and M-8 has significantly difference with the models of M-4 and M-5 but has no vary within the models of M-3, M-6, M-7 and M-9.

From above the results, with 12.5, 15 and 20 cm soil dressing; the weight and number of paddy and grain were almost low production in open system percolation compared to closed system percolation. The vegetative grows and productions of rice plants were found higher with 20 cm soil dressing models. According to Sukuthai *et al.* (2005), rice plants growth and yields were lower in open system percolation than the closed system percolation without using soil dressing models. Rice grain weight may loss due to accumulation of Cd. This findings can be attributed the oxidation –reduction state of the soil which is related to percolation. Finally, it suggests that the rice yield in the open system percolation model was affected mostly by Cd-contaminated soil when compared the closed system percolation model.

Table 7: Number and weight of paddy and rice grain and grain fill, water content and 1000 kernel weight.

Year	Percolation system	Model	Paddy		Rice grain		Grain fill (%)	Water content (%)	Grains (1000 kernel weight) (gm)
			Number of paddy/hill	weight of paddy/hill (gm)	Number of grains/hill	Weightof grains/hill (gm)			
2009	Open	M-1	$688^{b} \pm 114$	$16.7^{b} \pm 2.5$	$579^{b} \pm 37$	$12.8^{b} \pm 2.4$	$93.6^{ab} \pm 3.8$	$5.7^{b} \pm 1.3$	$24.6^{b} \pm 0.8$
	Open	M-2	$718^{ab} \pm 229$	$18.1^{ab} \pm 5.6$	$630^{b} \pm 48$	$13.7^{b} \pm 1.9$	$94.9^{ab} \pm 2.6$	$6.2^{ab} \pm 0.9$	$24.0^{b} \pm 0.7$
	Open	M-3	$572^{b} \pm 90$	$13.8^{b} \pm 2.5$	$510^{b} \pm 31$	$11.1^{b} \pm 2.0$	$92.2^{b} \pm 2.3$	$6.2^{b} \pm 1.1$	$24.0^{ab} \pm 1.5$
	Closed	M-4	$725^{a} \pm 110$	$15.5^{b} \pm 2.6$	$700^{a} \pm 49$	$15.4^{a} \pm 4.1$	$94.0^{ab} \pm 2.1$	$5.9^{ab} \pm 1.2$	$24.3^{a} \pm 0.5$
	Closed	M-5	$761^{a} \pm 203$	$18.8^{a} \pm 4.9$	$667^{ab} \pm 32$	$14.7^{ab} \pm 4.6$	$93.6^{ab} \pm 1.7$	$5.8^{ab} \pm 1.0$	$24.3^{a} \pm 0.6$
	Closed	M-6	$758^{a} \pm 192$	$18.9^{a} \pm 5.1$	$718^{a} \pm 718$	$15.3^{a} \pm 4.2$	$95.7^{ab} \pm 2.6$	$6.0^{a} \pm 1.1$	$23.6^{ab} \pm 0.6$
2010	Closed	M-7	$1120^{a} \pm 320$	$23.7^{a} \pm 7.0$	$973^{a} \pm 274$	$18.4^{a} \pm 4.9$	$86.9^{a} \pm 4.9$	$9.1^{a} \pm 0.4$	$22.9^{ab} \pm 0.1$
	Open	M-8	$868^{b} \pm 202$	$18.9^{b} \pm 4.5$	$781^{b} \pm 184$	$14.6^{b} \pm 3.6$	$90.1^{ab} \pm 6.2$	$8.7^{ab} \pm 0.3$	$22.7^{b} \pm 0.1$
	Closed	M-9	$1113^{a} \pm 286$	$24.7^{ab} \pm 6.5$	$988^{a} \pm 249$	$19.6^{ab} \pm 4.9$	$88.6^{b} \pm 4.2$	$8.3^{b} \pm 1.3$	$24.2^{ab} \pm 0.1$
	Open	M-10	$1024^{ab} \pm 313$	$22.3^{ab} \pm 7.0$	$963^{a} \pm 292$	$18.0^{ab} \pm 5.6$	$94.2^{ab} \pm 3.4$	$8.1^{ab} \pm 0.7$	$22.4^{b} \pm 0.1$

Note: Means within the same row followed by the * letter are not significantly different to each other at $p>0.05$ by DMRT.

Chapter 5: Influence of percolation pattern to uptake of cadmium by rice plants in a polluted paddy fields with using soil dressing models

5.1 Introduction

Soil pollution has an adverse effect on the plant production. Therefore, pollution of soil must be maintained for life to flourish. Heavy metal pollution in soil is one form of pollution that has an adverse effect on plant growth and production. The toxic effects of Cd on biological systems have been reported by Mukherjee *et al.*, 1984 and Sharma *et al.*, 1985. Cd which is a non-essential metal and a powerful enzyme inhibitor (Lockwood, 1976), is considered to be an extremely significant pollutant because of its high toxicity and great solubility in water. Moreover, there are many methods to prevent Cd uptake by rice plants from contaminated paddy fields. One of the most popular methods is under flooding of paddy fields. Percolation patterns are related to the hydraulic conductivities of the soil layers and hydraulic conditions such as groundwater level (Adachi *et al.*, 1992), which may acts as a controller of soil redox potential and consequently the uptake of Cd in rice plants. Therefore, the purpose in this section was to clarify the influence of percolation patterns to uptake of Cd from soil dressing polluted paddy field models.

5.2 Concentration of cadmium in roots

The Cd content in the roots in different soil layers was measured for the two percolation systems. Concentration of Cd in roots of closed system percolation has no significant difference ($p>0.01$) with the open system percolation. The soil layer`s roots (I, II and III) in open system percolation (7.5, 33.0 and 5.4 mg/kg) were higher than closed system percolation (4.3, 18.0 and 3.2 mg/kg),respectively as shown in Fig. 77. In above results, Cd amassed in the II layer`s roots and two times higher uptake in open system percolation comparatively to closed system percolation. Concentrations of Cd in roots were higher than the stems and leaves and rice grain due to directly diminish within the soil. Accumulation of Cd in roots was the highest than the total Cd in plant (Jarvis *et al.*, 1976 and Yujing *et al.*, 2008) which is sustenance to the present study.

5.3 Cadmium concentration in stems and leaves

Accumulation of Cd in stems and leaves by rice plants in open system percolation were higher (0.83 mg/kg) comparatively in closed system percolation (0.53 mg/kg) that is not statistically significant difference at $p>0.01$, as shown in Fig.78. This might be occurred due to Cd solubility in submerged condition decreases with formation of Cd sulfides. In soil reduction condition, sulfate ion can be reduced sulfide ion which reacts with Cd and produce relatively insoluble Cadmium - sulfide (Iimura, 1981) which mechanisms supported to the closed system percolation.

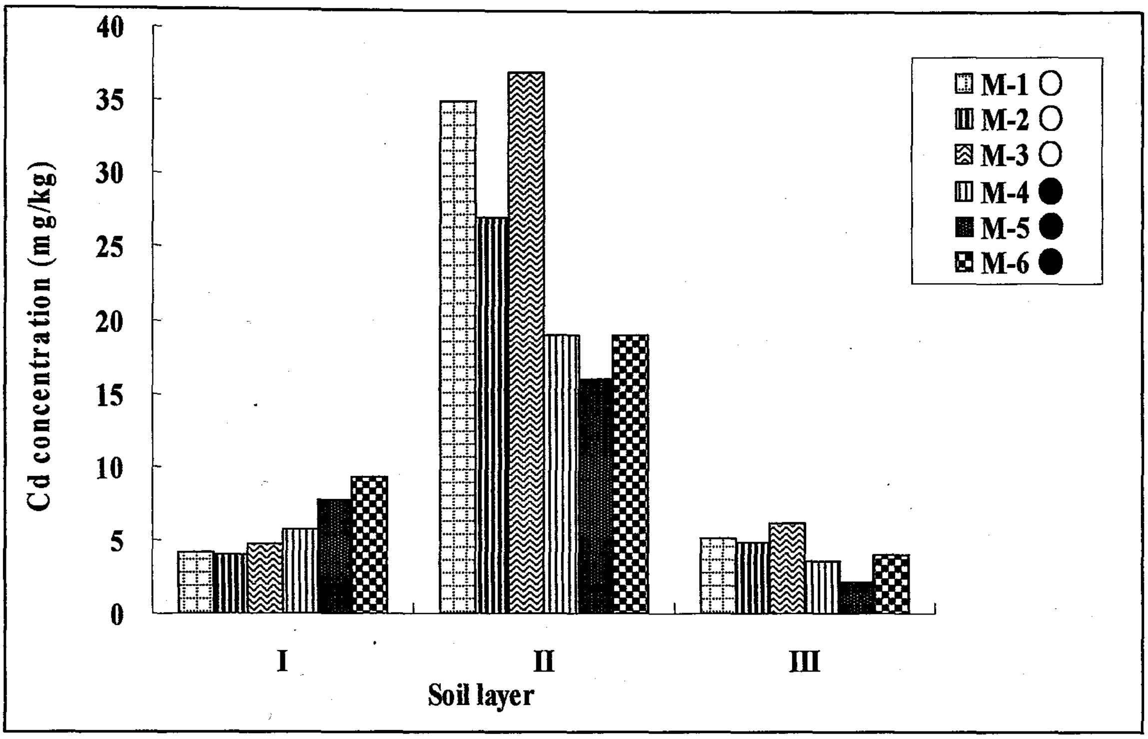

Fig. 77: Cadmium concentration in roots of different soil layers in the open and closed system percolation models in 2009.

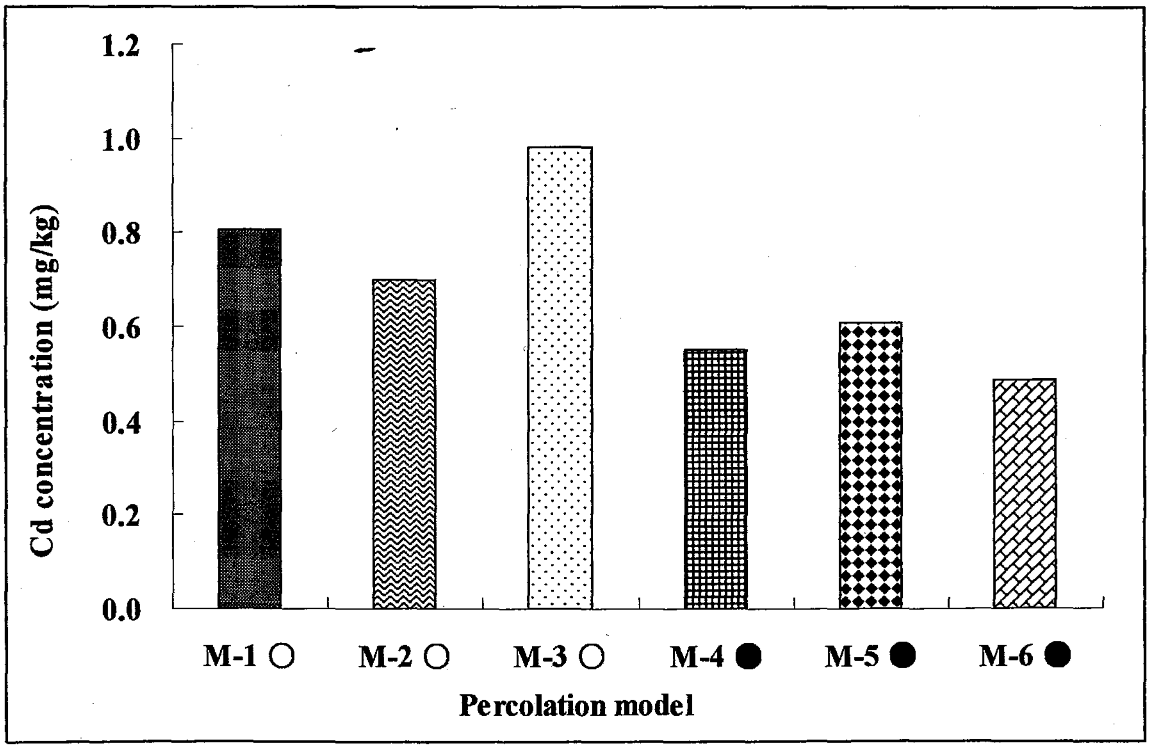

Fig. 78: Cadmium concentration in the stems and leaves of the rice plants in 2009

5.4 Cadmium concentration in the brown rice

Examination of Cd concentration in brown rice revealed that percolation patterns influenced the uptake of Cd and Cd the mobilization in rice plants. This mobilization depends upon the soil oxidation-reduction condition. With 12.5 cm soil dressing models, the amount of Cd content in brown rice of the models M-1, M-2 and M-3 were higher in open system (0.2 mg/kg) than the models of M-4, M-5 and M-6 in closed system percolation (0.1 mg/kg) due to oxidation in through submerging paddy field as shown in Fig. 79. With 15 and 20 cm soil dressing treatment, the average concentration of Cd in brown in open system percolation (M-8 and M-10) were 0.10 and 0.12 mg/kg and in closed system percolation (M-7 and M-9) were 0.03 and 0.03 mg/kg as shown in Fig. 80. On above of the results, comparatively with same soil dressing treatment showed that Cd accumulation in brown rice, stems and leaves and roots were higher than the closed system percolation models. In this study, Cd accumulation by rice plants depends on soil redox potential and percolation pattern. According to Ono *et al.*, (2003) stated that Cd uptake by rice plants depends on soil pH and variety of rice. On the other hand, Skuthai *et al.*, (2005) observed that DO value in the soil layer of open system percolation was higher than in closed system percolation which is promoted to accumulation of Cd by rice plants. However, in closed system percolation there was less oxygen fusion, which might occur slightly Cd uptake by plant from contaminated soil.

Thus, the transformation of Cd might be prevented when soil layer was in reduction condition. . Many scientists have been reported that accumulation of Cd by rice plants is decreased with submerging conditions of the soil layer due to produce insoluble Cd or other heavy metal. Closed system percolation models related to submerging condition of soil layer with 12.5 cm groundwater level and thus low accumulation of Cd by rice plants.

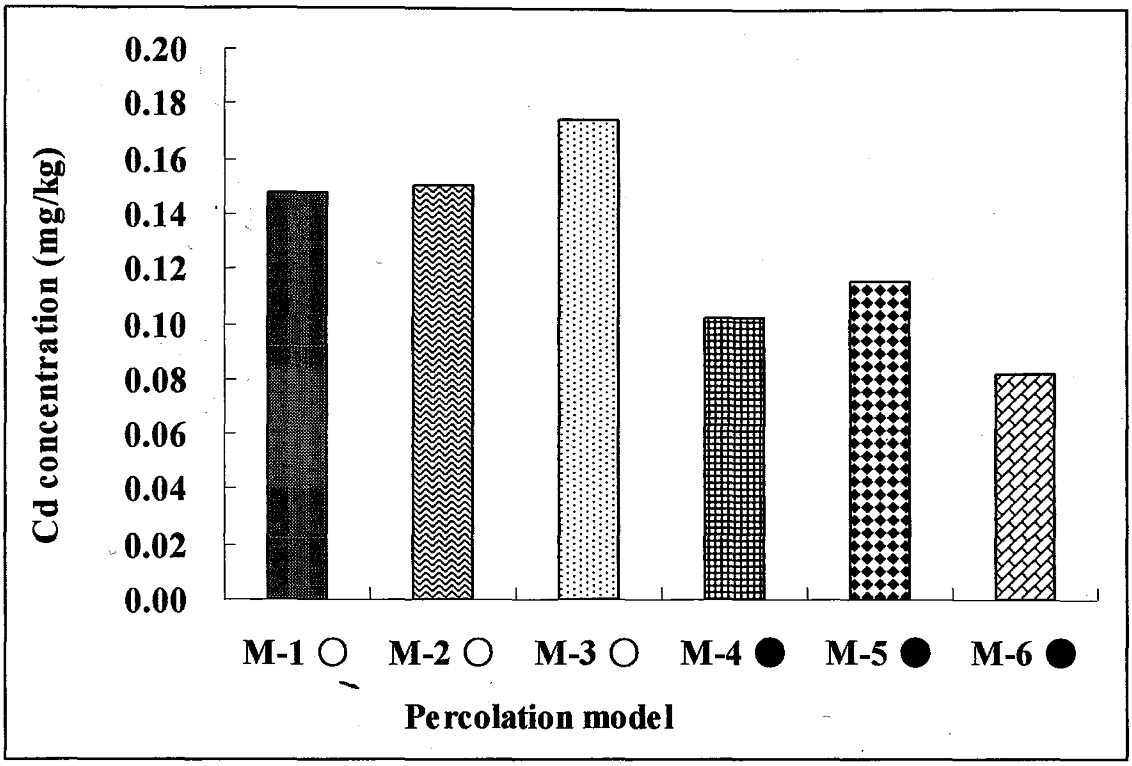

Fig. 79: Cd concentration in brown rice- 2009

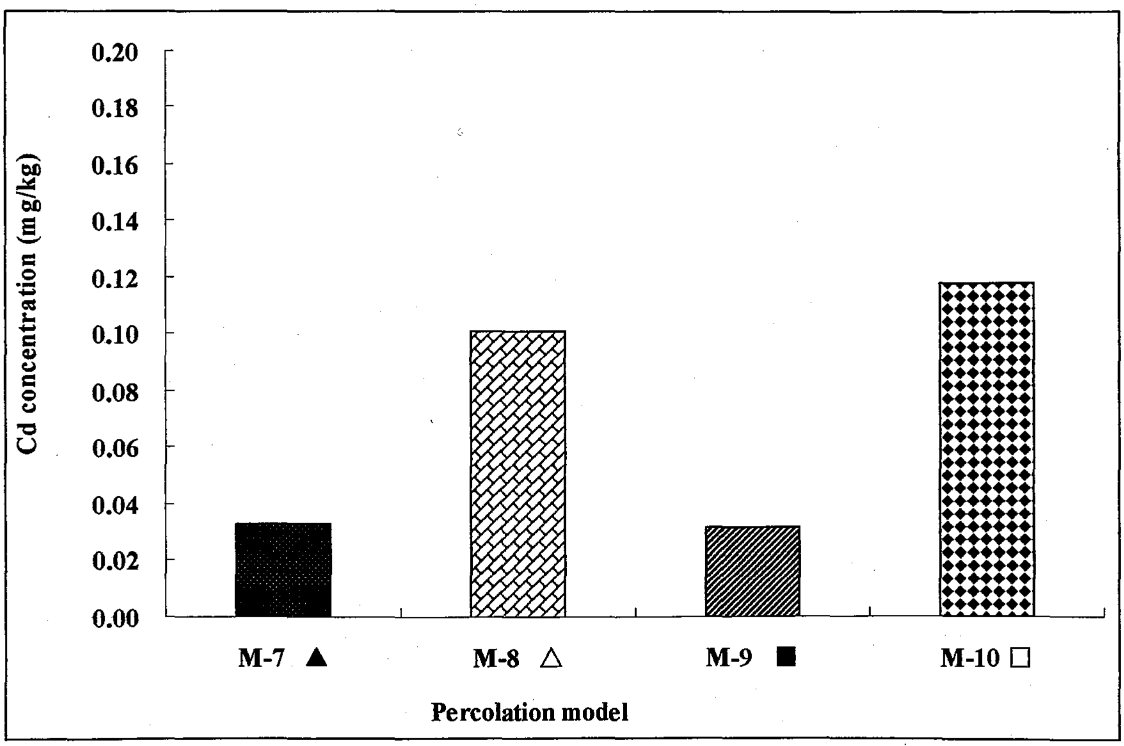

Fig. 80: Cd concentration in brown rice -2010.

Chapter 6: Summary

The experiment was conducted in the green house with open and closed system percolation models. There are two system of percolation: open and closed system percolation and those systems were constructed with 12.5, 15 and 20 cm soil dressing with stratified polluted paddy fields. Open system percolation known as well- drained and closed system percolation known as ill- drained paddy field. However, in this experiment stratified paddy field model column was used in which the actual soil profile of paddy field was maintained. Percolation pattern control the redox potential of soil layers which is actual to paddy field. So the aim of the study is to clarify the influence of percolation pattern on growth and yields of rice plants and accumulation of Cd with soil dressing polluted paddy fields models.

The open system percolation has showed positive pressure in plow layer but plowsole and subsoil were negative pressure due to unsaturated condition of those soil layers by atmospheric air and in additionally said that water pressure of plowsole and subsoil layers were lower than the air entry pressure. On the other hand, in closed system percolation pattern showed positive pressure of plow layer, plowsole and subsoil due to saturated condition of those soil layer by water. The total potential of water pressure in plowsole and subsoil of open system percolation were less than the closed system percolation but total potential energy loss was less than that of the open system percolation due to the condition of plowsole.

The average water requirement was controlled by the impermeable layer of both percolation systems. The drained water from subsoil was gradually decreased of both percolations. Finally, percolation rate of the open system percolation (38.9 mm/day) was lower than the closed system percolation (41.9 mm/day).

In the open system percolation, plowsole and subsoil temperatures were almost similar to the air temperature. The experiment of closed system percolation; the soil layer`s (plow layer, plowsole and subsoil) temperatures were higher than flood water and air temperature due to all of soil layer were untapped just like as the actual paddy field. The ample diffusion of heat in the open system percolation due to higher temperature will increase the diffusion rate of soil aeration.

The Eh value in plow layer of all models was about -190 mV after flooding condition and that tendency was like as actual paddy fields. From the start of the experiment, the Eh value in closed system percolation models of plow layer, plowsole and subsoil were less than 300 mV and gradually decrease that value and -200 mV were observed in late

June to October and this might be saturated condition of soil layer. On the other hand, in open system percolation; the Eh value of plowsole and subsoil layer was gradually increased up to about 300~650mV due to those layers were in unsaturated condition.

During the growth stage, the plant length and number of stem in open system percolation were low than the closed system percolation. But the number of leaf of rice plants was same and calculated has not significance difference between open and closed system percolation. The length, number and weight of panicles per hill in closed system percolation were higher than the open system percolation. In the harvesting period, the 14^{th} leaf was dry about 78% in closed system percolation but 43% in open system percolation; this result indicated the difference of photosynthesis ability of rice plants in two systems during ripening time. Both percolation systems, the average dried weight of roots in plow layer (174.0 g / column) was almost similar in 2009 and 2010. In 2009, the average dried weight of root in II layer and III layer (33.0 and 6.3 g/column) in open system percolation were higher than closed system percolation (16.0 and 2.5 g/ column), respectively due to oxidizing condition of plowsole and subsoil in open system percolation. But the models of M-7, M-8, M-9 and M-10 in 2010, the dried root weight were in layer I (167.0, 218.0, 186.0, 171.0 g/column), layer II (32.5, 45.6, 38.2 23.0 g/column) and layer III (6.8, 9.1, 6.6 and 3.3 g/column). In this case the root of rice plants was able to growth up to the subsoil. So Cd uptake by rice plants cannot prevent by soil dressing if plowsole and subsoil became under oxidative condition.

The average weight of total straw in M-1, M-2, M-3, M-4, M-5, M-6, M-7, M-8, M-9 and M-10 were 10.7, 13.8, 11.9, 14.2, 14.1, 15.1, 15.5, 10.8, 13.2 and 14.6 g/ hill. Moreover average straw weight was higher in closed system than that the open system percolation system. With 12.5, 15 and 20 cm soil dressing; the weight and number of paddy and grain were almost low production in open system percolation compared to those in closed system percolation. This findings can be attributed the oxidation –reduction state of the soil which is related to percolation.

Moreover, percolation pattern effected on accumulation of Cd in grains, stems and leaves and roots. The soil layer`s roots (I, II and III) in open system percolation (7.5, 33.0, 5.4 mg/kg) were higher than closed system percolation (4.3, 18.0, 3.2 mg/kg). Accumulation of Cd in stems and leaves by rice plants in open system percolation were higher (0.83 mg/kg) comparatively to closed system percolation (0.53 mg/kg). With 15 and 20 cm soil dressing treatment, the average concentration of Cd in brown in open system percolation (M-8 and M-10) were 0.10 and 0.12 mg/kg and in closed system percolation (M-7 and M-9) were 0.03 and 0.03 mg/kg. On above of the results, comparatively with same soil dressing treatment showed that Cd accumulation in open system percolation of brown rice, stem and leaves and roots were higher than the closed system percolation models.

Chapter 7: Conclusion

Alongside factors such as soil pH, temperature, anaerobic bacteria, heavy metal concentration, gravel size and soil fertility, the percolation pattern is an important factor for the growth and development of rice plants. The difference of percolation system affected not only rice growth and yields but also accumulation of Cd by rice plants. Percolation pattern control the oxidation- reduction status of soil, consequently uptake of heavy metal by rice plants. In oxidation condition of soil, plants more absorb of Cd due to mobilize of soluble of heavy metals. Cd concentration in brown rice was higher in open system percolation than that in the closed system percolation; this result suggested that open system percolation promotes Cd uptakes in rice plants due to oxidizing condition of plowsole and subsoil. So to reduce the uptake Cd in a closed system percolation with reduction condition of plow layer, plowsole and subsoil will be an effective tool with soil dressing in a polluted paddy field. Soil dressing is very effective method to minimize the Cd pollution. If the plowsole and subsoil were constructed with polluted soil and those layer were oxidized so the thickness of soil dressing (15- 20 cm) is not available for application on the Cd polluted paddy fields and also flood water condition in the time of blooming period is not an effective method to minimize accumulation of cadmium. So percolation pattern can evaluate the soil dressing technique for the effect on Cd pollution on growth, yields and accumulation of

Cd in every part of rice plants.

Chapter 8: Future research plan

- The percolation pattern can be evaluated with arsenic, Zinc, Nickel, Cobalt and copper polluted soil.
- The wheat plant and various kinds of vegetables can be operated with percolation pattern.
- The percolation pattern can be evaluated with 25, 30 and 40 cm soil dressing.
- The percolation pattern can be operated with various concentration of cadmium (5, 10, 15 mg/kg) content in polluted soil.
- The percolation model can be operated with the ground water level at 15 cm, 20 cm, 25 cm, 30 cm, 35 cm, 40 cm, 50 cm and 55 cm.

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