THE REACTION OF SEVEN *CENCHRUS CILIARIS* L. CULTIVARS TO FLOODING

E. R. ANDERSON*

ABSTRACT

In pots a range of flooding tolerances was found in seven Cenchrus ciliaris *cultivars. The tall, rhizomatous cultivars (Tarewinnabar, Nunbank, Boorara, Biloela and Molopo) were more tolerant than the short, non-rhizomatous cultivars Gayndah and American. Any difference between the two groups on morphological adaptation alone was discounted as the cultivar with the greatest rhizome development (Molopo) was the least flood tolerant of the tall cultivars. A positive interaction between depth and duration on the effect of flooding on plant growth and survival was recorded. At short durations plants were more severely affected if completely covered by water than if some parts of the leaves were exposed. As long as plants were not totally inundated depth of flooding was not significant. However, at longer durations depth of flooding became significant.*

INTRODUCTION

In Central Queensland more than 200,000 hectares of land prone to seasonal flooding are included within the Brigalow Development Scheme (Anon. 1963). The soils subject to flooding are alluvial clays of medium to heavy texture. Floods last 2–10 days, with from incomplete submersion of grasses to many feet of water. Water movement is slow over most of the area with the slowest currents away from the main channels. The longer a flood lasts, the deeper is the water and the slower its movement (Anderson 1970a).

There is little information on the reaction to flooding of the sown grasses being used. Selection has been based on their ability to withstand dry conditions, or drought, rather than flooding. The buffel grasses (*Cenchrus ciliaris* L.) have been the most reliable, persistent and widely used in the region (Sillar 1963; Bisset 1964, 1966; Coaldrake and Russell 1969), but little information is available on the flooding tolerance of the various cultivars. Biloela is reputed to be intolerant of flooding (Barnard 1967). There is also some evidence that buffel grasses have relatively poor flooding tolerance and *Panicum coloratum* cultivars good flooding tolerance (Anderson 1970b; Cameron and Mullaly 1970).

In order to define the flood tolerance of a range of *Cenchrus ciliaris* cultivars, and their reaction to depth and time of flooding, three experiments were carried out at Mackay.

MATERIALS AND METHODS

Approximately 5 kg of soil was placed in each 22 cm diameter polyester pot exposed in an open-sided glasshouse. The soil was an alluvial grey-brown clay of medium to heavy texture. The properties of these alluvial soils have been described by Isbell (1962) and Reeve, Isbell & Hubble (1963). The chemical status was similar to that already reported (Anderson 1972a). Particle sizes were (%): clay—48, silt—20, fine sand—19, coarse sand—13. Root debris was removed on a 9.5 mm mesh sieve prior to potting.

Flooding was achieved by placing the pots in clear plastic bags containing water. These were held upright by attachment to an overhead trellis. Water was maintained at the required levels by periodic topping. The water used was obtained from the reticulated town supply. The following water analysis was provided by the Mackay

* Queensland Department of Primary Industries, Mackay, Queensland, 4740.

City Council (pH 7.6–7.8, total dissolved solids 230–260 p.p.m., hardness 80–90 p.p.m. $CaCO_3$, chlorine 0.25—0.30 p.p.m. combined Cl, CO_2 dissolved 1–2 p.p.m., SiO_2 33–36 p.p.m., Ca 50–55 p.p.m., Mg 30–35 p.p.m.). The technique used has been more fully described by Anderson (in press).

An excess of seed was sown and the stand thinned to five plants per pot two weeks after germination. No fertilizer was applied.

Treatments in the three experiments (Table 1) were arranged in randomized block designs. Results are presented as the number of plants surviving at the end of each experiment and dry weight production.

TABLE 1

Details of three experiments in which the effect of height and duration of flooding on cultivars of Cenchrus ciliaris *was studied.*

Expt. No.	Treatments: *C. ciliaris* cultivars	Treatments: Flood duration (days)	Treatments: Flood height and age of plants at flooding (days)	Replication	Date flooded
1	Biloela Molopo Tarewinnabar	5, 10, 20	23 cm at 28 days (40%)*, and 23 cm (30%) and 46 cm (60%) at 56 days	4	Jan. and Feb., 1967
2	American Biloela Boorara Gayndah Molopo Nunbank Tarewinnabar	10, 15, 20, 25, 30	46 cm at 90 days	3	Mar., 1969
3	American Molopo Tarewinnabar	6, 12, 18, 24	0, 25, 50 and 100% coverage at 90 days	3	Feb., 1970

* Figures in parenthesis are estimated plant submergence.

RESULTS

Experiment 1

There were no significant treatment effects due to age when flooded or to depth of flooding and data are not presented. There were highly significant cultivar effects (Figure 1). Tarewinnabar had the best survival and Molopo the worst. The longest flooding (10 and 20 days) significantly reduced the survival of Molopo. Survival of Tarewinnabar and Biloela was reduced only by 20 days flooding with Tarewinnabar better than Biloela ($P = 0.05$).

Experiment 2

There was little difference in mean flooding tolerance between Tarewinnabar, Nunbank, Boorara, Biloela and Molopo (Table 2). These five cultivars showed greater tolerance than Gayndah and American. Only Gayndah and American plants were completely killed by greater than 20 days flooding with Gayndah showing slightly more tolerance than American. Gayndah was first seriously affected after 20 days while American was badly affected after 15 days with some reaction after 10 days. Although all cultivars suffered greater mortality with increasing length of flooding, this did not reach a significant level for Tarewinnabar. Significant losses were shown for Nunbank after 30 days flooding, Boorara after 25 days and Biloela and Molopo after 20 days. An increase in survival for Molopo and Biloela occurred at 30 days.

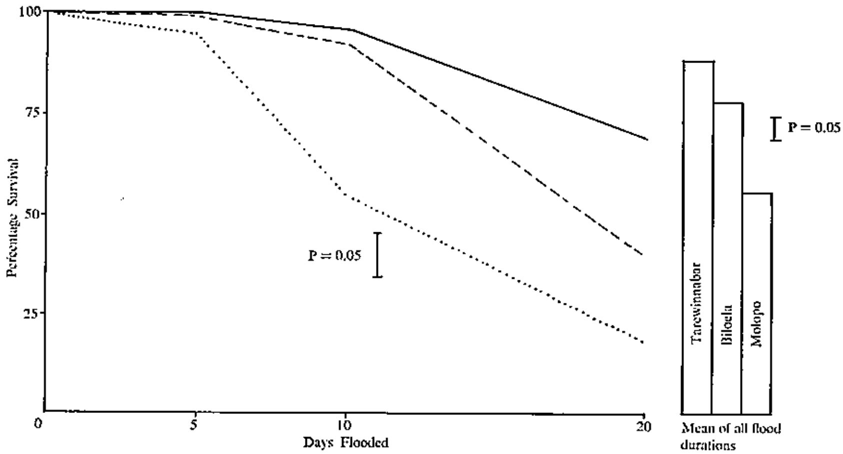

FIGURE 1
Effect of flooding on the survival of three *Cenchrus ciliaris* cultivars
(——— Tarewinnabar, — — — — Biloela, ... Molopo)
[Experiment 1]

The water height was maintained at 46 cm above the soil surface for all cultivars. This meant that Gayndah and American, which were lower growing than the other cultivars, had a greater proportion of their foliage submerged (Table 3).

TABLE 2
The effect of duration of flooding on the survival of plants of seven Cenchrus ciliaris *cultivars expressed as a percentage of the control (unflooded) (Experiment 2)*

C. ciliaris cultivars	Treatments — Days Flooded 0	10	15	20	25	30	Cultivar Mean (b)
	% Survival (a)						
Tarewinnabar	100 (2.35)*	100 (2.35)	86 (2.19)	86 (2.19)	72 (2.03)	65 (1.94)	84 (2.17)
Nunbank	100 (2.35)	100 (2.35)	100 (2.35)	86 (2.19)	71 (2.02)	36 (1.52)	80 (2.13)
Boorara	100 (2.35)	100 (2.35)	86 (2.20)	71 (2.02)	53 (1.77)	56 (1.81)	77 (2.08)
Biloela	100 (2.35)	100 (2.35)	93 (2.27)	56 (1.82)	28 (1.39)	79 (2.11)	74 (2.05)
Molopo	100 (2.35)	100 (2.35)	86 (2.20)	33 (1.47)	44 (1.64)	59 (1.86)	68 (1.98)
Gayndah	100 (2.35)	100 (2.35)	8 (1.97)	0 (0.71)	5 (0.88)	0 (0.71)	35 (1.49)
American	100 (2.35)	41 (1.60)	5 (0.88)	5 (0.88)	0 (0.71)	7 (0.91)	20 (1.22)

* Square root ($x + \frac{1}{2}$) transformation used for analysis.
L.S.D. (P = 0.05) — (a) (0.52); (b) (0.21).

TABLE 3

The number of leaves (or part of leaves) per pot of Cenchrus ciliaris *cultivars not covered by water, and estimated percentage plant submergence, at the commencement of flooding. (Experiment 2).*

Cenchrus ciliaris cultivar	No. of leaves wholly or partly above water	Percentage plant submergence
Molopo	95	65
Biloela	70	76
Tarewinnabar	56	79
Boorara	55	71
Nunbank	49	79
Gayndah	15	96
American	10	98

Experiment 3

With 50% submergence Tarewinnabar and Molopo were more flood tolerant than American ($P = 0.05$) (Table 4). 100% mortality was first recorded after 12 days flooding for American, and 18 days (data not presented) for Tarewinnabar and Molopo. Tarewinnabar showed greater survival than Molopo after 12 days flooding. At 25% submergence Tarewinnabar showed 12% survival after 24 days while all plants of Molopo were killed after 18 days (data not presented).

After 6 days 100% submergence caused the greatest reduction in dry matter yields in Molopo and American with little difference between 25% and 50% (Figure 2). There was no significant effect of percentage submergence at this stage on Tarewinnabar. After 12 days flooding least reduction in dry matter yields occurred with 25% submergence, although this was only significant with the more flood susceptible American. The same trend occurred after 18 days flooding with the least reduction occurring in the more flood tolerant Tarewinnabar. After 24 days flooding there was no difference between any submergence for American, while 25% submergence had least effect on Tarewinnabar, and 50% least effect on Molopo.

DISCUSSION

Results from all three experiments have established that there is a difference in flood tolerance between buffel grass cultivars. When all cultivars were tested together in experiment 2, it was shown that the tall cultivars had better flood tolerance than the

TABLE 4

The effect of duration of flooding on the survival of plants of three Cenchrus ciliaris *cultivars when 50% submerged (Experiment 3)*

Days Flooded	Tarewinnabar	*C. ciliaris* cultivars Molopo	American
		% Survival	
0	100 (2.35)*	100 (2.35)	100 (2.35)
6	79 (2.11)	77 (2.09)	44 (1.64)
12	34 (1.48)	5 (0.88)	0 (0.71)

* Square root ($x + \frac{1}{2}$) transformation used for analysis.
L.S.D. ($P = 0.05$) = (0.654).

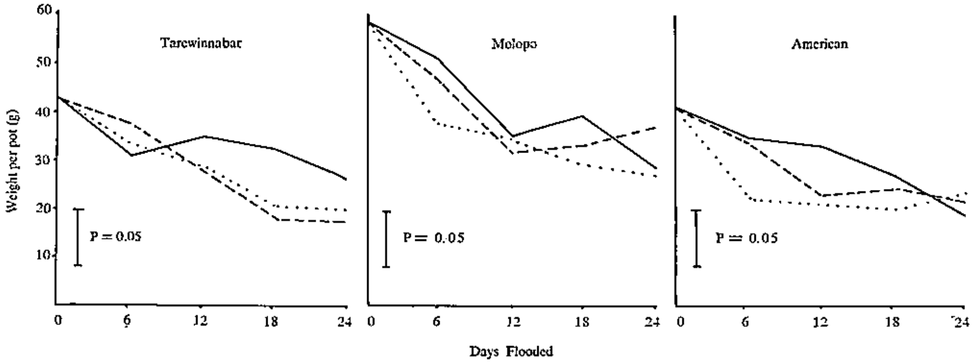

FIGURE 2

Effect of flooding depth (plant submergence, ——— 25%, — — — 50%, ... 100%) on the weight per pot (g) of three *Cenchrus ciliaris* cultivars [Experiment 3]

short ones. Although the differences were often slight there was an indication that the order of tolerance was Tarewinnabar, Nunbank, Boorara, Biloela, Molopo, Gayndah, American. These cultivars were flooded with a constant height of water (46 cm), which meant that the two short cultivars, Gayndah and American, were almost totally covered while the tall cultivars were approximately 75% covered (Table 3).

Although there were different percentage submergences on the seven buffel cultivars in experiment 2, the range of tolerances obtained has been, in part, verified. Experiment 3 showed that although American was disadvantaged, presumably by its smaller stature, it had much less flood tolerance than Tarewinnabar and Molopo when similarly flooded. Also, Tarewinnabar was more tolerant of flooding than Molopo. In experiment 2 Molopo and Biloela had more "leaves" exposed while Molopo was the least submerged of the tall cultivars, yet they were the most affected by flooding, indicating that their lesser flood tolerance was real. A similar result from experiment 1 where the order of flood tolerance was Tarewinnabar, Biloela, Molopo, supports this. The results for Tarewinnabar, Boorara and Nunbank in experiment 2 should be valid as they received the same degree of submergence (Table 3).

The results for Gayndah remain inconclusive other than that this cultivar is presumably disadvantaged because of its smaller size when compared to tall cultivars and when completely submerged it is intolerant of flooding.

In experiment 3 an interaction between depth and duration of flooding on plant growth and survival was recorded. At short durations, depth of flooding *per se* was not always important. In this instance plants were more severely affected if covered by water than if some parts of the leaves were exposed to air (Molopo and American after 6 days flooding and Tarewinnabar after 12 days—Figure 2). At longer durations, depth of flooding became significant. The individual cultivars varied in response to the depth × duration interaction because of their different degrees of flood tolerance. The anomaly of greater growth being produced by Molopo at 50% submergence compared to 25% and 100% submergence at 24 days duration cannot readily be explained. However, some difficulty did occur in the collection of all material, due to degeneration when plants have died, and this may have contributed. A longer flood period for Tarewinnabar should have resulted in similar weights for the three submergences.

When total inundation did not occur on *Paspalum dilatatum* there was no obvious difference in flooding effect when water depth varied (Colman & Wilson 1960). This same effect was also recorded on the three buffel grasses in experiment 1 when even at the deepest flooding only 60% of the plant was covered. With temperate species, however, damage was greater as flooding depth increased (Rhoades 1967) and it is possible differences exist between temperate and tropical species.

The ameliorative effect of some exposed leaves could be due to a source of oxygen supply from the exposed leaves to the roots, as has been suggested by various authors as Cannon (1925) and Greenwood (1967); or as a means of transpiration of a toxic substance such as ethanol (Kenefick 1962).

Apart from the height, the greatest morphological difference between the tall and short cultivars is that the former are rhizomatous and the latter are not (Barnard 1967). Williams and Barber (1961) and Coult (1964) have suggested that aerenchyma tissues may serve either as an oxygen reservoir, or else as a system allowing the maximum amount of root or rhizome structure, with the minimum quantity of living tissue, thus achieving an economy in oxygen consumption per unit volume of root or rhizome. It could be inferred that the presence of rhizomes in tall cultivars allows a greater maintenance oxygen concentration in the "roots" which contributes to their better survival. However, of the tall cultivars, Molopo has the greatest rhizomatous development (Barnard 1967) but the least flood tolerance. Consequently, morphological adaptation alone does not appear to be an entirely satisfactory explanation of flooding tolerance. Crawford (1969) also points out the inadequacy of the morphological explanation of flooding tolerance and favours the role of metabolic adaptations to anaerobic environment, which results in the production and accumulation of ethanol and acetaldehyde (McManmon and Crawford 1971) so poisoning the metabolism.

The greater survival potential of Tarewinnabar over Molopo has been shown (Anderson 1973) to be due to its superior tiller survival (and concomitant leaf survival) and root tolerance to anaerobic conditions. Other than the hypothesis already submitted, causative effects are unknown.

There was a difference between the survival period of the same grasses in the simulated experiments, although the relative flooding tolerances between them remained the same. In experiments 2 and 3 the grasses were flooded at the same age to relatively similar submergences, yet those in experiment 2 were apparently less affected than in experiment 3. However, the maximum daily temperature during flooding in experiment 2 ranged from 25°C to 30°C (mean 28°C) while in experiment 3 it ranged from 27°C to 32°C (mean 30°C). It has been reported by Finn *et al* (1961), Rhoades (1967), and Beard and Martin (1970) that flooding tolerance of grasses is reduced with higher temperatures. It is thought that this temperature effect is the main cause of the differences that occurred between the experiments.

The unexpected increase in survival in experiment 2 of Biloela and Molopo at the longest flooding periods is not able to be explained. Although they were markedly reduced in vigour as assessed by a rating of the degree of chlorosis and weight of intact roots (unpublished data) the *in situ* plants nevertheless were still "alive". This increase has not been recorded in the other experiments in this series (experiment 1 and 3) or in a number of other experiments conducted (unpublished).

While there can be no direct application to the field it has been previously observed with some *Panicum* species (Anderson 1972b) that the relative flooding tolerance under simulated conditions was repeated in the field. It is not known if the same applies to the *Cenchrus* cultivars. It is known that buffel grasses have less flood tolerance than *Panicum coloratum* cv. Bambatsi and Kabulabula and *P. maximum* cv. Sabi, and are killed after 6 days' flooding in the field (Anderson 1970b). Where flooding occurs irregularly and is not severe (less than 6 days) it is thought that buffel grasses could be used in pasture mixtures. Only the tall free-seeding cultivars should be used, i.e. Tarewinnabar, Nunbank, Boorara and Biloela. The short cultivars, especially American, have the disadvantage of being completely submerged apart from having poorer flood tolerance. Although the tall cultivars may be killed in many floods they will regenerate from seed (Anderson 1972a). To ensure seed production (for regeneration) lenient grazing would be required during the summer growing season when floods are likely to occur.

ACKNOWLEDGEMENTS

Financial assistance f om the Australian Meat Research Fund and assistance with statistical analysis by Miss E. A. Goward, Biometry Branch, Department of Primary Industries, Brisbane, is gratefully acknowledged.

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(Accepted for publication September 1, 1973)