# GRAIN SORGHUM AS A TEST CROP TO RECLAIM PRIME FARMLAND DISTURBED FOR COAL MINING[1]

by

R.I Barnhisel and J.L. Powell[2]

---

**ABSTRACT** Data are presented to summarize experiments having the following objectives: 1) Determine the yield potential of selected grain sorghum cultivars. 2) Determine the effect of soil depth and the previous cropping history on grain sorghum yield. 3) Determine the effect of liming the subsoil prior to topsoil replacement on grain sorghum yield.

In general, grain sorghum is a good test crop for the evaluation of reclamation success (i.e., productivity) of prime farmland, however, wide variations occur between varieties. Grain sorghum responded to increased soil depth covering the cast overburden, with the greatest yield increase occurring between the 20 and 60 cm depth treatments and a lesser yield response between 60 and 100 cm treatments. The previous cropping history affected grain sorghum yields. Plots that had been in alfalfa and tall fescue during the initial five years of this study outyielded those that were in a corn-wheat-soybean rotation. The application of lime to the acidic subsoil resulted in a significant yield increase.

ADDITIONAL KEY WORDS: soil depth, subsoil liming, bond release, target yield.

## INTRODUCTION

The Surface Mining Control and Reclamation Act (SMCRA) of 1977 mandates that the coal operator demonstrate the return of surface mined land to its original productivity. Several test crops may be used in various states to meet the performance standards of current regulations. In Kentucky, corn (<u>Zea mays</u> L.) must be grown one of the three years required for demonstrating the return of

---

[1] Paper presented at the 1989 Reclamation Conference sponsored by the American Society for Surface Mining and Reclamation and the Canadian Land Reclamation Association, August 27-31, 1989, Calgary, Alberta, Canada. The investigation reported in this paper (No. 89-3-112) is in connection with a project of the Ky. Agr. Exp. Sta. and is published with approval of the Director.

[2] R.I. Barnhisel, Professor of Agronomy and Geology, University of Kentucky, Lexington, KY and J.L. Powell, Route # 3, Central City, KY. 42330.

Proceedings America Society of Mining and Reclamation, 1989 pp 309-316
DOI: 10.21000/JASMR89010309

https://doi.org/10.21000/JASMR89010309

productivity, while various crops may be utilized the other two years. Wheat (Triticum aestivum L.) has been successfully grown on prime and non-prime sites, including cast-overburden, and yields are affected by cultivar selection and depth of replaced soil (Barnhisel et al., 1988a). In that study, three soil depths were used: 25, 50, and 75 cm in a randomized 3 x 3 factorial experimental design. A significant yield response to soil depth was found between the 25 and 50 cm treatments but not between 50 and 75 cm.

Studies to determine the minimum depth of soil necessary to achieve a post-mining productivity equal to pre-mining productivity has resulted in numerous publications (Deane, 1977; Farmer et al., 1974; Nielsen and Miller, 1980; Power, 1978; Power et al., 1981; Russell, 1977; Sandoval and Gould, 1978; Sindelar et al., 1973; Taylor and Gardner, 1963; and Zimmerman and Kardos, 1961). The crop being grown strongly influences the topsoil depth requirement, as do the chemical, physical, and mineralogical nature of the spoil material underlying the topsoil. Where spoil properties do not restrict root growth, less topsoil is needed to provide a rooting media for optimum crop production (Grandt, 1978 and Barnhisel et al., 1988a,b).

The rational for using grain sorghum as a test crop for evaluating various treatments in both non-prime and prime farmland reclamation projects is because it has several traits that reduce the risks of crop failure. It withstands stress drought better than corn or soybeans (Glycine max (L.) Merr.) by becoming semi-dormant, and its more fibrous root system is more efficient in extracting soil moisture. Pollination of sorghum is not as severely affected by hot temperatures as that of corn. When moisture and nutrients are adequate, grain sorghum produces extra tillers and seed heads, whereas during drought only the primary tiller will produce a seed head. Grain sorghum will also withstand excessive moisture conditions better than either corn or soybeans.

Coal companies are searching for ways to reduce costs and minimize risk, yet meet performance standards of SMCRA. To obtain information needed to make recommendations about the use of grain sorghum in mine land reclamation, field research projects were established with the following objectives: 1) Determine the yield potential of selected grain sorghum cultivars. 2) Determine the effect of soil depth and the previous cropping history on grain sorghum yield. 3) Determine the effect of liming the subsoil prior to topsoil replacement on grain sorghum yield.

## METHODS AND MATERIALS

The two studies reported here were conducted on different surface mines operated by Peabody Coal Company. These sites (Alston and River Queen) have been used in earlier-reported studies, hence only brief details on plot construction and spoil and soil characteristics will be given here. At both sites, two soils were replaced as a mixture. The soil mixture consisted of the Sadler (Glossic Fragiudalf, fine-silty, mixed, mesic) and the Belknap (Aeric Fluvaquent, coarse-silty, mixed, acid, mesic). The Ap horizon or topsoil was segregated from the B or subsoil horizon for each soil in both experiments.

Lime was applied at the Alston and River Queen sites as calcitic limestone at 11 Mg ha$^{-1}$ and 15 Mg ha$^{-1}$, respectively. This lime was applied following topsoil replacement and prior to the establishment of any experiments. P and K fertilizers were applied at different times throughout the experimental period when needed as 0-46-0 and 0-0-60, respectively and the rates used were according to soil test recommendations published in AGR-1.[3/] Nitrogen was also applied in the form of ammonium nitrate as a split application of 150 kg N $ha^{-1}$ at planting and 50 kg N $ha^{-1}$ as a side-dressing about 40 days after emergence.

The grain sorghum was seeded in 76 cm rows at a rate of 8 kg $ha^{-1}$ using a no-till drill. Grain was harvested using a plot combine, weighed to the nearest 0.1 kg, and yields were corrected to a standard 15% moisture. Following statistical analyses, data were rounded to the nearest 5 kg $ha^{-1}$.

## Effect of Previous Crop Rotation and Subsoil Liming

The Alston Surface Mine was the location of this experiment. Although details of plot construction are given elsewhere (Barnhisel, 1983 and Barnhisel et al., 1988b), briefly, the six treatments consisted of three soil depths (given below) and two lime rates (0 and 45 Mg $ha^{-1}$). For two of the soil depth treatments, lime was incorporated into the upper 10-15 cm of the acidic subsoil prior to replacement of the topsoil. The subsoil depths were 40 and 80 cm. For the third treatment, the lime was incorporated into spoil overburden materials prior to its being topsoiled. Both the subsoil and the 20 cm of topsoil which was applied to the entire area were replaced with scraper pans.

The sequence of crops grown on this site is given in Table 1. Changes in soil bulk density values and alfalfa yields were reported in an earlier publication (Barnhisel et al., 1988b). Funks G1602 grain sorghum variety was seeded in the first week of May.

## Effect of Grain Sorghum Cultivars

The second experiment on River Queen was adjacent to the area on which corn hybrids were evaluated and a more detailed description of plot construction is given elsewhere (Powell et al., 1988). The soil was replaced with scraper pans in which approximately 80 cm of subsoil was deposited and, following leveling with a dozer, 20 cm of topsoil was replaced.

Both the number and selection of grain sorghum varieties were changed some each year, based upon availability of space and entries provided by cooperating seed companies for this cultivar testing study. In all cases, five replications were used each year and plots consisted of 2 rows, 76 cm apart and 13 meters long. However, plots were trimmed to 11 meters prior to being harvested with the plot combine.

## RESULTS AND DISCUSSIONS

In Kentucky, the USDA-SCS has not established target yields for grain sorghum for the prime farmland soils that are likely to be disturbed by surface mining. However, they have estimated the yield potential of corn on the two soils used in these experiments. Corn yields would be expected to be about 6600 and 6900 kg $ha^{-1}$ for the Sadler and Belknap soils, respectively. Based on the relative proportions of the areas that the

---

[3] AGR-1 Lime and Fertilizer Recommendations, Kentucky Agricultural Experiment Station, University of Kentucky, Lexington, KY.

Table 1. Crop rotations utilized at the Alston Surface Mine Site prior to the grain sorghum study in 1986.

| Year | Plot Subtreatments* 1 | 2 | 3 | 4 |
|---|---|---|---|---|
| 1978 | Alfalfa | Corn | Soybeans | T. Fescue |
| 1980 | Alfalfa | Soybeans | Corn | T. Fescue |
| 1981 | Alfalfa | Corn | Wheat/Soybeans | T. Fescue |
| 1982 | Alfalfa | Wheat/Soybeans | Corn | T. Fescue |
| 1983 | Alfalfa | Corn | Wheat | T. Fescue |
| 1984 | Corn | Corn | Corn | Corn |
| 1985 | Corn | Corn | Corn | Corn |
| 1986 | Gr. Sorghum | Gr. Sorghum | Gr. Sorghum | Gr. Sorghum |

* Plot Subtreatments will be used to identify crop rotations in subsequent grain sorghum yield tables.

Sadler and Belknap comprise, the pro-rated yield potential for corn for these studies would be about 6700 kg ha$^{-1}$. Over the past 10 years, the state-wide average yield difference between corn and grain sorghum is 1480 kg ha$^{-1}$. Hence, the target yield of 5220 kg ha$^{-1}$ was estimated to be for the restored mixed soil. According to SMCRA regulations, values are considered equal if they fall within the LSD$_{(.10)}$ statistical variation limit. The LSD$_{(.10)}$ is subtracted from each year's data, hence the target yield is not necessarily constant. In addition, a yield reduction may be allowed due to damage from adverse weather conditions, insects, or pests, including grazing animals. However, in Kentucky, such a reduction cannot exceed 10%.

## Effect of Cultivar Selection on Grain Soybean Yield

Grain sorghum yields from the variety experiment are summarized in Table 2. Based on the discussion presented earlier, the target for the restored soil mixture equalled 4245, 4240, 4185, and 4410 kg ha$^{-1}$ for 1985, 1986, 1987, and 1988, respectively. In 1985, 9 cultivars exceeded the target yield value, whereas in 1986, 1987, and 1988, only 1, 4, and 2 varieties met the target yield goals in those respective years.

Only one of the entries screened in this experiment exceeded the target yield more than one year out of four. Unfortunately, space did not allow testing all 27 varieties for the entire 4-year period, and some cultivars were added while others were dropped. The growing seasons of both 1987 and 1988 were moisture deficient, but at different times. In 1987, the drought occurred in late July and early August, whereas in 1988, it occurred in late May and June. The average yields for those years were 3345 and 3250 kg ha$^{-1}$, respectively. Although there are differences in maturity within the cultivars tested, this did not appear to influence yield either of the two drought years. The two highest yielding varieties in 1988

Table 2. Grain sorghum yield as a function of cultivar.

| Brand - Hybrid | Maturity Group | Yield* 1985 | 1986 | 1987 | 1988 |
|---|---|---|---|---|---|
| | | kg ha$^{-1}$ | | | |
| Northrup King - 2778 | 3 | 5460 | 4140 | 4680 | ---- |
| Taylor Evans - Y101G | 3 | 5160 | 3240 | 3840 | 3000 |
| Funks - G1602 | 3 | 4800 | 3360 | ---- | ---- |
| Funks - G522DR | 3 | 4620 | 2820 | 2640 | 3420 |
| Funks - RA787 | 3 | ---- | ---- | ---- | 3840 |
| Taylor Evans - Dinero | 3 | 4560 | 2940 | 2700 | 2760 |
| Taylor Evans - Dinero E | 3 | ---- | 2820 | ---- | ---- |
| Northrup King - 2779 | 3 | ---- | ---- | 3240 | 2640 |
| Northrup King - 2660 | 3 | 4320 | 3540 | 2100 | 3540 |
| Northrup King - S9740Y | 3 | ---- | ---- | ---- | 3600 |
| Northrup King - 734G | 3 | ---- | ---- | ---- | 2220 |
| Asgrow - Topaz | 3 | 4260 | 2460 | 3360 | 3000 |
| Funks - G1711 | 4 | 4260 | 3720 | 3420 | 3900 |
| Taylor Evans - Y45G | 1 | 4140 | 4320 | ---- | ---- |
| Northrup King - 2244 | 2 | 4020 | ---- | ---- | ---- |
| DeKalb - DK42Y | 2 | 3840 | ---- | 3420 | 2700 |
| DeKalb - M565 | 2 | ---- | ---- | 2580 | 3360 |
| So. States - SS174 | 3 | 3540 | 3900 | ---- | ---- |
| Pioneer - 8333 | 3 | 3540 | 4020 | 4380 | 2640 |
| Pioneer - 8515 | 3 | 3540 | 4020 | 4440 | 1860 |
| Pioneer - 8226 | 3 | ---- | ---- | 3300 | 2580 |
| Taylor Evans - Y77 | 2 | 3480 | ---- | ---- | ---- |
| Asgrow - GS 712 | 4 | ---- | 4080 | 3120 | 5100 |
| Taylor Evans - Y75 | 2 | ---- | 2820 | 2860 | 5460 |
| Asgrow - Mustang | 3 | ---- | 2840 | 4800 | 2820 |
| Garst - 5511 | 3 | ---- | ---- | ---- | 3120 |
| Garst - 5521 | 3 | ---- | ---- | ---- | 3420 |
| LSD$_{(.10)}$ | | 975 | 980 | 1035 | 810 |

* Cultivars listed according to 1985 yield values. Dashed lines indicate variety was not planted.

were of maturity groups 2 and 4, respectively, whereas in 1987, the highest two varieties were classified within maturity group 3.

In 1987, mechanical problems with the plot combine caused a delay in harvest and excessive bird damage occurred. In general, all varieties had losses: some were estimated to be as large as 25%. If the maximum yield correction due to pests allowed by SCMRA is made, the target yield would become 3765 kg ha$^{-1}$, however, only one additional hybrid would be added to the list meeting the target yield value for Phase III bond release. For 1988, even if maximum corrections were to be allowed due to the early drought, the number of cultivars meeting the target yield level would not have been different.

**Effects of Previous Crop Rotation and Subsoil Liming**

The yield data for grain sorghum at the Alston Surface Mine, are given in Table 3. Many of the treatments exceeded the target yield for Phase III bond release, estimated to be 4620 kg $ha^{-1}$.

For the prime farmland treatment having a limed subsoil (100 cm L) , three of the four plot subtreatments resulting from the various crop rotations met the target yield level. Similarly, three of the four subtreatments of the limed subsoil, non-prime farmland (60 cm L) also exceeded the target of 4620 kg $ha^{-1}$ for prime farmland. None of the plots in which only topsoil was replaced directly over spoil met the target yield for prime farmland.

Significant differences were associated with the previous sequence of crops grown on the site, soil depth, and liming the upper 10-15 cm of the subsoil prior to replacement of the topsoil. Grain sorghum yields were more nearly consistent with the hypothesis that yields from deeper soils and/or subsoil liming would be expected to be greater than those from shallow and/or acidic subsoils. Such a yield response to neither soil depth nor subsoil liming was not found for alfalfa on these same plots during 1979 - 1983 (Barnhisel et al., 1988b). Grain sorghum yields from those treatments which had been in either alfalfa or tall fescue exceeded the yields from the corn-wheat-soybean rotation in every case except one (60 cm, limed treatment). This effect was still prevalent even though the entire area had been planted to corn for two intervening years.

The lime applied to the subsoil resulted in a numerically greater yield in all cases and, in

Table 3. Grain sorghum yield as a function of soil depth, previous crop, and subsoil lime treatment.

| Soil Depth | Plot Subtreatment 1 | 2 | 3 | 4 | $LSD_{(.10)}$ |
|---|---|---|---|---|---|
| cm | | | kg $ha^{-1}$ | | |
| 100 NL* | 5175 | 4165 | 3900 | 4100 | 605 |
| 100 L | 6250 | 4500 | 4840 | 6520 | 680 |
| 60 NL | 3830 | 4225 | 4435 | 4165 | 455 |
| 60 L | 4370 | 4975 | 5240 | 5375 | 710 |
| 20 NL | 2755 | 875 | 1680 | 3160 | 610 |
| 20 L | 3225 | 2555 | 2220 | 2620 | 365 |
| $LSD_{(.10)}$ | 580 | 570 | 795 | 590 | --- |

* Subsoil or spoil not limed (NL); subsoil or spoil limed (L).

six of the eight cases, a significantly greater yield. The exceptions were subtreatment 1 on the 60 cm soil depth and subtreatment 2 on the 100 cm soil depth. Liming the spoil materials did not produce consistent results, since in three cases the lime treatment increased the grain sorghum yield, and in one case liming decreased yield, but not significantly.

Of the eight possible comparisons between similar subsoil lime treatments with different depths, i.e., 100 cm versus 60 cm, only three differed significantly. Two of these significant differences were from the "alfalfa" subplot treatment and one was from the area that was in tall fescue from 1979 to 1983. For the other 5 comparisons, the shallower soil depth resulted in a numerically greater yield, but none was significantly greater.

In comparisons between similarly limed or non-limed treatments in which only 20 cm of topsoil was replaced versus either 40 or 80 cm of subsoil, all cases significantly favored the presence of replaced subsoil. Furthermore, in all 16 cases these differences were significant.

## CONCLUSIONS

1. The use of grain sorghum as a test crop to determine the return of soil productivity following reconstruction of prime farmland is very promising. It is subject to drought stress, but is less affected than corn.

2. There were significant differences among varieties, and the order with respect to yield over time was different. Some varieties were near the top both years, others near the bottom, whereas others changed rankings when subjected to drought stress. Additional testing is continuing in order to assist coal operators in selecting varieties of grain sorghum.

3. The previous cropping sequence, soil depth, and subsoil liming significantly affected grain sorghum yields. Yields were highest following either alfalfa or tall fescue. The deeper the soil, the higher the yield. Liming the subsoil prior to replacement of the topsoil increased grain sorghum yields.

## LITERATURE CITED

http://dx.doi.org/10.2134/jpa1988.0304

Barnhisel, R.I., J.L. Powell, and W.O. Thom. 1988a. Use of soft red winter wheat for reclamation of surface-mined lands in western Kentucky. I. Effects of cultivar selection, soil depth, and ripping. J. Prod. Agr. 1:304-308.

Barnhisel, R.I., J.L. Powell, J.R. Armstrong, M.L. Ellis, and F.A. Craig. 1988b. Effect of soil depth, liming, and subsoiling of reconstructed prime farmland on alfalfa production. Mine Drainage and Surface Mine Reclamation. Vol II: Mine Reclamation, Abandoned Mine Lands and Policy Issues. USDI, Bureau of Mines. Information Circular/1988 IC 9184 pp. 266-273.

Barnhisel, R.I. 1983. The environmental consequence of burial depth of toxic spoils and of excessive compaction of prime land on the growth of agronomic plants. Final report published by USDI, OSM. Division of Technical Services, Washington, D.C., 175p.

Deane, K.C. 1977. Vegetation of acidic or alkaline tailings. In J.L. Thames (ed.) Reclamation and Use of Disturbed Lands in the Southwest. The Univ. of Arizona Press, Tucson, AZ. pp. 248-261.

Farmer, E.E., R.W. Brown, B.Z. Richardson, and P.E. Parker. 1974. Revegetation research on the Decker coal mine in southwestern Montana. USDA Forest Serv. Res. Paper. 162 pp.

Grandt, A.F. 1978. Mined-land reclamation in the Interior Coal Province. J. Soil and Water Conserv. 33: 62-68.

Nielsen, G.A., and E.V. Miller. 1980. Crop yields on native soils and mine soils: A comparison. J. Soil and Water Conserv. 35: 44-46.

Powell, J.L., R.I. Barnhisel, and C.G. Poneleit. 1988. The role of corn variety and population in meeting target yield level for Phase III bond release. Mine Drainage and Surface Mine Reclamation. Vol II: Mine Reclamation, Abandoned Mine Lands and Policy Issues. USDI, Bureau of Mines. Information Circular/1988 IC 9184 pp. 257-265.

Power, J.F. 1978. Reclamation research on strip mined land in dry regions. In F.W. Schaller and P. Sutton (ed.) Reclamation of Drastically Disturbed Lands. ASA, CSSA, SSSA. Madison, WI. pp. 521-535.

Power, J.F., F.M. Sandoval, R.E. Ries, and S.D. Merill. 1981. Effects of topsoil and subsoil thickness on soil water conter http://dx.doi.org/10.2136/sssaj1981.03615995004500010027x a dis Soc. A

Russell, R. Scott. 1977. Plant Root Systems - Their Function and Interaction with the Soil. McGraw-Hill Book Co., London. 298 pp.

Sandoval, F.M., and W.L. Gould. 1978. Improvement of saline and sodium affected disturbed land. In F.W. Schaller and P. Sutton (eds.). Reclamation of Drastically Disturbed Lands. ASA, CSSA, and SSSA. Madison, WI. pp. 485-504.

Sindelar, B.W., R.L. Hodder, and M.E. Majerus. 1973. Surface mined land reclamation in Montana. Montana Agr. Exp. Stn. Res. Rep. 40. Montana State Univ., Bozeman, MT. 40 pp.

Taylor, H.M., and H.R. Gardner. 1963. Penetration of cotton seedling tap roots as influenced by bulk density, moisture content and soil strength. Soil Sci. 96:153-
http://dx.doi.org/10.1097/00010694-196309000-00001

Zimmerman, R.P., and L.T. Kardos. 1961. Effect on bulk density of root growth. Soil Sci. 91: 280-288.
http://dx.doi.org/10.1097/00010694-196104000-00012