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Dehydration tolerance and drought survival of summer dormant Moroccan ecotypes of cocksfoot (*Dactylis glomerata* L.)

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Abstract. Summer dormancy in perennial grasses is a major trait conferring plant survival and persistence in Mediterranean areas. The aim of the present study was to characterize the effect of summer dormancy on dehydration tolerance in six Moroccan ecotypes and two cultivars "Kasbah" and "Porto" of *Dactylis glomerata* in a glasshouse experiment. Measurements included the ratio of green/senescent aerial tissues, soil water evolution, water content in survival organs and plant survival rate. D8 and D9 ecotypes showed high senescence when soil moisture was 5%, while Kasbah (dormant cultivar) was at 52% of areal senescence. Proportion of senescent tissue reached 98% for all ecotypes at soil humidity of 1.9%. Under severe drought, water content of apices decreased to reach 0.31 g H_20 g^{-1} dry weight, which was a lethal value for four tested ecotypes and cv. Porto. Except for Kasbah, D1 and D6, which remained alive with little hydrated apices. The soil moisture associated with 50% of plant mortality was 2.5% for Porto and D8 but decreased to 1.9% for D14. Kasbah, D1 and D6 could survive until 1% soil moisture. These results are ascribed to efficient strategies of both dehydration avoidance and tolerance in the best surviving genotypes.

Keywords. Cocksfoot – Drought tolerance – Dehydration – Summer dormancy.

Tolérance à la déshydratation et survie à la sécheresse d'écotypes marocains de dactyle* (Dactylis glomerata *L.) à dormance estivale

Résumé. *La dormance estivale chez les graminées pérennes est un trait majeur conférant la survie et la persistance dans les régions méditerranéennes. Le but de ce travail est de caractériser la dormance et la tolérance à la déshydratation de six écotypes marocains et de deux cultivars de* Dactylis glomerata *en conditions contrôlées. La progression de la sénescence foliaire, de la teneur en du sol, l'hydratation des organes de survie et le taux de survie des plantes ont été mesurés. La sénescence a atteint 98 % pour l'ensemble des écotypes à l'humidité de sol de 1,9 %. Sous sécheresse extrême, le contenu d'eau des apex a diminué drastiquement jusqu'à 0,31 g H_20 g^{-1} MS considérée comme létale pour quatre écotypes et Porto, à l'exception de Kasbah, D1 et D6, qui ont maintenu une survie avec des apex faiblement hydratés. L'humidité de sol associée à 50 % de mortalité est 2,5 % pour Porto et D8, mais seulement de 1,9 % pour D14 alors que Kasbah, D1 et D6 ont survécu jusqu'1% d'humidité du sol. Ces résultats sont attribués à une efficace combinaison d'évitement et de tolérance à la déshydratation chez les écotypes les plus résistants.*

Mots-clés. *Dactyle – Tolérance à la sécheresse – Déshydratation – Dormance estivale.*

I – Introduction

For forage plants growing in areas subject to prolonged and severe summer drought, the most important agronomic character is not the ability to produce during drought but the ability to survive, recover in autumn and grow actively during the rainy seasons (Volaire *et al*., 1998b). Different adaptations have evolved among the grasses of the Mediterranean region ensuring their

survival during the arid summer. One important trait associated with remarkable persistence in perennials under arid conditions is summer dormancy, which causes a reduction in the surface area of the plant thus conserving moisture but at the same time retains sufficient living tissue for regrowth in the autumn (McWilliam, 1968). Morocco being a major center for diversity of perennials has provided a wide range of genetic variation within these species. Moroccan ecotypes of cocksfoot showed 97% drought survival, whereas ecotypes of European origin exhibited only 59% survival (Knight, 1966). While summer dormancy is common in herbaceous plants growing in semi-arid conditions, it has been shown that some of these plants are very dehydration tolerant even when not dormant (Volaire *et al*., 2001; Volaire, 2002). This study aimed to rank the Moroccan populations of cocksfoot previously characterized for summer dormancy according to their dehydration tolerance and drought survival.

II – Materials and methods

Six cocksfoot ecotypes (D1, D6, D8, D9, D10 and D14) collected in different regions of Morocco and evaluated previously for their summer dormancy (Shaimi *and al,* 2009) and two cultivars (cvs) cv Kasbah and cv Porto were tested. Cv "Kasbah" was selected in Australia from Moroccan germplasm collected in an area with 270 mm average annual rainfall. It is very summer dormant and drought resistant. The productive cultivar "Porto" was bred from Portuguese material originating from oceanic climate (Oram, 1990).

The experiment was undertaken in a glasshouse at INRA (Rabat, Morocco) in autumn, winter, spring and summer 2007, using 21-cm PVC pots containing the same quantity of substrate 70% of sand, 10% of clay and 20% of peat. Seeds of cvs "Porto" and "Kasbah" and the 6 ecotypes were sown in separate pots on 19 November (25 plants per pot). Pots of each genotype were fully irrigated and were defoliated when necessary until first of June, when the soil moisture was adjusted to 31 % and irrigation stopped. One or two pots of each genotype were successively re-watered after 7, 12, 15, 18, 21, 25, 28 and 33 days of drought and soil moisture was measured regularly by gravimetry. Two pots of each genotype were irrigated throughout the period as controls. All pots were fully randomized. For 3 weeks following each rehydration, the number of plants that regrew from the surviving plants was counted. The data were analysed using the appropriate analysis of variance and regression models in the SAS (SAS, Inc., Cary, North Carolina, USA).

III – Results and discussion

Biomass production: During spring, dry matter production differed significantly (P<0.0001) between genotypes (Fig 1). Porto exhibited the highest production; followed by D6 and D9 ecotypes. Kasbah yielded 48% less than Porto, and accumulated as much biomass as D10, D8 and D14 ecotypes, while D1 was the least productive. In the summer, biomass production of irrigated plants decreased by 43% on average (Fig. 1) with significant differences between genotypes (P<0.0001). Porto maintained the highest production and D1 had the lowest. Kasbah and D9 had the same production slightly higher than D6 and D8 (Fig. 1). After 21 days of drought, recovery yields amounted on average to 77% of those of irrigated plants. But, only Kasbah, D6 and D1 ecotypes could produce aerial biomass after a severe drought of 33 days.

Senescence: The fraction of senescent tissues varied significantly according to drought duration (P = 0·0001). Senescence reached 96% after 25 days of drought for D8, D9, D10 and D14. But since the 28th day of drought all genotypes reached full aerial senescence. D8 and D9 were faster to reach senescence. Senescence was correlated to aerial biomass produced in summer following each drought rehydratation (r = 0.226).

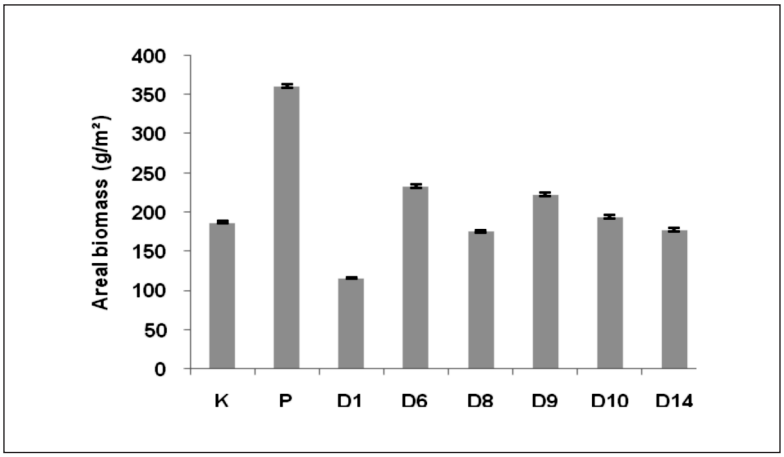

Fig. 1. Spring production of aerial dry matter (g/m²) of 6 Moroccan ecotypes and 2 cultivars Kasbah (K) and Porto (P) of *Dactylis glomerata*.

Water content of leaf bases: The water content in apices differed significantly according to drought progression (P = 0.0001), and ranged from 4.75 to 0.33 g H_20 g^{-1} d. wt. Dehydration of leaf bases progressed more quickly in ecotypes D1 and D14. Responses of the ecotypes D9 and D14 were intermediate. However, mortality was substantial in all genotypes except Kasbah and D1, especially when the last surviving leaf bases had a water content below 0.38 g H_20 g^{-1} d. wt. The water content of last surviving leaf bases were 0.48, 0.45 and 0.54 g H_20g^{-1} d wt of Kasbah, D1 and D6 ecotypes after 33 days of drought.

Plant survival: All genotypes displayed 100% survival when drought duration did not exceed fifteen days (Fig. 2). Plant mortality started after 18 days of drought and genotypes differed markedly since then. Porto had lost 40% of plants when all others genotypes survived at more than 86%. Plants of ecotypes D9, D8 and Porto died at relatively higher soil moisture than those of Kasbah, the other ecotypes being intermediate. The soil moisture associated with 50% mortality was 2.5% for D8 and Porto and 1.9% for D14 ecotype. High levels of survival was reached by Kasbah and D1 at 1.8%, soil moisture.

Dehydration tolerance: As soil water content decreased in pots, aerial tissues of D8 and D9 were faster to senesce, followed by Kasbah, D10, D6 and D14. In addition, Kasbah, D8, D9 and D10 reached almost full aerial senescence and had more hydrated tissue at soil water content of 2.5%· The dehydration of leaf bases progressed more quickly in Porto and D8, while responses of the other ecotypes were intermediate. However, mortality was substantial in D8 and Porto cv at soil moisture of 1.9%, especially when the last surviving leaf bases had a water content below 0·38 g H_20g^{-1}dw. After 33 days of drought, only Kasbah, D1 and D6 ecotypes displayed some survival (15, 15 and 5% respectively) and the water content of last surviving leaf bases were 0.48, 0.45 and 0.54 g H_20g^{-1} dw. Plants of Porto and D8 died at a higher soil water content than those of Kasbah and D1, the other genotypes being intermediate. The soil water content associated with 50 % mortality was 2.5 % for Porto and D8 ecotype and 1.4% for Kasbah and D1. Under extreme drought only D1, D6 and Kasbah exhibited some survival.

D6 and D10 leaf base water content was low (0.58 g H_20g^{-1}) but their survival rate was high (80%). Volaire *and al* (1998b) also showed that plant survival depends more on how long the surviving tissues can maintain cell integrity at given moisture content, rather than on the actual minimum threshold of dehydration reached by tissues. Under the experimental conditions tested,

Kasbah, D6 and D1 were the most tolerant to tissue and soil dehydration, while able to avoid the effects of drought for longer, (Levitt, 1972; Sugiyama and Nikara, 2004). Our results show a great variability in dehydration tolerance within highly summer dormant ecotypes of cocksfoot that can be exploited for future breeding programs (Volaire and Norton, 2006).

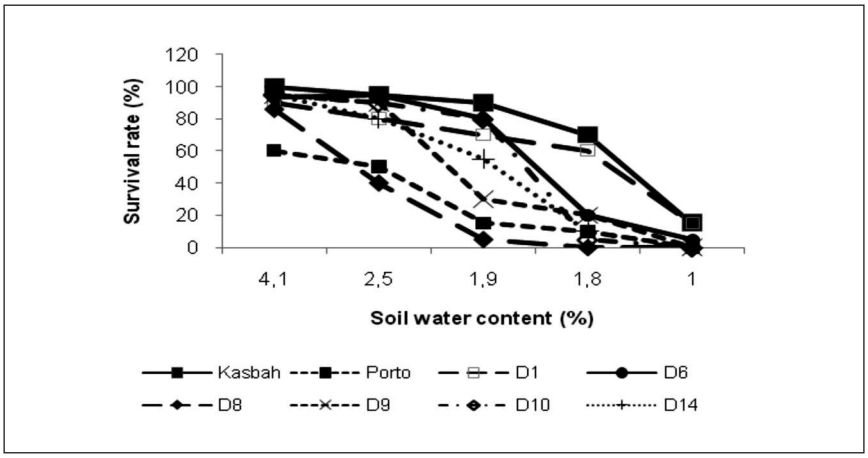

Fig. 2. Drought survival rates as affected by water soil content (%) for 6 Moroccan ecotypes and 2 cultivars Kasbah (K) and Porto (P) of *Dactylis glomerata.*

IV – Conclusions

We analyzed plant material previously characterized for its summer dormancy and showed that the ecotypes which survived best after severe drought displayed combined strategies, with both drought avoidance by senescence of aerial tissue to reduce transpiration, and dehydration tolerance in apices that can remain alive at low hydration and low soil water content. We are now investigating the genetic determination of summer dormancy in order to support plant breeding for new cultivars that would be productive and highly drought tolerant (PRAD project).

Acknowledgments

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