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Dock-control via microwave – energetic and financial considerations

A powerful microwave device was tested for the non-contact control of dock weed on grassland. The optimum treatment times for a maximum re-sprout rate of 20 % were determined in three different trial variants. Energy requirement, costs and fuel consumption were also established.

Keywords
Broad-leafed dock plants, *rumex*, weed-control, microwave

Abstract
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Broad-leaved dock (*Rumex obtusifolius*) is a common but unwelcome plant in meadows and pastures, as cattle find it unpalatable and tend to avoid it. This is due to high levels of oxalates and tannins in the plant. The feed value according to [1] is given as „1“ (very low). Because of their vigorous growth habit dock species are very competitive and are therefore seen as appropriating the space and nutrients of valuable fodder crops. Reserves stored in the well-developed roots of dock plants form the basis of their huge regenerative capacity when damaged, e.g. after moving or grazing.
The chief methods of dock control in organic farming are manual. On the one hand the flower heads are removed from the fields to prevent self-seeding, and on the other they are controlled directly by digging up and removing the dock roots.

Can microwaves provide a solution?

Organic farming is interested in a largely automated procedure for dock control. Microwave technology is a non-contact method of heating dock plant roots in the ground to such a high temperature that proteins denature, DNA is destroyed and hence the plant dies. Heating time and energy input are the key factors in the success of this procedure.

The prototype and trial variants

A self-propelled prototype was built following various preliminary trials with positive outcomes (**figure 1**). Its principal components are a generator (1), a high-voltage unit with cooling fan (2) and a hydraulic adjustable head with magnetrons and waveguide exits (3). Twelve magnetrons together supply an output of 18 kW. Each magnetron carries the microwaves in a separate open-ended waveguide. The exits are arranged in two columns of six lines, giving rise to a total exit area of 18 × 18 cm. Ground sensors ensure that heating is possible only when the microwave head is fully lowered. The openings are covered by a replaceable mica sheet to protect the open waveguides from dirt.

Prior to treatment isolated dock plants were marked on the study areas and measured with a high-precision RTK GPS. Plant treatment was carried out with different heating times in order to identify an optimum time. Soil moisture on the sites was also determined.
Three variants were tested:
- Variant 1: Permanent heating at full power output (100 % power output)
- Variant 2: „Pulsed“ heating at full power output (pulse). Here the heating time was interrupted at intervals with

the aim of obtaining improved temperature distribution in the root: e.g. heat 10 s – wait 10 s – heat 10 s etc.

- Variant 3: Permanent heating at 25 % power output (25 % power output). This setting was intended to clarify whether energy optimisation of the procedure was possible by an appropriate extension of heating time at reduced heat output

Statistical considerations and the heating times determined

265 plants of variant 1, 157 of variant 2 and 86 plants of variant 3 fed into the statistical considerations. The target value for the re-sprouting rate was set at a maximum of 20 % (**figure 2**). This allowed optimum theoretical heating times to be calculated by linear regression. These were very close for unpulsed (28 s) and pulsed (27 s) heating time. At 25 % power output the heating time almost quadrupled at 101 s. These theoretical values served as a basis for variant comparison in energy terms.

The results of variants 1 and 2 were compared in a GLS model. Soil moisture and heating time were continuous variables. A distinction was also made between pulsed and unpulsed heating times. The F-test revealed no significant interactions between the parameters of soil moisture, heating time and pulse. Soil moisture only exerted a slight influence on the re-sprouting rate of dock roots. With the available variation range of soil moisture values there is evidence of only a slight tendency towards higher re-sprouting rates with increased soil moisture (0.13 % higher re-sprouting per 1 % increase in soil moisture).

Heating time and pulsing had a significant effect on re-sprouting rates. On average the treatment of plants at pulsed heating intervals was approximately 5 % more effective than that with permanent heating ($F_{1,25} = 6.26$, $p = 0.02$). When heating time was increased by one second, the plant mortality rate rose by approximately 3 % ($F_{1,25} = 122.78$, $p < 0.001$).

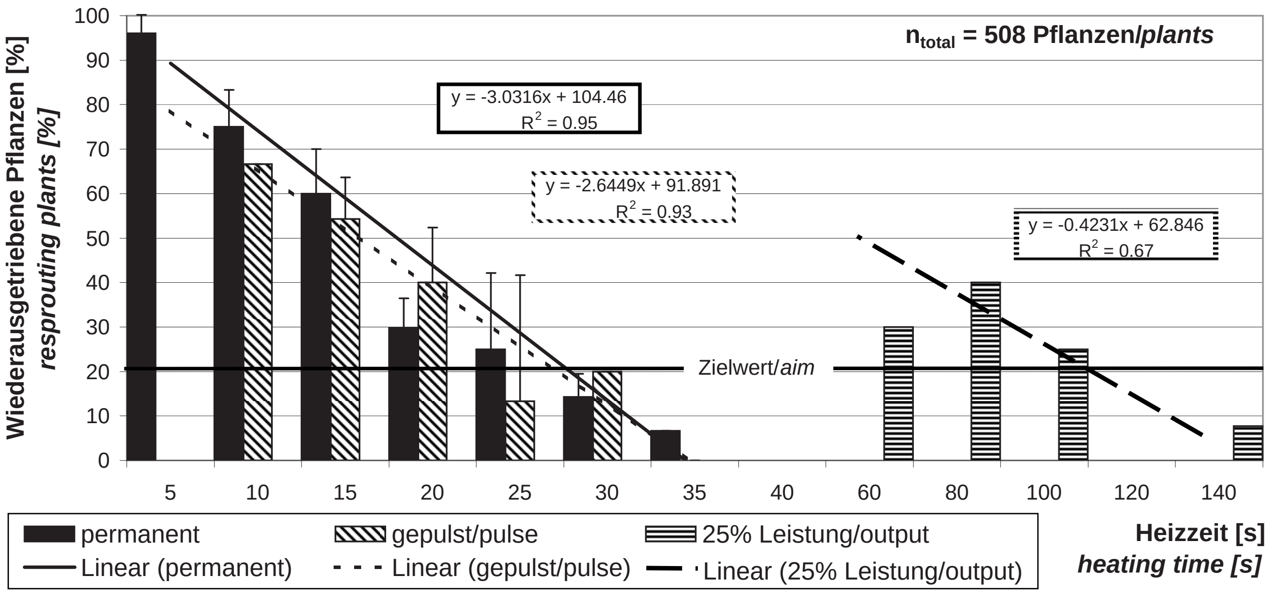
Fig. 1

Self-propelled microwave-prototype. 1 = generator, 2 = high-voltage unit with cooling fan, 3 = hydraulic adjustable head with magnetrons and waveguide exits. Photo: ART

Energy used

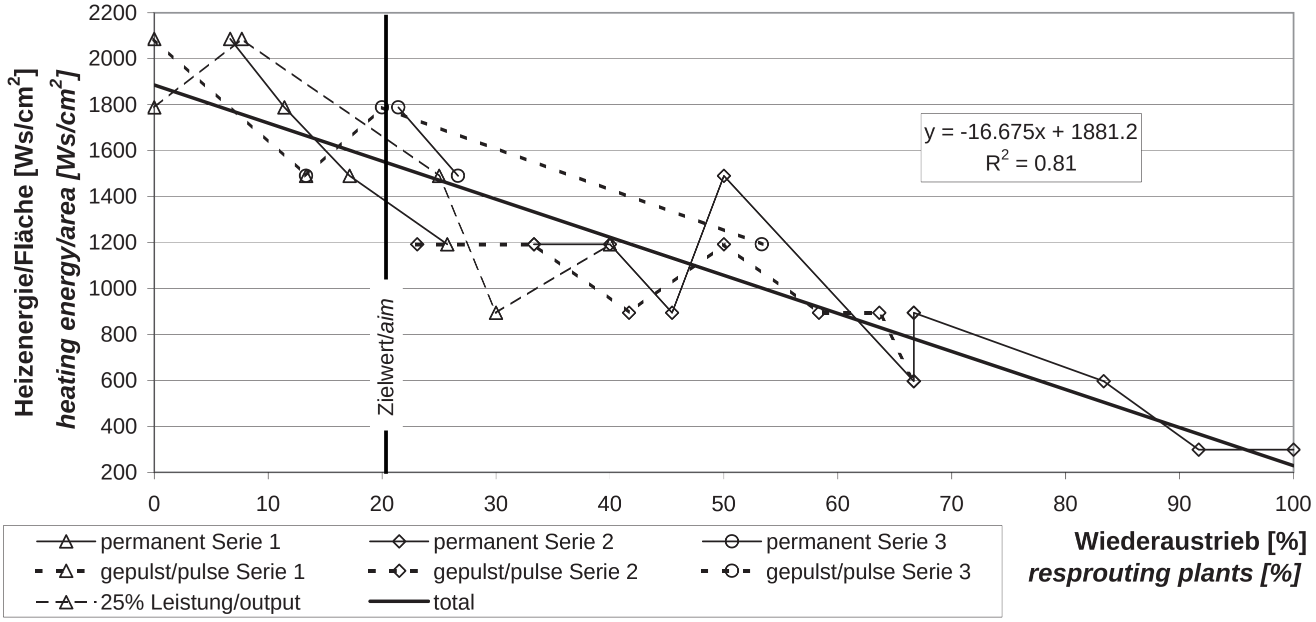
Heating energy is calculated from the magnetron power output [W] multiplied by the heating time used [s]. Heating energy/area [Ws/cm^2] is therefore a measurement of the amount of energy needed in this machine configuration to obtain a particular mortality rate (**figure 3**). The target value of maximum 20 % re-sprouting is achieved at approximately 1550 Ws/cm^2 (0.0004 kWh/cm^2). The dispersion of the data indicates that the site (series) plays a subordinate role in successful treatment.

Fig. 2



Percentage of re-sprouting plants (with standard digression) after different microwave heating times (18 kW) in 2008

Fig. 3



Heating energy input/area and re-sprouting plants in all field trial series

Fuel input and costs

The question of the requisite fuel input was answered in purely mathematical terms. In order to determine same the following assumptions were made:

Efficiency in microwave generation is around 50 % of the power supplied. A generator with double the electrical output of the microwave heating capacity is therefore required. According to [2], 272 g fuel/kWh is needed for a diesel unit to generate 36 kWh of power. Diesel fuel has an average density of 0.83 kg/l. The cost of diesel was estimated at EUR 1.10 per litre.

To the heating time of variant 2 (pulsed) were added an average 6 s in standby mode for interval out-time. The cost projection shown in **table 1** can therefore be carried out for actual energy input.

Depending on the variant selected, considerable quantities of fuel should be reckoned with for the actual heating process in dock control. Assuming moderate population densities of 2000 dock plants/ha, 160–220 l diesel/ha would be required. 800–1 100 l diesel would be necessary for extremely weedy populations of 10 000 dock plants.

In addition to the actual cost of fuel for heating, the total cost of the procedure also has to include the cost of fuel for idling between individual treatments, the power consumption of the towing vehicle and purchase costs as well as miscellaneous fixed and variable costs. Due to the extended heating times in the pulsed and the reduced-power variant the area treated per hour is also comparatively lower, which is reflected in the cost of the procedure.

Conclusions

The field trials carried out in 2008 show that the use of microwave to control dock plants does work in principle. The target mortality rate of 80 % can be achieved with 18 kW microwave output in a heating time of 28 s. If heating takes place at timed intervals by switching the microwave on and off, this slightly reduces the actual heating time to 27 s compared with the continuously heating variant. Here account must also be taken of the time when the microwave device pauses even though the generator is running. At 25 % power output the heating time has less than quadrupled at 101 s. This variant therefore does better in a relative comparison. The indication is that longer

Table 1

Energy use and costs of the microwave device

	Heating power	Generator-output	Heating time	Interval out-time	Fuel consumption per dock plant	Fuel cost per dock plant
	kW	kW	s	s	l	€
Variant 1 (100 %)	18,0	36,0	27,9		0,09	0.10
Variant 2 (pulsed)	18,0	36,0	27,2	6,0	0,11	0.12
Variant 3 (25 %)	4,5	9,0	101,3		0,08	0.09

heating times at lower power output are more efficient from an energy point of view. Microwave technology in the form of a self-propelled high-performance unit is impractical, however, because of its high energy consumption.

Literature

Books are signed with ●

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