

Phyllode fall and nutrient content in a mulga (*Acacia aneura* F.Muell. ex Benth.) community in central Australia in response to rainfall

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Abstract. The fall of phyllodes from *Acacia aneura* F.Muell. ex Benth. (mulga) in central Australia was studied over 22 months from mid-1958 at four locations within a livestock reserve north of Alice Springs in the Northern Territory, in order to identify rainfall or seasonal triggers. Phyllode fall increased by at least an order of magnitude for short periods following rain of 15–20 mm or more on a ‘mature’ mulga site and similar trends were apparent for ‘young’ and ‘desert form’ mulga on the same site, and on a second, independent, ‘mature’ site. When rates of phyllode fall were high after substantial rain, at both ‘mature’ locations, ~30% of nitrogen and ~50% of phosphorus were withdrawn before abscission, suggesting that mulga was markedly conservative of these nutrients. Conversely, under dry conditions, when phyllode fall was relatively low ($<200 \text{ mg m}^{-2} \text{ day}^{-1}$), concentrations of nitrogen and phosphorus in fallen phyllodes were higher. Concentrations of potassium, calcium, magnesium and sodium did not vary consistently with increasing rate of phyllode fall, although overall levels of calcium and potassium were considerably higher in the second ‘mature’ location. This legacy study is of renewed interest given the potential of mulga communities to contribute to national carbon stocks, and the consequent need for robust field-based data on growth dynamics and carbon fluxes.

Keywords: litterfall, arid shrubland, nitrogen, phosphorus, nutrient withdrawal, carbon sequestration, rainfall trigger.

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Introduction

From mid-1958 to April 1960 a study of the time patterns in the shedding of phyllodes by *Acacia aneura* F.Muell. ex Benth. in a central Australian mulga community in response to rainfall was conducted. The nutrient content of the phyllodes was also examined. At the time there were no published studies of leaf or phyllode fall in arid Australian plant communities. Studies on the rates of fall of leaves and other plant materials on to the soil surface most commonly considered forest vegetation in the middle latitudes of the northern hemisphere. An early review of published data worldwide was undertaken by Bray and Gorham (1964).

In 2004, Liu *et al.* (2004) conducted a meta-analysis of litterfall observations in Eurasian forests (min-max leaf litterfall $23\text{--}1075 \text{ g m}^{-2} \text{ year}^{-1}$), and Neumann *et al.* (2018) analysed litterfall collected by a European monitoring network (mean \pm s.d. leaf litterfall $260 \pm 119 \text{ g m}^{-2} \text{ year}^{-1}$). An equivalent global summary for drylands has not been undertaken, but Holland *et al.* (2015) collated globally available

litterfall observations to 1997 that included 31 records for drylands. The mean leaf litterfall for these 31 records was $298 \text{ g m}^{-2} \text{ year}^{-1}$ (range of minimum to maximum of $13\text{--}862 \text{ g m}^{-2} \text{ year}^{-1}$). In a dry forest in Mexico, measured litterfall ranged from 277 to $344 \text{ g m}^{-2} \text{ year}^{-1}$, including non-foliar components (Búrquez *et al.* 1999). Thus, global data suggest that dryland vegetation shed a similar weight of leaves annually to more mesic vegetation. Leaf litterfall was positively correlated with the annual rainfall sum irrespective of species and forest types (Bray and Gorham 1964; Liu *et al.* 2004; Neumann *et al.* 2018). The rate of leaf shedding increased seasonally during summer months for evergreen species when rainfall was deficient (Bray and Gorham 1964). Deciduous species, however, had peak litterfall in autumn, when leaves senesce.

Published work in Australia is concentrated on *Eucalyptus* forest communities in south-eastern and south-western Australia (e.g. Hatch 1955; McColl 1966; Adams and Attiwill 1991). According to Pook *et al.* (1997) and Crockford and Richardson

(1998), leaf fall in evergreen eucalypts had a clear seasonal pattern, and temperature (or daylength), rainfall, and soil moisture could trigger leaf fall. There is scant information on litterfall for arid and semiarid woodlands and shrublands in Australia (Neumann *et al.* in press) where aridity is delimited by a median annual rainfall of <350 mm (Bureau of Meteorology 2005). Hart (1995) studied litterfall of *Callitris-Eucalyptus* communities in central New South Wales and McIvor (2001) measured litterfall in eucalypt woodlands in Queensland. Limited information on litterfall in mulga shrublands suggests that season is not influential. Wilcox (1960, 1974) found that maximum 'leaf and seed (pod)' fall appeared to occur only after substantial rains following a period of very low rainfall in a mulga community in Western Australia. Winkworth (1973) also reported peak rates of phyllode fall after rain in a central Australian mulga community. Burrows (1976) concluded that litterfall from mulga in south-west Queensland appeared to be independent of both season and rainfall, but his 4-weekly sampling regime may have been too infrequent to detect short-term rainfall responses. However, south-west Queensland has a particularly favourable water regime for mulga and is bioclimatically different from the rest of the mulga zone (Nix and Austin 1973). Consequently, mulga growth and phyllode fall may be a more continuous process in that region than elsewhere.

Nutrient cycling is important given Australia's old and strongly leached soils, but there is usually sufficient nitrogen due to large atmospheric pools and nitrogen-fixing bacteria. In contrast, phosphorus can be limiting, but on a global scale, resorption of phosphorus in Australian ecosystems is relatively efficient (Du *et al.* 2020). Burrows (1976) assessed levels of nitrogen and phosphorus in litterfall in a mulga community, comparing them with pre-abscission levels, and concluded that nutrient conservation was less than might be expected for the infertile soils there. He proposed that mulga depended on a 'tight extrinsic cycle' of nutrients achieved through its extensive root system and that, coupled with nutrient withdrawal before abscission, efficient cycling could be achieved.

Modelling analysis and remote sensing suggest that growth anomalies in semiarid ecosystems of the southern hemisphere, particularly those in Australia, can have substantial impacts on global carbon dioxide concentration (Poulter *et al.* 2014). Within Australia, the eucalypt woodlands of Queensland are an important contributor to national carbon stocks (Burrows *et al.* 2002). Given the wide distribution of mulga communities across arid and semiarid Australia, these communities are also potentially substantial carbon sinks. Mulga communities in south-west Queensland and north-west New South Wales, in particular, are now being used for carbon sequestration under the Avoided Deforestation and Human Induced Regeneration mechanisms of the Emissions Reduction Fund (ERF 2020; R. B. Hacker, pers. comm.). The robustness of these assessments for mulga communities Australia-wide is constrained by limited information on growth dynamics and carbon fluxes, with the possible exception of south-west Queensland (Fensham *et al.* 2012).

We investigated the relationship between rainfall and phyllode fall, and observations on the initiation of growth, in a central Australian mulga community to identify rainfall or seasonal triggers and to test which patterns found elsewhere apply to this species in central Australia. In addition, we investigated the

relationship between the phyllode fall data and the nutrient content of the phyllodes. Although the measurements were confined to phyllode fall under canopies, we estimated the role of mulga in carbon storage and carbon cycling by accounting for community-wide canopy cover, to indicate the potential of mulga communities to contribute to national carbon stocks.

Methods

Study area

The study sites were located in a mulga community within a livestock reserve some 24 km north of the township of Alice Springs in the Northern Territory of Australia, at an elevation of ~670 m. The reserve encompassed a watering point, Sixteen Mile Bore, at ~23°30'S, 133°50'E. The reserve was only used for brief periods by grazing cattle and thus the vegetation was in near pristine condition except within ~100 m of the bore (D. J. Nelson, pers. comm.). At Alice Springs (elevation 580 m), mean annual rainfall at the time of the study was ~267 mm (283 mm in 2020), with 190 mm falling in the summer months from October to March. The rainfall is highly variable on both annual and monthly time scales (Bureau of Meteorology 2020). Temperatures ranged from mean monthly minima and maxima of 4°C and 19°C in July, to 21°C and 35°C in January. Rainfall and temperature means were based on data collected between 1941 and 2020 (Bureau of Meteorology 2020).

Mature mulga trees on the reserve typically reached a height of 5 to 6 m. They were the only tree species present on the study sites. Occurring on the gentle slope (~1 : 500) of a deeply weathered peneplain, they tended to be grouped together into linear groves, several trees wide and 100 m or more long. The groves were situated more or less along contour lines. The intergrove areas were usually several times wider than the groves, and in most places had a sparse ground cover of a perennial tussock grass, *Eragrostis eriopoda* Benth. Locally in the intergroves there were clumps of young mulga with individuals ranging in height from ~0.5 to 2.0 m. The phyllodes of the common variety of *Acacia aneura* present on the site were ~1–3 mm wide, 1 mm thick and 3–10 cm long.

Methods of collection

Phyllode traps were made by covering square wooden frames on one side with cotton mosquito netting. The wood was of cross-section ~2 × 2 cm and the interior dimensions of the resulting frames were 75 × 75 cm, giving a collection area of 0.5625 m². The traps were made large enough, on the basis of a preliminary trial, for there usually to be measurable amounts of phyllode material (>0.01 g) fallen in 1 or 2 weeks and yet not so large that they were difficult to install flat on the usually heterogeneous ground surface near the bases of mulga trees. The frames were laid out flat so that the mosquito netting was in contact with the underlying soil surface. The latter had previously been cleared by carefully removing litter from the immediate area to be covered by the frames; otherwise minimal disturbance was caused in the vicinity of each trap.

Placement of traps

On 10 June 1958, 12 traps were placed under mulga in groves within a fenced 5 ha experimental area (hereafter termed the

‘mature-1’ site) 2.6 km north of the bore. Rainfall was measured daily at this site. Positions for traps were chosen subjectively to meet the following requirements: adequate representation within the groves present on the site; reasonably dense foliage vertically above each trap; minimum obvious interference with any instruments already installed (e.g. rain gauges; see Slatyer 1965). The canopy cover at the ‘mature-1’ site was ~20% overall and soils were red earth.

On 30 September 1958, an additional 15 traps were set out as follows.

1. Five traps under young mulga (≤ 2 m tall) in thickets located in intergroves within the ‘mature-1’ site, hereafter called the ‘young’ location.
2. Three traps under individuals of the ‘desert form’ of *Acacia aneura* (more recently identified as *Acacia minyura* Randell) within the ‘mature-1’ site, hereafter the ‘desert form’ location. There were several individuals of this variety located in the intergroves. The variety was characterised by phyllodes 3 to 4 mm wide, ~1 mm thick, 1 to 2 cm long, broader and lighter in colour than the common variety. It usually had a shrub growth habit.
3. Seven traps under parts of two groves contained in a 0.8 ha fenced site (hereafter the ‘mature-2’ site) that had been heavily grazed by horses previously and was ~3 km from the ‘mature-1’ site. This site was in a shallow un-incised drainage line and soils were loamier than those at the ‘mature-1’ site. Canopy cover of mulga was <20% across the ‘mature-2’ site.

Collections were made regularly from all traps until 12 April 1960.

Treatment of collected phyllodes

For most of the collection period, fallen phyllodes were gathered from the traps every 2 weeks. After the first 9 months it became evident that the rate of fall of phyllodes increased greatly in the first week or two after a substantial fall of rain. In consequence, the measurements were intensified to ~weekly collections at such times to get more detailed insight into phyllode fall dynamics.

At collection times, the phyllodes were gathered into paper envelopes, one envelope per trap. The samples were dried overnight at 105°C and weighed. The oven-dried phyllodes were stored in air-tight jars until chemical analyses were carried out. No collection was made of any flowers, fruits or branches which fell into the traps.

Chemical analyses of nitrogen, phosphorus, potassium, calcium, magnesium and sodium content were conducted on finely ground phyllode material. Citations for analytical methods for specific nutrients are unknown but see Williams and Twine (1967) for representative methodologies. The chemical analyses were limited to phyllodes from the ‘mature-1’ and ‘mature-2’ locations, because there was insufficient material from the ‘young’ and ‘desert form’ locations.

Nitrogen was determined by the Kjeldahl method, using concentrated sulfuric acid and potassium sulfate for the digestion, together with selenium as a catalyst. Phosphorus was determined colourimetrically at 400 nm by means of the molybdate-vanadate yellow colour complex. The aliquot for colouring-up was taken from a triple acid digest containing perchloric, sulfuric and nitric acids. The other elements were

determined from an HCl extract of the ash from ~2 g of the ground material. The ignition took place in a muffle furnace at ~500°C. Calcium was determined by titration of a precipitate of the oxalate with standard potassium permanganate solution. Magnesium was determined on the filtrate from the calcium oxalate by precipitation as magnesium ammonium phosphate, solution of the washed precipitate in dilute HCl and colourimetric determination of the phosphate. Potassium and sodium were determined using an EEL flame photometer.

Data analyses

We calculated average phyllode fall by collection period ($n = 63$ for the ‘mature-1’ location), for the four locations (‘mature-1’, ‘young’, ‘desert form’, ‘mature-2’). Daily on-site rainfall measurements were plotted against the phyllode-fall time series. Tests for significant relationships between phyllode fall and rainfall were not used due to the inconsistent timeframes of phyllode fall sampling (see ‘Treatment of collected phyllodes’). For instance, comparing weekly with biweekly data would have violated the comparability of the observations. We linked phyllode fall and nutrient data for the ‘mature-1’ and ‘mature-2’ locations and used segmented regression to detect breakpoints in the data. We used paired *t*-tests to check for significant differences between locations and treatments, after excluding the ‘mature-1’ data collected before inclusion on 30 September 1958 of the ‘mature-2’ site. The data used in these analyses are presented in the Supplementary material Table S1, available at the journal’s website. All analyses and visualisations were computed using the R language and environment (R Development Core Team 2016).

Results

Phyllode fall

There was a close association between substantial falls of rain and onset of increased mean rates of phyllode fall of up to an order of magnitude (Fig. 1a, b). Rainfalls of ~5 mm or less in the interval between collections produced no discernible effect on the rate of phyllode fall in the ‘mature-1’ location. Six small falls of ~1–6 mm, totalling 26.9 mm and occurring between 23 November 1959 and 7 December 1959, were also ineffective. An isolated fall of 14.7 mm on 3 October 1959 was followed by an approximate doubling of the rate of phyllode fall at the ‘mature-1’ location in the next week. However, in March 1959 a total of 15.9 mm of rain over three successive days (11.4, 2.5 and 2.0 mm) produced no appreciable change in the pattern of phyllode fall. Fourteen days later on 30 March 1959 when another 18.8 mm fell, there was an order of magnitude increase in the rate of phyllode fall at the ‘mature-1’ location during the following week. It seems likely that the soil had retained sufficient moisture from the earlier event to supplement that from the 30 March fall.

The results suggest that ~15–20 mm is the minimum rainfall necessary for a major phyllode fall (defined as an order of magnitude or greater increase in rate) following several months of very little rain.

Examples of a time lag between rain and an increase in the rate of phyllode fall are apparent (Fig. 1) in late March–early April 1959, late May 1959, early October 1959, and mid to late

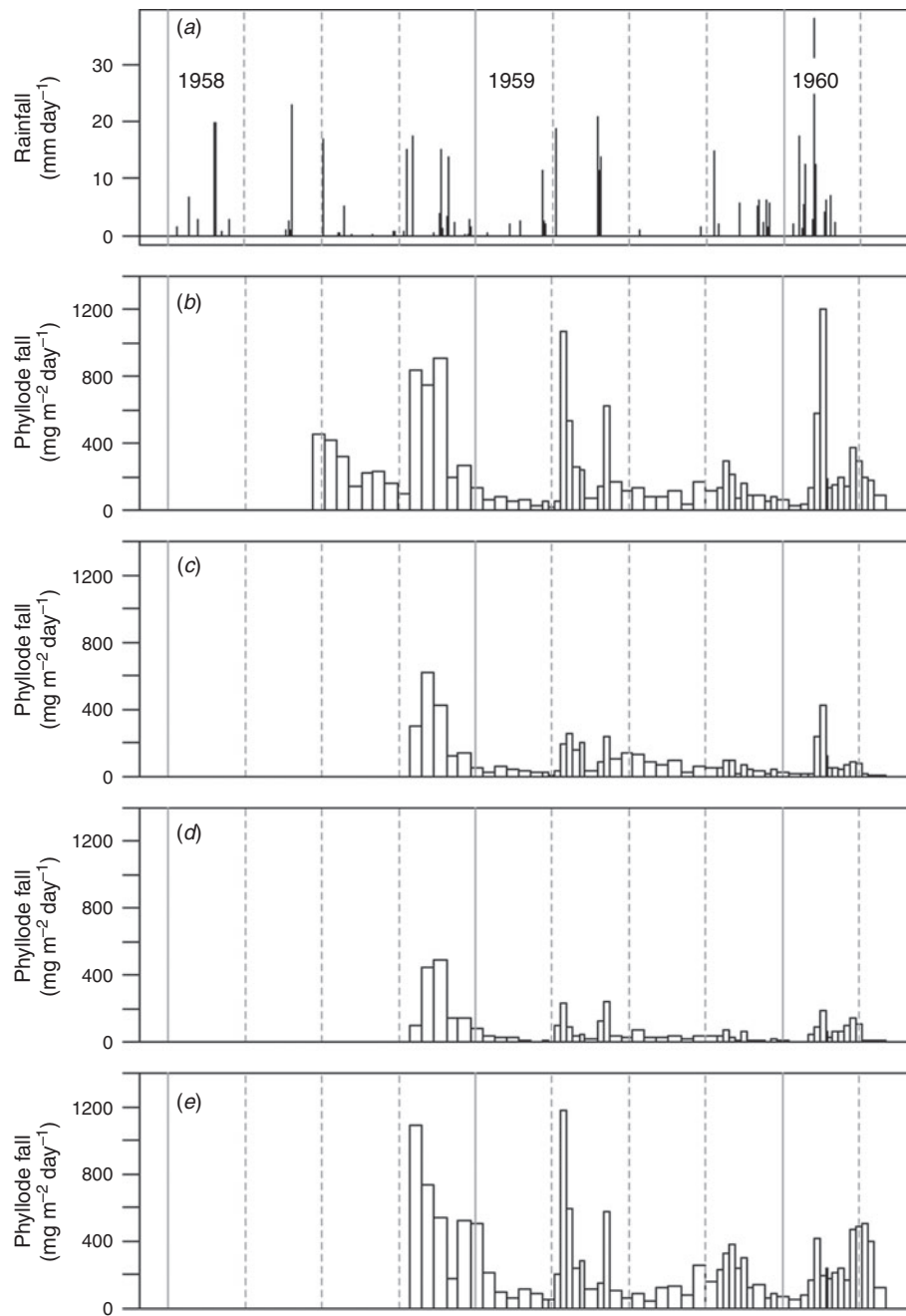


Fig. 1. Daily rainfall observations (a) compared against phyllode fall collections at four locations: (b) 'mature-1' (number of traps $n = 12$); (c) 'young' ($n = 5$); (d) 'desert form' ($n = 3$) and (e) 'mature-2' ($n = 7$). Phyllode fall was averaged by collection period, which varied in length and was mostly 7 and 14 days. The vertical dashed lines indicate 3-month periods and the vertical solid lines represent 1 January (start of year).

January 1960. Taken together, these cases suggest a lag of about a week or slightly less.

The length of time between successive substantial rainfalls may affect the pattern of phyllode fall. With two such rains less than 2 weeks apart, as in mid to late January 1960, the rate of phyllode fall, already increased by an order of magnitude after the first rain, increased still further after the second rain (Fig. 1b–e). Lesser second peaks were apparent in April to May 1959, with six weeks

between successive falls (Fig. 1b, c, e). The 'young' and 'desert form' mulga had only about half of the 'mature-1' phyllode fall, while the amount or timing of phyllode fall at the 'mature-2' location (Fig. 1e) was similar to that at the 'mature-1' location. For the whole observation period, the phyllode falls at the 'young' and 'desert form' locations were slightly different from one another using paired *t*-tests ($P = 0.003$), whereas the 'mature-1' and 'mature-2' locations were not significantly different ($P = 0.174$).

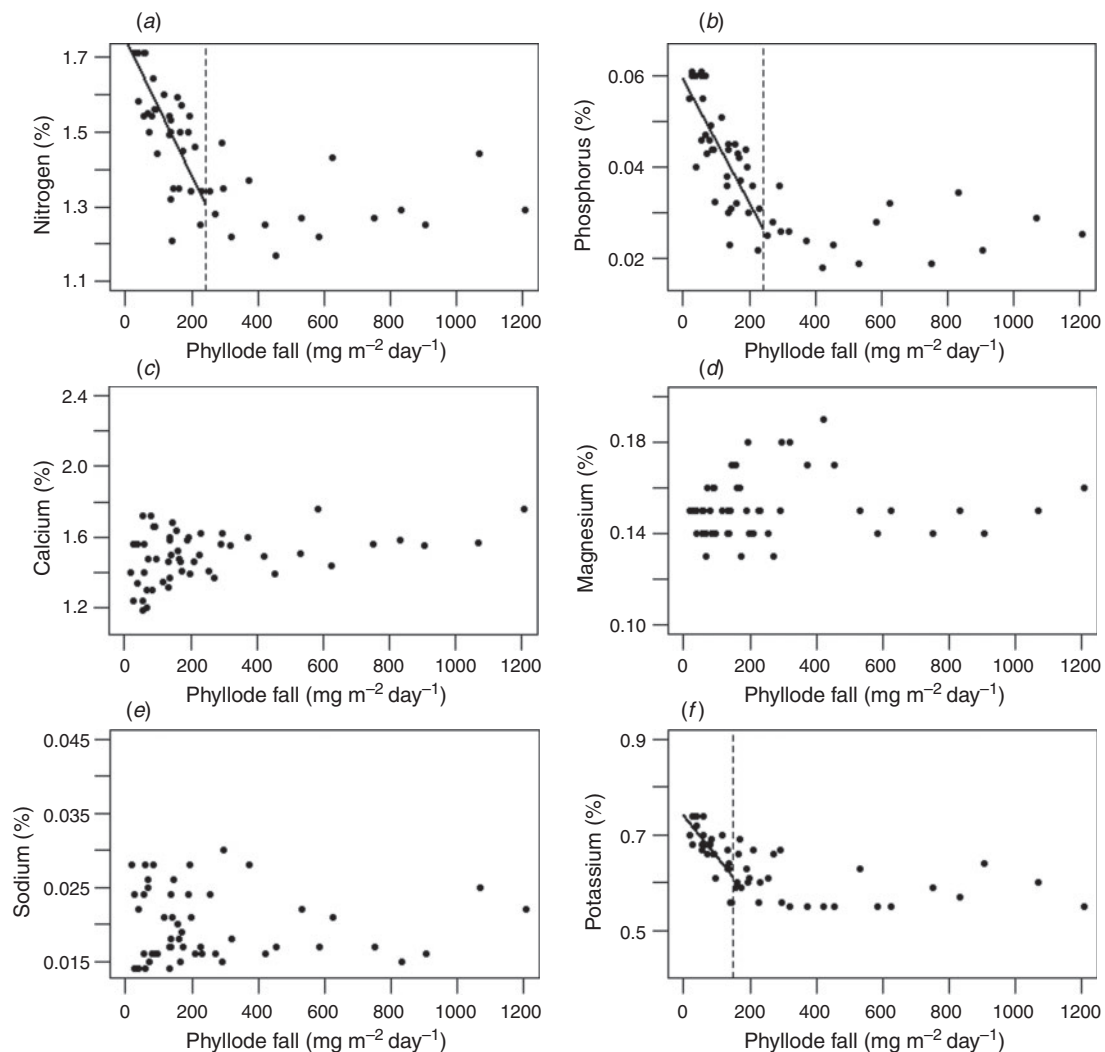


Fig. 2. Nutrient concentrations in phyllodes versus phyllode fall for the 'mature-1' location. Every dot represents one collection period ($n = 63$). Results are shown by analysed nutrient: nitrogen (a), phosphorus (b), calcium (c), magnesium (d), sodium (e) and potassium (f). The vertical dashed lines indicate statistically significant breakpoints, where the correlation changes. We added solid line segments, if trend was significant ($P < 0.001$). Coefficient of determination (R^2) for nitrogen = 0.555, for phosphorous $R^2 = 0.558$, and for potassium $R^2 = 0.578$.

Nutrient analyses

Significant inverse relationships between the rate of phyllode fall and concentrations of nitrogen and phosphorus in the phyllodes were identified for both 'mature-1' and 'mature-2' locations (Figs 2a, b, 3a, b) up to a value of ~ 200 and $\sim 400 \text{ mg m}^{-2} \text{ day}^{-1}$ respectively. A significant inverse relationship between the rate of phyllode fall and concentration of potassium in the phyllodes was also found but only for the 'mature-1' location, whereas there was a positive relationship between the rate of phyllode fall and concentration of sodium in the phyllodes in the 'mature-2' location only. For some nutrient concentrations (nitrogen, calcium, magnesium and potassium) a paired t -test showed significant differences ($P < 0.001$) between the two locations (Fig. 4). The greatest differences in absolute terms were for potassium and calcium and both were larger at the 'mature-2' location (Fig. 4).

Discussion

Phyllode fall

At the time of this study, R. O. Slatyer was also working at the 'mature-1' location. He reported (Slatyer 1962) that 3–4 days after a rainfall of at least 13.7 mm, the mulga phyllodes reached maximum values of relative water content. Thus, the sharp increases in the rate of phyllode fall observed soon after substantial rainfall in this study (Fig. 1) probably occurred because *Acacia aneura* lost its dormancy induced by low soil moisture and began active growth. It is likely that older phyllodes were shed as soon as shoot elongation and new phyllode enlargement began. A brief delay between the stimulus of plentiful soil moisture and the resultant response of resumption of active metabolism is to be expected, given Slatyer's (1962) results. Both Wilcox (1960, 1974) in Western Australia and Winkworth (1973) in central Australia also observed peak rates of mulga

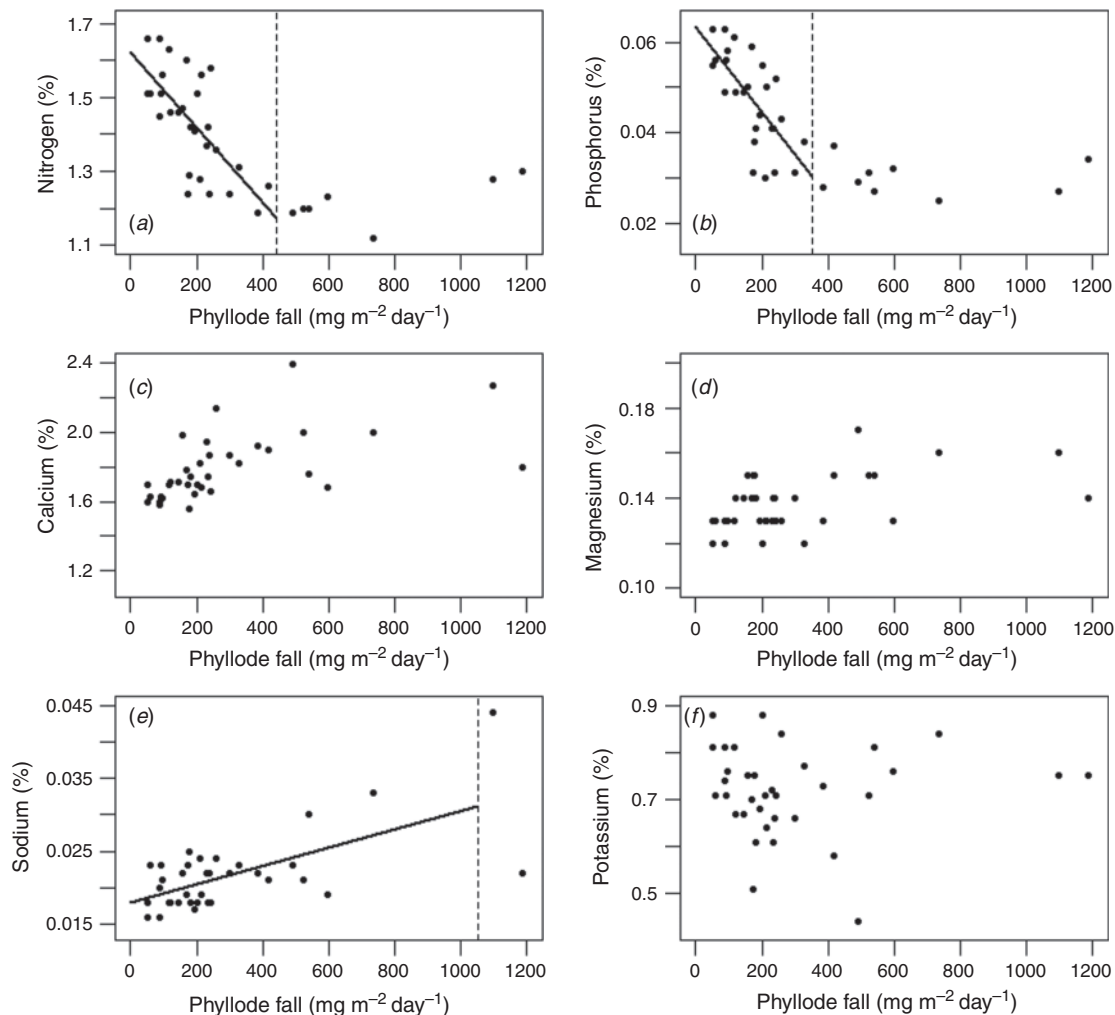


Fig. 3. Nutrient concentrations in phyllodes versus phyllode fall for the 'mature-2' location. For details of display see Fig. 2. Coefficient of determination (R^2) for nitrogen = 0.479, for phosphorous R^2 = 0.482, and for sodium R^2 = 0.341.

phyllode fall after substantial rain. Mulga litterfall in Queensland, on the other hand, appeared to be independent of season and rainfall (Burrows 1976), although the 4-weekly sampling regime used in Burrows' study may have been insufficient to detect short-term rainfall responses. Annual average rainfall at Burrows' (1976) mulga site was 75% higher than that at Alice Springs (see Nix and Austin 1973 for a bioclimatic analysis of the mulga zone) and rainfall during his study was above average, in contrast to this study, where rainfall over the phyllode-collection period was below the long-term average.

We noted differences in phyllode fall between the four locations, in terms of magnitude and timing (Fig. 1*b–e*). The initiation of a major fall of phyllodes will likely be dependent on variables such as age of trees, efficiency of the branches in promoting trunk flow of water, root distribution, season and local soil permeability (e.g. Slatyer 1962, 1965). Some of these factors will influence soil moisture availability and others will affect the tree's ability to take up water.

Slatyer's (1962) results also indicated that, if rain fell again a month or so later, the trees would still be growing slowly or perhaps just entering growth dormancy. A high proportion of

their phyllodes would probably have been produced in response to the earlier rainfall and be relatively young. This could explain why a secondary peak in the rate of phyllode fall was less than the peak which followed the first rain after a dry period, in this study (e.g. April–May 1959; Fig. 1). Mulga can also shed phyllodes under severe drought conditions, which may lead to the death of the plants (D.J. Nelson, pers. comm.). These conditions were not experienced during this study but prevailed in subsequent years to 1966 (see Marsden-Smedley *et al.* 2012 for the definition of drought).

There were some anomalous results. One is the heavy fall of phyllodes in the 'mature-1' location after rains in early October 1958 (Fig. 1), which appeared to peak about a month after the rain whereas later episodes of heavy phyllode fall lasted for only a week or two. This result may be an artefact of the 2-weekly sampling regime used at that time. The second apparent departure from the commonly observed pattern occurred in March 1960, when the rate of phyllode fall rose to a minor peak at all four locations about a month after the last major rain. There was a general flowering of mulga at that time and some additional phyllode shedding may have been associated with reproductive

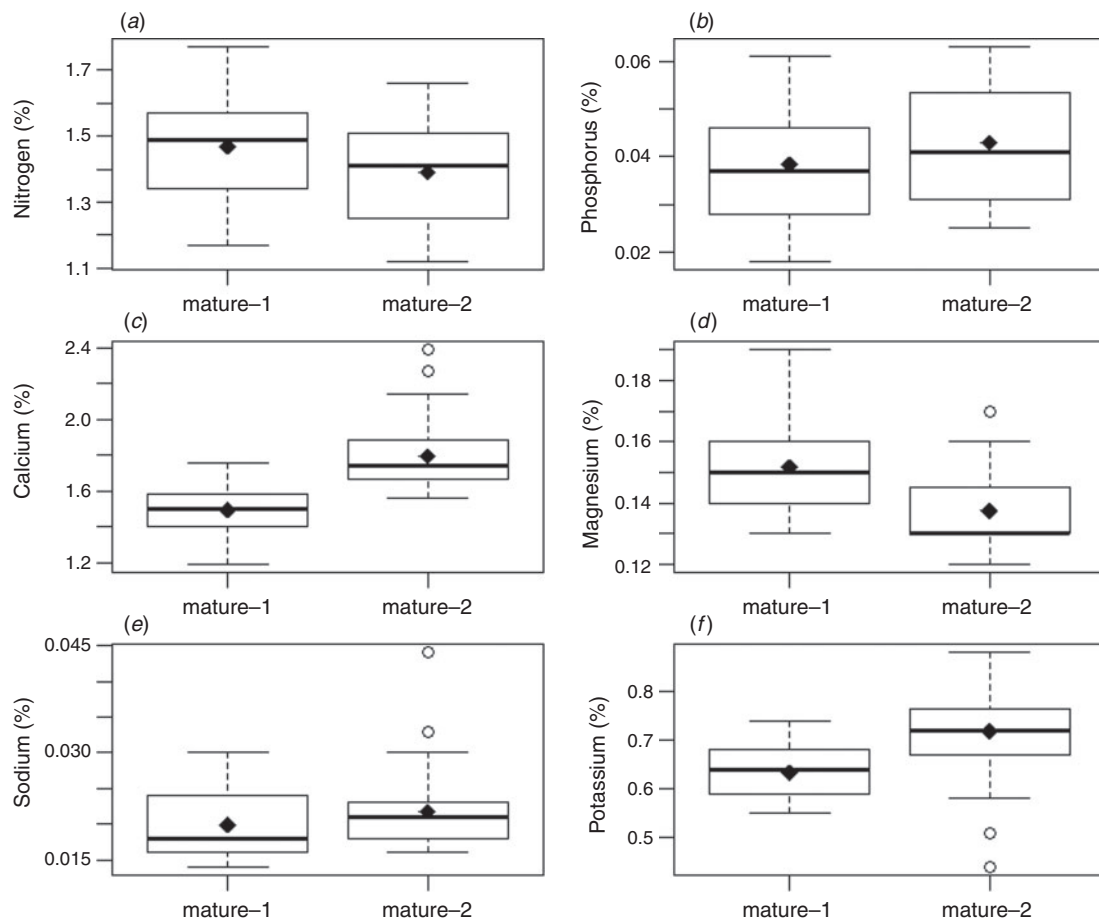


Fig. 4. Nutrient concentrations compared for 'mature-1' and 'mature-2' locations. The letter designations are for each element as indicated in the caption for Fig. 2. The box represents the median and the 25th and 75th percentiles, the whiskers extend to 1.5 of the interquartile range, the values outside this range are indicated by circles and the diamonds show the arithmetic means. Paired *t*-tests indicate significant differences for nitrogen, calcium, magnesium and potassium ($P < 0.001$). For phosphorus P -value = 0.034 and for sodium $P = 0.428$.

processes. The peak phyllode fall in late October–early November 1958 may also have been associated with flowering but there were no phenological records being kept at the time.

Our results and the available literature suggest that major phyllode falls after heavy rains were a physiological response of mulga to increased soil water availability. When the plants were in growth dormancy it is likely that loss of phyllodes was accidental and physically caused (e.g. detachment by wind, birds, insects). In that case, there would have been no physiological trigger to initiate withdrawal of nutrients and thus during dormancy nitrogen and phosphorus reached their highest observed concentrations (see Figs 2, 3). We can hypothesise that during the declining phase of major phyllode fall episodes, as soil moisture stress gradually increased, some phyllodes were still being shed under physiological control, enabling withdrawal of some nitrogen and phosphorus, whereas others were being lost by physical agency without nutrient withdrawal.

Nutrient cycling

It is generally recognised that nitrogen and phosphorus are physiologically mobile when leaves are shed (Crockford and

Richardson 1998; Drenovsky *et al.* 2019). Potassium can also be mobile (Ruck and Gregory 1955; Stenlid 1958; Guha and Mitchell 1966; Turner and Lambert 1983). However, in this study potassium withdrawal was only apparent at the 'mature-1' location (Figs 2a, 4). Burrows (1976) reported the withdrawal of 50–60% of phosphorus before abscission in mallee eucalypts and mulga and withdrawal of ~50% of nitrogen in mallee but only ~25% in mulga. Burrows (1976) proposed that the leguminous nitrogen-fixing mulga did not require tight intrinsic cycling of nitrogen and instead relied on an efficient extrinsic cycle. Since nutrient content of phyllodes before abscission was not measured in our study we cannot explore the point further.

Accumulation of calcium and magnesium in physiologically shed leaves is widely reported (Ruck and Gregory 1955; Stenlid 1958; Guha and Mitchell 1966; Thomas 1969; Turner and Lambert 1983) but there was no such evidence in our data (Figs 2, 3). We noted significantly more calcium and potassium and significantly less magnesium in phyllodes from the 'mature-2' location compared with those from the 'mature-1' location (Fig. 4). Sodium was the only nutrient that increased in concentration with increasing phyllode fall for the 'mature-2' location and thus showed a

contrasting behaviour to the main nutrients, nitrogen, phosphorus and potassium (Fig. 3). This result had the lowest coefficient of determination and may simply be attributable to site differences and/or past grazing, in the absence of any replication.

Phyllode fall at rates exceeding $\sim 200 \text{ mg m}^{-2} \text{ day}^{-1}$ accounted for $\sim 71\%$ by weight of the total fall over the entire measurement period at the 'mature-1' location. For rates of phyllode fall exceeding ~ 200 and $\sim 400 \text{ mg m}^{-2} \text{ day}^{-1}$ at the 'mature-2' location, the proportion by weight of the total fall over the entire measurement period was ~ 74 and $\sim 47\%$ respectively. The substantial withdrawal of nitrogen ($\sim 30\%$) and phosphorus ($\sim 50\%$) at times of high rates of phyllode fall (see Figs 2, 3) suggests that the mulga tree is markedly conservative of the available nitrogen and phosphorus resources.

Carbon cycling

Low carbon flux of mulga of $\sim 149 \text{ mg C m}^{-2} \text{ day}^{-1}$ (assuming 50% carbon content and observed average phyllode fall $297 \text{ mg m}^{-2} \text{ day}^{-1}$) results in $\sim 54 \text{ g C m}^{-2}$ transferred from canopies to the ground every year within the groves of the 'mature-1' site. We note that this is considerably less than mean leaf litterfall observed in other dryland vegetation of $149 \text{ g C m}^{-2} \text{ year}^{-1}$, assuming 50% carbon content (Holland *et al.* 2015). Intergroves have considerably less canopy cover and, based on our data for 'desert form' mulga (Fig. 1), the phyllode fall in intergroves is $\sim 36\%$ ($106 \text{ mg m}^{-2} \text{ day}^{-1}$) compared with mature mulga in groves. The assumption of 20% overall canopy cover reduces the carbon flux due to phyllode fall in this central Australian mulga community to $11 \text{ g C m}^{-2} \text{ year}^{-1}$ under dry conditions (annual rainfall 194 mm in 1958 and 140 mm in 1959). Phyllode fall measured in this study represents $\sim 17\%$ of the $64 \text{ g C m}^{-2} \text{ year}^{-1}$ net primary production (i.e. carbon allocated into plant biomass) calculated with the BIOS2 modelling environment. BIOS2 combines meteorological, soil and vegetation to derive carbon and water fluxes across Australia and is used for calculating the Australian carbon budget (Raupach *et al.* 2001; Haverd *et al.* 2013). Linking data on phyllode fall observed in this study with measurements of grass and herbaceous production, above and below ground tree growth and mortality would capture the main carbon fluxes in mulga and enable validation of the BIOS2 results, that to date are largely unchecked for mulga ecosystems. Our results and the available literature suggest that mulga through phyllode shedding has considerable but variable effects on terrestrial carbon storage and cannot be ignored in national or global accounting, given that mulga systems cover ~ 150 million ha (Silcock *et al.* 2016). Expected reductions in the present lengthy fire interval of 20–100 years common for mulga communities (Murphy *et al.* 2013) will need to be incorporated in future estimates of carbon fluxes and nutrient cycling in mulga.

Despite being collected over six decades ago now, this legacy data gave us new insights into arid mulga ecosystems. This would not have been possible without the 'off-site' storage of data sheets and records by the lead author and his willingness to make this hard-won data accessible to the scientific community.

Conflicts of interest

The authors declare no conflicts of interest.

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