Increasing the seed production of summer-dormant, drought-tolerant cocksfoot

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Abstract
Recent research has demonstrated summer-dormant, hispanica cocksfoots (*Dactylis glomerata* spp *hispanica Roth*.) to be amongst the most drought-tolerant temperate perennial grasses yet commercialised. However, whether cultivars of this subspecies become available to farmers is dependent upon seed growers being able to produce seed profitably and so far this has been problematic. Australian seed growers can profitably grow seed of *Dactylis glomerata* spp *glomerata* cultivars at plant densities of 180-200 plants/m^2 or less so trials were established to identify whether such low, commonly-used densities are a constraining factor that might require modification to obtain commercially acceptable seed yields in hispanica cultivars. A field trial comparing *Dactylis glomerata* spp *glomerata* cv Currie with *Dactylis glomerata* spp *hispanica* cv Kasbah, each sown at 3 plant densities (200, 400 and 500 plants/m^{-2}), was established. A dry finish to the growing season caused seed yield of the later flowering cv Currie to be significantly reduced (347 kg/ha) in comparison to the earlier flowering Kasbah (450 kg/ha) and although at this stage any density-related yield differences were non-significant indications were that yield of Kasbah might increase with plant density. An earlier pot trial had also indicated that seed yield of Kasbah was most sensitive and reduced if the crop experienced water stress within the Zadoks growth stage range of 56.6 (75% inflorescence emerged) to 63.8 (50% anthesis), than at growth stages either before or after this range. These results have implications for those growers with available irrigation. Research continues to study the effects of plant density on seed yield focussing on older mature swards.

Keywords
Orchard grass, Spanish cocksfoot, plant density, moisture deficit, germination, hispanica cocksfoot

Introduction
The first cultivars of *Dactylis glomerata* spp *hispanica* to be developed in Australia, cvv. Kasbah and Berber, were bred by J. Carpenter at the Waite Institute in the late 1960's, and were then released as public cultivars (Oram 1990). Both cultivars, derived from populations collected in the semi-arid regions of southern Morocco, express high levels of summer dormancy and consequently are very drought tolerant (Norton *et al*. 2006a). These cultivars were effectively lost to Australian agriculture during the next two decades of the 1970's and 1980's when low commodity prices of wool, beef and sheep meat caused farmers in the drier mixed farming zones to reduce investment in pasture improvement (Rex Oram pers. com.). The droughts of the 1980's however, led to a rekindling of interest in drought tolerance traits among researchers and the rediscovery of the potential of summer dormancy to improve persistence. The superior drought tolerance conferred by the summer dormancy trait has been reconfirmed in the southern Australian droughts of the past two decades during which cv Kasbah has consistently persisted better than many other cultivars or species especially when the dry periods became severe and extended (Norton *et al*. 2001; Hackney *et al*. 2006; Hayes *et al*. 2010a). This work with perennial grasses complemented concurrent discoveries in farming systems research showing that pastures containing perennial species tended to confer greater sustainability benefits than those reliant upon annual species because of their greater soil water use, and ability to reduce the rate of nitrate leaching.

However, the extension of this technology was frustrated largely by the unavailability of seed of these grasses. This is primarily because seed growers were unable to obtain commercially viable yields of these hispanica cultivars. The reason for this is unclear as it may either be due to inappropriate agronomic recommendations such as inadequate plant density or, as has been suggested by seed company agronomists, that hispanica, summer-dormant cultivars such as Kasbah are inherently of low seed yielding capability. Australian grass seed producers have extensive experience of successfully growing seed of *Dactylis glomerata* spp *glomerata* cultivars such as Currie and Porto. However, using the same agronomic recommendations they are unable to consistently produce seed of *Dactylis glomerata* spp. *hispanica*

cultivars profitably. Surveying of seed industry agronomists prior to the commencement of the research reported here indicated that the plant density of Kasbah cocksfoot seed crops rarely exceeded 180-200 plants m^{-2} and was often lower. It is important to note that these are the densities recommended for cultivars of *glomerata* cocksfoots such as Porto or Currie. Furthermore, there appears to be no research published on this topic although some work was undertaken suggesting that plant densities much higher (400 plants /m^2) than those commonly found in farmer fields were necessary to maximise seed yields in cv Berber, a plant of similar morphology to Kasbah (J. Carpenter unpublished research). Carpenter (1968) also observed that even though Berber and Kasbah originated in semi-arid environments their seed yield could be severely restricted if plants experienced moisture deficit during reproductive growth. Given that there is renewed interest in producing seed of *hispanica* cocksfoot cultivars and that some of this production is likely to occur in regions where irrigation is available, it is timely to consider the role of plant density in seed yield production and to identify that period of reproductive growth when seed development of the hispanic cocksfoot plant is most constrained by moisture deficit. Consequently, two trials were undertaken, one in the field comparing two cocksfoots of different subspecies and morphologies under three different plant densities, and the other in the glasshouse examining the effect of moisture deficit applied to cv Kasbah at different stages during reproductive growth.

Materials and Methods

In the field trial two cultivars were selected for study, *Dactylis glomerata* spp *glomerata* cv Currie and *Dactylis glomerata* spp *hispanica* cv Kasbah (Oram 1990). Currie was considered to be an appropriate cultivar against which to compare Kasbah as it has been available since the late 1950's and there is consequently considerable experience and confidence among seed growers in dealing with this cultivar. Each cultivar was sown at a rate sufficient to obtain plant densities of 200, 400 and 500 plants/m^2 taking into account variation in seed weight, germination percentage and the likely establishment achieved. Each plot was 4.6 m^2 in area, with rows spaced 20 cm apart and the experiment was arranged as a randomised complete block design with four replications. The trial was located at the Ginninderra Research Station of CSIRO in Canberra (35.18 S, 149.06 E, 610 m altitude) at a freely draining location in the paddock. The soil at the test site was a yellow sodosol (Isbell 1996). Sowing occurred in early spring on the 3rd September 2012. Fertiliser was applied at that time at the rate 22.5 kg N/ha and 19 kg P/ha and in early September 2013, N was applied at 50 kg/ha. Seed harvest did not occur until early January of the following season, 2013/2014, at which time 2 m of row was randomly selected from each plot and harvested for seed yield. The seed was threshed, cleaned and tested for germination.

A second trial to examine the effect of moisture deficit occurring over the period of reproductive growth in cv Kasbah was also undertaken. Three Kasbah plants were grown in 20 cm wide pots each containing approximately 5.5 kg of a freely-draining potting mix. The period during which moisture deficit was imposed began on 14 September (day 258 of the year) and continued until 6 November (day 311 of the year). The pots were divided into seven groups of eight pots with each group experiencing a period of water deficit once (a period of 7 to 8 days) during the reproductive growth period. Water deficit was imposed by withholding irrigation from the group of pots during this period. Relative water content (Barrs and Weatherley 1962) of the youngest fully expanded leaf was used to measure the degree of plant water deficit experienced on the last day that moisture was withheld on four different droughted pot groups throughout the trial period. Growth stage was also measured on all plants during this trial using the system of Zadoks et al(1974). Data analyses employed ANOVA in Genstat for Windows 16.

Results and Discussion

Although Canberra received 622 mm in 2013 which is close to the mean annual rainfall, only 20 mm of this fell in October in the months leading up to seed harvest (Table 1). This is substantially less than the median rainfall of 55 mm which can be expected in October.

Seed yields of the different plant densities and cultivars are presented in Table 2. In this trial there were no significant differences due to plant density and any interaction between cultivar and plant density was also not significant. However, the mean seed yield of cv Kasbah across the 3 plant densities was 450 kg/ha, significantly greater than the yield of cv Currie, 347 kg/ha. The lower yield limit for a seed crop of cocksfoot

to be considered commercially is approximately 400 kg/ha (N. Phillips, G. Stewart pers. com.). Accordingly the yield of cv Kasbah was high enough to be commercially viable whereas cv Currie did not achieve this seed yield level.

Given that Kasbah flowered in early September whereas Currie flowered almost one month later in late September / early October (Oram 1990) it seems likely that the dry October conditions impacted more severely on seed yield development of the later flowering Currie than on the earlier flowering Kasbah.

Table 1. Monthly rainfall (mm) and mean monthly maximum and minimum temperatures at Gininnderra Research Station during the period from trial sowing (September 2012) to seed harvest (January 2014).

	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan
Rain	53	78	33	56	85	79	28	10	12	108	56	29	69	20	105	21	8
Max Temp.	16	20	24	27	32	26	24	21	16	12	12	13	18	20	23	28	31
Min Temp.	3	5	10	13	15	14	12	7	4	3	3	3	6	5	8	12	13

Nevertheless, the results suggest that a positive correlation between plant density and seed yield might exist in cultivar Kasbah under growth conditions where moisture deficit during the reproductive stage is less severe. This is possible because a non-significant yield increase of 130 kg/ha, occurred in Kasbah with 500 plants/m^2 compared to 200 plants/m^2. Certainly this possibility deserves ongoing investigation. In addition, as this was a first year crop, on-going studies are necessary to measure seed yield with older, mature swards of this perennial grass. Indeed to assess commercial viability it will be necessary to maintain the crop swards for a number of years before a full evaluation of the effects of the different plant densities can be obtained.

Table 2: Seed yield (kg/ha) of the cocksfoot cultivars, Currie and Kasbah, sown at three plant densities.

Plant density (plants/m^2)	Currie	Kasbah
200	315	387
400	364	446
500	362	517

In the trial to study the effect of moisture deficit imposed at different plant growth stages on seed yield and germinability the measurement of relative water content (RWC) was undertaken to verify that the withholding of irrigation from the droughted pots did succeed in imposing a substantial level of moisture deficit on the affected plants. Thus RWC was measured on plants from 6 pots of both droughted and fully irrigated plants on the 17th and 25th October and the 1st and 9th November.

Table 3: The effect of moisture deficit imposed at different plant growth stages on seed yield and seedlot germination of Kasbah cocksfoot.

Zadoks growth stage/date/day of year	Seed yield (g)	Seedlot germination (%)
55.4/ 18 Sept/ 261	4.846	78.3
56.6/ 24 Sept/ 267	1.123	2.6
57.9/ 3 Oct/ 276	2.613	24.7
61.3/ 12 Oct/ 284	2.67	24.2
63.8/ 19 Oct/ 292	2.501	11.6
66.2/ 26 Oct/ 299	3.211	49.2
66.8/ 2 Nov/ 305	4.58	70.6
LSD (P>0.05)	**1.572**	**26.1**

The values of RWC measured on these dates were 30, 35, 32 and 46% for the droughted plants and 94, 91, 98 and 95% for the well-watered plants, indicating that the withholding of irrigation did subject the plants to substantial moisture deficit.

The stage of reproductive growth during which moisture deficit was imposed had a pronounced effect on both seed yield and seedlot germinability (Table 2). Thus moisture deficit imposed at the earliest growth stage tested (Zadoks 55.4, 50% inflorescence emergence) had much less effect on both yield and germinability than when the deficit was imposed just 6 days later at Zadoks 56.6. Seed yield and seedlot germinability seemed to be most reduced by moisture deficit when imposed during the period when the growth stages ranged from Zadoks 56.6 (75% inflorescence emerged) to 63.8 (50% anthesis).

Conclusions

These two trials indicate that moisture deficit during reproductive growth can have a major negative impact on seed yield and germinability of cocksfoot. Irrigation, if available and applied during this period should be able to overcome this constraint. Studies of the effect of plant density on seed yield were inconclusive but provide support for the need to continue research on this topic as it is possible that when moisture deficit is not so severe, seed yield may be positively correlated with plant density. On-going measurement of the effects of plant density on seed yields in older, mature swards is also required as under commercial conditions cocksfoot grass seed crops must be maintained for several years and it is possible that plant density may change over time.

Acknowledgements

I wish to thank Colin Shields and Peter Tyndall for technical assistance and NSW DPI for financial support.

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