ESTABLISHING NATIVE WARM SEASON GRASSES ON EASTERN KENTUCKY STRIP MINES[1]

by

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Abstract: We evaluated various methods of establishing native warm season grasses on two reclaimed Eastern Kentucky mines from 1994 - 1997. Most current reclamation practices incorporate the use of tall fescue (*Festuca arundinacea*) and other cool-season grasses/legumes that provide little wildlife habitats. The use of native warm season grasses will likely improve wildlife habitat on reclaimed strip mines. Objectives of this study were to compare the feasibility of establishing these grasses during fall, winter, or spring using a native rangeland seeder or hydroseeding; a fertilizer application at planting; or cold-moist stratification prior to hydroseeding. Vegetative cover, bare ground, species richness, and biomass samples were collected at the end of each growing season. Native warm season grass plantings had higher plant species richness compared to cool-season reclamation mixtures. There was no difference in establishment of native warm season grasses as a result of fertilization or seeding technique. Winter native warm season grass plantings had higher vegetative cover compared to spring seeded plots. Fall native warm season grass plantings were failures and cold-moist stratification did not increase plant establishment during any season. As a result of a drought during 1997, both cool-season and warm season plantings were failures. Cool-season reclamation mixtures had significantly more vegetative cover and biomass compared to native warm season grass mixtures and the native warm season grass plantings did not meet vegetative cover requirements for bond release. Forbs and legumes that established well included pale purple coneflower (*Echinacea pallida*), lance-leaf coreopsis (*Coreopsis lanceolata*), round-headed lespedeza (*Lespedeza capitata*), partridge pea (*Cassia fasiculata*), black-eyed susan (*Rudbeckia hirta*), butterfly milkweed (*Asclepias tuberosa*), and bergamot (*Monarda fistulosa*). Result from two demonstration plots next to research plots indicate it is possible to establish native warm season grasses on Eastern Kentucky strip mines for wildlife habitat.

Additional Key Words: wildlife habitat, big bluestem, indiangrass, little bluestem, side-oats grama, tall fescue conversion, Appalachian strip mine, reclamation.

Introduction

Coal mining, especially surface mining, is often harmful to numerous environmental resources. The Surface Mining and Control Act of 1977 was an effort to require mine operators to reduce the environmental impacts from surface mining. This legislation required revegetation of land disturbed by mining in an effort to control runoff, erosion, and stream sedimentation. Because the primary focus of any reclamation strategy is bond release (Drake 1980), many mine operators have historically selected the pasture as their post-mine land use option. The primary plant species seeded on these sites include KY-31 tall fescue (*Festuca arundinacea*), perennial ryegrass (*Lolium perenne*), birdsfoot trefoil (*Lotus corniculatus*), and sericea lespedeza (*Lespedeza cuneata*). These species are used because they are inexpensive, readily available, establish quickly, and result in bond release (Green and Franz 1986).

Unfortunately, reclamation strategies designed to meet bond release may not provide good habitat for livestock or wildlife. Tall fescue, a primary grass species used in standard reclamation mixtures, has a mutualisitic relationship with an endophytic fungal infection (*Acremonium coenophialum*) that allows infected plants to increase seed germination and production concomitant with greater drought and disease resistance (Ball et al. 1993, Siegel et al. 1985). This infection causes

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numerous nutrition and reproductive problems including fescue toxicosis, fescue foot, fat necrosis, agalactia, and reproductive disorders in cattle, horses, sheep, and mice (Heimann et al. 1981, Hemken et al. 1979, Lechtenberg et al. 1975, Zavos et al. 1987). Furthermore, the grass does not provide habitat or creates nutritional problems for certain wildlife species that live and/or consume it (Barnes et al. 1995, Coley et al. 1995, Conover and Messmer 1996 a,b, Guiliano et al. 1994, Madje and Clay 1991).

An alternative to seeding introduced cool-season grasses and legumes is to use native warm season grasses (NWSG). These grasses provide excellent wildlife habitat (Capel 1995) and mid-late summer livestock forage and hay (Ball et al. 1991). Previous research on the use of NWSG on mine spoil have produced mixed results depending on a variety of environmental and climatic variables (Drake 1980, Vogel 1981, 1987, Bonfert and Ashby 1984, Anderson and Birkenholz 1980, Bell and Unger 1981). Furthermore, these studies were conducted under highly controlled, small plot experiments that do not provide a realistic picture to large scale use on a mine.

The problems associated with establishment on mine spoil include the length of time these grasses require to reach maturity which results in delay of bond release (Anderson and Birkenholz 1980), high soil temperatures, pH, and low moisture that limit germination and establishment (Bell and Unger 1981), and seed availability and expense.

Reclamation attempts using NWSG often fail as a result of high seedling mortality that can be attributed to the drought-like conditions occuring on mine spoil (Rodgers and Anderson 1989). If NWSG are planted in the fall or early spring, establishment might be improved (Schram and Kalvin 1978, Anderson and Birkenholz 1980). Cool-moist stratification (seed priming) may reduce the time it takes for NWSG seed to break dormancy (Capel 1995, Weisner 1990, Emal and Conard 1973, Hauser 1986) and allow quicker establishment on mine spoil prior to the onset of adverse climatic conditions.

The goal of this project was to determine if it is feasible to establish NWSG on Appalachian mine spoil. Specifically, we wanted to: 1) measure the effect of planting date on the establishment of NWSG, 2) measure the effect of cool-moist stratification on NWSG, 3) determine the effect of fertilization on NWSG, and 4) compare NWSG establishment using a hydro-seeder or a native range notill drill.

Methods

Study Sites

This study was conducted at two locations in the Eastern coal field (rugged interior portion of the Cumberland plateau) physiographic province of Kentucky, which lies within the appalachian coal field region covering more than 29,150 hectares from Pennsylvania to Alabama. This highly eroded plateau ranges in elevation from 300 to 435 m with numerous slopes exceeding 30 degrees. Rainfall averages 114-124 cm and is evenly distributed throughout the year with an average growing season of 180 days.

This region is characterized ecologically as the mixed mesophytic forest type (Braun 1950) of the Eastern deciduous forest. Pre-mining vegetation is characterized by a diversity of dominant canopy trees including oaks (*Quercus* spp.), maples (*Acer* spp.), hickories (*Cayra* spp), American beech (*Fagus grandifolia*), yellow poplar (*Liriodendron tulipifera*), yellow buckeye (*Aesculus octandra*), and white basswood (*Tilia heterophylla*). Common understory woody species include flowering dogwood (*Cornus florida*), sourwood (*Oxydendrum arboreum*), American holly (*Ilex opaca*), and magnolias (*Magnolia* spp.). Due to the rugged landscape of this area, contour and mountain top removal strip mining are the most common methods of removing coal. Both methods drastically alter the soil and vegetation composition and the remaining mine spoil available for revegetation is the overburden of crushed shale and rock with no topsoil. Xeric conditions are created on typical reclaimed Appalachian mine sites due to the drastic alteration of mine spoil. Soils are altered through the excessive compaction of mine spoil which reduce pore space and produce bulk densities that restrict root growth and air or water movement (Vogel 1987). Sites at two locations were selected for study that occurred on level to nearly level grade and had a similar post-mine treatment and experimental approval from state and federal inspectors.

Study site one was located on the Golden Oaks Strip mine in Letcher county. Soil pH ($\bar{x} = 7.28$; range 5.4 - 8.1) was not different ($t = 0.39$; $P = 0.35$) between sites at Golden Oak. Soil P ranged from 11 ppm to 283 pp (block one $\bar{x} = 77.4$; block two $\bar{x} = 205.73$) on the Golden Oak site and was different between blocks ($t = -2.16$; $P = 0.02$). Soil K was not different between sites at Golden Oak ($\bar{x}$= 199.89; range 146-268; $t = 0.28$; $P = 0.39$).

Study site two was located on the University of Kentucky Laurel Fork mine located in Breathitt county approximately 30 km from study site one. Soil pH at this site was 6.7 with no potential acidity. Mineral levels were comparable to site one. Soil P was 272 ppm and K was 209 ppm. There was 1827 ppm calcium, 1007 ppm magnesium, and 10 ppm zinc in the mine spoil.

Three experiments were designed and implemented on these sites during the four year study. Two studies were implemented at the Golden Oak site. The initial experiment compared the establishment of NWSG to the standard reclamation mixture, compared establishment methods of NWSG, and examined the impact of fertilization on NWSG establishment. The second year experiment was based on year one results and only three treatments were implemented: the standard reclamation mixture and drilling or hydroseeding with fertilizer. The experiment at the UK Laurel Fork site was initiated based upon early results of the Golden Oak experiments. The only establishment method utilized was hydroseeding with fertilizer. In this study we wished to examine the impact of different seeding dates and cold-moist stratification on NWSG establishment.

Study plot size for all experiments was 0.1 ha. The native warm season grass mixture used was developed by Sharp Brothers Nursery and marketed by Quail Unlimited (Table 1). Retail cost was $111.00/hectare to seed at normal seeding rates. We used this mixture because we felt it was a cost-effective mixture that would actually be used by mine operators if we were successful in establishing the grasses on mine spoil. All NWSG plots were seeded at a rate of 10 pounds pure live seed/acre, which is double the normal seeding rate (Capel 1995) with a resulting cost of $222.00/hectare for seed.

All standard mixtures at both locations were seeded with a hydroseeder. NWSG plots at Golden Oak were either drilled with a native rangeland drill or with the standard hydroseeding method. NWSG plots at Laurel Fork were seeded using the standard hydroseeding method.

The reclamation standards varied on each site according to normal procedures used by hydroseeding crews and mine reclamation procedures and permits on file with the Kentucky Department of Surface Mining. The standard mixture used on the Golden Oak mine was red clover (*Trifolium pratense*) (18%), KY 31 tall fescue (16%), perennial *rye (Lolium perenne)* and winter rye (*Lolium subulatum*) (16%), timothy (*Phleum pratense*)(14%), annual rye-grass (*Secale cereale*) (7.5%), and birdsfoot trefoil (*Lotus corniculatus*) (9%). The standard mixture at this site was seeded at a rate of 60 lbs/acre. Standard plots were fertilized with 434 lbs/acre 18-46-0 fertilizer and paper mulch. NWSG fertilization plots at this site received 197 kg/acre 0-46-0 because nitrogen isn't required to establish NWSG (Reardon and Huss 1965, Rehm et al. 1972). Seeding on this site was conducted during June 1994 and 1995.

The reclamation standards used at the Laurel Fork site varied by season. The winter standard mixture was 34% tall fescue, 14% orchardgrass (Dactylis glomerata) , 10.5% birdsfoot trefoil, 9% sericea lespedeza, 7% red clover and yellow sweetclover (Melilotus officinalis), 6% perennial ryegrass and striate lespedeza (*Lespedeza striata*), and 1.4% redtop (*Agrostis gigantea*). The spring standard mixture was 22% perennial ryegrass, 21% orchardgrass, 17.5% birdsfoot trefoil, 10.5% red clover and yellow sweetclover, 9% Korean lespedeza (*Lespedeza stipulacea*), 2% redtop (*Agrostis gigantea*), and 1% weeping lovegrass (*Eragrostis curvula*). The standards on this site were hydroseeded with 180 L/ha liquid lime, 380 kg/ha 18-46-0 fertilizer, and paper mulch. NWSG plots received the same application of lime, fertilizer and paper mulch. The cold-moist stratification of the NWSG seed was accomplished by soaking the seed overnight in water, drip-dried for three hours, and placed in a 4 C walk-in cooler for 28 days (Capel 1995). The seeds were planted within 12 hours after removal from the cooler. Seeding on this site was conducted during May 1995 and September 1995.

Plant communities were sampled at the termination of the growing season at each location. Percent vegetative cover, bare ground, percent cover by dominant species, and species richness were recorded from 10, randomly selected, one-meter square quadrats (Daubenmire 1959, Higgins et al. 1994). Individual plant seedling counts were conducted in 30 randomly selected, 1 foot-square quadrats at site one. Seedling counts were not conducted at site two. All above-ground plant material in five randomly selected one-meter square quadrats was clipped by hand to determine biomass (Skousen 1990, Higgins et al. 1994). The clippings were collected, bagged, and oven-dried at 60 C for six days to determine biomass (Bonham 1989).

Data were analyzed using randomized block analysis of variance. The block x treatment interaction was significant ($P < 0.05$) for all variables measured at both locations. Therefore, blocks were analyzed separately at each location. Treatment effectsas the null hypothesis were measured using the following orthogonal contrasts at site one:

1) the standard reclamation is not different from NWSG.

2) hydroseeding NWSG is not different from drilling NWSG.

3) fertilized NWSG are not different from unfertilized NWSG.

4) there are no interactions between seeding method and fertilization.

Means at site two were compared using a Fisher's least significant difference mean comparison test. All data were analyzed using PROC GLM software (SAS 1985) and data are considered significant at the 0.05 level. Only plots where marestail was removed were included for analysis at the Laurel Fork mine site.

Results

Golden Oak Experiments

There was no treatment effect on NWSG seedling establishment in block one of the first experiment (Table 2). More NWSG seedlings were established using a hydroseeding method in block two (Table 2). In the second experiment there was no difference in seedling establishment in block two; whereas in block one more seedlings were established using a hydroseeding method (Table 2). Mean percent cover in the plots seeded with the standard reclamation mixture for the first growing season were 14.2% ± 3.6 for block one and 38.3% ± 4.8 for block two in experiment one. The mean percent cover for plots seeded to the standard in blocks one and two of experiment two were 8.4% ± 1.7 and 13.9% ± 3.7, respectively.

None of the treatments met or exceeded the 80% vegetation coverage required for bond release on block one during the second and third growing seasons (Figure 1). The standard mixture consistently had higher vegetation coverage than any of the NWSG plots (Figure 1). Neither the seeding method or the addition of fertilizer resulted in higher percent vegetative cover of NWSG (Figure 1).

The plots seeded to the standard mixture in block two exceeded the 80% cover requirement for bond release by August of the second growing season (Figure 2). The standard mixture had greater percent cover during all seasons when compared to the NWSG treatments (Figure 2). During August of the second growing season (peak growth period for NWSG) the fertilized and hydroseeded plots in this block approached the 80% bond release requirement (Figure 2).

There were no differences in percent vegetation cover during the second growing season except during August on both sites where the standard mixture had greater plant cover than the NWSG (Figure 3) for plots seeded in experiment two. There was no difference in percent NWSG cover as a result of establishment method except during September in site one where the was higher plant cover in the hyrdoseeded plots (Figure 3). None of the plantings met or exceeded the 80% bond release requirement during this experiment.

The standard mixture plots had lower percent bare ground than any NWSG plots for any of the experiments conducted at the Golden Oak Site. Mean percent bare ground for the standard mixture during the second growing season on site one was 47.4 ± 7.8 compared to 88.6 ± 2.7 for the NWSG. Mean percent bare ground for the standard mixture on site two was 29.0 ± 4.3 compared to 84.9 ± 2.7 for the NWSG. During the third growing season standard mixture plot mean bare ground was 44.5% ± 3.3 and was lower than NWSG mean bare ground percent of 79.7 ± 1.8.

A large scale NWSG applied with fertilizer by hydroseeding was successful and after two growing seasons had higher percent cover(N = 25 samples, $\bar{x}$ = 53.2% ± 31.3), lower bare ground ($\bar{x}$ = 60.8 ± 25.0), and higher species richness ($\bar{x}$ = 5.1 ± 1.2) than the research plots directly across a haul road.

By the fourth growing season there were no differences in vegetation cover, bare ground, or species richness between any of the treatment plots. This was attributed to a large scale invasion of sericea lespedeza (*Lespedeza cuneata*).

There were no differences in plant species richness throughout each year of the study (Figure 4). The NWSG unfertilized plots consistently had lower plant species diversity compared to fertilized plots. There were no differences in plant species diversity between NWSG and the standard mixtures for either experiment one or two (Figure 4).

The control plots had greater biomass than any of the NWSG plots (Figure 5) for each year of study. The fertilized NWSG plots had greater biomass than the unfertilized NWSG plots (Figure 5).

Laurel Fork Experiment

The winter and spring standards both met or exceeded the 80% vegetative cover bond release requirement and had more vegetative cover than any of the NWSG treatments during the first two growing seasons (Figure 6). The fall standard also had greater vegetative cover than the NWSG and met the minimum bond release cover requirement (Figure 6). The cold-moist NWSG treatments always had lower vegetative cover (Figure 6) and higher bare ground than the non-cold-moist treatments. The percent cover for the w-nwsg treatment was higher than the s-nwsg treatment in Block 1 but not in Block 2 during the first growing season. By the second growing season, there was no difference in percent cover between spring and winter NWSG plantings (Figure 6).

In a demonstration plot adjacent to the research plots, a spring NWSG planting without fertilizer had greater percent cover (N = 10 samples, $\bar{x}$ = 70.0% ± 23.7), less bare ground ($\bar{x}$ = 60.8 ± 25.0), and greater plant species richness ($\bar{x}$ = 5.1 ± 1.2) than the research plots.

All nwsg treatments, had a higher average mean bare ground compared to the winter and spring standard reclamation treatments. The average percent bare ground for the s-cm-nwsg treatment was higher than the s-nwsg treatment in Block 1.

There were no differences in plant species richness between the standard mixtures and the NWSG during the first growing season (Figure 7). By the end of the second growing season, all the NWSG treatments except those planted in the fall, had a greater plant species richness than the standards. Within the NWSG plantings, species richness for the s-nwsg plantings was greater than the cold-moist NWSG treatments during each growing season except in block two, year two (Figure 7).

In a small demonstration plot, various native forbs were examined for their suitability for use on Eastern Kentucky strip mines. A 3m long row of seeds was hand planted of various species. The species that had greater than 70% establishment were pale purple coneflower (*Echinacea pallida*), lance-leaf coreopsis (*Coreopsis lanceolata*), round-headed lespedeza (*Lespedeza capitata*), partridge pea (*Cassia fasiculata*), black-eyed susan (*Rudbeckia hirta*), butterfly milkweed (*Asclepias tuberosa*), and bergamot (*Monarda fistulosa*)

At the termination of each growing season, the standard mixtures had higher biomass than any of the NWSG treatments (Figure 8).

Discussion

It is possible to establish NWSG on Eastern Kentucky strip mines, particularly on difficult sites where the standard mixtures do not establish at a level required for bond release. The sites at Golden Oak were known to be troublesome and had been seeded several times with a standard mixture without establishing a plant stand that would meet bond release requirements (Roger Profitt, pers. comm.). Golden Oak mining officials often have to seed standard mixtures several times before establishing 80% vegetation cover. In one plot, the standard mixture failed to establish and we seeded NWSG over the top of this mixture. By the end of the third growing season, the only plants left in this plot were NWSG. Furthermore, within each NWSG plot there were patches of grasses that had more than 80% plant cover. Side-oats grama (*Bouteloua curtipendula*) established the best on this mine site. Little bluestem (*Schizachryrium scoparium*) and indiangrass (*Sorgastrum nutans*) also established well. Perhaps the best stand of NWSG on this mine were in the large 20 ha field that was seeded the same year. Of the 25 samples taken, 12 plots had NWSG percent cover greater than 70% and 9 plots met or exceeded the 80% cover required for bond release.

The biggest detriment to establishing NWSG on these mines is the crushed rock planting medium. Drake (1980) observed that establishment of NWSG was directly related to the thickness of the loess soil layer, which is absent on these mines. Within each plot, both standards and NWSG, there was substantial variation in plant cover and bare ground. This resulted primarily from the size of the crushed rock spoil. In some areas, the rock size was so large that no plants could become established on the exposed rock. Furthermore, these mine spoils do not have an even distribution of nutrients or pH.

It has been documented that excessive soil temperatures, low pH (acid conditions), and low moisture all limit the success and germination of NWSG (Bell and Unger 1981). Numerous authors have concluded NWSG establishment on mines is difficult because mine spoils become droughty by early summer (Rodgers and Anderson 1989, Bell and Ungar 1981, Brenner et al. 1994). Side-oats grama established the best on these sites because it is adapted to xeric conditions and poor soils (Packard and Mutel 1997). Indiangrass and little bluestem also established well and are dominant plants in Kentucky barrens and prairies (Chester et al. 1997). These areas have environmental and edaphic conditions that are similar to a reclaimed mine.

The establishment of these grasses our mine sites and other studies was slow (Hsu et al. 1985, Beckman et al. 1993). Our results show that these grasses can establish quicker than the 10-15year establishment prediction of Anderson and Birkenholz (1980). Our results also disagree with Kuenstler et al. (1980) that indicated prairie grasses were not suitable for strip mine reclamation.

While the grasses were slow to establish, the majority of side-oats grama matured and produced seed the first year and indiangrass, little bluestem, and switchgrass matured and produced seed the second growing season. This means the root systems were well established (Bonfert and Ashby 1984) and the plants could withstand drought, a common phenomenon on these mines.

Results from the Laurel Fork experiment show that planting a nurse crop is not advisable for establishing NWSG. The dense mat of residual rye may have contributed to the relatively low establishment rate of the NWSG treatments by increasing seed/seedling mortality. Some possible causes of seed and seedling mortality could be due to avian predation, failure of the seeds to germinate in an appropriate germination site on the mine spoil, and seeds that germinated on top of the residual plant mat may have experienced increased seedling mortality due to wind and sun exposure. Furthermore, the residual rye may have created excellent growing conditions for marestail and the competition by marestail may have contributed to seedling mortality of the NWSG.

Our results also show that either hydroseeding or drilling NWSG can work but hydroseeding with fertilization resulted in the best stands at Golden Oak. However, the best stand of NWSG was eastablished at a demonstration plot at UK Laurel Fork which was seeded with a TYE® native rangeland drill.

Numerous studies have documented increased germination of NWSG with cold-moist stratification (Beckman et al. 1993, Emal and Conard 1973, Hsu et al. 1985, Hauser 1986, Weisner 1990). Cold-moist stratification did not increase NWSG stands in this stydy. This could be a result of the light, fluffy seeds sinking to the bottom of the mixing tank and not being applied to mine spoil or seedling damage as a consequence of being forced through small openings of the spraying unit. It may also been a function of the residual mat of annual rye in that seeds may have reached the mat, germinated, and died because their root systems could not reach the substrate and the plants dessicated and died.

Results from this study show that spring is best for establishing NWSG. However, winter seedings also did well on the Laurel Fork site. It has been hypothesized that seeds planted in late fall or early spring establish more readily than late spring or summer because freezing temperatures and moisture assist in breaking seed dormancy (Shramm and Kalvin 1978, Anderson and Birkenholz 1980). Vogel (1974) indicated that early spring, March 1 to April 15 are the best times for seeding. We would concur based on our data.

The information generated from this study shows that fertilization aids in the establishment of NWSG on these sites. Rehm et al. (1972) reported that nitrogen and phosphorus were required for maximum forage production. However, the number or percentages of big bluestem and side-oats grama in fertilized and unfertilized plots were not different after four years. Stubbendieck and Nelson (1989) observed applying nitrogen resulted in higher yield of little bluestem and indiangrass. However, Reardon and Huss (1965) found that nitrogen is only effective with sufficient soil moisture which is often lacking on these mines.

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Table 1. Quail Unlimited native warm season grass mixture used in seeding experimental plots at Golden Oak and Laurel Fork mines, 1994-1996.

Common Name	Scientific Name	Lbs. Pure Live Seed/Acre	Percent of Mixture
Big Bluestem	*Andropogon gerardii*	1.8	30
Indiangrass	*Sorgastrum nutans*	2.0	33
Little Bluestem	*Schizarchyrium scoparium*	1.5	25
Sideoats Grama	*Bouteloua curtipendula*	0.5	8
Switchgrass	*Panicum virgatum*	0.2	4
Illinois Bundleflower	*Desmanthus illinoensis*		< 1
Partridge Pea	*Cassia fasiculata*		< 1
Black-eyed Susan*	*Rudbeckia serotina*		< 1
Maximillian Sunflower*	*Helianthus maximiliani*		< 1
Purple Prairie Clover	*Petalostemum purpureum*		< 1
Upright Coneflower*	*Rabibida columifera*		< 1
Grayheaded Coneflower	*Ratibida pinnata*		< 1
Pitcher Sage*	*Salvia azurea*		< 1
Indian Blanket*	*Gallardia pulchella*		< 1
Lanceleaf Coreopsis	*Coreopsis lanceolata*		< 1
Gayfeather*	*Liatris pyncnostachya*		< 1
Lead Plant	*Amorpha canescens*		< 1
Roundhead Lespedeza	*Lespedeza capitata*		< 1

* indicates the species is not native to Kentucky.

Table 2. Mean establishment of Quail Unlimited mixture of native warm season grass seedlings at Golden Oak Mine, Letcher County, KY during the first growing season.

		1994				1995			
		Block One Seedlings (#/0.3m^2)		Block Two Seedlings (#0.3m^2)		Block One Seedlings (#/0.3m^2)		Block Two Seedlings (#/0.3m^2)	
Treatment	N	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE	$\bar{x}$	SE
Hydroseed	10	4.2[a]	0.8	10.15	1.4				
Hydroseed & fertilizing	10	4.5[a]	0.8	11.77	0.6	12.5[a]	2.2	3.5[a]	0.8
Drill	10	4.3[a]	0.8	4.15	0.8				
Drill & fertilize	10	4.3[a]	0.6	4.02	0.6	6.8[b]	1.0	3.4	0.8

[a,b]Means within columns followed by different letters are different ($P \leq 0.05$).

Figure 1. Mean percent vegetation cover (N = 10 m^2 samples) of five treatments (hydroseeding Quail Unlimited native warm season grass mixture (NWSG), H; hyrdoseeding with fertilization of NWSG, H + F; drilling NWSG with Tye rangeland seeder D; drilling NWSG with fertilization D+ F; and standard cool season grass/legume mixture of tall fescue, red clover, timothy grass, birdsfoot trefoil, and perennial, annual, and winter rye grass) planted in 1994. Samples reflect the second and third growing season on block one, Golden Oak mine site located in Letcher county, Kentucky.

Figure 2. Mean percent vegetation cover (N = 10 m^2 samples) of five treatments (hydroseeding Quail Unlimited native warm season grass mixture (NWSG), H; hyrdoseeding with fertilization of NWSG, H + F; drilling NWSG with Tye rangeland seeder D; drilling NWSG with fertilization D+ F; and standard cool season grass/legume mixture of tall fescue, red clover, timothy grass, birdsfoot trefoil, and perennial, annual, and winter rye grass) planted in 1994. Samples reflect the second and third growing season on block two, Golden Oak mine site located in Letcher county, Kentucky.

Figure 3. Mean percent vegetation cover (N = 10 m^2 samples) of three treatments (hydroseeding with fertilization of a Quail Unlimited native warm season grass mixture (NWSG), H + F; drilling with fertilization of a QU NWSG with Tye rangeland seeder D + F;; and standard cool season grass/legume mixture of tall fescue, red clover, timothy grass, birdsfoot trefoil, and perennial, annual, and winter rye grass) planted in 1995. Samples reflect the second growing season at Golden Oak mine site located in Letcher county, Kentucky.

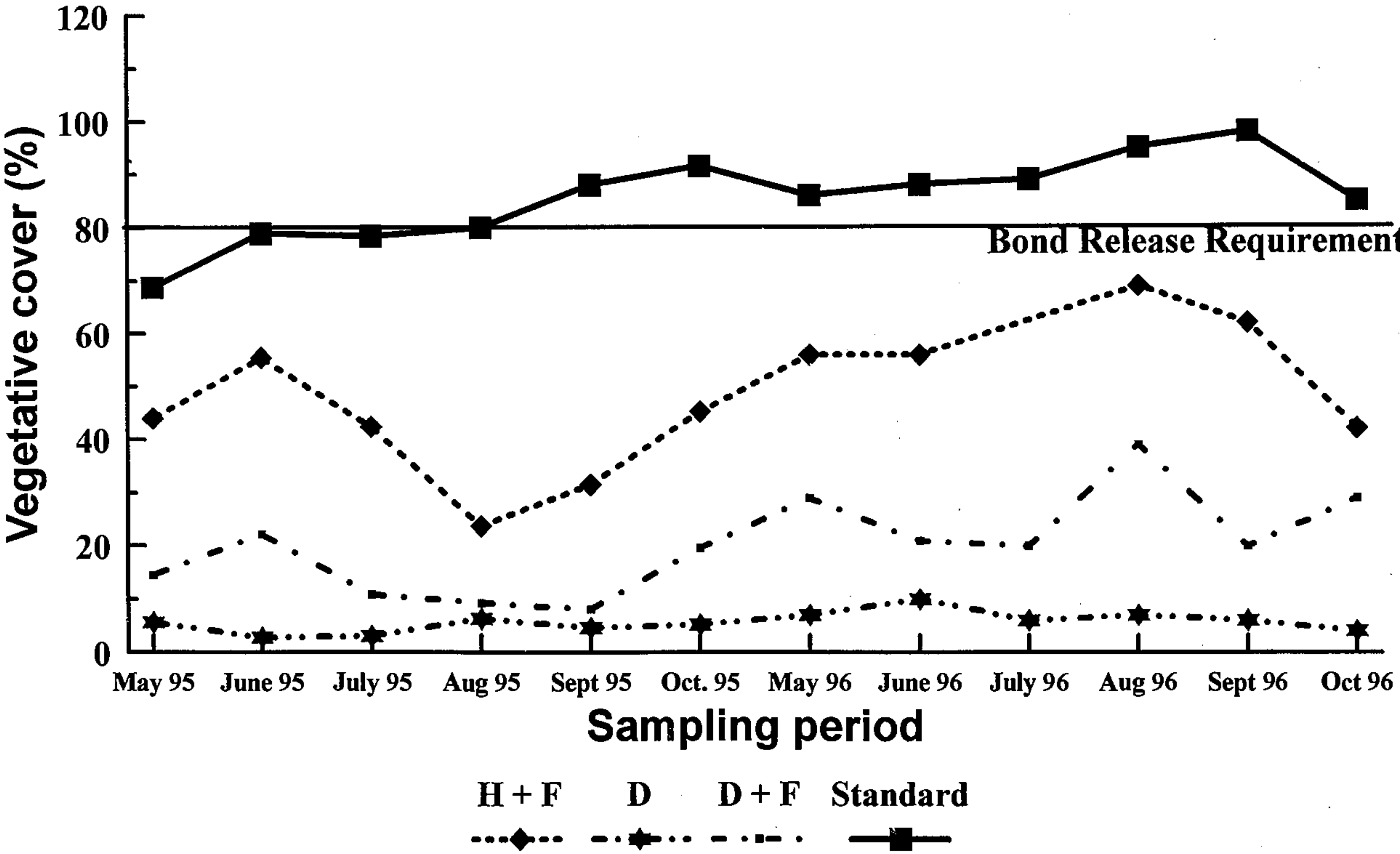
Figure 4. Mean plant species richness (N = 10 m^2 samples) of five treatments (hydroseeding Quail Unlimited native warm season grass mixture (NWSG), H; hyrdoseeding with fertilization of NWSG, H + F; drilling NWSG with Tye rangeland seeder D; drilling NWSG with fertilization D+ F; and standard cool season grass/legume mixture of tall fescue, red clover, timothy grass, birdsfoot trefoil, and perennial, annual, and winter rye grass) planted in 1994. Samples reflect the second and third growing seasons on Golden Oak mine site located in Letcher county, Kentucky.

Figure 5. Mean plant biomass (N = 10 m^2 samples) of five treatments (hydroseeding Quail Unlimited native warm season grass mixture (NWSG), H; hyrdoseeding with fertilization of NWSG, H + F; drilling NWSG with Tye rangeland seeder D; drilling NWSG with fertilization D+ F; and standard cool season grass/legume mixture of tall fescue, red clover, timothy grass, birdsfoot trefoil, and perennial, annual, and winter rye grass) planted in 1994. Samples reflect the second and third growing seasons on Golden Oak mine site located in Letcher county, Kentucky.

Figure 6. Mean percent vegetation cover (N = 10 m^2 samples) sampled during the first and second growing season of a standard cool season grass/legume treatment planted during the winter (ws), spring (ss), or fall (fs) of 1995 and Quail Unlimited native warm season grass mixtures planted during the winter (wsnwg), spring (snwsg), or fall (fnwsg) without cold-moist stratification and during the spring (snwsg-cm) and fall (fnwsg-cm) with cold-moist stratification on the University of Kentucky Laurel Fork mine.

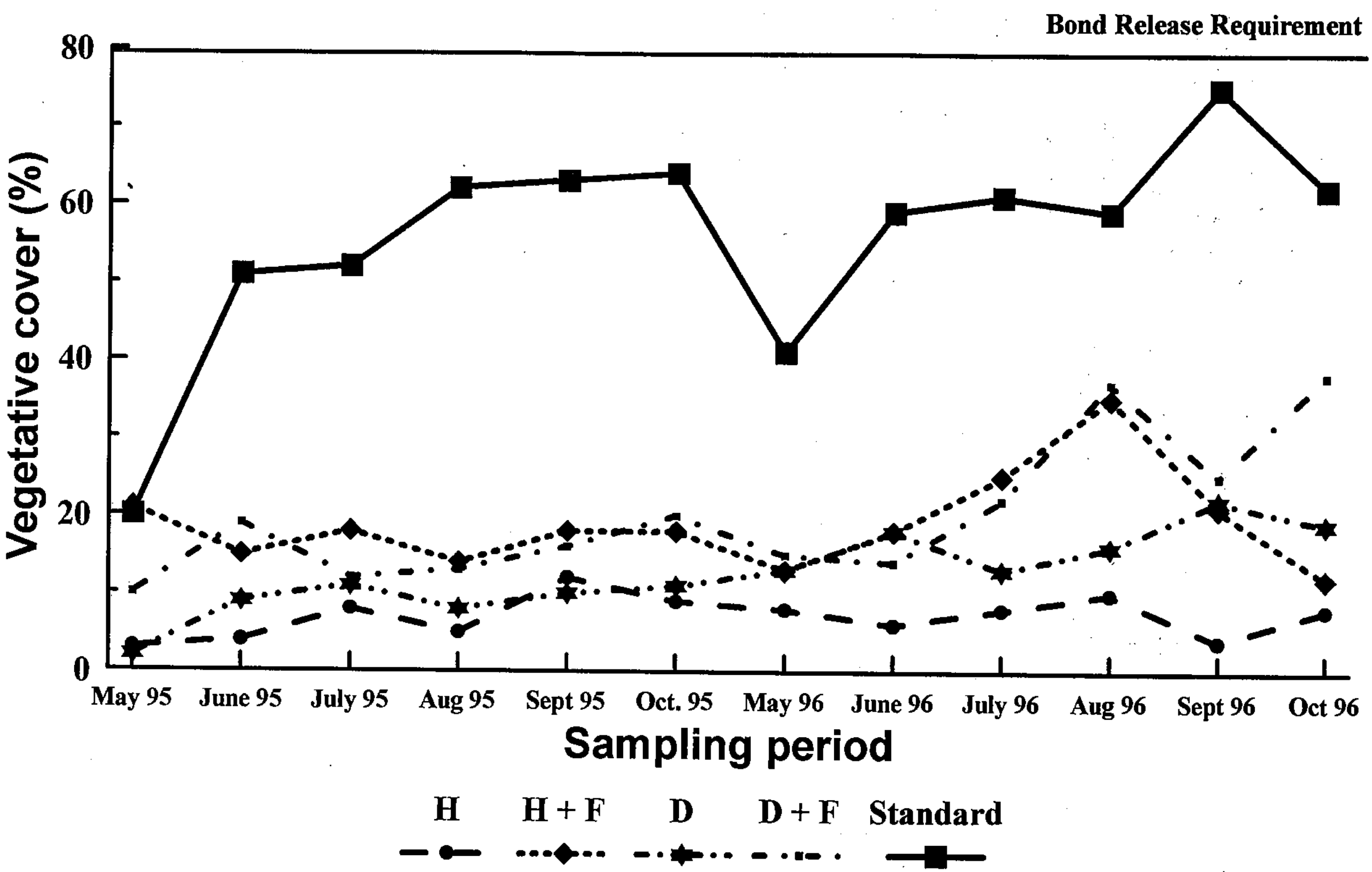
Figure 7. Mean plant species richness (N = 10 m^2 samples) sampled during the first and second growing season of a standard cool season grass/legume treatment planted during the winter (ws), spring (ss), or fall (fs) of 1995 and Quail Unlimited native warm season grass mixtures planted during the winter (wsnwg), spring (snwsg), or fall (fnwsg) without cold-moist stratification and during the spring (snwsg-cm) and fall (fnwsg-cm) with cold-moist stratification on the University of Kentucky Laurel Fork mine.

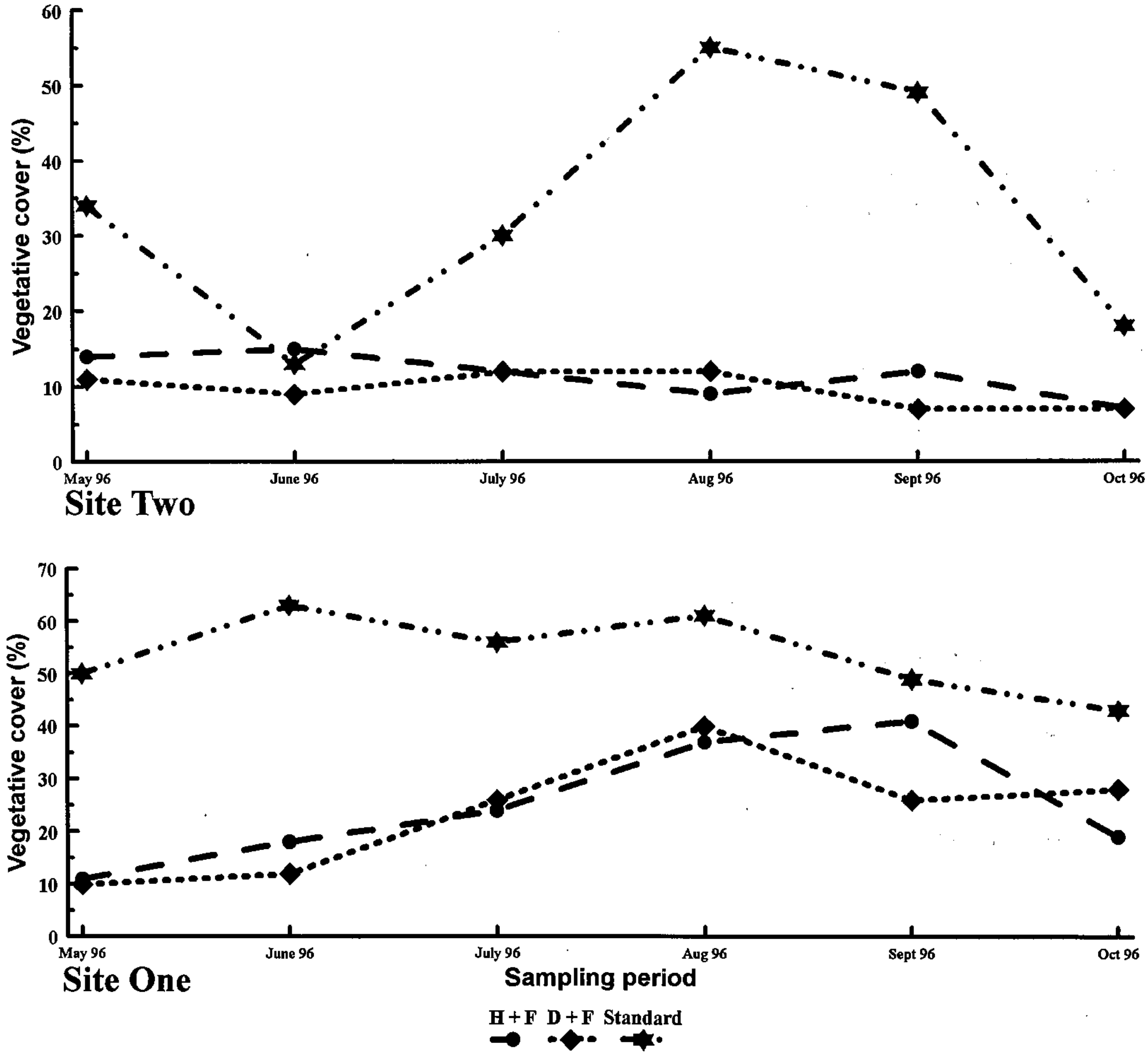
Figure 8. Mean plant biomass (N = 10 m^2 samples) sampled during the first and second growing season of a standard cool season grass/legume treatment planted during the winter (ws), spring (ss), or fall (fs) of 1995 and Quail Unlimited native warm season grass mixtures planted during the winter (wsnwg), spring (snwsg), or fall (fnwsg) without cold-moist stratification and during the spring (snwsg-cm) and fall (fnwsg-cm) with cold-moist stratification on the University of Kentucky Laurel Fork mine.

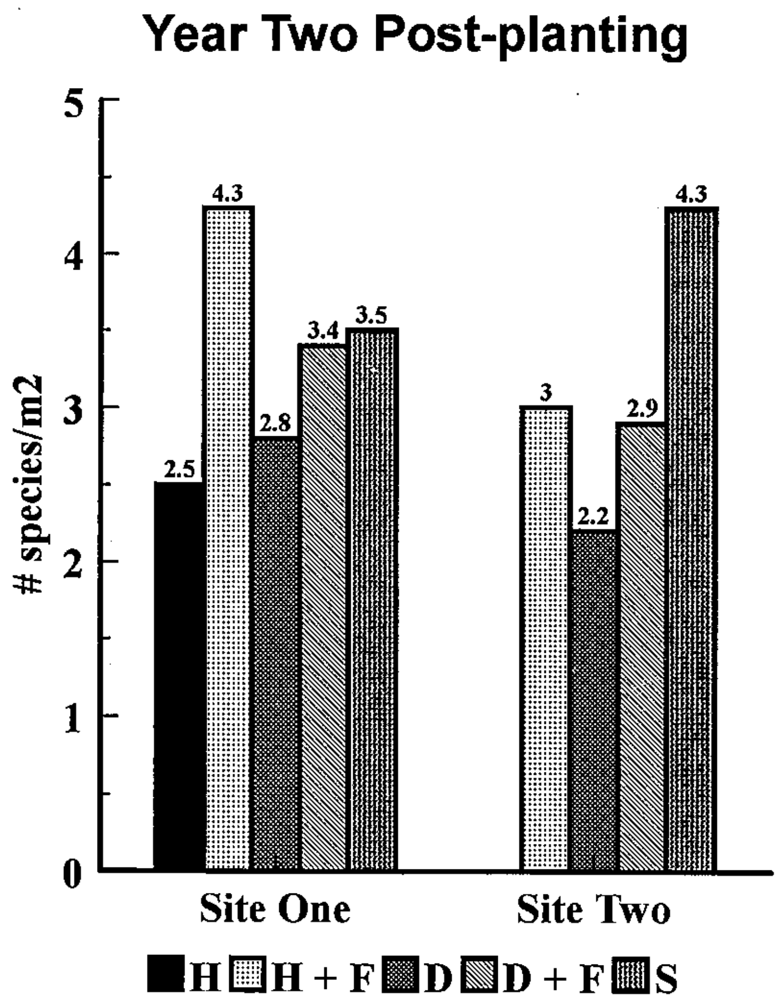


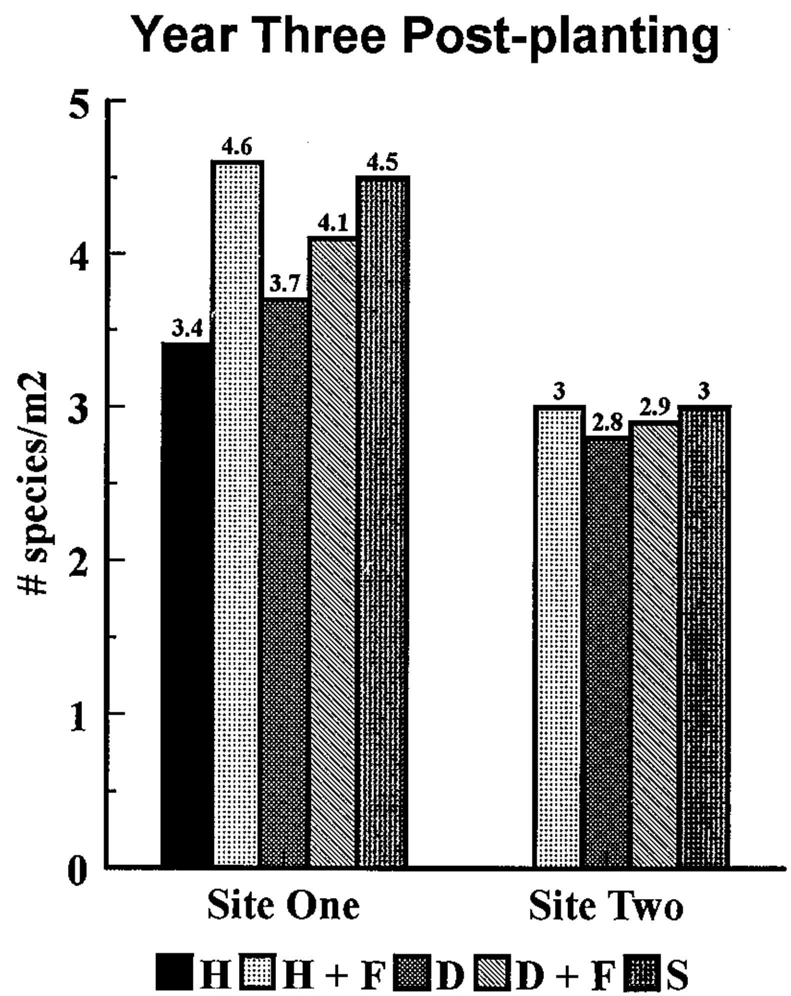
120
100
80
60
40
20
0
Vegetative cover (%)
Bond Release Requirement
May 95
June 95
July 95
Aug 95
Sept 95
Oct. 95
May 96
June 96
July 96
Aug 96
Sept 96
Oct 96
Sampling period
H + F
D
D + F
Standard

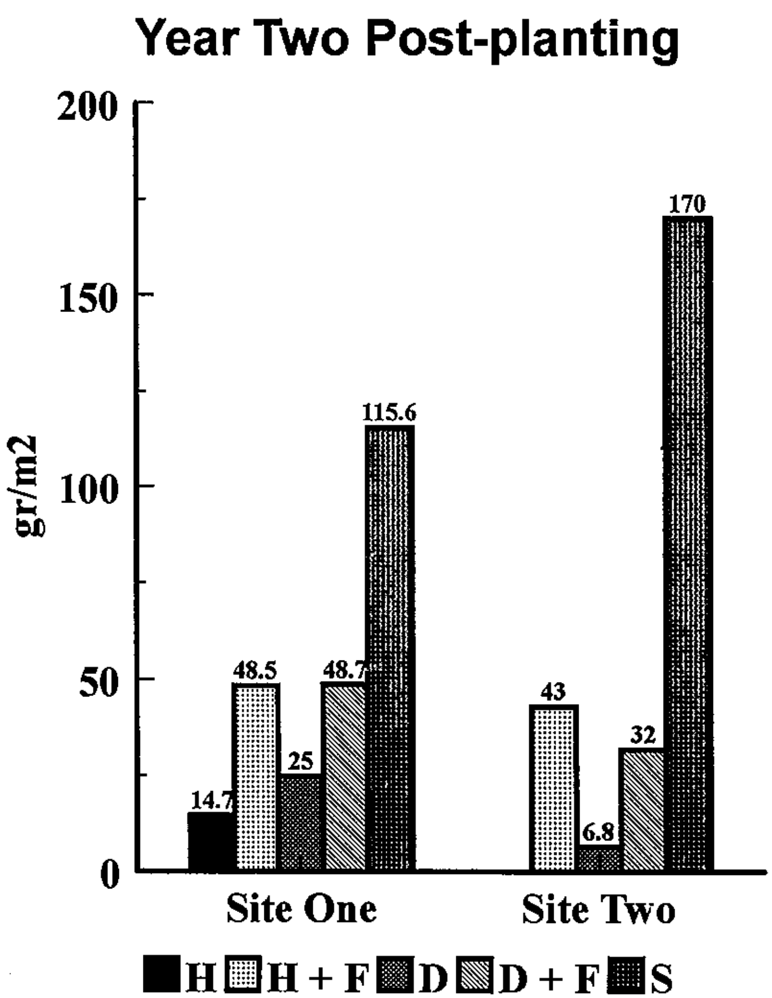
626

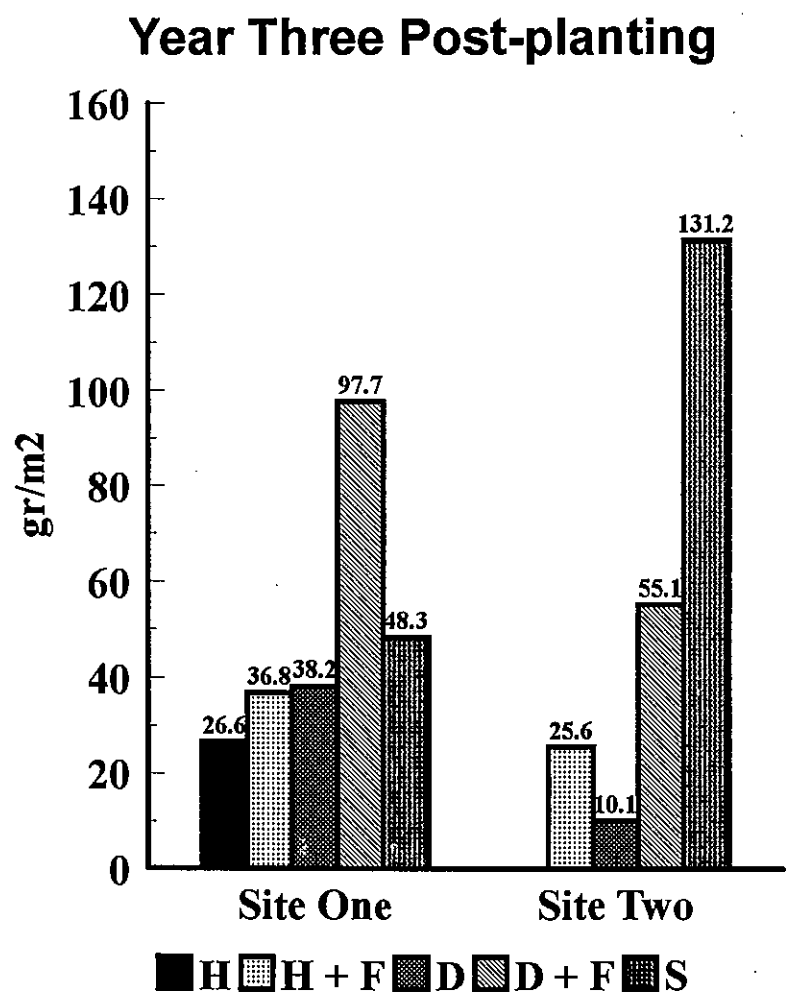

Bond Release Requirement
80
60
40
20
0
Vegetative cover (%)
May 95
June 95
July 95
Aug 95
Sept 95
Oct. 95
May 96
June 96
July 96
Aug 96
Sept 96
Oct 96
Sampling period
H
H + F
D
D + F
Standard

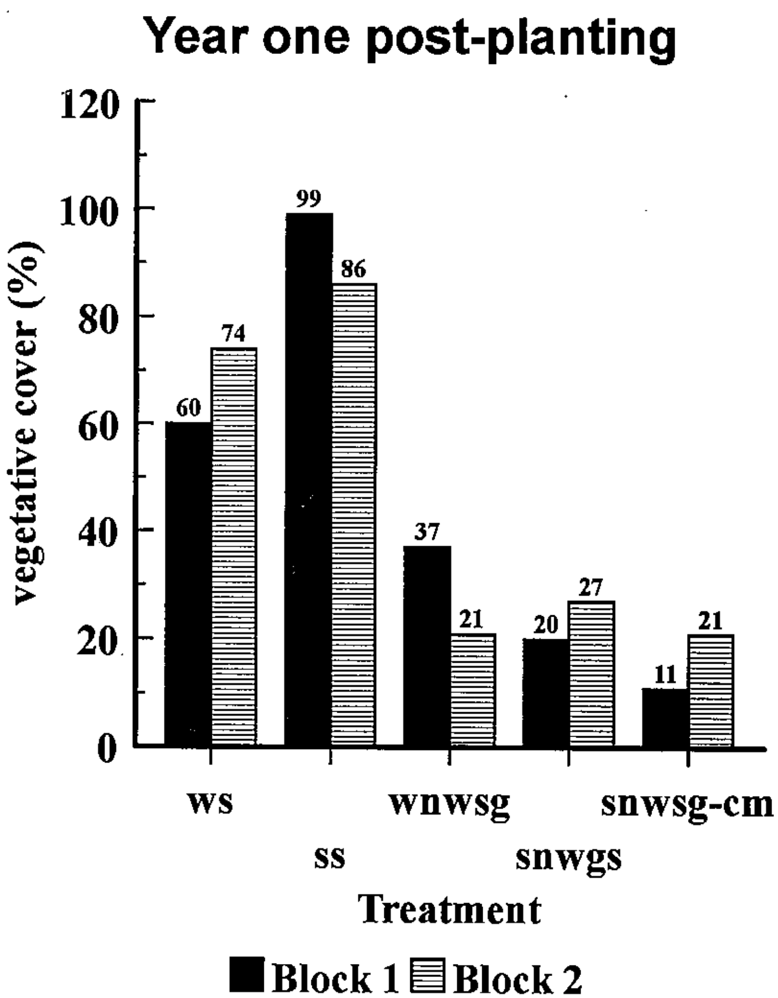

60
50
40
30
20
10
0
Vegetative cover (%)
May 96
June 96
July 96
Aug 96
Sept 96
Oct 96
Site Two
70
60
50
40
30
20
10
0
Vegetative cover (%)
May 96
June 96
July 96
Aug 96
Sept 96
Oct 96
Site One
Sampling period
H + F
D + F
Standard

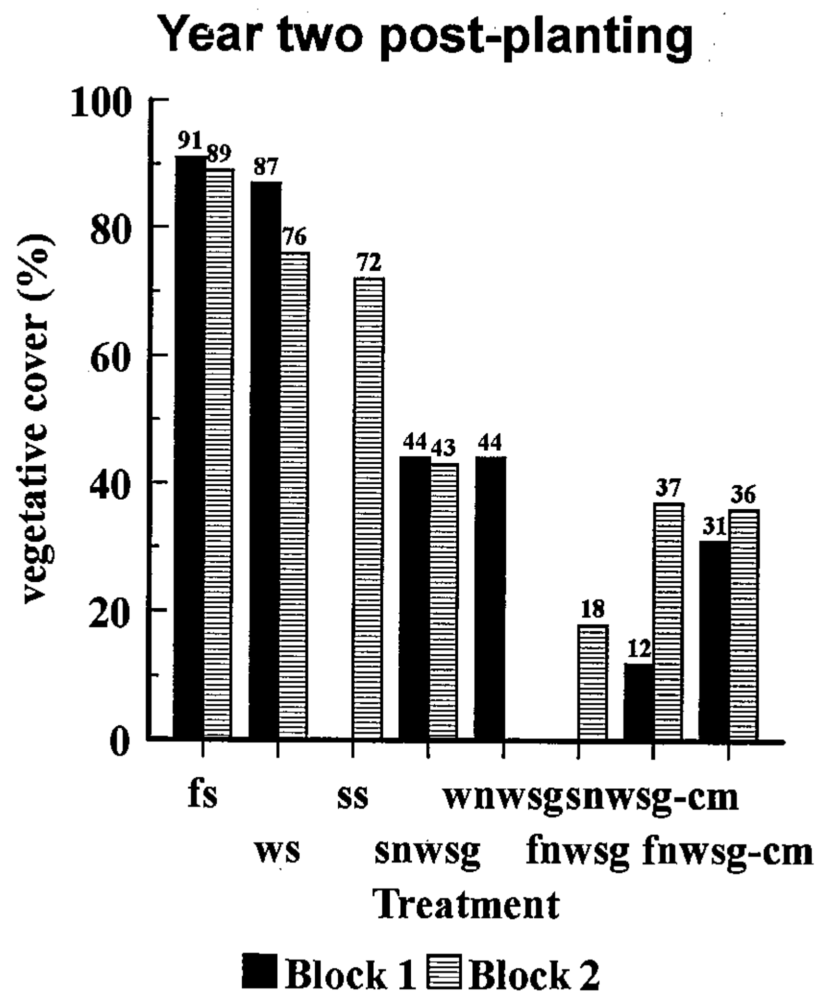

Year Two Post-planting
species/m2
5
4
3
2
1
0
4.3
3.4
3.5
2.8
2.5
3
2.9
4.3
2.2
Site One
Site Two
H
H + F
D
D + F
S


Year Three Post-planting
species/m2
5
4
3
2
1
0
4.6
4.5
4.1
3.7
3.4
3
2.8
2.9
3
Site One
Site Two
H
H + F
D
D + F
S

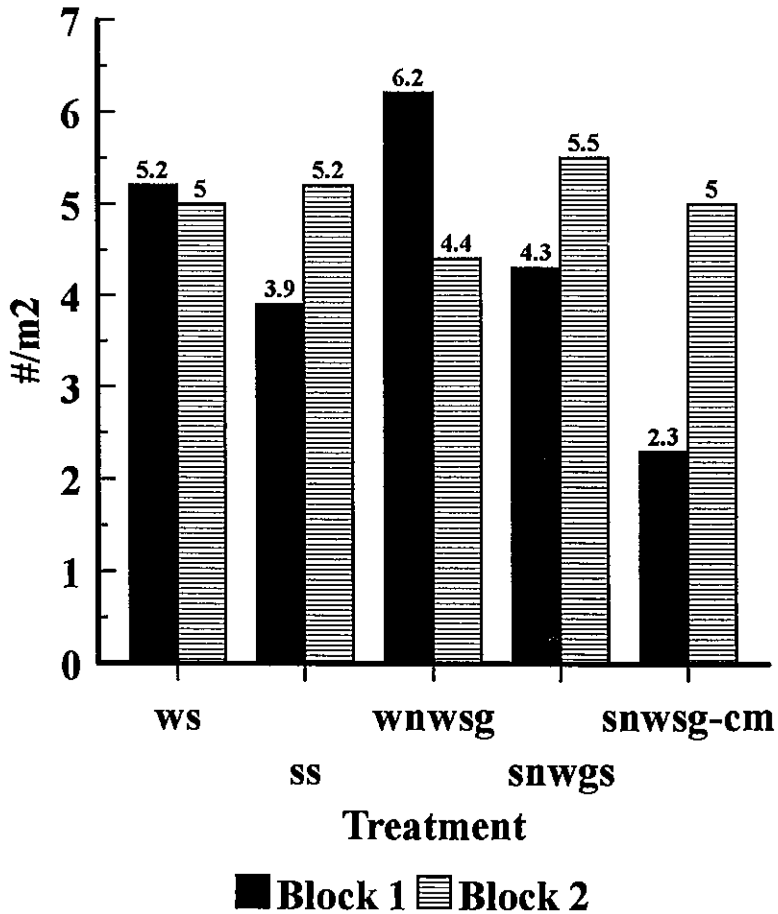

Year Two Post-planting
gr/m2
200
150
100
50
0
14.7
48.5
25
48.7
115.6
43
6.8
32
170
Site One
Site Two
H
H + F
D
D + F
S


Year Three Post-planting
gr/m2
160
140
120
100
80
60
40
20
0
26.6
36.8
38.2
97.7
48.3
25.6
10.1
55.1
131.2
Site One
Site Two
H
H + F
D
D + F
S

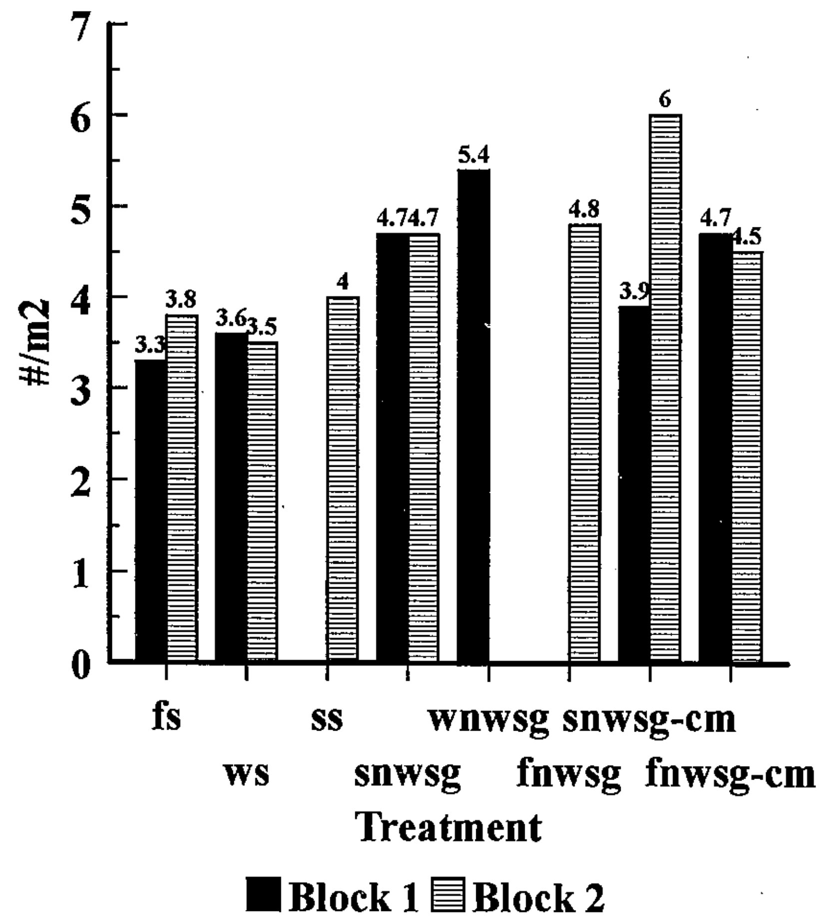

Year one post-planting
120
100
80
60
40
20
0
vegetative cover (%)
60
74
99
86
37
21
20
27
11
21
ws
ss
wnwsg
snwgs
snwsg-cm
Treatment
Block 1
Block 2

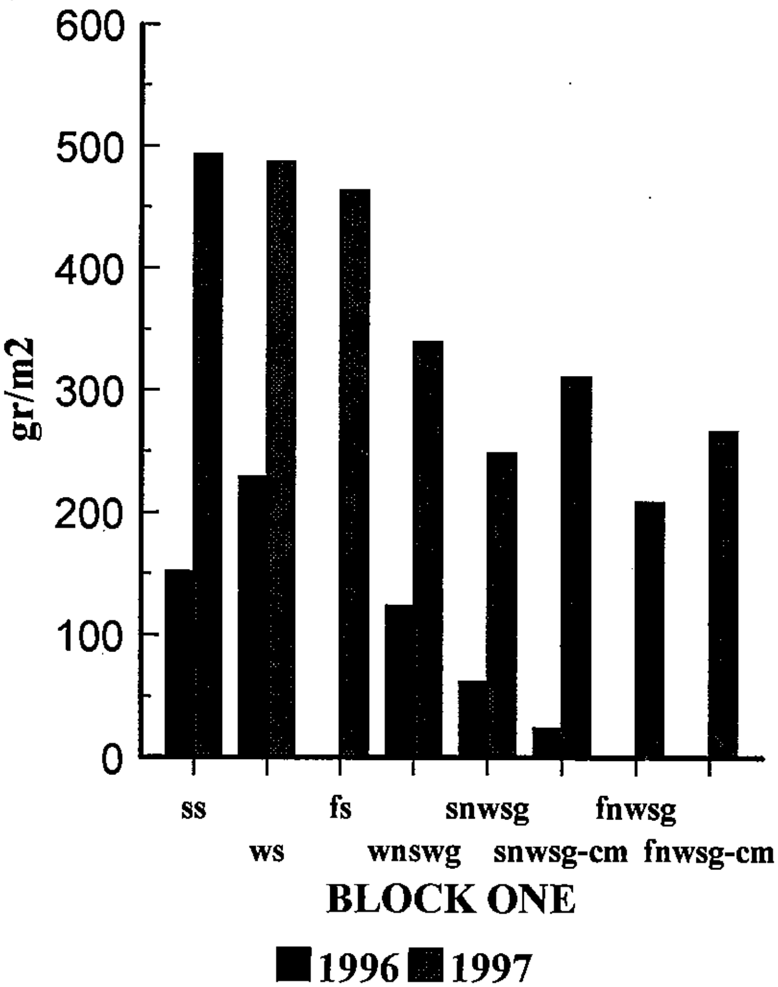

Year two post-planting
100
80
60
40
20
0
vegetative cover (%)
91
89
87
76
72
44
43
44
18
12
37
31
36
fs
ws
ss
snwsg
wnwsg
fnwsg
snwsg-cm
fnwsg-cm
Treatment
Block 1
Block 2

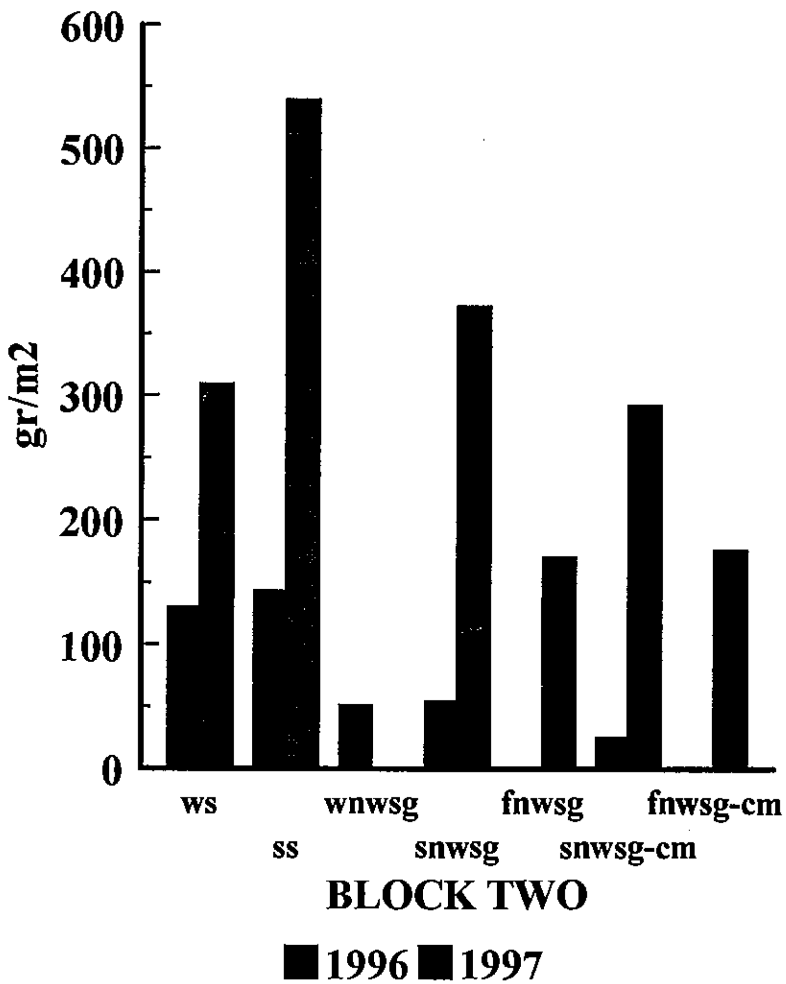
Year one post-planting



Year two post-planting




600
500
400
300
200
100
0
gr/m2
ss
ws
fs
wnswg
snwsg
snwsg-cm
fnwsg
fnwsg-cm
BLOCK ONE
1996
1997


600
500
400
300
200
100
0
gr/m2
ws
ss
wnwsg
snwsg
fnwsg
snwsg-cm
fnwsg-cm
BLOCK TWO
1996
1997