Peshawar.

ECOLOGY OF *CHRYSOPOGON AUCHERI* AND *CYMBOPOGON JWARANCUSA*
II. SEEDLING DEVELOPMENT

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Summary

A description of shoot and root morphology is essential for understanding the seedling establishment process of dominant forage grasses found on arid and semiarid rangelands in

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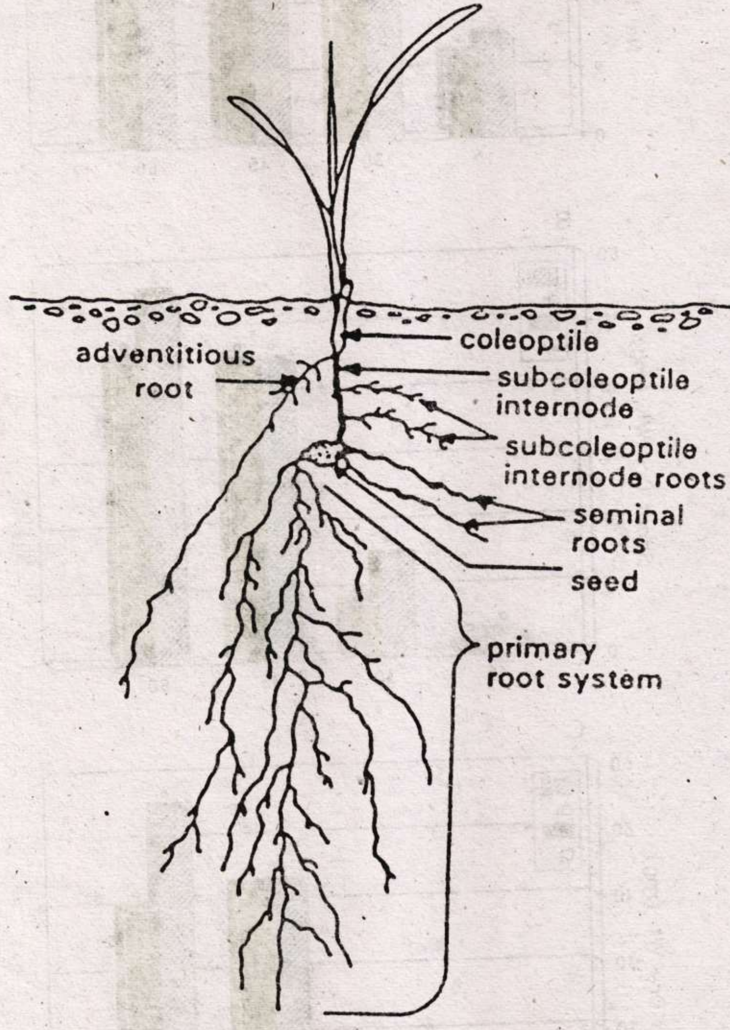
Baluchistan. A controlled environment study was conducted to determine differences in leave and tiller development and root development between seedlings of *Chrysopogon aucheri* (Boiss.) staph. and *Cymbopogon jwarancusa* (Jones) Schult. at 15, 30, 45, and 60 days after emergence. *Chrysopogon aucheri* seedlings generally had greater, but not significantly greater, tiller and leaf development and shoot biomass than *Cymbopogon jwarancusa* seedlings. *Chrysopogon aucheri* seedlings had greater total numbers, total lengths, and biomass of primary, seminal, and adventitious roots than *Cymbopogon jwarancusa* seedlings. Both species showed evidence of subcoleoptile internode elongation and subcoleoptile internode root development characteristic of "panicoid-type" seedlings. The different types of grass seedling morphology are discussed in relation to seedling establishment on arid and semiarid rangelands.

Introduction

Seedling development is a critical stage in the establishment of perennial grasses on arid and semiarid rangelands such as those in Baluchistan. Frequently, competitive advantages gained during the seedling stage are maintained in the mature plant stage (Coyne and Bradford 1985). High success in seeding establishment is often associated with rapid root and shoot growth, a robust growth habit, and resistance to environmental stress (McKell 1972). In dry regions, rapid seedling root elongation allows roots to grow along the descending moisture front in subsurface soils (Harris 1967, Buckly 19782, Simanton and Jordan 1986).

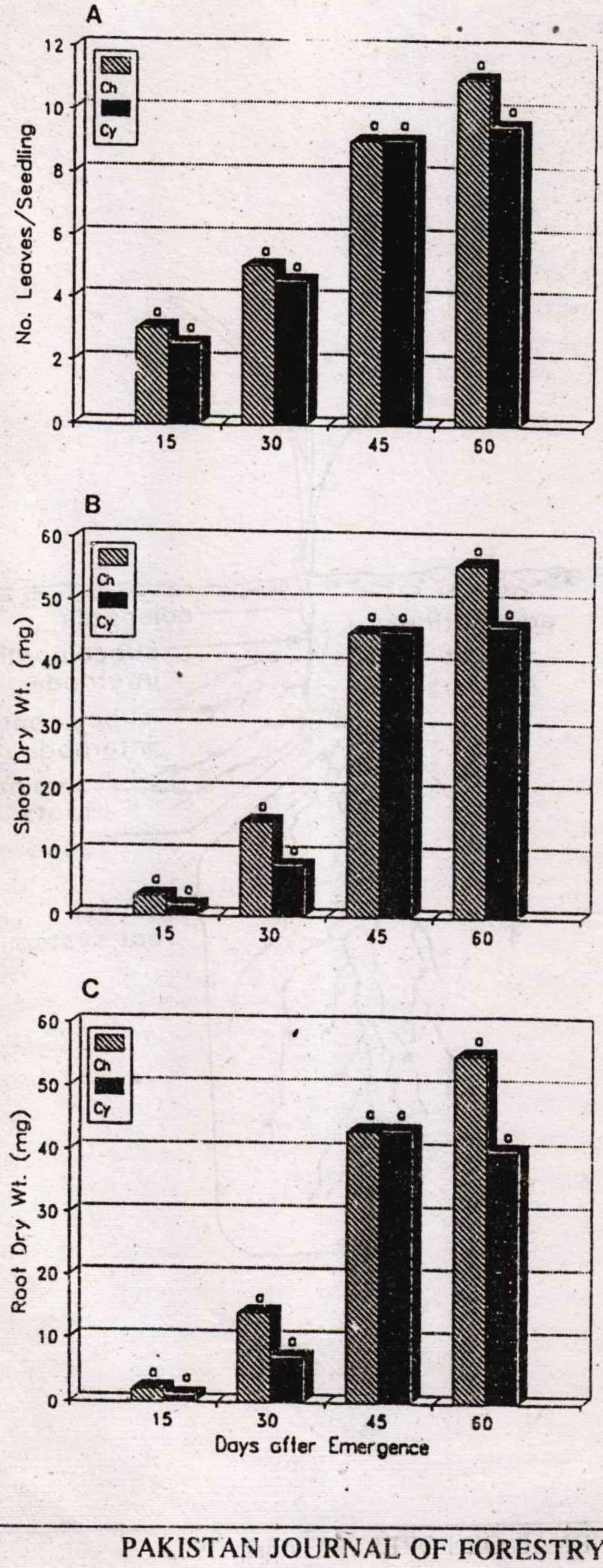
Seedling development and morphology have been used to classify grasses and to provide a basis for understanding the establishment processes in grasses. Hoshikawa (1969) classified 219 species from 88 general into six seedling types based on root morphology and observed that nearly all species of the same genus were of the same seedling type. More recently, Newman and Moser (1988) described the seedling root morphology of nine cool season and nine warm-season perennial forage grasses commonly used in the northern USA. In both studies (Hoshikawa 1969, Newman and Moser 1988), most of the warm-season grasses had an elongated subcoleoptile internode with subcoleoptile internode root development ("panicoid-type" seedling) (Fig. 1). The col season grasses had little or no subcoleoptile internode elongation and had seminal root development ("festucoid-type" seedling) (Fig. 1). Adventitious roots, which become the major root system of established plants, originate at the base of the coleoptile, which is at the depth of seeding for festucoid seedlings and is placed near the soil surface by subcoleoptile internode elongation for panicoid seedlings. Adventitious root development can be severely restricted in temperature and water stressed surface soils on arid and semiarid rangelands (Hyder et al. 1971, Wilson et al. 1976). Hoshikawa (1969) examined one *Cymbopogon* species (species unknown) and found it was a panicoidtype seedling.

Figure - 1



coleoptile
adventitious
root
subcoleoptile
internode
subcoleoptile
internode roots
seminal
roots
seed
primary
root system

Figure - 2



A
No. Leaves/Seedling
Ch
Cy
B
Shoot Dry Wt. (mg)
C
Root Dry Wt. (mg)
15
30
45
60
Days after Emergence

Information is lacking on seedling development and morphology of dominant, warm-season, forage grasses in Baluchistan. This study was designed to characterize the seedling root and shoot development of *Chrysopogon aucheri* (Boiss.) Staph. and *Cymbopogon jwarancusa* Jones) Schult. in an effort to better understand their establishment requirements.

Materials and Methods

Chrysopogon aucheri and *Cymbopogon jwarancusa* seeds, collected near Quetta, Baluchistan in summer 1987, were stored at 20°C and 40% relative humidity until May, 1989 for this experiment. Due to the low and slow germination of *Chrysopogon aucheri*, approximately 10,000 seeds were sown on two layers of paper towels in aluminum trays (16 x 33 x 2 cm) to obtain 60 germinated seeds at the same time. Ten days later, 100 seeds of *Cymbopogon jwarancusa* were sown on two layers of Whatman No.1 filter paper in Petri dishes to obtain 60 germinated seeds at the same time. Paper media in trays and dishes were saturated with distilled water when necessary, and trays and dishes were covered with polyethylene film to reduce evaporative losses and stabilize relative humidity. Trays and dishes were kept in a growth room with a night/day temperature regime of 20/25°C and a 12-h photoperiod. A light intensity of 500 μ mol. m_2 sec [1] (photosynthetically active radiation) was maintained during the daytime period. Germinated seeds (radicle approximately 2 mm in length) were transplanted (1.5 cm deep) into pots (6.5 cm diameter, 25 cm deep) filled with 80% washed sand and 20% loam soil (v/v), simulating soil conditions in the field near Quetta. The pots were placed in a growth room under the previously described environmental conditions. For the first 15 days after transplanting, pots were watered to field capacity with distilled water every third day. After this 15-days period, pots were watered to field capacity with distilled water or ¼ strength Highland solution (Highland and Arnon 1950) on an alternating basis every third day. Seedlings were thinned to one per pot after reaching the second leaf-stage 9 to 10 days after emergence.

Seedlings were destructively harvested at 15, 30, 45, and 60 days after emergence to observe root and shoot development. Seedlings from each pot were carefully washed to remove adhering soil and nearly all roots were retained. Root morphology was assessed according to the root system identification model of Newman and Moser (1988). Root measurements included: primary root number, length, and dry weight; seminal root number, length, and dry weight; and adventitious root number length, and dry weight. Roots and rootlets exceeding 2 mm in length were counted as separate roots. Root and shoot samples were dried at 60°C for 48 h to determine dry weights. Seedling shoot development was quantified by recording tiller number and leaf number every other day throughout the experiment.

The experiment was arranged in a split plot design with harvest date as the main plot and species as the sub plot. There were 10 replications (pots) for each species at each harvest date. Seedling development data were subjected to repeated measures analysis of variance, and mean comparisons were made using Fisher's least significant difference test (LSD) at the $P < 0.05$ level.

Results

Chrysopogon aucheri generally had greater, but not significantly greater tiller development, leaf development (Fig. 2A), and total shoot and root biomass (Fig. 2 B and C) than *Cymbopogon jwarancusa* over the 60-days growing period. Seedlings of both species initiated their

Figure - 3

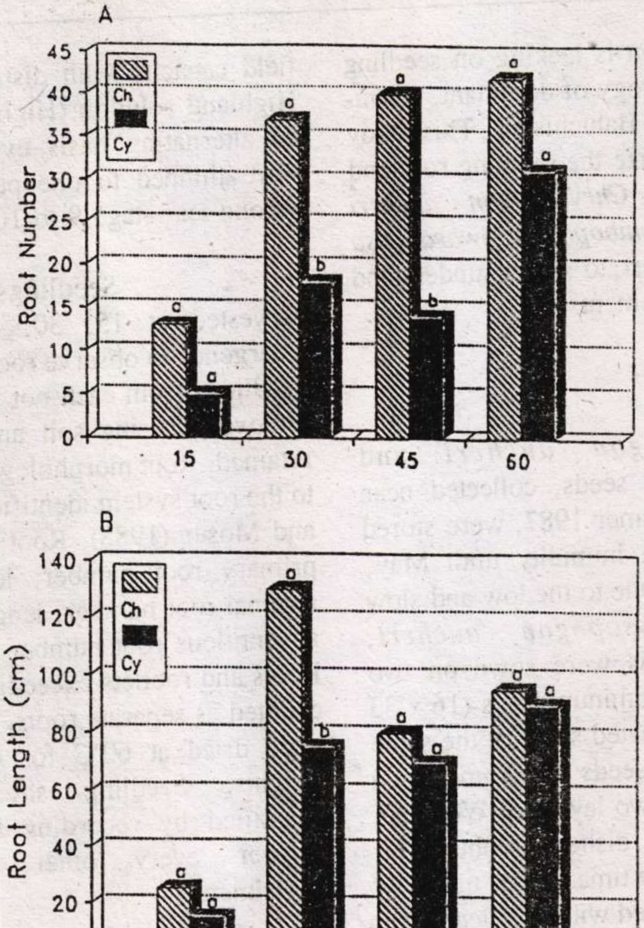
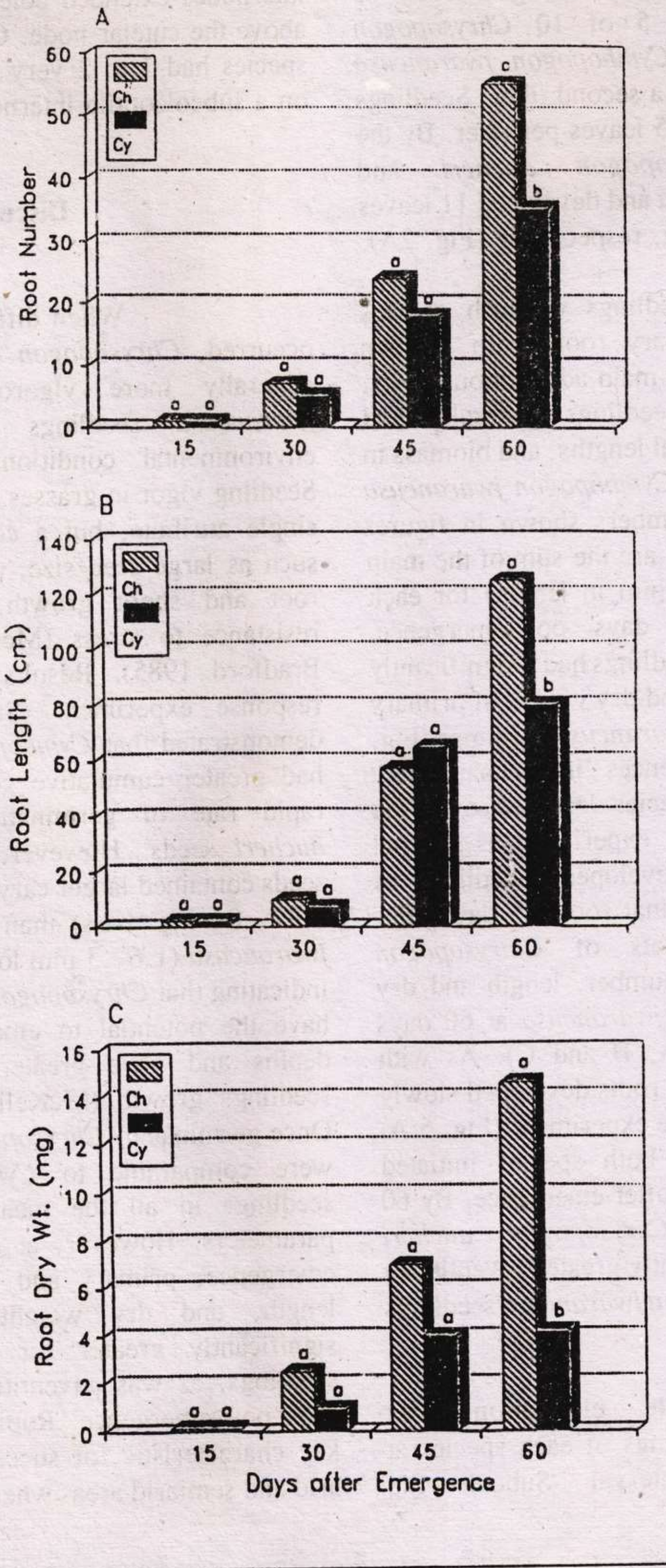

A
Ch
Cy
Root Number
45
40
35
30
25
20
15
10
5
0
a
a
a
b
a
b
a
a
15
30
45
60
B
Ch
Cy
Root Length (cm)
140
120
100
80
60
40
20
0
a
a
a
b
a
a
a
a
15
30
45
60
C
Ch
Cy
Root Dry Wt. (mg)
7
6
5
4
3
2
1
0
a
a
a
b
a
a
a
a
15
30
45
60
Days after Emergence

Figure - 4


A
Ch
Cy
Root Number
60
50
40
30
20
10
0
a
a
a
a
a
a
c
b
15
30
45
60
B
Ch
Cy
Root Length (cm)
140
120
100
80
60
40
20
0
a
a
a
a
a
a
a
b
15
30
45
60
C
Ch
Cy
Root Dry Wt. (mg)
16
14
12
10
8
6
4
2
0
a
a
a
a
a
a
a
b
15
30
45
60
Days after Emergence

first tillers by 45 days after emergence. By 60 days after emergence, 5 of 10 *Chrysopogon aucheri* and 3 of 10 *Cymbopogon jwarancusa* seedlings were initiating a second tiller. Seedlings of both species had 4 to 5 leaves per tiller. By the last harvest, *Chrysopogon aucheri* and *Clymbopogon jwarancusa* and developed 11 leaves and 9 leaves per seedling, respectively (Fig. 2A).

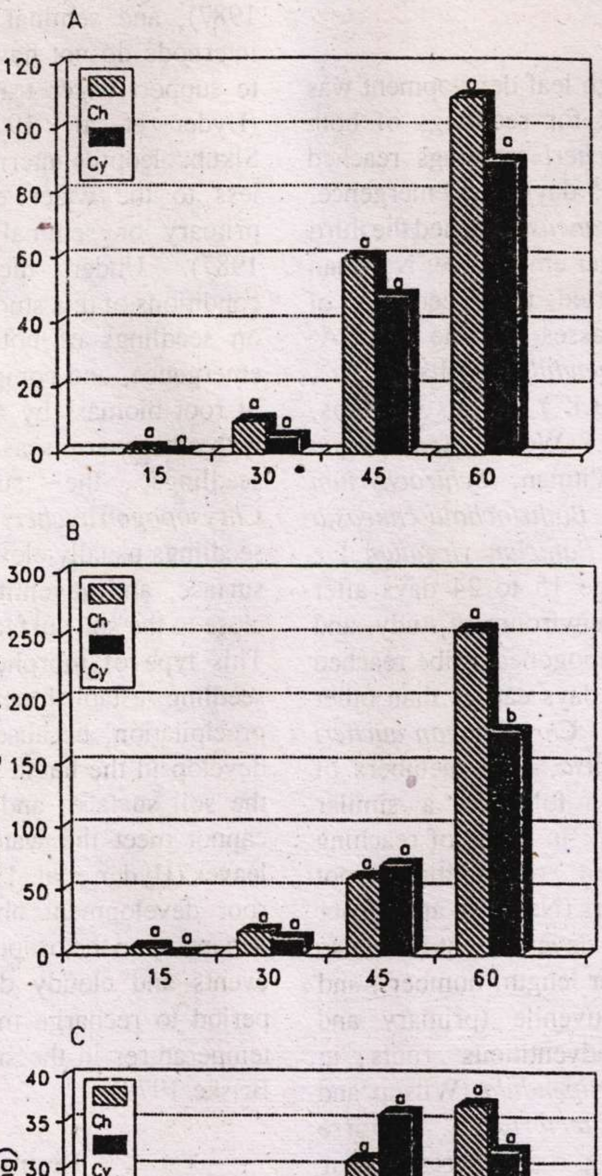
Even though seedlings of each species developed 1 main primary root, 1 to 2 main seminal roots, and 5 to 7 main adventitious roots, *Chrysopogon aucheri* seedlings generally had greater total numbers, total lengths, and biomass in each root category than *Cymbopogon jwarancusa* seedlings. Total root numbers shown in figures (Figs. 3 A, 4 A, and 5 A) are the sum of the main roots and rootlets (> 2 mm in length) for each root category. By 30 days post-emergence, *Chrysopogon aucherai* seedlings had a significantly greater number, length, and dry weight of primary roots than *Cymbopogon jwarancusa* seedlings (Fig. 3 A,B and C). Differences in primary root development between species lessened over the remaining 30 days of the experiment as seminal and adventitious roots developed. Seedlings of both species initiated seminal roots 15 days after emergence. Seminal roots of *Clhrysopogon aucheri* were greater in number, length and dry weight than *Cymbopogon jwarancusa* at 60 days post-emergence (Fig. 4 A, B and C). As with seminal roots, adventitious roots developed slowly over the first 30 days of the experiment (Fig. 5 A, B and C). Seedlings of both species initiated adventitious roots 15 days after emergence. By 60 days post-emergence, *Chrysopogon aucheri* seedlings also had significantly greater adventitious root length than *Cymbopogon jwarancusa* seedlings (Fig. 5 B).

Subcoleoptile elongation was observed on 4 of 10 seedlings of each species at the 15 days harvest interval. Subcoleoptile internodes extended coleoptile nodes 5 to 15 mm above the cutelar node. Only one seedling of each species had 1 to 2 very small (2 mm long) roots on a subcoleoptile internode.

Discussion

When differences between species occurred, *Chrysopogon aucheri* seedlings were generally more vigorous than *Cymbopogon jwarancusa* seedlings under the controlled environmental conditions of this experiment. Seedling vigor in grasses is not characterized by a single attribute, but a combination of attributes such as large seed size, rapid germination, rapid root and shoot growth, tillering ability, and resistance to stress (McKell 1972, Coyne and Bradford 1985). Results from the germination response experiment (Saleem and Call 199-) demonstrated that *Cymbopogon jwarancusa* seeds had greater cumulative germination and a more rapid rate of germination than *Chrysopogon aucheri* seeds. However, *Chrysopogon aucheri* seeds contained larger caryopses (4.5 .4 mm long, 0.97 04 mg mass) than those of *Cymboopgon jwarancusa* (1.6 .3 mm long, 0.47 .03 mg mass) indicating that *Chrysopogon aucheri* seedlings may have the potential to emerge from greater soil depths and have greater resources for initial seedlings growth (McKell 1972, Fenner 1983). Once germinated, *Chrysopogon aucheri* seedlings were comparable to *Cymbopogon jwarancusa* seedlings in all the measured shoot and root parameters. However, at 30 and 60 days sport-emergence, primary and seminal root number, length, and dry weight, respectively, were significantly greater for *Chrysopogon aucheri* seedlings, as was adventitious root length at 60 days post-emergence. Rapid root elongation is a key characteristic for successful establishment in arid and semiarid areas where surface soils can dry

Figure - 5



A
Root Number
120
100
80
60
40
20
0
Ch
Cy
a
15
30
45
60
B
Root Length (cm)
300
250
200
150
100
50
0
b
C
Root Dry Wt. (mg)
40
35
30
25
20
15
10
5
Days after Emergence

quickly after a precipitation event (McKell 1972, Plummer 1943).

Even though leaf development was not significantly different for seedlings of both species, *Chrysopogon aucheri* seedlings reached the third leaf stage about 15 days after emergence, whereas *Cymbopogon jwarancusa* reached the third leaf stage about 18 days after emergence. Newman and Moser (1988) reported that seedlings of several warm-season grasses in the USA, including *Bouteloua curtipendula* (Michx.) Torr., *B. gracilis* (Willd. ex H.B.K.) Lag. ex Griffiths, *Eragrostis tricodes* (Nutt.) Wood, *Andropogon gerardii* var. *Gerardii* Vitman, *Schizachyrium scoparium* (Michx.) Nash, *Bothriochola caucasia* (Trin.) C.E. Hubb., and *Panicum virgatum* L., reached the third leaf stage 15 to 24 days after emergence in a controlled environment study, and that members of the Andropogoneae tribe reached the third leaf stage 3 to 8 days earlier than other warm-season grass species. *Chrysopogon aucheri* and *Cymbopogon jwarancusa*, both members of the Andropogoneae tribe, followed a similar pattern of leaf development, in terms of reaching the third leaf stage when adventitious root development typically occurs (Newman and Moser 1988). Rapid leaf and tiller development have also been associated with greater length, number,. and order of branching of juvenile (primary and secondary roots) and adventitious roots in seedlings of *Bouteloua curtipendula* (Wilson and Briske 1979) and *Bromus tectorum* L. (Aguirre 1989). The sooner seedling roots increase their depth and volume of soil penetration, the greater is the probability of successful establishment in arid and semiarid regions as moisture becomes limiting in upper soil layers (Plummer 1943, Cook 1980, Buckly 1982, Aguirre 1989).

Successful establishment of grass seedlings requires the formation of adventitious roots. The primary root, under normal conditions, is a short-lived structure (Tischler and Voigt 1987), and seminal roots and the subcoleoptile internode do not have sufficient xylem diameters to support water transport to maturing seedlings (Hyder et al. 1971, Wilson et al. 1976). Sikubcoleoptile internode roots probably contribute less to the water economy of the shoot than primary or seminal roots (Tischler and Voigt 1987). Under the favorable environmental conditions of this study, adventitious roots initiated on seedlings of both species by 15 days after emergence, and comprised the greatest proportion of root biomass by 45 days after emergence. As with other warm season grasses with panicoid-type seedlings, the subcoleoptile internode of *Chrysopogon aucheri* and *Cymbopogon jwarancusa* seedlings usually elevates the coleoptile to the soil surface, and adventitious roots typically develop close to the soil surface (Tischler and Voigt 1987). This type of morphology can be detrimental to seedling establishment in regions with limited precipitation, because adventitious roots may not develop in the harsh environment associated with the soil surface, and primary and seminal roots cannot meet the water requirements of seedling leaves (Hyder et al. 1971). Successful adventitious root development and plant establishment may depend upon the proper sequencing of precipitation events and cloudy days during the recruitment period to recharge moisture and ameliorate high temperatures in the surface soil layer (Silson and Briske 1979).

Results from this controlled environment study may vary considerably from results obtained under field conditions. Temperature, moisture, and nutrient conditions were considerably more favorable in the laboratory than in the field near Quetta, and most importantly, seedlings of the more palatable *Chrysopogon auchseri* were not subjected to defoliation. Seedlings of both species have been observed at protected sites near Quetta and other regions of Baluchistan (Saleem, personal observation). *Cymbopogon jwarancusa* may have a greater potential for germination than *Chrysopogon aucheri*, but once germination has occurred the fewer *Chrysopogon aucheri* seedlings may have equal or greater vigor and establishment success on areas protected from grazing.

ACKNOWLEDGEMENTS

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FIGURE CAPTIONS

Figure 1. Grass seedling root morphology (from Newman and Moser 1988).

Figure 2. Mean number of leaves per seedling (A), mean seedling shoot dry weight (B), and mean seedling root dry weight (C) of *Chrysopogon aucheri* (Ch) and *Cymbopogon jwarancusa* (Cy) in relation to time (days) after emergence. Values for species at each time interval with different letters are significantly different ($LSD_{.05}$).

Figure 3. Mean primary root number (main root and rootlets >2mm) (A), root length (B), and root dry weight (C) of *Chrysopogon aucheri* (CH) and *Cymbopogon jwarancusa* (Cy) seedlings in relation to time (days) after emergence. Values for species at each time interval with different letters are significantly different ($LSD_{.05}$).

Figure 4. Mean seminal root number (main root and rootlets >2mm) (A), root length (B), and root dry weight (C) of *Chrysopogon aucheri* (Ch) and *Cymbopogon jwarancusa* (Cy) seedlings in relation to time (days) after emergence. Values for species at each time interval with different letters are significantly different ($LSD_{.05}$).

Figure 5. Mean adventitious root number (main root and rootlets >2mm) (A), root length (B), and root dry weight (C) of *Chrysopogon aucheri* (Ch) and *Cymbopogon jwarancusa* (Cy) seedlings in relation to time (days) after emergence. Values for species at each time interval with different letters are significantly different ($LSD_{.05}$).