Stieg, Detlef

Test bench for the assessment and optimization of thermal weed control devices

The success of abatement in the use of thermal operating weed control devices may, in practice, be subject to considerable fluctuations. As a result for this propose it is presumed that the temperature distribution of such devices is not homogenous, which previously could not be shown due to lack of data. For this reason a test method for systematically testing was developed for verification of hand driven thermal weed control devices to attest the above-mentioned hypothesis. Test criterion is the distribution of temperature profiles in the working area of the devices by different operational speeds. It successfully has been shown that the temperature depends on operational speed and that heterogeneous temperature distributions can be proven very good.

received 15 April 2014
accepted 20 May 2014

Keywords
Thermal weed control, flame-scarfing devices, temperature distribution, test bench

Abstract
Landtechnik 69(4), 2014, pp. 176–179, 2 figures, 7 references

Technical equipment for thermal weed control has a disadvantage towards chemical plant protection strategies respective considerably higher labor costs [1; 2; 3]. In scopes where, due to legal regulations or voluntary commitments, the use of chemical products for plant protection is prohibited, thermal weed equipment is an option. Application examples for this propose are municipal areas (on pavements) as well as organic farming.

Thermal weed control devices can technically be classified into two main groups: hot-water devices and flame weeding devices / hot-air devices. Knowledge is scarce about the technical optimization potential in terms of the necessary use of energy. It shall be assumed that the temperature distribution in the working area is unequal. This is why optimization requirements concerning the success of the thermal weed control and energy efficiency exists. With the development of a test bench for manual thermal weed equipment with working width up to 900 mm, this hypothesis shall be proofed to increase the availability of information for manufacturers and operators of such machines.

The aim is to quantify the temperature courses within the working area, their exposure time as well as their distribution quality. In addition, the biological effectiveness of the methods under reproducible conditions shall be proofed. This study shows first results out of preliminary investigations to point out the general suitability of the test bench.

There are reports in the literature which indicates by which thermal treatment a lethal damage of plants can be assumed [3; 4]. Depending on the damage mechanisms, minimum temperatures of 60–70 °C at a residence time of 1 second or temperatures higher than 110 °C at a residence time of 0.1 seconds are valid.

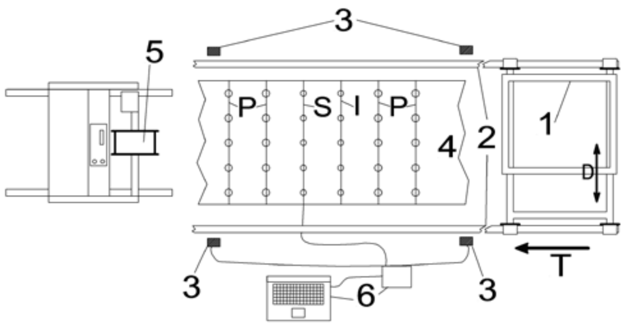
First approaches for determining the quality of work of thermal weed devices have already been described by Bohne and Hensel [5; 6]. The use of thermoplastic indicators allows them the verification of an adequate heat exposure of flame-scarfing in tillage farming.

Test methodology

To prove the previously assumed heterogeneous temperature distribution in the working area of the devices, the test methodology shall meet the following requirements:

- Measurement of time curves of spatial distributed temperatures in the working area
- Realization of constant working speed above the target area
- Universal and reliable method for hot water- and flame-scarling- / hot air devices

Fig. 1



Sketch of test bench with: 1 waggon with top slide, 2 rails, 3 photoelectric relays, 4 target surface with holes for thermocouples (S), model plants (P) and indicators (I), 5 winch, 6 device for data sampling and data storage, T direction of travel, D direction of displacement

- Verification of the technical measurement by controlling the biological effectiveness
- The possibility of using thermoplastic indicators in accordance to [5; 6] for purposes of comparison

The test bench consists of a positioning facility with rails, winch and rail vehicle, on which the test device is placed (**Figure 1**). The traversing velocity of the rail vehicle can be adjusted by an electronic speed control on defined values within the range of 0.34–1.5 m/s. Time-measuring is performed by two light barriers.

A wooden plate as target area is positioned between the rails, drilled holes (diameter = 50 mm) in the grid of 200 x 300 mm serve as positioning points for different measuring equipments. This enables to place temperature sensors, thermoplastic indicators as well as model plants. In general, there are six rows, each of them with a space of 300 mm. Within a row, there are 5 positioning points with a spacing of 200 mm. Therefore, the width of the target area amounts to 800 mm, the length from the first up to the last planting row amounts to 1 500 mm. The length of the whole rail track is 6 m. The upper slider, which is positioned on the top of the rail vehicle can be moved laterally over a range of +/- 200 mm. Therefore, the whole working area of the test device can be measured fine-resolved in several stages.

As temperature sensors 1 mm diameter mineral-insulated NiCrNi thermocouples (type K) are used. These are installed 20 mm underneath the wooden plate, longitudinal in working direction with an angel of approx. 45 degrees to a horizontal plane. The heat transfer medium exposed free length of the thermocouples amounts 25 mm. Apart from the mechanical protection, the lowered position of the thermocouple serves the simulation of shadowing effects by plants or parts of plants as well as concealed centres of vegetation [7]. The data logging occurs simultaneous at all installed thermocouples with a cycle time of 0.08 sec.

Test procedure

A flame weeding device with a nominal working width of 850 mm was examined. This device had 8 burner ports, which were installed under an insulated cover with a width of 850 mm and a length of 500 mm. The distance from one burner port to the other resp. to the side wall of the insulated cover amounts at least 95 mm. The flame weeding device was moved over the target area in two rounds with four different velocities. For the second round, the upper slider with the device was offset by 120 mm to the side. Hereby a measuring grid with altogether 8 positions with a distance of max. 120 mm was reached. The tests were repeated 3 times. Only the thermocouples were used as measuring instruments. For the presentation and valuation in **Figure 2**, only the four thermocouples whose positions were fitted completely in the working area were taken into account.

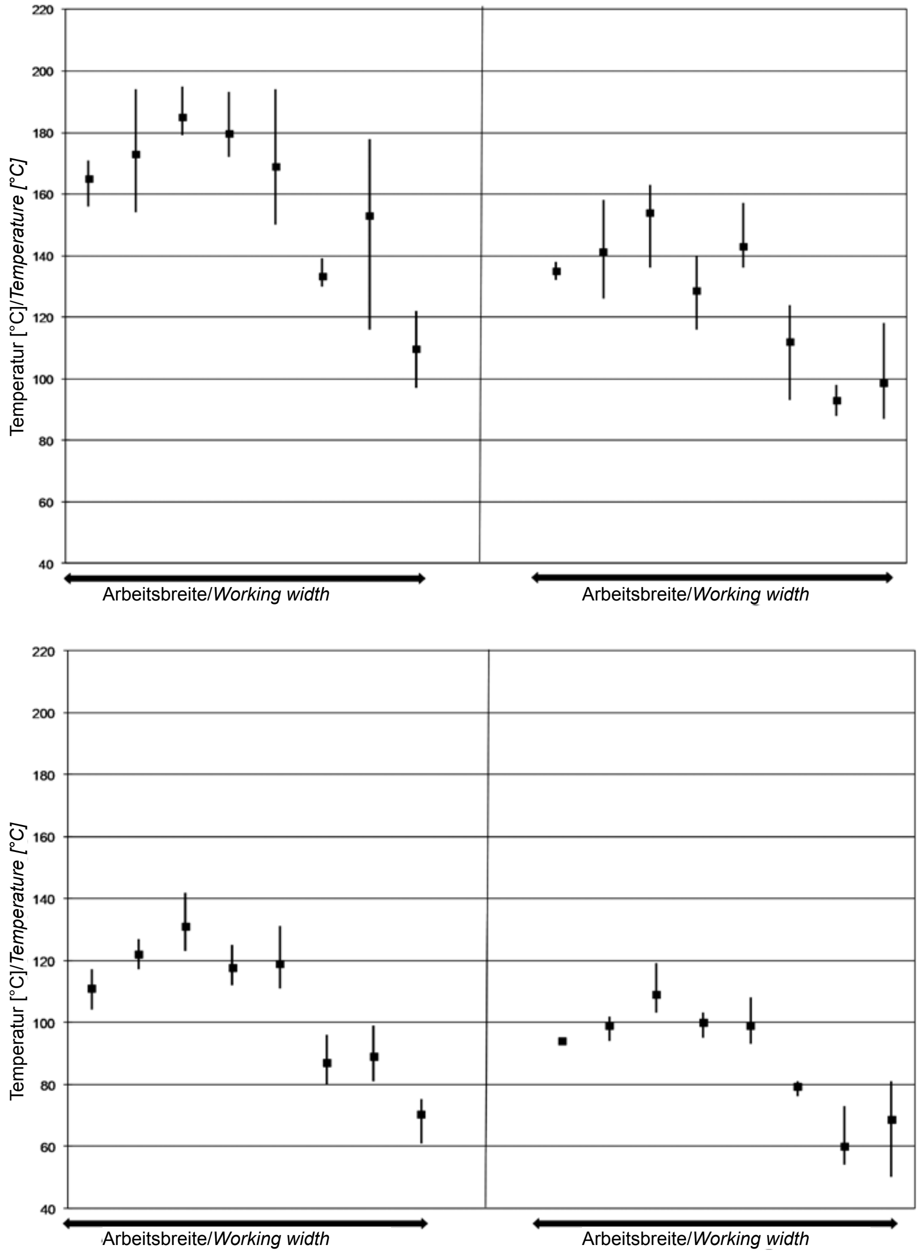
Results and discussion

The maximum temperatures which were determined in the measurements with a working speed of 0.35 m/s are in the range of 97–195 °C. In the tests with a working speed of 0.81 m/s, the temperatures are in the range of 50–119 °C (**Figure 2**). Noticeable are the large ranges of temperatures of the repeat measurements. These are at its highest when the working speed is at its lowest and consist up to a range of 62 °C.

The maximum temperatures which were reached in the working area of the flame weed device are decreasing with increasing velocity. Moreover, it is evident that the achieved temperature maxima in the working area, across the working width differ significantly but show reproducible pattern. These results support the hypothesis of the heterogeneous temperature distributions of thermal weed control devices. In the light of energy efficiency, the temperatures differences measured in these tests are not acceptable. The required minimum temperature resp. minimum duration impact for several model plant species in conjunction with the presented test method cannot yet be estimated. Further information on the subject is expected from the plant experiments which will be examined parallel.

Interesting is the fact that the temperature distribution is not only heterogeneous transversely to the working direction; it is also heterogeneous to the length. That connection evidenced by the variation of the temperature maxima of replicates. The mean values with associated range are obtained from the same thermocouples. That's why differences in dynamic behaviour of the thermocouples as a cause may be foreclosed. By calibration of the measuring chains in a dismantled state as well as logging the temperatures immediately before the start of a test run, temperature differences between the individual thermocouples as well as the ambient temperature can be limited in a range smaller than +/- 3 K. In addition. The variations of working speed (+/- 20 mm/s) show no clear context with the temperature levels so they also cannot explain the partly large range of temperatures. As a conclusion, the large range of tem-

Fig. 2



Maximum temperatures (arithmetical mean and span) across the working width (850 mm) of the thermal weed control device at working speed of 0.35 m/s (top left), 0.42 m/s (top right), 0.53 m/s (down left) and 0.81 m/s (down right), (n = 3)

peratures can not depend on measurement uncertainties of the test bench, in fact they must show a distinctive behaviour of the testing device.

Conclusions

First measurements confirm that the developed methodology and test facility is basically suitable for detecting the heterogeneity of temperature fields in the working area of hand driven thermal weed control devices. However, the mentioned minimum temperatures which were determined by other studies cannot be confirmed yet by the results of the preliminary experiments to biological efficiency that were carried out parallel.

With this test bench, different devices can be tested. Specific information relating to dose-response relation for different model plants and growth stages can be obtained. Further expansion potential can be found in:

- to determine the optimum sensor spacing in regard to the necessary spatial temperature resolution and under consideration of costs,
- an extension (Scale-up) of the test bench for the testing of larger (mounted/ self-propelled) devices while retaining the general test methodology,
- an enhancement of interpretation abilities of the measured values in regard to biological effectiveness with various plant morphologies.

References

[1] Entrop, A.-P.; Ralfs, J.-P. (2007): Möglichkeiten und Grenzen der thermischen Unkraut- und Ausläuferregulierung in Erdbeeren 2005/06. Mitteilungen des Obstbauversuchsringes des Alten Landes 62(8), S. 281–287

[2] Merz, F.; Lehneis, T. (2010): Pflanzenschutz auf Wegen und Plätzen. Landinfo 1, S. 34–40

[3] Verschwele, A. (2008): Unkräuter auf Wegen und Plätzen. http://www.jki.bund.de/de/startseite/institute/pflanzenschutz-ackerbau-und-gruenland.html unter Flyer, Zugriff am 5.5.2014

[4] Dierauer, H. (2000): Abflammen. Merkblatt. Forschungsinstitut für biologischen Landbau. http://orgprints.org/00003409, Zugriff am 2.4.2014

[5] Bohne, B.; Hensel, O.; Edler von der Planlitz, B. (2011): Thermische Unkrautregulierung: Praxistaugliche Bestimmung der Wirkung. Landtechnik 66(5), S. 363–365

[6] Bohne, B.; Hensel, O. (2012): Einsatz von Thermoplasten zur Steigerung der Effizienz bei der thermischen Unkrautregulierung. Landtechnik 67(6), S. 441–444

[7] Gude, J. M. (2012): Wirksamkeit der Unkrautbekämpfung mittels Laser in Abhängigkeit verschiedener biologischer und technisch-physikalischer Parameter. Dissertation, Rheinische Friedrich-Wilhelms-Universität Bonn

Author

Dipl.-Ing. Detlef Stieg is researcher at the Institute of Application Techniques in Plant Protection of the Julius Kühn-Institute, Federal Research Centre for Cultivated Plants, Messeweg 11/12, 38104 Braunschweig, Germany e-mail: detlef.stieg@jki.bund.de