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Seedling Emergence and Establishment of Direct-sown Paddy Rice in Soils Incorporated with Substances Produced in Reductive Paddy Soil*

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Abstract : Although seedling emergence and establishment is inhibited by soil reduction in the direct sowing of paddy rice into puddled and leveled soil, the reasons for this are not clearly understood. This experiment was carried out to clarify whether substances produced in reductive flooded paddy soil could be inimical to seedling emergence and establishment of paddy rice seed sown into flooded soil. As typical substances produced in reductive soil, sulfide, acetic acid, and ferrous iron were added to flooded soil before sowing. Seedling emergence and establishment was poor when the amount of addition was large in all substances. Thus, it seemed that substances produced in reductive soil could be one of the direct causes of seedling emergence and establishment inhibition. Ferrous iron seemed to be the most harmful among the substances tested. But inhibition of seedling emergence and establishment by the substances was attenuated when the seeds were coated with calcium peroxide.
Key words : Acetic acid, Direct sowing, Ferrous iron, Paddy rice, Seedling emergence, Seedling establishment, Sulfide.

水田土壌の還元生成物を添加した土壌における直播水稲の出芽・苗立ち* : 萩原素之・井村光夫**(信州大学農学部・**石川県農業短期大学)

要　旨 : 水稲の湛水土壌中直播において土壌還元は出芽・苗立ちを阻害することが知られているが，その原因は解明されていない．出芽・苗立ちの阻害は湛水土壌における還元生成物の害作用によるものではないかと考え，代表的な還元生成物（硫化物，酢酸，二価鉄）が出芽・苗立ちに与える影響を調査した．これらの還元生成物を湛水土壌に添加して水稲種子を土壌中に播種したところ，添加量が多い時は，いずれの還元生成物も出芽・苗立ちに対して阻害的であることがわかった．したがって，還元生成物は出芽・苗立ちの直接的阻害要因の1つと考えられた．供試した還元生成物の中では二価鉄の阻害作用が比較的大きいようであった．しかし，過酸化石灰による種子被覆は還元生成物による出芽・苗立ち阻害作用を緩和した．
キーワード : 酢酸，出芽，水稲，直播，苗立ち，二価鉄，硫化物．

Several workers[2,4,8,13] reported that seedling emergence and establishment in DIPPS[3], direct sowing of paddy rice into puddled and leveled soil, was inhibited by soil reduction. However, the reason why soil reduction inhibits seedling emergence and establishment has not been elucidated. Izawa[8] pointed out that organic acid produced in flooded soil during the process of soil reduction was likely to be related to the seedling emergence and establishment inhibition by soil reduction. In this report, influences of several typical substances produced in reductive paddy soil on seedling emergence and establishment of direct-sown paddy rice were investigated.

* An outline of this report was presented at the 188 th meeting of Crop Science Society of Japan (October, 1989).

Materials and Methods

Dry seeds of paddy rice cultivar Koshihikari (*japonica*) were used for seed coating treatment as shown in Table 1. Coated seeds of each treatment were produced by an ordinary method a day before sowing. Dry soil was puddled in a vat and kept flooded for 2 days before mixing the additives shown in Table 1 with the soil. The amounts of additives were fixed at those which can be produced in flooded paddy soil within a few weeks after flooding, according to the related literature, Asami[1], Kobo et al.[9], Takai et al.[14,15] and Motomura et al.[10], for example. Plots were made for each combination of coating and additive treatment. One vat for each plot was used and 35 seeds were sown in a vat at 1 cm depth in soil 3 days after puddling. The soil was kept flooded at a depth of 1 cm in a

growth chamber under natural daylight controlled at 20°C throughout the experimental period. Only seedlings which grew up to seedling emergence were sampled 21 days after sowing. Percentage of seedling emergence and of second foliage leaf emergence, plant height, longest root length, shoot and root dry weight were recorded.

Results

Results are shown as averages of seed coating treatments and of additive treatments. Since the main purpose of the present experiment is to clarify the influences of substances produced in reductive soil on seedling emergence and establishment, results are described as for coating treatment briefly and then as for additive treatment.

1. Seed coating treatment

Treatment II was the most superior in all aspects of seedling growth (Fig. 1—6), and the difference with treatmnet I was significant except for the longest root length and root dry weight. Though data are not shown, the difference in total dry weight between the treatments was significant at the 5% level, and total dry weight in treatmnet II was significantly higher than the other treatments. In this way, Calper (treatment II) reduced the harmful effect of substances produced in reductive paddy soil. Watanabe[17] reported that mixed coating of Calper and a kind of montmorillonite-type clay (mixing ratio of

Table 1. Treatments.

Seed coating treatment	Materials and amounts*
I	No-coating
II	Calper** 100%
III	Calper 100%, Japanese acid clay 50%, Olivine 100%
IV	Japanese acid clay 50%, Olivine 100%, Gypsum 25%

Additive treatment	Substance and amount*** of addition	
C	No-addition	
su, SU	Sodium sulfide	20 mg, 40 mg
ac, AC	Sodium acetate	0.5 me, 1.0 me
fe, FE	Iron(II) sulfate	150 mg, 300 mg

Plots were made for each combination of seed coating and additive treatment.

* Shown by the percentage to dry seed weight.

** A promoter of seedling emergence and establishment, consists mainly of 35% of calcium peroxide and 25% of gypsum.

*** Amount per 100 g dry soil as S^{2-}, acetic acid and Fe^{2+}.

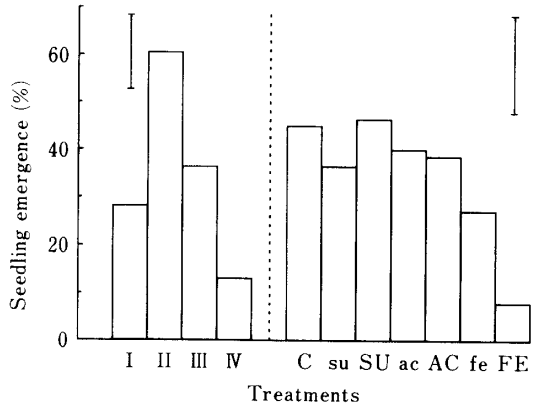

Fig. 1. Seedling emergence percentage.
Difference within seed coating treatment and that within additive treatment were significant at 1% and 5% level, respectively. Bars in the figure show LSD at 5% level; this is the same in the following figures.
Results are shown as averages of seed coating treatments and of additive treatments. This is the same in the following figures.

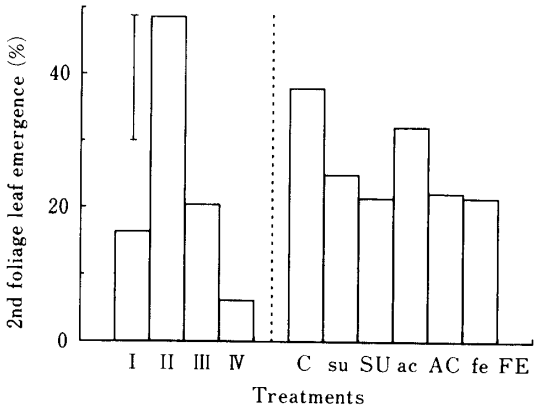

Fig. 2. Second foliage leaf emergence percentage.
Difference within seed coating treatment and that within additive treatment were significant at 1% level and not significant at 5% level, respectively.

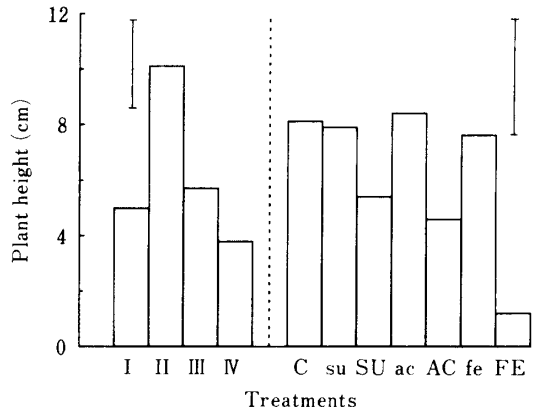

Fig. 3. Plant height.
Difference within seed coating treatment and that within additive treatment were significant at 1% and 5% level, respectively.

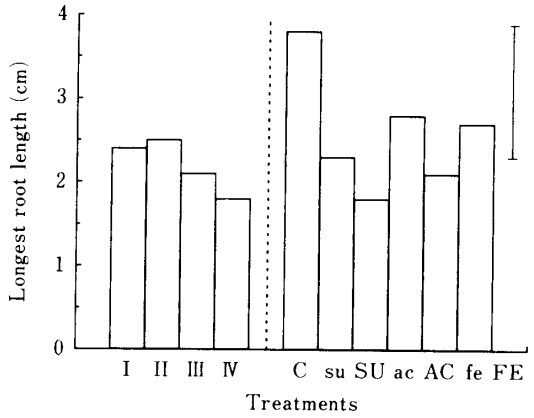

Fig. 4. Longest root length.
Difference within seed coating treatment and that within additive treatment were not significant at 5% level and significant at 1% level, respectively.

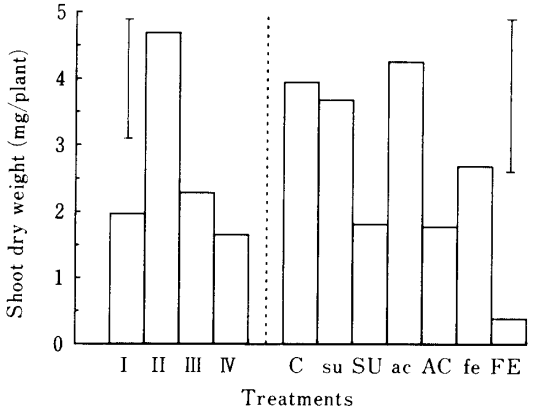

Fig. 5. Shoot dry weight.
Difference within seed coating treatment and that within additive treatment were significant at 1% and 5% level, respectively.

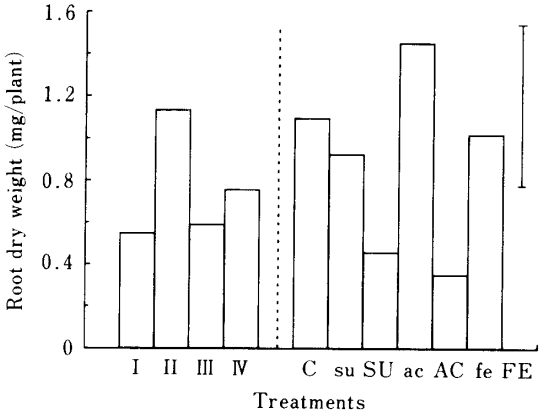

Fig. 6. Root dry weight.
Difference within seed coating treatment and that within additive treatment were not significant at 5% level and significant at 5% level, respectively.

Calper : clay ranging from 1 : 0.125 to 1 : 1 in weight) enhanced the effect of seedling emergence and establishment promotion by Calper. However, Japanese acid clay, a similar clay type, was not effective as shown by the results of treatment III in Figs. 1—6, and treatment IV gave the worst results in all aspects of growth except for root dry weight. Judging from the present experiment, using clay for coating had a reverse effect on seedling emergence and establishment promotion. The reason for this is not clear at present.

2. Additive treatment

Seedling emergence percentage (Fig. 1) tended to be lower when ferrous iron was added. In treatment FE, the percentage was significantly lower than treatment C, while in treatment fe, not significantly lower. In other treatments, it was not much different from treatment C. Second foliage leaf emergence percentage (Fig. 2) was not significantly different between the treatments. However, in treatment FE, the second foliage leaf emergence percentage was zero, and first foliage leaf emergence percentage (data not shown) was nearly zero. Plant height (Fig. 3) in treatments with a small amount of additive was much the same in treatment C. On the other hand, it tended to be shorter than treatment C in treatments with a large amount of additive. Conspicuous shortness of plant height in treatment FE was due to very rare foliage leaf

emergence. Longest root length (Fig. 4) in treatments with additive was shorter than treatment C, and was much shorter in treatments with a large amount of additive. Root elongation was hardly observed in treatment FE. Shoot dry weight (Fig. 5) was the highest in treatment ac but the difference with treatment C was not significant. Lowest shoot dry weight, which was significantly lower than treatment C, was obtained in treatment FE. Shoot dry weight was lower in treatments with large amount of additive than in small amount of additive. Root dry weight (Fig. 6) generally showed the same tendency as shoot dry weight. Root dry weight was nearly zero in treatment FE, because root elongation was hardly observed as described above.

Discussion

Calper coating treatment reduced the harmful effect of additives. However, though no data are shown, the effect of Calper coating tended to be weaker when the amount of additives was larger. Thus, sulfide, acetic acid and ferrous iron could be harmful to seedling emergence and establishment when they are produced in flooded soil in large amounts. Previously, we pointed out that the soil oxidizing effect of Calper seemed to play an important role in its seedling emergence promotion, because local soil reduction around a seed which was responsible for the decline of seedling emergence was delayed by the soil oxidizing effect[4]. The effect of Calper coating in the present experiment, however, seems to be brought about not only by a soil oxidizing effect. Acetic acid seemed to be inimical to seedling establishment because in treatment ac and AC, some seedlings died after foliage leaf emergence. Since at high pH toxicity of organic acid tends to be lower[16] and Fe^{2+} becomes insoluble, the effect of alkalinity of Calper in addition to its possible effect of oxidizing S^{2-} and Fe^{2+} into a non-toxic form and supplying oxygen to a seed on the promotion of seedling emergence and establishment will have to be examined.

Since the additive used as a source of ferrous iron was in sulfate form and contained SO_4^{2-}, which could be a source of sulfide (S^{2-}), bad seedling growth in treatment fe and FE may be due not only to ferrous iron but also to sulfide. Nojima and Tanaka[12] observed inhibition of germination and plumule elongation of paddy rice caused by sulfide contained in paddy field soil solution. Hirano and Sato[7] reported that sulfide contained in extract solution of soil inhibited elongation of plumule and seminal root. The harmful effect of sulfide on seedling growth was also observed in the present experiment. However, Nakayama[11] reported that influence of iron sulfide on germination was small. These sugest that sulfide in insoluble form is less harmful than that in soluble form and that effect of sulfide in treatment fe and FE was small because sulfide most probably existed in an insoluble form of iron sulfide.

Judging from the present experiment, ferrous iron seemed to be relatively more harmful than the other substances. Mixed coating of Calper and a substance which changes ferrous iron into insoluble form, potassium hexacyanoferrate(II) or potassium hexacyanoferrate(III), resulted in earlier seedling emergence and foliage leaf emergence, suggesting that ferrous iron was responsible for the inhibition of seedling emergence and establishment[6]. When rice seed is sown into flooded soil without Calper coating, the red-brown area, which is presumed to be iron oxide, is often observed in the soil surface above the seed. This suggests that a considerable amount of iron occurs around the seed. When this is taken into account, the importance of ferrous iron as an inhibiting factor of seedling emergence and establishment can be seen.

Additives contained Na^+ in sulfide addition (su and SU) and acetic acid addition (ac and AC) treatment. But even if all Na^+ was dissolved in soil solution, its concentration in each treatment was calculated to be no higher than 0.04% and 0.06%, respectively. The effect of Na^+ on seedling emergence can safely be ignored, since rice is very tolerant of salinity during germination[18]. However, the effect of Na^+ on seedling growth, though it is considered to be small judging from the concentration, can not be completely denied because rice is very sensitive to salinity at the 1- to 2-leaf stage[18]. The effect of substances produced in reductive paddy soil on seedling establishment needs to be more closely investigated in future research.

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* In Japanese. The title is translated by the present authors.

** In Japanese with English summary or abstract.

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