NO-TILL ESTABLISHMENT OF SWITCHGRASS AND CAUCASIAN BLUESTEM

by

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(ABSTRACT)

Cool-season perennial grass growth is suppressed during hot, dry summers. This "summer slump" reduces the availability of grazable forage. Tall-growing perennial warm-season grasses that produce 65 to 75% of their yield in midsummer may provide needed herbage during this period of reduced cool-season forage production. However, establishment of perennial warm-season species is slow and inconsistent when compared to cool-season species. Before these warm-season species can be relied on for summer forage production, a successful establishment methodology must be developed. A study was conducted to evaluate the influence of atrazine [2-chloro-4(ethylamino)-s-triazine] and carbofuran on establishment of switchgrass (*Panicum virgatum* L.) and Caucasian bluestem [*Bothriochloa caucasica* (Trin.) C. E. Hubbard]. Treatments of carbofuran at 0 and 1.1 kg atrazine/ha placed in the row with the seed and of atrazine broadcast at 0, 1.1, and 2.2 kg/ha were imposed in all possible combinations. Another study investigated the influence of limestone, P, and carbofuran on the establishment of switchgrass. Treatments included carbofuran at 0 and 1.1 kg/ha, limestone at 0 and 4.48 Mg/ha, and P at 0 and 22 kg/ha in all possible combinations. Seedling growth rate, leaf appearance rate, plant height, and leaf elongation rate (LER) of seedlings were recorded. Seedling weight and populations were determined at the sixth leaf stage of development. Yields of forage and botanical compositions were also measured in the establishment year. Establishment was further evaluated with yield measurements the year after seeding. Carbofuran application increased first year yield, seedling weight, population, leaf appearance rate, and seedling growth rate. Atrazine reduced seedling population, weight, leaf appearance rate, LER, and yield. Carbofuran partially moderated atrazine influence. The 2.2 kg rate of atrazine tended to injure the switchgrass more than the Caucasian bluestem. In the study investigating limestone and P, carbofuran increased yield, seedling weight, seedling population, LER, seedling growth rate, and leaf appearance rate. The greatest yield, leaf appearance rate, and LER occurred with applications of P and carbofuran. Even though initial soil pH was 5.1, limestone broadcast prior to planting did not influence seedling measurements and yields in either year. These plantings were made during 1985 and 1986, which were the driest summers in recent years. In spite of the moisture stress, acceptable stands of perennial warm-season grasses were established in both experiments in both years. Including 1.1 kg granular carbofuran/ha in the row, and broadcast application of 1.1 kg atrazine/ha at planting will improve establishment of perennial warm-season grasses. Where the P levels in the soil are low, a broadcast application of 22 kg P/ha improves chances for successful establishment.

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Chapter 1

Introduction

Reduced growth of cool-season perennial forage grasses during warm summer months is a serious problem in Virginia. Cattle stocking rates are often dictated by the limited grass supply in July and August rather than periods of excess grass in early spring. Tall-growing perennial warm-season grasses such as switchgrass (*Panicum virgatum* L.) and Caucasian bluestem [*Bothriochloa caucasica* (Trin) C. E. Hubbard] could possibly complement forage programs during the summer period of low cool-season grass production. Perennial warm-season grasses have not been used extensively in the southeast USA. Several experiment stations in the mid-Atlantic region are beginning research to investigate adaptation and forage value of these species.

Establishment is a major problem encountered with the warm-season species. Establishment failures or the need for two complete growing seasons for establishment of usable stands are common using conventional planting methods. No-till planting is becoming increasingly popular for forage crop establishment. This type of planting provides for greater soil moisture retention and a reduction of soil erosion when compared to conventional seeding methods. Since no-till planters are available through soil conservation districts and other groups, this technology is experiencing rapid farmer acceptance within the state. No-till establishment of perennial warm-season forage grasses could possibly eliminate some of the problems associated with their establishment. If so, adoption of these species in the southeast and mid-Atlantic regions of the USA is possible.

Several questions must be answered before no-till establishment of perennial warm-season grasses can become a recommended practice.

1. Will no-till seedings provide an advantage in perennial warm-season grass establishment similar to that observed with the cool-season species?

2. Will atrazine at the time of no-till seeding provide early-season weed control and facilitate perennial warm-season grass establishment?

3. Does atrazine have any phytotoxic effect on perennial warm-season grass seedings?

4. What rate of atrazine at seeding will provide adequate weed control early in the seeding year with a minimum of injury to the perennial warm-season grass seedlings?

5. Will carbofuran enhance the establishment of perennial warm-season grasses?

6. Will limestone and P surface applied prior to no-till seeding provide adequate fertility to establish perennial warm-season grasses in infertile sites?

This study investigated several specific points with the goal of determining a management scheme for no-till establishment of perennial warm-season species. The following hypotheses were tested.

1. That no-till planting can be an effective method of establishing two perennial warm-season forage grass species.

2. That atrazine applied at the time of no-till planting will provide early weed control for the perennial warm-season grass species without injury to the seedlings.

3. That establishment of no-till seedings of perennial warm-season grasses can be improved by using broadcast applications of limestone and P.

4. That carbofuran improves the establishment of perennial warm-season forage grass seedlings established using no-till procedures.

A review of the factors influencing the establishment of perennial warm-season grasses is presented in Chapter 2. Chapter 3 describes the effects of atrazine and carbofuran on switchgrass and Caucasian bluestem establishment. Chapter 4 summarizes the influence of limestone, P, and carbofuran on switchgrass establishment. Overall conclusions are presented in Chapter 5.

Chapter 2

Literature Review

Adaption and Distribution

Tall-growing, perennial warm-season grasses are an important part of the total native species resource (Warnes et al., 1971) and provide forage in the hot summer months when cool-season species are nonproductive. The scarcity of available forage in midsummer is an important limitation to the size of grazing herds in Pennsylvania (Griffin et al., 1980). Warm-season grasses have been reported to produce 60 to 65% of their yield in midsummer, while cool-season grasses typically yield 60 to 65% of their production in May (Jung et al., 1978).

Switchgrass (*Panicum virgatum* L.), one of the warm-season perennial species native to the Great Plains, offers great potential for use in pasture, hay, and range (Eberhart and Newell, 1959). As early as 1904, agronomists noted the desirable characteristics of this species (Lyon and Hitchcock, 1904). Switchgrass is one of the dominant species of the true or tall grass prairies and flood plains of the Great Plains (Weaver and Fitzpatrick, 1932). Switchgrass is distributed from Canada to Central America and from the Atlantic coast to Nevada. Usually found in large bunches, switchgrass spreads by thick, scaly, creeping rhizomes. The inflorescence is a large open panicle (Hitchcock, 1950). The functional, fertile floret consists of a hard, shiny lemma and palea tightly enclosing the caryopsis.

Switchgrass is adapted to a wide range in soil pH (4.9 to 7.6), precipitation (40 to 260 cm/yr), and average annual temperature (17 to 26 degrees C) (Duke, 1978). The successful occupation of a diversity of habitats over a great geographical range reflects the high degree of variability exhibited by this species (Porter, 1966). Based on habitat and morphological characteristics, "upland" and "lowland" types have been described. Upland types are 0.9 to 1.5 m tall, semidecumbent, fine-stemmed, early maturing, and found on loamy or sandy soils. Lowland types are 0.6 to 3.0 m tall, robust, coarse, thick-culmed, with large, wide panicles, longer leaves, and shorter rhizomes than upland types, and are found primarily on fine textured soils (Church, 1940; Cornelius and Johnston, 1941; Eberhart and Newell, 1959; Porter, 1966). Studies of chromosomes numbers and plant variation on 59 isolates from Wisconsin to Arizona showed a polyploid series of 18 to 108 somatic chromosomes with no geographical segregation or morphological distinction on the basis of chromosome number (Nielsen, 1944).

Seed of Caucasian bluestem [*Bothriochloa caucasica* (Trin) C.E. Hubbard] was sent to the United States in 1929 by the Botanic Garden at Tiflis, Georgia, USSR. Caucasian bluestem seed was given the P.I. number 78758 and distributed to several experiment stations. The same material was widely distributed by the Soil Conservation Service nursery, Manhattan, Kansas, under the number K.G. 40 (Harlan, 1952).

The Oklahoma Experiment Station in 1952 began an intensive investigation of the generic section bothriochloininae. In the course of assembling materials for the study, a second introduction of Caucasian bluestem was obtained from the Royal Botanical Gardens at Kew, England (Harlan et al., 1958). The natural distribution of *B. caucasica* is not known. Soviet botanists reported the grass as occurring in southern Kazakhstan, southern Uzbekistan, western Tadzhikistan, and the Caucasus, Georgia, Dagestan, Armenia, and Azerbaidzhan (Harlan and Chheda, 1963).

Agronomic characteristics

Several studies have shown the merits of utilizing switchgrass and Caucasian bluestem in pasture grazing programs. In grazing trials in Missouri, Roundtree et al. (1974) reported the carrying capacity of switchgrass and Caucasian bluestem to be two to three times higher than that of 'Alta' fescue (*Festuca arundinacea* Schreb.) from mid-July through September. Although response of warm-season species to nitrogen fertilization can be great (Balasko et al., 1984), significant summer forage yields with little fertilizer input have been reported (Balasko et al., 1984; Beaty and Powell, 1976; Griffin and Jung, 1981; Krueger and Curtis, 1979). Krueger and Curtis (1979) reported average daily gains of yearling steers of 0.93 and 0.76 kg for switchgrass and big bluestem (*Andropogon gerardii* Vitman), respectively, in South Dakota, while Roundtree et al. (1974) reported 0.75 to 1.5 kg/day gain for cattle in Pennsylvania on switchgrass and bluestem pastures. Evaluation of switchgrass forage quality by Newell and Moline (1978) showed average crude protein and in vitro dry matter disappearance (IVDMD) in mid-July of 8.4 and 51.0% respectively. If properly managed, stand life of switchgrass pastures may exceed 20 years (Soil Conservation Service, 1969). Switchgrass tolerance to atrazine aids in weed control for establishment (Martin et al., 1982), and allows switchgrass use in grass waterways where herbicide runoff is a problem (Smith, 1972). Heavy, vigorous root systems and underground stems also make switchgrass a valuable cover for soil conservation (Eberhart and Newell, 1959).

Vigor

A trait of seeds and seedlings important to establishment of the crop is vigor. Vigor as defined by Ching (1973) is: "the potential for rapid uniform germination and fast seedling growth under general field conditions." As defined by Copeland (1976), seedling vigor can be measured by: (1) speed of germination, (2) uniformity of germination and plant development under nonuniform conditions, (3) ability to emerge through crusted soil, (4) germination and seedling emergence from cold wet pathogen-infested soils, (5) normal seedling morphological development, (6) crop yield, and (7) storability of seed under optimum or adverse conditions. The positive relationship between speed of germination and seedling vigor is well documented (Copeland, 1976). Germination and seedling growth are affected by factors such as seed size, dormancy in seeds, and environmental conditions. The relationship between seed size and seedling vigor has been evaluated by numerous researchers. Laboratory germination studies by Green and Hanson (1969) showed significant effects of seed size on speed of germination in sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.], blue grama [*Bouteloua gracilis*

(Willd, ex. H.B.K.) Lag. ex Steud.], Grenville switchgrass, A6606 switchgrass, and yellow Indiangrass [*Sorghastrum avenaceum* (Milhx.) Nash]. The heavier seeds of all five cultivars germinated faster than lighter seeds. Influence of seed weight varied greatly between species and between varieties within species. Emergence studies by Kneebone and Cremer (1955) showed seedlings from large seeds of buffalograss [*Buchloe dactyloides* (Nutt.) Engelm.], yellow Indiangrass, sand bluestem (*Andropogon hallii* Hack.), sideoats grama, and switchgrass emerged earlier and grew at a faster rate than seedlings from small seeds. Faster emergence of seedlings from larger seeds of various other grasses has also been reported (Rogler, 1954; Vogel, 1963; Walley et al., 1966). Seed size has also been shown to affect mature plant traits (Kneebone, 1972). Larger seeds produce more vigorous seedlings and have reserve energy stored within them.

No-till establishment

No-till seeding requires the suppression of existing vegetation so that new seedlings can emerge. Warm-season grasses are particularly slow to establish and competition from existing vegetation, including weeds can be severe (Warnes et al., 1971; Robbocker et al., 1953). Competition from existing grass sod reportedly reduced the growth and development of Sudangrass [*Sorghum biocolor* (L.) Moench] (Sprague et al., 1962). Switchgrass required almost complete sod suppression during the first 6 weeks after seeding for successful establishment in Nebraska (Samson and Moser, 1982). Glyphosate and paraquat have been widely used in no-till legume establishment into pastures, but little information is available on their use with no-till grasses. Atrazine has been used successfully in establishing big bluestem and switchgrass (Martin et al., 1982). Carbofuran increased the yield of forage legumes (Thompson and Willis, 1970), but information on its use with grasses is not available.

Herbicides in no-till establishment

Sprague (1952) substituted chemicals for mechanical vegetation control. His work with sodium trichloroacetate (TCA) emphasized the importance of an effective herbicide in sod seeding. A herbicide used in no-till seeding must give quick, complete control of resident vegetation without leaving residue harmful to emerging seedlings (Sprague, 1960).

The use of atrazine [2-chloro-4-(ethylamino)-6-(isopropylamion)-s- triazine], glyphosphate [N-(phosphonomethyl) glycine], or paraquat (1,1′dimethyl-4, 4′bypyridnium ion) in no-till seeding of perennial grasses has not been investigated extensively in the Southeast. In Canada, paraquat and glyphosate broadcast at 2.2 kg/ha gave 70% control of cool-season sod 6 weeks after a June application (Waddington and Bowren, 1976). In England, glyphosate at 1.0 kg/ha applied in a 7.5 cm band on a cool-season sod improved establishment of Italian ryegrass (*Lolium multiflorum* L.) when compared to paraquat (Squires, 1976). On six cool-season sods in Wales, there was 89% desiccation after 2 weeks when glyphosate was broadcast at 1.8 kg/ha in late summer and 86% with paraquat broadcast at 1.1 kg/ha (Cromack et al., 1978). In Missouri, paraquat broadcast at 1.1 kg/ha in fall suppressed a cool-season sod by 75%

and glyphosate broadcast at 2.2 kg/ha gave a 95% reduction in sod cover (Peters and Lowance, 1979).

Samson and Moser (1982) reported that paraquat at 0.3 kg/ha plus atrazine 2.2 kg/ha or glyphosate broadcast 1.1 or 2.2 kg/ha permitted successful establishment of switchgrass. They reported that an established stand of seeded and resident warm-season grasses ready for grazing will generally occur at the end of the first growing season.

Atrazine controls a wide variety of annual weeds in certain warm-season range grasses. However, many grasses that are tolerant to atrazine when established are susceptible as seedlings. Martin et al. (1982) demonstrated a wide range of tolerance among warm-season range grasses. Switchgrass and big bluestem seedlings were atrazine tolerant. However, indiangrass [*Sorghastrum nutans* (L.) Nash], sideoats grama [*Bouteloua curtipedula* (Michx.) Torr.], and sand lovegrass [*Eragrostis trichodes* (Nutt.) Wood] were not sufficiently tolerant to use atrazine at establishment.

Tolerance to the S-triazines is due to metabolic degradation. Detoxification of atrazine has been documented in corn *[Zea mays* (L.)]. and sorghum (*Sorghum vulgare* Pres). Detoxification can occur through modification of the atrazine molecule by N-dealkylation, Z-hydroxylation, or gluthione conjugation or any combination of the above pathways (Shimbukuro, 1967; Lamoureux et al., 1970, 1973). Reaction to atrazine also depends on soil properties. Lavy (1968) reported that the absorption of the S-triazines increased and plant uptake of C^{14} atrazine decreased as soil acidity, organic matter, and clay content increased. LeBaron (1970) also showed that atrazine activity in soil was reduced by increased soil acidity and organic matter.

Results of field studies by Martin et al. (1982) and Bahler et al. (1984) indicated that the use of atrazine to establish certain perennial warm-season grasses was feasible for the high tolerance group, switchgrass, plains bluestem, and caucasian bluestem. Their work reported a 2.2 kg/ha level of atrazine as being the minimum required rate for effective weed control. McKenna and Wolf (1986) reported that atrazine levels above 1.1 Kg/ha could be phytotoxic to switchgrass and Caucasian bluestem in no-till seeding research conducted in Virginia.

Carbofuran in no-till establishment

Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate), an insecticide has been used to a limited extent in no-till alfalfa seeding. Rogers et al. (1984) in North Carolina indicated that early spring alfalfa plantings were significantly improved when carbofuran was used at seeding. This advantage was not noted in the fall or in late spring seedings.

The role of carbofuran in seedling establishment is a matter of conjecture. Grybauskas et al. (1986) reported the results from 5 years work with alfalfa and carbofuran. Improvements in stand and yield due to carbofuran were only observed in three of 13 trials. In trials where responses to carbofuran were obtained, insect damage was not apparent and increased stands and yields may have resulted from carbofuran suppressing damping-off. Growth chamber studies with (*Pythium spp.*) showed that the percentage of seedlings exhibiting damping-off symptoms was significantly reduced but varied with rate of carbofuran application. In vitro, fungal biomass was also significantly suppressed in carbofuran amended media.

Very little information is available concerning the use of carbofuran with perennial warm-season grasses. Bryan et al. (1984) reported the effects of carbofuran were inconsistent when used in no-till establishment of switchgrass. Carbofuran increased the stand and yield of switchgrass significantly in the first year of their study. Seedling numbers per square meter increased in one of three experiments. In the second year, carbofuran increased switchgrass percentage, height, and dry matter yield in one experiment. Wolf et al. (1983) reported that the success of no-till alfalfa was improved by the addition of a granular carbamate insecticide (carbofuran). Granular carbofuran controlled early season insects and possibly provided a growth stimulating effect, resulting in increased stands and provided better yields. McKenna and Wolf (1987) reported that, where carbofuran was included at planting with the seed in no-till establishment, switchgrass seedlings were more numerous, heavier, and grew more rapidly than did the seedlings without carbofuran. They suggested that carbofuran was acting as a growth stimulator and suggested that additional investigation be made into this response.

Summary

Perennial warm-season grasses have not been used extensively in the Southeast and mid-Atlantic regions of the USA. These species however, do have a wide adaptation over much of the Plains states and can be grown in our region. Switchgrass and Caucasian bluestem have the potential of providing mid-summer grazing when perennial cool-season species are unproductive. Many of the sites for perennial warm-season grass establishment lend themselves to no-till planting to avoid erosion and provide a mulch for water retention during seedling development.

The Perennial warm-season grasses have the ability to produce substantial forage under infertile conditions. This would provide an additional justification for the introduction of perennial warm-season grasses in our region. An investigation of surface-applied fertility is important because incorporation of plant nutrient elements is not possible with no-till planting.

Prolonged seedling emergence and slow development is characteristic of perennial warm-season species. Under the more humid conditions of the Southeast and mid-Atlantic regions, weed competition during early seedling development could be a problem. Switchgrass and Caucasian bluestem have demonstrated tolerance to atrazine applied at seeding. It is important to test atrazine under more humid conditions and with no-till planting, as most of the published work has been done in drier climates and under conventional planting methods.

Carbofuran influence on early seedling development and growth has been observed in some species but has not been investigated widely with perennial warm-season grass species. Carbofuran has been reported to be fungicidal, insecticidal, and growth regulatory. Although, the activity of carbofuran is unknown, any addition to the seeding methodology to improve the emergence time and subsequent growth of perennial warm-season species is worth investigating. The goal of establishment is to enable the seedlings to outgrow their competition and provide useable forage as quickly as possible.

Literature Cited

Bahler, C. C., K. P. Vogel, and L. E. Moser. 1984. Atrazine tolerance in warm-season grass seedlings. Agron. J. 76:891-895.

Balasko, J. A., D.M. Burner, and W.V. Thayne. 1984. Yield and quality of switchgrass grown without soil amendments. Agron. J. 76:204-208.

Beaty, E. R., and J. D. Powell. 1976. Response of switchgrass, *(Panicum virgatum* L.) to clipping frequency. J. Range Manage. 29:132-135.

Bryan, W. B., T. A. Mills, and J. A. Cronauer. 1984. Sod-seeding switchgrass, and tall fescue into hill land pasture. J. Soil and Water Cons. 39(1)70-72.

Ching, T. M. 1973. Biochemical aspects of seed vigor. Seed Sci. and Tech. 1:73-88.

Clark, D. C., and L. N. Bass. 1970. Germination experiments with seeds of Indian ricegrass, [*Oryzopsis hymenoides* (Roem. and Schult.) Ricker.]. Proc. Assoc. Off. Seed Anal. 60:226-239.

Copeland, L. O. 1976. Principles of seed science and technology. Burgess Publishing Co., Minneapolis, Minnesota.

Cornelius, D. R., and C. O. Johnston. 1941. Differences in plant type and reaction to rust among several collections of (*Panicum virgatum* L.) Am. Soc. Agron. J. 36:115-124.

Coukos, D. J. 1944. Seed dormancy and germination in some native grasses. J. Am Soc. Agron. 36:337-345.

Cromack, H. T. H., W. I. C. Davies, A. Rowlands, E. I. Prythech, and J. Davies. 1978. The replacement of old swards using herbicides and cultivation techniques. *In*: Proc. 1978 British Crop Protection Conf. Weeds. 1:333-339.

Duke, J. A. 1978. The quest for tolerant germplasm, p. 1-61.*In* 1.: G. A. Jung (ed.) Crop tolerance to suboptimal land conditions. Am. Soc. Agron. Special Public. no. 32.

Eberhart, S. A., and L. C. Newell. 1959. Variation in domestic collections of switchgrass, (*Panicum virgatum* L.) Agron J. 51:613-616.

Griffin, J. L., and G. A. Jung. 1881. Yield and forage quality of (*Panicum virgatum* L.) *In*: Proc. 14th Int. Grassl. Congr. Lexington, Ky. J. A. Smith and V. W. Hays (eds.) p. 491-494.

Griffin, J. L.,and P. J. Wangsness, and G. A. Jung. 1980. Forage quality and evaluation of two warm-season range grasses using laboratory and animal measurements. Agron J. 72:951-956.

Grybauskas, A. P., M. A. Decker, L. R. Vaugh, and K. I. Abdel-Gawad. (1986). A non-target effect of carbofuran on damping-off in alfalfa. *In*: Proceedings of the American Phytopathological Society (Potomac Division) Meeting. April 1-3, Washington D. C.

Harlan, J. R. 1952. Caucasian bluestem. Okla. Agr. Exp. Stn. Forage crop leaflet no. 7.

Harlan, J. R., Celarier, R. P., Richardson, W. L., Brooks, M. H., and Mehra, K. L. 1958. Studies on Old World Bluestems II. Okla. Agr. Exp. Stn. Tech Bull. T-72.

Harlan, J. R., and Chheda, H. R. 1963. Studies on the origin of Caucasian bluestem, [*Bothriochloa caucasia* (Trin.) C. E. Hubbard] Crop Sci. 3:37-39.

Hitchcock, A. S. 1951. Manual of the grasses of the United States; 2nd ed. revised by Agnes Chase. USDA Misc. Publ. 200. U. S. Government Printing Office, Washington, D. C.

Jung, G. A., C. F. Gross, R. E. Kocher, L. A. Burdette, and W. C. Sharp. 1978. Warm-season range grasses extend beef cattle forage. Pennsylvania Agric Exp. Stn. Sci. in Agric. 64:211-219.

Kneebone, W. R., and C. L. Cremer. 1955. The relationship of seed size to seedling vigor in native grass species. Agron. J. 47:472-477.

Krueger, C. R., and D. C. Curtis. 1979. Evaluation of big bluestem, Indiangrass, sideoats grama, and switchgrass pastures with yearling steers. Agron J. 71:480-482.

Lamoureaux, G. L., R. H. Shimabukuro, H. R. Swanson, and D. S. Frear. 1970. Metabolism of 2-chloro-4 ethylamino-6-isopropylamino s-traizine (atrazine) in excised sorghum leaf sections. J. Agric. Food Chem. 18:81-86.

Lamoureaux, G. L., L. E. Stafford, R. H. Shimabukuro, and R. G. Zaylskie. 1973. Atrazine metabolism in sorghum: Catabolism of glutatione cunjugate of atrazine. J. Agric. Food Chem. 21:1020-1030.

Lavy, T. L. 1968. Micromovement mechanisms of s-triazines in soil. Soil Sci. Soc. Am. Proc. 32:377-380.

LeBaron, H. M. 1970. Ways and means to influence the activity and the persistance of triazine herbicides in soils. Residue Rev. 32:311-353.

Martin, A. R., R. S Moomaw, and K. P. Vogel. 1982. Warm-season grass establishment with atrazine. Agron. J. 74:916-920.

McKenna, J. R., and D. D.Wolf. 1987. No-till switchgrass establishment as affected by lime, phosphorous, and carbofuran. p. 106-110 *In*: Proc. Am. Forage and Grassld. Conf., Springfield, IL

McKenna, J. R., and D. D. Wolf. 1986. No-till warm season grass establishment as affected by atrazine and carbofuran. p.49-50. *In*: Proceedings of an International Symposium on Establishment of Forage Crops by Conservation Tillage: Pest Management. State College, PA

Newell, L. C., and W. L. Moline. 1978. Forage quality evaluation of twelve grasses in relation to season of grazing. Nebr. Agric. Exp. Stn. Bull. 283.

Nielson, E. L. 1944. Analysis of variation in (*Panicum virgatum* L.) J. Agric. Res. 69:327-353.

Panciera, M. T., and G. A. Jung. 1984. Switchgrass establishment by conservation tillage: planting date responses of two varieties. J. Soil Water Conserv. 39:68-70.

Peters, E. J., and S. A Lowance. 1979. Herbicides for renovation of pastures and control of tall ironweed *(Veronia altissima)*. Weed Sci. 27:342-345.

Porter, C. L. 1966. An analysis of variation between "upland" and "lowland" switchgrass, (*Panicum virgatum* L.), in central Oklahoma. Ecology 47:980-992.

Robocker, W. C., J. T. Curtis, and H. L. Ahlgren. 1953. Some factors affecting emergence and setablishment of native grass seedlings in Wisconsin. Ecology 34:194-199.

Rogers, D. D., D. S. Chamblee, J. P. Muller, and W. V. Campbell. 1984. Fall no-till seeding of alfalfa into tall fescue as influenced by time of seeding and grass and insect supression. Agron. J. 77:150-157.

Rogler, G. A. 1954. Seed size and seedling vigor in crested wheatgrass. Agron J. 46:216-220.

Roundtree, B. H., A. G. Matches, and F. A. Martz. 1974. Season too long for your grass pasture? Crops Soils 26(7):7-10.

Samson, J. F., and L. E. Moser. 1982. Sod seeding perennial grasses into eastern Nebraska pastures. Agron. J. 74:1,055-1,060.

Shimabukuro, R. H. 1967. Atrazine metabolism and herbicidal selectivity. Plant Physiol. 42:1269-1276.

Smith, D. C. 1972. Chemical tolerant switchgrass to help control water pollution. Soil Conserv. 38:78.

Soil Conservation Service. 1969. Plants for conservation in the North east. Switchgrass (*Panicum virgatum* L.). Cons. Plant Sheet NE-2 Soil Cons. Serv., USDA. Broomall, Pa.

Sprague, M. A. 1952. The substitution of chemicals for tillage in pasture renovation. Agron J. 44:405-409.

Sprague, M. A. 1960. Seedbed perparation and improvement of unplowable pastures using herbicides. *In*: Int. Grassl. Cong. 8th Proc., Reading, England p 264-266.

Sprague, M. A., R. D. Iinicki, R. W. Chase, and A. H. Kates. 1962. Growth of forage seedlings in competition with partially killed grass sods. Crop Sci. 2:52-55.

Squires, N. R. W. 1976. The use of band applications of three herbicides in the establishment of direct drilled grasses and legumes by WRO one-pass sowing technique. *In*: Proc British Crop Production Conf. Weeds. 2:591-602.

Thompson, L. S., and C. B. Willis. 1970. Effect of nematicides on root lesion nematodes and forage legume yield. Can. J. Plant Sci. 50:577-581.

Vogel, W. G. 1963. Planting depth and seed size influence emergence of beardless wheatgrass seedlings. J. Range Manage. 16:273-274.

Waddington, J., and K. E. Bowren. 1976. Pasture renovation by direct drilling after weed control and sward suppression by herbicides. Can J. Plant Sci. 56:985-988.

Warnes, D. D., L. C. Newell, and W. J. Moline. 1971. Performance evaluation of some warm-season prairie grasses in Nebraska environments. Nebr. Agric. Exp. Stn. Res. Bull. 241.

Weaver, J. E., and T. J. Fitzpatrick. 1932. Ecology and the relative importance of the dominants of the tall-grass prairie. Bot. Gaz. 93:112-150.

Whalley, R.D.B., C. M. McKell, and L. R. Green. 1966. Seed physical characteristics and germination of hardinggrass [*Phalaric tuberosa* var. Stenoptera (Hack.)(Hitch.)]. J. Range Manage. 19:129-132.

Wolf, D. D., H. E. White, and D. R. Ramsdell. 1983. No-till alfalfa establishment, a breakthrough in technology. Crops Soils 35(11):13-15.

Chapter 3

No-till Warm-Season Grass Establishment as Affected by Atrazine and Carbofuran

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Abstract

Forage availability in summer is an important limitation to the size of grazing herds in the southeastern USA. Tall-growing, perennial, warm-season grasses that produce 65 to 75% of their yield in mid-summer may provide needed summer grazing; however, their establishment is often slow and inconsistent when compared to cool-season species. Methods are needed to improve establishment and make these species less vulnerable to annual weed competition. Plantings of two tall-growing, perennial, warm-season grasses were made in Blacksburg, VA located at 37° 11′ N° 80° 25′ W at 610 m elevation on a Groseclose loam soil (clayey, mixed, mesic Typic Hapludult). Establishment of switchgrass (*Panicum virgatum L.*) and Caucasian bluestem [*Bothriochloa caucasica* (Trin.) C. E. Hubbard] using no-till procedures was evaluated with treatments of carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate) at 0 and 1.1 kg/ha and atrazine [2-chloro-4-(ethylamino)-6-isopropylamino) -s-triazine] at 0, 1.1, and 2.2 kg /ha in all possible combinations. Seedling growth rate and leaf appearance rate were recorded prior to the sixth-leaf stage of development. Seedling weights, populations, and heights were measured at the sixth- leaf stage of development. Leaf elongation rates were measured for leaves 7, 8, and 9. Yields of forage and percentage perennial warm-season grass in the harvested herbage were determined in the year of planting and the year after planting. Our data indicate that 1.1 kg carbofuran/ha, placed in the row with the seed at the time of no-till planting enabled seedlings to develop faster, elongate more rapidly, and provide more and heavier seedlings than without carbofuran. Atrazine reduced herbage yields as well as population, weight, development, and leaf elongation rate of seedlings. The addition of carbofuran moderated the detrimental influence of atrazine. Direct statistical comparison of species was not possible due to separate plantings; however, atrazine at 2.2 kg/ha appeared to injure the switchgrass more than the Caucasian bluestem. Atrazine at 1.1 kg/ha was not detrimental to either species. Yields in the year after planting further confirmed these observations. Carbofuran at the time of planting increased yields in all four experiments and with both species. Atrazine at 1.1 kg/ha increased yields for both species in the year after seeding; however, in three of four switchgrass experiments, atrazine at 2.2 kg/ha reduced yields the year after planting. This reduction was not observed in Caucasian bluestem. All stands were nearly pure planted species the year after planting. Atrazine and carbofuran at 1.1 kg/ha were considered the best recommendation for establishment of switchgrass and Caucasian bluestem.

Additional index words: Switchgrass (*Panicum virgatum* L.), Caucasian bluestem [*Brothriochloa caucasica* (Trin.) C. E. Hubbard], No-till establishment, Leaf appearance rate, Growth rate, Leaf elongation rate, Seedling populations, Seedling weight.

Introduction

Tall-growing, perennial warm-season grasses may be an important potential resource to provide forage in hot summer months when cool-season species typically are non-productive (Warnes et al., 1971). Low availability of forage in mid-summer has been an important limitation to the size of grazing herds (Griffin et al., 1980). Stocking rates for pastures typically result in under-utilized spring herbage because of the nonuniform seasonal distribution of dry matter production. In Pennsylvania, warm-season grasses produce 65 to 75% of their seasonal yield in mid-summer. This is in contrast to cool-season species that produce 60 to 66% of their seasonal yield in spring (Jung et al., 1978). In grazing trials in Missouri, Roundtree et al. (1974) reported the carrying capacity of switchgrass (*Panicum virgatum* L.) and Caucasian bluestem [*Bothriochloa caucasica* (Trin.) C. E. Hubbard] to be two to three times higher than that of 'Alta' tall fescue (*Festuca arundinacea* Schreb.) from mid-July through September. A combination of warm-and cool-season pastures could provide a constant balance of grazeable herbage throughout the growing season.

Developing productive stands of warm-season grasses may limit their incorporation into forage systems. Establishment of perennial warm-season species has been difficult when compared with cool-season species (Panciera and Jung, 1984). Warm-season species are slow to establish dense ground cover (Warnes et al., 1971; Robocker et al., 1953). This slow vegetative development makes these species vulnerable to weed competition in the seedling year.

Atrazine [2-chloro-4(ethylamino)-6-(isopropylamino)-s-triazine] suppresses a wide variety of annual weeds growing with perennial warm-season grass species (Bahler et al., 1984). Some warm-season perennial grasses are tolerant to atrazine when established but are susceptible as seedlings. Martin et al. (1982) demonstrated a wide tolerance for atrazine among warm-season range grasses. Switchgrass and Caucasian bluestem were two of the most tolerant species. Bahler et al. (1984) showed switchgrass and Caucasian bluestem to have the highest survival of various warm-season grass seedlings in the greenhouse when using 3.4 kg atrazine/ha. They also conducted a field study on a loamy sand (Udic Haplustoll) and a silty clay loam (Typic Argiudoll). Atrazine reduced stands in the loamy sand more than in the silty clay loam. Martin et al. (1982) also indicated that preemergence applications of atrazine in the field caused less stand reduction in switchgrass and big bluestem (*Andropogon gerardi* Vitman), than in Indiangrass [*Sorghastrum nutans* (L.) Nash], sand lovegrass [*Eragrostis trichodes* (Nutt.) Wood], and sideoats grama [*Bouteloua curtipendula* (Michx.) Torr.]. In both studies, seedling height and number were reduced by increasing atrazine from 1.1 to 3.4 kg/ha (Bahler et al.,1984; Martin et al., 1982).

Carbofuran (2,3-dihydro-2,2-dimethyl-7-benzofuranyl methylcarbamate), an insecticide, has been used in no-till switchgrass establishment to improve seedling establishment (McKenna and Wolf, 1987). Carbofuran at 1.1 kg/ha increased yield, seedling weight, seedling population, and seedling developmental rate of switchgrass in the seedling year. This agreed with results reported by Bryan et al. (1984) that carbofuran increased stand and yield of interseeded switchgrass in the seedling year. The objectives of our research were to evaluate carbofuran application at the time of no-till planting and to determine an acceptable rate of atrazine to use as a pre-emergent herbicide for switchgrass and Caucasian bluestem establishment.

Methods and Materials

Soil and Location

Plantings of switchgrass and Caucasian bluestem were made in Blacksburg, VA, located at 37° 11′ N°80° 25′ W at 610 m elevation. The soil was a Groseclose loam soil (clayey, mixed, mesic Typic Hapludult). There was no impediment to root development to 2 m. Soil samples were taken prior to planting. Soil ph was determined on 1:1 (v/v) soil-water slurries and Mehlich I extractable nutrients were determined according to procedures outlined by the Council on Soil Testing and Plant Analysis (1980).

Treatments

A randomized complete block design included four replications with plots 1.8 by 6.1 m. The same experiment was planted in 1985 and 1986. Paraquat at 0.28 kg/ha was applied at planting across all plots. Caucasian bluestem and

'Pathfinder' switchgrass were planted in separate but adjacent experiments at 1.8 kg/ha and 4.5 kg/ha of pure live seed, respectively, on 10 May 1985 and 23 April 1986. Treatments included granular carbofuran placed in the row with the seed at 0 and 1.1 kg /ha in all combinations with atrazine broadcast sprayed on the day of planting at 0, 1.1, and 2.2 kg /ha. Paraquat and atrazine were applied as a broadcast spray in 280 L/ha of water (30 gal/acre) using 276 kPa (40 lb/inch^2) pressure and flat fan nozzels (786 mL/min) with a back pack sprayer. A wetting agent (1.25 mL/L of Ortho x-77) was added in the paraquat sprayings. Spraying was done under wind conditions less than 223 cm/s (5 mph).

Previous crops

Spring no-till plantings were made in 1985 and 1986 into previous crops of foxtail millet *(Setaria italica* L.) and cereal rye (*Secale cereale* L.). The rye had been planted in the fall and harvested as haylage prior to seeding of the warm-season grasses. Millet was grown and harvested the previous season and provided a non-living residue in the spring for warm-season grass establishment. The rye and millet areas were located in adjacent sites but the previous crops could not be considered treatments. There were four separate experiments in both 1985 and 1986, each warm-season grass planted into rye stubble and each planted into millet stubble.

Fertility

Nitrogen was broadcast at 35 kg/ha using ammonium nitrate 1 month after seeding for both warm-season grasses. No fertilizer other than N was used in the seeding year. In the year after seeding, 75 kg nitrogen/ha was applied as ammonium nitrate to the switchgrass and Caucasian bluestem when the plants reached the seventh-leaf stage. The differential N application was applied to avoid stimulating weed competition in the seeding year. After establishment, a higher N level was applied to increase warm-season grass yields.

Seedling Measurements

Seedling growth rate and leaf appearance rate measurements were made prior to the sixth-leaf stage of development in 1986. Seedling growth rates were calculated by regressing height measurements taken at 2-day intervals. Seedling leaf appearance rates were obtained from observations of the seedlings during expansion of the first six leaves. A score given at each observation indicated the number of fully expanded leaves (Fig. 1). A value of 1 represented a single visible leaf. Leaf appearance rates were calculated from regression analysis using observations taken at approximately 2-day intervals. The reciprocal of leaf appearance rate would indicate approximately a plastochron index value.

The next set of measurements were obtained at the time when the seventh leaf was emerging, when the warm-season grasses were beginning to tiller. Seedling height was measured as the length of the longest extended leaf. Seedling

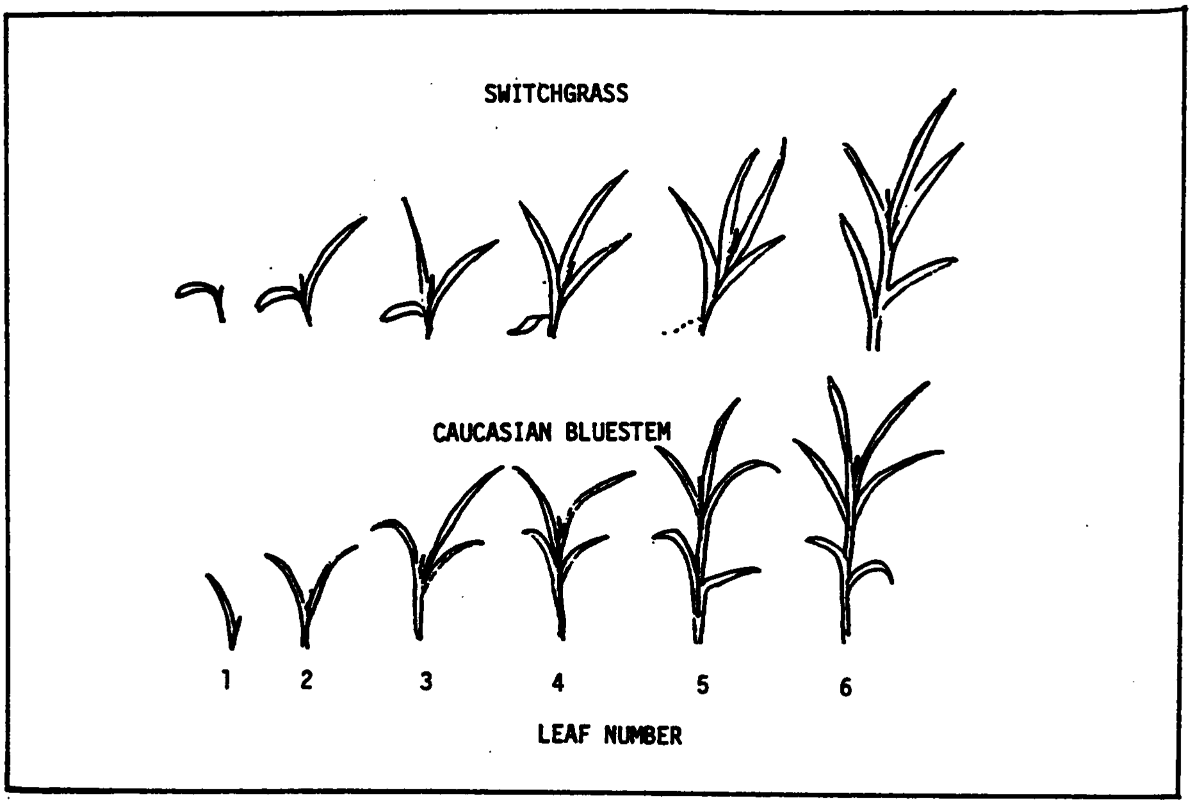

Figure 1. **Switchgrass and Caucasian bluestem seedling stages and score used to determine leaf appearance rates.**

populations were also counted and at the same time seedlings were harvested to determine above ground weight of seedlings. They were cut at ground level and oven-dried at 70°C.

Leaf elongation rates were measured during the expansion of leaves 7, 8, and 9. Leaf elongation was determined from uniform individual seedlings identified and tagged at the time of six fully developed leaves. Daily lengths of leaves 7, 8, and 9 were summed when present. Regression analysis was then used to obtain leaf elongation rates (LER).

Yield Measurements

The 1985 planting of Caucasian bluestem in the rye stubble was harvested for yields to leave a 15-cm stubble on 6 Aug. and 11 Oct. 1985. Switchgrass in the rye stubble was harvested for yield to leave a 25-cm stubble on 6 August 1985. Neither the switchgrass nor the Caucasian bluestem planted in 1985 into the millet area was harvested for yields in 1985 due to weed and volunteer millet competition. These plots were clipped uniformly in July and Aug. 1985 at a 25-cm height to remove competition but not injure the slowly developing perennial warm-season species. The 1985 plantings of switchgrass were harvested on 13 June 1986 at jointing stage and the Caucasian bluestem at early head stage on 15 July 1986. Cutting height was 7 cm.

The 1986 plantings were not harvested for yields in the seedling year due to drought conditions. All plots were uniformly cut to 25 cm on 9 Aug. 1986 to reduce crabgrass (*Digitaria sanguinalis* L.) and foxtail millet, competition. The 1986 plantings of both grasses were harvested for yields on 21 July 1987 to leave a 7-cm stubble height. Percentage perennial warm-season grass in the harvested herbage was estimated visually and yields reported on a weed free, dry-matter basis.

Data Analyses

All data were subjected to an analysis of variance and probabilities of differences among main effects and interactions are reported as percentages. Means are reported for main effects of carbofuran and atrazine rates since few interactions had probabilities below 5%. There were significant year by treatment and year by previous crop interactions for seedling and yield measurements; therefore, data are presented by years and previous crops. Where interactions were significant at the 0.05 level and are important biologically, a detailed discussion is presented.

Results and Discussion

Normal rainfall occurred in May and July 1985 (Table 1) but rainfall was less than 50% of normal in April 1985 and was 35% below normal in June. In 1986, plantings were again made in dry soil and early seedling development occurred during a period of dry weather. April, May, and June of 1986 received only one-third of the long-term rainfall means. Only 82 mm of rainfall were measured April through June in 1986 compared to 184 mm in the same time period in 1985. Even with dry conditions early establishment was successful. Rainfall during the year after planting was low in both 1986 and 1987, where deficits accumulated during the entire growing season of May through August. No-till procedures minimized soil water usage by the previous crop and conserved accumulated water so that limited rainfall after planting was not critical to emergence. Also, the no-till seed bed was firm and appeared to allow soil water to move toward the seed that was planted at a depth of 2.5 cm. Even with dry conditions early establishment resulted in adequate seedlings to provide a full stand. Temperatures throughout the three years were slightly higher than normal but exhibited none of the extremes experienced in precipitation (Table 1).

Switchgrass emergence occurred 19 days after planting in 1985 and 22 days after planting in 1986 in the rye stubble. Switchgrass emergence in the millet areas was nearly the same as the switchgrass in both years, occurring at 15 and 24 days in 1985 and 1986, respectively. In both years and in both previous crops, Caucasian bluestem emerged approximately a week later than switchgrass.

The relatively low soil fertility reported in the methods and materials approximate the type of field that would be selected for perennial warm-season grass establishment in Virginia. Soil tests prior to seeding indicated pH 5.2, 48 ppm P, 157 ppm K, 552 ppm Ca, and 53 ppm Mg in the rye area and pH 5.8, 17 ppm P, 157 ppm K, 732 ppm Ca, and 120 ppm Mg in the millet area. No harvest was made for plantings into the millet plots in the seedling years in either 1985 or 1986. Weed competition and dry weather conditions did not seem to mask initial or subsequent influences of carbofuran and atrazine. Seedling measurements were made before weeds caused serious competition. These data indicate that, where seedling development was adequate and weeds were clipped during the establishment year, then a productive stand the year after planting was achieved.

Table 1. Rainfall, temperature, and departure from long term (LT) means for growing seasons of 1985, 1986, and 1987, Blacksburg, VA.†

Month	Year 1985	Year 1986	Year 1987	LT	Year 1985	Year 1986	Year 1987
	Accumulated				Departure		
	Precipitation (mm)						
Apr.	36	25	197	89	-53	-64	108
May	93	29	51	92	1	-63	-41
June	55	28	37	90	-35	-62	-53
July	92	100	79	93	-1	7	-14
Aug.	189	84	42	87	102	-3	-45
Sept.	13	98	168	91	-78	7	77
	Temperature (°C)						
Apr.	12.8	12.6	8.7	10.7	2.1	1.9	-2.0
May	16.4	14.9	17.5	15.3	1.1	-0.4	2.2
June	19.5	20.2	21.0	19.2	0.3	1.0	1.8
July	20.8	23.3	23.1	21.5	-0.7	1.8	1.6
Aug.	19.1	20.1	22.9	21.1	-2.0	-1.0	1.8
Sept.	17.0	18.2	17.8	17.6	-0.6	0.6	0.2

†Observations made 4.8 km from experimental site.

Switchgrass

Carbofuran Influences

Year of seeding: Switchgrass seedling height, seedling weight, seedling LER, and first-year biomass yields were increased in the presence of carbofuran (Table 2). Seedling height at the sixth leaf stage was three times greater with plots treated with 1.1 kg carbofuran/ha and LER doubled from the seventh through ninth leaf compared to the control without carbofuran. Seedling populations increased 64% in the carbofuran treated plots compared to those plots which received no carbofuran at planting. Yield of switchgrass was greater with the carbofuran treatment and reflected greater vigor and competitive ability as compared with the check in the 1985 planting.

Seedling growth rate, height, population, LER, and weight increased with the addition of carbofuran in the 1986 planting into rye stubble (Table 2). The seedings into millet residue in 1986 showed an increase of 27% in growth rate and an increase of 37% in seedling population compared to seedlings without carbofuran.

Year after seeding: The 1986 harvest of switchgrass planted in 1985, and the 1987 harvest of switchgrass planted in 1986 revealed a dramatic benefit of carbofuran. Yields were higher where carbofuran was placed in the row at planting than the check. Yield increases in 1986 were 1.8 and 2.5 Mg/ha following rye

Table 2. Switchgrass seedling growth rate, leaf appearance rate, height at sixth leaf, leaf elongation rate (LER), population, seedling weight, yield, and percentage of switchgrass (BC) as affected by atrazine and carbofuran in the year of no-till establishment.

Treatment		Seedling measurements						Dry matter	
		Growth	Leaf						
Carbo.	Atr.	rate†	Appear.†	Ht.‡	LER§	Pop.‡	Weight‡	BC	Yield
-----kg/ha-----		mm/d	no./d x 10^{-3}	mm	mm/d	no./m^2	mg/pl	%	Mg/ha
			PREVIOUS CROP RYE, 1985 PLANTING						
0.0	--	.¶	.	41	24	92	37	55	0.24
1.1	--	.	.	131	61	255	82	72	0.91
LSD 0.05		.	.	36	15	61	31	NS	0.46
--	0.0	.	.	98	48	231	84	29	0.48
--	1.1	.	.	74	37	157	46	99	0.71
--	2.2	.	.	.	.	132	49	63	0.54
LSD 0.05		.	.	NS	NS	75	NS	37	NS
			Probability of a difference between means (%)						
Carbofuran		.	.	00	00	00	01	25	02
Atrazine		.	.	17	14	03	10	01	87
Carbo. x Atr.		.	.	44	68	01	76	64	98
			PREVIOUS CROP RYE, 1986 PLANTING						
0.0	--	1.6	53	26	13	143	322	.	.
1.1	--	2.6	70	57	24	193	400	.	.
LSD 0.05		0.8	14	25	07	NS	NS	.	.
--	0.0	2.4	69	61	18	221	348	.	.
--	1.1	2.4	66	40	19	183	395	.	.
--	2.2	1.5	49	22	17	99	340	.	.
LSD 0.05		1.0	18	3.1	NS	66	NS	.	.
			Probability of a difference between means (%)						
Carbofuran		03	02	02	00	07	18	.	.
Atrazine		10	06	04	80	00	69	.	.
Carbo. x Atr.		74	78	13	39	04	34	.	.
			PREVIOUS CROP MILLET, 1986 PLANTING						
0.0	--	3.1	67	70	26	122	158	.	.
1.1	--	4.1	76	96	34	186	187	.	.
LSD 0.05		1.0	NS	NS	NS	NS	NS	.	.
--	0.0	5.1	84	127	30	194	215	.	.
--	1.1	3.6	73	81	36	163	172	.	.
--	2.2	2.1	56	43	24	115	130	.	.
LSD 0.05		1.3	15	46	NS	85	66	.	.
			Probability of a difference between means (%)						
Carbofuran		06	13	16	27	11	28	.	.
Atrazine		00	00	00	38	05	04	.	.
Carbo. x Atr.		35	51	75	40	52	10	.	.

†Growth rate and leaf appearance rate measured prior to emergence of seventh leaf.
‡Height, population, and weight of seedlings taken when the sixth leaf was fully expanded.
§LER is calculated from measurements of leaf elongation for all leaves beginning when the seventh leaf emerged and followed through expansion of leaves eight and nine.
¶Measurements not taken.

and millet, respectively. In 1987, yields increased 1.0 Mg/ha in both residues where carbofuran was used. Carbofuran residues are probably not responsible for yield increases observed the year after seeding. Planting with carbofuran increased seedling populations and seedling vigor in the year of establishment. This improved stand development resulted in vigorous plants the next season and enabled the carbofuran-treated seedlings to grow more competitively the next year.

Atrazine Influences

Year of seeding: Plantings of switchgrass made in 1985 responded negetively to atrazine (Table 2). Rates of 1.1 and 2.2 kg atrazine/ha reduced seedling weight at the 10% level when compared to the control; however, there was no difference between the two atrazine rates. Seedling population responded in a similar manner with both levels of atrazine reducing the switchgrass population significantly when compared to the treatments without atrazine. Percentage of switchgrass in the harvested herbage was higher when either application rate was compared to the control. There was a trend toward higher yields with 1.1 kg atrazine/ha compared to the 0 and 2.2 kg atrazine/ha application.

Switchgrass plantings made in 1986 into rye stubble exhibited no reduction in seedling growth rate, leaf appearance rate, and population where atrazine was applied at 1.1 kg/ha as compared to the check, however, 2.2 kg atrazine/ha caused a reduction in seedling growth rate, leaf appearance rate, and population when compared with 0 and 1.1 kg atrazine/ha. There was a reduction in height at the

Table 3. **Yields of switchgrass and Caucasian bluestem as influenced by atrazine and carbofuran in the year after no-till establishment in 1985 and 1986.**

Treatment		Previous crop and year of planting							
		Rye		Millet		Rye		Millet	
Carbo.	Atr.	1985	1986	1985	1986	1985	1986	1985	1986
-----kg/ha----		---Mg/ha---							
		SWITCHGRASS				CAUCASIAN BLUESTEM			
0.0	--	3.10	1.46	5.79	4.06	1.34	3.29	4.52	6.51
1.1	--	5.58	2.47	7.56	5.09	2.44	4.88	5.83	7.33
LSD 0.05		1.54	0.62	1.14	0.82	0.86	0.25	0.64	0.49
--	0.0	4.55	2.32	4.68	5.41	1.51	4.27	3.36	6.53
--	1.1	3.79	2.03	7.88	4.71	3.05	4.23	5.62	7.18
--	2.2	4.68	1.55	7.46	3.61	1.11	3.81	6.55	7.06
LSD 0.05		NS	0.77	1.39	1.00	1.05	0.31	0.79	NS
		Probability of a difference between means (%)							
Carbofuran		00	01	00	00	01	00	02	00
Atrazine		57	02	01	00	04	04	01	08
Carbo. x Atr.		15	51	07	20	06	29	69	93

1.1 kg/ha rate and and a further reduction at 2.2 kg atrazine/ha. In the 1986 plantings into a millet residue, all seedling observations except LER revealed a reduction or a trend toward reduction with 1.1 kg atrazine /ha when compared with the check. When atrazine was applied at 2.2 kg/ha, the trends were toward a further decrease in seedling leaf development, LER, seedling height, seedling population, and seedling weight; however, only seedling population was reduced significantly.

Year after seeding: Yields of switchgrass where 1.1 kg atrazine/ha was applied were equal to the control in three experiments but greater than the control where planted into millet in 1985 (Table 3). Yields of switchgrass where 2.2 kg atrazine/ha was applied were lower than the control in two experiments. In the other two experiments there were no differences between the 1.1 and 2.2 kg atrazine/ha treatments. Atrazine treated plots at 2.2 kg/ha never produced higher yields than plots receiving 1.1 kg/ha and produced lower yields in two of four experiments. Atrazine at 1.1 kg/ha was an advantage or no disadvantage in all experiments. Stands were nearly 100% of the seeded warm-season species for all treatments the year after planting. Vigorous seedlings, high yields, and nearly pure stands resulted where carbofuran and atrazine were included in the year of seeding.

An interaction between carbofuran and atrazine was observed in the measurements of seedling population in the 1985 and 1986 plantings in rye. Carbofuran influenced the magnitude of the atrazine response but not the direction, thus the atrazine influence was not masked by averages reported in Table 2.

Caucasian bluestem

Carbofuran Influence

Year of seeding: Caucasian bluestem plantings into the rye area in 1985 benefited from carbofuran. Carbofuran at 1.1 kg/ha increased all seedling measurements, yields, and percentages of Caucasian bluestem in the herbage (Table 4). Seedling height and LER were increased by 95% with carbofuran as compared with the check. Seedling population and yield were more than doubled and seedling weight and botanical composition of Caucasian bluestem in the herbage increased by 33% with carbofuran compared with the check.

Plantings in 1986 into rye stubble did not benefit greatly from carbofuran except for an increase in seedling population and seedling weight. However, a trend toward an increase was observed in all seedling measurements. Plantings into millet residue responded similarly to those in the rye residue in 1986. Only leaf appearance rate increased where carbofuran was applied.

Year after seeding: Yields were increased the year after planting in all four Caucasian bluestem experiments (Table 3). The influence of 1.1 kg/ha of carbofuran at seeding was seen in the year after seeding with yield increases of 0.82 to 1.5 Mg/ha by early summer.

Table 4. Caucasian bluestem seedling growth rate, leaf appearance rate, height at sixth leaf, leaf elongation rate (LER), population, seedling weight, yield and percentage switchgrass (BC) as affected by atrazine and carbofuran in the year of no-till establishment.

Treatment		Seedling measurements						Dry matter	
		Growth	Leaf						
Carbo.	Atr.	rate†	Apper.†	Ht.‡	LER§	Pop.‡	Weight‡	BC	Yield
-----kg/ha-----		mm/d	no./d x 10⁻³	mm	mm/d	no./m²	mg/pl	%	Mg/ha
				PREVIOUS CROP RYE, 1985 PLANTING					
0.0	--	.¶	.	68	51	207	50	63	0.93
1.1	--	.	.	104	70	612	74	94	2.39
LSD 0.05		.	.	33	14	175	21	11	0.46
--	0.0	.	.	94	66	504	90	81	1.72
--	1.1	.	.	79	55	448	54	94	2.16
--	2.2	.	.	.	.	227	42	61	1.10
LSD 0.05		.	.	NS	NS	210	26	13	0.57
				Probability of a difference between means (%)					
Carbofuran		.	.	04	01	01	03	00	00
Atrazine		.	.	35	10	02	00	03	01
Carbo. x Atr.		.	.	76	34	30	69	27	22
				PREVIOUS CROP RYE, 1986 PLANTING					
0.0	--	2.0	79	11	20	295	73	.	.
1.1	--	2.5	86	24	20	445	110	.	.
LSD 0.05		NS	NS	NS	NS	91	24	.	.
--	0.0	1.7	72	09	18	309	77	.	.
--	2.7	2.3	90	24	23	368	91	.	.
--	2.2	2.3	85	21	20	433	107	.	.
LSD 0.05		0.9	13	NS	NS	111	29	.	.
				Probability of a difference between means (%)					
Carbofuran		11	19	25	99	01	00	.	.
Atrazine		08	02	53	74	05	11	.	.
Carbo. x Atr.		79	68	63	36	12	15	.	.
				PREVIOUS CROP MILLET, 1986 PLANTING					
0.0	--	3.6	70	93	20	191	132	.	.
1.1	--	3.8	80	86	22	247	192	.	.
LSD 0.05		NS	08	NS	NS	NS	39	.	.
--	0.0	4.0	75	115	21	240	205	.	.
--	1.1	3.7	73	81	24	256	147	.	.
--	2.2	3.3	78	73	19	162	132	.	.
LSD 0.05		NS	NS	NS	NS	NS	48	.	.
				Probability of a difference between means (%)					
Carbofuran		76	02	70	48	19	00	.	.
Atrazine		50	50	18	55	17	01	.	.
Carbo. x Atr.		58	15	88	66	28	14	.	.

†Growth rate and leaf appearance rate measured prior to emergence of seventh leaf.
‡Height, population, and weight of seedlings taken when sixth leaf fully expanded.
§LER calculated from measurements of leaf elondgation for all leaves beginning when the seventh leaf emerged and followed through expansion of leaves eight and nine.
¶Measurements not taken.

Atrazine Influence

Year of seeding: Atrazine at 2.2 kg/ha resulted in lower seedling populations, seedling weights, and percentages of Caucasian bluestem as compared with the control in 1985 (Table 4). However, 1.1 kg atrazine/ha increased or did not change any seedling measurements except seedling weight. Seedling weight at the sixth leaf stage was reduced from 90 to 54 mg/seedling where 1.1 kg atrazine/ha was used. Atrazine application at 2.2 kg/ha reduced both yields and percentages of Caucasian bluestem in the herbage by 0.62 Mg/ha and 20%, respectively, when compared to the control. However, at 1.1 kg atrazine/ha, percentages and yields of Caucasian bluestem increased over both the control and 2.2 kg atrazine/ha treatments.

The 1986 Caucasian bluestem plantings exhibited equal or higher seedling measurements for the 1.1 kg atrazine/ha treatments as compared with the control except for a decrease in seedling weight (Table 4). Atrazine at 2.2 kg/ha either reduced or did not change seedling measurements as compared with the 1.1 kg rate from plantings made into either previous crops. In eight comparisons, 2.2 kg atrazine/ha either reduced or did not change seedling measurements as compared to the control. In the four remaining comparisons, the seedling measurements were similar between 1.1 and 2.2 kg rates; thus, 2.2 kg atrazine/ha was never an advantage. Atrazine at 1.1 kg/ha appeared to either benefit or not harm establishment.

Year after seeding: Yields in the year after seeding where 1.1 kg atrazine/ha was applied were either greater or equal to the control in both years and both previous crops (Table 3). In three of the four experiments, the 2.2 kg atrazine/ha treatment either decreased yields or was equal to the 1.1 kg rate. In three of four experiments, yields from the 2.2 kg atrazine/ha treatments either decreased or were equal to the control. Recommendations made from these data would include use of 1.1 kg atrazine/ha since in nearly all experiments yields were equal to or greater than the control.

Establishment appeared to be influenced by previous crop although the comparison cannot be confirmed statistically. In three of four experiments, yields in the year after seeding were higher in the millet residue plots than in the rye plots. This might be attributable to the fact that the rye prior to harvest withdrew large amount of water before the warm-season grasses were planted. In the millet area, the non-living mulch would tend to conserve rather than use water prior to warm-season grass seeding. Observations at the time of seeding indicated that the soil in the millet areas was friable and had a higher level of moisture in the seeding zone compared to the rye area. In contrast, the surface of the soil in the rye areas was crusted and appeared to lack adequate amounts of water at seeding depth. The available moisture might also explain another treatment difference. Weed competition in 1985 and 1986 was much higher in the millet than the rye areas. Atrazine appeared to benefit the warm-season grass in the millet residue seeding more than in the rye stubble. Even under moisture stress, both switchgrass and Caucasian bluestem were established. Both species in the year after planting exhibited nearly pure stands of warm-season herbage and very acceptable first- harvest yields. Atrazine and carbofuran at 1.1 kg/ha would be recommended for establishment of switchgrass and Caucasian bluestem.

References

Bahler, C. C., K. P. Vogel, and L. E. Moser. 1984. Atrazine tolerance in warm-season grass seedlings. Agron. J. 76:891-895.

Bryan, W. B., T. A. Millsie, and J. A. Cronauer. 1984. Sod-seeding switchgrass and tall fescue into hill land pasture. J. Soil Water Conserv. 39(1):70-72.

Council on Soil Testing and Plant Analysis. 1980. Handbook on reference methods for soil testing. 1111 Plant Sci. Bldg., Univ of Georgia, Athens, GA.

Griffin, J. L., and G. A. Jung. 1981. Yield and forage quality of *(Panicum virgatum* L.) *In*: Proc. 14th Int. Grassl. Congr. Lexington, KY. Published by Westview Press, Boulder, CO. (eds.) J. A. Smith and V. W. Hays.

Jung, G. A., C. F. Gross, R. E. Kocher, L. A. Burdette, and W. C. Sharp. 1978. Warm-season range grasses extend beef cattle forage. Penn. Agric. Exp. Stn. Sci. Agric. 64:211-219.

Lamoureux, G. L., K. E. Stafford, R. H. Shimabukuro, and R. G. Zaylskie. 1973. Atrazine metabolism in sorghum: catabolism of glutatione conjugate of atrazine. J. Agric. Food Chem. 21: 1020-1030.

Martin, A. R., R. S. Moomaw, and K. P. Vogel. 1982. Warm-season grass establishment with atrazine. Agron. J. 74:916-920.

McKenna, J. R., and D. D. Wolf. 1987. No-till switchgrass establishment as affected by lime, phosphorus, and carbofuran. *In*: Proc. Am. Forage Grassld. Conf., Springfield, IL. American Forage and Grassland Council, Lexington, KY.

Panciera, M. T., and G. A. Jung. 1984. Switchgrass establishment by conservation tillage: planting date responses of two varieties. J. Soil Water Conserv. 39:68-70.

Robocker, W. C., J. T. Curtis, and H. L. Ahlgren. 1953. Some factors affecting emergence and establishment of native grass seedlings in Wisconsin. Ecology 34:194-199.

Roundtree, B. H., A. G. Matches, and F. A. Martz. 1974. Season too long for your grass pasture? Crops Soils 26(7):7-10.

Shimabukuro, R. H. 1967. Atrazine metabolism and herbicidal selectivity. Plant Physiol. 42:1269-1276.

Warnes, D. D., L. C. Newell, and W. J. Moline. 1971. Performance evaluation of some warm-season prairie grasses in Nebraska environments. Nebr. Agric. Exp. Stn. Bull. 421.

Chapter 4

No-till Switchgrass Establishment as Affected by Limestone, Phosphorus, and Carbofuran

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Abstract

Cool-season perennial grass productivity falls sharply during hot, dry summer weather. This "summer slump" has been observed at many locations in the United States and especially in the Southeast. Perennial, tall-growing, warm-season forage grasses produce abundant herbage during the summer and could make a contribution to southeastern forage systems. However, the relatively long period commonly required to produce grazable stands of warm-season grasses is problematic. Before these warm-season species can be incorporated into a summer forage system, problems with establishment need to be investigated. Research was undertaken to evaluate the influence of limestone, P, and carbofuran (2,3-dihydro-2,2, _dimethyl-7benzofuranyl methylcarbamate) in the establishment of switchgrass (*Panicum virgatum* L.) using no-till procedures. Plantings were made both in 1985 and 1986 into a killed sod in Blacksburg, VA located at 37° 11′ N° 80 ° 25′ W at 610 m elevation. The soil was a Groseclose loam (clayey, mixed, mesic Typic Fragiudult) with a fragipan at 45 cm. Treatments included carbofuran at 0 and 111 kg/ha placed in the row with the seed, limestone at 0 and 4.48 Mg/ha, and P at 0 and 22 kg/ha in all possible combinations were broadcast 6 months prior to planting. Seedling growth rate and leaf appearance rate were recorded through the sixth-leaf stage of development. Seedling weights, populations, and heights were determined at the sixth leaf stage of development. Leaf elongation rates were measured for leaves 7, 8, and 9. Yields of forage and percentages of switchgrass in the harvested herbage were determined in the year of planting and the year after planting. The data indicate that carbofuran increased all measurements in the year of seeding. Yields in the year after planting revealed a positive continuing influence of carbofuran. Phosphorus application increased yields in the 1986 harvest of the 1985 planting but no affect was observed in the 1987 harvest of the 1986 planting. Limestone had no affect the year after seeding in either experiment. Carbofuran applied at planting in the row with the seed and P applied prior to no-till planting in areas with low P soil test levels are considered good recommendations for establishment of switchgrass.

Additional index words: Switchgrass (*Panicum virgatum* L.) Growth rate, Leaf elongation rate, Leaf appearance rate, Seedling populations, Seedling weight.

Introduction

Summer production by cool-season grasses often limits the carrying capacity of pastures. Cool-season grasses typically make 60 to 70% of their yearly production before 1 June and much of the remainder will be produced after 1 September. As temperatures increase and soil water is limited, growth is reduced. Consequently, if a cool-season pasture is grazed intensively during the spring, there may be very little grass for summer. The need for a species to fill this "summer slump" period in the northeast was reported by Jung et al. (1974). Similar work in Missouri (Anderson and Matches, 1983) found cool-season grasses to be unproductive in mid-summer as compared with warm-season grasses. Forage production by cool-season species in summer is usually low in quality as well as quantity as compared with warm-season species (Roundtree et al. 1974; and Jung et al. 1974). Where a cool-season pasture is to be grazed continuously, production is typically stockpiled and grazed as mature summer aftermath, which has low feed quality. Warm-season grasses provide most of their grazing days during the summer. Tall-growing, perennial, warm-season grasses typically make more than 70%

of their production after 1 June and provide mid-season forage for beef cattle (Balasko et al., 1984). By having a portion of the available pasture in perennial warm-season grasses, a producer can increase carrying capacity during the growing season.

Poor summer forage productivity is of special concern in the southeastern states (Burns et al., 1984). Soils are mostly Alfisols and Ultisols with acid subsoils and low water availability. Periods of high summer temperature and limited soil moisture are of longer duration than in many northern locations, compounding the problem of forage availability and quality.

An obstacle to introduction of perennial warm-season species is establishment. Burns et al. (1984) in North Carolina report two growing seasons were necessary for the establishment of switchgrass and flacidgrass (*Pennisetum flacci* L.). With slow establishment, especially in conventional seedbeds, the erosion hazard is great. This is particularly true on the highly erodible soils found in the southeast USA. Samson and Moser (1982) reported similar problems in the fine-textured soils of eastern Nebraska.

Establishment of perennial warm-season grasses such as switchgrass to provide summer grazing needs to be investigated in the mid-Atlantic and southeastern USA. No-till technology may be a way to solve establishment problems. No-till planting has become increasingly popular throughout the Southeast. This type of planting generally increases soil moisture retention and reduces soil erosion compared to conventional establishment. Higher soil moisture levels should result in improved establishment.

Studies with no-till alfalfa conducted by Wolf et al. (1983) indicated that carbofuran, an insecticide, increased stand, yield, and percentage of alfalfa in the year of establishment. Bryan et al. (1984) reported that carbofuran increased stand and yield of interseeded switchgrass in the seedling year. McKenna and Wolf (1987) found that 1.1 kg carbofuran/ha increased switchgrass yield, seedling weight, seedling population, and seedling developmental rate. Carbofuran represents a possible management tool to aid in switchgrass establishment.

Development of a reliable method to establish switchgrass was the objective of this study. We wanted to accomplish this in soil with low fertility and with a minimum of soil disturbance. Target soils for the introduction of perennial warm-season species in the mid-Atlantic and Southeast are typically low in P and pH. For this reason, limestone and P treatments were included along with carbofuran. The expectation is that techniques useful for switchgrass establishment might also be helpful in establishment of other warm-season grasses.

Materials and Methods

Plantings of 'Blackwell' switchgrass (1985) and 'Cave-in-rock' switchgrass (1986) were made at the Agronomy Research Farm in Blacksburg, VA at 37°11' N° 80°25' W at 610 m elevation. The soil was a Groseclose loam (clayey, mixed, mesic Typic Fragiudult) with a fragipan at 45 cm. A randomized complete block design included four replications in 1985 and three replications in 1986, with 1.8 by 6.1 m plots. Treatment variables included all combinations of broadcast P at 0 and 22 kg/ha, limestone at 0 and 4.48 Mg/ha, and carbofuran at 0 and 1.1 kg/ha. Limestone and P were applied in the fall for the 1985 planting and in early spring for the 1986 planting. Dicamba (2-methoxy-3,6-dichlorobenzoic acid) and 2,4-D (2,4-dichlorophenoxy acetic acid) were applied in the fall preceding establishment to control broadleaf perennial weeds. Paraquat at 0.28 kg/ha was applied two weeks prior and at planting. Atrazine at 1.7 kg/ha was applied to all plots before planting. All herbicides were applied as a broadcast spray in 280 L/ha of water (30 gal/acre) using 276 kPa (40 lb/inch^2) pressure and flat fan nozzles (786 ml/min) with a back pack sprayer. A wetting agent (1.25 ml/L of Ortho x-77) was added for all paraquat sprayings. Spraying was done under wind conditions of less than 223 cm/s (5 mph). Switchgrass was seeded on 10 May 1985 and 23 April 1986 using a no-till drill at a rate of 4.5 kg/ha of pure live seed. The carbofuran was placed in the row with the seeds at planting.

Fertility

Six months after broadcast application of P and limestone, soil tests were taken. These samples were taken at 5, 10, and 15 cm depths. Water-soil pH (1:1 v:v) and Mehlich I procedures were used to determine extractable nutrients as outlined by the Council on Soil Testing and Plant Analysis (1980). Nitrogen as ammonium nitrate was broadcast at 35 kg/ha 1 month after switchgrass seeding. The low N application in the seeding year was selected so as not to encourage weed competition. No fertilizer other than N was used in the seeding year. In the year after seeding, 75 kg N/ha was applied as ammonium nitrate to the switchgrass when plants reached the seventh-leaf stage.

Seedling Measurements

The first series of measurements which preceded the seventh-leaf (tillering) stage of development, included seedling growth rate and leaf appearance rate. Seedling growth rates were calculated by regressing height measurements against time from measurements taken at 2-day intervals from emergence until the sixth leaf expanded. Seedling leaf appearance rates were obtained from measurements of the first six expanding leaves by counting the number of visible leaves. Leaf appearance rates were calculated from regression analysis using observations taken at approximately 2-day intervals.

The next set of measurements was obtained at the time of tillering when the seventh leaf was emerging and tillering began. Seedling height was measured from soil level to the top of the sixth leaf. Seedling populations were counted when the seventh leaf appeared and random seedlings were harvested to determine above ground weight of seedlings. Seedlings were cut at ground level and ovendried at 70°C. Leaf elongation rates were measured during expansions of leaves 7, 8, and 9. Leaf elongation was determined from uniform seedlings identified and marked when they had six fully developed leaves. Daily lengths of leaves 7, 8, and 9 were recorded and totaled. Regression analysis of total length against time was used to obtain leaf elongation rates (LER).

Yield Measurements

First harvest of herbage in 1985 was taken on 2 August when plants were at an an early head stage of development. They were cut to a 15-cm stubble height. In 1986, the first harvest was made on 15 June when the grass was beginning to joint. The cutting was made at a 25-cm height. Second harvest was made in late September in both years. Dry matter yield and percentage switchgrass were determined. In the year after the 1985 planting, a harvest was made on 11 June 1986, and the 1986 planting was harvested on 23 June 1987. Switchgrass was in the jointing stage when harvested the year after seeding. Percentage of switchgrass in the harvested herbage was estimated visually and yields reported on a weed-free, dry matter basis. Herbage was sampled from the first cutting, dried, and ground. The ground forage was weighed, ashed, and prepared for analysis of ten elements on an Inductively Coupled Plasma spectrophotometer.

Data Analyses

All data were subjected to an analysis of variance and probabilities of differences among the main effects and interactions were reported as percentages. Means are reported for main effects of carbofuran, P, and limestone, since few interactions had probabilities below 5%. Where interactions were significant at the 0.05 level and were important biologically, a detailed discussion is presented. There were significant year by treatment interactions for seedling measurements and yields; therefore, data the year of planting are presented by years. Yields in the year after planting showed no interactions between years, these data are averaged over both years.

Results and Discussion

Normal rainfall occurred in May and July of 1985 (Table 1) but rainfall was less than 50% of normal in April 1985 and was 35% below normal in June 1985. In 1986, plantings were made in dry soil and early seedling development occurred during a period of dry weather. April, May, and June of 1986 received one third of the long-term rainfall means. Only 82 mm of rainfall were measured during April through June in 1986 compared to 184 mm in the same time period in 1985. Rainfall during the year after planting was low in both 1986 and 1987 when deficits accumulated during the entire growing season of May through August.

The site used for this study had not been cropped or fertilized for more than 20 years. The area had low levels of fertility and the vegetation was a mixture of cool-season grasses and weeds. The sites are representative of areas proposed for introduction of perennial warm-season grass species in the southeastern USA. Soil P and pH levels were low and a fragipan existed at 45 cm. Soil tests prior to seeding in 1985 indicated a pH of 5.1, 4 ppm P, 71 ppm K, 267 ppm Ca, and 33 ppm Mg. The site planted in 1986 had a pH of 5.6, 5 ppm P, 93 ppm K, 768 ppm Ca, and 54 ppm Mg. Soil samples taken at 6 months after limestone and P application in both experiments revealed no pH or P differences due to treatment at any depth tested or in either year. The differences can be explained by dilution and the slow movement of applied nutrients.

Carbofuran Influence

The most apparent influences of carbofuran were seen in early seedling development (Table 5). Seedling growth rate increased 33% in 1985 and 16% in 1986 where carbofuran was used. Leaf appearance rates increased both years with carbofuran treatment compared with seedlings from the check. The seedlings with carbofuran averaged 25% taller at the sixth-leaf stage in 1986. The leaf accumulation rate of switchgrass in the seventh through ninth leaf revealed a decided promotion of seedling development by carbofuran. In both years, LER increased by 35 to 43%, seedlings were heavier, and seedling populations were higher where carbofuran was used. Faster seedling leaf development was observed in the carbofuran treatments when compared to non-carbofuran treatments in the 1985 planting. Seedings with carbofuran placed in the row with the seed grew more rapidly than those in non-carbofuran treatments in 1985. Although not significant in 1986, growth rate and leaf appearance rates tended to increase where carbofuran was used. Yields from carbofuran treatment each seeding year were increased by 0.75 Mg/ha compared to the control. Five of the ten elements analyzed in switchgrass tissue decreased where carbofuran was used at time of seeding (Table 6). This was probably a dilution effect as the yields with carbofuran were higher than the check. Concentrations of three elements remained the same, and Cu and Zn levels were inhigher where carbofuran was used at the time of seeding.

Phosphorous Influence

Seedlings were two times as heavy at the sixth leaf stage in the P plots compared to those without added P in the 1985 planting (Tab Switchgrass yields in 1985 were 1.0 Mg/ha greater where P was broadcast the fall applied. In 1986 the influence of P was minimal. Broadcast P did not influence any seedling measurements or yields in the second year of the study. There was an increase in P in the switchgrass tissue where P was applied (Table 6). There was also an decrease in Zn and Cu in the tissue where 22 kg/ha of P was broadcast. In one of eighteen observations in the 1985 and 1986 plantings, there was an interaction between P and carbofuran in LER. Carbofuran influenced the magnitude of the P response. Where carbofuran and P were included in the treatment, the length of leaves 7 through 9 was higher than when carbofuran or P were the only treatments.

Table 5. Switchgrass seedling growth rate, leaf appearance rate, height at sixth leaf, leaf elongation rate (LER), population, seedling weight and yield as affected by limestone P, and carbofuran in the year of no-till establishment.

Treatment†			Seedling Measurement						Yield		
			Growth	Leaf					Harvest		
Lime	P	Carbo.	Rate‡	Appear.‡	Ht.§	LER¶	Pop	Wt.	1st	2nd	Total
Mg/ha	------kg/ha------		mm/d x 10^{-3}	no./d	mm	mm/d	no./m^2	mg/pl	----------Mg/ha----------		
						1985 PLANTING					
0.00	--	--	5.8	15	65	28	328	137	1.46	1.11	2.57
4.48	--	--	5.4	15	46	27	314	140	2.01	1.21	3.22
LSD 0.05			NS	NS	NS	NS	NS	NS	0.36	NS	0.39
--	0	--	5.4	14	49	26	323	94	1.20	1.18	2.39
--	22	--	5.8	15	61	30	318	184	2.27	1.14	3.42
LSD 0.05			NS	NS	NS	NS	NS	29	0.36	NS	0.39
--	--	0.0	4.5	14	43	22	249	90	1.26	1.40	2.66
--	--	1.1	6.7	16	68	34	392	188	2.21	0.93	3.14
LSD 0.05			1.5	2	NS	06	73	29	0.36	0.16	0.39
					Probability of a difference between means (%)						
Lime			68	83	17	58	69	81	01	25	00
P			59	08	35	14	89	00	00	63	00
Carbofuran			01	00	06	00	00	00	00	00	00
Lime x P			78	00	92	44	34	58	30	07	85
Lime x carbofuran			53	34	12	73	73	69	81	26	80
P x carbofuran			72	99	47	04	93	00	28	78	27
						1986 PLANTING					
0.00	--	--	7.5	21	91	41	251	327	0.61	4.24	4.85
4.48	--	--	5.8	19	77	41	224	335	0.51	4.26	4.77
LSD 0.05			NS	NS	NS	NS	NS	NS	NS	NS	NS
--	0	--	6.2	20	90	39	236	312	0.53	4.09	4.62
--	22	--	7.1	20	78	44	238	350	0.59	4.42	5.00
LSD 0.05			NS	NS	NS	NS	NS	NS	NS	NS	NS
--	--	0.0	6.3	20	72	30	154	173	0.20	4.32	4.52
--	--	1.1	7.0	21	96	53	321	488	0.91	4.18	5.10
LSD 0.05			NS	NS	23	07	68	85	0.15	NS	NS
					Probability of a difference between means (%)						
Lime			15	15	20	84	39	84	18	93	78
P			42	96	28	15	95	35	44	22	19
Carbofuran			57	44	05	00	00	00	00	62	06
Lime x P			85	02	46	94	37	49	71	39	37
Lime x carbofuran			80	28	93	37	44	84	18	72	98
P x carbofuran			80	18	91	50	98	65	52	19	17

†Limestone and P broadcast 6 months prior to seeding, carbofuran applied in row with seed at planting
‡Growth rate and leaf appearance rate measured prior to emergence of seventh leaf.
§Height, population, and weight of seedling taken when sixth leaf fully expanded.
¶LER is calculated from measurements of leaf elongation for all leaves beginning when the seventh leaf emerged.

Table 6. Nutrient composition of switchgrass as affected by limestone, P, and carbofuran treatments. Data are averages of tissue harvested in the seeding year of 1985 and 1986.

Treatment†			Nutrient element									
Lime	P	Carbo.	P	K	Ca	Mg	Zn	Mn	Fe	Cu	Al	B
Mg/ha	----kg/ha----		---------------------------------ppm									----------------------------------
0.00	--	--	48	345	81	71	0.48	1.7	1.2	0.23	0.39	0.19
4.48	--	--	47	317	80	75	0.47	1.5	1.2	0.24	0.34	0.20
			NS	NS	NS	NS	NS	*	NS	NS	NS	NS
--	0	--	44	331	79	70	0.50	1.7	1.3	0.24	0.37	0.22
--	22	--	52	330	82	76	0.45	1.5	1.2	0.22	0.36	0.17
			**	NS	NS	NS	*	NS	NS	*	NS	NS
--	--	0.0	50	309	87	78	0.45	1.8	1.3	0.22	0.34	0.20
--	--	1.1	46	353	74	68	0.50	1.5	1.2	0.24	0.40	0.18
			**	NS	**	**	*	*	**	*	NS	NS
LSD 0.05			3.0	52	5.7	8	0.05	0.25	0.06	0.02	0.10	0.09
			Probability of a difference between means (%)									
Lime			39	27	75	29	53	05	73	51	33	91
P			00	97	23	10	02	15	09	03	91	23
Carbofuran			01	09	00	01	04	02	00	03	27	66
Lime x P			84	98	83	58	99	29	21	24	54	76
Lime x Carbofuran			84	98	83	58	99	29	21	24	54	76
P x Carbofuran			61	45	03	08	28	46	37	19	21	24

*,** Indicate significant difference between mean at the 0.05 and 0.01 levels, respectively.
†Lime and P applied broadcast 6 months prior to seeding and carbofuran applied in the row with the seed at planting.

Limestone Influence

Limestone application increased first harvest yield and total first year yield for the 1985 planting (Table 5). An application of 4.48 Mg limestone/ha did not influence seedling measurements. In the 1986 planting, limestone had no influence in all seedling and yield observations. In two of eighteen observations in 1985 and 1986 plantings, there were interactions between limestone and P. Some differences although significant, have no biologically interpretative value.

Harvests in the Year after Establishment

Harvests of 1985-planted switchgrass in early summer 1986 revealed a continuing positive influence of carbofuran and P (Table 7). The response to carbofuran was also evident in 1987 for the 1986 planting date. Averaging data over 2 years, carbofuran at planting increased yields in the year after establishment by 1.0 Mg/ha. A yield enhancement was also observed with P application. Although P treatment differences were not significant at the 0.05 level for yield in 1986, they were at 0.06. Over the 2 years, P influenced yield in the year after seeding. Lime did not appear to influence yield the year after seeding.

Table 7. Switchgrass yield the year after no-till establishment as affected by limestone, P, and carbofuran.

Treatment†			Establishment year		
Lime	P	Carbo.	1985	1986	Avg
Mg/ha	-----kg/ha-----		------------Mg/ha------------		
0.00	--	--	4.30	7.20	5.75
4.48	--	--	3.90	7.12	5.51
			NS	NS	NS
--	0	--	3.37	6.87	5.14
--	22	--	4.83	7.46	6.14
			**	NS	**
--	--	0.0	3.87	6.68	5.28
--	--	1.1	4.81	7.65	6.23
			**	**	**
LSD 0.05			0.85	0.61	0.81
Probability of a difference between means (%)					
Lime			33	77	68
P			00	06	01
Carbofuran			01	00	00
Lime x P			23	31	30
Lime x carbofuran			84	64	70
P x carbofuran			02	35	08

*,** Indicate significant differences between means at the 0.05 and 0.01 levels, respectively.
†Limestone and P applied broadcast 6 months prior to planting and carbofuran applied in the row with seed at planting.

Summary

These data suggest a potentially grazeable and acceptable switchgrass grass stand can be established in the seeding year if one provides adequate weed suppression, P, and carbofuran. Switchgrass was in an early heading stage when the first harvest in the seeding year was taken in 1985. Regrowth was retarded more in the most vigorous high yielding plots than in the less vigorous low yielding plots apparently because a higher proportion of the total leaf area was removed with the harvest from the former treatments. This resulted in depressed yields in the second harvest from the vigorous high yielding plots and perhaps placed these initially better stands at a disadvantage in regrowth. The low yielding stands with short plants at first harvest had good regrowth in the second harvest, thus the advantage shown by the carbofuran and P treatments in the first harvest was not apparent in the second cutting in late September. Switchgrass was harvested in the jointing stage in the year of planting in 1986. With a 25-cm cutting height, removal of leaf area was more moderate than in 1985; and the regrowth of plants in the high yielding plots did not appear to be as retarded as in 1985. However, the plots with weak low yielding stands tillered and filled in the bare spots. Again, by the second harvest there was no significant difference in yield due to treatment.

One of the objectives of this research was to determine if a useable stand of switchgrass could developed in the seeding year. A second goal was to see if this was possible in a site of low fertility. With the application of 22 kg/ha P and 35 kg N/ha we were able to harvest 3.4 Mg/ha of forage in two cuts during 1985 and 5.0 Mg/ha in one cut during 1986 in the year of establishment. Even with below average moisture and minimum fertility, useable stands of switchgrass were established and substantial yields were obtained. This would be even more impressive if switchgrass production were compared to cool-season species under similar conditions.

The highest yields in the year after establishment in 1985 were obtained where carbofuran and P were both included. The influence of P in the year after planting was apparent in both years of the study. This work indicated that the addition of 1.1 kg carbofuran/ha produced more and larger seedlings than the plantings without carbofuran. There was no indication in this work that carbofuran was acting as an insecticide. Carbofuran appeared to provide an unexplained growth-stimulatory activity to switchgrass. This response occurred early in the seedling development phase but the benefit carried into the year after seeding. Future work might investigate the possible growth-stimulatory ability of carbofuran. The most impressive result of this experiment was the fact that even under some of the driest conditions in recent years, very acceptable stands of switchgrass were established.

References

Anderson, B., and A. G. Matches. 1983. Forage yield, quality, and persistence of switchgrass and Caucasian bluestem. Agron. J. 75:119-124.

Balasko, J. A., D. M. Burner, and W. V. Thayne. 1984. Yield and quality of switchgrass grown with and without soil amendments. Agron. J. 76:204-208.

Bryan, W. B., T. A. Mills, and J. A. Cronauer. 1984. Sod-seeding switchgrass and tall fescue into hill land pasture. J. Soil Water Conserv. 39(1): 70-72.

Burns, J. C., R. D. Mochrie, and D. H. Timothy. 1984. Steer performance from two perennial *Pennisetum* species, switchgrass, and a fescue-'Coastal' bermudagrass system. Agron. J. 76:795-800.

Council on Soil Testing and Plant Analysis. 1980. Handbook on reference methods for soil testing. 1111 Plant Sci. Bldg., Univ. of Georgia, Athens, GA.

Jung, G. A., J. A. Balasko, F. L. Alt, and L. P. Stevens. 1974. Persistence and yield of 10 grasses in response to clipping frequency and applied nitrogen in the Allegheny highlands. Agron. J. 66:517-521.

Jung, G. A., R. E. Kocher, L. A. Burdette, and W. C. Sharp. 1978. Warm-season range grasses extend beef cattle forage. Sci. Agric. 25(2):6.

McKenna, J. R., and D. D. Wolf. 1987. No-till warm-season grass establishment as affected by atrazine and carbofuran. *In*: Proceeding of an International Symposium on Establishment of Forage Crops by Conservation Tillage: Pest Management. R. R. Hill, Jr.,R. O. Clements, A. A. Hower Jr., T. A. Jordan, and K. E. Zeiders (eds.). United States Regional Pasture Research Laboratory, University Park, PA.

Roundtree, B. H., A. G. Matches, and F. A. Martz. 1974. Season too long for your grass pasture? Crops Soils 26(7):7-10.

Samson, J. F., and L. E. Moser. 1982. Sod-seeding perennial grasses into eastern Nebraska pastures. Agron. J. 74:1055-1060.

Wolf, D. D., H. E. White, and D. R. Ramsdell. 1983. No-till alfalfa establishment, a breakthrough in technology. Crops Soils 35(11):13-15.

Chapter 5

Conclusion

Tall-growing, warm-season, perennial grass species can be established using no-till procedures in the southeast USA. The use of split applications of paraquat, a non-selective herbicide, along with atrazine were effective in controlling weeds and aiding the establishment of a perennial warm-season grass. In soils with low P levels, a broadcast application of P in the fall preceding no-till planting aided in stand establishment. The most important treatment for successful seedling development and stand establishment was carbofuran. In ten experiments over 2 years where carbofuran at 1.1 kg/ha was delivered with the seed at planting, growth rate, leaf appearance rate, height, LER, population, and weight of seedlings were increased by carbofuran. This influence was also manifested in higher yields and percentage of planted species in the seeding year and the year after seeding. This study did not investigate the nature of the activity of carbofuran; however, carbofuran appeared to act as a growth stimulator, particularly in the early stages of seedling development. Seedlings were larger and more vigorous compared to the control without carbofuran in both the year of planting and the year after seeding.

Insects did not visibly affect the perennial warm-season grass seedlings during the period of seedling germination. Early development of seedlings occurred during a period where the soil was so dry that a fungicidal affect seems unlikely.

Atrazine at 1.1 kg/ha appeared to be beneficial in no-till perennial, warm-season, grass establishment. This was especially evident in the experiment where volunteer millet was a problem. The effect of atrazine was most apparent where weed competition was severe. In the seedings in rye stubble where weed competition was partially controlled by the droughty conditions that prevailed in both 1985 and 1986, more seedling injury was observed with the 2.2 kg atrazine/ha application compared with the 1.1 kg atrazine/ha treatment level. This might be partially explained if the seedlings in the rye area were under more stress. Under moisture stress, they would be expected to grow more slowly than those in the plots where the previous crop did not remove so much moisture. The rye haylage undoubtedly removed a significant amount of moisture from the soil prior to perennial warm-season grass planting. The millet, which was killed by frost in the fall, provided a spring time moisture-conserving role before the perennials were planted.

In practically all cases, the switchgrass was more susceptible to atrazine injury than was the Caucasian bluestem. Even the low (1.1 kg/ha) rate of atrazine reduced values of several seedling parameters. In the lime- P-carbofuran study, switchgrass was no-till seeded into a weak open sod. In this study, atrazine was applied at 1.7 kg, a rate that could possibly injure the seedlings. With this type of previous crop, weed control appeared to be satisfactory and injury to the switchgrass seedlings was less noticeable than in either the rye or millet previous crop areas. This might be because the weed pressure, especially the summer annual weeds, was not as heavy as in the sites where cropping had occurred in the previous year. However, the amount of dead organic matter on the surface may have tied up some atrazine and prevented seedling injury.

Although P application 6 months prior to planting did not influence establishment when applied without carbofuran, the combination of carbofuran and P produced some of the highest yields and seedling measurements in 1985 and 1986. Lime did not have an influence on stand establishment or yield in either year.

The stage of development when the first cutting was taken in the seeding year of switchgrass appeared to be critical. This was especially true in the carbofuran-treated plots. The seedlings where carbofuran was used at seeding grew faster and matured more rapidly than the seedlings in plots without carbofuran. They were tall, and a greater amount of leaf area was removed with harvest. The short seedling plants in the non-carbofuran plots had a greater amount of their leaf area below cutting height than did the seedlings where carbofuran was applied at planting. Recovery in these non-carbofuran plots was much faster than in the plots where carbofuran was used. My recommendation would be to make the first harvest in the seeding year while there was still a significant amount of leaf area below cutting height to provide photosynthetic area for rapid seedling recovery. When this was not done, annual grassy weeds became a problem.

A reservation to consider before a blanket recommendation to establish these species in the mid-Atlantic and southeastern regions of the USA is the potential for weediness. Once established, switchgrass and Caucasian bluestem are very competitive species. They are prolific seeders and grow well when competing cool-season species are in a period of reduced productivity. A panicum species, fall panicum (*Panicum dichotomiflorum* L.) is already a competitive weed in corn fields and seems to be well adapted to the same edaphic conditions as switchgrass and Caucasian bluestem. Futher investigation of this potential for weediness should preceed the adoption of these species into existing forage systems.

Several recommendations concerning establishment of certain perennial warm-season grasses in the southeast and mid-Alantic areas can be made based on this work.

1. Apply broadcast P in the fall prior to seeding if soil test indicates low P levels.

2. Apply atrazine at 1.1 kg/ha pre-emergence.

3. Apply 1.1 kg/ha of granular carbofuran in the row with the seed at planting.

4. Make first harvest in seeding year when the warm-season grass is in a vegetative stage to minimize the amount of leaf area removed and enhance the regrowth potential of the seeding.

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