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Highlight: *Seedlings of Pathfinder, Nebr. 28, and experimental ey switchgrass (*Panicum virgatum *L.) strains were grown in a growth chamber and harvested 1, 2, 3, 4, 6, 8, and 10 weeks following emergence for detection of seedling growth differences among strains. Leaf areas and dry weights of leaf blade and stem axis (stem and leaf sheath) generally increased significantly with each harvest from 4 to 10 weeks. Stem axis and leaf blade dry weights were significantly greater with Pathfinder and ey, respectively, than with Nebr. 28. Final leaf area was significantly greater with ey than with the other strains. Thus, Nebr. 28 (early-maturing) would be less competitive with weeds during establishment than Pathfinder or ey (both are late-maturing). Relative growth rate (RGR), net assimilation rate (NAR), and leaf area ratio (LAR) were similar for all strains, although at the first harvest Nebr. 28 had a lower LAR than the other two strains. RGR, NAR, and LAR generally declined with each successive harvest. The strains appeared to have the same capacity to produce above ground biomass but photosynthate partitioning differed as indicated by leaf and stem comparisons.*

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Difficulties in establishment of warm season perenı grasses present a major problem in the improvement existing pasture and range areas, or in establishing pastures land currently used for field crops in the Great Plains. Ra seedling growth of these warm-season perennial grasses essential for successful stand establishment. The developm and evaluation of strains having improved seedling grov characteristics needs urgent attention. The use of grov analysis formulae offers a quantitative way to docum rapidity of seedling growth characteristics (Cooper, 1967; Johnston et al., 1972).

The dry weight yield of a plant depends on: (a) ini capital, (b) relative growth rate, and (c) length of the grow season (Watson, 1952). The initial amount of photosynth area and seedling vigor is determined largely by the amount initial capital, which is measured as seed weight (Black, 19 Beveridge and Wilsie, 1959; and Stickler and Wassom, 196

Relative growth rate (RGR) has been reported to b useful tool in studying differences in seedling vigor (Coo 1967; Johnston et al., 1972; and Radford, 1967). RGR measure of the weight increase per unit of plant weight pres per unit of time (g/g/wk). Since it is based upon initial wei differences due to seed or seedling size are eliminated. Ot growth parameters include net assimilation rate (NAR), net increase in dry weight per unit of leaf area per unit of ti ($g/dm^2/wk$) and leaf area ratio (LAR), the ratio of leaf are total plant weight. NAR represents the apparent net photosynthesis of a plant and as such is subject to all the environmental factors which affect carbon exchange. LAR of plants may be affected by any factor which changes the proportion of photosynthetic to nonphotosynthetic tissue. Differences between plants in photosynthate partitioning into leaves and stems may account for differential growth rates (Blackman, 1919). The distribution of a large amount of assimilate into leaf tissue during early growth stages may contribute exponentially to final productivity.

Switchgrass (*Panicum virgatum* L.) is an important component of grass seedings in the eastern half of the Great Plains. Because of the difficulties encountered during establishment of warm season prairie grasses, we studied several growth parameters of three switchgrass strains to evaluate variation in seedling growth characteristics. Two commonly used varieties, Nebr. 28 and Pathfinder, and one experimental strain, ey, were used in the study. Nebr. 28 (early-maturing) was developed by selection from a collection in Holt County, Northeastern Nebraska. Pathfinder (late-maturing) is a synthetic variety developed from selected clones from southeastern Nebraska and northern Kansas. Ey (late-maturing) was derived from intercrossing four selected clones from Kansas with clones from central Nebraska.

Materials and Methods

Pathfinder, Nebr. 28, and ey switchgrasses were grown from seed in 20-cm plastic pots. Plants were grown in a growth chamber with a 15-hour photoperiod using both incandescent and fluorescent bulbs. Day temperature was maintained at 26°C and night temperature at 20°C.

Two days after emergence, plants were thinned to 15, 14, 13, 12, 10, 8, and 6 plants per pot for the 1, 2, 3, 4, 6, 8, and 10 week harvest time intervals following emergence, respectively. The experiment was a completely random design with three replications. Thus, each treatment mean includes a minimum of 18 plants.

At each harvest the number of stems and leaves per plant was recorded. Following clipping at the root stem junction area, the plants were separated into leaf blade and stem axis (stem and leaf sheaths). The length and width at mid-point were measured for calculating leaf area. Plant samples were oven dried for 48 hours at 70°C for dry weight determination. Stem and leaf material was ground to pass a 40-mesh screen in preparation for total nonstructural carbohydrate analysis.

Leaf blades of various ages and sizes from each strain were measured by an electronic leaf area machine (LI-COR Model LI-3000 portable area meter) to determine the factor needed to multiply the length X width value to obtain leaf area. That factor was 0.637, 0.604, and 0.647 for Pathfinder, Nebr. 28, and ey, respectively, with no adjustment needed for age of leaves.

Net assimilation rate (NAR), relative growth rate (RGR), and leaf area ratio (LAR) were computed as follows:

$$NAR = [(W_2 - W_1)(\log_e A_2 - \log_e A_1)] / [(A_2 - A_1)(t_2 - t_1)]$$

$$RGR = (\log_e W_2 - \log_e W_1) / (t_2 - t_1)$$

$$LAR = \frac{[(A_2 - A_1)(\log_e W_2 - \log_e W_1)]}{[(\log_e A_2 - \log_e A_1)(W_2 - W_1)]}$$

where W_1, A_1, W_2, and A_2 are dry weights and leaf areas at times 1 and 2 (Radford, 1967). Only topgrowth (plant material above the root stem junction area) was used for growth analyses because recovery of root material at the early harvests was highly variable.

Topgrowth was analyzed for total nonstructural carbohydrates (TNC) as described by Smith (1969).

Table 1. Leaf area (cm²) and cumulative leaf blade dry weight (mg) of three switchgrass strains for 10 weeks following emergence.[1]

	Leaf area/plant			Leaf blade dry wt./plant		
Week	Pathfinder	Nebr. 28	ey	Pathfinder	Nebr. 28	ey
1	0.47g	0.33g	0.46g	0.65t	0.51t	0.69t
2	1,67g	1.08g	1.61g	3.40t	2.37t	3.07t
3	3.89g	2.57g	3.78g	8.48t	5.95t	8.46t
4	6.99g	4.25g	7.22g	17.85t	11.07t	17.85t
6	26.04f	18.84fg	26.23f	75.04t	56.61t	71.95t
8	70.33d	46.48e	68.69d	254.29r	178.44s	241.61rs
10	136.69b	119.65c	169.28a	600.08p	507.49q	691.24o
Mean	35.15i	27.60j	39.61i	137.11x	108.92y	147.84x

[1] Numbers within rows and columns for each growth parameter followed by the same letter do not differ at the 5% level using Duncan's New Multiple Range test.

Table 2. Cumulative stem axis dry weight (mg) and percent leaf blade of total topgrowth of three switchgrass strains for 10 weeks following emergence.

	Wt. of stem axis/plant[1]			Percent leaf blade		
Week	Pathfinder	Nebr. 28	ey	Path-finder	Nebr. 28	ey
1	0.25d[2]	0.24d	0.34d	72	68	67
2	1.58d	0.95d	1.33d	68	71	70
3	4.13d	2.88d	4.02d	67	67	68
4	10.29d	5.27d	9.48d	63	68	65
6	49.70d	37.13d	45.13d	60	60	61
8	225.40c	152.27c	174.40c	53	54	58
10	627.33a	517.07b	590.57ab	49	50	54
Mean	131.24x	102.26y	117.90xy	51	52	56

[1] Stem axis includes stem and leaf sheath.
[2] Numbers within rows and columns followed by the same letter do not differ at the 5% level using Duncan's New Multiple Range test.

Results and Discussion

Significant variation for leaf area per plant existed among harvest and strain means with a significant interaction. As expected, leaf area increased at each successive harvest, particularly between the 8- and 10-week harvests (Table 1). Leaf area per plant of Pathfinder and ey were very similar until the 10-week harvest. Leaf area of ey increased at a faster rate between the 8- and 10-week harvests than did the other strains.

As with leaf area, leaf blade dry weights were similar for ey and Pathfinder except between the 8- and 10-week sampling periods, when ey's leaf blade dry weight increased faster than did that of Pathfinder. Thus, leaf area and leaf blade dry weights followed similar patterns, which agrees with the results of Johnston et al. (1972) for wheatgrasses.

Table 3. Number of leaves and stems per plant of three switchgrass strains for 10 weeks following emergence.[1]

	Number of leaves/plant			Number of stems/plant		
Week	Pathfinder	Nebr. 28	ey	Pathfinder	Nebr. 28	ey
1	1.9a	1.7a	1.7a	1 x	1 x	1 x
2	2.4a	2.1a	2.3a	1 x	1 x	1 x
3	3.0a	2.8a	3.0a	1 x	1 x	1 x
4	3.5a	3.0a	3.4a	1 x	1 x	1 x
6	3.9a	3.9a	3.9a	1 x	1 x	1 x
8	6.8b	5.9b	6.5b	2.3x	1.5x	2.0x
10	11.3c	12.4c	12.8c	3.2y	3.0y	3.8y

[1] Numbers within rows and columns for each growth parameter followed by the same letter do not differ at the 5% level using Duncan's New Multiple Range test.

Table 4. Growth parameters of three switchgrass strains for 10 weeks following emergence.[1]

Growth interval week	NAR[2] (g/dm^2/wk)			LAR[2] (cm^2/g)			RGR[2] (g/g/wk)		
	Pathfinder	Nebr. 28	ey	Pathfinder	Nebr. 28	ey	Pathfinder	Nebr. 28	ey
1–2	.42abc	.49a	.36abc	417a	342b	422a	1.70a	1.66a	1.46a
2–3	.30cd	.32bcd	.33bcd	323b	307bc	332b	0.96bcd	0.98bc	1.09b
3–4	.29cd	.21d	.28cd	276bcd	278bcd	282bcd	0.79bcdef	0.58ef	0.79bcdef
4–6	.34bcd	.40abc	.30cd	224def	223def	242cde	0.76bcdef	0.90bcdef	0.72cdef
6–8	.40abc	.38abc	.35abc	170fg	162fg	187efg	0.67cdef	0.62def	0.65def
8–10	.37abc	.46ab	.38abc	127g	125g	145g	0.46f	0.58ef	0.56ef
Mean	.35z	.38z	.33z	256yz	240y	268z	0.89z	0.89z	0.88z

[1] Numbers within rows and columns for each growth parameter followed by the same letter do not differ at the 5% level using Duncan's New Multiple Range test.
[2] NAR = net assimilation rate; LAR = leaf area ratio; and RGR = relative growth rate.

Stem axis dry weights increased with each successive sampling period. Pathfinder generally yielded more stem axis material than the other strains at all harvests (Table 2). As with leaf blade dry weights, Nebr. 28 consistently had lower stem axis dry weights than did the other strains. Total topgrowth was very similar for Pathfinder and ey. Thus, leaf blades comprised a higher dry weight proportion of topgrowth in ey than in Pathfinder or Nebr. 28 (Table 2).

Warnes and Newell (1969) and Warnes et al. (1971) reported that late-maturing strains of switchgrass and Indiangrass (*Sorghastrum nutans* (L.) Nash) gave superior initial stand establishment compared with short-season strains under field conditions at twelve locations in Nebraska. They reported that superior seedling vigor of the late-maturing grass strains increased their competition with weeds and thus better stands were obtained than with the early-maturing strains. Thus, with the greater leaf area of ey and greater total topgrowth of ey and Pathfinder (both are late-maturing), they would be expected to be more competitive with weeds than would Nebr. 28 (early-maturing).

There was no significant difference among strains in numbers of leaves and stems per plant at each harvest (Table 3). The strains tillered following the 6-week harvest. At the 10-week harvest all stems had approximately equal numbers of leaves. After the 10th week, seed heads emerged on Nebr. 28, and Pathfinder and ey were in the late boot stage.

No significant difference existed among strains for RGR and NAR (Table 4). Johnston et al. (1972) reported no significant differences for RGR and NAR among four wheatgrasses but did report significant differences in leaf blade and stem axis dry weights as we are reporting. Among selections of the four wheatgrasses studied by Johnston et al. (1972), plants of *Agropyron repens* (L.) Beauv. produced 100% more forage at all sampling periods than did those of *Agropyron desertorum* (L.) Gaertn., but the relative growth rates were similar. RGR has been used to detect differences in seedling vigor; however, it appears that leaf area and leaf:stem dry weight ratios should also be used for indicators of grass seedling growth differences.

RGR declined significantly throughout the sampling period for all strains. Johnston et al. (1972) reported a similar relationship in four *Agropyron* species.

The significant decline in LAR (Table 4) between the first and last sampling periods represents the increasing amount of tissue structure found in stems with time. Because of the higher leaf areas measured for ey (Table 1) and the higher stem weights for Pathfinder (Table 2), ey would be expected to have higher LAR values. Among the three strains, Nebr. 28 had lower dry matter yields with consistently lower LAR's, although these differences were not significant at all harvests.

More work is needed to establish the exact role of TNC in seedling vigor of forage grasses. Smith (1972) reported TNC values ranging from 6.3 to 17% of field-grown established forage grasses harvested at beginning of anthesis. The TNC levels of topgrowth were 1.0% or less among all treatments and there were no significant differences among treatment means.

Conclusions

Significant genetic variation existed among the three switchgrass strains for seedling leaf and stem development. Leaf development is critical for successful establishment of grasses. Ey had the greatest leaf area and leaf blade dry weight. Leaf area ratio (LAR) was greater in ey, although not significantly so at all harvests. Our data suggest that leaf area and total topgrowth are the seedling characteristics chiefly responsible for the superiority of late-maturing switchgrass strains in seedling establishment over early-maturing strains as reported by Warnes and Newell (1969) and Warnes et al. (1971).

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