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EFFECTS OF GROWTH SUBSTANCES ON COOL-TEMPERATURE SEEDLING VIGOR IN RICE[1]

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Abstract

Preliminary studies were conducted to determine the value of gibberellic acid (GA) and other selected growth substances as stimulants to seedling establishment of rice (*Oryza sativa* L). The response of various rice cultivars to these substances also was investigated.

The application of GA in water solutions by soaking the seeds increased germination rate and seedling height, and decreased root growth. A response was obtained with concentration of GA from 0.1 to 1000 ppm. Adequate seedling vigor was obtained at 10 ppm. Treatment of seeds for 12 hours gave approximately the same response as treatment for 24 or 48 hours. After treatment, and drying the seeds, a response persisted up to 30 days when germinated.

Ethylene enhanced growth but was less effective than GA. The combination of GA with Ethylene produced a response similar to GA alone. Kinetin was not effective on seedling or root development and naphthaleneacetic acid (NAA) retarded shoot and root development of all cultivars.

Differences were observed among cultivars in seedling vigor and their response to growth substances. In general, early maturing cultivars from California were more responsive to GA than cultivars from Arkansas, Louisiana, or Texas.

Identification and use of cultivars with good seedling vigor, and proper use of growth stimulating substances are useful approaches to improving stand establishment of water-sown rice under cold-water conditions.

Introduction

It is a standard practice in California to sow presoaked rice seed into about 15 cm of water. The fields are kept flooded to this depth until the crop is near maturity. Cold water temperature at rice sowing time delays stand establishment. The seedlings

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developed under water emerge in 12 to over 20 days depending on temperature. Vigorous seedlings, under cold water conditions exhibit more rapid and uniform germination and plant development (Rutger and Peterson 1972). A major goal for rice improvement in California is the development of cultivars with high yields that are resistant to lodging, mature early, and have good seedling vigor at cool temperatures. Most commercial cultivars grown in California show relatively good seedling vigor but further improvements are desirable.

The effect of plant growth substances on rice plants has been studied by many research workers in recent years (Murakami 1970; Ku *et al.* 1970; Hirada and Vegara 1971; Martin 1971; Williams and Peterson 1973; Ogawa *et al.* 1976; Paual and Mishrya 1976; Ries and Wert 1977; and Biswas and Choudhuri 1977), but their use to improve cool-temperature seeding vigor needs further study.

The present studies were initiated to determine the effects and possible value of plant growth substances as stimulants to seedling establishment in relation to cold tolerance.

Material and Methods

A series of experiments were conducted in the laboratory and the greenhouse at Davis, California, during July to December of 1977 using a temperature controlled growth chamber and a temperature controlled water bath in the greenhouse.

Three rice cultivars, Calrose, Calrose 76 and Italica Livorno were used in several experiments, Additionally, 14 cultivars from various U.S. rice producing areas were evaluated for seedling vigor response to gibberellic acid (GA) and several other growth substances.

GA concentrations of 0.1, 1.0, 10, 100, 1000 ppm and 0 ppm as a check were used in experiment one. Randomized complete block designs, with four replications of 20 seedlings for each treatment were used in the growth chamber and three replications of 100 seedlings for each treatment in the water bath.

The seedling height was measured after 15 days' growth at a constant 18C in darkness in a growth chamber. Temperature in the water bath ranged between 18–20C and water level was 15 cm, above the seeds.

In another experiment, a single concentration of 10 ppm GA, ethylene, napthaleneacetic acid (NAA) and kinetin were used to compare their effects on rice seedlings. Treatments were conducted both in the growth chamber and in the water baths.

For all experiments, the seeds were presoaked 2 hours in 1% sodium hypochloride solution (1 ml of 6% Chlorox to 100 ml of distilled water). The purpose was to reduce the effectiveness of germination inhibitors to produce more uniform germination as well as to reduce the incidence of water molds and other fungal contamination (Mikkelsen and Sinah, 1961). After 2 hours, the seeds were rinsed 3 times with distilled water and then soaked in various concentrations and lengths of time in solutions of GA or other growth substances.

Results and Discussion

I. Effects of GA on seedling shoot and root growth

The effects of various concentrations of GA on rice shoot and root growth in the growth chamber are shown in figure 1. Shoot response at 0.1 ppm was very small but from 1 to 1000 ppm the response was linear for all three cultivars. Calrose and Calrose 76, a short stature version of Calrose exhibited nearly identical responses to GA at all concentrations. Italica livorno, a cultivar with exceptional seedling vigor showed a similar but less rapid increase at concentrations from 1 to 1000 ppm. At this highest concentration, shoot length of all three cultivars was the same.

GA had an inhibiting effect on root growth. Again, Calrose and Calrose 76 were nearly identical in response and Italica livorno was similarly inhibited but with root lengths nearly double that of the other two cultivars.

Nanda and Kaur (1967), Singh and Darra (1971), and Sinha (1969) have reported shoot stimulation to rice from GA treatments. Digby and Waering (1966) attributed the increase size of seedlings both to a rapid increase in cell division and to cell enlargement. The reduced root length agrees with the findings of Salim and Todd (1968). Harada and Vergara (1971, 1972) investigated growth patterns and their responses to GA among tall and short lines of rice. They found that some, but not all, short-stature cultivars exhibited a greater response to GA than tall ones. They attributed observed differences to endogenous GA concentrations. Our results showing similar responses to tall Calrose and short Calrose 76 suggest no differences in endogenous GA levels of these two cultivars. However, the Italica livorno check treatment produced seedlings approximately the same height as the other two cultivars with 10 ppm GA. The possibility exists that Italica livorno, although tall, may have higher levels of GA naturally present.

Effects of the length of the GA soaking treatments at 10 ppm are illustrated in figure 3. A minimum of 12 hours was needed for treatment effectiveness. Results were similar for 12, 24, and 48 hour soaking treatments. Another experiment determined the duration of the effectiveness after soaking at 10 ppm for 24 hours and then allowing the seeds to dry for various numbers of days. Response of the treated seeds was nearly identical when germinated 1, 2, 5, and 10 days after treatment. A small decline in response was evidenced at 20 and 30 days after treatment, figure 3.

II. GA sources

There are (about 50) known gibberellins, all having the same basic ring structure. The previous experiment was done using aqueous solutions of pure crystalline gibberellin. A comparison was made between this source and a 10% active ingredient of Gibberellin A_3 produced and marketed by Abbott Laboratories. After adjusting for concentration differences, seeds of the cultivar Calrose were treated with concentrations of 0, 1, 10, 100 and 1000 ppm. Treated seeds were sown on the soil surface under 15 cm of water controlled at 18–20C. Shoot lengths were measured after 15 days. Results, shown in figure 4 indicate essentially identical responses from the two sources of GA. The

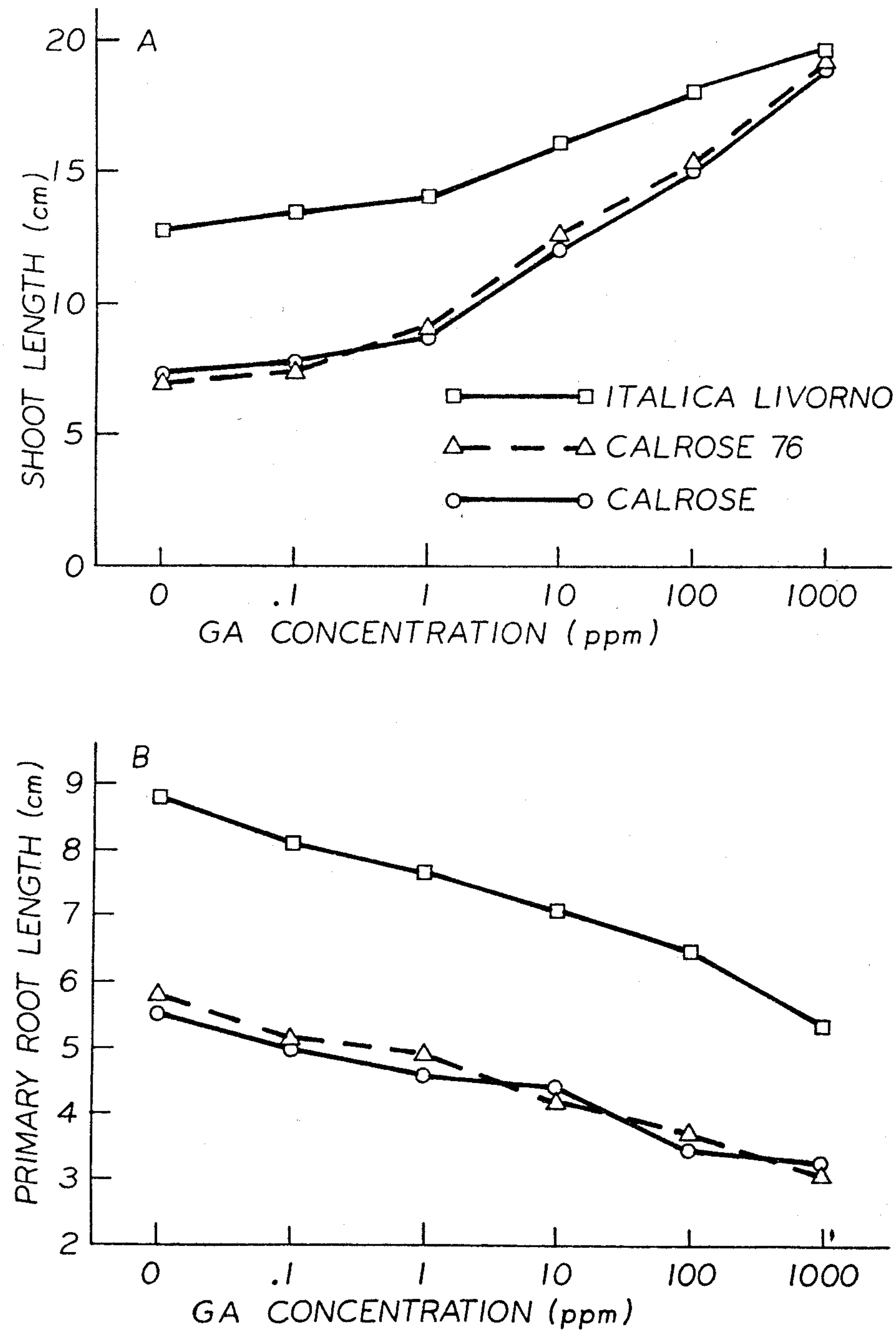

Fig. 1. Effect of various concentrations of GA on shoot length (la) and primary root length (lb) of 3 cultivars.

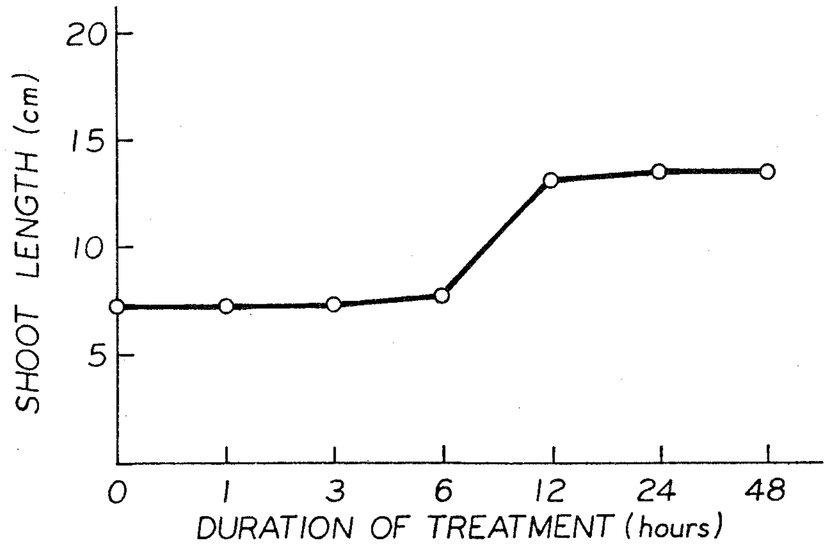

Fig. 2. Effect of the duration of presoaking with GA on shoot length of Calrose 76.

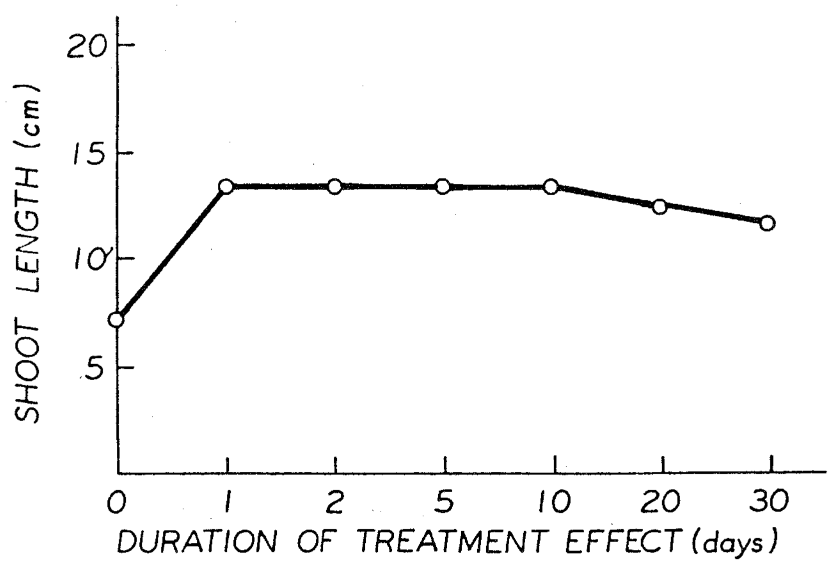

Fig. 3. Duration of GA treatment effects after drying the seed for various numbers of days before germination of Calrose 76.

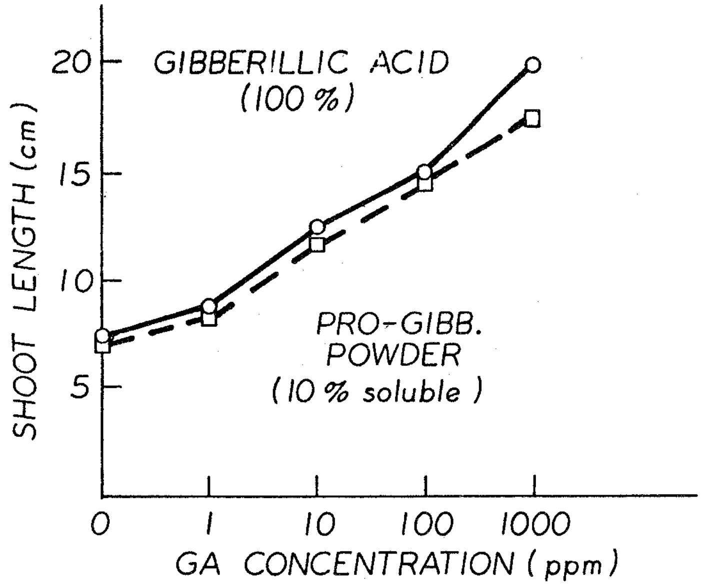

Fig. 4. Response of Calrose rice seedlings to two sources of GA.

response of seedlings grown under the cold water conditions were similar to those reported from the growth chamber.

III. Response of rice seedlings to various growth substances and combinations when seeds are sown under water

Seedling responses of rice to GA, ethylene, kinetin, and naphthaleneacetic acid (NAA) were investigated singly and in combination. Results were measured in terms of percent germination and shoot length. In this study, the treated seeds were sown in soil and covered to a depth of 5 mm. The sown seeds were then submerged in 15 cm of water controlled at 18–20C. Results were measured in terms of germination percentage and shoot length after 15 days in the water bath, table 1.

Fifty percent of the seeds of the check treatment germinated and the shoot length averaged 7.7 cm. GA treated seeds germinated 85.4% and had shoots averaging 20.1 cm. Ethylene treated seeds showed 70.5% germination and shoot length double that of the check but less than GA treated seeds. The combination of ethylene and GA was equivalent to GA alone. Kinetin showed a small increase over the check treatment both in germination and shoot length. NAA depressed germination and shoot growth. When kinetin and NAA were combined with GA, some improvement resulted over kinetin and NAA alone but less than GA alone.

A subsequent study compared GA treated and untreated seeds when they were sown immediately after treatment compared with allowing continued germination in the treatment solutions until shoots were from 1–3 mm in length. As in the previous experiment, seeds were covered with 5 mm soil plus 15 cm of water at 18–20C.

Table 1. *Effects of various growth substances and their combinations on germination and seedling growth of rice (Variety Calrose 76)*

Growth substances and combinations(1)	Germination %	Shoot Length cm
Check	50.1	7.7
GA	85.4	20.1
Ethylene	70.5	15.8
Kinetin	65.8	10.1
NAA	50.3	5.8
GA + Ethylene	84.2	18.7
GA + Kinetin	76.8	14.4
GA + NAA	66.7	10.8

(1) Seed were treated with 10 ppm for each growth substance previous to sowing.

The pre-germination treatment was slightly less than GA combined with pre-germination, and slightly better than GA alone as measured in terms of seedlings that survived. The check treatment had 50.1% survival compared with 85.4 to 95.2% for treated seeds, figure 5. These same treatments when measured by shoot length exhibitdd a substantial advantage to GA treatment as shown in figure 6.

IV. Response of U.S. rice cultivars to various growth substances

Table 2 shows the response of different U.S. cultivars to various growth substances. Shoot lengths of all cultivars were affected by GA treatment but the effect was greater on California cultivars than cultivars from the South. The effect of ethylene was less than GA. Kinetin had essentially no effect on seedling growth and NAA decreased seedling growth. Ku *et al.* (1970) reported that growth rate of the rice coleoptile was increased by low concentrations of ethylene, especially in oxygen concentration lower than that in the air. Carbon dioxide enhanced this response. Biswas and Choudhuri (1977) reported that kinetin increased growth and yield of rice and retarded senescence of leaves when applied at 3 different stages of growth. Paual and Mishrya (1976) found that IAA (similar action as NAA) had no significant effect on seedling growth.

Four of the 8 California cultivars had short stature (Calrose 76, M7, M9, and ESD 7) but their response to GA was no different than the tall ones. Cultivars from Arkansas, Louisiana, and Texas were less responsive than those from California. Our studies provided no evidence on the basis for differences in response among cultivars. The difference in endogenous gibberellins is a possibility.

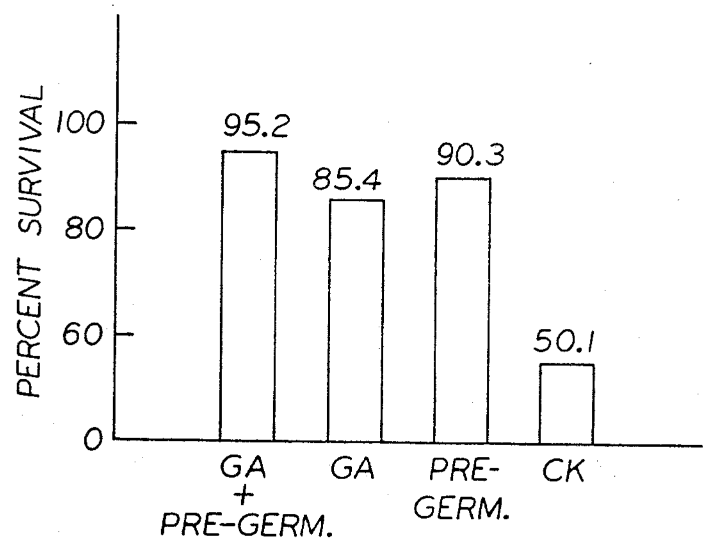

Fig. 5. Effect of GA alone and in combination with pre-germination on rice germination.

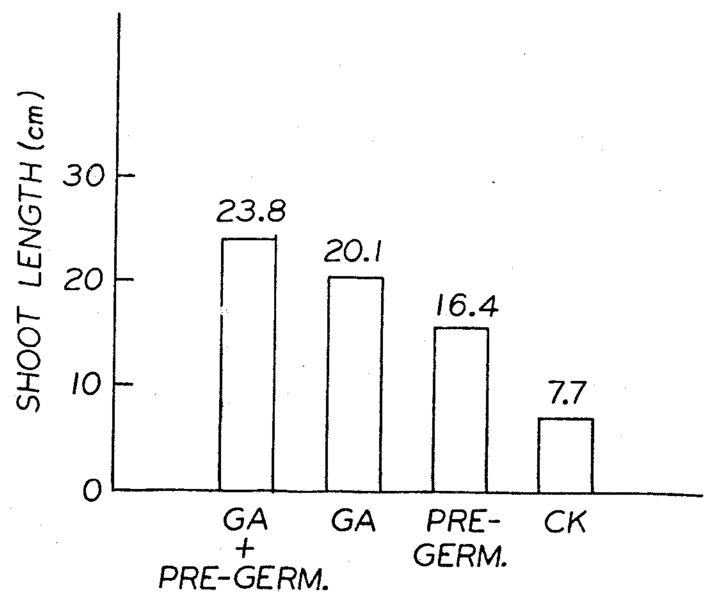

Fig. 6. Effect of GA alone and in combination with pre-germination on rice shoot elongation.

Table 2. *Effects of various growth substances on shoot length of 17 U.S. rice cultivars grown in the growth chamber.*

		Treatment (10 ppm)				
	Control		Ethylene	Kinetin		
	cm	cm	cm	cm	cm	
Calrose	10.0	13.6 (++)	11.2 (+)	9.8 (0)	7.1 (–)	California
Calrose 76	9.8	13.5 (++)	11.1 (+)	9.7 (0)	6.6 (–)	California
M–5	9.5	12.1 (++)	11.3 (+)	9.6 (0)	6.4 (–)	California
M–7	8.8	11.2 (++)	10.4 (+)	9.1 (0)	6.0 (–)	California
M–9	10.2	13.8 (++)	11.5 (+)	10.0 (0)	7.3 (–)	California
S–6	9.1	12.3 (++)	11.0 (+)	9.4 (0)	7.0 (–)	California
ESD–7	10.3	13.7 (++)	11.6 (+)	9.8 (0)	7.7 (–)	California
CS–M3	9.7	12.3 (++)	10.7 (+)	9.5 (0)	6.5 (–)	California
Nova 76	7.9	9.7 (++)	8.2 (+)	7.8 (0)	5.1 (–)	Arkansas
Bonnet 73	7.8	9.4 (+)	8.1 (+)	7.7 (0)	5.3 (–)	Arkansas
Nortai	7.9	9.5 (+)	8.3 (+)	7.8 (0)	5.2 (–)	Arkansas
Vista	7.4	9.8 (+)	8.0 (+)	7.5 (0)	5.4 (–)	Louisiana
Nato	7.5	9.9 (+)	8.2 (+)	7.4 (0)	5.1 (–)	Louisiana
Saturn	7.4	9.7 (+)	8.1 (+)	7.5 (0)	5.5 (–)	Louisiana
Labelle	7.0	9.5 (+)	8.4 (+)	7.1 (0)	5.6 (–)	Texas
Brazos	7.1	8.8 (+)	7.6 (+)	7.0 (0)	5.7 (–)	Texas
Lebonnet	7.0	8.6 (+)	7.5 (+)	7.2 (0)	5.3 (–)	Texas

Remarks: (++) = High response. (+) = Low response.
(0) = No response. (–) = Negative response.

V Relationship between agronomic characters and GA response

Plant charactets associated with GA response are shown in Table 3. In general, California cultivars had good cold tolerance and seedling vigor. They also showed a good response to GA. Cultivars exhibiting low cold tolerance usually had poor seedling vigor, and showed low response to GA. Cultivars from southern States, Arkansas, Louisiana and Texas generally showed low response to GA.

Varieties with short stature and early maturity usually showed high response to GA. This observation agrees with those of Murakami (1970) and Martin (1971).

Williams and Peterson (1973) reported genotypic differences in alpha-amylase activity and seedling development. They observed that low alpha-amylase activity levels in certain cultivars could limit their early seedling development, but the *indica* varieties were apparently limited in seedling growth less by alpha-amylase activity and starch hydrolysis than by subsequent metabolic process. In general, large and heavy seeds produce more vigorous seedlings and showed more response to GA. Osterli

Table 3. *Relation between plant characters of rice cultivars and GA response in the growth chamber.*

Cultivar	Origin	Plant type	Maturity period	Cold tolerance	Seedling[1] vigor	GA response
Calrose	California	Tall	Late	High	Medium	High
Calrose 76	California	Short	Late	High	Medium	High
M–5	California	Tall	Medium	High	Medium	High
M–7	California	Short	Late	High	Medium	High
M–9	California	Short	Early	Low	Low	High
S–6	California	Tall	Medium	Low	Medium	High
ESD–7	California	Short	Early	Low	High	High
CS–M3	California	Tall	Late	Low	Medium	High
Nova 76	Arkansas	Tall	Late	Low	Low	Low
Bonnet 73	Arkansas	Tall	Late	Low	Low	Low
Nortai	Arkansas	Tall	Late	Low	Low	Low
Vista	Louisiana	Tall	Late	Low	Low	Low
Nato	Louisiana	Tall	Late	Low	Low	Low
Saturn	Louisiana	Tall	Late	Low	Low	Low
Labelle	Texas	Tall	Late	Low	Low	Low
Brazos	Texas	Tall	Late	Low	Low	Low
Lebonnet	Texas	Tall	Late	Low	Low	Low

(1) Seedling vigor is used to indicate the overall ability of seeds to emerge their aerial parts from the soil (or water) in a sub-optimal environment (Heydecker, 1960, 1972).

(1972) compared rice cultivars with different mean seed size and seedling vigor at 18 and 30C and found that varieties with large seeds tended to produce more vigorous seedling at both temperature.

It was concluded from these studies that GA and possibly ethylene are promising substances that could be used on rice seed to improve stand establishment of water sown rice. These treatments would be most useful under conditions of low water temperatures. GA treatments may improve survival of seedlings in situations of silt deposition over the seeds after sowing. Cultivars differ greatly in their seedling vigor and response to GA. Field trials will be required to determine results under variable conditions and to determine if an economic advantage results.

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植物生長素對低溫下水稻秧苗生長勢之影響

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本試驗目的在評估 Gibberelic acid (GA)及某些植物生長素是否對促進水稻秧苗成活或生長有效，同時研究這些植物生長素對不同生殖質來源的稻品種是否有不同效應。

稻種子經 GA 溶液浸漬處理後可促進發芽速度及秧苗高度，但稻根發育有減低情形，GA 濃度在 0.1 至 1000 ppm 間對發芽及秧苗生長勢有影響，GA 在 10ppm 可促進適度秧苗生長勢，稻種子處理 12 小時之效果與處理 24 小時或 48 小時情形相同無太大差異，稻種子經處理 GA 後乾燥放置 30 天再發芽仍有效應即 GA 效果可維持一個月。

Ethylene 可促進水稻秧苗生長但其效果不如 GA 大，混合使用 GA 及 Ethylene 之效果與單獨僅使用 GA 效果相同 Kinetin 對水稻秧苗及根系發育並無效果 Naphthaleneacetic acid (NAA) 對所有稻品種之苗長及根系均有不良抑制作用。

稻品種間秧苗生長勢顯然有差異，不同品種間對植物生長素之反應亦不同，一般言之，美國西部加州稻早熟品種比美國南方德州稻晚熟品種對 GA 較有反應且效果亦佳。

尋求并利用優良稻品種之秧苗生長勢及選擇適宜的植物生長素，可有效改進低溫下水稻秧苗生長勢使其能成長正常。