WINTER SURVIVAL AND PHYSIOLOGY OF CONTRASTING FALL DORMANCY SELECTIONS OF ALFALFA

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ABSTRACT

Our objective was to determine the physiological changes that accompany selection from within a germplasm for contrasting fall dormancy reaction. Selection for greater fall dormancy improved winter survival of CUF 101 from 1 to 93%. The more fall dormant CUF 101 had higher sugar concentrations in buds and roots. Roots of the more fall dormant CUF 101 also contained higher soluble protein concentrations when compared to the other CUF 101 germplasms. Root protein extracts obtained in Dec. from the more fall dormant CUF 101 contained at least one polypeptide not found in protein extracts of the other CUF 101 germplasms. Efforts to characterize changes in gene expression that accompany winter hardening of these germplasms are underway.

KEYWORDS

Sugar, starch, protein, electrophoresis, lucerne, winter hardiness, stress tolerance

INTRODUCTION

It is widely observed that alfalfas with reduced vegetative growth in fall are more winter hardy than cultivars that continue shoot growth late into fall. Nondormant cultivars are distinguished from dormant cultivars by their erect shoot growth in fall. In contrast, dormant cultivars produce short shoots in fall that grow prostrate along the soil surface. Our keen interest in nondormant alfalfas is based on our observation that they exhibit extremely rapid shoot regrowth after defoliation (Volenec, 1985). The major limitations preventing widespread use of nondormant alfalfa in temperate regions are lack of freezing tolerance and poor winter hardiness (Stout, 1985; Stout and Hall, 1989). Our understanding of the biological mechanisms underlying fall dormancy is virtually nonexistent. Our objective was to determine the physiological changes that accompany selection from within a germplasm for contrasting fall dormancy reaction.

MATERIALS AND METHODS

Plant Culture and Sampling. Three cycles of selection for enhanced ("L") or decreased ("H") fall dormancy reaction using several cultivars as source populations were completed in Davis, CA. Seedlings were established in May at the Agronomy Research Center, Purdue University, West Lafayette, IN. Beginning in Sept. roots and crowns were dug to a depth of approximately 25 cm, packed with ice and transported to the laboratory where they were washed free of soil under a stream of cold water. Crowns were severed from roots and white crown buds removed. Roots were divided into the uppermost 2.5 cm ("root tops") and the remainder of the root system. Root tissues were frozen on solid CO_2, and lyophilized. Tissues were ground to pass a 1-mm screen, and analyzed for sugar, starch, and soluble protein concentrations.

RESULTS AND DISCUSSION

Response to Selection for Contrasting Fall Dormancy. Three cycles of selection for contrasting fall dormancy reaction altered fall height of some, but not all alfalfa germplasms. Selection for less fall dormancy increased height of Norseman from 19 to 35 cm, whereas selection for more fall dormancy in the already very fall dormant Norseman reduced shoot height in fall only slightly (to 14 cm). Lahontan responded to selection for greater fall dormancy by reducing height from 38 cm in the original cultivar to 28 cm in the more fall dormant Lahontan. Fall height of the less fall dormant Lahontan was similar to the original cultivar (40 cm). In CUF 101, selection for greater fall dormancy reduced height from 50 to 36 cm in CUF-L, while selection for less fall dormancy had no effect (CUF-H, 50 cm). Wadi Qurayat, the least fall dormant germplasm in the study did not respond to selection with heights averaging 53, 49 and 54 cm for the original cultivar, the more fall dormant, and the less fall dormant selections, respectively.

Winter Survival. As anticipated, fall dormancy reaction was associated with winter survival. Norseman and selections from it survived winter well (93% survival or greater), whereas Wadi Qurayat and its selections were completely winter killed ($\leq$ 1% survival). Lahontan survival ranged from 76 to 86%. CUF 101 (CUF-O) and the less fall dormant CUF-H essentially winter killed ($\leq$ 7% survival). In contrast, selection for greater fall dormancy resulted in excellent winter survival (93%) of CUF-L in both years of the study. Sheaffer et al. (1992) reported that fall growth influenced winter hardiness of alfalfa more than any other feature they studied. Nondormant alfalfa cultivars died over winter irrespective of cutting management or location, while the most fall dormant cultivar had the best winter survival regardless of cutting schedule and location. Because of the close association between fall growth and winter hardiness, these authors recommended using fall growth as a predictor of winter hardiness in alfalfa improvement programs.

The relationship between fall height and winter survival is illustrated in Fig. 1. Averaged over both years shoot heights of 40 cm or less resulted in good winter survival in the seeding year for these germplasms at this location. Survival was reduced markedly, however, as plant heights approached 50 cm. We focused our biochemical analyses on CUF 101 and its selections because of the significant improvement in survival that accompanied selection for greater fall dormancy in CUF-L.

Hardening-Induced Changes in Composition of CUF 101 Tissues. Selection for contrasting fall dormancy reaction did not alter root starch concentrations which averaged 403, 378, and 392 mg/g for CUF-O, CUF-L, and CUF-H, respectively. Although sugar concentrations were similar in Sept., CUF-L accumulated higher sugar concentrations in white crown buds (data not shown) and roots (Fig. 2) by Dec. when compared to CUF-O and CUF-H. Castonguay et al. (1995) reported that crowns of cold-tolerant, fall dormant 'Apica' and 'Rambler' alfalfas accumulated more sugar, especially stachyose and raffinose, than CUF 101.

Protein concentrations also increased in roots of CUF-L during winter hardening (Fig. 3). Accumulation of root protein, and in particular, vegetative storage proteins (VSP), during winter hardening of alfalfa has previously been reported (Volenec *et al.*, 1991; Hendershot and Volenec, 1993; Li *et al.*, 1996). All three CUF germplasms accumulated VSPs to approximately equal levels, whereas CUF-L accumulated a 23 kDa polypeptide in Dec. not observed in roots of CUF-O or CUF-H (data not shown). The nature of this polypeptide remains to be determined, but its association with the greater winter hardiness of CUF-L is noteworthy.

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Figure 1

The relationship between fall height and winter survival. Data were averaged over two winters at West Lafayette, IN, USA. The cultivar CUF 101 (CUF-O) and populations selected for greater (CUF-L) and less (CUF-H) fall dormancy are identified.

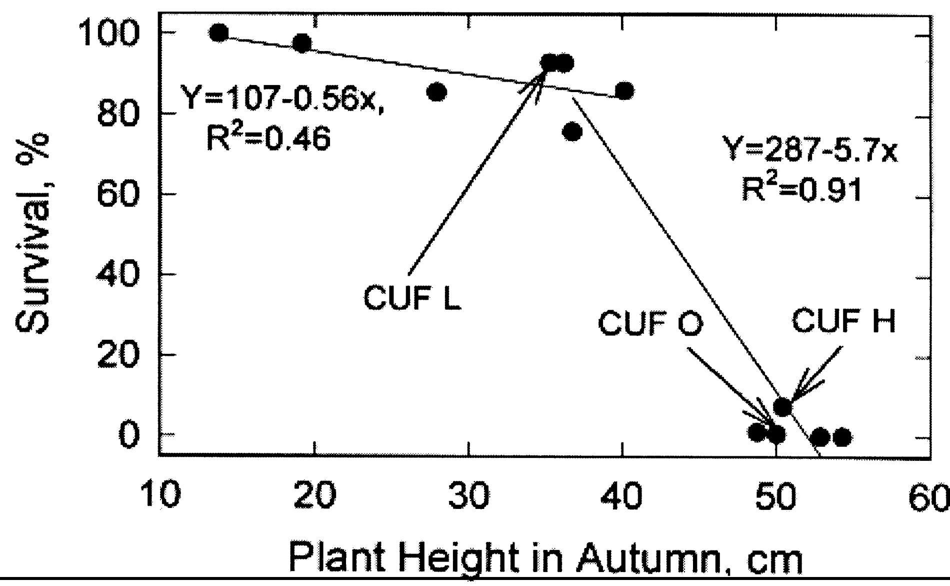

Figure 2

Hardening-induced changes in soluble sugar and protein concentrations in roots of CUF 101 (CUF-O) alfalfa and populations selected for greater (CUF-L) or less (CUF-H) fall dormancy. Data are averages over two winters at West Lafayette, IN, USA. The standard error of the mean is shown where larger than the symbol.