TRRF Report on 2004 Research

Physiological Bases for Texas Rice Ratoon Crop Management

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Funding provided: $35,000
Objective 1. Determine if an increase in ratoon yield that is often associated with low cutting height of the main crop is a result of: a) a decrease in shading due to removal of upper vegetative material and wind-rowed straw, b) a relative increase in photosynthetic capacity of the developing ratoon crop, c) a progressive removal of inhibition that is caused by the presence of upper growth on the main crop stems, and/or d) a more optimal proportion of tillers near the base of the plant with good supporting resources and a longer developmental period.

Progress and Results 1.
A low cutting height of the main crop, especially with a tool providing a sharp cut and pulverizing action such as a flail mower, stimulates ratoon crop yield. If we can establish the mechanisms for this benefit, then we might be able to find alternative, less expensive ways to achieve the same benefit. Furthermore, we need to be prepared to rationally coordinate other ratoon yield enhancement treatments and management schemes with the beneficial flail mowing treatments if we are to achieve 6000 pounds per acre ratoon yields.

During the past season, we were able to narrow the list of possible mechanisms by which flail mowing benefits ratoon crop yield. What follows is a series of small arguments.

i. Flail mowing of the main crop was conducted in two different ways in a research-plot study in 2004. For some plots, the grain was harvested by combine as usual. A flail mower quickly followed, with a 2” cutting height. In other plots, the grain was not harvested and the whole plant, including the grain, was cut down to 2” with the flail mower. Ratoon stand was much poorer for those plots in which the grain was not harvested first, therefore a low cutting height obtained with a flail mower does not guarantee the good ratoon stand that is needed for good ratoon yield. Instead, several possible factors can explain this difference in stand. The additional straw is physically or chemically inhibiting the ratoon crop growth, or the extra material that has to be mowed is preventing an efficient chop by the flail mower, and either the presence of the relatively large pieces of the straw or the duller cut of the stalk are somehow inhibiting the ratoon crop growth. Very vigorous genotypes, such as XL-7, were more able to grow out of the stand inhibition resulting from cutting the entire plant. This weakly suggests that the inhibition is not due to a duller cut of the stalk because a physical injury of the plant would usually result in a proportional decrease in the potential yield rather than a setback to the vigor.

ii. In another research-plot study conducted in 2004, the entire plants, including grain, were flail mowed, but three different cutting were used – 2, 4 and 6 inches. The plots cut at 6” had much better ratoon stand, and the stand of the 4”-cut plots was somewhat better than the 2”-cut ones. These results suggest that a chemical inhibition due to the presence of the extra straw was probably not a factor because the differences in the mass of vegetation cut were much less than the differences in resulting stand. What was probably happening in this study was that the 6” height was tall enough to be above the mat of straw. Supporting the conclusion that the inhibition is not chemical are the results obtained by
producers indicating that a low cutting height with the flail mower stimulates ratoon crop yield. A low cutting height means more straw and thus potentially more chemical inhibition, but the opposite results are being obtained, thus chemical inhibition seems unlikely whether through direct release of some chemical from the straw or indirectly through increased substrate for microbial action leading to low oxygen conditions in the flood water.

iii. The above two studies also allow us to suggest that yet another possible explanation of the advantages of flail mowing is not likely to be a major factor. The possible explanation was the removal of an inhibitory signal sent down the stem from the panicle (this inhibitory signal can prevent new tiller development), the more stem that was removed then the more inhibitory signal that was removed. This scenario seems unlikely for the above studies because 1) when the 2” cutting height was used for cutting both the whole plants and the harvest residue, then the results were quite different although the amount of inhibitory signal that was removed was the same, 2) when the cutting height was varied but the whole plant was cut, then the stand was better with the somewhat taller cutting height (6”), but the amount of inhibitory signal removed would have been somewhat less, so these results are contrary to the hypothesis that removal of an inhibitory signal is a major advantage to flail mowing.

iv. From these preliminary results, the primary advantages of flail mowing for ratoon yield appear to lie in the system, namely a clean low cut with a good chop so that mainly basal tillers are formed (basal tillers typically form a larger panicle but take longer to develop). The good chop helps prevent straw matting and wind-rowing which can either physically inhibit the developing tillers or can shade them excessively. The clean cut minimizes any harm to the tillers, and also provides a uniform cut to the field. Uniformity indirectly benefits yield in several ways – by allowing relatively good uniformity in grain at harvest, this means less greens or over-mature grain, and better timing of agrochemical treatments and other management practices because of the better uniformity of plant development.

v. Some tentative conclusions can be drawn concerning the use of flail mowing following harvest of the main crop as a tool for enhancing ratoon crop yield: 1) if a 6” cutting height performs as well as a 2” or 4” height, then the 6” height would be preferred because it is more tolerant against possible inhibition due to straw matting; 2) because neither chemical nor physiological (inhibition signal) inhibition appear to be a major factor corrected by flail mowing, then agrochemical treatments or management schemes that encourage vigorous growth of the developing ratoon tillers would be complementary to the benefits from flail mowing; and 3) the advantage of the low cutting height is probably physiological, but the advantage of using the flail mower to achieve the low cutting height is probably in its ability to minimize the matting. The results from the 2004 flail mowing studies did not allow us to determine if the matting primarily caused shading or a physical inhibition of tiller growth.

**Economic Analysis 1.** The economic advantages of a low cutting height have been estimated previously by McCauley and Turner and Jund. The economic advantages of
using a flail mower to achieve the low cutting height rather than cutting low with the
combine will come from several factors: 1) increased efficiency of main crop harvest
because the higher cutting height means less trash, 2) a disadvantage due to an extra pass,
in this case with the flail mower, 3) an advantage due to the better chop/pulverization
achieved by the flail mower. This appears to be the main advantage because it decreases
straw matting and allows better ratoon stand. I’m going to estimate this at a minimum of
1000 lbs/A, 4) some possibility of decreased chemical or water use due to increased
uniformity of the ratoon crop, but I’m assuming that this is not applicable with the current
practices being used; 5) an improved milling quality due to increased uniformity of grain
maturation due to increased uniformity of the ratoon stand (part of the increased
uniformity is due to the low cutting height and not the flail mowing per se), and 6) there
will be an advantage due to the amenability of the flail mowed fields to use of
management schemes, including fertility, and PGR treatments to push the ratoon crop for
good vegetative growth. The only factor I’ve put a number on at this point is increased
yield. At $7/cwt and 10 cwt/A increase and $10/A decrease for extra pass and 80,000
acres (40% on average of Texas acres ratooned, and 200,000 acres of rice), then a rough
estimate of economic advantage to Texas rice producers is $4.8 million.

Next Steps in Research 1. Document the ratoon crop yield advantage of flail mowing of
main crop at 6” cutting height vs. 6” cutting height achieved by combine. Do this for
popular cultivars. Assess the effects of PGRs and management schemes to promote early
vegetative growth of the ratoon crop.

Objective 2. Evaluate a gibberellin treatment applied to the ratoon crop soon after stand
has been re-established for ability to encourage rapid growth of the young ratoon tillers
with possible benefit of rapid canopy closure and increased yield. (This objective was
modified to focus on the identification of plant growth regulators and management
schemes to enhance ratoon tiller numbers, and thus stand.)

Progress and Results 2. Most of the acreage in Texas is planted in varieties with good
ratoon potential, thus the limitations in consistent ratoon stand are likely to be due to an
interaction of environment and physiology. The bases for early, vigorous and uniform
ratoon stand establishment were addressed because there are indicators that large yield
improvements can be made at this stage.

Are there agrochemical or management schemes that can potentially increase the number
of ratoon tillers? We know from our research in the previous years that the gibberellic
acid treatment can stimulate the vigor of ratoon tillers once they have initiated (see
objective 3), but it doesn’t do any good to stimulate the vigor of the ratoon tillers unless
they are there in the first place.

Yes, there are agrochemical or management schemes that can increase the number of
ratoon tillers. In 2004 and previous years, we’ve identified a number of treatments that
can stimulate ratoon tiller number. This is the area for which we probably made the most
exciting progress during this last year. Our ability to find a number of ways to increase
tiller number is indicative that we are gaining an increased understanding of the limitations to tiller establishment, which is important to ratoon stand establishment and yield.

There are several points of evidence for this claim:

i. As mentioned under Objective 3, gibberellic acid treatment significantly increased ratoon tiller number (doubled) in one research plot study. Gibberellic acid is the plant growth hormone, and is usually used as a PGR for increasing plant growth, not for starting new growth. There are situations, however, where it can force a tiller bud to break out of a certain kind of dormancy.

ii. Benzyladenine nearly doubled the number of ratoon tillers in a replicated research-plot study. Benzyladenine is present in several PGRs, and is known as the plant branching hormone.

iii. TIBA, (triiodobenzoic acid), another commercially available PGR, significantly stimulated the number of basal ratoon tillers relative to those higher up the stem. The basal ratoon tillers are usually preferred because they make larger panicles as long as they have time to mature.

iv. An increase in the amount of sunlight available to the base of the ratoon plants significantly increased the number of ratoon tillers in one research-plot study. The increase was achieved by placing white plastic under the rows to reflect light back off of the soil. Other colors of plastic did not increase the number of ratoon tillers.

v. In the study above, a specific red color of plastic inhibited the number of ratoon tillers. This strongly suggests the involvement of something called the phytochrome system, which is a hormonal kind of response in plants that is triggered by changes in the sunshine due to shading by green leaves. The red plastic mimicked the effect of this kind of shading based on how the plant responds physiologically. The inhibition of tillering due to shading from green leaves has been observed in other kinds of grasses.

vi. In a greenhouse study of two years, we decreased the amount of UV light that the rice plants received. The number of tillers was decreased when the UV was decreased below normal. Low UV light triggers another kind of hormonal response in plants that happens naturally when plants are shaded by green leaves. When we want the ratoon tillers to initiate and develop early before harvest of the main crop, then we are sometimes asking them to grow in the shade of the main crop growth. Plants like to grow new branches in the light not in the shade, and have developed mechanisms to inhibit this kind of development. We want the tillers to develop because we know we will give them their sunshine fairly soon, but we have to fight against these natural plant mechanisms. The use of PGRs to stimulate new tiller development is one obvious way of fighting back. These PGRs that we know can stimulate ratoon tiller production act against these mechanisms (like the shading effects involving phytochrome and low UV light). Because shading is not the only factor that can inhibit tillering, but is likely to trigger a similar chain of events in the plant leading to the tiller inhibition as the other factors, when we can identify these environmental inhibitory factors then we are also identifying
specific mechanisms of inhibition that we know something about because of these common chains of events among inhibitory mechanisms. This gives us good clues about what PGRs to use and when to further improve upon the set of identified PGRs or management schemes to improve the consistency and earliness of ratoon stand, which is a primary limiting factor to achieving ratoon yields in the 6000 pounds per acre range.

vii. Two more PGRs that are not normally used for this purpose significantly increased ratoon tiller numbers (from 30 tillers per row-foot of the non-treated to 40-42 tillers per row-foot) in a research-plot study this year. Both of the PGRs, if proven to be efficacious, are likely to be economically beneficial because of their low chemical cost and potential to be tank-mixed with other chemicals already being applied at the appropriate developmental stage.

**Economic Analysis 2.** We should be able to achieve ratoon yields of at least half that of the main crop. This last year, the average ratoon yield was about 39% of the average main crop yield (Jim Stansel. 2004 – Texas Rice Crop Statistics), then we are at about 80% of the minimum ratoon to main crop yield that we should be able to achieve. Although a number of factors in ratoon cropping can be improved, we know that a prominent factor for improvement is the ratoon stand. Assuming the adoption of other practices that might help improve ratoon stand, we might still need to address the physiological limitations to stand, such as those identified by manipulating the light environment as mentioned in the studies above, and likely to be important as suggested by the ability of the PGR treatments to improve stand. If we can improve ratoon tiller count an average of 25% (to account for the 80% of the minimum ratoon to main crop yield ratio), then we would expect a yield increase of about 600 pounds per acre. Assuming that the PGRs are fairly inexpensive (they are commercially available) and can be applied with other treatments (the timing for this should usually work), then the rough estimate of the economic advantage of these PGRs to improve ratoon stand is [(7/cwt X 6 CWT/A) - $15/A application] X 80,000 acres (40% on average of Texas acres ratooned, and 200,000 acres of rice), then a rough estimate of economic advantage to Texas rice producers is $2.1 million.

**Next Steps in Research 2.** Need to repeat some of these studies. Start optimizing rates, timing, and tank-mixing potentials of the potential PGRs. Testing compatibility with gibberellic acid and other treatments that primarily act to promote vigorous growth. In the case of the management schemes, make sure we understand the physiology being influenced. Obviously, the use of the plastics and UV- levels are research tools not production management tools, but because these environmental factors cause a chain of physiological events that encourage or discourage ratoon tiller initiation, then there does exist PGR (plant hormones) options that can alter the chain of events to our benefit. The Plant Physiology project seems to be closing in on a set of tools for improving ratoon stand, but we need to keep working on making this set more robust.

**Objective 3.** Facilitate the transfer of a specific PGR treatment (Gibberellin at several days post-flowering) to the producers through a) additional large-field testing, and b) a
second season of testing this PGR treatment on the most common varieties in use in Texas.

**Progress and Results 3.** Can a gibberellic acid treatment be applied before main crop harvest to stimulate early growth of ratoon tillers so that they will be “up-and-running” by main crop harvest? This ensures that the ratoon crop will be as early as practically feasible for the particular field. This is important for two reasons: 1) any delay in maturation of the ratoon crop can cause a lot of greens at harvest (the grain simply doesn’t mature if the weather gets too cold), and 2) getting an early ratoon stand can increase the potential yield. This is because the sooner the ratoon crop fills the spaces between the plants, then the sooner the crop can maximize the capture of the sunlight falling on the field. Maximum capture of the sunlight means more photosynthesis by the field, which means more carbohydrates and reduced nitrogen are available to fill the panicles.

Yes, a gibberellic acid treatment can be applied before main crop harvest to stimulate early growth of ratoon tillers, resulting in increased ratoon yield without loss in main crop yield or either crop’s grain quality, and with net economic benefit to the producer.

There are several points of evidence for this claim:

i. Several years of study have indicated that ratoon yield can be increased significantly by about 500 pounds per acre when a gibberellic acid treatment is applied to the main crop at a rate of 3 to 5 grams of active ingredient (a.i.) per acre starting several days after peak flowering. Cocodrie ratoon yields have been increased to this extent in approximately half of the studies conducted, with significant yield increases seen at Beaumont and Eagle Lake. In the studies for which no significant yield increase was observed, there was often a natural explanation. For example, in one study fungal diseases of the ratoon crop overwhelmed our ability to detect yield differences.

ii. Significant increases in yield, again of approximately 500 pounds per acre, have been seen in other genotypes. The testing of the response of the genotypes has been more limited with respect to number of studies. In particular all of the research plots at the main site (Beaumont) for this study in 2004 were destroyed by a funnel cloud that occurred soon before harvest of the main crop (see figure). Indications are that the same gibberellic acid treatment regime will result in significant ratoon yield increases for those cultivars and hybrids with a more vigorous growth habit and otherwise healthy for ratooning. The yield increases have been seen for XL-7 and XL-8, in addition to Cocodrie.

Example of extensive lodging in Physiology plots due to funnel cloud in late July 2004

iii. The gibberellic acid treatment significantly increased the length of ratoon tillers when
measured shortly before harvest of the main crop. Measurements were made on four tillers per plant on plants obtained from similar positions within the plots. This indicates that the gibberellic acid treatment accelerated growth of the ratoon tillers.

iv. In another study, significantly more stems of the gibberellic acid-treated plots had ratoon panicles compared to non-treated plots when measured one month after main crop harvest.

v. In one study, the gibberellic acid treatment significantly increased the number of ratoon tillers (49 per row-foot vs. 26 for the non-treated). Although this increase in tiller number was not a likely explanation for an increased ratoon yield in the study (because 26 tillers per row-foot might have been adequate), the study nonetheless indicates the ability of an appropriately timed gibberellic acid treatment to increase ratoon tiller development.

vi. The large-field testing has been difficult to summarize neatly. There have been a number of studies conducted in different parts of the Texas Ricebelt and on different cultivars and in different seasons, but I have no solid data from these large-field tests to say that the treatment works. The most difficult part is getting a good measure of yield for the various treatments. There are several producers who believe that it is beneficial.

**Economic Analysis 3.** A combination of factors allow us to suggest that the treatment can be of economic benefit. One is the low cost of the treatment of about $1-2 per grams a.i. with 3 to 5 grams applied per acre. The gibberellic acid treatment is appropriate for tank-mixing with stinkbug treatments. At $7/cwt and 5 cwt/acre, then the net profit is at least $25/acre. Given that no adverse effects are known, and that the treatment cost is low, the treatment is economically justified. At the above values, if 80,000 acres (40% on average of Texas acres ratooned, and 200,000 acres of rice) are ratooned, then the net benefit to Texas rice producers can be $2 million per year.

**Next Steps in Research 3.** This treatment is not of enough economic benefit to be applied by itself, but it has promise to be tank-mixed and applied with stink-bug treatments that are often applied during grain filling. The Plant Physiology project needs to be teaming up with the Entomology project to test these tank-mixes. In addition, the research to date has focused on optimizing the gibberellic acid treatment at the several-days post-flowering period. We need to optimize the rates for when the compound is applied during grain filling, and perform this for the common cultivars used in Texas rice production.

**Additional objectives addressed:**

**Objective 4.** Analyze rice response to seasonal high nighttime temperatures to determine how to maximize grain set and fill.

**Progress and Results 4.**
In the Texas ricebelt during a typical growing season there is always a possibility that temperatures will be high enough to hurt yield. This is especially true if the temperatures are high during sensitive periods of plant development. The sensitive periods are when
the various parts of the flower are starting to form, that period during flowering and right after this when the self-pollination occurs and grains start to form by seed set, and to a lesser extent during grain filling when the quality of the grain can be hurt. Based on literature from Asian rice research, the main effects are probably due to high night temperatures. This is because the sensitive reproductive events usually occur at night. The mechanisms by which heat stress causes losses in grain yield and quality in cultivars and environmental conditions common to Texas were examined in initial studies. Understanding the mechanism is necessary for efficient development of new genotypes, management schemes, or agrochemical treatments to address the situation.

How to avoid losses in main crop yield due to periods of high temperature? To understand the effects of high nighttime temperatures, we needed to be able to measure rice plant response under a realistic range of nighttime temperatures, while not also changing other environmental factors at the same time (otherwise any results we obtained might be due to the change in the other variable and not the temperature). The Plant Physiology project designed and constructed a novel way of heating the plants with near-continuous adjustment to precisely maintained temperatures at whatever regime for the day/night pattern that we wanted. All of this was done without enclosing the plants in any sort of chamber, thus avoiding any change in humidity or light. The apparatus has been used in several small studies this season. We are in the process of accumulating replicated datasets and are keeping the apparatus in continuous use.

**Economic Analysis 4.** Temperatures in the Texas ricebelt do not get high enough to decrease yield every year, but sometimes do. Assuming this happens once in five years, and that the average yield loss is 10% (different areas will be influenced differently and development varies within fields and even on the individual plants). Assuming all this, then, an average annual loss across the Texas rice belt would be about $1.8 million. These agrochemical treatments are commercially available, and would only be applied to limited acreage in certain years, so the overall average annual application costs would be fairly small.

**Next Steps in Research 4.** The Plant Physiology project needs to continue these studies, so that we can understand the mechanisms involved. This knowledge will influence the direction we take to develop applications to minimize yield and quality losses. We’ve just gotten the system up-and-running this past season.

**Objective 5.** Focus on evaluation of potential plant growth regulators to minimize inhibition of seed set and related rice plant responses to stress.

**Progress and Results 5.** A common way by which an environmental stress can lead to a decline in yield or quality is through disruption of the plant’s ability to deliver food (also called the photosynthate or sugars or reserves) to the developing grain. This is also commonly seen when stresses cause poor development of other plant parts, for example tillers. The most likely weak link in the system for delivering photosynthate to the developing grain or other plant parts was examined for its role in yield response to stress. Simultaneously, potential plant growth regulators with ability to alter the activity of the
putative weak link were evaluated. If we are correct that this is the weak link, then an agrochemical treatment specifically addressing it would be useful until the breeding for cultivars with less susceptibility could catch up.

An environmental stress or, for that matter, any kind of stress affects rice yield or quality through a certain chain of events. For example, heat stress is possibly altering the activity of a particular biochemical function that needs to stay in a certain optimal range to allow the delivery of the photosynthate (food) to a developing plant part. If this activity is altered just at the wrong time, for example by high nighttime temperatures for four or five nights in a row right during peak flowering, then there is a good chance that the photosynthate that is needed to supply the setting seeds will not be adequately provided and the final yield will be poor because of low grain number. The situation might not be so different for insect damage or disease in which the leaves might be destroyed (thus destroying the ability to photosynthesize) or the vessels carrying the photosynthate (sugars) from the leaves to other parts of the plant is blocked or otherwise disrupted. There is always a chain of events, but, especially in the case of environmental stresses, which are relatively invisible compared to insects and diseases, the challenge is to know what the chain is. We need to know this so that we can home in on an improvement strategy, hopefully first by developing some sort of agrochemical treatment or management scheme until a targeted varietal improvement program can be carried out. This is why the Plant Physiology project has typically tried to examine potential agrochemical treatments from the onset of a study, so that not only can we use them as research tools to manipulate the plant response to a stress (which helps us tear into the mechanism quickly), but we can also move them, or a cousin compound, along toward application as quickly as possible if they act in a beneficial way for crop yield or quality.

There is a biochemical function that looks like it might be a weak link in rice plant response to a number of environmental stresses. This is because it has a central role in delivery of photosynthate to growing plant parts. During this last season, we initiated several studies examining the role of this particular biochemical function and the effects of certain chemical compounds that can influence its activity. Two of the three compounds, if efficacious, would be likely to be economically feasible to use in commercial production. The other compound would not be economical, but can give us clues about what a cousin compound with commercial potential might look like.

**Economic Analysis 5.** The argument here is essentially that of Economic Analysis 4. For Objective 5, the Plant Physiology project is trying to build a set of PGRs that can help prevent yield or quality loss due to certain environmental stresses, including high nighttime temperature stress. The other stresses that we are concerned with include the heat stress during grain filling as it affects grain quality, and ratoon tiller initiation, but I’m going to hold the estimate at $1.8 million per year for the Texas rice producers until we are able to demonstrate results for these other stresses.

We thank the Texas Rice Research Foundation for their support.