SEEDLING VIGOR OF *FESTUCA ARUNDINACEA*, *PANICUM VIRGATUM*, AND *BOTHRICHLOA CAUCASIA* AND THEIR RESPONSE TO ADDED NUTRIENTS[1]

GORDON GULLAKSON, L. E. FOOTE AND J. A. JACKOBS

Former Undergraduate Research Assistant, Former Graduate Research Assistant, and Professor of Crop Science, Department of Agronomy, University of Illinois, Urbana, Illinois.

This experiment was undertaken as one of a series of studies at the University of Illinois, in an attempt to find more desirable means of establishing vegetation on cut and fill areas along highways. These areas consist of subsoils of low fertility and/or poor physical characteristics which present very unfavorable growing conditions. Great seedling vigor and the resulting rapid establishment which secures the soil from erosion is extremely important in the stabilization of these areas.

Seedling growth and vigor of tall fescue *(Festuca arundinacea)*, switchgrass (*Panicum virgatum*) and Caucasian bluestem (*Bothrichloa caucasia*) were compared on three soils of varying chemical and physical composition, with and without added fertilizer. Tall fescue is a grass originally found in cool, humid regions and the other two species are warm, humid and semi-humid grasses. Tall fescue is grown extensively and does best in heavy soils with a high humus content, but is widely adapted and is grown under irrigation on desert soils which have a low humus content (Hoover, et al., 1948; Fergus, 1952; Hallowell, et al., 1960). Switchgrass is a vigorous, native, perennial, sod-forming grass that occurs throughout the United States under a wide variety of climatic conditions. It grows in all types of soil, but thrives best in moist lowlands when the soil is of relatively high fertility (Hoover, et al., 1948). Caucasian bluestem is grown in the U.S.S.R., England, and the United States and is reported productive, persistent under use, aggressive and winter-hardy. It was introduced into the United States in 1929 from the Botanical Gardens, Tiflis, Georgia, U.S.S.R. (Celarier and Harlan, 1955).

Plummer (1943) emphasized the importance of the initial root growth of grasses in their ability to compete with other vegetation. Ability to take up and utilize soil nutrients is also important in plant competition. Evans (1960) found that the principal competitive factors in the annual grassland species he studied was the ability to take up and use soil nitrogen. The relative requirements for nitrogen and phosphorus are also very important. The order of increasing nitrogen and phosphorus requirements has been shown to be (1) *Aristida* species, (2) *Andropogon scoparius* and (3) *Panicum virgatum*. This is the relative order in which the three species invade abandoned fields (Rice, et al., 1960).

Materials and Methods

The soils used in this study varied widely in physical properties and nutrients and were designated A, B and C. Soil A was a black silt, clay loam topsoil used in the Agronomy Greenhouse at the University of Illinois. Soil B was a red, sandy loam subsoil and Soil C was a light grey colored clay. Both were collected from roadside banks in Illinois. Soil B had only scattered plants growing at the site and the Soil C site was bare of vegetation. Table 1 presents soil test values and the textural analyses (Laverty, 1962; Bouyoucos, 1951). Tall fescue, Caucasian bluestem and switchgrass were grown alone and in combination of all three. The fertility treatments were none and a complete fertilizer. All combinations of these gave 24 treatments (4 x 2 x 3), replicated three times.

Table 1. Soil test values and textural analysis of the three experimental soils.

Item	Soil A	Soil B	Soil C
pH	5.8	6.9	7.9
P_2	55	27	24
P_1	25	17	4
Lbs. K Available/A.	232	216	148
% Sand	13.0	77.0	3.0
% Silt	53.0	8.0	39.5
% Clay	34.0	15.0	57.5
Textural Classification	Silty, clay loam	Sandy loam	Clay

Treatments with added nutrients received a 10-10-10 fertilizer at the rate of 800 p.p.m. which equals 80 p.p.m. of N_2, P_2O_5, and K_2O. The soil was placed in six-inch clay pots which were set in clay watering saucers. The moisture moved up through the soil by capillary action. Soils A and B became moist to the top in one to two days but Soil C remained dry in the top ½ to ¾ inches. Cellophane was then placed over each pot containing Soil C, enabling the soil to become moist to the surface. All seeds were pregerminated in order to eliminate differential emergence interference by the soils. A germinated seedling was planted in a small hole and the soil was gently pressed back around the plant. Extra seedlings were planted in each pot. Since Soil C crusted rapidly when exposed, cellophane was placed over the pots containing this soil during the middle of the first two days. In combination treatments, the seedlings were planted in a systematic arrangement to facilitate identification. After one week, the seedlings were thinned to nine plants per pot. The species grown in combination were thinned to three plants of each species per pot.

Plant heights, from the soil surface to the tip of the tallest and/or longest leaf, were taken at the end of one week and at five-day intervals thereafter until the 42nd day. On the 42nd day after planting, the top growth was harvested and oven-dried. The roots were washed free of soil and dried. Root and top dry weights in grams were taken. In the combination treatments, the tops of each species were harvested separately. No attempt was made to separate the roots according to species. Due to the presence of the combination or competition treatment, all values were placed on a per plant basis. An analysis of variance was run and the data were subjected to an orthogonal single degree of freedom analysis. All results discussed are significant at the 5% level of probability. The data from within the combination treatments were analyzed both collectively with the other treatments

[1]*The work was sponsored by the U. S. Department of Commerce, Bureau of Public Roads, and the Illinois Division of Highways.*

and separately by the single degree of freedom method.

Results and Discussion

Fertilizer increased the growth rate (plant height) about equally after 12 days, whether species were alone or in combination. Root and top weights were also increased by fertilizer (Table 2). These results were expected. Fertilizer had a much greater effect on the top weight and final height of Caucasian bluestem than on switchgrass or tall fescue. Without fertilizer, tall fescue had the greatest seedling vigor while Caucasian bluestem had the greatest response to fertilizer (Figures 1 and 2). The response of tall fescue and switchgrass to fertilization was about equal (Figure 1). Tall fescue showed greater vigor than switchgrass under all the experimental conditions. When fertilized, Caucasian bluestem showed more vigor as reflected in top weights at the end of the experiment and in height after the 22nd day.

Table 2. The effect of fertilizer on root and top growth (weight in grams per plant, oven dry, average of three soils).

Treatment	Tops	Roots
Fertilizer	.210	.074
No fertilizer	.072	.035

The species grown in combination had a greater average height and produced a greater weight of root material per plant (.069 g. vs. .048 g.). Both tall fescue and switchgrass grew taller when grown in combination than when grown alone (Figure 3). Caucasian bluestem had about the same height whether grown alone or in combination. From this there is an indication that both tall fescue and switchgrass were able to obtain nutrients not available to the other species. Caucasian bluestem, on the other hand, appeared to be able to obtain nutrients only from the same sources as tall fescue and/or switchgrass. The dry top weights indicate that tall fescue was the most vigorous species when grown in combination; that Caucasian bluestem was the most vigorous when grown alone; and switchgrass was least vigorous under all conditions (Figure 3). Height does not seem to have been a good measure of vigor in switchgrass. The final height of switchgrass was greater than that of Caucasian bluestem and almost equal to the height of tall fescue (Figure 3). However, the top weight of switchgrass was much less than that of the other species.

In the fertile soil, Soil A, the grasses grew relatively better alone than in combination. However, in Soils B and C, where the physical and/or chemical characteristics of the soils were more likely to be the limiting factor, the species grew better in combination (Table 3). This would also point to a differential ability of the species to obtain nutrients under adverse conditions.

The addition of fertilizer increased the shoot/root ratio (fertilized 2.87 vs. non-fertilized 2.45). Similarly, on the fertile soil, Soil A, the ratio was greatest (3.04 vs. 2.47). When the species were grown in combination, the ratio was reduced (2.22 vs. 2.80). Thus, in combination, the relative amount of root growth was increased. Since both top weight and height were also increased, this would tend to show that intra-species competition for nutrients was greater than inter-species competition. Caucasian bluestem produced relatively more root material (i.e., had a lower shoot/root ratio) than did switchgrass. The ratios were 2.47 and 3.09, respectively. Fertilizer had a relatively greater affect in increasing the shoot/root ratio on the poor soils than on the fertile topsoil (Table 4).

Caucasian bluestem was least vigorous at the start but during the experiment it grew faster under some conditions and overtook both of the other species when grown alone. When grown in combination, it

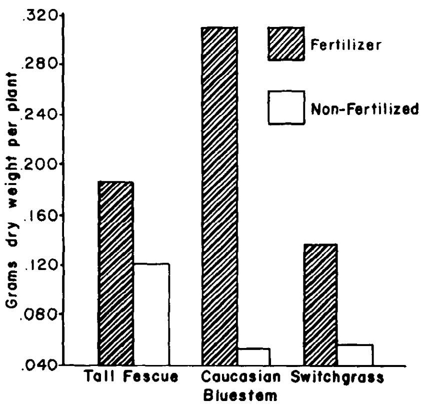

FIGURE 1. Top weights of the three species with and without fertilizer.

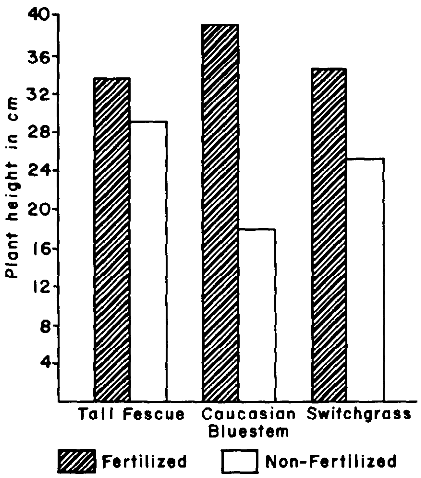

FIGURE 2. Final height as affected by additional nutrients.

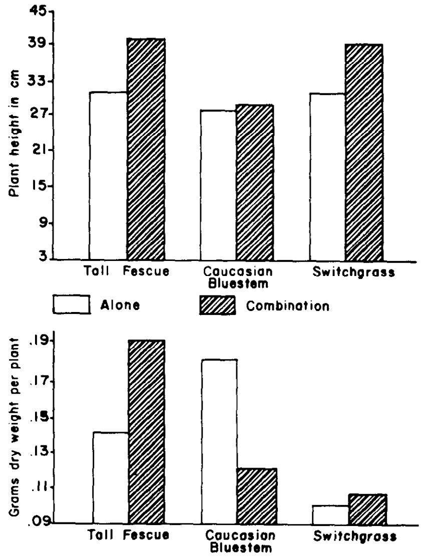

FIGURE 3. Final height and top weight of species grown alone and in combination.

Table 3. Top weight per plant of grasses grown on fertile topsoil and on infertile subsoil, alone and in combination (grams, oven dry).

Soil	Grown in combination	Grown alone
Soil A	.118	.143
Soils B and C	.157	.111

Table 4. Shoot/root ratios as affected by soil fertility and additional fertilizer.

Soil	Added Fertilizer	No Added Fertilizer
Soil A	2.93	3.16
Soil B and C	2.83	2.09

equaled or surpassed switchgrass by the end of the experiment.

The difference in ability of the species to respond to "favorable" physical and chemical characteristics of different soils as well as the differing ability of species to "overcome" unfavorable conditions is shown further in Figure 4. On the sandy loam soil, where fertility was a limiting factor, Caucasian bluestem grew more rapidly than switchgrass whether in combination or not. However, on Soil C, where either a physical or a chemical condition other than lack of N, P or K was present, switchgrass grew as well or better.

Each species exhibited differing ecological traits which can be used to help place the species in a "niche." Tall fescue had the greatest seedling vigor during the early part of the experiment and continued to be the most vigorous under fertile soil conditions, Soil A, whether added nutrients were present or not. Tall fescue thus did best on the "heavy" fertile soil which contained the most nitrogen. As shown in this experiment, there are good reasons why tall fescue is so widely used in bank stabilization and in pastures, why it invades Kentucky bluegrass (*Poa pratensis*) and other sod areas, and why stands of tall fescue tend to remain relatively pure.

Caucasian bluestem has an ability to respond to added nutrients and and to make rapid growth in the late seedling stages. These factors, and its seemingly lower intraspecies competition, would tend to make it adaptable to single species seedings. Also, its low shoot/root ratio and relatively large root development, plus rapid growth rate under high fertilization, suggest that it may be a good species to use in stabilizing areas where the soils are excessively erosive.

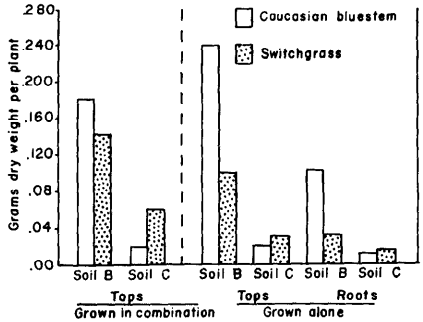

FIGURE 4. The contrasting top and root weights of Caucasian bluestem and switchgrass on Soil B, a sandy loam, and Soil C, a clay.

Switchgrass, with its ability to endure under adverse conditions and in association with other species, seems ecologically well adapted in the tall grass prairies.

Summary

Seedling vigor of three grass species on three soils of varying fertility and physical condition were compared under two fertility treatments—alone and in combination of all three.

1. Caucasian bluestem responded more to added nutrients than tall fescue and switchgrass.

2. When grown in combination, the average plant height of tall fescue and switchgrass was greater than when the two species were grown separately. The average weight of the fescue plants was greater. The increases were achieved without a reduction in the competing species, Caucasian bluestem. Thus, during the seedling period, the associated grass species produced more plant material than each grass component grown separately.

3. When nutrients were added, Caucasian bluestem had the greatest seedling vigor after the 22nd day of the experiment.

4. Tall fescue had greater vigor on unfertilized soils than did the other two species.

5. The growth of Caucasian bluestem was repressed relatively more by adverse physical and/or chemical properties of a soil (even when N, P and K were added) than was the growth of the other two species.

6. Tall fescue produced more dry matter per plant in mixtures than in pure stands.

LITERATURE CITED

BOUYOUCOS, G. J. 1951. A recalibration of the hydrometer method for making mechanical analysis of soils. Agron. Jour. 43:434-438.

CELARIER, R. P. AND J. R. HARLAN. 1955. Studies in old world bluestem. Okla. Agr. Exp. Sta. Tech. Bull. T-58.

EVANS, R. A. 1960. Differential responses of thee species of annual grassland type to plant competition and mineral nutrition. Ecol. 41:305-310.

FERGUS, E. N. 1952. Kentucky-31 fescue, culture and use. Ky. Agr. Exp. Cir. 497.

HALLOWELL, E. A., et al. 1960. Introduced grasses and legumes, pasture and range plants. Phillips Petroleum Co., Bartelsville, Okla.

HOOVER, M. N., M. A. HEIN, W. A. DAYTON AND C. O. Erlanson. 1958. The main grasses for farm and home. *In* Grass. Yearbook of Agriculture. 639-700.

LAVERTY, J. C. 1962. The Illinois method determining available phosphorus in soils. Dept. of Agron. Univ. of Illinois. AG-1861.

PLUMMER, A. P. 1943. The germination and early seedling development of twelve range grasses. Jour. Amer. Soc. Agron. 35:19-39.

RICE, E. L., W. T. PENFOUND, L. M. ROHRBAUGH. 1960. Seed dispersal and mineral nutrition in succession in abandoned fields in central Oklahoma. Ecol. 41:224-228.