SEEDING TWO NATIVE GRASS SPECIES ON RECLAIMED PHOSPHATE MINEDLANDS[1]

by

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Abstract. The Florida phosphate industry is striving to reclaim minedlands to native upland habitat. Direct seeding native species is potentially more economical than planting seedlings, however, direct seeding expertise is lacking. The Brooksville, Florida Plant Materials Center has been working with the Florida Institute of Phosphate Research to develop seeding technology for native Florida upland species. A series of studies were seeded on a reclaimed minedland site of sand tailings and sand tailings capped with overburden, near Bartow, Florida in 1997 through 1999. The purpose of the research was to study the influence of seeding method, rate and date on establishment success of wiregrass (*Aristida beyrichiana* Trin. & Rupr.) and lopsided indiangrass [*Sorghastrum secundum* (Ell.) Nash]. Drilling was compared with broadcasting. Debearded indiangrass and wiregrass successfully emerged from drilled and broadcast treatments in 1997. However, debearding severely damaged a large percentage of the brittle wiregrass seed, making drilling uneconomical. In 1998, indiangrass was broadcast at 215, 430 and 645 pure live seed/m^2. Plant densities were similar for the high and medium rates, and 2 – 3 times lower for the lowest rate. Wiregrass densities were all 5 plants/m^2 or less from 430, 645 and 860 pls/m^2 broadcast treatments. Wiregrass could not overcome a droughty spring and high weed competition at any of the rates used. In 1999, wiregrass and indiangrass were broadcast in January and May to test influence of seeding date. Despite a droughty spring, both species emerged relatively well from both treatments. Winter seedings may be advantageous for wiregrass, but only if weed competition is low and adequate soil moisture is available.

Introduction

There is a growing movement in Florida, especially in the phosphate industry, to reclaim upland sites with native species. Direct seeding has the potential to be the most economical method for revegetation when compared to planting seedlings. However, several problems associated with native plants have hampered reseeding efforts. Seeds from native species are often light, with awns or hairy appendages that preclude harvest and planting with conventional equipment. Desirable native species often lack seedling vigor, and are poor competitors with weedy species. In addition, some native species may undergo seed dormancy and only germinate during a given season.

In 1995, under a previous agreement with the Florida Institute of Phosphate Research (FIPR), the Brooksville, Florida Plant Materials Center (PMC) established seeding methodology trials on two reclaimed minedland sites near Bartow, Florida, using wiregrass (*Aristida beyrichiana* Trin. & Rupr.) and lopsided indiangrass [*Sorghastrum secundum* (Ell.) Nash] (Pfaff and Gonter, 1996). Plots were planted in May, at the beginning of the rainy season. Despite problems with severe competition from introduced pasture species, much information was gathered from these studies. Indiangrass readily established, although plant densities were low. Wiregrass did not establish. Low plant densities were thought to be primarily due to the season of seeding, seeding rate and weed competition. Problems associated with the three seeding methods employed in this study also contributed to poor stand establishment. Drilling showed potential for establishing indiangrass. However, the drill used in this study was not capable of handling light chaffy seed.

Bisset (1995) was able to successfully establish several native species, including wiregrass, by broadcasting mature chopped native material on a reclaimed minedland site near Bartow, Florida in December. Bisset estimated that wiregrass was distributed at a rate of 538 pure live seed/m^2 (50 pls/ft^2) (personal conversation). In north Florida, Seamon (1998) reported successful wiregrass establishment, when a wiregrass mix collected with a Flail-Vac Seed Stripper was broadcast on plots of bare mineral soils with a hay blower. The seed was planted in February. Possibly due to a dry spring, most seedlings did not emerge for two years. Seeding rate was estimated to be

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over 3,200 pls/m^2 (300 pls/ft^2). Wiregrass seedlings emerged well from plots that had been disked prior to seeding. However, plots that were simply burned off or were not disturbed had no seedling emergence. It appears that planting into disturbed bare mineral soils is important for successful wiregrass stand establishment.

The purpose of this study is to research the effect of seeding method, seeding rate and planting date on the establishment of wiregrass and lopsided indiangrass in monoculture and mix.

Materials and Methods

Lopsided indiangrass seed was collected from Ft. Cooper State Park in 1995 through 1998, using a Flail-Vac Seed Stripper. Wiregrass seed was collected from Avon Park Air Force Bombing Range in 1995 through 1998 with the Flail-Vac. Initially, seed from both species was debearded using a Clipper debearder. Chaff was then removed using an air-screen cleaner. Purity obtained for the indiangrass was 95%. Purity of the wiregrass was approximately 50% due to broken seed. Wiregrass seed is very brittle, and the debearder caused a great deal of seed breakage. A hammermill appears to be a better instrument for debearding wiregrass seed. Although awns aren't completely removed and some breakage occurs in the hammermill, the seed is not processed as long as in the debearder, therefore breakage is reduced. After it was determined in 1997 that debearding wiregrass was not economical, only the indiangrass seed was debearded. The wiregrass seed was still scalped with an air-screen cleaner to remove large sticks and stems.

The study site is near Bartow, Florida, on reclaimed minedlands provided by Cargill Fertilizer, Inc. It is composed of three acres of sand tailings, and an adjacent three acres of sand tailings capped with 6 or more inches of overburden. Sand tailings are generally consistently coarse and droughty. Texture of the overburden plots at the study site varied greatly. On the west end, where the overburden cap was thinnest, the texture was coarse sands with very low water holding capacity. On the east end, the overburden contained a large loam fraction, which has a high water holding capacity, and crusts heavily when dry.

The freshly reclaimed study site needed no weed control in January 1997. Vacant plots were disked and sprayed with glyphosate throughout the growing season in 1997 - 1999 to control weeds. However, heavy late summer rains often interfered with weed control and allowed crabgrass (*Digitaria sanguinalis*), natalgrass (*Rhynchelytrum roseum*) and hairy indigo (*Indigofera hirsuta*) to establish seed banks at the site.

All plots were packed before seeding with a cultipacker. Plots were 3 x 15 meters (10' x 50') in size. Due to a lack of seed, generally 4 replications were used on overburden plots and 3 replications on sand tailings. Winter and summer studies were planted in January and May 1997 through 1999, on both overburden and sand tailings. Each study built on the information gained from the previous year.

1997 Seedings

The first winter study was planted on January 28, 1997 as a randomized complete block. Monocultures of debearded seed of both grass species were seeded using an air drill built by Pounds Motor Company of Winter Garden, Florida. This drill was specifically designed to handle light chaffy seed and keep it from bridging in the drill. It has an aggressive brush system in the hopper, and forced air blows the seed through the drop tubes. An indiangrass/ wiregrass/ *Liatris* (primarily *L. elegans* and *L. tenuifolia*) mixture of debearded seed was also drilled. All monoculture broadcast treatments used debearded seed, and were planted using a hand-held Cyclone seeder. A mixture of beards-on wiregrass, debearded indiangrass and *Liatris* were broadcast using a seed blower. All broadcast plots were packed with a cultipacker after seeding.

Lopsided indiangrass and wiregrass seeding rate in drilled and broadcast monoculture treatments was 645 pls/m^2 (60 pls/ft^2). The exception to this was the wiregrass drill treatment. It was seeded at a rate of 800 - 860 pls/m^2 (75-80 pls/ft^2), due to the aggressive brush system of the air drill. In broadcast mix treatments, wiregrass and indiangrass were planted at a rate of 645 and 430 pls/m^2 (60 and 40 pls/ft^2) respectively. *Liatris* was also added to the January mix treatments at a rate of 130 pls/m^2 (12 pls/ft^2).

The first summer study was planted on May 20, 1997 using the procedure outlined above. However, drill treatments were planted using a Tye drill with a warm season grass attachment, borrowed from the Quicksand, KY PMC. Seeding rates were the same as for the January seeding, except that wiregrass was drilled at 645 pls/m^2.

1998 Seedings

The second series of winter plots were broadcast seeded on January 21, 1998, with emphasis placed on seeding rates. Only indiangrass was debearded for this planting, and broadcast with a Cyclone seeder. Beards-on wiregrass was broadcast in monoculture and mix with a seed blower. Plots were packed before and after seeding with a cultipacker.

January monoculture plots were broadcast at three rates: Wiregrass - high (860 pls/m^2), medium (645 pls/m^2), and low (430 pls/m^2); indiangrass - high (645 pls/m^2), medium (430 pls/m^2), and low (215 pls/m^2); wiregrass/indiangrass mixtures - high (430 and 215 pls/m^2, respectively) and low (430 and 108 pls/m^2, respectively). Mixtures contained approximately 55 pls/m^2 of *Liatris*. Treatments were replicated four times on overburden and three times on sand tailings in randomized complete blocks.

The second summer series of plots were planted on May 11, 1998. Indiangrass and wiregrass were broadcast at one monoculture rate of 645 pls/m^2 in the same manner as above. Wiregrass and indiangrass were broadcast as a mixture at one rate of 430 and 215 pls/m^2, respectively. These three treatments were planted on vacant plots within the January 1998 study, so that planting date effects could also be studied.

An additional indiangrass seeding method study was planted in May of 1998. Treatments compared broadcasting indiangrass seed with a Cyclone seeder, versus drilling with a Truax grass drill. Seed was drilled at the approximate rates of 215 and 430 pls/m^2, and broadcast at a rate of 430 pls/m^2. Slight modifications had to be made to the Truax to keep the seed from bridging in the drop tubes. Each treatment was replicated 3 times on both overburden and sand tailings in a randomized complete block design.

1999 Seedings

The third series of winter studies were planted on January 12, 1999. To study the effect of seeding date on wiregrass and lopsided indiangrass establishment, both species were broadcast in monoculture at a seeding rate of 645 pls/m^2 in January in a split plot design. Main plots were species and subplots were planting date. Subplots included a January and May treatment. Plots were replicated three times on both overburden and sand tailings. Wiregrass seed was broadcast with a seed blower. Debearded indiangrass seed was broadcast with a cyclone seeder. Plots were packed before and after seeding with a cultipacker.

In a separate January study, the influence of indiangrass on wiregrass densities in mixture plantings was considered. Wiregrass was broadcast at 860 pls/m^2 with three different rates of indiangrass (0, 108 and 215 pls/m^2) and 55 pls/m^2 *Liatris* seed. Seed was broadcast with a seed blower. Plots were replicated three times in a randomized complete block design.

As mentioned above, the third and final series of summer plots were planted on May 4, 1999 within the January 1999 split block design. Wiregrass and indiangrass were seeded using the same rate and methods as for the January plots.

Meter square quadrats (two per plot) were randomly established on all plots at six months. These were used to evaluate treatments for plant density, size, vigor, percent canopy and weed cover at 6, 12 and 24 months after seeding. Statistical analysis was conducted using MSTAT-C (Michigan State University, 1988).

Results and Discussion

Weather patterns varied greatly between the three years of this study. Rainfall amounts for Hooker's Prairie, which is located within five miles of the study site, are shown in Table 1. The spring of 1997 was wet, with 7 inches of rainfall recorded at Hooker's Prairie in April. March and April precipitation is very critical for winter-planted seedlings. The first three months of 1998 were reported as being exceptionally wet at Hooker's Prairie. However, almost no rainfall was received in the critical month of April. This dry period was also accompanied by high winds. Rainfall amounts were very low the first four months of 1999. High winds accompanied the dry conditions, and new seedlings were literally sand blasted on the sand tailings. Precipitation adequate to sustain May planted seedlings did occur during the summer season in 1997, 1998 and 1999.

Table 1. Inches of monthly rainfall at Hooker's Prairie from 1996 through 1999.

	1996	1997	1998	1999
	Inches of Precipitation			
January	5.18	0.93	2.50	2.50
February	1.74	0.86	12.58	0.44
March	5.45	2.17	6.84	0.45
April	0.73	7.12	0.37	1.52
May	10.38	1.87	2.07	4.34
June	3.32	6.00	0.83	8.87
July	4.39	9.49	7.31	5.51
August	9.62	2.41	4.29	7.87
September	4.89	8.05	13.01	10.07
October	3.43	3.32	0.30	2.26
November	0.86	5.94	3.11	2.18
December	1.67	8.51	1.94	2.16
Total	51.66	56.67	55.15	48.17

Seeding Method

Three types of drills were tested in this study, and two types of broadcast methods. In the January 1997 planting, the air drill designed by Pounds Motor Co. handled the debearded indiangrass and wiregrass

seed fairly well. It has an aggressive brush system, which pulls the seed to the drop tube openers. The seed is then sucked into the drop tubes and blown through to prevent bridging or clogging. However, the air pressure through the tubes was so great that it blew the seed out of the furrows. Seeding depth was increased to offset this problem, and the planting depth of the drilled mix was deeper than the planting depth for the drilled monoculture treatments. The air pressure could be adjusted to some extent; however, decreasing the air pressure decreased the amount of seed output. Depth placement using this drill was difficult to determine because seed was distributed throughout the upper two inches of the soil.

The Cyclone seeder distributed debearded wiregrass and indiangrass seed very uniformly. The seed blower handled the chaffy wiregrass seed mix very well, though distribution over the surface of the plots was uneven. The ideal seedbed for this method was a moist soil surface with grooves for the air-blown seed to collect.

Overall, broadcasting produced the greatest plant densities for both species (Table 2). Direct seeding success criteria for Florida soils have not been developed. On surface minedlands in the western US, 43 plants/m^2 is considered a satisfactory stand of seeded native plants (Cook et al., 1974; Thornburg, 1982). Coarse droughty soils in Florida may not be able to sustain such high seedling densities. In its natural environment in Florida, mature wiregrass averages 5 plants/m^2 (Clewell, 1989). However, initially higher seedling densities would be expected to reduce weed competition. Most of the January 1997 treatments exceeded the native wiregrass average of 5 plants/m^2 on both overburden and sand tailings.

Table 2. Average plant densities of January 1997 monoculture broadcast (BC) and drilled (DR) indiangrass and wiregrass on overburden and sand tailings 6 months after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
Indiangrass–BC (645 pls/m^2)	177a	46ab*
Indiangrass–DR (645 pls/m^2)	96b	76a
Wiregrass–BC (645 pls/m^2)	65b	14bc
Wiregrass–DR (860 pls/m^2)	36b	5c

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

A seeding rate of 645 pls/m^2 was actually too high for indiangrass. After two years indiangrass densities in broadcast plots had diminished by approximately 60% on both soil types. Due to excessive competition between seedlings, plants in broadcast plots were smaller and less vigorous than those in drilled plots. Drilling provided better seed placement. Wiregrass, on the other hand, proved to be very persistent once established, even on broadcast plots with high seedling densities. After two years, wiregrass treatments suffered 10% or less seedling losses.

Table 3. Average plant densities of January 1997 broadcast (BC) and drilled (DR) mixtures of indiangrass and wiregrass on overburden and sand tailings 6 months after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
Indiangrass–BC (430 pls/m^2)	88a	26b*
Indiangrass–DR (430 pls/m^2)	79ab	86a
Wiregrass–BC (645 pls/m^2)	39bc	4b
Wiregrass–DR (645 pls/m^2)	17c	3b
Total Plants - BC	127	30
Total Plants- DR	96	89

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

Wiregrass and indiangrass were also drilled and broadcast as a mixture in January of 1997 (Table 3). Even at a reduced seeding rate, indiangrass dominated the mix and inhibited wiregrass germination. After two years, however, indiangrass densities decreased 50% or more, while wiregrass treatments only decreased by 10% or less. Wiregrass actually became the dominant species in the mix. It appears wiregrass is very susceptible to competition at emergence; yet, once established, this species has excellent persistence.

The Tye drill used for the May 1997 planting could not handle the seed as well as the air drill used in January. The Tye drill operated on a gravity flow system. It was able to meter out debearded indiangrass seed fairly efficiently. However, because the debearded wiregrass seed was very light, the hopper had to be over half full for it to meter out efficiently. On this drill, the drop tubes are placed behind the double disk openers. The furrow partially closed up before the seed could fall into it, causing a large percentage of the seed to be left on the soil surface. Planting depth was increased to overcome this problem, however placement was not precise. This system showed no advantages over broadcasting, except for placement of seed in rows, which reduces competition between seedlings.

Results for May 1997 monoculture treatments are shown in Table 4. Greatest densities for both species were again obtained by broadcasting.

Indiangrass broadcast plant densities on overburden plots were excessively high. The Tye drill was not successful in seeding wiregrass, although seeding date may have been a contributing factor. Broadcast wiregrass treatment densities were low, but still met native stand averages of 5 plants/m^2. Weed competition was observed to be higher in May overburden plots than in January plots, though herbicide treatments were applied prior to planting. Weed competition undoubtedly contributed to low wiregrass emergence in overburden plots. Competing weeds were primarily crabgrass, natal grass, and hairy indigo.

Table 4. Average plant densities of May 1997 monoculture broadcast (BC) and drilled (DR) indiangrass and wiregrass on overburden and sand tailings 6 months after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
Indiangrass–BC (645 pls/m^2)	117a	34a*
Indiangrass–DR (645 pls/m^2)	57b	21a
Wiregrass–BC (645 pls/m^2)	7c	5a
Wiregrass–DR (645 pls/m^2)	1c	0.2a

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

Indiangrass again dominated mixture treatments in the May 1997 plantings (Table 5). However, all mixture treatments had poor emergence on sand tailings. A dry, windy August may have contributed to seedling desiccation. Almost no wiregrass emerged from any of the mixture treatments.

Table 5. Average plant densities of May 1997 broadcast (BC) and drilled (DR) mixtures of indiangrass and wiregrass on overburden and sand tailings 6 months after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
Indiangrass–BC (430 pls/m^2)	28a	2a*
Indiangrass–DR (430 pls/m^2)	46a	7a
Wiregrass–BC (645 pls/m^2)	2b	0.3a
Wiregrass–DR (645 pls/m^2)	1b	0.2a
Total Plants-BC	30	2
Total Plants-DR	47	7

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

In May of 1998, a Truax grass drill was used to compare drilling with broadcasting indiangrass. One of the advantages of drilling is that seed can be placed precisely at a given depth and row spacing. Seeding rates can also be reduced compared to broadcasting, which leaves approximately half of the seed on the soil surface.

Table 6. Average plant densities of May 1998 drilled and broadcast indiangrass on overburden and sand tailings at 6 months after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
BC- Medium Rate (430 pls/m^2)	84a	97a*
DR- Medium Rate (430 pls/m^2)	8b	17b
DR- Low Rate (215 pls/m^2)	9b	14b

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

The Truax drill was able to handle the chaffy indiangrass seed fairly well. It has a very vigorous auger system that keeps the seed from bridging, and aggressively pulls it into the drop tubes. As with all new equipment however, some problems had to be overcome. The disk openers would not turn in the sand tailings. The drop tubes of the chaffy seed box were positioned to open directly over the point where the two blades of the disk openers met. If these did not turn, the seed would collect there and not be metered out evenly. This problem was overcome by moving the drop tubes back to another hole. A few of the appendages on the indiangrass seed remained after debearding, causing enough resistance to keep the seed from flowing easily. This problem could be overcome in the future by increasing processing times in the debearder to more fully polish seed hulls. Leaving indiangrass seed in the debearder longer may cause more seed damage. However, better flowing seed would greatly increase consistent stand establishment.

Broadcast treatments produced very high densities on both soil types (Table 6). Drilled treatment densities were substantially lower, due primarily to poor seed flow. Doubling drilled seeding rate to broadcast levels did not increase seedling densities. Future studies need to be conducted to precisely determine optimum drilled indiangrass seeding rates, once mechanical difficulties are overcome.

Seeding Rate

Indiangrass and wiregrass were broadcast in monoculture at three seeding rates in January of 1998 (Table 7). Unfortunately, erratic rainfall and heavy weed competition caused much variability in the data. Rainfall was unusually heavy the first three months of 1998. This appeared to stimulate high weed competition early in the year, especially on overburden plots. Lack of any appreciable rainfall in April, coupled with high winds, decimated populations of the less vigorous

native grasses that had emerged. Coarser, sandy overburden plots had lower weed competition than did overburden with a higher clay loam fraction. This translated to relatively high seedling densities for both species on the sandy replications, graduating to virtually no surviving seedlings on the heavier soils. The net result was that density data on overburden plots was erratic, e.g., high seeding rates produced lower seedling densities than did medium, or low rates.

Some interesting observations could be made from the indiangrass treatments, however. This was the species most able to overcome unfavorable conditions. Indiangrass seedling densities were similar for the high and medium rates on both soil types. The low indiangrass seeding rate produced substantially lower plant densities than did the medium rate. If the western criteria of 43 plants/m^2 is used, then, based on these data, it appears that a 215 pls/m^2 broadcast seeding rate is too low. It also appears there is no advantage in doubling the seeding rate to 645 pls/m^2. This high rate has in fact been observed to cause severe competition between seedlings, and high seedling mortality.

January 1998 planted wiregrass seedling densities were very low and generally did not reach the native stand average of 5 plants/m^2 at any of the seeding rates used in this study. This species appears to be extremely sensitive to weed competition and rainfall, which had a greater effect on seedling emergence than did seeding rate.

Table 7. Average plant densities of January 1998 broadcast indiangrass and wiregrass in monoculture at three seeding rates on overburden and sand tailings one year after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
Indiangrass		
High Rate (645 pls/m^2)	33ab	42a*
Medium Rate (430 pls/m^2)	44a	35ab
Low Rate (215 pls/m^2)	14ab	14ab
Wiregrass		
High Rate (860 pls/m^2)	3b	4b
Medium Rate (645 pls/m^2)	4b	4b
Low Rate (430 pls/m^2)	5b	3b

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

To test wiregrass seedling sensitivity to competition with other species in a native mix, wiregrass was broadcast with indiangrass at three rates in January 1999 (Table 8). Unfortunately, weather patterns were once again very erratic in 1999. Only 4.9 inches of rain fell in the first four months of 1999, compared to an average of 15.5 inches for the first four months of the previous three years. Droughty conditions were accompanied by high winds. Remarkably, wiregrass densities for all treatments on overburden plots were above the native standard of 5 plants/m^2. Fortunately, weed competition was low, and had much less influence on seedling emergence compared to 1998. Indiangrass densities appeared to be too low to significantly effect wiregrass emergence under these droughty conditions at either rate.

Table 8. Average plant densities of wiregrass broadcast with indiangrass at three rates in January 1999 on overburden and sand tailings 6 months after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
Rate 1		
Wiregrass (860 pls/m^2)	11ab	0.3a*
Liatris (55 pls/m^2)	3bc	1a
Rate 2		
Wiregrass (860 pls/m^2)	9ab	1a
Indiangrass (108 pls/m^2)	5abc	2a
Liatris (55 pls/m^2)	3bc	2a
Rate 3		
Wiregrass (860 pls/m^2)	8ab	0.3a
Indiangrass (215 pls/m^2)	7ab	4a
Liatris (55 pls/m^2)	3bc	1a

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

Stand densities on the January 1999 planted sand tailings plots were almost nil for all species. Droughty conditions and blowing sand decimated seedlings that did emerge. These studies provided a good opportunity to establish seeding rate thresholds for wiregrass and indiangrass in monoculture and mixtures. Further experiments may be necessary to develop data under less extreme conditions.

Seeding Date

Throughout these studies, seeding date often appeared to have a strong influence on seedling establishment. A final series of studies were planted in 1999 to specifically address the affect of January versus May planting dates on wiregrass and indiangrass emergence (Table 9). Droughty weather conditions in 1999 negatively influenced seedling emergence. However, much good data was still obtained. Weed competition was fortunately not a significant factor in this study. There was no significant difference between wiregrass stand densities in January versus May on overburden plots. Had more rainfall been received in the spring of 1999, it is possible that January wiregrass

seedling densities would have been much higher. This conclusion is based on wiregrass performance in the 1997 studies. Both seeding dates were well above the natural standard of 5 plants/m^2. Timely summer rains gave May seedlings a much needed boost to become established on overburden plots. However, conditions were too dry and windy for wiregrass to establish on sand tailings at either seeding date.

Table 9. Average plant densities of wiregrass and indiangrass broadcast in January and May 1999 on overburden and sand tailings at 1 year and 6 months, respectively after planting.

Treatment	Over-burden	Sand Tailings
	Plants/m^2	
Indiangrass – January	107b*	21a*
Indiangrass – May	236a	30a
Wiregrass - January	15c	0.3b
Wiregrass - May	10c	0b

*treatment means followed by different letters are significantly different by Tukey's HSD at P≤0.05

Indiangrass established relatively well on both soil types on both dates. It was able to take advantage of summer rains to become established on overburden plots. Lopsided indiangrass is a very good candidate for use in a native seed mix for reseeding critical area sites. It was able to establish despite severe conditions. It may not persist on all sites, but may be an effective native "nurse crop" to help other species such as wiregrass become established.

Conclusions

Based on this series of studies, broadcasting generally produced the highest plant densities for both species whether planted alone or in a mixture. Lopsided indiangrass established fairly well in drilled treatments. Drilling with a chaffy seed drill may be advantageous for planting this species if seed is adequately debearded. Drilling generally requires lower seeding rates, which can reduce seed costs substantially.

In the short term, optimum broadcast seeding rate levels for indiangrass were found to be 430 pls/m^2 (40 pls/ft^2) on overburden and sand tailings. Drill seeding rates were not precisely determined. Typically, seeding rates for drilling are half of broadcast rates. Further research will be needed to verify this for indiangrass. Initial studies did indicate doubling the seeding rate to broadcast levels did not significantly increase seedling densities. One to three-year survival data was not yet available for all studies. Seedling establishment data will continue to be monitored for two more years. Long-term survival will provide a more reliable measure of optimum seeding rates.

Optimum wiregrass broadcast seeding rates could not be established in these studies. Rainfall and weed competition had a profound effect on wiregrass seedling establishment. Wiregrass could not establish in extremely harsh conditions, no matter the seeding rate used. When conditions were favorable, broadcast rates of 640 to 860 pls/m^2 (60 to 80 pls/ft^2) produced adequate stands on both soil types.

Study data indicated there was no significant advantage to a winter seeding date for either species. Indiangrass emerged well at any date when adequate moisture was available. A winter seeding date may be more advantageous when seeding wiregrass. However, this may again be due to lack of weed competition and the occurrence of timely winter rains.

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