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Effects of water and nutrient additions on the timing and duration of phenological stages of resprouting *Terminalia sericea*

H. Moyo *,1, M.C. Scholes, W. Twine

Authors School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, WITS 2050 Johannesburg, South Africa

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ABSTRACT

There is limited information about the factors that affect phenology of coppicing trees. This study examined the effects of water and nutrient additions on the phenology of coppicing *Terminalia sericea* trees in a semi-arid savanna in South Africa. Cut trees were exposed to different levels of water and nutrient (nitrogen and phosphorus) supplementations over a period of two years. Phenological stages monitored fortnightly included leaf bud presence, leaf presence and fruit production. Leaf presence followed a similar distribution to bud presence, peaking during the wet season (November–April), with the low water and high nutrient additions having the highest significant effect. Change in leaf color from the typical silvery green to yellow was delayed to later in the wet season, while higher leaf numbers were recorded during the wet seasons for trees supplemented with water and nutrients. Results indicate that the increase in water and nutrient availability has direct consequences for extending the growing season of resprouting trees. This extension has positive effects on increasing the photosynthetically active period, thus potentially increasing the carbon gain and growth of trees. Although generally low throughout the study in all treatments, fruit presence was mainly in supplemented trees.

1. Introduction

Phenology is the study of the annual growth cycle of plants with respect to the timing of their flowering, fruit production, development of new leaves and leaf senescence (Chidumayo, 2001; Norman, 1989; Seghieri et al., 2009). Phenology is a dominant and often overlooked aspect of plant ecology, from the scale of individual tree species to whole ecosystems (Cleland et al., 2007). The timing of tree phenological events is important for regrowth of trees in most environments as it is a trait highly responsive to changes in environmental conditions (Pinto et al., 2011). Phenology in relation to coppicing has been particularly overlooked, with most published data referring primarily to undamaged mature trees (Archibald and Scholes, 2007; Chidumayo, 2001).

Coppicing is a common response of trees to damage, enabling survival after severe disturbances such as cutting (Kaschula et al., 2005b; Hardesty, 1984). In systems prone to disturbances, such as savannas, the ability of savanna tree species to coppice is a key attribute of their resilience and productivity (Kaschula et al., 2005b; Shackleton, 2001). Regrowth of trees through coppicing is more obvious in dry savanna ecosystems than in the wet tropics because there is a lower probability of successful regeneration through seeds and also due to higher incidences of herbivory and drought (Del Tredici, 2001). After a cutting event, the early growth rate of coppice shoots is faster than seedlings or cuttings, because coppice shoots benefit from the already established existing root system (Forrester et al., 2003; Hardesty, 1984). Coppice shoots have an early onset of growth and have a continuous development of new nodes until late into the dry season (Laureysens et al., 2005).

Although resprouting has become recognized as a key functional trait in plant ecology over the past decade (Lawes and Clarke, 2011), there is still limited information about the physiology and growth strategies of resprouting trees in savannas (Neke, 2004; Pote et al., 2006). Available information about the influence of disturbance and cutting frequency comes from ecosystems that are different from savannas. In savannas, water, rather than temperature, has often been reported as more limiting for the growth of plants (Archibald and Scholes, 2007; Broadhead et al., 2003; Sankaran et al., 2008; Scholes and Walker, 1993). It is important to know how the various factors such as availability of water and nutrients interact in order to influence coppice growth. Such information is essential for assessing the ecological impacts of disturbances impacting trees, and for designing management strategies aimed towards sustainable production of coppice, e.g. for fuelwood. Also, there are few data indicating how soil nutrient limitation and

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* Corresponding author at: University of the Witwatersrand, Johannesburg, South Africa.

E-mail address: hmthunzi@gmail.com (H. Moyo).

[1] Current address: School of Animal, Plant and Environmental Sciences, University of the Witwatersrand, WITS 2050 Johannesburg, Gauteng, South Africa. Tel.: +27 720932227.

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soil moisture interact to influence the physiological processes involved in the response of trees to cutting (da Silva et al., 2008; Henderson and Jose, 2010).

This study set out to investigate the effects of water and nutrient additions on the timing of phenological stages of coppicing *Terminalia sericea* trees. The question asked was: how does an increase in resource availability influence the timing and duration of the phenological stages in coppicing trees? Altering the length of the growing season through rainfall changes and temperature fluctuations can have direct influences on plant processes such as leaf growth (Archibald and Scholes, 2007). Following this reasoning, it was hypothesized that water and nutrient additions will cause late dry season leaf flush and extend leaf survival into the subsequent dry season, thus potentially extending the growing season. Therefore, a longer growing season would result in an increase in overall productivity. This would be caused by supplemented trees photosynthesizing for longer and accumulating carbon for extended periods compared to trees with no water and nutrient additions.

The species chosen for this study was *T. sericea* Burch. ex. DC, also known locally as silver cluster leaf. *T. sericea* was chosen as the study species because it is typically abundant in dense stands in the study area, known to coppice vigorously, the widely used source of firewood in southern Africa, and more knowledge of its regenerative capacity can contribute to management recommendations for sustainable utilization. *T. sericea* is an important part of the everyday life of communal villagers, contributing financially when wood is sold or through burning as a source of energy (Neke, 2004; Shackleton, 1993; Shackleton et al., 2004).

2. Methods

2.1. Study site

The study was conducted at the Wits Rural Facility (WRF), a 350-ha research station owned by the University of the Witwatersrand, in the central savanna lowveld of Limpopo Province, South Africa (24° 30′ S; 31° 06′ E). The study site is semi-arid, with a mean annual rainfall of ~650 mm, concentrated in the summer season (between October and April) (Kaschula et al., 2005a; Neke et al., 2006; Shackleton, 1997). The study spanned a two year period (Sept 2010–Sept 2012), starting at the end of the dry season of 2010, during the period when trees begin to leaf-flush. Rainfall totals over the study period were above-average (825 and 915 mm in years 1 and 2, respectively). The mean annual temperature is 22 °C (Neke et al., 2006; Shackleton, 1993). Drought events are common and occur about every once a decade (Neke, 2004). The most common soil types in this region are the shallow, sandy, nutrient poor lithosols, underlain by granitic gneiss (Kaschula et al., 2005a; Kaschula et al., 2005b; Neke et al., 2006; Shackleton, 2001). The vegetation is dominated by tree species in the Combretaceae (notably *T. sericea*) as well as Mimosaceae (e.g. *Acacia gerrardii* Benth) families, characteristic of the Mixed Lowveld Bushveld vegetation type (Shackleton, 2001; Neke et al., 2006; Shackleton, 1993).

2.2. Experimental design

A 3 × 3 factorial experiment (nine plots) that was replicated in three sites was established in September 2010 to determine the effects of water and nutrient additions on the coppice response of *T. sericea*. All three sites were on the slope crests, and therefore had shallow, coarse-textured and dystrophic soils (Neke, 2004; Shackleton, 1997; Shackleton, 1999). Ten trees were selected per plot, with the number totalling 270 for the experiment. Although there were differences in the initial stump diameter, single-stump trees were selected based on the initial tree stump diameter; which was standardized (from 5–9 cm) to control its effects on coppice response. In rare cases where single stump trees could not be used, multi-stump trees of a combined basal area falling in the range of trees measuring between 5 and 9 cm in diameter were used. Stumps of that diameter range were considered medium-sized and were chosen because it has been suggested that larger stumps take a shorter time to respond to a cutting event, positively influencing initial coppice growth through having a larger residual root system (Shackleton, 1997).

Tree cutting in this study was conducted manually using a chain-saw towards the end of the dry season in September 2010. Trees were cut at a standard height of approximately 25 cm from the ground, since research has shown that cutting height influences coppice response (Ibrahima et al., 2007; Kaschula et al., 2005b; Khan and Tripathi, 1986; Shackleton, 1997). A 30 cm radius was marked around each tree and grass cleared to reduce competition for water and nutrients. Grass was also cleared for trees that were not supplemented with water or nutrients. Long-term average monthly (18 years) rainfall data for the WRF records was used to derive water treatments. Water addition treatments were as follows;

1. Control (W_0) — no water additions through-out the study,
2. Low (W_+) — trees were supplemented with an amount of water 0.5 times the long-term mean rainfall for that month and,
3. High (W_{++}) — trees were supplemented with the long-term mean rainfall for that month.

This monthly amount of rainfall was then divided by four to obtain weekly amounts for supplementing trees for a period of about 18 months beginning in September 2010. Water was applied next to the base of each stump.

For the experimental plots that had nutrient additions, nitrogen (N) and phosphorus (P) were supplied in a commercial fertilizer in the form of ammonium phosphate, with a total of 80 kg N ha^{-1} for the high fertilizer addition treatment and 40 kg N ha^{-1} for low fertilizer addition treatment. Considering that the amount of fertilizer was added once at the beginning of each of the two growing seasons (therefore twice during the study — in October 2010 and October 2011), this amount (160 kg N ha^{-1} in total was added) was regarded as a high rate of N application in several studies (Le Roux and Mentis, 1986; Mbatha and Ward, 2010; Tilman, 1987). A commercial dry fertilizer blended as 4:3:4:1 (N, P, K, Zn) and mixed according to 120 g/kgN and 90 g/kgP was purchased. Fertilizer additions were as follows (Fig. 1);

1. Control (N_0) — no fertilizer additions through-out the study,
2. Low (N_+) — 0.13 g of N and 0.1 g of P per tree, and
3. High (N_{++}) — 0.27 g of N and 0.2 g of P per tree.

The dry fertilizer was applied by coring a hole next to the base of the stump with a diameter of 3 cm and a depth of about 10 cm and depositing the fertilizer into the hole. The assumption was that all the fertilizer that were added using this mechanism were utilized exclusively by the tree. Fertilizer was added after the first rains fell in October 2010 and also in October 2011.

2.3. Phenological stages monitored

Every two weeks (from December 2010 to September 2012), phenological stages for each resprouting tree were estimated visually. Phenological stages monitored fortnightly were:

(i) Leaf bud initiation — described as the proportion of foliage that consisted of leaf bud initials (juvenile and unexpanded leaves) on a tree. Leaf bud initials were estimated as 100% (when leaf bud initial presence on a tree was at maximum), 75% (when leaf bud initial presence on a tree had reduced by about 25% from the previous estimated presence), and so on.
(ii) Presence of yellow leaves (% yellow leaves) — estimation of foliage that showed any slight discoloration or change from the normal silvery-green color to yellow, brown etc. of present leaves on the tree. Classification was estimated as 100% (when