A Morphological Method to Investigate the Injurious Effects of Herbicides on Rice Plant

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INTRODUCTION

Intensive studies were conducted in Korea and in Japan on the injurious effects of herbicides to rice plant, especially under various soil conditions and abnormal climates in recent years. Recently, Ryang[7] reported the problems of herbicidal injuries on growth and yield of rice in Korea. This report mentions about a method to investigate morphologically injurious effects on rice plant by some herbicides which may cause formative responses in plants.

In the investigation, the rice plant is considered to consist of a series of shoot units based on the concept of 'shoot unit'[10], each comprising a stem segment, an internode, with an apical leaf, a basal tiller bud and upper and lower roots (Fig. 1). The leaf emergence is usually synchronized with the emergence of a bud locating two shoot units below and with the emergence of roots locating three shoot units below, by the concept.

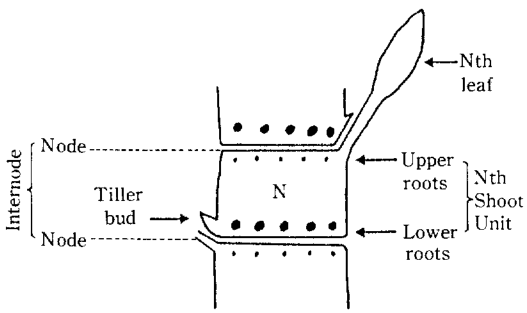

Fig. 1. The schematic shoot unit of rice plant (Modified from Yamazaki, *et al.*[10]).

MORPHOLOGICAL EFFECTS OF THE PHENOXY HERBICIDE ON RICE PLANT

Phenoxyacetic acid herbicides and their mixtures are still in common use by rice farmers of Japan, because they are not expensive for farmers, as well as they are still effective for controlling broad-leaved annual and perennial weeds in rice fields. However, phenoxys are occasionally phytotoxic to rice under high or low temperature conditions, even when they are applied at the recommended application time before the panicle differentiation stage of the crop. They cause various damages to rice, for instance, the reduction of tillering, the formation of tubular and dwarfed leaves, the leaf burning, and the aberrant root formation[6].

Gross morphological responses of rice plant to 2,4-D or MCPA were investigated by many researchers[1,2,5,6], but they were not precisely enough to know damages on rice at the vegetative stage by each leaf, each tiller, and each group of roots. So, morphological effects of MCPA were investigated on leaves, tillers and roots of successive shoot units of rice plant[8].

The commercial product of MCPA ethylester (1.4% granule) was applied at doses of 0.1, 0.2, 0.4 and 0.8 kg ai/ha to rice plant at the 7th leaf emerging or elongating stage, under high (30-35 ℃, night-day, respectively), middle (22.5-27.5℃) and low (15-20℃) temperature conditions.

Results obtained are illustrated diagrammatically in Fig. 2, in which a leaf just emerging at the time of MCPA application is expressed as the Nth

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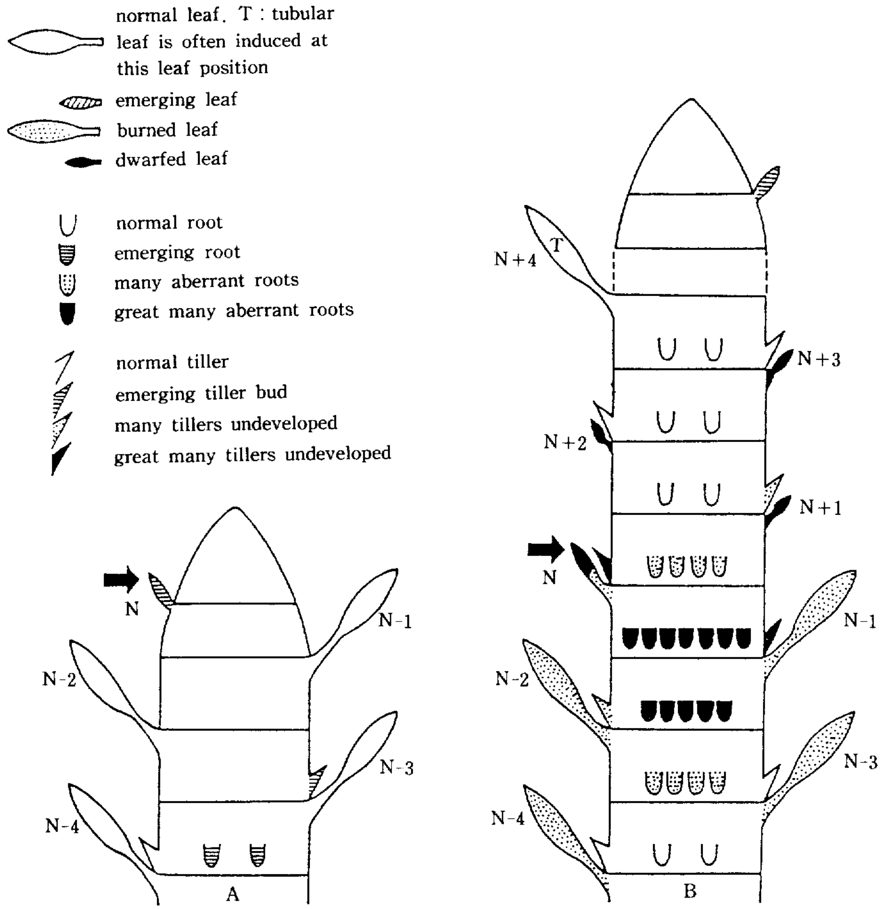


Rice plant at the time of MCPA treatment (the N leaf emerging stage)

Rice plant affected by MCPA treatment

Fig. 2. Diagram of morphological injuries of rice plants treated with MCPA. Horizontal lines indicate nodes. Arrows indicate the N leaf which was just emerging at the time of MCPA treatment. The number of roots more than two means an increased number of roots emerged. Aberrant roots are those which stopped growing at their initial stage or are less than 3 cm in length.

leaf. In this experiment, a tiller bud of the N-2 shoot unit (axillary bud of the N-3 leaf) and roots of the N-3 shoot unit were found emerging when the N leaf was emerging as shown in Fig. 2 A, as same as by the concept. Fig. 2B shows morphological injuries of leaves, tillers and roots caused by MCPA treatment.

Effects on shoots of rice

The number of tillers per hill was strikingly reduced by MCPA treatment, especially under the high temperature or at the high dose of the chemical in this experiment (Table 1). And, at severely injured plants, tillers of four shoot units which developed after the treatment were damaged as shown diagrammatically by damages of tillers at N-2, N-1, N and N+1 shoot units of Fig. 2B. The most severely damaged tiller buds were those of the N-1 and N shoot units. Tillers at the higher position than these four shoot units

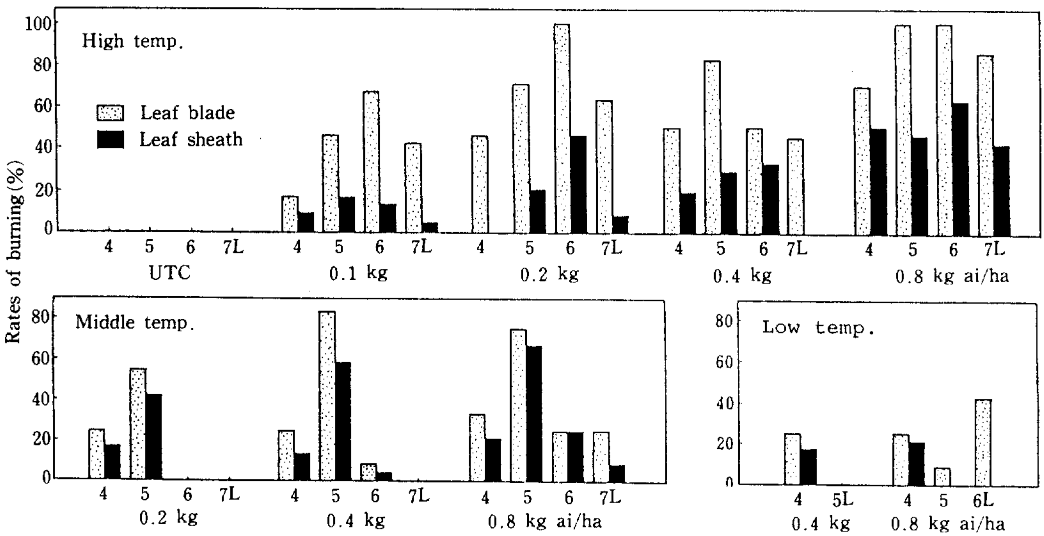
Table 1. The tiller number per hill (20 days after MCPA treatment).

Temperature	Treated doses(Kg ai/ha)				
	0	0.1	0.2	0.4	0.8
High	100%	28%	28%	19%	13%
Middle	100	38	31	31	23
Low	100	67	63	42	35

usually developed to normal ones and rice plants used to recover the number of tillers per hill in field conditions. No tubular leaf appeared under the high temperature in this experiment, but the lower the temperature was, or the higher the applied dose was, the more tubular leaves were formed by the MCPA treatment. They were mainly the leaves which located above the N leaf by four shoot units, that is, N+4 leaf on each stem as shown in Fig. 2B. Their tubular structure was quite the same as that of 2,4-D induced ones[5]. Many shoots which produced tubular leaves died later as inner new leaves usually could not emerge through tubularly tightened outer leaves, and, therefore, in field conditions, rice plants were injured severly under low temperature because of increased dead shoots and of delayed recovery of their growth.

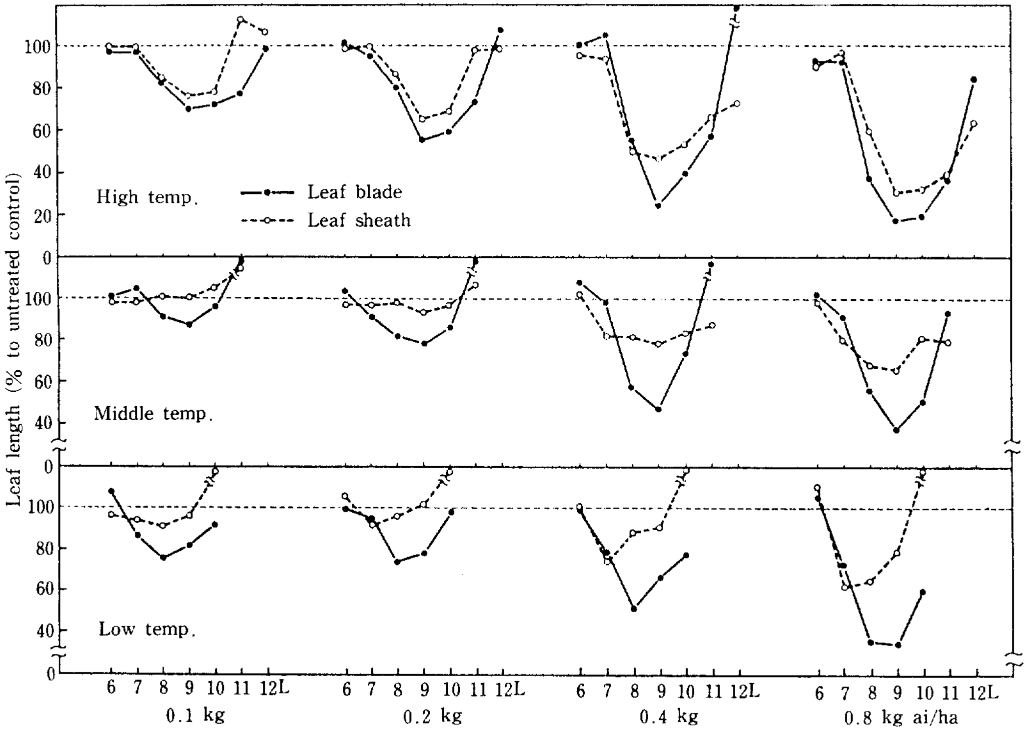
Yellowing and burning of lower leaves were common symptoms of rice plants treated with MCPA or 2,4-D. In this experiment, too, MCPA treatment caused the burning of lower leaves, particularly, of lower leaf blades, and the burning were found to occur only on leaves which had elongated completely or had been elongating at the time of treatment(Fig. 3). Therefore, Fig. 2 B shows that N-4, N-3, N-2 and N-1 leaves were burned and the N leaf which was elongating at the treatment was occasionally burned. On the other hand, new leaves located above the N leaf that emerged after the treatment were not yellowed or burned at all. The higher the temperature or the higher the dose of MCPA was, the more was the burning of lower leaves. In each leaf, blade burned more than sheath (Fig. 3).

The reduction of leaf length appeared at successive three to four new leaves which emerged after the treatment in this experiment (Fig. 4). These dwarfed leaves were diagrammatically indicated in Fig. 2B as short ones, that is, N (emerging at treatment), N+1, N+2 and N+3 leaves. High temperature and high dose of MCPA enhanced the adverse effect on leaf length. Leaf blade was more susceptible to the treatment than



4-7[L] : Leaf position, 0.1-0.8 kg ai/ha : Treated dose of MCPA
UTC : Untreated control

Fig. 3. Rates of burning in leaf blades and sheaths (13 days after treatment).



6-12[L] : Leaf position, 0.1-0.8 kg ai/ha : Treated dose of MCPA.

Fig. 4. Lengths of leaf blade and sheath.

leaf sheath.

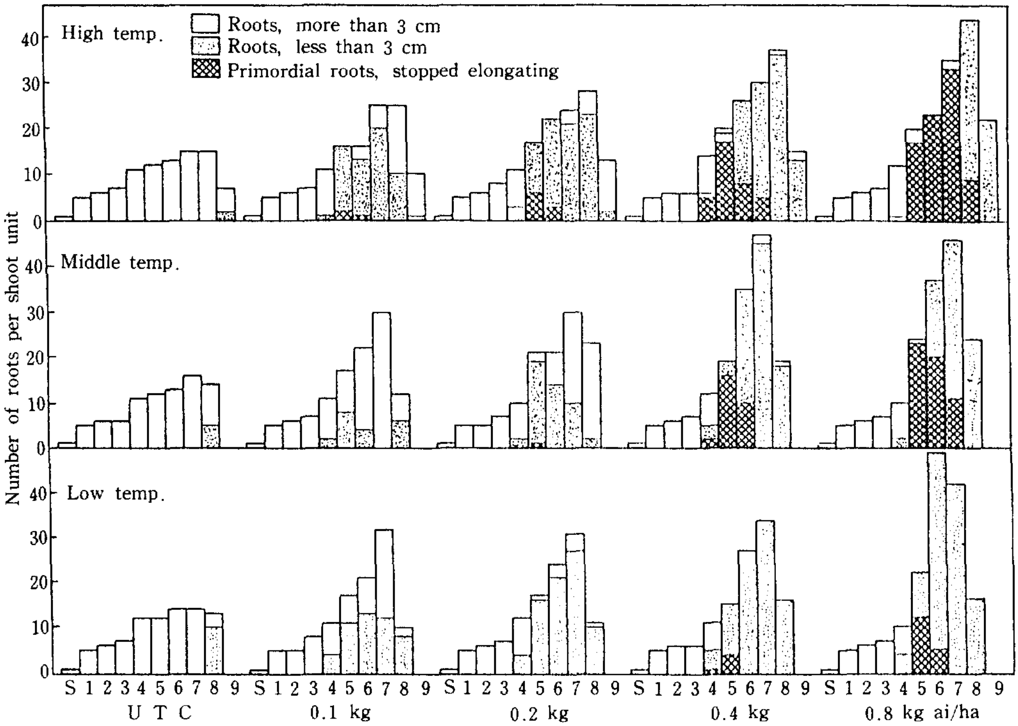
Effects on roots of rice

When MCPA was applied at the 7th leaf emerging stage of rice plants, roots of the 4th shoot unit were emerging. Aberrant root formation, which was designated with an abnormally increased number of roots per shoot unit and with increased proportions in them of both stunted ones less than 3 cm in full length and root initials which stopped growing, was particularly severe in successive four shoot units which developed after the MCPA treatment. The number of roots of the most affected shoot unit was as many as three times that of untreated control plants (Fig. 5).

Fig. 2B shows diagrammatically these abnormalities of roots, where the number of roots, especially aberrant roots, of N-2, N-1, N and N+1 shoot units was found markedly increased. Roots which emerged above these four shoot units showed a normal development and their number was almost equivalent to that of the untreated control.

The total number of roots of injured shoot units was about the same under high, middle and low temperature, but the proportion of undeveloped root initials in them was the more as temperature was the higher. When treated dose of MCPA was the higher, the number of roots of injured shoot units was the more and proportion of undeveloped root initials in them was the higher (Fig. 5).

As mentioned above, the phytotoxicity of MCPA to rice plant appeared on leaves, tiller buds and roots of several definite shoot units. By analyzing precisely their morphological abnormalities, it was expected that the degree of injury of plants at MCPA treated in fields and the possibility of recovery of their growth could be investigated more in detail. Furthermore, it is natural that the degree of MCPA injury of rice may be influenced by growth stages of the crop, temperature or various field conditions at treatment. These



S : Seminal root, 1-9 : Number of shoot unit, 0.1-0.8 kg ai/ha : Treated dose of MCPA, Number of roots : Total of upper and lower roots, UTC : Untreated control.

Fig. 5. Number of roots per shoot unit.

should be studied in future to use MCPA or other phenoxyacetic acid herbicides more safely in rice fields.

MORPHOLOGICAL EFFECTS OF THE SULFONYLUREA HERBICIDE ON RICE PLANT

In recent years, bensulfuron methyl (BSM) (methyl 2-[[[[[(4, 6-dimethoxy-pyrimidin-2-yl) amino]carbonyl]amino]sulfonyl]methyl]benzoate), a new sulfonylurea herbicide for paddy rice, has become very popular to Japanese rice farmers as the herbicide for the so-called 'one-shot' application. Prevailing commercial products of bensulfuron methyl are mixtures with other active ingredients. One of them is the mixture with dimepiperate (DP) [*S*-(1-methyl-1-phenylethyl) piperidine -1-carbothioate], which was found to be effective to reduce the phytotoxicity of bensulfuron methyl to rice plant when two chemicals were applied in combination.

Many studies were conducted on both herbicides physiologically, practically or in other aspects, including the safening effect of dimepiperate[9,11], but morphological responses of rice plant were not investigated detail yet, although they were necessary to study physiological or developmental aspects of rice injuries in paddy fields caused by herbicidal activities.

Commercial products of bensulfuron methyl (0.17% granule), dimepiperate (10% granule) and the mixture (BSM 0.17%+DP 10% granule) were applied at doses of 0.051 and 0.102 kg ai/ha, 3 and 6 kg ai/ha, and 0.051+3 and 0.102+6 kg ai/ha, respectively, to rice plant at the 5th leaf elongating or the 6th leaf emerging stage under the outdoor condition. Rice seedlings were transplanted at shallow depths in paddy soil, that was, at 0 cm with roots being buried into surface soil and at 1 cm, to investigate herbicidal injuries under the unsuitable cultural condition. These shallow transplanted seedlings were frequently found in machine-transplanted paddy fields. Clay loam soil was mainly used for the experiment, and comparing with it, sandy loam one was also used because herbicidal effects on rice plant were usually severe in the latter[3,4].

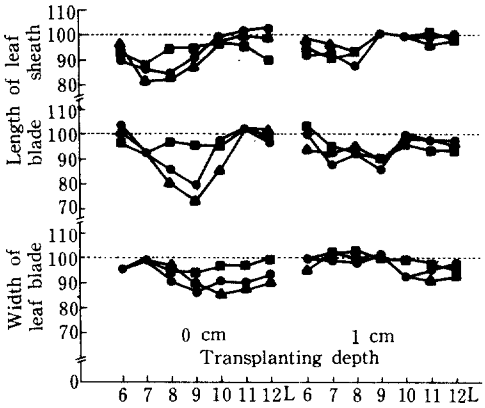
Injurious effects of bensulfuron methyl on rice plant were morphologically investigated on its every shoot unit. These consisted of the decrease of the narrowed leaf blade and the inhibition of formation and elongation of roots at several shoot units which developed just after the herbicide application. Both injuries on shoots and on roots appeared in synchronizedly growing organs of successive shoot units, and there was a close relation between degrees of injury in shoots and roots.

Application of bensulfuron methyl and dimepiperate in combination alleviated the growth inhibition of rice plant in a tiller, a leaf and roots of each shoot unit, so safening effects of dimepiperate to the crop were comfirmed.

Effects on shoots of rice

The number of tillers per hill was slightly reduced by bensulfuron methyl treatment in this experiment, not because of the death of tiller buds, but because of the delay of their emergence at a few shoot units which developed after the treatment. Also, the emergence of each of three to four leaves at successive shoot units were delayed for one or two days after the treatment. The reduction of leaf length appeared at three to four leaves which delayed to emerge after the treatment, and leaf blade was more susceptible to the treatment than leaf sheath. The widths of leaf blades of these dwarfed leaves were slightly, about 10%, reduced to be as narrowed leaves (Fig. 6).

The transplanting depth of seedlings affected the degree of injury, and herbicidal effects were severer on rice shoots transplanted at 0 cm depth, than on ones at 1 cm in which injuries were only



● : Bensulfuron methyl+dimepiperate (0.051+3kg ai/ha)
▲ : Bensulfuron methyl (0.051 kg ai/ha)
■ : Dimepiperate (3 kg ai/ha)

Fig. 6. Lengths of leaf sheath and blade and width of leaf blade (% to untreated control).

slight in this experiment (Fig. 6). The higher dose of applied herbicides or the sandy loam paddy soil caused severer injuries on rice than the lower dose or clay loam one did. Safening effects of dimepiperate to reduce injuries on shoots were clear, when it was applied in combination with bensulfuron methyl (Fig. 6).

Effects on roots of rice

As bensulfuron methyl and dimepiperate were applied at the 5th leaf elongating or the 6th leaf emerging stage of rice plant, roots of the 3rd shoot unit were emerging, and their number was

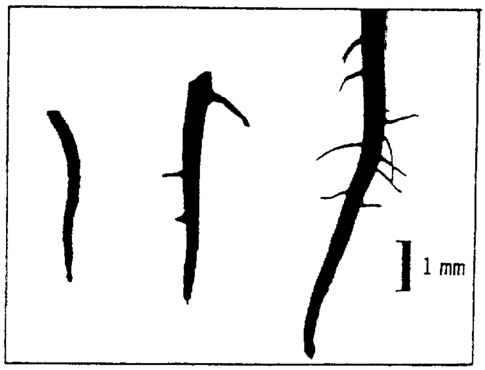


Fig. 7. Aberrant roots caused by the treatment of bensulfuron methyl.

a already determined. Herbicidal effects on roots appeared mainly from the 3rd to the 6 or 7th shoot units. Aberrant root formation, which was designated with an abnormally decreased number of roots per shoot unit and with increased proportions in them of more shortened ones with abnormal branching (Fig. 7), was particularly severe in successive two shoot units which developed after the herbicide treatment (Fig. 8).

The transplanting depth of rice seedlings affected the degree of injury, and herbicidal effects were severer on roots transplanted at 0 cm depth, too, than on ones at 1 cm in which injuries were slight in the experiment. Safening effects of dimepiperate to reduce injuries on roots were clear when it was applied in combination with bensulfuron methyl (Fig. 8). Dimepiperate, itself, did not cause any injury on rice roots in

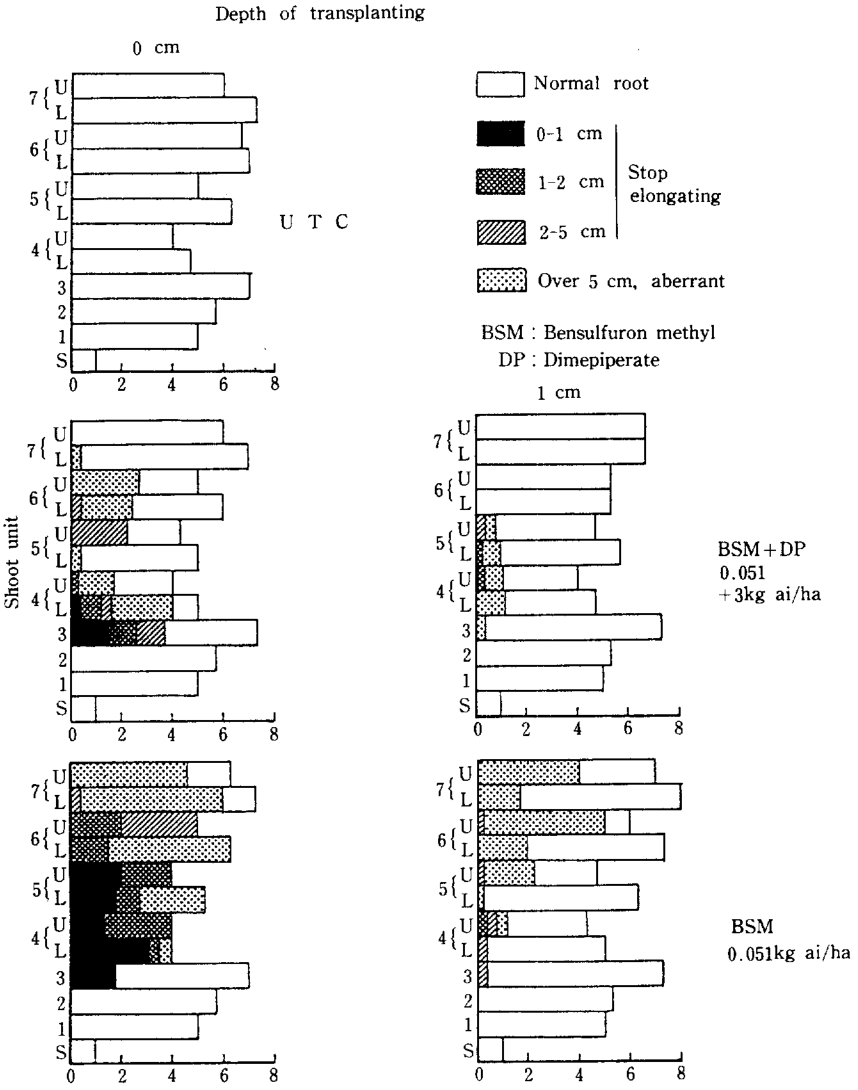


Fig. 8. The number and lengths of roots in shoot units. (28 days after treatment ; Clay loam soil) S : Seminal root, 1-7 : Shoot unit, U : Upper root, L : Lower root, UTC : Untreated Control

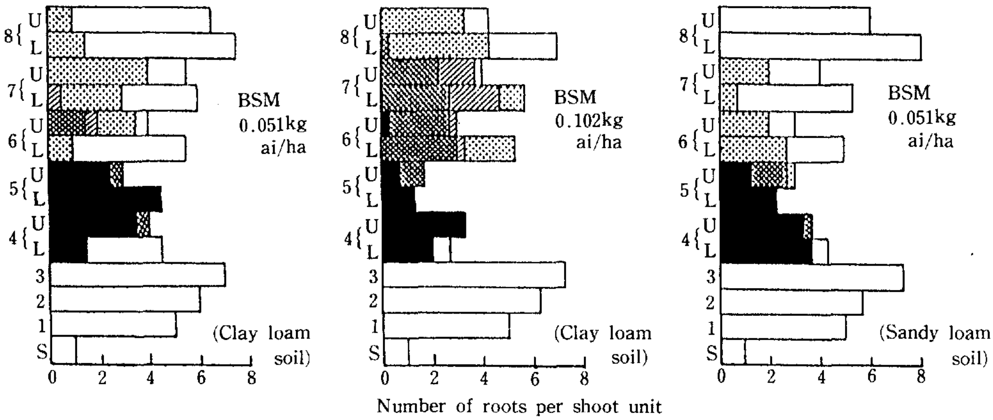


Fig. 9. The number and lengths of roots in shoot units. (28 days after treatment) S : Seminal root, 1-8 : Shoot unit, U : Upper root, L : Lower root, Columns : Same as Fig. 8

this experiment. The higher dose of applied herbicides or sandy loam soil caused severer injuries in plants than the lower dose or clay loam one did (Fig. 9).

Bensulfuron methyl is one of the excellent rice herbicides used commonly in Japan now, and it can be applied safely on paddy rice with only slight effects which are practically unimportant, under the application method in the recommendation. However, rice cultivation methods of farmers are occasionally unsuitable for the application of many herbicides, and also, disappointedly, over-dose application of herbicides are frequently seen. These morphological observations are useful to know the degree of injuries caused by bensulfuron methyl, and to find how to avoid them at paddy fields.

CONCLUSION

Investigations by the morphological method are not many in herbicide studies, especially, for rice herbicides. However, in practical sense, these should be conducted more because herbicidal injuries or growth recoveries of rice plant after damages are usually caused through morphological changes or the regrowth of organs of the plant. And also, for physiological studies, the herbicidal activity in rice plant can be studied more in detail by investigations on the change of form in each organ.

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