

MLHD, a decision support system for rational use of herbicides

Decision support systems in potato production: bringing models to practice

Kempenaar, C.; van den Boogaard, R.

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12. MLHD, a decision support system for rational use of herbicides: developments in potatoes

C. Kempenaar and R. van den Boogaard

MLHD, short for Minimum Lethal Herbicide Dose, is a Dutch concept that further rationalises herbicide use in integrated weed control. The concept has been developed since the mid 1990's, and comprises two distinct elements: (1) a weed species and stages dependent dose advice and (2) sensing techniques that allow predictions of herbicide efficacy and the need for additional treatments. The second element is an innovation in weed control; herbicide doses are partly based on readings from sensing techniques. The MLHD concept is ready for use in practice for photosynthesis-inhibiting herbicides, which are used in many arable and vegetable crops.

In this paper, the MLHD concept and background is explained. Results from studies focused on use of the MLHD concept in weed control and haulm killing in potatoes are presented. Examples of on farm research and farmers' perceptions are given. In addition, MLHD online, the web based MLHD decision support system and some prospects are presented and discussed.

Introduction

MLHD is a concept that supports rational herbicide use in integrated weed control. MLHD means Minimum Lethal Herbicide Dose. The concept was originally developed by Ketel *et al.* in the 1990's (e.g. Ketel & Lotz, 1997). Ketel developed decision support rules (DSR) which related a minimum lethal dose of photosynthesis-inhibiting herbicides to the size of annual weeds and he added a sensing technique to the concept that allowed an assessment of the efficacy of the herbicide treatment shortly after application. The latter is an innovation in weed management. The assessment is used to predict whether the reduced herbicide dose will be effective or if an additional treatment is needed. The MLHD concept was tested and further developed in on-farm research from 1998 to 2002. The original MLHD concept was modified during that period using feed back of farmers and others (advisors, contractors, weed control scientists) involved. Today, the MLHD concept is a DSS for more rational use of photosynthesis-inhibiting herbicides. Advice on doses is specific to the given weed situation, with differentiation for weed species present, development stages of the weeds and assessments of herbicide efficacy. Sensing techniques that are used to assess the effects of herbicide treatments are absorption (PS1-meter), fluorescence (PPM-meter) and reflection (Crop scan meter). Weather effects are taken into account by simple comment lines.



Figure 1. MLHD-PS1-meter.

Since 2001, the MLHD DSS has been available on the internet in a model named MLHD online. In this paper, information on MLHD online version 2002 is presented. But first, the MLHD concept is explained in more detail for potatoes.

The MLHD concept

MLHD is a new concept that further rationalises weed control in arable crops. It fits in any weed control strategy where herbicides are used; in one-spray systems, in low-dosage systems (LDS) and in integrated weed control systems. The MLHD concept basically consists of three steps:

1. Advice on a minimum lethal herbicide dose is obtained from MLHD online (www.mlhd.nl), which generates advice on the basis of field-specific information on the crop, weeds (species and stages) and weather. Underlying decision support rules are explained in the next paragraph.
2. Shortly after application (2 days or more), a sensing technique is used to assess whether the dose will be effective. Measurements are done on 5 to 10 plants of the 5 most troublesome annual weeds in the crop (the readings will tell if the weeds will die or not). Sometimes measurements are also done on crop plants to assess whether the crop is affected by the treatment or not.
3. A decision is made whether additional weed control is needed based on the readings of the measurements under step 2 and crop and weed information. If readings are below a certain level, MLHD online advises an additional treatment. In an LDS, the measurements can be repeated shortly before the next treatment to improve the quality of the advice.

More information on the steps in MLHD is given in a manual in Dutch on the internet (Kempenaar, 2002). The aforementioned step 2 is only relevant for herbicides that affect photosynthesis shortly after treatment, but where it takes much longer before effects can be seen with the naked eye, which is *e.g.* the case for photosynthesis-inhibiting herbicides.

How does the MLHD measurement work? The PS1-meter, for example, produces a reading (figure) on a scale of 0 to 100. The leaf of a weed or crop plant is clipped in the PS1-meter which measures the proportional damage to the photosynthetic apparatus. The higher the reading, the greater the effect (damage) on the plant. In the case of photosynthesis-inhibiting herbicides, a reading of > 80 from the youngest measurable leaf two days after treatment predicts that the weed will die. A reading of > 65 indicates a good level of control, but some plants may survive. An example of predictions of herbicide efficacy based on such readings is given in Table 1. Details on the PS1-sensing technique are given in (Kempenaar & van den Boogaard, 2002). Figure 1 shows a picture of the PS1 sensing technique. The PS1-technique is developed and patented by ATO b.v. in Wageningen.

Table 1. Example of MLHD-measurements on young *Solanum nigrum* plants in a greenhouse experiment.

Dose of Sencor WG (80 % metribuzin)	Reading PS1-meter, 2 days after treatment	Efficacy 14 days after treatment
0 g/ha	9	No effect
10 g/ha	45	Growth reduction
50 g/ha	75	Dead plants
100 g/ha	85	Dead plants

The MLHD model

In the mid 1990s Ketel studied the relation between plant size and the minimum number of herbicide molecules needed to kill a plant (Ketel & Lotz, 1997, Ketel & Lotz, 1998). His studies were mainly done with photosynthesis-inhibiting herbicides metribuzin and fenmedifam and the weeds *Chenopodium album* and *Polygonum persicaria* (annual broadleaved weeds). From his studies, he derived the original MLHD formula:

$$\text{MLHD} = \text{FW}_{\text{leaf}} \times T \times \text{MW}_{\text{herb}} \times R \times 10^{-4}$$

Where:

FW_{leaf} = mean fresh weight of the leaves per surface unit [g]

T = target size, composed of the number of target sites (chloroplasts) per gramme of leaf fresh weight and the number of herbicide molecules needed to inactivate one target

MW_{herb} is the molecular weight of the herbicide

R is a ratio parameter

and 10^{-4} is a scale constant.

Standard values for T and R were estimated with regression analysis on data from greenhouse experiments.

In the current MLHD model, Ketel's formula is the backbone for the advice on doses. However, some modifications have been applied since 1999. Fresh weight is translated into development stage because farmers are not interested in assessing the weights of weeds. Also, a parameter for weed sensitivity class has been introduced. Finally, a parameter that corrects for weather effects and formulation has been added. In the current version of MLHD online, corrections for weather effects are given in text boxes.

The PS1 sensing technique

The effectiveness of herbicides can be determined using the PS1 technique which measures light-induced changes in absorbance at around 820 nm (Genty and Harbinson 1996). This wavelength is specific for reactions occurring in photosystem I (PS1). If herbicides block electron transport from photosystem II to photosystem I, reactions in photosystem I will be affected.

In the light, $P700^0$ is oxidised to $P700^+$, which is subsequently reduced to $P700^0$ once more by electrons coming from photosystem II. At 820 nm $P700^0$ and $P700^+$ have a different absorbance. In the PS1-meter a leaf is first placed in the dark, then a flash of light is applied. The oxidation and reduction following this flash of light is measured from the changes in absorbance at 820 nm. This gives a measurement of the extent of blocking of reduction of $P700^+$ by herbicides.

In Figure 2 the measurement principle is shown. In figure A there is no herbicide effect and after a pulse of light there is complete reduction of $P700^+$ to $P700^0$. The meter will indicate 0% damage. In figure B a herbicide blocks photosynthesis completely, $P700^+$ is not reduced to $P700^0$. The meter will indicate 100% damage. In case C there is partial inhibition of photosynthesis. In this case the meter indicates 45% damage.

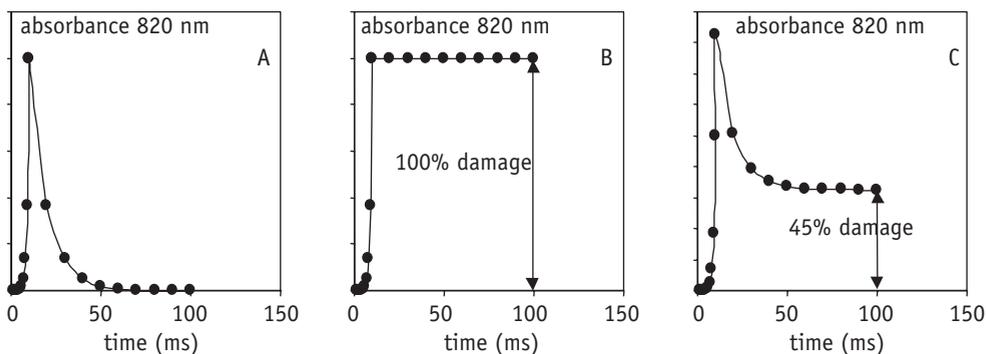


Figure 2. Measurement of absorbance at 820 nm indicates damage to the photosynthetic apparatus: A = normal functioning photosynthetic apparatus, B = 100 % blocked photosynthetic apparatus and C = 45 % blocked photosynthetic apparatus.

The dynamics of PS1-readings with time are shown in Figure 3. Mean values of PS1-readings at 1, 2, 4 and 6 days after application of Sencor to young *Solanum nigrum* plants are shown. In the situation where the plants were lethally treated (180 g/ha), the PS1-values rapidly increase above 80. Sub-lethally treated plants show an increase in PS1-reading, but after some days the PS1-readings drop back to the levels of the untreated situation.

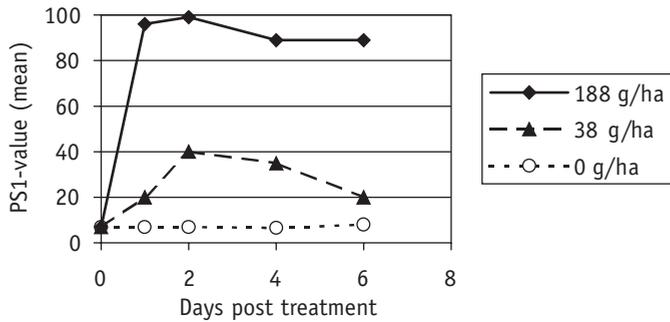


Figure 3. PS1-readings on young *Solanum nigrum* plants treated with differing doses of Sencor in a greenhouse pot experiment.

On farm research

Since 1998, MLHD has been tested in on farm research. The testing was done on commercial arable crops on farms in the Netherlands. In the tests, one part of the crop was treated according to common practice and the other part according to MLHD. Herbicide use, level of weed control and yield were assessed for both systems. For example, this kind of testing was done in sixteen ware potato crops in 1998 - 2001. Common practice in the potato crops was an LDS of Sencor (metribuzin) sometimes combined with Basagran (bentazon) or Titus (rimsulfuron). In a few cases a soil

Table 2. Results from on farm research in 16 ware potato crops in 1998 - 2001 in the Netherlands.

	Common practice	MLHD
Use of contact herbicides (kg/ha)	0.3	0.2 *
Herbicide efficacy on scale 1-10	7.9	7.7
Relative yield (%)	100	103

* the difference from common practice would have been larger if soil herbicides were also taken into account

herbicide was applied as well. On average 30 % less herbicide was used with MLHD while the level of weed control remained good. Higher yields were observed in MLHD-treated crops. This is explained by a milder effect on the crop of the lower MLHD dose. The response of weeds and crops to herbicide treatments is species specific. In many cases, we demonstrated that less-sensitive species are less affected by the herbicides, and this can be visualised by the MLHD measurements. An example is available from measurements in an onion crop. Weeds such as *Stellaria media* that are relatively sensitive to Basagran and Actril 200 (ioxynil) yielded a PS1-reading of > 80 2 days after treatment while a species such as *Senecio vulgaris* gave a PS1-reading in the order of 50. The onion crop gave a PS1-reading in the order of 25.

Farmers experiences with MLHD

The on-farm research provided feed back that was used further to develop the MLHD concept. A summary of the feedback is given in Table 3, which is the outcome of an evaluation study in 2002. The evaluation showed that farmers, advisors, and contractors are most interested in the efficacy measurements of MLHD, especially in uncertain situations when they feel that the dose may not have been high enough or when it suddenly rains after a spray. Some farmers also like to measure the response of the crop to the herbicide treatment. The aspects evaluated are ranked in increasing order of usefulness/interest. At present slightly more than 100 MLHD-meters are used in practice in The Netherlands

Table 3. View on aspects of the MLHD concept by users on a scale of 1 (not useful) to 9 (very useful).

Aspect of MLHD	Rating
A system that reduces environmental side effects	4
A system that shows social responsibility	4
A system that minimises costs of herbicides	4
A system that advises on low doses of herbicides	5
A system that predicts herbicide efficacy shortly after treatment	7
A system that visualises the crop response on herbicide use	7

Potato haulm killing and MLHD

Currently there are experiments to test whether the MLHD concept can also be applied for rational use of products for haulm destruction in potato (leaf dessicants). An additional sensing technique is used in the experiments. A Crop-scan meter is used to determine the amount and the activity of the biomass of the potato haulm (canopy)

shortly before application. The reading of the Crop-scan meter is used to generate a minimum effective dose of the potato dessicant. The Crop-scan measures reflection of the canopy, which indicates the biomass (LAI) and its activity.

In addition to Crop-scan, step 2 of the MLHD concept can be applied to predict whether the applied dose will indeed be effective or not. DSR (decision support rules) are available for the registered products in The Netherlands. These DSR however, are not yet in MLHD online, but probably will be in the near future.

MLHD online

The 2002 version of MLHD can be viewed in Dutch on www.mlhd.nl. MLHD online was developed in a joint project with Opticrop b.v. in Vijfhuizen, the Netherlands and the intellectual property of MLHD DSR belongs to Plant Research International b.v.. Opticrop is a company that is specialised in Agro ICT, focused on the Dutch agribusiness. MLHD online version 2002 is still a prototype version.

The core of MLHD online is a spreadsheet model in which the user enters information on the weeds he wants to control. In return, MLHD online advises on dose. A layer of screens guides the user through the model (Figure 4). Firstly, when MLHD online is accessed, a screen with general information on MLHD online is shown. The user can choose between several crops. When potato is chosen, a screen with herbicide options in potatoes and sensitivity of weeds to these herbicides is shown. Upon selection of a herbicide-weed combination, a table with dose-advice based on weed stage is

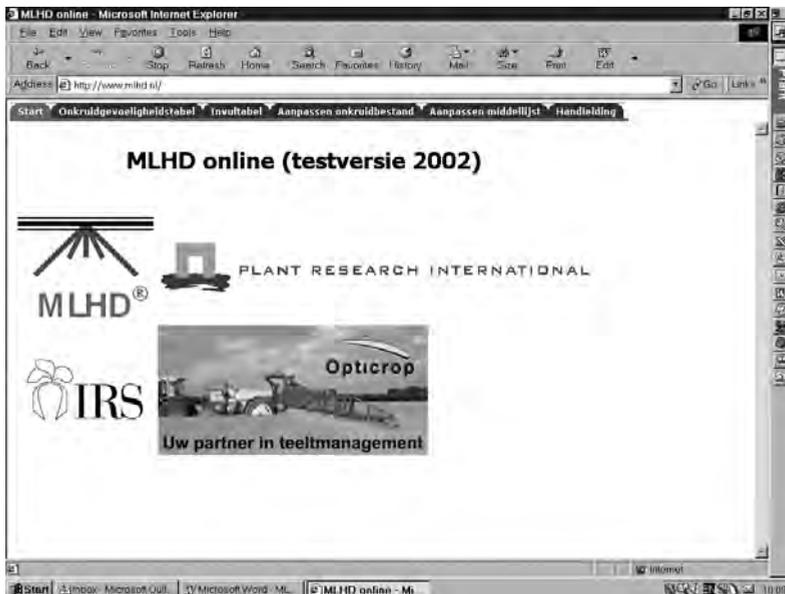


Figure 4a. Screen shot of MLHD online (www.mlhd.nl): opening screen.

	Alleen flow	Basagran	Probaat Unuron Flowable	Sensor Wg	Sensor Wg + Basagran
akkermelkdistel	++	-	++	-	-
akkerwinnaaije	++	-	++	+++	+++
hanspoot	-	-	-	++	++
hoogwilde	-	-	-	-	-
levik	++	++	++	+++	+++
hemerantel	+	-	+	++	++
kousalle	++	+++	++	+++	+++
kleefkruid	+	++	+	-	++
kleine brandnetel	+++	++	+++	+++	+++
knwek	-	-	-	+	+
melden	++	+	++	++	++
melganzveuet	+++	+	+++	++	++
ruar	++	+++	++	+++	+++
perzikkruid	+	++	+	+++	+++
rasgrassen	++	-	++	+	+
stroafgras	+	-	+	+++	+++
varkensgat	++	-	++	++	++
waterpeper	-	++	-	+++	+++
witte knolde	++	++	++	+++	+++

Figure 4b. Screen shot of MLHD online (www.mlhd.nl): weeds - herbicides sensitivity table.

Dosering bepaald voor een vervolgbespotting op basis van een PSI meting van van 65 tot 80
 Als de bespotting 2 of meer dagen geleden is uitgevoerd, is het te verwachten resultaat: goed.
 Het vervolgdoseeradvies is dan ook: Enkele ontappers mogelijk, aanvullende bestrijding hoeft niet.
 Handhaving onderzocht tabel voor de te herbieren dosering bij een eventuele vervolgbespotting.

Onkruidsoort (aantal)	Gewicht plantjes (g)	Doseering (l/ha)	+	++	+	-
kleinbladig gestrekt	0,02	0,00	0,00	0,00	0,00	1,5
1 blaadjes	0,04	0,03	0,03	0,03	0,03	3
2 blaadjes (hoogte ca. 2cm)	0,07	0,02	0,04	0,06	0,06	3
3 blaadjes (eerste uitlopers bij grassen)	0,1	0,04	0,06	0,08	0,08	3
4 blaadjes (hoogte ca. 5cm)	0,2	0,10	0,12	0,17	0,17	3
6 blaadjes (3 uitlopers bij grassen, >> 5cm)	0,4	0,20	0,25	0,35	0,35	3

- Het advies is gericht op gebruik van Sensor WG bij een LDS.
- Let op rasgevoeligheid van aardappelen voor dit middel.
- De werking van Sensor WG kan versterkt worden door een combinatie met Basagran (zie MLHD-tabel Sensor WG/Basagran), MCPA of Tilus.
- De combinaties hebben echter ook beperkingen, zie hiervoor specifieke advisering aangaande deze combinaties.
- Voor bestrijding van grassen, zie advisering aangaande specifieke grassenmiddelen.

PSI meting:
 PSI meting: van 65 tot 80

Figure 4c. Screen shot of MLHD online (www.mlhd.nl): dose advice table.



Figure 4d. Screen shot of MLHD online (www.mlhd.nl): dose advice table corrected for PS1-measurements.

presented. If data from measurements of efficacy are available and entered, modified advice will be presented. Some user-friendly options are added to allow rapid comparison of different strategies or situations. Also, text boxes with background information on crops, strategies, weather effects and herbicides are included.

Prospects

MLHD appeals the most to farmers who are interested in either minimising herbicide use while maintaining a good level of weed control, or minimising the effect of herbicides on the crop. Other uses of MLHD are when coupled with the sensing techniques in situations where there is much uncertainty on the efficacy (e.g. rain after application) or in experimental situations (e.g. testing additives). A limitation is that MLHD is only ready for use in practice for photosynthesis-inhibiting herbicides. It is important that the MLHD database is extended beyond these herbicides. R&D at Plant Research International is focused on the extension. For example, DSR are available for glyphosate and glufosinate ammonium applied to annual weeds. They will be added to MLHD online shortly. R&D on sulfonyl urea compounds is current.

MLHD online will probably be linked in 2003 to a model that takes into account weather effects on herbicide efficacy. At present, such a model, named GEWIS, is available in The Netherlands, from Opticrop b.v (e.g. Hoek, 2002). GEWIS advises on the optimal timing of pesticides in relation to 20 weather and product factors.

MLHD requires an investment of time and money by the user. In return, the user saves on herbicide costs and may have a higher crop yield. The investment of time and money is limiting use of MLHD in practise. Farmers that have the time and are interested in optimal crop production are most interested in MLHD. A small group of farmers gets an additional benefit for using MLHD. They produce for an EKO-label (Milieukeur). When they apply certain herbicides with MLHD, they get fewer penalty points. Here MLHD is seen as good agricultural practice. Broadening this perception is an aim of the people involved in the development of MLHD. Most recently, the largest pesticide distributor in The Netherlands, Agrifirm b.v. in Bleiswijk, became involved.

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Name of the DSS

Ideotyping-potato

Who owns the DSS, Principal author's, address,...

Anton Haverkort, Plant Research International, Wageningen University and Research Centre, P.O. Box 16, 6700 AA Wageningen, The Netherlands
anton.haverkort@wur.nl

What questions does it address?

- what yields are expected when management changes?
- what yields are expected in dry or wet years, with and without irrigation?
- what yields are expected when crop characteristics are changed (e.g. a changed base temperature for development, deeper rooting, stopping leaf growth and death when full ground cover is reached)
- which crop characteristics have to be combined to obtain a benefit (e.g. frost resistance and earlier planting are only beneficial when irrigation takes place, if not the soil is too dry during tuber bulking)

What input is needed?

Long runs (30 years) of weather data such as maximum and minimum daily temperatures, precipitation, solar radiation and evapotranspiration; soil characteristics from which rooting depth and water holding capacity can be derived. Long term actual yields of potato to verify model performance.

Who is it for, who are the intended users?

- conventional potato breeders to predict the possible impact of changed crop characteristics
- genetic engineering companies to calculate the impact of far fledged (combinations of) changed genetic properties
- research institutions and commercial companies developing strategies to optimize yields through proper use of genetics, environment and crop management (GxExM). IDEOTYPING POTATO allows a risk analysis before introducing new genotypes into new environments

What are the advantages over conventional methods (whatever those may be)

The conventional method of the identification of ideal genotypes for particular environment consists of screening many genotypes and detecting the best adapted ones. With IDEOTYPING POTATO the optimal set of 'genes' can be calculated before starting a breeding program for such an environment. New areas can quickly be scanned for potential suitability and many years can be analysed for risk of climatic hazards.

How frequently should the DSS be used or its values be updated?

IDEOTYPING POTATO can be used at any time anywhere. Calculating yields can be done when the need for the DSS arises, as long as suitable input data are available

What are the major limitations, and what scientific / technical enhancements would be desirable?

Extending it to quality characteristics requires models and data