PROBLEMS WITH USING THE HERBICIDE TEBUTHIURON FOR CONTROLLING *SERIPHIUM PLUMOSUM*

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INTRODUCTION

Seriphium plumosum, commonly known as slangbos (this name used hereafter) is a shrub, indigenous to South Africa, occurring predominantly in the Fynbos and Grassland Biomes (Figure 1). The species has invaded mesic grasslands in the eastern part of the country. As the plants are unpalatable to livestock and tend to out-compete palatable grasses, their proliferation has reduced the carrying capacity of many areas (Snyman, 2009).

Farmers attempt to eradicate or at least reduce the abundance of slangbos. A popular approach is to treat it with herbicides, most commonly soil-applied products such as tebuthiuron (IUPAC name 1-(5-*tert*-butyl-1,3,4-thiadiazol-2-yl)-1,3-dimethylurea; chemical formula $C_9H_{16}N_4OS$). Tebuthiuron is non-selective, meaning that it can potentially kill any plant that absorbs it. It is highly effective in killing and keeping out vegetation; for example, it is used to keep paved roads, railways, sidewalks (pavements) and fencelines permanently devoid of vegetation (United States Environmental Protection Agency, 1994). The herbicide is typically applied to the base of the target slangbos plant (although this level of precision is not available when applied aerially), where it enters the soil following rain. The volume of soil that it poisons is potentially lethal to any plant (slangbos or other) that has a root therein. A notable advantage of using tebuthiuron is that it needs only to be applied in small quantities directly onto the ground. This means that a) a person applying the herbicide (the operator) needs to carry only a relatively small amount of poison to be able to treat a large number of plants, and b) the time to treat one plant is short (compared with e.g. a full cover spray).

Tebuthiuron has a long half-life – that is, it breaks down slowly in the soil and remains toxic for a considerable period. A half-life of about one year is commonly reported in literature (e.g. U.S. Department of Agriculture, Soil Conservation Service, 1990; Helling, 2005), but may be as low as 20 days under certain conditions (Cerdeira et al., 2007), or “considerably greater” than 15 months in high-carbon or low rainfall environments (Chang and Strizke, 1977). The one year half-life estimate may be associated with areas receiving between 1000 and 1500 mm rainfall per year (Chang and Strizke, 1977). Emmerich (1985) reported, but did not substantiate, that the half-life may be as long as 61 months and that tebuthiuron reaches non-detectable levels in soil after three to seven years. Gilliom (2007) gave an estimate of 1050 days (nearly three years) for the chemical to reach non-detectable levels in the soil.

Slangbos invasions are seen as being damaging to the environment and to agriculture. Paradoxically, application of tebuthiuron is often used as a solution to the problem, although the herbicide itself is a potent, long-lasting, non-selective toxin. This paper addresses some of the effects of tebuthiuron on the grassland environment, provides evidence that other herbicides can kill slangbos, and considers whether there is a role for tebuthiuron in slangbos control.

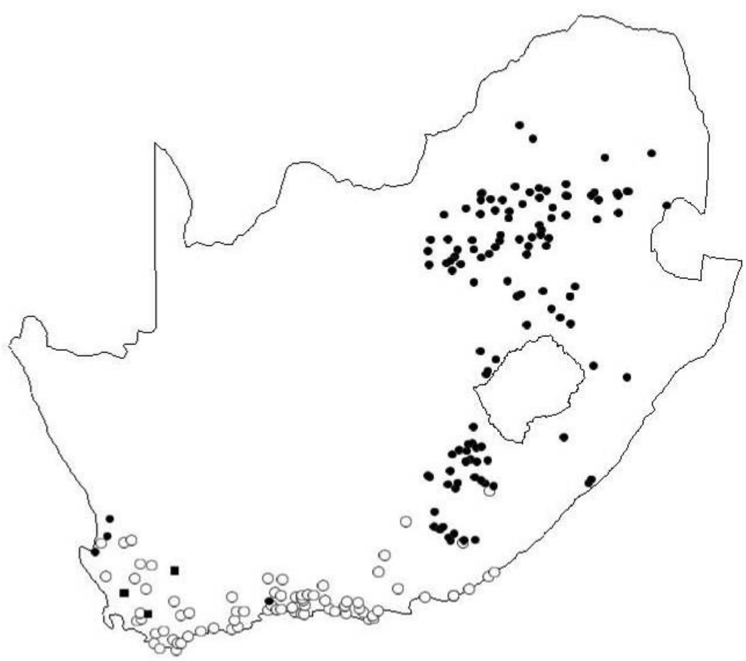

Figure 1. Distribution of *Seriphium plumosum* in South Africa, shown as formerly classified as *Stoebe vulgaris* (closed circles), *Stoebe plumosa* (open circles), and *Stoebe cinerea* (closed squares). Data from Acocks (1954).

THE PROBLEM OF BARE PATCHES

A common consequence of using tebuthiuron in veld is that it forms bare patches. Initially, these are typically small (Figure 2A), because the volume of soil into which they dissolve is small. Patches that are several years old are usually larger (Figure 2B), and while the size dynamics of such patches over time have not been studied, it is a tenable hypothesis that they have increased in size over time (Figure 3). Further to having a long half-life, tebuthiuron also remains active in the soil because it is not readily adsorbed onto soil particles (in particular clay), giving it a low Sorption Coefficient (Koc) (Vogue et al., 1994). The properties of having a long half-life, and a low Koc, combine to give tebuthiuron a Pesticide Movement Rating of "Very High" (Vogue et al.,1994), meaning that the chemical has a high ability to move through the soil while remaining biologically active. This would explain how bare patches could grow over time.

The formation of bare patches, if they are larger than the original slangbos plant (which many are), nullifies any value derived from applying the herbicide in the first place. The target plant is killed, certainly, but a) grasses do not colonise the bare areas, and b) there will probably be a nett decrease in the total amount of grass, because the herbicide-affected area is larger than the slangbos-affected area ever was.

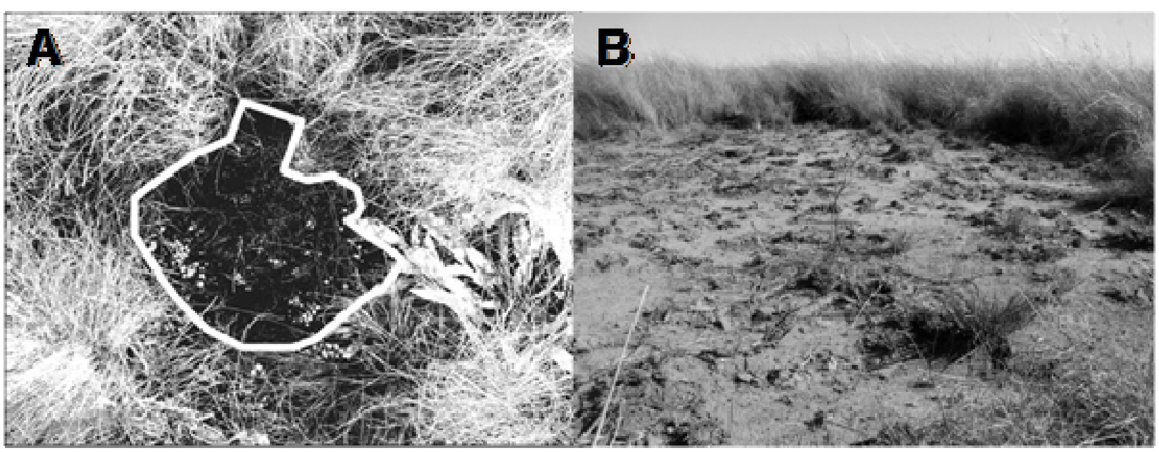

Figure 2. A) Small dead patch (delimited by white line) caused by a pellet of tebuthiuron applied aerially. The patch is approximately 0.1 m across. B) Large dead patch several years after bushes within the patch had been individually treated with tebuthiuron. The patch is approximately 2 m across.

Figure 3. A bare patch, approximately 1 m in diameter, showing the decaying remnant of a slangbos stump (delimited by circle). The plant had been treated with tebuthiuron approximately three years earlier.

A key question about the bare patches is how long they persist. All herbicides degrade in the environment (in this case the soil) at some rate, and the relation between concentration and time approximates exponential decay. Hypothetically, therefore, concentrations would never disappear, but rather tend toward zero. A further issue is of importance here: the concentration necessary for the herbicide to be biologically active. For example a herbicide, after four half lives, would be reduced to approximately 6% of its original amount. If this concentration was too low to have any meaningful biological effect, then plants would re-establish. Assuming a half-life of one year in the case of tebuthiuron, then it would be anticipated that its effects would disappear after four years if a concentration of 6% was not biologically effective.

To test the effects of tebuthiuron in the soil Du Toit and Sekwadi (2012) planted grass (oats) and dicotyledonous (cabbage) seeds in soil that had been treated with tebuthiuron, to control slangbos, between two and eight years earlier. Soil collected from untreated adjacent grassland several meters away served as a control. After eight weeks, survival in the control was approximately 90%, while in the tebuthiuron-treated soils only 4 of 170 plants were alive, although these showed obvious effects of lethal poisoning (complete senescence except for the growing tip – this was the pattern of mortality in all the other plants). In practical terms, therefore, mortality of seedlings growing in soil treated up to 8 years previously was complete (Figure 4).

The problem with the formation of bare patches, therefore, is that the patches are greater in size than the initial slangbos plant, appear to increase in size over time, and can preclude colonisation by plants for at least eight years.

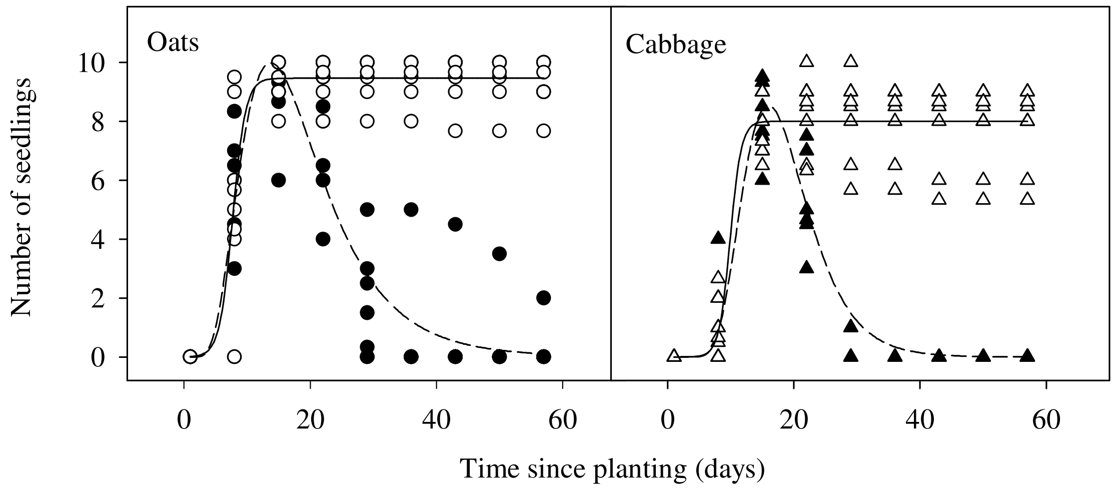

Figure 4. Survival curves for Oats and Cabbage seedlings planted in soil treated (closed markers; dashed line) and not treated (open markers; solid line) with tebuthiuron between two and eight years previously. Du Toit and Sekwadi, 2012.

THE PROBLEM OF NON-TARGET PLANTS

Most plant species in grasslands, sometimes around 90%, are not grasses but rather 'forbs', which are typically perennial herbaceous or lightly-woody shrubs (van Wyk, 2004). However, most of the biomass of grasslands is indeed grass (Morris, 2004), and this is the valuable component for livestock production. Because of this, agriculturalists have tended to focus solely on the grass component of grasslands, and largely ignore the forb component. However, forbs can play a very important role even in agricultural systems, especially considering that many forbs are legumes. Legumes are plants that have a symbiotic relationship with *Rhizobium* bacteria, and have the ability to convert atmospheric nitrogen (N_2) into the plant-available nitrogen compound ammonia (NH_3). This nitrogen immediately benefits the legume, but over time – through the processes of grazing and senescence – naturally fertilizes the soil with nitrogen. This means that the nitrogen content (and hence forage quality) of grasslands that have legumes is higher than those without legumes (Tilman et al., 1997; Mulder et al., 2002).

Tebuthiuron kills plants by destroying chlorophyll (Ross and Childs, 2011). Sometimes, a plant that has been poisoned will lose all its leaves, and then sprout new leaves. These leaves die, and the cycle continues until the plant has exhausted all its reserves and dies. It follows that the plants that would presumably be most susceptible to tebuthiuron poisoning would be those with extensive root systems (they stand a higher chance of encountering tebuthiuron) and a relatively small aerial component (a small amount of tebuthiuron can easily kill all the leaves). This growth structure is typical of grassland legumes, as noted by van Wyk (2004): "The bulk of the biodiversity of the grasslands is underground, not above ground. What you see is just the 'tip of the iceberg'".

EFFECT OF OTHER HERBICIDES ON SLANGBOS

Slangbos is susceptible to other herbicides, such as glyphosate and metsulfuron methyl (du Toit, unpublished data; Figure 5).

Glyphosate is a non-selective herbicide that is applied as a full-cover spray onto the above-ground portion of the plant. It has a relatively short half-life (c 65 days) and a very high Koc value – the herbicide is immediately adsorbed onto soil particles, rendering it unavailable to plants (Vogue et al., 1994; Giesy, 2000). Its Pesticide Movement Rating is "Extremely Low" (Vogue et al., 1994). However, because it is a non-selective herbicide, non-target plants adjacent to the target plant are usually also killed, resulting in a bare patch; it is therefore usually not recommended for use in rangelands. However, because of the non-persistence of the herbicide, the bare patches are usually colonised relatively quickly (Figure 5A). Despite its low persistence, Glyphosate would be a poor choice for slangbos control because of its non-target effects.

Metsulfuron methyl is a selective herbicide (it kills dicotyledenous plants and not grasses) when applied as a full-cover aerial spray. It also has residual pre-emergent properties in the soil, meaning that herbicide that reaches and enters the soil can prevent the germination of seeds. However, non-target grass plants are not affected, and can fill the space left by the dead target plant (Figure 5B). Its soil half-life is c 75 days, and its Pesticide Movement Rating is "high" (Vogue et al., 1994) – it must be remembered, however, that despite remaining active and having the ability to shift through the soil, its activity is restricted to germinating seeds, not established plants. Metsulfuron methyl appears to be a good choice for slangbos control, especially for small plants, because adjacent grass plants can quickly fill the space that the slangbos previously occupied. For controlling large plants, there may be a risk that the bare patch, which remains after the slanbos plant has died, may not colonise quickly owing to the pre-emergent properties of the herbicide. This affect would, however, probably be relatively short, and can be mitigated by avoiding over-wetting of the target plant, which would minimise the amount of the herbicide reaching the soil.

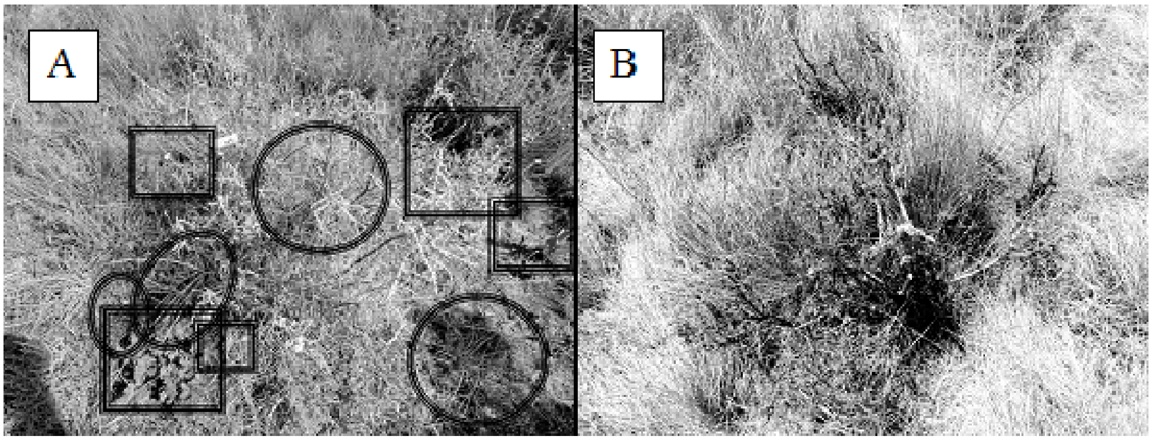

Figure 5. A) A slangbos plant killed using the non-selective, non-residual herbicide Glyphosate. Highlighted are grasses (circles), forbs (squares) and sedges (ovals) that have colonised the patch within six months of treatment. B) A slangbos plant killed using the selective, residual (seeds only) herbicide metsulfuron methyl.

IS THERE A ROLE FOR TEBUTHIURON IN SLANGBOS CONTROL?

To answer this question, consider several scenarios:

1. Veld that is completely invaded by slangbos, with only few remnant grass plants remaining;
2. Veld that is partially – say 50% - invaded by slangbos;
3. Veld that has a very high density of young slangbos seedlings, and the biomass is predominantly grass; and
4. Veld that is lightly invaded by slangbos at a very low density.

In scenario 1, a uniform application of tebuthiuron (e.g. from an aeroplane) would likely kill the population of slangbos. To recover, however, plants would need to recruit, and recruitment would be hindered by the presence of tebuthiuron in the soil. Additionally, plants recruiting in a largely bare (following the death of slangbos) area would have little competition from other plants (because there are very few), and may be able to explore and exploit nutrients in a larger volume of soil than if there were competition, i.e. have a larger root system. This would increase the chance of encountering a patch of toxic soil, and hence of mortality. Additionally, the zone of influence of the herbicide would probably increase over time as it moved through the soil.

In scenario 2, the slangbos could be selectively (spot treatment) or non-selectively (aerial treatment) poisoned. The problem, as for scenario 1, is that grass would not be able to recolonise the bare patches, so the problem would not be solved in the long-term. Non-target effects may be very high.

In scenario 3, the application density of tebuthiuron would be very high, which would likely reduce the total grass component and hence exacerbate the problem. Non-target effects would be very high (grass and legumes).

In scenario 4, tebuthiuron would have little effect on the composition of the veld, because it would be applied at a low density. However, because it is at a low density it would be simple to use less-damaging herbicides that had minimal non-target effects, such as metsulfuron methyl.

Despite these arguments, it is acknowledged that there are grasslands that have been treated (especially aerially) with tebuthiuron that do appear to have recovered their grass component and improved their condition. However, the long-term effects (especially considering movement of the toxin within the soil) through the formation of bare patches, and the non-target (particularly legume) mortality and hence reduction in quality, have not been considered or measured.

CONCLUSION

The general conclusions are that tebuthiuron should not be used for slangbos control because:

1. The long active half-life and drift through the soil are likely to result in the formation of bare patches, which reduce the amount of forage available to animals;
2. Non-target effects may be severe, especially regarding the quality of food available for grazers; and
3. Any benefits derived through its use are likely to be short-term, but nullified or reversed in the long-term.

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