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Gibberellic Acid Seed Treatment in Rice

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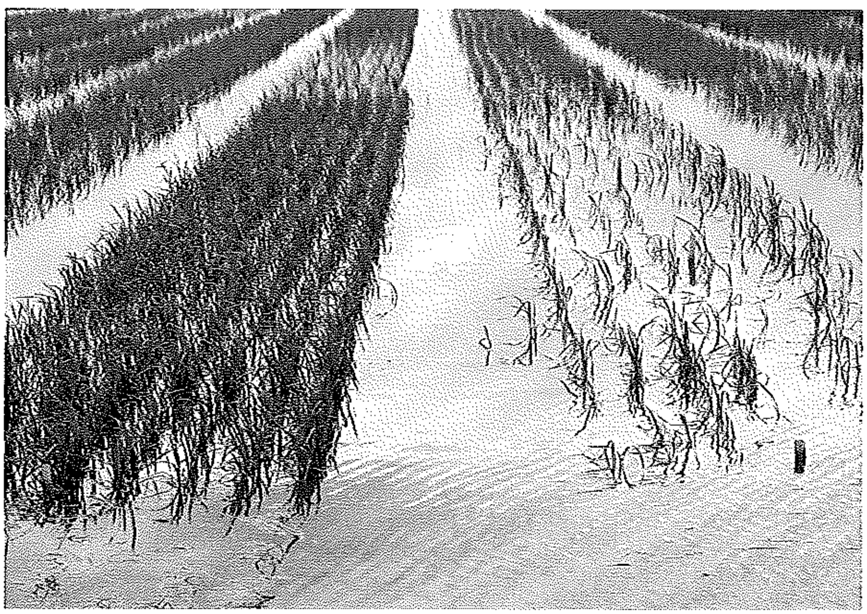

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Preface

Gibberellic acid (GA_3) was the first naturally occurring plant growth regulator (PGR) labeled for use on rice in the U.S. (as RELEASE, Abbott Laboratories, North Chicago, IL). This new area of PGR use in rice is due in large part to the research that is summarized in this bulletin. Dr. Dunand realized that semidwarf rice was responsive to gibberellic acid and conducted many of the fundamental studies necessary to demonstrate the feasibility of its use as a seed treatment for rice. These studies included experiments on the effect of GA_3 on stand establishment using different varieties, seeding depths, and seeding rates.

GA_3 is now profoundly influencing rice production in the southern United States. This bulletin describes the cultural and varietal problems related to emergence that needed to be addressed and provides the step by step approach leading to the use of GA_3 as a seed treatment. Dr. Dunand's pioneering work to demonstrate the use of GA_3 as a tool in U.S. rice production serves as an excellent example of how universities and industry can work cooperatively to provide safe and useful products to the agricultural community.

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Gibberellic Acid Seed Treatment In Rice

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Introduction

Varietal Differences

Seedling vigor is poor in many long-grain rice (Oryza sativa L.) varieties grown in the southern U.S. Comparisons consistently rate long-grain seedling vigor lower than medium-grain varieties (1). Current studies demonstrate poor seedling vigor in a majority of the seven most important long-grain varieties recommended to rice growers in Louisiana. As of 1991, 3 years of university test data for these seven varieties rated four varieties poor, two fair, one good, and no variety excellent.

A particular sub-group of long-grain varieties, the semidwarfs, developed specifically for their ability to resist lodging, exhibit the poorest seedling vigor. In a test of seedling vigor, the semidwarf 'Lemont' ranked fifth of seven long-grain varieties evaluated by the Emergence Index (2). Improving seedling vigor in semidwarf varieties is important due to their position in U.S. rice markets. Lemont was the most widely grown variety in the mid-South states of Arkansas, Louisiana, Mississippi, and Texas in 1989 and 1990. Semidwarf varieties accounted for more than 40% of the rice acreage those years (3,4).

Environmental Conditions

Adverse environmental conditions during germination and emergence impact all varieties. Rainfall in excess of 2 to 3 inches creates water-logged, oxygen-poor soil for seed planted below the soil surface. These low oxygen levels retard germination and emergence.

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Cool temperatures after spring planting slow the metabolic conversion of endosperm starch to sugars in the seed. These sugars fuel the germination and emergence processes, which are slowed by the reduced availability of those sugars.

Louisiana soils harden as they dry following soaking rains or surface irrigation (flushing). This crusting of the silt loam soils of southwest Louisiana and the heavy clay soils of central and northeast Louisiana impedes the emergence of seedlings.

Varieties that exhibit poor seedling vigor under ideal conditions are further disadvantaged by adverse environmental conditions. Poor seedling vigor is manifested in production fields by emergence that is slow and uneven. Slow emergence increases the chance of exposure to adverse environmental conditions and prolongs that exposure when it occurs. Thus, varieties that exhibit poor seedling vigor struggle longer and are less likely to overcome oxygen-poor soil, cool temperatures, and crusted soil.

Slow emergence also prolongs the period during which the germinating seed and seedling are most susceptible to soilborne diseases, reducing seedling density and producing weak, unhealthy seedlings (5).

Cultural Practices

Farmers engage in two cultural practices--shallow planting and repeat flushing--in an effort to assist the germination and emergence of varieties exhibiting poor seedling vigor. The practice of planting shallow (less than 1 inch below the soil surface) is an attempt to minimize the distance newly germinated shoots must travel to the soil surface to emerge as a seedling. Shallow planting minimizes exposure to oxygen-poor soil, minimizes the length of time the newly emerging seedling is dependent upon endogenous sugars for fuel, and minimizes the period of susceptibility to soilborne diseases. However, much less moisture is available in shallow soil than in deep soil, and shallow soil moisture is often inadequate for optimum germination.

In the absence of timely rainfall, the farmer provides adequate moisture for germination by flushing. (Flushing is surface irrigation accomplished by flooding then draining a field as quickly as possible.) Flushing, however, can cause crusting as the soil dries, requiring subsequent repeated flushing to soften the crust until emergence is complete. Flushing often leaves standing water in 'pot holes' in fields with uneven surfaces, leaving areas of water-logged soil. Rainfall after a flush can water-log an entire field. Seed in pot holes or whole fields of seed can rot. Also, pumping water to flush a field costs time and money.

Poor seedling vigor is manifested not only by slow but also by uneven emergence. In varieties that exhibit poor seedling vigor, some seedlings will have reached the 3- to 4-leaf stage as others only begin to emerge. This age difference continues throughout the growing season. Management decisions timed according to crop age, such as postemergence pesticide and fertilizer application, flooding, and harvest, are made more difficult and/or inefficient when crop age varies widely.

Uneven crop age may reduce milling yields. Optimum milling yields occur when grain moisture ranges between 18 and 21% (6). Grain harvested from an uneven crop may have significant portions of underripe (moisture too high) or overripe (moisture too low) grain.

Gibberellic Acid

Hastening and increasing elongation of newly germinated rice shoots decreases the time it takes the shoots to reach the soil surface, decreasing the chance and duration of exposure to adverse soil environment. Increasing shoot elongation also increases the depth to which seed can be planted, allowing planting to depths where moisture is adequate for germination. Flushing for germination or to relieve crusting is required less often, if at all. Increasing elongation reduces time to final stand, producing a crop of more uniform age. In these ways, increasing elongation of newly germinated rice shoots improves seedling vigor.

Elongation in germinating rice planted below the soil surface occurs in two structures, the mesocotyl and coleoptile. Their elongation pushes the shoot through the soil surface, at which time the seedling is said to have emerged. Poor stand establishment in semidwarf varieties has been related to short mesocotyl length (7).

Gibberellic acid has a striking effect on plant growth. Gibberellic acid increases elongation in grasses, resulting in longer than normal plant parts (8). Mesocotyl and coleoptile elongation have been shown to be increased by gibberellic acid (9). Certain semidwarf varieties respond to gibberellic acid (10), and gibberellic acid seed treatment has been shown to double stand (11).

The importance of improving seedling vigor in long-grain varieties is evident. Studies were conducted to determine the response of long-grain varieties and in particular Lemont, a semidwarf, to seed treatment with gibberellic acid. The effect of gibberellic acid on seedling vigor was measured as changes in emergence and stand establishment.

Materials and Methods

Experiments were conducted from 1987 through 1990. Standard commercial practices were used for dry seedbed preparation. Land was disced in early spring, disced again, then roller harrowed as final seedbed preparation before planting.

Plot management followed standard recommended practices for rice production (1). Fertilizer, 300 lb/A of 7-21-21 NPK with 1.2% zinc, was applied at planting. Propanil (Stam M4 - Rohm and Haas Co., Independence Mall West, Philadelphia, PA 19105) at 3 lb/A and thiobencarb (Bolero 8EC - Valent USA Corp., P.O. Box 8025, Walnut Creek, CA 94596-8025) at 2 lb/A were tank mixed and applied at the 2- to 3-leaf stage of rice for postemergence weed control.

Dry seed was drill-seeded into a dry seedbed using a small-plot grain drill. Plot size was 3.5 (6 rows on 7-inch row spacings) x 20 ft.

Seed was treated with RELEASE, a gibberellic acid seed treatment from Abbott Laboratories (1401 Sheridan Road, North Chicago, IL 60064) by dry-mixing seed and RELEASE in a jar mill. Seed was treated in 3-lb. lots to allow adequate mixing, and all lots were mixed for 5 minutes.

Gibberellic Acid Rate Study

The efficacy of gibberellic acid at different rates was studied in 1987, 1988, and 1989. Lemont seed was treated with gibberellic acid at rates of 0 (control), 10, and 100 ppm (mg gibberellic acid/kg seed). Seed was planted deep (3 inches) at a seeding rate of 100 lb/A (39 seeds/ft^2). The study was designed as a randomized complete block with four replications. Seedling density data were collected and, from it, various seedling vigor evaluations were made each year. Mesocotyl elongation data were collected in 1987 and 1988. Ten seedlings were selected at random from plots and mesocotyl length measured at 24 days after planting (DAP).

Planting Depth Study

The efficacy of gibberellic acid at different planting depths was studied in 1987 and 1990. Lemont seed was treated with gibberellic acid at 0 (control) and 10 ppm and was planted at a seeding rate of 100 lb/A. Two planting depths were used. Shallow-planting placed seed less than 1 inch below the soil surface. Deep-planting placed seed 3 inches below the soil surface and well into moisture adequate for germination and growth during emergence.

The experimental design was a randomized complete block with four replications. Treatments were arranged as a split plot where main plots were planting depths and subplots were gibberellic acid concentrations. The design facilitated independent water management of the main plots, which allowed flushing shallow-seeded plots without watering deep-seeded plots. Flushing shallow-seeded plots was necessary to initiate germination and remedy subsequent soil surface crusting. Shallow-seeded plots were initially flushed 1 day after planting and then several times over the next 2- to 3-week period. Deep-seeded plots were never flushed more than once and then only after emergence was complete. Seedling density data was collected and seedling vigor evaluated both years.

Seeding Rate Study

The efficacy of gibberellic acid at different seeding rates was studied in 1987 and 1990. Lemont seed was treated with gibberellic acid at 0 (control) and 10 ppm and was planted deep (3 inches). Two seeding rates were used, 50 and 100 lb/A. The experiment was designed as a randomized complete block with four replications and a factorial (2x2) arrangement of treatments. Both years, seedling density data were collected and seedling vigor evaluations were made.

Variety Study

In 1990, five long-grain varieties (Cypress, Gulfmont, Lacassine, Millie, and Texmont) were evaluated for response to gibberellic acid seed treatment. Cypress, Gulfmont, Lacassine, and Texmont are semidwarfs, while Millie is a short stature variety. Each of these varieties is generally similar to Lemont although Cypress, Lacassine, and Millie have slightly better seedling vigor. Also, Millie has a mature plant height 3 to 4 inches taller than Lemont. Seed of each variety was treated with gibberellic acid at concentrations of 0 (control) and 10 ppm. Seed was planted deep (3 inches) at a seeding rate of 100 lb/A.

Seedling density data were collected in 1990 for all five varieties. The five varieties were part of a larger study in which individual plots contained many varieties and experimental lines. To accommodate this larger study in the field, each variety/ experimental line was assigned a single specific row in a given plot. This precluded data analysis across varieties. Thus, data for each variety were analyzed separately. Experimental design was a randomized complete block with four replications.

Data and Evaluations

In the variety study, emergence counts were taken 24 DAP only and, for each variety, were taken from the center 10 feet of the single row containing that variety. No other seedling vigor evaluations were made.

In all other studies, seedling density was monitored over time from approximately 1 to 3 weeks post-planting. Emergence counts were begun at the first sign of emergence (coleoptile penetrating the soil surface). All emergence counts were cumulative. Counts were taken from the center 10 feet of the center two rows in each plot.

Three other indicators of seedling vigor were evaluated using the seedling density data. "Time to 50% emergence" is the number of days between planting and the emergence of half the final number of seedlings. It is determined retroactively once emergence is complete by plotting emergence counts versus time (days) and estimating to the nearest day the occurrence of 50% emergence. "Time to stand" is the minimum number of days between planting and the establishment of an agronomically satisfactory stand. Ten plants/ft^2 is considered the minimum average stand necessary for optimum crop productivity. Time to stand, taken from the same plot of counts vs. time, is the number of days from planting to emergence of 10 plants/ft^2.

"Emergence index" is calculated using a formula that considers both rate of emergence and final stand (12).

$$\text{Emergence Index} = \sum_{n=0}^{t-1} X_n(t-n)/t$$

where X_n = number of emerged seedlings on the nth count/number of seeds planted

n = number of count

t = total number of counts

Using this formula, emergence index can range from 0 (no emergence during period of evaluation) to 100 (100% emergence at the beginning of evaluation period).

In all four studies, mean separation was accomplished using the Duncan's multiple range test (P=0.05).

Table 1.--The effect of environment (year) and concentration of gibberellic acid, GA_3 (RELEASE), used as a seed treatment on seedling emergence of deep-seeded (3 in.) rice (Oryza sativa 'Lemont') over time; Rice Research Station, Crowley, LA

Year	GA_3 conc. (ppm)	Days after planting 10	12	15	24
		(plants/ft^2)			
1987	0	2b[1]	6d	9e	9d
	10	11a	16bc	19bc	19b
	100	10a	14c	16c	16c
1988	0	0[2]b	0[2]e	3f	8d
	10	0[2]b	1e	12de	18bc
	100	0[2]b	2e	12d	16c
1989	0	0[2]b	1e	2f	7d
	10	12a	19a	24a	25a
	100	12a	18ab	22ab	20b

[1] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.
[2] Statistical analysis was conducted taking into consideration the zero variance associated with the data.

Results and Discussion

Gibberellic Acid Rate Study

Gibberellic acid seed treatment significantly increased seedling emergence. The amount of increase was influenced by the environment, and the results presented in Table 1 show the significant interaction of environment and gibberellic acid seed treatment on emergence in Lemont rice. Due to cool, wet weather after planting, emergence in 1988 was delayed 5 days compared with emergence in 1987 and 1989. Even with the 5-day delay, without gibberellic acid seed treatment, final stands (24 DAP) were equivalent in each year. With gibberellic acid seed treatment, emergence was increased, and the greatest increase occurred in 1989. This is reflected in final stand. Final stand in 1989 was increased 3-fold over the control by gibberellic acid, and in 1987 and 1988, the increase was 2-fold. Environment also had a significant effect on gibberellic acid rate response. Although both the 10 and 100 ppm rates of gibberellic acid significantly increased seedling emergence each year, the 10 ppm rate produced significantly higher final stands in 1987 and 1989.

Seedling vigor evaluations using the previously discussed emergence data show a significant interaction between environment and gibberellic acid seed treatment on time to 50% emergence, time to stand (10 plants/ft^2),

Table 2.--The effect of environment (year) and concentration of gibberellic acid, GA_3 (RELEASE), used as a seed treatment on seedling vigor evaluations of deep-seeded (3 in.) rice (Oryza sativa 'Lemont'); Rice Research Station, Crowley, LA

Year	GA_3 conc. (ppm)	Time to 50% emergence (days)	Time to stand[1] (days)	Emergence index (r.u.)
1987	0	12c[2]	16[3]b	15d
	10	10d	10c	40bc
	100	9d	10c	34c
1988	0	16a	19[3]a	7e
	10	14b	15b	18d
	100	14b	15b	18d
1989	0	17a	---[3]	6e
	10	10d	9c	48a
	100	10d	9c	44ab

[1] Stand = 10 plants/ft^2.
[2] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.
[3] In some or all replications for a treatment, stands never reached 10 plants/ft^2, precluding calculation of time to stand. Consequently, the data were treated as missing data in the statistical analysis.

and emergence index (Table 2). In general, gibberellic acid reduced time to 50% emergence and time to stand, and environment significantly influenced the degree of reduction. Time to 50% emergence was reduced 3 and 2 days in 1987 and 1988, respectively. In 1989, the reduction was 7 days. Similar responses but larger reductions were noted in time to stand. In 1987 and 1988, time to stand was decreased 6 and 4 days, respectively. In 1989, without gibberellic acid, adequate stands (10 plants/ft^2) were not achieved. With gibberellic acid, time to stand was 9 DAP. The other seedling vigor parameter, emergence index, which favors fast emergence and good stands, was increased by gibberellic acid. As with time to 50% emergence and time to stand, environment significantly influenced the magnitude of the response to gibberellic acid. Emergence index was increased 2- to 3-fold in 1987 and 1988, and increased 7- to 8-fold in 1989. Although gibberellic acid affected all three seedling vigor parameters, the effect was independent of rate of gibberellic acid. Thus, gibberellic acid seed treatments at 10 and 100 ppm were equally affected by environment in the degree to which the two rates of gibberellic acid either reduced time to 50% emergence and time to stand or increased emergence index.

In the gibberellic acid rate study, mesocotyl elongation was evaluated in 1987 and 1988. There was a significant interaction between environment

Table 3.--The effect of environment (year) and concentration of gibberellic acid, GA_3 (RELEASE), used as a seed treatment on mesocotyl elongation of deep-seeded (3 in.) rice (Oryza sativa 'Lemont'); Rice Research Station, Crowley, LA

Year	GA_3 conc. (ppm)	Mesocotyl length (mm)
1987	0	28b[1]
	10	38a
	100	36ab
1988	0	11c
	10	17bc
	100	29ab

[1] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.

and gibberellic acid seed treatment (Table 3). In 1987, mesocotyl length was significantly increased by the 10 ppm rate of gibberellic acid, and in 1989, mesocotyl length was significantly increased by the 100 ppm rate. Although the 100 ppm rate in 1987 and the 10 ppm rate in 1989 increased mesocotyl length, the increases were not significant.

Planting Depth Study

Seedling emergence between 10 and 24 DAP was influenced significantly by the interaction of planting depth, environment, and seed treatment with gibberellic acid (Table 4). Due to slow initial emergence in 1987, stand at 10 DAP was low (≤3 plants/ft^2) and unaffected by planting depth or gibberellic acid. However, in 1990, gibberellic acid increased initial stand (10 DAP) by 25% at the shallow (<1 inch) planting depth and 5-fold at the deep planting depth (3 inches). The initial stand from deep-seeded rice treated with gibberellic acid was not significantly different from the stand from shallow-seeded rice, untreated or treated with gibberellic acid.

After initial emergence, increases in stand in shallow- and deep-seeded rice caused by gibberellic acid seed treatment were influenced primarily by environment and planting depth (Table 4). Due to significant interactions between environment and gibberellic acid, increases in stand by gibberellic acid at 12 and 15 DAP were 3-fold greater in 1990 compared with 4-fold greater in 1987. Significant interactions between planting depth and gibberellic acid on stand occurred at 12, 15, and 24 DAP. At the shallow planting depth, gibberellic acid had no significant effect on stand. In comparison, at the deep planting depth, gibberellic acid significantly

Table 4.--The effect of environment (year), planting depth, and seed treatment with gibberellic acid, GA_3 (RELEASE), on seedling emergence of rice (Oryza sativa 'Lemont') over time; Rice Research Station, Crowley, LA

Year	Planting depth (in.)	GA_3 conc. (ppm)	Days after planting 10	12	15	24
			(plants/ft²)			
1987	<1	0	3c[1]	13	28	28
		10	3c	12	26	26
	3	0	0[2]c	3	9	9
		10	1c	9	14	16
1990	<1	0	15b	24	28	28
		10	19a	26	30	27
	3	0	3c	7	10	9
		10	16ab	23	24	22
Year x GA_3 concentration						
1987		0		8c	18b	
		10		11c	20b	
1990		0		16b	19b	
		10		24a	27a	
Planting depth x GA_3 concentration						
	<1	0		19ab	28a	28a
		10		19a	28a	26a
	3	0		5c	9c	9c
		10		16b	19b	19b

[1] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.
[2] Statistical analysis was conducted taking into consideration the zero variance associated with the data.

increased stand 10 to 11 plants/ft². The ability of gibberellic acid to produce consistent increases in stand under different environmental conditions and at deep planting depths is agronomically desirable.

The three seedling vigor evaluations were each influenced differently by environment, planting depth, and gibberellic acid seed treatment (Table 5). Of the three, time to 50% emergence was significantly affected by the interaction between environment and planting depth (Table 5). Regardless of gibberellic acid seed treatment, in 1987, time to 50% emergence was the same at both planting depths, and in 1990, time to 50% emergence was significantly earlier at the shallower planting depth. With gibberellic acid seed treatment, time to 50% emergence and emergence index were significantly influenced by environmental conditions (Table 5), and time to 50% emergence, emergence index, and time to stand (10 plants/ft²) were significantly influenced by planting depth (Table 5). In 1987, time to 50% emergence and emergence index were unaffected by gibberellic acid. In

Table 5.--The effect of environment (year), planting depth, and seed treatment with gibberellic acid, GA_3 (RELEASE), on seedling vigor evaluations of rice (Oryza sativa 'Lemont'); Rice Research Station, Crowley, LA

Year	Planting depth (in.)	GA_3 conc. (ppm)	Time to 50% emergence (days)	Emergence index (r.u.)	Time to stand[1] (days)
1987	<1	0	12	43	12
		10	12	40	12
	3	0	12	12	19
		10	12	24	13
1990	<1	0	10	58	10
		10	9	61	8
	3	0	11	17	19
		10	10	52	9
Year x Planting depth					
1987	<1		12a[2]		
	3		12a		
1990	<1		10c		
	3		11b		
Year x GA_3 concentration					
1987		0	12a	28c	
		10	12a	32bc	
1990		0	11b	37b	
		10	10c	56a	
Planting depth x GA_3 concentration					
	<1	0	11b	50a	11b
		10	11b	51a	10b
	3	0	12a	15c	19a
		10	11b	38b	11b

[1] Stand = 10 plants/ft^2.
[2] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.

contrast, in 1990, favorable environmental conditions allowed gibberellic acid to significantly reduce time to 50% emergence and significantly improved emergence index. The decrease in time was 1 day, and the increase in emergence index was 50%.

In both years, the influence of planting depth was consistent. At the shallow planting depth, gibberellic acid had no significant effect on seedling vigor. In contrast, at the deep planting depth, time to 50% emergence was decreased 1 day, emergence index was more than doubled, and time to stand was decreased 8 days. These differences were significant.

Table 6.--The effect of environment (year), seed treatment with gibberellic acid, GA_3 (RELEASE), and seeding rate on seedling emergence of deep-seeded (3 in.) rice (<u>Oryza</u> <u>sativa</u> 'Lemont') over time; Rice Research Station, Crowley, LA

Year	GA_3 conc. (ppm)	Seeding rate (lb/A)	Days after planting 10	12	15	24
			(plants/ft²)			
1987	0	50	0[2]c[1]	2	5	5
		100	0[2]c	3	9	9
	10	50	0[2]c	3	6	8
		100	1c	9	14	16
1990	0	50	0c	1	3	2
		100	1c	4	6	6
	10	50	4b	8	10	9
		100	9a	17	19	17
Seeding rate						
		50				6b
		100				12a
GA_3 concentration						
	0					6b
	10					12a
Year x GA_3 concentration						
1987	0			3c	7c	
	10			6b	10b	
1990	0			2c	4c	
	10			13a	14a	
GA_3 concentration x Seeding rate						
	0	50		2c	4c	
		100		4bc	7b	
	10	50		5b	8b	
		100		13a	17a	

[1] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.
[2] Statistical analysis was conducted taking into consideration the zero variance associated with the data.

Seeding Rate Study

There was a significant interaction between environment, gibberellic acid seed treatment, and seeding rate on initial emergence (Table 6). As previously noted, initial emergence was late in 1987. The result was emergence of no more than 1 plant/ft² and no effect on emergence by seeding rate or gibberellic acid. Initial emergence in 1990 was increased significantly by gibberellic acid, and the effect doubled as seeding rate doubled. At the low seeding rate, gibberellic acid increased initial stand 4 plants/ft², and at the high seeding rate, the increase was 8 plants/ft².

Following initial emergence, environment and seeding rate, independently, significantly interacted with gibberellic acid to affect stand (Table 6). At 12 and 15 DAP, there was a greater increase in stand from gibberellic acid in 1990 than 1987. In 1990, gibberellic acid increased stands an average of 10 plants/ft^2 at 12 and 15 DAP, respectively. In 1987, the increases were no greater than 3 plants/ft^2. In addition, increases in stand resulting from increasing seeding rate from 50 to 100 lb/A were greater with gibberellic acid. Without gibberellic acid, increasing seeding rate increased stands 2 and 3 plants/ft^2 at 12 and 15 DAP, respectively. With gibberellic acid, the increases were 8 and 9 plants/ft^2, respectively. At the completion of emergence, final stand (24 DAP) was influenced primarily by seeding rate and gibberellic acid (Table 6). On average, increasing seeding rate from 50 to 100 lb/A and treating seed with gibberellic acid each effectively doubled final stand.

Seedling vigor as denoted by 50% emergence was altered by seeding rate. By increasing seeding rate from 50 to 100 lb/A, a small but significant decrease of 1 day in 50% emergence occurred (Table 7). The effect of gibberellic acid on seedling vigor as denoted by 50% emergence, time to stand (10 plants/ft^2), and emergence index was influenced by environment (Table 7). In 1990, the environmental conditions resulted in gibberellic acid having more pronounced effects on 50% emergence, emergence index, and time to stand (10 plants/ft^2) than in 1987. In 1990, time to 50% emergence and time to stand were significantly decreased 2 and 3 days, respectively, and emergence index was significantly increased 4-fold by gibberellic acid. In 1987, gibberellic acid had no significant effect on time to 50% emergence, time to stand, and emergence index. Inherent increases in seedling vigor caused by raising seeding rate were improved by gibberellic acid (Table 7). Without gibberellic acid, at the 50 lb/A seeding rate, time to stand did not occur during the 24-day observation period. (Final stand at 24 DAP was less than 10 plants/ft^2.) In comparison, increasing seeding rate to 100 lb/A caused time to stand to occur at 13 DAP. With gibberellic acid, time to stand at the 50 lb/A seeding rate was 14 DAP, making the treatment equivalent to the 100 lb/A seeding rate without gibberellic acid. Increasing seeding rate to 100 lb/A with gibberellic acid decreased time to stand to 11 DAP. This was an 3-day improvement compared with the 50 lb/A seeding rate with gibberellic acid. A similar improvement in emergence index was noted. Increasing seeding rate from 50 to 100 lb/A raised emergence index 7 units. With gibberellic acid, the corresponding increase in emergence index was 17 units.

Table 7.--The effect of environment (year), seed treatment with gibberellic acid, GA_3 (RELEASE), and seeding rate on seedling vigor evaluations of deep-seeded (3 in.) rice (Oryza sativa 'Lemont'); Rice Research Station, Crowley, LA

Year	GA_3 conc. (ppm)	Seeding rate (lb/A)	Time to 50% emergence (days)	Time to stand[1] (days)	Emergence index (r.u.)
1987	0	50	12	---[3]	7
		100	12	12[3]	13
	10	50	13	---[3]	10
		100	12	12	24
1990	0	50	13	---[3]	3
		100	12	14[3]	10
	10	50	11	14[3]	18
		100	10	10	38
Seeding rate					
		50	12a[2]		
		100	11b		
Year x GA_3 concentration					
1987	0		12a	12[3]b	10bc
	10		12a	12[3]b	17b
1990	0		12a	14[3]a	7c
	10		10b	11c	28a
GA_3 concentration x Seeding rate					
	0	50		---[3]	5c
		100		13[3]a	12b
	10	50		14[3]a	14b
		100		11b	31a

[1] Stand = 10 plants/ft^2.
[2] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.
[3] In some or all replications for a treatment, stands never reached 10 plants/ft^2, precluding calculation of time to stand. Consequently, the data were treated as missing data in the statistical analysis.

Variety Study

Of the five varieties tested, all but one had a significant increase in final stand due to seed treatment with gibberellic acid (Table 8). Texmont had the largest increase in stand (5-fold). Smaller but statistically significant increases in stand for Cypress, Gulfmont, and Millie ranged between 30 and 75%. Stand of Lacassine was increased 40%, but due to a high degree of variability, the increase with Lacassine was not significant.

Table 8.--Rice (Oryza sativa L.) variety seedling vigor response (stand at 24 DAP) to seed treatment with gibberellic acid, GA_3 (RELEASE), and deep seeding (3 in.) in 1990; Rice Research Station, Crowley, LA

GA_3 conc. (ppm)	Variety				
	Cypress	Gulfmont	Lacassine	Millie	Texmont
	(plants/ft^2)				
0	7b[1]	9b	9a	14b	3b
10	11a	16a	13a	19a	16a

[1] Means followed by the same letter in a column are not significantly different at P=0.05 according to the Duncan's multiple range test.

Conclusions

Seed treatment with gibberellic acid as RELEASE can dramatically increase emergence, stand, and seedling vigor of deep-seeded semidwarf rice drill planted into a well-prepared seedbed under late spring conditions in southwest Louisiana. The effect is, in part, through promotion of elongation of the mesocotyl. In the semidwarf variety Lemont, gibberellic acid can be equally effective in such disparate concentrations as 10 and 100 ppm (mg gibberellic acid/kg seed). Since the labeled rate of gibberellic acid as a seed treatment is 22 to 44 ppm, there is a safe window for application error without diminishing efficacy. Also, at a seeding rate of 100 lb/A, a concentration of 44 ppm gibberellic acid represents 0.07 oz/A. Due to this low usage rate and the natural occurrence of gibberellic acid, the environmental impact of gibberellic acid in rice is negligible.

In a late spring environment, seeding rate can be reduced and planting depth increased by gibberellic acid. Seed treatment with gibberellic acid can be equivalent to 50 lb seed/A at planting under favorable environmental conditions. Under unfavorable conditions, the equivalent could be less than 50 lb/A. Date of planting, seedbed status, and anticipated environmental conditions after planting would dictate the amount of reduction in seeding rate with seed treated with gibberellic acid. Reducing seeding rate could more than offset the material and application costs associated with the seed treatment. In addition, gibberellic acid can allow planting as deep as 3 inches, which will allow planting to depths where moisture is usually adequate for germination and growth during emergence. This can reduce early season water use associated with flushing, also economically beneficial.

Of overall major significance is the ability of seed treatment with gibberellic acid to increase rate of emergence and, consequently, promote quicker establishment of an adequate stand (10 plants/ft) in semidwarf long-grain rice dry planted in late spring. The faster the crop is established, the lower the chances are that unfavorable environmental conditions and disease will adversely affect germination, emergence, and seedling growth. Emergence enhanced by gibberellic acid can promote an earlier and more uniform rice crop. The earlier the crop is established, the earlier the crop can be harvested, increasing the potential for ratoon production. Uniformity in the crop increases the effectiveness of fertilizer and pesticide applications and other management practices based on growth stage of the crop. A uniformly growing crop can be flooded evenly and is more likely to have optimum grain quality due to uniformity of maturity at harvest.

Grain yield could be increased by gibberellic acid when suboptimal stands (<10 plants/ft^2) are increased to adequate stands (10 plants/ft^2) by the seed treatment. In this case, the yield increase would be due to gibberellic acid improving stand.

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