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Promotion of Seedling Emergence of Paddy Rice from Flooded Soil by Coating Seed with Potassium Nitrate

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Abstract : Emergence and establishment of seedling of paddy rice sown into flooded soil are poor but promoted when seeds are coated with O_2 generator CaO_2. It has been commonly understood that this is because CaO_2 supplies O_2 to the seed germinating in the anaerobic flooded soil. However, it is known that even in CaO_2-coated seed, emergence of foliage leaf is restrained unless O_2 is supplied from flooded water or air through coleoptile after seedling emergence.

The effect of seed coating with KNO_3, which generates no O_2 by itself but oxidizes soil, on emergence and establishment of seedling of paddy rice sown into flooded soil was investigated.

In KNO_3-coated seeds, emergence and establishment of seedling began earlier, and the percentage of seedling emergence and of foliage leaf emergence were higher than in non-coated seeds. KNO_3 showed much the same or a rather more conspicuous effect than CaO_2 at lower temperature.

These results suggest that the major cause of the poor emergence and establishment of seedling in paddy rice sown into flooded soil is not O_2 deficiency in flooded soil. Thus, whether O_2 supply to a seed is essential for, and why CaO_2 is effective for, promotion of emergence and establishment of seedling would have to be examined in further more details.

Key words : Calcium peroxide, Direct sowing, Foliage leaf emergence, Germination, Paddy rice, Pelleted seed, Pottassium nitrate, Promotion of seedling emergence.

硝酸カリウムの種子被覆による水稲の湛水土壌中からの出芽促進：萩原素之*・井村光夫（石川県農業短期大学）

要　旨：水稲種子を湛水土壌中に播種すると，出芽・苗立ちが不良となるが，酸素発生剤である CaO_2 を種子に被覆して播種した場合には出芽・苗立ちが促進される．これは，CaO_2 が嫌気状態の湛水土壌中で発芽している種子に酸素を供給するためと一般に理解されてきた．しかし CaO_2 を被覆した種子でも，出芽後は，鞘葉を通じて湛水中または空中から酸素が供給されなければ，本葉抽出が抑制されることが知られている．

本実験では，それ自身では酸素を発生しないが，土壌を酸化する KNO_3 の種子被覆が湛水土壌中に播種した水稲の出芽・苗立ちにおよぼす効果を調査した．

KNO_3 被覆種子では無被覆種子に比べて出芽・苗立ちが早まり，出芽・苗立ち率も高まった．KNO_3 の効果は温度が低い場合には，CaO_2 とほぼ同等ないし，むしろより顕著な傾向であった．

これらの結果は，湛水土壌中に播種した水稲の出芽・苗立ち不良の主要な原因は湛水土壌中の酸素不足ではないことを示唆している．したがって，出芽・苗立ちの促進に種子への酸素供給が必須かどうか，また，CaO_2 がなぜ出芽・苗立ちを促進するのかがさらに詳細に調査される必要があろう．

キーワード：過酸化石灰，出芽促進，硝酸カリウム，水稲，直播，発芽，被覆種子，本葉抽出．

Direct sowing of paddy rice into puddled and leveled soil (DIPPS)[7] is a new method of direct sowing. In the former method of sowing seeds onto the flooded soil surface, namely direct sowing in a flooded paddy field, seedling establishment was unstable because of floating seedling caused by a decrease in specific gravity of a plant during the period of germination and elongation of foliage leaf[13]. In DIPPS, seeds are sown into flooded soil at a depth of about 1 cm to prevent floating of seedling, and, as a result, lodging resistance is improved, which is also important along with seedling establishment for higher and stable yield. In this method, seeds coated with oxygen generator calcium peroxide (CaO_2), which promotes seedling emergence from flooded soil, are used.

It has been commonly understood that CaO_2 promotes seedling emergence by supplying O_2 to the seed germinating in the anaerobic flooded soil[3,15]. However, from an anatomical study revealing the developmental process of vascular system in rice seedling, the

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germination of CaO_2-coated seed was identified as that under anaerobic conditions[12]. And after seedling emergence, even in CaO_2-coated seed, a sufficient amount of O_2 supply to a seed from the flooded water or from the air over the flooded water through coleoptile is necessary for promoting foliage leaf emergence[13]. Our close observations on the oxidation-reduction state of the soil in the vicinity of CaO_2-coated seed made clear that seedling emergence was inhibited when local soil reduction occurred in the vicinity of the seed[8]. These results suggest that soil reduction is one of the major factors inhibiting emergence and establishment of seedling. We consider that an oxidizing effect of soil in the vicinity of a seed by CaO_2, to which no attention had been paid so far, is playing an important part in the mechanism of seedling emergence promotion by CaO_2. One of the aims of this experiment was to examine whether O_2 supply to a seed is essential for promoting seedling emergence of paddy rice from flooded soil. And the other was to examine whether O_2 supply to a seed before seedling emergence is essential for promoting foliage leaf emergence. For these purposes, whether KNO_3, which has soil oxidizing effect but no O_2 generating effect by itself, promotes emergence and establishment of seedling of paddy rice sown into anaerobic flooded soil was investigated.

Materials and Methods

Dormancy broken dry seeds of *japonica* paddy rice cultivar Kagahikari were coated with materials as shown in Table 1. CAL-88 is a seedling emergence promoter containing 16% of CaO_2. As potassium nitrate (KNO_3) could not be coated to seeds only by itself, gypsum, which is one of the ingredients of CAL-88, was used as a binding material. Oribin was also used in order that seeds could be coated easily. Oribin is a powdered rock which consists mainly of magnesium oxide and is mixed in Calper-A, one of seedling emergence promoters containing CaO_2. In KNO_3 and Oribin treatments, the same amount of gypsum as that in CAL treatment was used.

Coated seeds were produced by using a rotating basin whose base was attached to the drive shaft of an electric moter. The basin was set at an angle so that slow rotation of the basin produced a good movement of seeds, which were placed in the basin, creating a vortex. Seeds were placed in the rotating basin, and coating materials and small amount of water were sprayed onto the seeds little by little before drying at room temperature for one night.

Table 1. Coating materials.

Treatment	Materials (amounts*)		
Control	Non-coated		
CAL	CAL-88 (200)		
KNO_3	KNO_3 (20)	Gypsum (25)	Oribin (100)
Oribin	Gypsum (25)	Oribin (100)	

* Percentage to the dry seed weight.

Vats 330 cm² and 5 cm deep were used as sowing beds. Each vat was filled with 1 kg of dry paddy field soil and the soil was puddled 3 days before sowing. Based on the research into the course of disappearance of dissolved O_2 in flooded soil[5,13,17], 3 days are long enough for complete disappearance of O_2. Two vats were used for each treatment for replication and 100 seeds per vat were sown at a depth of 1 cm in the soil. The soil was kept to be flooded 1 cm deep after sowing, and emergence of seedling and of foliage leaf were investigated at 16°C, 20°C and 24°C under natural daylight in growth chambers.

Results

As shown in Fig. 1, seedling emergence began much earlier in KNO_3 and CAL than in Control and Oribin at lower temperature. This was because the days before the beginning of seedling emergence was more prolonged in Control and Oribin than in KNO_3 and CAL as the temperature declined. The emergence of the first leaf (Fig. 2) and the second leaf (Fig. 3) also tended to be earlier in KNO_3 and CAL than in Control and Oribin at lower temperature.

The reason for restrained seedling emergence and foliage leaf emergence in Oribin is not clear, but it seems that the hardness of the seed pellet is related to the reason. When materials without promotive effect on seedling emergence are coated to seed, the materials

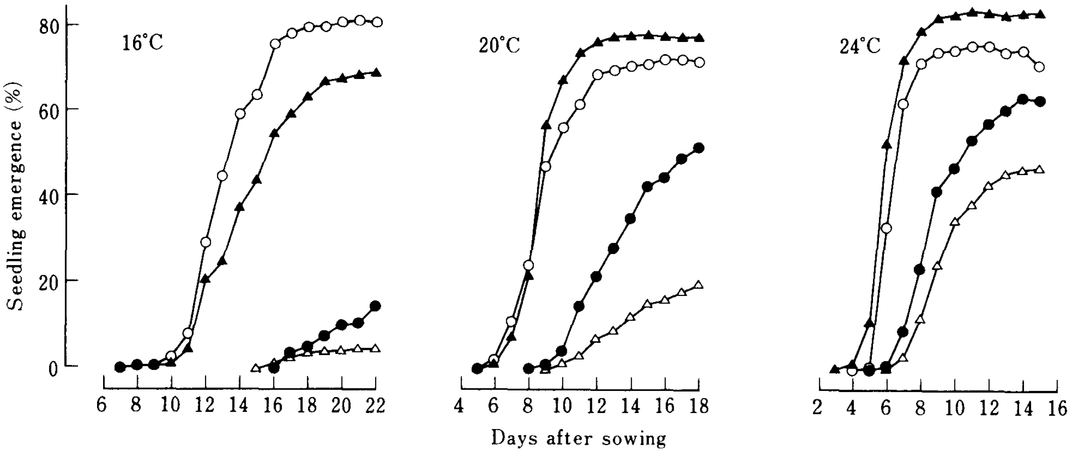

Fig. 1. Changes with time in the seedling emergence percentage.
● ; Control, ▲ ; CAL, ○ ; KNO_3, △ ; Oribin.

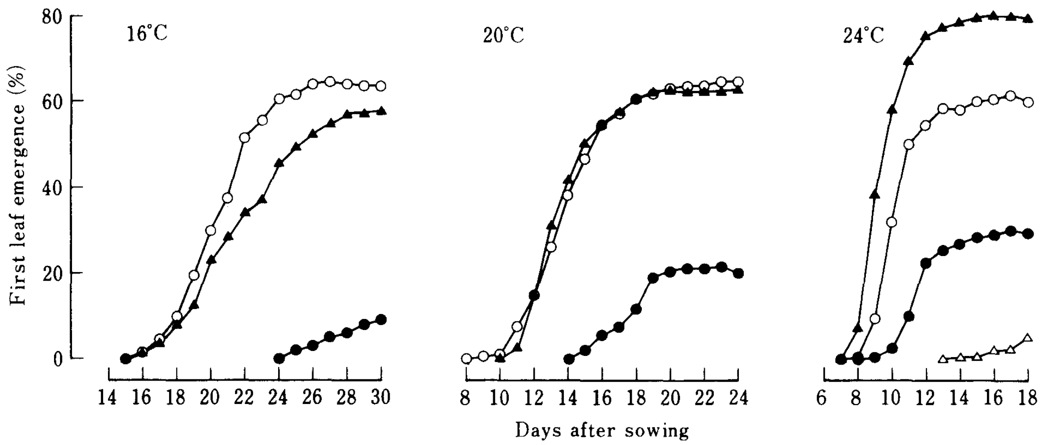

Fig. 2. Changes with time in the first leaf emergence percentage.
Symbols are the same as in Fig. 1.
Emergence of the first leaf was not observed in Oribin at 16°C and 20°C.

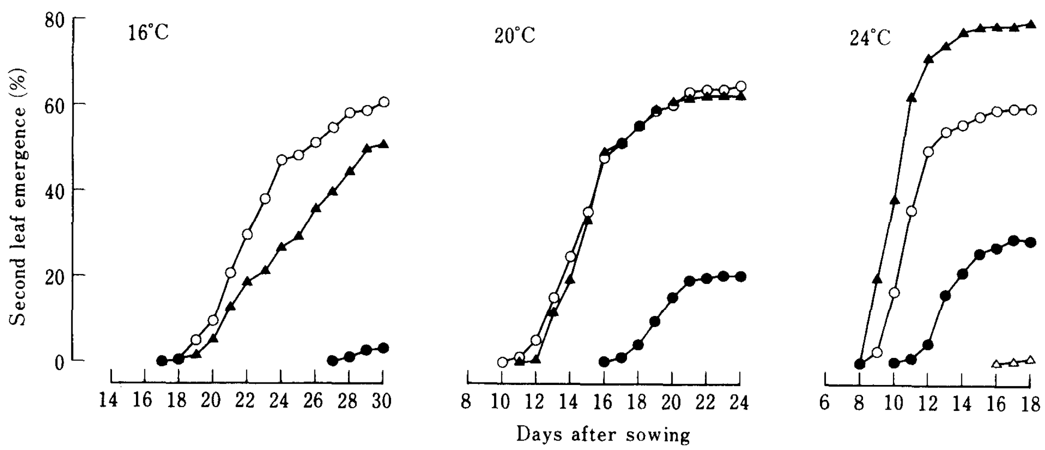

Fig. 3. Changes with time in the second leaf emergence percentage.
Symbols are the same as in Fig. 1.
Emergence of the second leaf was not observed in Oribin at 16°C and 20°C.

would be nothing but a physical obstacle to the elongation of coleoptile.

The final percentage of seedling emergence and foliage leaf emergence is shown in Table 2.

At 16°C, the percentage of seedling emer-

Table 2. Percentage of seedling emergence and foliage leaf emergence.

Temperature		Treatment				Days after
		Control	CAL	KNO_3	Oribin	sowing
16°C	Seedling emergence	14.5^b	68.5^a	80.5^a	4.5^b	22
	1 st leaf emergence	9.0^b	57.5^a	63.5^a	0.0^b	30
	2 nd leaf emergence	3.0^b	50.5^a	60.5^a	0.0^b	30
20°C	Seedling emergence	51.5^b	77.0^a	71.5^a	19.5^b	18
	1 st leaf emergence	20.0^b	62.5^a	64.5^a	0.0^b	24
	2 nd leaf emergence	20.0^b	62.0^a	64.5^a	0.0^b	24
24°C	Seedling emergence	63.0^{bc}	83.0^a	71.0^{ab}	47.0^c	15
	1 st leaf emergence	29.5^c	79.5^a	60.0^b	5.0^d	18
	2 nd leaf emergence	28.5^c	79.0^a	59.5^b	1.0^d	18

Values followed by a common letter within a row are not significantly different at the 5% level according to Fisher's LSD test.

gence and foliage leaf emergence were extremely low in Control and Oribin, while the percentage of seedling emergence and foliage leaf emergence exceeded 60% and 50%, respectively, in CAL, and 80% and 60%, respectively, in KNO_3.

At 20°C, in Control, though the percentage of seedling emergence exceeded 50%, that of foliage leaf emergence was very low; in Oribin, the percentage of seedling emergence was much lower than in Control, and foliage leaf did not emerge; in CAL and in KNO_3, the percentage of seedling emergence exceeded 70% and that of foliage leaf emergence 60%.

At 24°C, in Control, though the percentage of seedling emergence exceeded 60%, that of foliage leaf emergence was lower than 30%; in Oribin, foliage leaf emergence was very poor, while the percentage of seedling emergence was nearly 50%; in CAL and KNO_3, emergence of seedling and foliage leaf were promoted, with the tendency of a more conspicuous effect in CAL.

Thus, at every temperature, the percentage of seedling emergence and foliage leaf emergence were significantly higher in KNO_3 and CAL than in Control, except the percentage of seedling emergence in KNO_3 at 24°C. KNO_3 showed much the same or a rather more conspicuous effect than CaO_2 at 16°C and 20°C, but at 24°C CaO_2 was more effective. The tendency of higher percentage of seedling emergence and foliage leaf emergence at lower temperature in KNO_3 was in contrast to the other treatments.

Discussion

In our experiment using the same cultivar but varying the amount of KNO_3, 10% of KNO_3 coating had no clear effect on the final percentage of seedling emergence and foliage leaf emergence. However, emergence of seedling and foliage leaf in KNO_3 began earlier than in Control and Oribin, which was a fact also observed in the present experiment as shown in Fig. 1～3. On the other hand, in another *japonica* paddy rice cultivar Koshihikari, 10% of KNO_3 coating made emergence of seedling and foliage leaf earlier and higher in percentage[9].

From the present experiment and these results, it is clear that seed coating with KNO_3 can promote emergence of seedling and foliage leaf. As KNO_3 has soil oxidizing effect but no O_2 generating effect by itself, KNO_3 can not be an O_2 supplier to a seed in a direct way. And, as yet, O_2 generating reaction during the plant metabolism of nitrate reduction in darkness is not known. Therefore, if it is limited to the period before seedling emergence, when the plant is not illuminated, there would be next to no possibility of KNO_3 working as an O_2 supplier to a seed even in an indirect way. In conclusion, it can be stated as follows: O_2 supply to a seed may not be essential for promoting seedling emergence of paddy rice from flooded soil. And O_2 supply to a seed before seedling emergence also may not be essential for promoting foliage leaf emergence.

The understanding that CaO_2 promotes emergence and establishment of seedling by supplying O_2 to a seed seems to be based on the understanding that O_2 deficiency in the flooded soil inhibits germination and elongation of coleoptile and foliage leaf. Though it is a well-known fact that paddy rice can germinate well under O_2-less conditions[1,14,18] such as on the moist filter paper put in a moistened gas stream of N_2, it is not fully examined whether the germination is also possible in O_2-less flooded soil. However, our conclusions suggest that O_2 deficiency in flooded soil is not the major cause of the decline of emergence and establishment of seedling of paddy rice sown into flooded soil. It would be also suggested that O_2 supply to a seed may not be the only possible mechanism of emergence and establishment of seedling promotion by CaO_2. As for whether O_2 deficiency in flooded soil is the major cause for the decline of emergence and establishment of seedling, further confirmation will be demonstrated in our subsequent report.

Sugawara[16] observed that in several upland crops, germination and respiration activity during germination were promoted by soaking the seeds in nitrate solution prior to germinating them on the moist filter paper in air or in 1.5% O_2. There are many other reports on the promotive effect of nitrate on germination[2,4,10,11]. In this experiment, as water is sprayed to seeds during the seed coating operation, there may be a possibility that seed coating operation had an effect of seed priming treatment. However, the promotive effect of nitrate on germination was generally observed under existence of O_2, and, to our knowledge, promotion of germination under anaerobic conditions as this experiment is not known. We suppose that the mechanism known so far as for the promotion of germination by nitrate, such as promotion of respiration, dormancy breaking or seed priming effect, do not give full explanation to our results.

Previously, we reported that the flooded soil around the CaO_2-coated seed was locally oxidized until around germination[7], and that the percentage of seedling emergence was higher when the oxidized area was kept larger at about the time of germination[8]. Soil oxidizing activity of KNO_3-coated seeds could be verified easily and visually, likewise in previous reports[7,8], by sowing them into the reduced flooded soil to which 1 mgg^{-1} of methylene blue was added as an oxidation-reduction indicator. The performance of the soil oxidizing activity of KNO_3-coated seed was found to be different from that of CaO_2-coated one. In CaO_2 seed, only the soil around it was strongly oxidized[7], while in KNO_3 seed, the whole upper soil layer was weakly oxidized. This would be because of the difference in oxidizing power and diffusibility between O_2 gas and NO_3^- ion. As soil oxidation was observed to be an effect common between CaO_2 and KNO_3, at least a part of the promotive effect of KNO_3 on emergence and establishment of seedling would be most naturally attributed to soil oxidation.

Here, suppose that the length of period of coleoptile elongation in the soil before seedling emergence and the oxidation-reduction state of soil with which the coleoptile contacts during the period are related to the percentage of seedling emergence. The following explanations are then given for the difference in temperature response of promotive effect on seedling emergence between KNO_3 and CaO_2.

At lower temperature, as it is supposed that the coleoptile elongates slowly and that it needs longer time to emerge in flooded water, KNO_3, which oxidizes not only the vicinity of a seed but also the whole upper soil layer, becomes more effective. On the other hand, at higher temperature, as it is supposed that the coleoptile elongates quickly and that it needs shorter time to emerge in flooded water, CaO_2, which oxidizes soil strongly, becomes more effective. However, these hypotheses are to be examined in further research.

When all these discussions and the fact that the germination of CaO_2-coated seed is, from an anatomical viewpoint, anaerobic[12] are taken into consideration, it seems that the oxidation of soil around the seed rather than O_2 supply to a seed may be more important for the promotion of emergence and establishment of seedling by CaO_2. Examination of the mechanism of emergence and establishment of seedling promotion by CaO_2 from this new viewpoint will give a key to the further stabilization of emergence and establishment of seedling in DIPPS which are not totally stable[6] in cases where the soil is reduced.

References

1. Alpi, A. and H. Beevers 1983. Effect of O_2 concentration on rice seedlings. Plant Physiol. 71 : 30—34.
2. Alvarado, A. D., K. J. Bradford and J. D. Hewitt 1987. Osmotic priming of tomato seeds : Effects on germination, field emergence, seedling growth, and fruit yield. J. Am. Soc. Hortic. Sci. 112 : 427—432.
3. Baker, A. M. and W. Hatton 1987. Calcium peroxide as a seed coating material for padi rice. I. Requirement for and provision of oxygen. Plant Soil 99 : 357—363.
4. Bradford, K. J., J. J. Steiner and S. E. Trawatha 1990. Seed priming influence on germination and emergence of pepper seed lots. Crop Sci. 30 : 718—721.
5. Evans, D. D. and A. D. Scott 1955. A polarographic method of measuring dissolved oxygen in saturated soil. Soil Sci. Soc. Amer. Proc. 19 : 12—16.
6. Hagiwara, M., M. Imura and S. Mitsuishi 1986. Influence of extreme soil reduction on emergence and establishment of paddy rice directly sown into puddled soil. Hokuriku Crop Sci. 21 : 21—23.*
7. ———, ——— and ——— 1987. Oxidation-reduction state in the vicinity of the paddy rice seed sown into flooded soil. Japan. Jour. Crop Sci. 56 : 356—362.*
8. ———, ——— and ——— 1990. Local soil reduction in the vicinity of the paddy rice seed coated with oxygen generating chemicals in relation to germination and emergence. Japan. Jour. Crop Sci. 59 : 56—62.*
9. ——— and ——— 1990. The mechanism of promotion of seedling emergence from flooded soil in paddy rice by calcium peroxide. Japan. Jour. Crop Sci. 59 (Extra issue 1) : 66—67.**
10. Hendricks, S. B. and R. B. Taylerson 1972. Promotion of seed germination by nitrates and cyanides. Nature 237 : 169—170.
11. ——— and ——— 1974. Promotion of seed germination by nitrate, nitrite, hydroxylamine, and ammonium salts. Plant Physiol. 54 : 304—309.
12. Imura, M. 1986. Anatomical studies on the vascular system mainly of the mesocotyl in the seedling organs of rice and several other gramineous crops. Spec. Bull. Ishikawa Agric. Coll. 17 : 1—50.*
13. Mitsuishi, S. 1975. Study on the direct underground sowing in the submerging field of rice. Spec. Bull. Ishikawa Agric. Coll. 4 : 1—59.*
14. Nagai, I. 1916. Some studies on the germination of the seed of *Oryza sativa*. J. Coll. Agric. Imp. Univ. Tokyo. 3 : 109—159.
15. Ota, Y. and M. Nakayama 1970. Effect of seed coating with calcium peroxide on germination under submerged condition in rice plant. Proc. Crop Sci. Soc. Japan 39 : 535—536.***
16. Sugawara, T. 1955. Influence of nitrates on germination of seeds under oxygen supply of various concentrations. Proc. Crop Sci. Soc. Japan 23 : 295—296.*
17. Takai, Y. and T. Kamura 1966. The mechanism of reduction in waterlogged paddy soil. Folia Microbiol. 11 : 304—313.
18. Taylor, D. L. 1942. Influence of oxygen tension on respiration, fermentation, and growth in wheat and rice. Am. J. Bot. 29 : 721—738.

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