2-Chloroethylphosphonic Acid as Ethylene Releasing Agent for the Stimulation of Rice and the Inhibition of Wheat, Barley, Rye and Oat Coleoptile Growth*

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It is well known fact that ethylene usually acts as an inhibitor of growth. Recently, we⁴⁾ have reported that ethylene stimulates the growth of intact rice coleoptiles. This is the first demonstration that ethylene stimulates the growth of intact plants.

It is of interest to know whether 2-chloroethylphosphonic acid (CEPA, Ethrel) stimulates coleoptile growth of rice since it has been well demonstrated that this chemical produces ethylene^{1,7)}. It is also of interest to know whether ethylene stimulates coleoptile growth of other cereal species since ethylene stimulation of rice coleoptile growth seems to correlate with the phylogenetic adaptation of rice plants to the germination under submerged conditions.

MATERIALS AND METHODS

Seeds of lowland rice (including wild species), wheat, barley, rye and oat were soaked for 1 or 2 days in a lighted incubator at 30°C. Germinated seeds were selected for the uniformity of coleoptile length (1–2 mm) and planted on 0.95% agar prepared in a small test tube (20×35 mm) in the rate of 6 seeds per a tube. The tube was enclosed in a wide-mouth-bottle (34×85 mm and 115 ml in volume) with a glass cap. Vaseline was applied to the cap to avoid the escaping the gas from the bottle. Six ml of water or CEPA solution was enclosed in the bottle as shown in the fig. 1, so the plants which were planted on the agar in the

test tube did not touch to the CEPA solution directly and were exposed to the ethylene gas evolved from CEPA. Various concentrations of CEPA solution were prepared by diluting the stock solution (24% CEPA) with diionized water. The bottle was kept in the dark at 25°C for 3 days.

RESULTS AND DISCUSSION

Length of the coleoptiles as affected by CEPA are shown in figs. 1, 2, 3 and 4. As shown in fig. 2 CEPA stimulated the rice coleoptile growth in not only cultivated species but also in wild species, *Oryza sativa* f. *spontanea* and *O. sativa* v. *fatua*. On the other hand CEPA inhibited the growth of wheat, barley, rye and oat coleoptiles as shown in figs. 2, 3 and 4.

Goeschl, Rappaport and Pratt²⁾ have demonstrated that a sharp increase in ethylene evolution and in radial expansion occurs when the elongation of the etiolated pea epicotyle is mechanically impeded as it would be while emerging from the soil. Both the increase in endogenous ethylene and the resulting increase in diameter appear to be proportional to the amount of mechanical resistance and would therefore adjust the emergence force and mechanical strength of the seedling to the prevailing soil conditions.

We⁴⁾ have suggested that submergence of rice seedlings provides a similar stress with analogous consequence since Yamada⁶⁾ and Kefford³⁾ have reported that the elongation of rice coleoptile is proportional to the depth of water in which the rice seeds are submerged—the deeper the water, the longer the coleoptiles.

It would be quite suggestive that wheat, barley,

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Fig. 1. Effect of various concentrations of CEPA on the elongation of 'Tan-ginbozu' (dwarf rice) coleoptiles. Bar indicates 'Mean $\pm$ standard error'.

rye and oat are upland crops and cannot germinate in submerged conditions. CEPA did not promote the coleoptile growth in such plants and gave rather inhibitory effect. An unusual function of the gas in *Oryza* species may suggest that phylogenetic adaptation to the germination in submerged conditions was occurred in those plants.

Recently, Ohta and Nakayama⁵⁾ also reported that the elongation of second leaf sheath of a rice variety was promoted with 50 to 100 ppm of Ethrel (CEPA). Those results with present findings coincide the previous report⁴⁾ that the effect of ethylene is not restricted to the coleoptile; the elongation of the first and second leaf sheath is also promoted although not so dramatically as that of the coleoptile.

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Fig. 2. Effect of various concentrations of CEPA on the elongation of cereal coleoptiles. A: Rice (lowland rice)—1. Norin No. 8, 2. Blue stick, 3. Patnai 23, 4. Badshabhog, 5. *Oryza sativa* f. *spontanea*, 6. *Oryza sativa* v. *fatua*, B: Wheat, Barley, Rye and Oat—7. Rye Petkus, 8. Wheat Norin No. 8, 9. Wheat Norin No. 10 (dwarf), 10. Naked barley Shikoku No. 32, 11. Oat Zenshin. Bar indicates 'Mean $\pm$ standard error'.

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Fig. 3. Stimulation of lowland rice and inhibition of wheat coleoptile growth by CEPA. A: 'Tan-ginbozu' (dwarf rice). B: Wheat 'Norin No. 10. Germinated seeds were selected for the uniformity of coleoptile length (1-2 mm) and planted on 0.95% agar prepared in a small test tube. The tube was enclosed in a wide-mouth-bottle with a glass cap. Vaseline was applied to the cap to avoid the escaping the gas from the bottle. Six ml of water or CEPA solution was enclosed in the bottle; so the plants which were planted on the agar in the test tube did not touch to the CEPA solution directly and exposed to the ethylene gas evolved from CEPA. The bottle was kept in the dark at 25°C for 3 days.

Fig. 4. Stimulation of lowland rice and inhibition of barley coleoptile growth by CEPA. A: Lowland rice Norin No. 8. Left: Control, Right: CEPA 240 ppm. B: Naked barley Shikoku No. 36. Left: Control, Right: CEPA 2400 ppm. Method of CEPA treatment is same as that of fig. 3. Photographs were taken after the agar was removed from plants.

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〔和 文 摘 要〕

エチレンを生成する 2-chloroethylphosphonic acid によるイネ子葉鞘伸長の促進およびコムギ、オオムギ、ライムギ、エンバク子葉鞘伸長の抑制

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イネおよびムギ類の催芽種子を管瓶に入れた寒天に植え、管瓶をさらに、2-chloroethylphosphonic acid (CEPA, Ethrel) の種々の濃度の溶液を入れた広口瓶に封入した。広口瓶の蓋にはワセリンをぬり、CEPA より発生したエチレン・ガスが外にもれないようにした。このように幼植物は CEPA 溶液に直接接触せず CEPA より発生するエチレン・ガスによって処理された。

その結果、CEPA は野生種を含めて供試したイネ品種のすべてで子葉鞘伸長を促進したが、ムギ類ではコムギ、オオムギ、ライムギ、エンバクのすべてで子葉鞘伸長を抑制した。

土壌のような物理的ストレスに合うと、エンドウ芽ばえはその幼芽および幼芽フックを含む先端数mmのところから著しくエチレンを発生し、その作用で伸長が抑制され、茎が太くなり土壌の物理的障害をつきやぶって空中に出芽しようようになるという報告 (Goeschl et al; *plant physiol.* **41**: 877-884, 1966) と本実験および筆者らの既報 (Ku et al.; *planta.* **90**: 333-339, 1970) の結果とあわせて考えると示唆にとんでいる。水中に播かれたイネでは水圧が同様に物理的ストレスとして作用しているものと思われ、エチレンが抑制作用を示すムギ類はエンドウと同じく陸上作物で無酸素又は低酸素状態における抵抗性が弱く水中発芽がない事実をみると、種子発芽におけるエチレンの役割の重要性を示唆している。エチレンのこのイネに対する特異な作用はイネの水中発芽性と関係あるものと思われる。