PLANTING & STAND ESTABLISHMENT

Tillage

Tillage contributes significantly to rice production costs, time, and effort, including equipment investment and operating costs (Espino et al., 2021). So, it is important to have a good grasp of the objectives of tillage, which include,

- Drying of soil
- Loosening of the soil to allow for subsequent land smoothing operations and application of preplant fertilizer
- Forming a uniform seedbed free of large clods
- Destruction of growing weeds
- Aeration to hasten decomposition of residue
- Release of nutrients in organic matter
- Burial of crop residue to reduce disease inoculum and keep floating residue from accumulating and suppressing crop growth

Typical tillage involves one or two passes with a chisel plow, one pass with a stubble disc, and another pass with a finish disc. Sometimes

soil will be very cloddy and require extra work to break down large clods. Fields should be laser leveled with a dual GPS scraper, as necessary. On non-leveling years, a triplane is used to maintain the ground level. After discing and leveling, a corrugated roller is used prior to flooding and planting. The final seedbed in a rice field does not have to be as fine as for direct seeding of row crops, and by comparison is quite coarse. More important is the uniformity of the surface so that there are no off-grade high and low spots and large clods do not protrude from the water after flooding.

Chiselplow. Many growers rely on heavy chiselplows as the first ground breaking operation in the spring. The chisels are usually mounted on a spring or have a coil configuration which helps lift the soil. Some are rigid chisels and penetrate slightly deeper and produce a more cloddy surface. Chisels have a lifting action and the objective is to loosen, aerate and dry the ground. Drying is important to facilitate subsequent ground work, to allow air to get in pore spaces, and to avoid destruction of soil structure which may be damaged by heavy equipment working on wet soils. Subsequent operations depend on dry soil, so it is important to allow adequate time for drying before proceed-

Figure 1. Fall chisel plow operation incorporating rice straw (left), and typical chisel shank (right).

Figure 2. Heavy-duty single offset disc, called a stubble disc, for use in fall straw incorporation (left). Lighter versions with smaller blades are used for spring tillage. On the right, a schematic overview of a typical single offset disc.

ing. A chisel shank and chiselplow operation are shown in Figure 1.

Discs. Heavy single offset discs are usually used after chiseling to work deeper and mix crop residue with the soil. Such discs have a rigid mainframe that supports two gangs of disc blades that operate at an angle to the direction of travel so that they penetrate the soil and roll it (Figure 2).

The front gang is set to cut in the opposite direction of the rear gang. The round blades may vary from 28” to 32,” and may have smooth or scalloped edges. This operation is important to continue drying the soil, facilitate soil contact for residue decomposition and to prevent residue from rising to the surface where it may be a problem.

One or two passes each with a stubble disc and finishing disc are usually necessary. These operations also destroy growing weeds to prevent them from getting a head start on the crop. As air enters the pore spaces, organic matter begins to decay more rapidly, which results in conversion of nutrients from their organic forms to mineral forms, called mineralization. Greater availability of nutrients, particularly nitrogen, is an important benefit of tillage. Rice soils which never dry and aerate are generally less fertile.

Plowing

Deep tillage with a moldboard plow (Figure 3) or disc plow is less commonly used because of higher cost and disturbance of the smoothness of the field. However, plows may be useful because they invert the soil and can completely bury residues and weed seeds. They also, however, leave the ground very rough and possibly out of level. Since they cut deeply, plows are not appropriate in fields with shallow surface layers or cacareous subsoils, where they may bring soil chemistry problems to the surface. Plowing is more common in row crop areas, but some growers may plow about every third year in rice-only areas. Over the long term, deeper tillage will deepen the plow layer and should benefit soil fertility and root growth.

Figure 3. Typical two-way moldboard plow.

Depth of Tillage

Tillage depth should be consistent with the overall objectives of land preparation, drying and loosening the soil, and burying residue. Typically, 6” to 8” is sufficient. Some shallow soils limit tillage depth while others have deeper topsoil. Rice roots are shallow and do not respond to deep tillage as some deep-rooted crops do. The supply of nutrients is more important than depth. Deeper soils tend to have a thicker layer of nutrient rich soil, so rice on such soils often performs better compared to performance on shallow soils.

Spring Residue Management

Most straw management work is done in the fall, but despite best efforts, there is often abundant straw in the typical spring seedbed, which must be managed. Good practices in the fall will help spring operations, particularly chopping, which assists with incorporation and decomposition. Uncovered straw will float and drift into corners, edges or high spots, reduce stand, and increase disease, so a goal of spring work is to cover as much straw as possible. Chisels and discs will partially cover straw but have the tendency to also bring some back up again. The only remedy is to do extra ground work if there is abundant straw still on the surface. It is probably not economical to continue to work the ground past one or two extra operations.

Land Planing

A land plane is simply a long, rigid rectangular (four wheels) or ‘A’ frame (three wheels) in the center of which a scrapper blade or bucket is set (Figure 4). As the operator pulls the plane across the field, soil fills the bucket and simultaneously spills forward out of the bucket, creating a churning action that breaks up the clods, improves their uniformity and fills in ruts from previous groundwork. The depth of cut of the scraper blade can be adjusted, but it typically cuts no more than an inch deep into the tilled soil. The smooth surface is ideal for fertilizer application because it facilitates uniform depth of placement. Typically, one pass with a plane is sufficient; although, some growers make a second pass at an angle to the first. Landplaning is a relatively slow and expensive operation. Planing only smooths the surface; it is not a substitute for leveling. However, land planing is important for maintaining the integrity of the leveling job and to fine tune it for the current season. With prevailing shallow water management, off grade spots and large clods represent potential weedy sites. Planes do not work well in wet soil since the soil must flow freely in and out of the bucket. Land planing packs the soil, and if it is moist, will stimulate early weed growth. Therefore, once the field is planed, subsequent operations must be done promptly. Preplant fertilizer is usually applied to the smoothed soil; although, some growers plane after fertilizer application.

Figure 4. Typical three wheel land plane.

Corrugated Rollers

Heavy corrugated rollers are commonly used as a final field operation to eliminate large clods and pack the soil, providing a more uniform surface compared to a disced seedbed (Figure 5). To some extent, the corrugations help keep seed evenly distributed. Seed planted in corrugated fields often settles into the bottom of the grooves, resembling drill seeded rice. Corrugated rollers are 15' to 24' wide and have ridges at 6" to 7" spacing around their circumference. This tool is consistent with shallow water management because large clods are either broken or pressed down in the seedbed. Liquid and dry fertilizer and herbicide applicators may be attached to the roller frame and allow growers to perform simultaneous operations. Rollers require dry soil for good operation. Moist soil will cake on the surface, and clean corrugations will not form in the soil.

Corrugated rollers are fairly cheap to operate unless additional operations are combined with them. These combined operations require additional controls in the tractor cab, and a skilled operator is important.

Alternative Tillage Systems

Examples of alternative systems include dry seeding, stale seedbed, and no-till. Dry seeding involves sowing unsoaked seed on the soil surface and shallowly covering it with soil using a corrugated roller or light harrow, or drill seeding as one would plant wheat. The seedbed in a drill-seeded field is prepared as for water seeding, except the goal is a finer, well-packed seedbed to precisely control seed depth. A smooth roller may benefit this operation. The stale seedbed method involves limited tillage in the fall or spring to help germinate weeds and provide alternative weed control strategies. There is more information about drill seeding and stale seedbed systems later in this chapter. Rarely, growers may drill directly into the field without otherwise tilling the soil, called 'no-till.' Growers use no-till to reduce tillage costs, get an earlier start and discourage weeds, which tend to be less severe when the soil is not disturbed. A heavier, specialized drill is usually needed to cut through residue and packed soil. This is rarely done because there is often some damage to the soil surface from harvesting or spraying equipment that must be repaired.

Seed Soaking

Most California rice fields are sown with soaked, pregerminated rice seeds. Soaking accomplishes two purposes. First, water replaces air inside the seed coat so that the seed is less buoyant and sinks more readily, helping to keep the seed from drifting and 'bunching.' Second, germination processes are started so that the seed will have a headstart when it is planted compared to dry-sown seed. A flooded rice field is an inhospitable environment, habitat for numerous pests and competitors of rice seed. During soaking, vital physiological processes begin, which are precursors to growth. Allowing the most vulnerable period of a seed's first hours of growth to take place in the relatively benign environment of a soaking tank helps assure its success in the field. Dry seeds sown into water tend to be more

Figure 5. Corrugated roller (left) and closeup of roller surface showing ridges that form corrugations (right).

susceptible to midge, shrimp and disease attack. Research has shown that the duration of soaking is roughly equivalent, in terms of plant growth, to sowing earlier by the same amount of time as the soaking (Grigarick et al. 1984).

Pregerminated seeds sprout quicker and anchor their roots into the soil, reducing the time of exposure to the different pest and environmental problems that affect early seedling development.

Water absorption and growth.

A rice seed absorbs moisture rapidly once it is placed in water and continues to increase its water content well beyond the time when it is ready for sowing (Figure 6). Early growth processes were observed at a steady 68ºF, somewhat cooler than the typical environment of a rice soaking tank (Williams, unpublished data). Water was absorbed rapidly during the first three

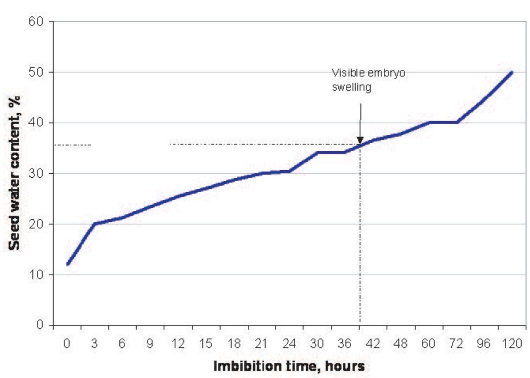

Figure 6. Rice seed water uptake at 68ºF. Visible embryo swelling first seen at 42 hours at seed water content of 36.5%, dry weight basis. (Williams unpublished data)

hours, and then the rate of absorption declined to a relatively steady rate thereafter. At 12 hours after imbibition, the seeds had a 'hydrated' look and moisture content over 25%, about doubling water content. The first visual sign of growth was swelling of the embryo and a change to a translucent character at 42 hours and moisture content of 36.5%. By 48 hours, the embryo was just beginning to split the hull, and by 60 hours the first shoots were breaking through.

Soaking

Soaking is typically done in steel bins (Figure 7), with dimensions of approximately 48" wide, 48" deep, and 51" high, and a volume of 62 to 64 cubic feet. Sodium hypochlorite or a similar disinfectant is usually added to the soaking water to help control bakanae, a fungal disease that causes seedling elongation and yellowing. (For more information on bakanae control measures, including soaking, see the Diseases chapter.) The bins have indentations at the bottom for forklifts to lift, invert and dump the seed into trucks. A full bin will hold up to about 2300 lbs of dry seed, and contains about 230 gallons of water (seed just covered). In other words, ten gallons of water is required for every hundredweight (cwt) seed, plus an additional gallon/cwt as the seed absorbs water. The exact amount of water for initial filling depends on the grain type, with medium grains requiring slightly more water than long grains. The bins are usually fitted with drains so that water can be drained.

Some seed soaking is also done in the same trucks that deliver the seed to the airstrip before

Figure 7. Typical rice seed soaking bins

planting. The advantage is reduced handling, no need for bins or forklifts and less labor. The disadvantage is that the large volume will generate more heat than small bins if seeding is delayed, and it is difficult to refill and cool the seed. Sprinklers are sometimes put on the trucks for cooling if seeding is delayed.

The metabolic activity of growth creates heat which will accumulate in the enclosed soaking bin. High outside air temperature will increase the rate of heat accumulation. As temperature rises, respiration rate increases, up to about 90ºF, and then starts to drop off. Oxygen levels also decline as the seed oxygen demand increases. If soaking proceeds too long, the combination of high, sub-lethal temperature and low oxygen will cause poor seedling vigor and delay in stand establishment. Loss of seedling vigor may lead to stand loss from pests and weather damage. Lethal temperatures for wet rice seeds have been reported from 104 to 113ºF.

Damaging temperatures can easily be reached if soaking is not done properly, and is regulated mainly by time of soaking and drainage. Recommended soaking guidelines are 24 hours in the soak water and 24 hours of draining, for a total pregermination time of 48 hours. Seed does not have to remain in the water for the entire duration of pregermination for early growth to begin. The seed should be sown promptly after 48 hours to avoid heat accumulation and oxygen depletion; however, some growers' practices vary significantly from these guidelines. There is some safety built into the guidelines, but problems with heat begin when 48 hours is greatly exceeded. When sowing is delayed by north wind or flooding delays, growers should attempt to cool the seed by refilling the soak tanks with fresh, cool water. Trucks with seed in them should be taken to a shady area, tarps removed and sprinklers put on top.

Adequate drainage is necessary to prepare the seed for sowing. During drainage, while pregermination continues, excess moisture drains away so the seed will more easily flow from the trucks and the aircraft spreaders. Poorly drained seed will stick together and resist flowing, resulting in poor seed distribution in the field.

Planting

Direct sowing requires soaked seed be flown directly onto the flooded field so that it comes to rest on the soil surface. It is important that the seed remain on the soil surface. Seed that is buried more than a centimeter in the soil will have low vigor or won't germinate because of inadequate oxygen. Rice seed needs a ready oxygen supply to sprout. Flood water replaces air in the soil and greatly reduces diffusion. Figure 8 shows how oxygen levels in the water and soil differ. Research by UC scientists and others showed that the oxygen level in a rice field drops to nearly zero within 6 to 10 hours of when a dry soil is flooded. In addition, the flood water reduces oxygen diffusion into the soil by a factor of over 10,000 times. (Patrick and Mikkelsen 1971).

The top centimeter of soil contains some oxygen which declines rapidly with depth. Burying seed severely reduces germination and emergence.

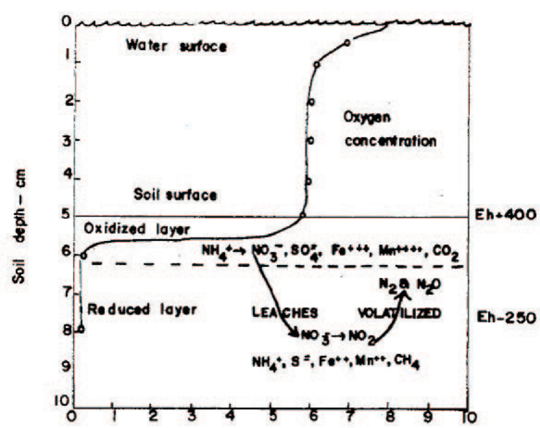

Figure 8. Oxygen levels in soil and water of a typical rice field. From: Plant Nutrient Behavior in Flooded Soils. (Patrick & Mikkelsen 1971)

Stand assessment

Minimum seedling population for maximum yield is dependent on many factors--sowing method, water management, planting date, variety, soil type and others. In 2015, a trial was conducted to determine optimal seed and plant density for maximum yield, using variety M.206 (Linquist, 2016). The results showed that plant density (plants/ft²) was about half of the seed density (Figure 9). In other words, only about half of the planted seeds germinated. Furthermore, maximum yields were achieved with about 25 plants/ft² (Figure 10). At half of that plant population (12.5 plants/ft²), yield potential declined to approximately 90%. While optimum seed and plant density may vary with different varieties and across years, these results provide guidance for stand assessment. UC Cooperative Extension has developed an online seeding rate calculator to assist with determining seeding rate based on variety and the desired stand density. The calculator is located at the UC Rice Online website.

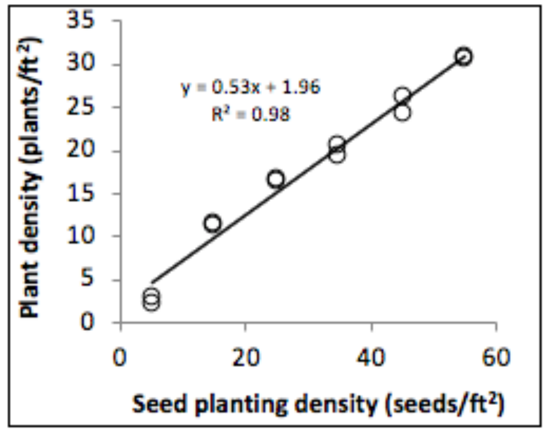

Figure 9. The relationship between seed density and plant density. Results are combined for the two planting dates, May 25 and June 1, and are for variety M.206.

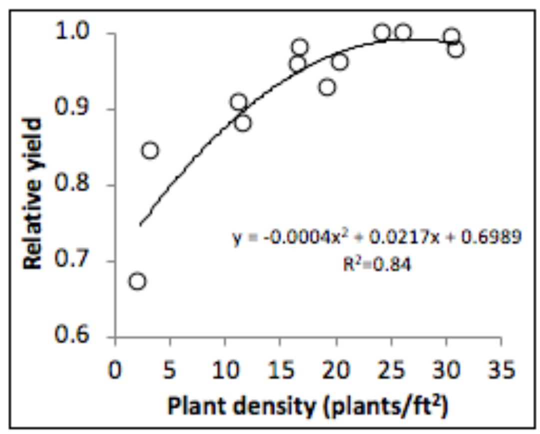

Figure 10. Relative yield versus plant density. Results are combined for the two planting dates, May 25 and June 1, and are for variety M.206.

Assessment of the stand soon after sowing is very important to ensure that pests (diseases, midges, shrimp) and burial have not wwreduced the stand to an unacceptable level. In cool weather, rice will germinate and grow slowly and less uniformly, and as temperatures warm the reverse is true. Optimum temperatures for germination and early seedling growth are in the range of 77 94ºF. Minimum temperature for germination is 54 56ºF, and maximum temperature is 104ºF. Seedling pests also respond to temperature, with diseases tending to be more damaging in cool weather, partially a result of poor growth and prolonged exposure of the rice.

Shrimp and midges, on the other hand, tend to be more severe during warm periods.

Early identification of insufficient stand is essential to successful reseeding. The longer the delay, the lower the success of replanting. Stand evaluation must be made within the field. A useful tool for looking at small plants is a sampling cylinder (Figure 11). Carefully push it slightly into the soil to avoid stirring up sediment, and observe the condition of seeds within the cylinder. By making it a known size, such as one square foot, one can make a count of healthy seedlings. Another version is a box fitted with a Plexiglas bottom. By pressing the box to the soil surface, seeds can be easily seen without mud obscuring them. Close examination of individual seedlings is necessary, so it is very helpful to have a hand lens. More information

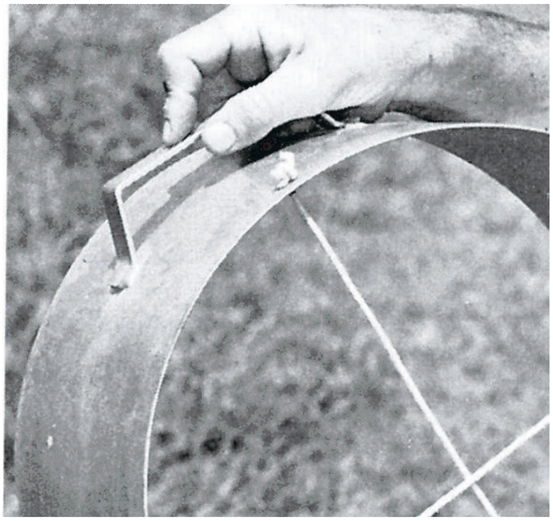

Figure 11. Sampling cylinder.

on stand establishment pests can be found in the sections on diseases and invertebrates.

Wind burial can reduce plant population, and bunching can leave large open areas, both of which may necessitate reseeding. Assessing a buried or bunched stand is difficult. Buried seeds may eventually succeed but finding them is difficult. A coarse screen with mesh just smaller than the seed can be fitted in a frame and pulled across the surface. Sluicing with water will reveal the seed, although it does take some work. A bunched stand leaves many areas under populated, while other areas having too thick a stand.

Reseeding

The decision to replant if stand density is less than optimal is an economic decision that growers will have to make based on their planting costs and expected lost revenues from reduced yield. If the decision to reseed has been made, identify and manage the possible impediments to success. Over the first few days of flooding many organisms establish in the field algae, crustaceans, insects, microorganisms some of which are potentially damaging to the rice. In addition, a layer of detritus composed of dead algae and diatoms may form on the soil surface which can deter root growth. To the extent possible, one should manage these problems with appropriate measures. As stated above, early diagnosis is important and the most important component of successful reseeding. Depending on the density of the stand, the reseeding rate can be from 50 to 100% of the original rate. Normal soaking procedures should be used so the new seed will start quickly. Depending on the time difference between first and second seeding, one may consider using an earlier maturing variety of the same market category to help with uniform maturity. Soaking of the new seed should be done according to standard guidelines (i.e. 24 hours soak, 24 hours drain). The new seed will perform better if the field is drained. However, drainage must be balanced against the potential loss of weed control.

Rice seed has dormancy inhibitors in the hull when it is first harvested. Currently-used varieties naturally lose their dormancy with time, and it is not necessary to do any special treatments prior to planting at normal dates. In the past, seed treatments had been beneficial to increase uniformity and rate of germination, both of which are affected by dormancy. Dormancy has been associated with chemical germination inhibitors in the hull and impermeability of the hull and seed coat to water. Sodium hypochlorite has been used in the soak water, at the rate of one gallon of 5.25% sodium hypochlorite per hundred gallons of water, a 1% solution, to alter the chemical germination inhibitors in the hull to improve speed of germination and early growth. Percent germination is not affected.

Wet seedbeds and delayed planting

Late spring rain may make it impossible to adequately dry the seedbed for optimum stand conditions. The result can be lower soil fertility, difficulty in land planing and rolling, precocious weed growth, difficulty in placement of aqua fertilizer, more algae, and delayed planting. If time permits, rework the ground, using a chisel-plow to speed drying. If the ground has not been worked, and there is a stand of vetch or other vegetation, let it grow as long as possible, and it will help dry the soil. If the ground is worked wet, expect some of the problems cited above and manage accordingly.

Drill Seeding

Drill seeding is used by some to reduce costs and manage herbicide resistant weeds. It is also the typical planting practice in the Sacramento-San Joaquin Delta region where dry seed is drilled into moist soil (as one might do with wheat). The light-weight, high organic matter soils of the region make water seeding less successful because the soil can bury the seed and prevent germination. High winds in the region may also impact seedling root anchoring under water seeding.

The primary issues in drill seeding are depth of seed placement and management of moisture for germination. Rice seedlings may not emerge well from deep planting. Studies in 1985 (Gunnell et al.) demonstrated reduced emergence as planting depth increased from ½ to 3”. Emergence percentage for M.202 was 100%, 100%, 92.5% and 20%, at ½”, 1”, 2”, and 3”, respectively. Deeply planted seeds took much longer to emerge and often came up twisted and bent. For current varieties, plant no deeper than 1 ½” to 2”. Growers who drill seed can plant to moisture or plant dry and irrigate the field to bring up the plants. The former is better to reduce weeds in the rice, but there is the risk of missing the moisture. Drill seeding into a dry seedbed and flush irrigating reduces that risk if done properly, but weeds are usually more of a problem. Either way, the permanent flood is established about a month later when the rice is at the 3 to 4 leaf stage.

Alternative Stand Establishment Methods for Weed Management

Continuously farmed rice affords few options for breaking weed population cycles. Consequently, the number of aggressive herbicide resistant weeds has built up over time. In heavily infested rice fields, conventional weed control strategies are ineffective and costly. The weed seed bank in the soil becomes increasingly dominated by resistant biotypes in these fields. Alternative stand establishment methods can reduce the resistant weed seed bank in the absence of traditional crop rotation.

These methods do pose some risk. However, with careful management, good yields are possible. Keep in mind that the primary objective is to reduce the population of resistant weeds and then return the field to a conventional water seeded system where weed control is once again cost effective. UC studies concluded that integrating cultural and chemical weed control practices is effective without significant reductions in yield (Figure 12). Integrating reduced tillage and a stale seedbed in rice systems will reduce herbicide resistant weed populations, delay the evolution of herbicide resistance, and reduce weed seed banks. Establishment techniques such as reduced tillage, stale seedbed or dry seeding may be used to manipulate weed species recruitment and expand herbicide options.

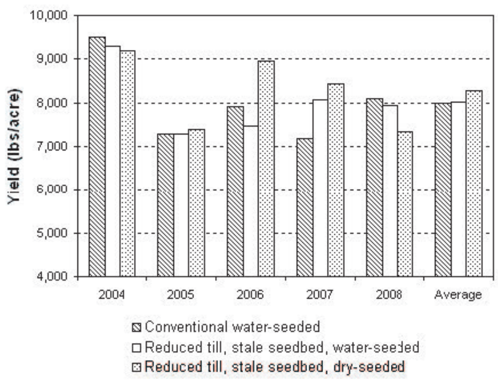

Figure 12. Grain rice yields under conventional and reduced till, stale seedbed waterand dry-seeded systems, 2004-2008, Biggs, CA

Planting into a Stale Seedbed

A stale seedbed is one where rice is planted into undisturbed soil. A stale seedbed approach encourages weeds to germinate by using irrigation prior to planting. Once the weeds are established, they are killed with non-selective herbicides, such as glyphosate (Roundup). In dry seeded rice, pendimethalin (Prowl) may be used for soil residual control of many grass species. These herbicides provide alternative mechanisms of action to control resistant species.

Fall Tillage versus Spring Tillage

A stale seedbed can be established with either fall or spring tillage. The preplant irrigation and weed control with a non-selective herbicide is the same for both circumstances. Fall seedbed preparation requires that the straw is well incorporated; an additional pass with a disc may be necessary. Flood the field for decomposition as usual. A prolonged winter flood should "melt" the clods to a relatively smooth soil surface by spring. If the field is cultivated in spring, apply P and K fertilizer during the cultivation operations prior to irrigation, weed germination, and herbicide application. Phosphorus left on the soil surface promotes algae growth. If it is inopportune to apply them during cultivation, they can be applied into the water 20-30 days after seeding.

Key points to remember for stale seedbed method

- Cultivate the field in the fall in the usual fashion.
- In the spring, flood the field to germinate weed seeds, preferably during warmer periods to encourage rice weed germination.
- Water grass and other grass seeds: maintain flood or saturated soil for 4 to 5 days.
- Sedge and broadleaf seeds: maintain flood or saturated soil for about 10 days.
- Dry-up the ground. Apply glyphosate to kill germinated weeds approximately 10 to 14 days after drain.
- Do not apply the herbicide until the rice weeds are vigorously growing. Applying too early will compromise control. Be patient.
- Do not disturb the soil after glyphosate treatment to avoid bringing more weed seeds to the surface.

Table 1. Example operations for planting rice using water seeded or dry seeded stale seedbed alternative stand establishment methods.

REDUCED TILL, STALE SEEDBED, WATER SEEDED	REDUCED TILL, STALE SEEDBED, DRY SEEDED
Preplant Weed Control • Flood the field to germinate weed seeds • Drain, then apply non-selective herbicide after the weeds are vigorously growing • Introduce flood for planting 2 days after herbicide application. **Seeding, fertility and water management** • Apply N at 20-60 lb /ac to soil surface (optional). a. Use ammonium sulfate if you typically see a benefit from sulfur. b. Use urea if you can flood quickly. c. Consider applying P and K in the fall. • Flood field. • Seed with pre-germinated seed at a heavier rate than usual (~200 lb/ac). There are two options following seeding 1. Drain field for stand establishment (especially if ground was not dried and soil oxygen concentration may be low) • Apply bulk of N (150 lb/ac) as urea immediately prior to permanent reflood • Top 1” of soil must be dry so that flood water will drive urea into soil and prevent N volatilization losses. 2. Maintain a continuous flood and raise water depth as seedlings develop. • Apply bulk of N (150 lb/ac) as ammonium sulfate at the 3-4 leaf stage of rice or when rice roots are well-developed. **Weed management** Weed management options when draining for stand establishment 1. Pre-plant glyphosate (Roundup). 2. Foliar herbicide application at 3 leaf stage of rice. 3. Into the water application after reflooding, or foliar application with rice 3-4 leaf stage to tillering and water lowered for 70% exposure of weed foliage. Weed management options with continuous flooded system 1. Pre-plant glyphosate (Roundup). 2. Into the water herbicides. 3. Foliar herbicide options at 1-3 tiller rice with water lowered if needed for 70% exposure of weed foliage	**Preplant Weed Control** • Flood the field to germinate weed seeds • Drain, then apply non-selective herbicide after the weeds are vigorously growing **Seeding, fertility and water management** • Pre-plant application of 1/3 total N. a. ~30-50 lb N/ac as ammonium sulfate. b. N may be applied with drill. c. Total N requirement may be a little higher than in a conventional water seeded system. • Seed at a rate of about 100 lb/ac. a. 5-7” spacing. b. Depth < 1” • Flush/drain to promote rice germination. a. Rice seed may not germinate in low spots with standing water. b. Rapid water movement in fields with lighter textured soils may bury the seeds in some areas and thin the stand. • May need to flush again prior to permanent flood, depending on the weather. Hot, windy weather can cause the soil to crust before the seedlings emerge. • Apply remaining 2/3 total N just prior to permanent flood. a. 100 to 120 lb N/ac as urea. b. Top 1” of soil must be dry so that flood water will drive urea into soil and prevent N volatilization losses. • Apply permanent flood when rice plants are large enough to be above water; typically between the 4 leaf and tillering stage. **Weed management** 1. Pre-plant glyphosate (Roundup). 2. Herbicide options: a. A pre-emergent herbicide application after the first flush of irrigation followed by a foliar application prior to permanent flooding. b. A foliar herbicide in tank mixture with a soil residual herbicide applied when rice is the 2-4 leaf stage. 3. Come back with a foliar herbicide application after permanent flood if needed to control a new flush of weed emergence. Water should be lowered for 70% weed foliage exposure to the herbicide.