Effect of Weedy Annuals on the Survival and Growth of Transplants Under Arid Conditions

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Abstract

A plant establishment study was conducted in the oil shale region of northeastern Utah where annual rainfall averages 200 mm. Treatments consisted of annual weed removal for 2 years, for 1 year, and no removal to test the impact of competition on survival of bare-root and container-grown transplants. Competition had a major negative effect on the survival and growth of fourwing saltbush (*Atriplex canescens*), winterfat (*Ceratoides lanata*), prostrate summer cypress (*Kochia prostrata*), and Russian wildrye (*Elymus junceus*). At the end of 4 growing seasons only 21% of the plants survived under normal site competition compared to 84% survival with 2 years of weed removal. The area of plant canopy under the influence of full competition averaged 0.95 dm² as compared with 4.03 dm² where competition was absent for 2 years for the same period.

Plant competition for soil water generally is extreme in arid regions. A dense stand of annual vegetation such as cheatgrass (*Bromus tectorum*), halogeton (*Halogeton glomeratus*) or Russian thistle (*Salsola pestifer*) may compete so intensely with seeded or transplanted species as to inhibit their establishment or reduce their vigor sufficiently to limit survival and growth. Whenever surface disturbance occurs, the invasion of annual species is especially acute. Thus, any manipulation of the vegetation or soil surface that increases water accumulation and retention for beneficial use by specific desirable plants would be advantageous.

Numerous researchers studying plant establishment under the constraints of stress environments have alluded to the need for controlling plant competition. Several of these are Holmgren (1956), Hubbard (1957), and Sanderson et al. (1963) in the establishment and growth of bitterbrush (*Purshia tridentata*), Guinta et al. (1975), Van Epps and McKell (1977), and staff of the Institute for Land Rehabilitation (1979) in establishing several shrub species, and Schubert (1977) in ponderosa pine (*Pinus ponderosa*) regeneration. Springfield (1970) found that grass competition adversely affected the survival of fourwing saltbush (*Atriplex canescens*) transplants in New Mexico. Studies in California (Clary 1974) indicated the need for controlling competition for 2 or more years.

In direct seeding, Plummer et al. (1968) specified that competition must be low enough for desired species to become firmly established. Several methods of removing unwanted vegetation were described. Keller (1978) emphasized the importance of reducing the annual grasses and forbs for successful range seeding in the sagebrush ecosystem. Evans and Young (1977) developed a herbicide revegetation system that provides management techniques to control competition in sagebrush (*Artemisia*) cheatgrass range-

lands. Whereas many revegetation studies have been carried out in areas receiving more than 30 cm of precipitation, this paper considers the effect of plant competition on the survival and growth of transplants in an area receiving less than 23 cm of precipitation.

Methods

The study was conducted in the oil shale region of northeastern Utah in an area of less than 225 mm of rainfall. Natural vegetation surrounding the research site is dominated by shadescale (*Atriplex confertifolia*) with sagebrush (*Artemisia tridentata* spp. *wyomingensis*) and greasewood (*Sarcobatus vermiculatus*) appearing in areas of deeper soils.

The study site was on a deep alluvial sandy loam fill which extended to a depth greater than 120 cm. A soil survey in 1977 described the soil as a loamy-skeletal, mixed, frigid, calciorthid, aridisol.

All planting stock was grown originally in containers in the greenhouse to provide uniformity among plants. The containers measured 6 × 6 × 15 cm. Plants were grown in a mixture of soil, sand, and peat moss of equal volume for approximately 7 months prior to field planting. At the time of planting they were divided into those to be planted as container stock and those designated as bare root transplants. The latter were removed from the container and the soil was shaken from the roots. Thus planting materials were similar in genetic and developmental aspects. However, this method of obtaining bare root plants yielded transplants with a greater fibrous root mass than those generally grown as typical bare-root stock.

The planting site was partially prepared during late summer of 1976 after seeds had been shed, by removing all annual and perennial plant growth, leaving the site in a fallowed condition for winter moisture accumulation. The entire site was weeded for annual seedlings by manual cultivation in the following spring leaving a uniform loose shallow soil mulch. Prior to planting on April 5, 1977, the site was fenced for rabbit and rodent control. The soil was moist from a wet snow storm 2 days earlier. Three competition treatments were established on 3 × 5.5-m plots: (1) a control where all indigenous seedlings were allowed to grow naturally following the planting; (2) 1 year of clean cultivation; and (3) 2 years of clean cultivation.

The 4 transplanted species were fourwing saltbush, (*Atriplex canescens*, ATCA), winterfat (*Ceratoides lanata*, CELA), prostrate summer cypress (*Kochia prostrata*, KOPR), and Russian wildrye (*Elymus junceus* ELJU). Four plants of each species were planted as bare-root and 4 as container-grown plants on a 70 × 70-cm grid in each of the 3 competition treatments. There were 4 replications. All plants received only 1 liter of water following planting though results from other studies in the area have been inconclusive as to its value. By May 19, the planting site was rather uniformly covered with a dense seedling growth of halogeton, Russian thistle and limited numbers of cheatgrass plants. All weed seedlings in the 1 and 2-year clean cultivation treatments were

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manually hoed or pulled at this time from around and between the transplants leaving a loose soil surface mulch. Both treatments were kept free of other plant growth for the remainder of the 1977 growing season and then in 1978 only the 2-year clean cultivation plots were maintained free from other plant competition. Yearly precipitation averaged 230 mm over the 3 years of the study.

Survival, plant condition, plant height, and cover data were obtained in the fall of each year. Plant condition was determined by visual examination, using a 3-numeral scale—0 for dead plants, 1 indicating that a plant was in poor condition, and a 2 indicating a vigorous, healthy plant. Plant height was measured from ground level to tip of the highest vegetative stem. Crown cover was estimated using a .25-m frame with 10-cm squares marked off in units.

Data were statistically analyzed at the end of the second year using the Duncan multiple range test at the 1% level. However, to follow the trends in survival and growth beyond the planned duration of the study, observations were made for 2 additional years.

Results

Effects of the 3 competition levels on survival were significant ($P<0.01$) among treatments averaged over all species. At the end of the second growing season, corresponding to the end of the treatment years, average survival of all species regardless of the type of plant material used was 47% for the control, 72% for 1 year of clean cultivation, and 91% for 2 years of clean cultivation. Two years later at the end of the fourth growing season, survival in the same treatment order was 21, 55, and 84%. Two years of clean cultivation were 4 times more effective for plant survival than when plants were exposed to natural competition.

A comparison of planting materials in relation to survival indicated significance ($P<0.01$). After 2 years bare-root stock showed a 64% survival, compared with 76% for the container stock. Two years later the survival was 49 and 57%, respectively.

The trend in transplant survival over 4 growing seasons in relation to the 3 competition levels and 2 types of plant materials appeared to become stable after 3 years (Fig. 1). Plant survival rapidly decreased when the annual plants in the 1-year clean cultivation treatment were allowed to compete for moisture during the second and third growing seasons, which indicated that these plants had not become fully established during the first few years following field planting. Plant mortality was highest for plants growing under natural competition, although the greatest losses occurred during the first growing season, especially those planted as bare-root stock. Relatively few plants died during the fourth growing season under 2 years of clean cultivation. By this time plants in the other 2 levels of competition appeared to have already reached an adjustment to the moisture stress environment.

Fig. 1. Percent survival trend comparing three competition levels and 2 methods of planting (BB = bare-root and CO = container transplants) over 4 growing seasons. Competition removal treatments, reading from left to right were; control 1 year removal, 2 years removal.

Fig. 2. Percent survival comparison of four plant species under 3 competition levels following 2 growing seasons. Competition removal treatments, reading from left to right were control, 1 year removal, 2 years removal.

Plant losses during the first few years of establishment must be expected as a normal consequence whether from artificial planting of transplants or from natural establishment especially where competition is a factor. Data from the Desert Experimental Range (West 1979) showed a large loss of natural seedlings during the first 2 years followed by a subsequent leveling off in plant mortality.

Survival of bare-root and container-grown plants was statistically different under natural competition and 1 year of clean cultivation. Container stock showed a higher survival rate in the fall for each of the 4 growing seasons (Fig. 1). The difference in survival between planting methods was less for 2 years of clean cultivation than for the other 2 levels of competition. Container-grown stock showed a survival rate of 25% under natural competition, 64% under 1-year competition removal, and 85% for 2 years of clean cultivation at the end of 4 growing seasons. In contrast, bare-root stock survival was 17% under natural competition, 45% under 1 year of clean cultivation, and 83% under 2 years of clean cultivation.

Survival of the various species in relation to the competition removal treatments at the close of the second growing season varied significantly ($P<0.01$) (Table 1 and Fig. 2). Prostrate summer cypress appeared to be more capable of withstanding the detrimental effects of plant competition during the first 2 years of establishment than the other 3 species. Russian wildrye was the least capable. Annual plant competition had a negative effect on the survival of fourwing saltbush when not controlled for at least 1 year (Fig. 3). Two years of competition suppression appeared to increase the survival of winterfat and russian wildrye grass greatly.

Fig. 3. Effect of 3 competition levels on percent plant survival between species over 4 growing seasons. Competition removal treatments, reading from left to right were; control 1 year removal, 2 years removal.

Table 1. Summary of fall data comparing treatments and species during the 4 years of the study. Means followed with the same letter are not significantly different at $P < 0.01$ value for each variable and within each factor.

Species ¹	Year	Survival treatments			Height treatments			Ground covered by plant canopy ² treatments		
		Control (%)	1 year (%)	2 year (%)	Control (cm)	1 year (cm)	2 year (cm)	Control (dm ²)	1 year (dm ²)	2 year (dm ²)
ATCA	1977	72	91	94	6	22	22	—	—	—
	1978	22e	81bcd	91ab	2fg	27bc	38ab	.07f	4.50bc	8.56
	1979	7	78	91	2	35	44	.06	4.70	8.42
	1980	7	78	91	2	31	36	.08	4.41	6.33
CELA	1977	94	87	97	13	17	18	—	—	—
	1978	72d	69d	94ab	11ef	17de	35abc	.37ef	1.73def	3.50cde
	1979	9	31	85	3	9	34	.19	.59	3.94
	1980	9	29	79	2	7	24	.05	.45	2.63
KOPR	1977	100	100	100	23	39	39	—	—	—
	1978	88abcd	91abc	100a	24cd	25cd	44a	1.50ef	4.39cd	13.26a
	1979	63	75	100	33	35	48	5.78	7.77	13.78
	1980	63	75	87	19	20	22	3.53	4.61	4.63
ELJU	1977	28	85	94	< 1	8	6	—	—	—
	1978	7f	47ef	81cd	< 1g	< 1g	10g	.01f	.01f	.15f
	1979	7	37	81	< 1	4	16	.05	.30	2.17
	1980	7	37	81	1	7	15	.13	.82	2.54

¹ATCA - Fourwing saltbush

CELA - Winterfat

KOPR - Prostrate summer cypress

ELJU - Russian wildrye grass

²No calculations were made on plant cover for 1977

On a scale of 0 to 2, uncontrolled competition resulted in an average plant condition rating of 0.55; 1 year of clean cultivation, 0.95; and 2 years of clean cultivation, 1.73. Two years later in the fall of 1980 plant vigor was 0.42, 1.05 and 1.67 respectively. There was no difference in plant condition rating between types of plant materials. Plant condition is a good indicator measurement as to the effect of the treatments on a plant's vitality and growth including its reproduction.

The interaction of competition treatments and species on plant condition was highly significant ($P < 0.01$). A significant ($P < 0.01$) difference was observed between the effects of 2 years of clean cultivation and the 2 competition levels at the end of the second growing season. Although not significant there was a generally observed difference in plant condition between plants grown in the control treatment and those in the 1-year clean cultivation. The average plant conditions of the 3 shrubs was uniformly good but the grass plants were poor in comparison. There was no significant difference in average plant condition of bare root and container grown plants.

Plant growth expressed as ground cover was highly significant ($P < 0.01$) in the categories of competition treatments, planting materials and the interaction between treatments and species. The total area of ground cover by planted species canopy where no competition was removed averaged 0.49 dm² at the end of the first 2 growing seasons. This compares with 2.66 dm² for 1 year of clean cultivation and 6.37 dm² for 2 years of clean cultivation. Plant cover of the 4 species showed various restrictions in relation to the 3 levels of plant condition (Table 1).

Fourwing saltbush, winterfat, and prostrate summer cypress transplants had a significantly larger cover area when grown for 2 years without competition than those under uncontrolled competition. The difference in size of plants in 1978 where subjected to the 2 competition treatments was many-fold. Russian wildrye, being a grass that goes dormant under these arid conditions, appears smaller in the fall than in the spring. Russian wildrye produced numerous seed heads in the spring when grown for 2 years without competition as compared with few seed heads under uncontrolled competition.

In the case of plant height there was a significant interaction ($P < 0.01$). At the end of the second growing season, the mean

height for plants in the control treatment was 10 cm, those in the 1-year clean cultivation treatment were 18 cm, and those in the 2 years of clean cultivation treatment were 32 cm. This compared with a height of 6, 16, and 24 cm for each treatment, respectively, at the end of the fourth growing season. Two years of clean cultivation resulted in an increase in plant height 4 times over the control after 4 years. Plant height was significantly ($P > 0.05$) greater from container-grown stock at 22 cm as compared with bareroot stock at 19 cm (Table 1).

Conclusions

Intense plant competition from weedy annual species has a negative influence on the survival and growth of perennial plant species transplanted either as bare-root or container-grown stock. Plant species most likely to survive are those which can endure competition from annual plants such as prostrate summer cypress. The effects of competition reduction are generally reflected in greater plant height and cover. Plant species most likely to withstand competition are those best adapted to a site. Species poorly adapted to a site apparently are not able to respond to the improved control of competition. These studies have substantiated the early work of Holmgren (1956), Hubbard (1957) and others as to the need for controlling competition when establishing vegetation through seeding or by transplants. Improved plant establishment in arid sites appears to be possible by controlling competition of annual weedy forbs and grasses for a period of 1 or 2 years.

Three or more growing seasons may be needed to determine the permanent establishment of plants under arid conditions. Plants under uncontrolled competition appear to stabilize their survival rate by the end of the third year. Springfield (1970) reported that fourwing saltbush transplants in the Southwest under no competition stabilized in survival during the fourth year following field planting, while the survival rate of those growing in competition with grass was still declining in the fifth year.

There are large variations among species as to the negative impact of plant competition on plant survival and growth. Prostrate summer cypress was noticeably more successful in its establishment success than fourwing saltbush, winterfat or Russian wildrye.

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