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Application of thermoplastics to increase efficiency during thermal weed control

To increase crop yield it is essential to minimize the competition by weeds, which can be reached by flame weeding. The effect is based on the input of heat energy which leads to plants death after a short time. A problem of flame weeding is the lack of practically orientated devices to adjust the equipment. The field experiments as described below show the correlation between weed reduction and deformation of an indicator material. The results demonstrate that this method can be used as a decision support to optimize the setting of a flame weeder.

Keywords
Flame weeding, weed control

Abstract
Landtechnik 67 (2012), no. 6, pp 441–444, 3 figures, 3 references

Flame weeding is a standard technique in farm-scale vegetable production. Nowadays the importance of flame weeding increases, particularly if the use of herbicides is generally not allowed or restricted as in organic farming or water protection areas. This control method is essential in vegetable crops like carrot, beetroot, onion and field salad. The trend of increasing energy costs requires a tight efficiency and process control. Moreover after a suboptimal flame weeding a cost-intensive manual weeding is necessary.

Some dose-response models were developed to forecast the success of the treatment [1]. Even if all input parameters are known, these theoretical models assume a calculation and they are inapplicable for an on-site control. Therefore the development of an alternative approach which allows the operator to adjust the flame weeder and check the efficiency while working is necessary. A promising approach is the use of indicator materials which e. g. react with a visible deformation of their shape at the desired temperature between 40 and 50 °C. Previous laboratory experiments with different indicator materials were successful [2, 3]. In the present study the utilization of this method under practical conditions is presented and the relationship between shrinking of the indicator material and the reduction of different weed species is described.

Material and Methods

The conducted study is divided into the following parts:

a) Field experiments for validation of the correlation between shrinking of indicator material and energy input.
b) Field experiments for testing the correlation between weed control and shrinking of the indicator material with different weed species.

Experiment a

This experiment was planned to verify the correlation between energy input and shrinking of the indicator material. The energy input was varied by changing the driving speed of the tractor in steps of 0.31 (100 %), 0.47 (65 %), 0.83 (31 %) and 1.69 m/s (18 %). The flame weeder was equipped with atmospheric burners and had a working width of about 1.5 m at a total power of 300 kW. The consumption of gas (propane) was 18 kg/h. The angle of the burners was set at 60° and the distance between burner and soil surface was 10 cm (**figure 1**). As temperature indicators stretched hollow PLA bodies with one side open (height 45 mm, volume 30 cm³) were used. They were put on the soil surface with the open side downwards (**figure 1**). The rate of shrinking after flaming was measured by placing the indicator with the open side on a steel plate to measure the highest and the lowest point with a marking gauge. The shrinking rate was defined in percent of the initial height (45 mm is equated to 100 %).

Experiment b:

The experiments took place at Hessische Staatsdomäne Frankenhausen as the extension farm of the University of Kassel (field 'Gartenbreite', soiltype: 'loam'). The experiment had a rand-

Fig. 1

Trial plot with flame weeder and indicator material after treatment (Photo: Björn Bohne)

omized block design with four repetitions. Each plot had a width of 1.5 m with the weed species sown in rows. The flame weeder had the same adjustment as described above.

At the target area (soil surface and burner) some thermocouple (Type K NiCr-Ni DIN IEC 584) were placed to record the air temperature for optimal control conditions. The diameter was 0.25 mm for the ones placed at soil surface and 3.0 mm for those at the burner. To vary the energy input the driving speed was changed on two levels (0.83 m/s and 1.69 m/s).

The sown weed species *Sinapis arvensis* L., *Capsella bursa pastoris* L., *Stellaria media* L. und *Chenopodium album* L. were typical for the test site. The flame weeding was carried out at the cotyledon stage (BBCH 10).

The temperature indicators and the experimental design were equal to experiment a, with the only exception that three stretched hollow PLA bodies were used in each repetition. The number of plants was counted before and three days after the treatment in each plot at two predefined spots (Size 50 x 50 cm; 2 500 cm²) to assess the plant control ratio. The control ratio was determined in percent from the initial population. Caused by adverse weather conditions some results of the species *Capsella bursa pastoris* L. could not be processed due to the scattered germination.

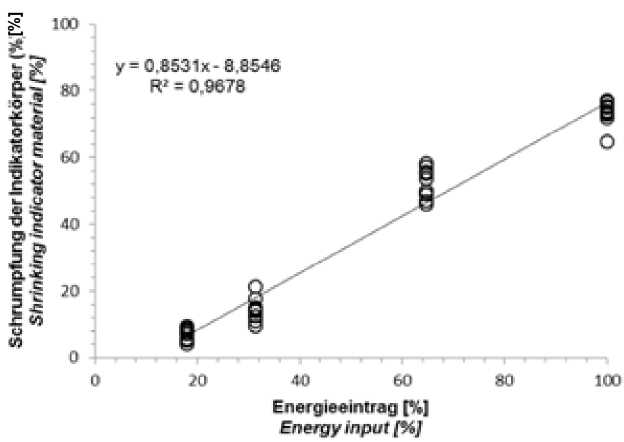
Results

The results of the experiment (**figure 2**) demonstrate the linear relationship between energy input and shrinking of the indicator material even under field conditions. The calculated Pearson correlation (r) was 0.984** (**level of significance $p \leq 0.01$) and the coefficient of determination $R^2 = 0.9678$.

With a driving speed of about 0.83 m/s the reduction was nearly 100 % in the populations of all investigated weeds. Therefore in the plant experiments described below the driving speed levels of 0.31 und 0.47 m/s were omitted.

A quantitative comparison between indicator material shrinking and plant control results (experiment b) leads to the correlation illustrated in **Figure 3**. The individual data points are based on the mean of four repetitions.

Fig. 2



Correlation between Energy input and Shrinking of indicator material

The positive correlation is evident. In the case of *Sinapis arvensis* L. the calculated Pearson correlation (r) was 0.896** (**level of significance $p \leq 0.01$). The changes in plant control during different energy inputs are clearly visible. In case of *Capsella bursa pastoris* L. the coefficient of determination (R^2) was less strong, therefore the Pearson correlation (r) was with about 0.796 (**level of significance $p \leq 0.01$) lower too. The higher quantity of measuring values at higher shrinkage is due to the adverse weather conditions during germination. The calculated R^2 of *Stellaria media* L. was 0.6053. The Pearson correlation (r) was 0.778 (** level of significance $p \leq 0.01$). The positive linear correlation between plant control and shrinkage of the indicator material is similar to *Sinapis arvensis* L.

The data points of *Chenopodium album* L. are at close quarters which lead to the Pearson correlation (r) about 0.831 (**level of significance $p \leq 0.01$).

Conclusions

The results of previous laboratory experiments could be confirmed by the field experiments. The used thermoplastic material reacted with a very adequate deformation to increasing heat energy input. A positive correlation between the intensity of the indicator material deformation and weed reduction could be proved as well. However, this correlation differs between the weed species. The strongest correlation was found with *Sinapis arvensis* L. and was on a lower level in other dicotyledonous weeds. This can be explained by the different sensitivity to a thermal treatment. That is why the demand of heat for a successful plant control varies.

The determined correlations appear sufficiently to conclude from the factor of deformation of the indicator material to the reduction of the weed population and hence the success of the treatment. For example in case of *Chenopodium album* L., if the indicator shrinkage is bigger than 50 % the weed control rate will be greater than 90 %. The indicator material can be used by the operator as a reference to optimize the process.

This fast and simple methodology can be used properly to control the effect of the flame weeder during the operation if an estimation based on empirical values is not sufficient or not possible. The development of an evaluation key with the necessary shrinking rate to control different weed species is conceivable.

Literature

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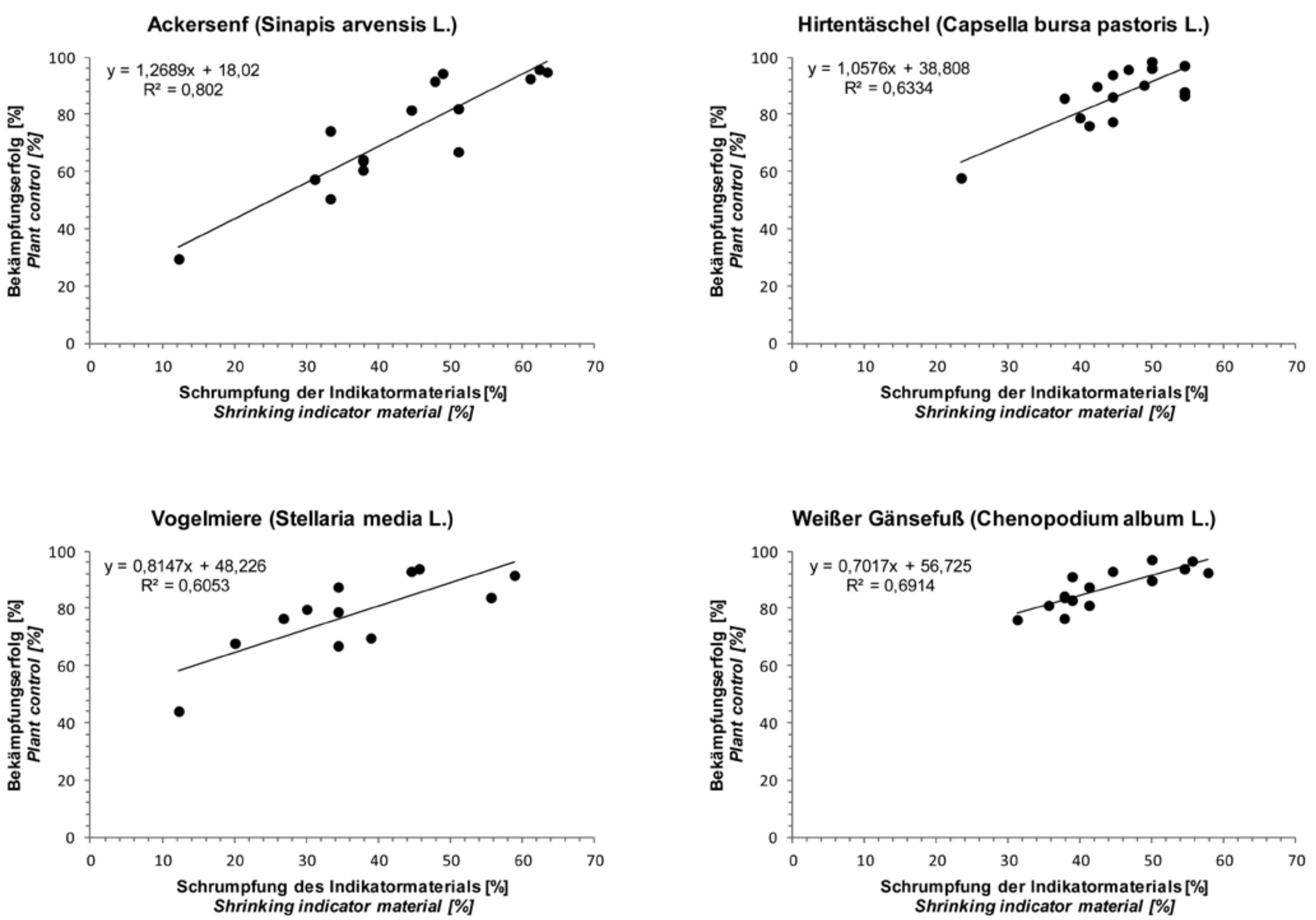
Acknowledgment

The described study was financed by the Federal Office for Agriculture and Food (BLE) in the framework: Promotion of innovation. Reference: PGI-06.01-28-1-53.039-07).

Fig. 3



Correlation between effect of treatment and shrinking of indicator material at different weed species