Mechanical defoliation as a management tool for kyllinga (*Cyperus brevifolius*) in irrigated pasture

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Summary

Kyllinga is a weed of increasing importance in irrigated pastures throughout northern Victoria and in southern New South Wales. It is unpalatable and stock avoid otherwise productive swards where it is present. Farmers commonly mow paddocks after grazing to reduce competition from ungrazed plants. Mown paddocks are subsequently irrigated, which may facilitate kyllinga seed dispersal. This paper reports on the impact of defoliation on kyllinga growth and seed production under controlled conditions and the effect of seed age, periods of desiccation and immersion in water on germination. Defoliation reduced the DM of whole plants, plant parts and the number of seedheads at successive harvests, but not cumulative seedhead production. Plants cut every six weeks to a height of 30 mm produced around 40% more seedheads than uncut plants. Germination was low in seed 0–18 days old, but rose with increasing seed age. Seed germinated in water. Consequently, irrigation water is a viable vector for kyllinga. Frequent mowing may provide a means of suppressing kyllinga infestations while ensuring that only a small proportion of seeds produced are capable of germinating.

Introduction

Kyllinga (*Cyperus brevifolius* (Rottb.) Hassk., synonyms: *Kyllinga brevifolia* Rottb., green kyllinga, globe kyllinga, Mullumbimby couch) is a perennial, rhizomatous, C4 sedge of tropical and subtropical origins (Johnson and Evans 1976, Holm *et al.* 1979, Sumaryono and Basuki 1986, Blaikie and Slarke 1993, Bryson and Carter 1994). When cut, crushed or heated, foliage and subterranean plant parts have a strong sweet, citrus-like odour caused by aromatic oils (Komai and Tang 1989). Kyllinga has been identified as an increasing weed problem in northern Victoria and pastures elsewhere including south-western New South Wales (NSW), Gippsland in south-eastern Victoria and West Australia (WA) over the last five to ten years (A. Somerville personal communication 1995, Henskens 1996, R. Taylor personal communication 1996). It is highly invasive in irrigated pastures and displaces sown species (Auld and Medd 1987, Blaikie and Slarke 1993). It is unpalatable to dairy cows and animals avoid grazing swards where it is present (Blaikie and Slarke 1993) and hence, kyllinga has the potential to reduce farm productivity. At present there are no practical means of controlling kyllinga in pasture. Both herbicides and non-chemical methods have failed to control infestations or prevent reinvasion of renovated pastures (Blaikie and Slarke 1993). Seed is the primary source of reinvasion into renovated pastures and considerable seed banks are formed in the soil (Henskens *et al.* 1996). Consequently, to be successful, any management strategy must reduce kyllinga seed production and dispersal. The mechanisms by which the weed is dispersed are not known and the only seed production and germination data comes from Indonesia and southern states of the US (Sumaryono and Basuki 1986, Molin *et al.* 1997). At present it is not known whether these results apply to kyllinga growing in Australian pastures.

In Indonesia, kyllinga flowers ten to eleven weeks after sowing. Three to five weeks after flower emergence seeds are sufficiently mature to germinate (Sumaryono and Basuki 1986). Kyllinga can thus produce two generations of seedlings during a single season. Kyllinga also produces large quantities of seed. Under glasshouse conditions in Indonesia, individual plants produced 34 seedheads during the growing season and each seedhead possessed about 100–120 seeds (Sumaryono and Basuki 1986). In Victoria, yields of 500 seedheads m^{-2} or 50 000–60 000 seeds m^{-2} have been obtained in irrigated pastures (Henskens *et al.* 1996).

In Victoria, pastures are often mown after they have been grazed, reducing ungrazed patches to the same height as the sward. Kyllinga can produce new flowerheads within two to three weeks of being defoliated to less than 50 mm above the soil surface. Mowing kyllinga infested paddocks may, therefore, promote weed seed production as well as facilitating its spread over the rest of the paddock and farm. Irrigation water has also been implicated as a vector in kyllinga dispersal (Blaikie and Slarke 1993).

The current study was undertaken to investigate:

i. the impact of mechanical defoliation (simulating mowing) on the growth and reproductive capacity of kyllinga,
ii. to determine the minimum age at which kyllinga seed can reliably germinate with or without a period of 'after-ripening' following removal from the plant and
iii. to establish whether water is a viable vector for kyllinga seed.

Materials and methods

Two experiments were conducted in a growth room at the Institute for Sustainable Irrigated Agriculture (ISIA), Tatura from June to December 1995 and in incubators at ISIA, Kyabram and the Institute for Integrated Agricultural Development, Rutherglen in 1995 and 1996.

Growth and seedhead production

The growth room study consisted of a 2 × 2 factorial with control design and four replicates. Kyllinga plants were grown from seed in pots with a 14 hour photoperiod and a 35/25°C day/night temperature regime. When plants had reached the 8–10 leaf stage, numbers were reduced to two even sized plants per pot. Treatments were imposed once the majority of plants had reached 100 mm in height. Treatments were: an uncut control and two different cutting heights, 30 and 50 mm above the pot surface, each imposed at three and six week intervals. Plants were destructively harvested immediately prior to the first defoliation and in subsequent harvests 6, 15 and 18 weeks later. At each harvest seed head numbers were counted, plants washed and separated into flower and seedhead, aerial shoot (leaf plus stem), rhizome and root portions, then dried and their weights recorded. Flower and seedhead numbers were recorded

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weekly. Plant reproductive capacity was evaluated in terms of flower and seedhead biomass and numbers and rhizome dry matter (DM). For the purposes of this study 'seed' refers to individual achenes enclosed in the two scales which are shed as a unit.

Germination with seed age and storage
Sixteen kyllinga plants were established from seed under the conditions described above and grown in four blocks. On 15 August (ten weeks after sowing), plants were defoliated to 20 mm above the soil surface. One week later seedheads were marked with colour-coded tags. New seedheads were tagged with different colours at approximately weekly intervals over the next seven weeks so that their maximum age could be determined. Seed age-classes (maximum seed age) were determined from the day after the previous age-class had been tagged to the time of harvest. All seedheads were harvested 62 days after the initial defoliation and segregated into the age-classes; 0–10, 11–18, 19–26, 27–32, 33–39,40–47, 48–53 and 54–62 days old. The results are presented in terms of the upper limit of each age-class. Seed was stored over silica gel at room temperature.

A seed germination experiment was conducted twice in an 8 × 2 × 2 factorial design (eight seed ages, two storage periods and two germination media) with four replicates. Germination was assessed twice, after 10 and 130 days of storage, respectively. Germination levels were determined from four replicate subsamples of 50 filled seeds from each age-class and storage period. Seeds were placed on moist blotting paper in Petri dishes and transferred to an incubator under a 14 h photoperiod and 35/25°C day/night temperature regime. After three weeks, germination was checked daily for a further six weeks. This procedure was repeated using moist potting mix and Petri dishes filled with water. All data from both experiments were analysed using GENSTAT 5 ANOVA procedures.

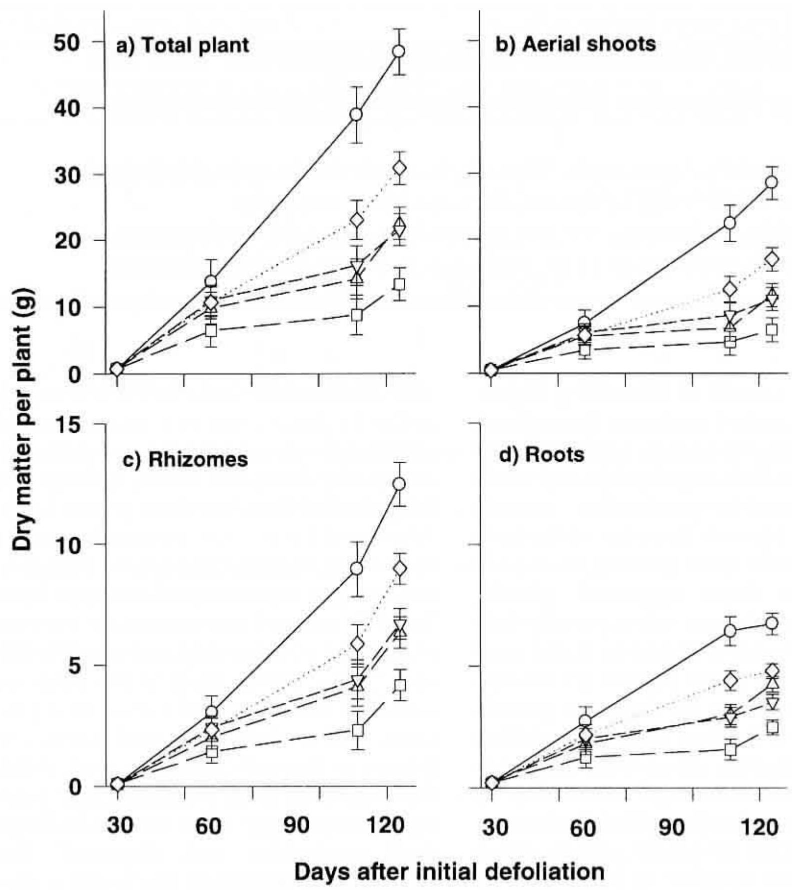

Figure 1. The effect of defoliation on the growth (g DM) of kyllinga plants. ○ never cut, □ cut to 30 mm every three weeks, △ cut to 50 mm every three weeks, ▽ cut to 30 mm every six weeks and ◇ cut to 50 mm every six weeks. Vertical bars indicate LSD (5%) values.

Results

Growth
All defoliation treatments significantly reduced total plant DM (Figure 1a). The severe cutting regime (to 30 mm in height every three weeks) had the most immediate impact on kyllinga growth, and caused a significant decrease in total plant weight after two defoliations (harvest two, day 42). Other treatment differences were not evident until harvest three, when plants defoliated every three weeks had been cut five times and those cut six-weekly had been cut only three times (Figure 1a). After 18 weeks (day 126) the total DM of uncut plants was around 48 g, while frequent, severe defoliation reduced plant DM by 70% to 13 g. Intermediate defoliation regimes (cut to 50 mm every three weeks or 30 mm every six weeks) reduced kyllinga biomass by 55% to 20 g. Lax defoliation (cut to 50 mm every six weeks) reduced plant DM the least, by 36% to 31 g. Both the frequency of cutting and the height to which plants were cut influenced total plant DM at the final harvest ($P=0.002$ and $P=0.005$, respectively), but did not interact.

Aerial shoots regrew rapidly after defoliation and significant treatment effects were not evident until harvest three when plants subjected to defoliation had been cut three to five times (day 107). The growth of below ground organs was more sensitive to defoliation. Rhizome biomass, and thus the capacity for vegetative expansion, was significantly lower in plants cut to 30 mm every three weeks compared with controls after just two defoliations (day 42, Figure 1c). At later harvest dates rhizome expansion (in terms of DM, node number and rhizome length) was significantly reduced by all defoliation regimes. The pattern of rhizome treatment affects followed total and aerial shoot DM (Figure 1a,b,c). Rhizomes of plants subjected to frequent, severe defoliation suffered the greatest reduction in DM (about 66%). Rhizomes of plants grown with intermediate levels of defoliation were reduced by 46–49%, while the least reduction, 28%, occurred under the lax regime (from Figure 1c). Root DM was similarly reduced by defoliation. At harvest four, roots of uncut plants weighed 6.7 g but only 2.5 g in those cut to 30 mm every three weeks (Figure 1d).

Seed production
Defoliation reduced seedhead biomass at each harvest relative to the uncut controls. By the third and fourth harvests (days 107 and 126), seedhead DM in uncut plants was 0.7–1.0 g, but only 0.1–0.3 g in defoliated plants (Figure 2a). This was due primarily to a lower number of seedheads present on defoliated plants (Figure 2b). At harvest two for example, plants subjected to two defoliations to 50 mm had less than half the number of seedheads of the uncut controls. By the end of the experiment uncut plants had produced approximately 138 seedheads compared with a range from 24 to 72 on defoliated plants (Figure 2b). Plants subjected to severe defoliation had fewer seedheads than those grown under intermediate defoliation regimes, which in turn possessed

fewer seedheads than plants under the least severe regime (Figure 2b).

Total cumulative seedhead production during the experiment ranged from 138 to 205 heads per plant (Figure 2c). Defoliation did not reduce the cumulative seedhead production. By the end of the experiment, plants cut to 30 mm every six weeks produced about 50% more seedheads than uncut plants and 25–40% more than those subjected to other defoliation regimes (Figure 2c).

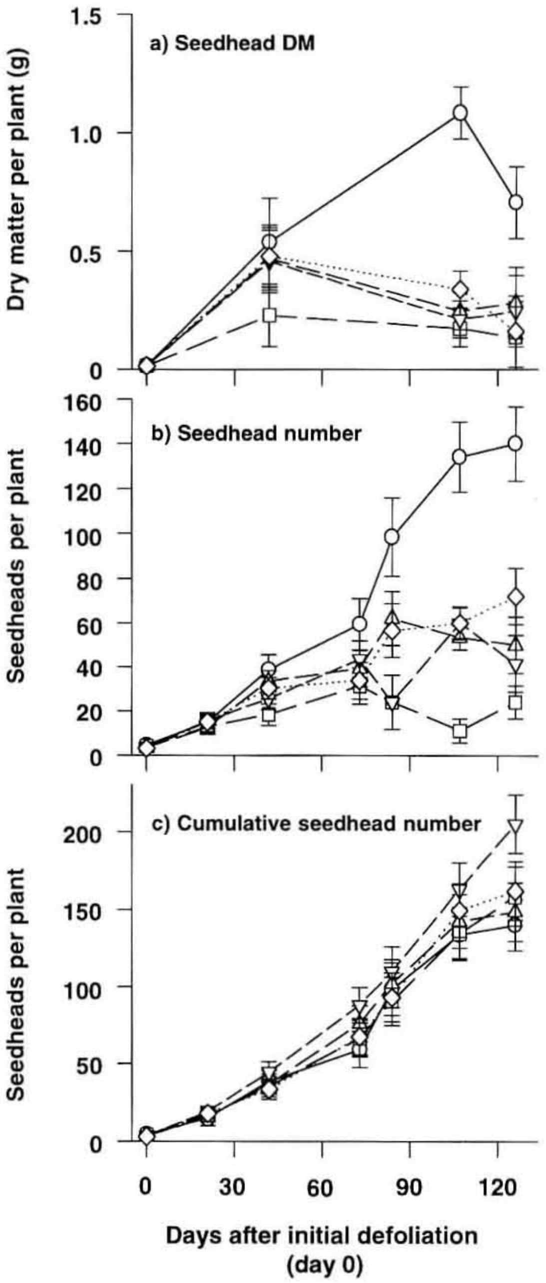

Figure 2. The effect of defoliation on a) seedhead DM (g per plant), b) seedhead numbers at each harvest date and c) seedhead production of kyllinga plants. ○ never cut, □ cut to 30 mm every three weeks, △ cut to 50 mm every three weeks, ▽ cut to 30 mm every six weeks and ◇ cut to 50 mm every six weeks. Vertical bars indicate LSD (5%) values.

Seed age and germination

Germination occurred in seed from all age-classes (Figure 3). Germination rates generally increased with increasing seed age on the plant. Only 1–10 % of seed up to ten days old germinated compared to 35–85% of seed 47–53 days old (Figure 3). Germination percentages peaked in 53 day old seed for both water treatments and on potting mix after 130 days storage, peaked at 49, 72 and 84%, respectively. Germination rates, subsequently declined to 29, 52 and 51% respectively in older seed (Figure 3).

Germination with storage

Kyllinga seed was capable of immediate germination and did not exhibit a dormancy period once removed from the parent plant (Figure 3). The length of time for which seed was stored, however, significantly ($P<0.001$) influenced percentage germination. Storing seed for 130 days increased the overall average germination rate by about 12%. There was a significant interaction ($P<0.001$) between seed age and length of storage. Seed older than 27 days showed a consistent increase (about 10–50%) in germination rate with increasing length of storage from 10 to 130 days (Figure 3).

Germination in water

The germination medium had no impact on germination percentage within each age class and there was no interaction with storage (Figure 3a,b).

Discussion

The results demonstrated that defoliation can reduce kyllinga growth and the biomass of its organs. Consequently, defoliation by mowing may have potential as a management tool for kyllinga. Interactions with other species in pasture swards will influence any impact of mowing on kyllinga. Consequently, the current work must be verified in the field. Particularly as kyllinga is known to produce allelochemicals which may contribute to its competitive ability (Komai and Tang 1989, Kawabata *et al.* 1994).

The growth of below ground organs and thus the potential for vegetative expansion was restricted by defoliation. The rhizomes of cut plants, for example, had significantly reduced biomass than control treatments after only one or two defoliations (Figure 1). This suggests that aerial shoot regrowth following defoliation was largely at the expense of rhizome and root growth and therefore supported by below ground reserves, which appeared to be only slowly replenished, as indicated by the continued depression in rhizome and root DM. Frequent mowing of infested pastures may, as a consequence, help reduce the rate of kyllinga spread by rhizomes. Unlike kyllinga in tropical regions (Sumaryono and Basuki 1986, Molin *et al.* 1997), in Victoria, kyllinga shoots senesce and the plants become dormant over the autumn and winter (Blaikie and Slarke 1993). As emerging shoots in early spring principally originate from existing rhizomes (Henskens *et al.* 1996), any measure that successfully suppresses or reduces rhizome growth during the growing season could lower the level of infestation in the following season.

Kyllinga shoots regrew rapidly after defoliation. It was not until harvest three, when plants had been cut three to five times, that there was a significant decline in aerial shoot and total plant biomass relative to uncut controls. Consequently, while mowing in the field may suppress kyllinga growth, repeated operations would be required throughout the growing season and any reduction is unlikely to be immediately apparent.

Although defoliating plants to 30 mm every three weeks gave the greatest reduction in kyllinga DM, in the field this regime might also affect the growth of sown pasture species. The six-weekly cutting regimes are more representative of current farmer practice. The results demonstrate that both the frequency and height to which plants are cut reduce kyllinga growth, but there was little or no difference between the total plant biomass and components of plants defoliated to 50 mm every three weeks compared to those defoliated to 30 mm every six weeks (Figure 1a). In practice, lowering the height of the mower or mowing more frequently at the usual height alone are unlikely to improve kyllinga control. Mowing may slow the expansion of kyllinga in the field, but alone is unlikely to eliminate the weed from infested pastures since it is known to invade moist areas in lawns and turf (Corrick 1977, Auld and Medd 1987, Hall *et al.* 1994, Kawabata *et al.* 1994).

Although defoliation has potential to reduce the long term growth of kyllinga and suppress root growth and vegetative expansion by rhizomes, seed production is the major source of infestation in the field (Henskens *et al.* 1996). Effective control strategies must, therefore, reduce seed production, dispersal and the seed bank. The efficacy of mowing as a tool for kyllinga control in pastures will rely on the relative ability of sown species to recover from mowing and out-compete kyllinga and on its impact on seed production.

Kyllinga has been reported to produce prolific quantities of seed in a variety of situations and climates (Sumaryono and Basuki 1986, Henskens *et al.* 1996, Molin *et al.* 1997). In Victoria, plants compensated for losses caused by defoliation so that the number of flower and seedheads present on plants at each cutting date were reduced relative to controls, but not the total number of seedheads produced over the experiment (Figure 2b,c). Plants defoliated every three weeks to 50 mm, for example, had higher cumulative seedhead yields (204) than uncut plants (144). Within each seedhead, seed numbers ranged from 80–120, a slightly wider range than previously reported by Auld and Medd (1987). Cumulative seed production in defoliated plants ranged from 11 900 to 24 600 seeds plant^{-1} over 18 weeks. This greatly exceeded the seed production data from Indonesia, in which plants grown in a glasshouse produced 34 seedheads or about 3400–4100 seeds plant^{-1} over a 20 week period (Sumaryono and Basuki 1986). The growth room data are consistent with field sites in Victoria. At these sites, cumulative seedhead production was estimated at around 500 seedheads m^{-2} or 50 000–60 000 seeds m^{-2} over the growing season (Henskens *et al.* 1996). Consequently, mowing in the field is unlikely to effectively reduce kyllinga seed production and thus may not reduce the level of infestation during the growing season. Mowing could actually contribute to the spread of kyllinga by physically moving seed around the paddock, facilitating seed dispersal by irrigation water and transporting seed about the farm on machinery. If, however, seed formed less than three weeks after flower emergence is unable to germinate, as is the case in Indonesia (Sumaryono and Basuki 1986), then frequent defoliation may still provide a useful means of suppressing viable seed formation.

The results demonstrated that only a low proportion (1–20%) of 0–18 day old kyllinga seed is able to germinate, compared with a maximum of 70–85% in seed 48–53 days old (Figure 3). Consequently, control measures should target periods early in the season or soon after infestations have been defoliated, when the proportion of viable seed is likely to be minimal. As kyllinga has been observed to produce flowers within two weeks of defoliation, herbicides should be applied to the regrowth or mowing repeated within 3–4 weeks.

Kyllinga seed was able to germinate immediately after removal from the seedhead, but as noted by Sumaryono and Basuki (1986), a period of desiccation improved the rate of germination. Germination rose from a maximum of about 50% after 10 days storage to around 70–85% after 130 days (Figure 3). Similarly, Sumaryono and Basuki (1986) found that a storage period of 1–2 weeks was sufficient to give significantly improved germination rates. This effect was overlaid by a significant interaction between seed age and storage period in which the germination rate of 0–18 day seed did not change with storage, whereas the percentage germination of all other age classes increased (Figure 3). Consequently, in the field the ability of all but very young seed removed from the plant to germinate may improve as seed dries between irrigation events. If kyllinga seed viability does improve following a period of desiccation in the field, then frequent mowing may help to ensure that much of the seed is sufficiently immature to minimize any increase in germination.

Kyllinga seed was able to germinate equally well in water or on potting mix within an age class of seeds or with different periods of storage (Figure 3). Cycles of wetting and drying experienced in the field are therefore, unlikely to reduce the rate of germination of kyllinga seed as dry storage followed by immersion in water neither inhibited nor increased germination. Water is thus a viable dispersal medium for kyllinga seed. Mowing followed by irrigation will, consequently, favour kyllinga dispersal within and between irrigated dairy farms in northern Victoria.

To conclude: frequent mowing (after each grazing or every 3–4 weeks), either alone or in combination with herbicide application or other management practices, may provide a tool for suppressing kyllinga growth and expansion while contributing to an eventual decline in the viable seed bank. Repeated defoliation has been shown to depress total plant and rhizome growth (Figure 1a,c) and may potentially reduce the rate of vegetative expansion of infestations. Defoliation did not depress cumulative seed production and in the field may facilitate seed dispersal. Regular mowing in the field may, however, ensure that the majority of seeds produced are unable to germinate, thus reducing accessions to the soil seed banks and reducing the likelihood of reinfestation.

Care would need to be taken to ensure that the machinery used is free of kyllinga seed after mowing infested paddocks for the first time after seedhead emergence or if six weeks or more has elapsed between mowing operations. This is because a high proportion of the kyllinga seed is likely to be viable at such times and may be dispersed about the paddock or property on farm equipment. Strategies that combine herbicide application with mowing to take advantage of the low germination rates in immature seed, would be more effective if the herbicide used also depresses subsequent seed production. Further work is required to confirm the results from these controlled environment studies under field conditions. Potential interactions between mowing and herbicide efficacy also need to be further investigated.

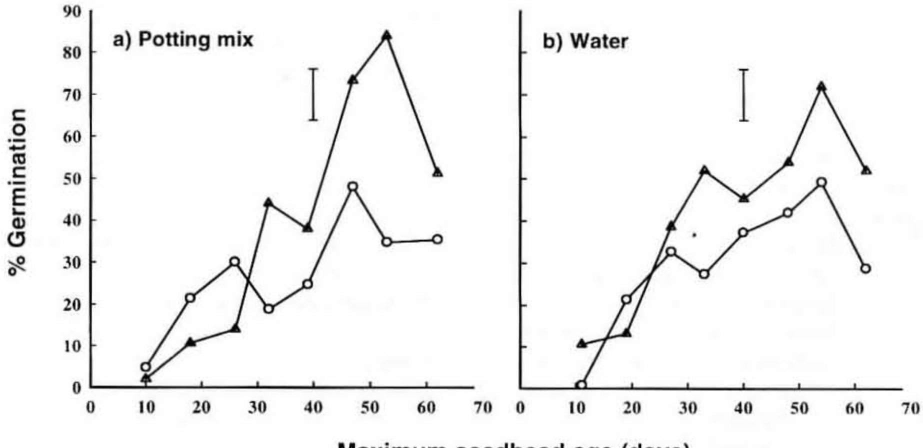

Figure 3. The effect of germination medium a) potting mix and b) water on the viability (per cent germination) of kyllinga seeds. ○ 10 days storage, △ 130 days storage. Vertical error bars represent LSD (5%) values.

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