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Hot water steam in dock control

Broad-leaved dock (***Rumex obtusifolius***) reduces productivity as well as forage quality in permanent grassland and is difficult to control. Steam is considered an excellent medium for the thermal control of broad-leaved weeds. Dock roots were treated in the soil down to a depth of ten centimetres with a hot-water/steam mixture (120° C at 30 bar). Treatment effects were strongly dependent on soil moisture and treatment time. With dry soil conditions, shorter treatment times were possible. Hence, for example, at 30 vol.-% soil moisture a treatment time of 30 seconds was necessary in order to achieve a weed mortality rate of 80 %. Here, 2.4 litres of water and 0.048 litres of diesel were required per plant, which corresponds to 96 litres of diesel for a weed infestation of 2 000 plants per hectare.

Keywords
Broad-leaved dock, *Rumex obtusifolius*, thermal weed control, steam, hot water

Abstract
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Broad-leaved dock (*Rumex obtusifolius*) causes problems in forage production on many permanent-grassland sites [1]. A ‘space invader’ with a high oxalic acid and tannin content, it reduces both the yield and quality of forage. Its extensive root system allows it to regenerate quickly after mowing [2]. Extremely competitive and highly capable of regeneration, this perennial is difficult to control without chemicals. Manual removal with a purpose-designed dock weeder is currently the norm in organic farming. This highly physically strenuous procedure allows the removal of up to 60 plants per hour (own measurements, unpublished). Clearing a hectare of land potentially infested with 2 000 dock plants therefore requires 33.3 hours of labour. For this reason, the agricultural research station Agroscope Reckenholz-Tänikon ART is searching for dock-control methods that can be automated. Initial studies show that treating the dock roots with a hot-water/steam mixture prevents resprouting.

Materials and Methods

The hot-water/steam mixture was produced with a commercially available high-pressure cleaner (Kärcher HDS 9/18-4 M). Setting the device to a pressure of 30 bar and an average water temperature of 120 °C at the outlet resulted in an average flow rate of 4.9 litres/min.

The high-pressure cleaner was transported on a trailer together with the requisite water tank (**figure 1**). Electricity was produced by a 380-V (15-kVA) generator. The diesel required to heat the water was taken from an external fuel tank. The amount of diesel consumed was determined gravimetrically after each test series, which generally consisted of 20 plants. The efficiency achieved by the device in this test resulted from the ratio of (a) the amount of energy theoretically necessary to heat the water to the appropriate temperature, to (b) the amount of energy of the actually measured diesel consumption. The hot-water/steam mixture was applied via a 10-m-long hose using an injection nozzle which we constructed ourselves (**figure 2**).

The method was tested on a total of 711 dock plants growing on permanent grassland and arable-forage acreage. Solitary plants at five locations were measured via high-precision RTK-GPS (real-time kinematic GPS, Trimble R7, Sunnyvale, CA, USA) for subsequent success monitoring. Length of treatment was 5, 10, 15, 20, 30 or 40 seconds. Soil moisture was determined by volume with core-cutter samples from a depth of 010 cm (dried at 105 °C).

Visual success monitoring of resprouting was carried out by means of GPS location of the plants four, eight and twelve weeks after treatment. Plants that had not resprouted after 12 weeks were deemed to have died off.

The statistical analysis was performed within the framework of a logistical regression with a linear mixed-effects model (glmm: generalised linear mixed-effects model, Tibco Spotfire S+ ® 8.1 for Windows, Somerville, MA, USA) which examined the influence of treatment time, soil moisture and location on the resprouting of the dock plants.

Fig. 1

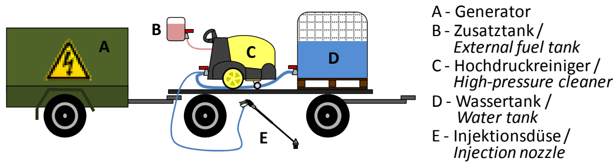


Diagram of the experimental setup with generator, high-pressure cleaner, external fuel tank, water tank and injection nozzle

Fig. 2

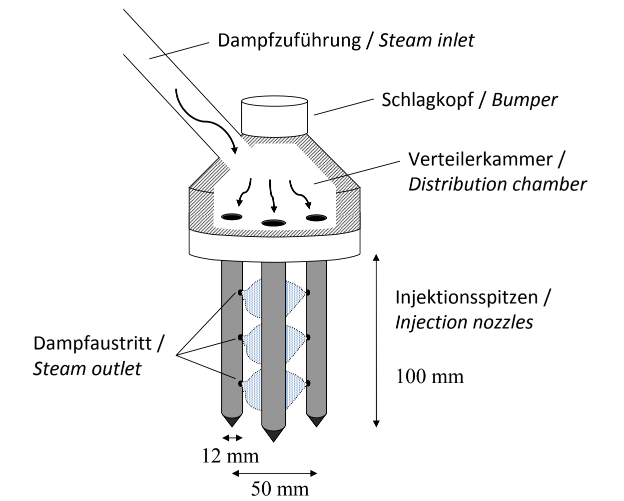


Diagram of the injection nozzle; the steam outlet is directed at the centre of the arrangement

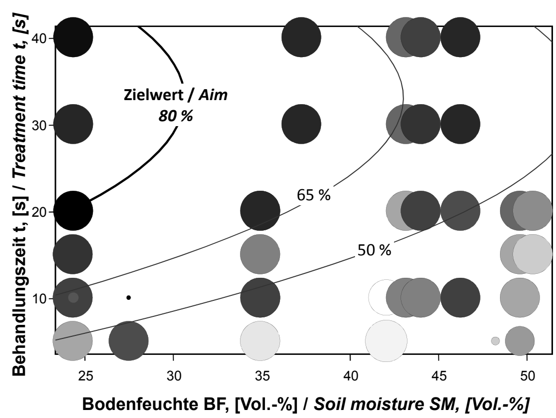
Results

Factors influencing resprouting

The statistical evaluation attests to the highly significant influence of treatment time (TT) ($p < 0.001$) and soil moisture (SM) ($p < 0.001$) on dock mortality rate when a hot-water/steam mixture is used. In addition, the treatment time is included in the statistical function with a quadratic effect ($p = 0.003$). In this way, a combination of the influences of treatment time and soil moisture leading to the same result in terms of mortality rate are illustrated (**figure 3**). The area of the circle is proportional to the number of treated plants per series (as a rule, n = 20). The colouring of the circle represents the mortality rate: the lighter the shading, the greater the mortality rate. To the left of the isolines lie the areas for which the combination of treatment time and soil moisture achieve the same mortality rate. Thus, for the sought-after mortality rate of at least 80 %, soil moisture must not be higher than 30 Vol.-%. Treatment time and soil moisture are fixed variables, whilst location is a random variable. The linear mixed-effects model is as follows:

$$\text{logit}\,(P[Y=1]) = -\,0.694 - 0.156 \cdot TT + 0.062 \cdot SM - 0.002 \cdot (TT)^2 \quad \text{(Eq. 1)}$$

Fig. 3

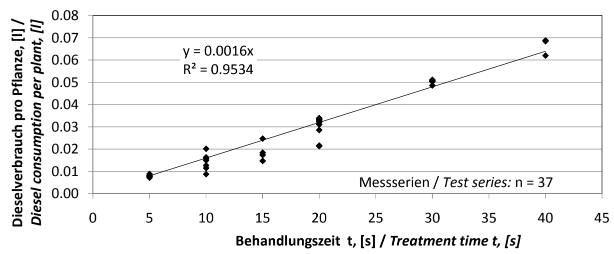


Function of mortality rate, treatment time and soil moisture. The size of the circles represent the number of plants (5 to 21 qty). The shades of grey represent the mortality rate: the darker the grey the higher the mortality rate. Areas of identical mortality rates are to the left of the isolines

Water and energy use

Determining the diesel consumption of a test series (**figure 4**) involves heating the water from approx. 15 °C to about 120 °C. The range shown is a result of tests being carried out at off-peak times.

Fig. 4



Diesel requirement per plant in function of the treatment time (one dot represents the average of 20 plants)

A treatment time of 17 seconds, which corresponds to a requirement of 1.4 litres water and 0.027 litres diesel per plant, is needed to achieve the sought-for dock mortality rate of 80 % in fresh soil (SM: 20 Vol.-%). At 30 Vol.-% soil moisture, this figure is 30 seconds, corresponding to 2.4 litres of water and 0.048 of diesel.

For first-time heating of water to treatment temperature by means of an instantaneous water heater inside the device itself, an average additional 12.2 litres of water and 0.24 of diesel are consumed. In these special experimental settings, the efficiency of the heating unit (ratio between the theoretical and measured energy required to reach the temperature of 120 °C) is 65 %.

Discussion

The studies show that it is possible to kill off dock plants through the use of a hot-water/steam mixture. This method for treating individual plants represents a further development of previous applications using water vapour for above-ground weed control over large areas [3; 4; 5] or for sterilising soils [6; 7]. With the method introduced in this paper, soil moisture strongly influences the success rate. The higher the soil moisture, the longer the necessary treatment times, and hence the higher the use of energy and water. With soil moisture levels of 30 Vol.-% and above, the success rate drops to under 80 %, even with long treatment times of 40 seconds. During the dry summer months, therefore, practical use is especially effective. For an assumed dock infestation of 2 000 plants per hectare and a soil moisture level of 30 Vol.-%, 4 850 litres of water and 96 of diesel are required to treat an area of one hectare. At 20 % soil moisture, 54 litres of diesel are still required. Compared to mechanical methods, the hot-water/steam method has the advantage of not requiring any movement of earth, and hence not encouraging the germination of dock seeds. In addition, it can be assumed that the soil in the region of the steam outlet is sterilised over a very small area. The unknown soil texture and the variability of the dock roots are factors that greatly influence the success of the treatment method. The challenge consists in applying the hot-water/steam mixture as directly to the roots as possible, in order to prevent losses and increase the success rate. The amount of earth unnecessarily warmed during the injection is not quantifiable. Bearing in mind soil moisture at the time of application constitutes an initial measure for decreasing the energy requirement.

Conclusions

The studies show that the control of dock weeds by means of superheated steam – an approach that is suitable for organic farming – is not only possible, but has proven very effective. The energy requirement must be rated as limiting for the method. The vast majority of farms have a high-pressure cleaner. The dock-control method presented in this paper could prove worthwhile if the double use of an available high-pressure cleaner with steam stage and an independent power supply were possible. Before its wider use in practice, however, it is crucial that the method be further optimised, and especially that the energy requirement per treated plant be decreased.

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