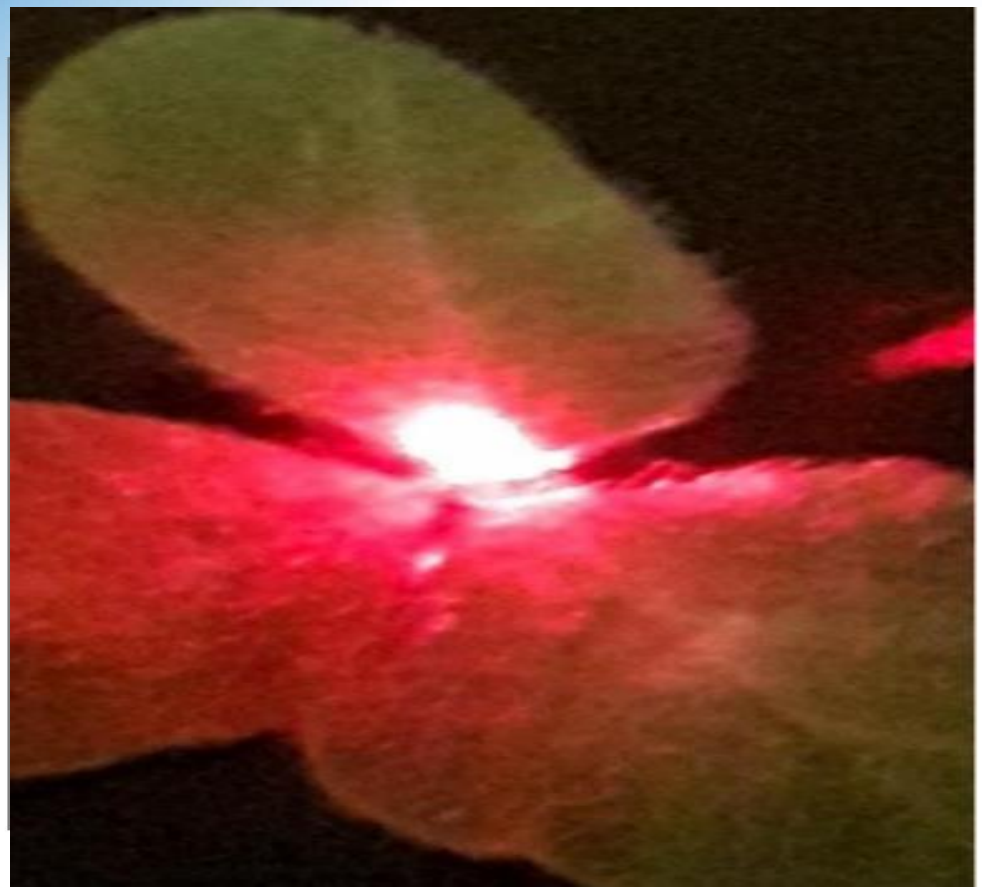
AI-Autonomous Robots for Agriculture – Weeding with Laser

WeLASER Summer School



Laser effect on living organisms

Associate Professor Christian Andreasen
Date 11 June 2023

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CSIC Consejo Superior de Investigaciones Científicas
FUTONICS
LZH Laser Zentrum Hannover e.V.
University of Copenhagen
AGREENCULTURE Smart robots for smart farming
COAG
Alma Mater Studiorum Università di Bologna
IETU Instytut Ekologii Terenów Uprzemysłowionych
Ghent University
van den borne aardappelen

Laser effect on living organisms

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Laser team, Copenhagen University

UNIVERSITY OF COPENHAGEN

The aim of the presentation:

- Why use laser beams as a new weed control methods?
- Principles of how to measure the effect on weeds and crops
- Show examples of the effect of laser on different organisms
- Conclusion

Herbicide application

Negative impact of mechanical weed control

- Soil erosion
- Dry out soils
- Increase mineralisation of organic matter
- Harm beneficial organisms (e.g., earthworms, spiders, predator beetles)
- Harm birds and bird nests

The skylark is a bird of open farmland

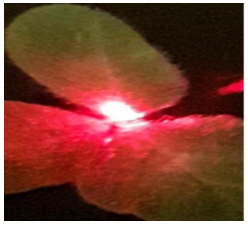
Reducing the impact of weed control on the environment

Using a 2 µm fibre laser beam with a diameter of 2 mm:

With 150 weeds m^{-2} the exposed area is

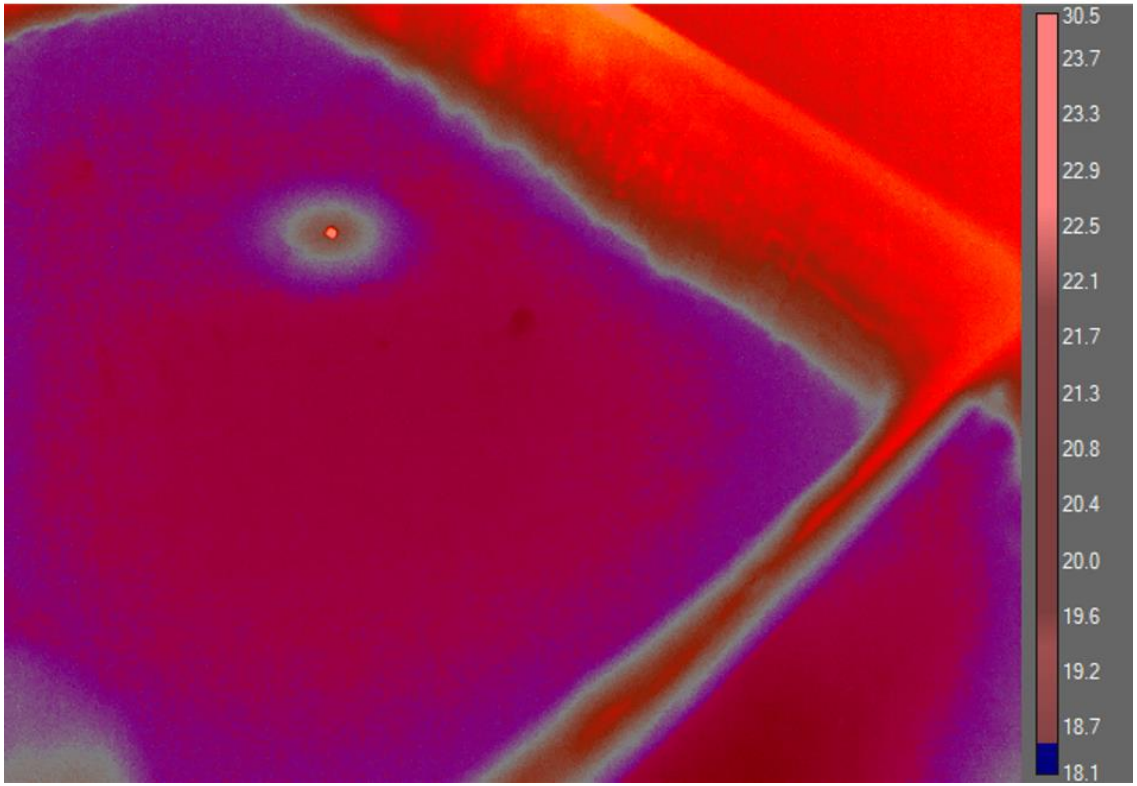
0.001^2 m^2 × 22/7 × 200 = 0.000629 m^2 ~

0.6 % of the area



Temperature increase limited to a very small area

Laser treatment at room temperature:
Only a very small spot is affected!



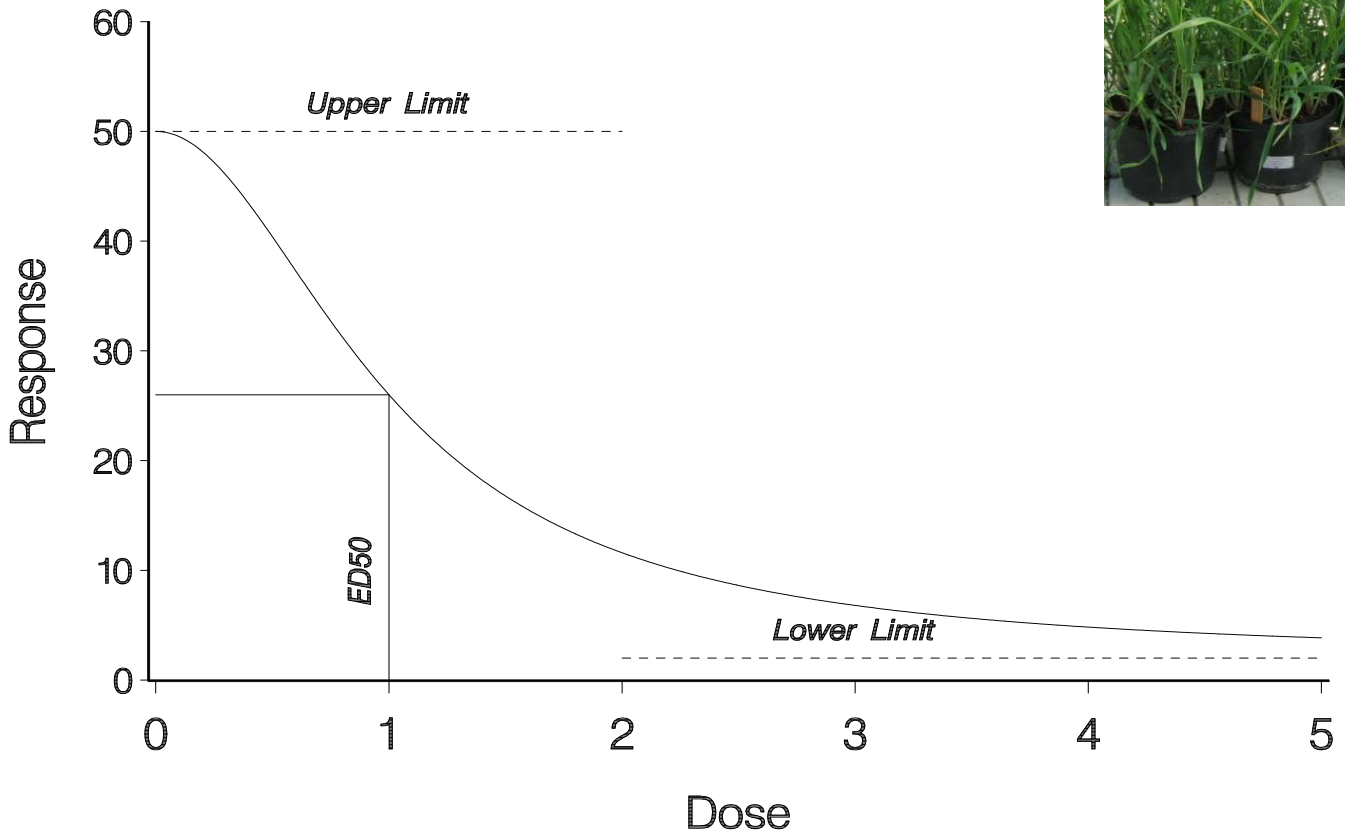
Blue: 18,5 °C

Soil surface temperature measurement with an infrared camera in a tray experiment

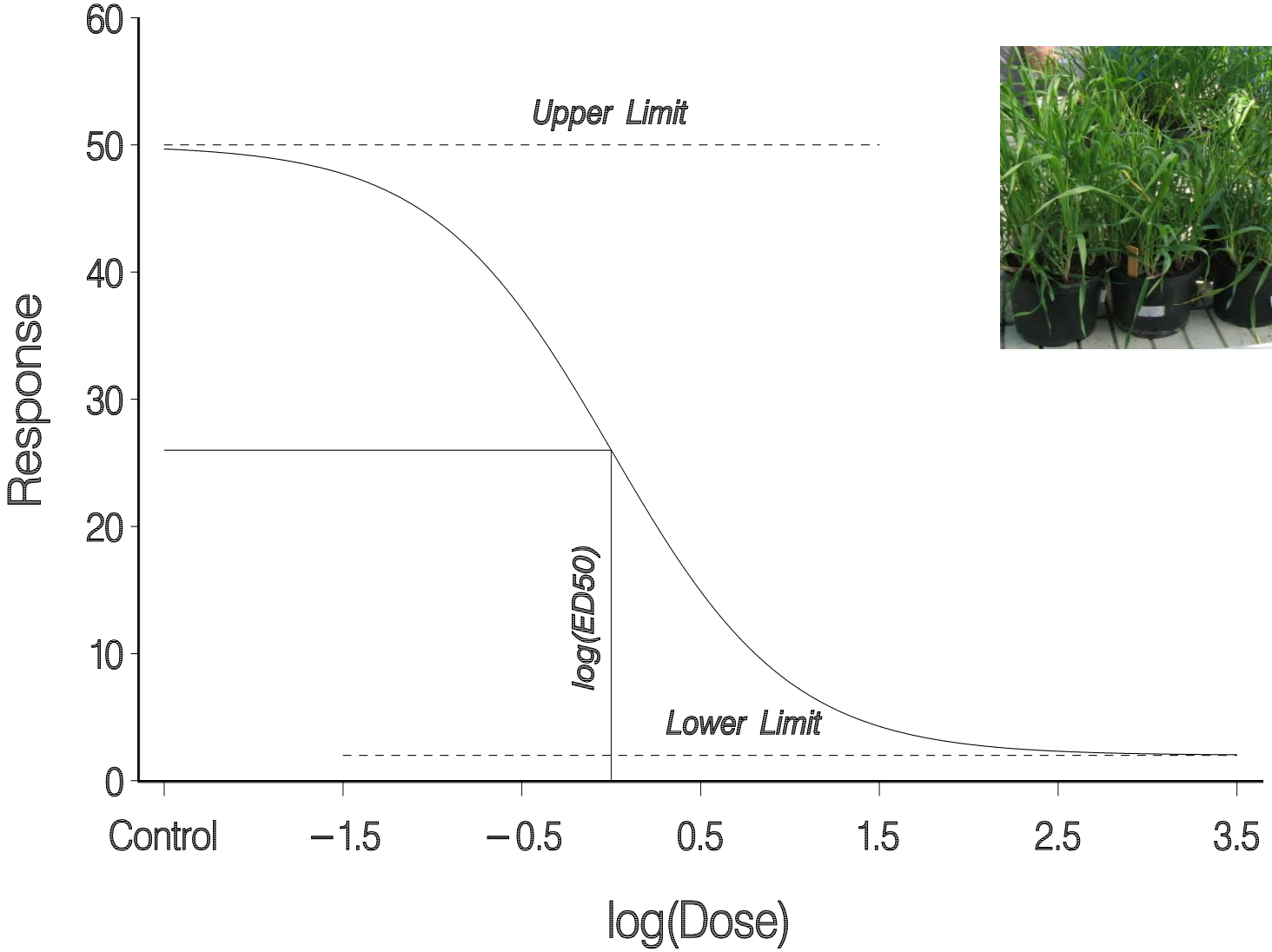
The kill of weeds!

Dose – response experiments with two replicates three weeks after treatment

Logistic Dose Response Curve



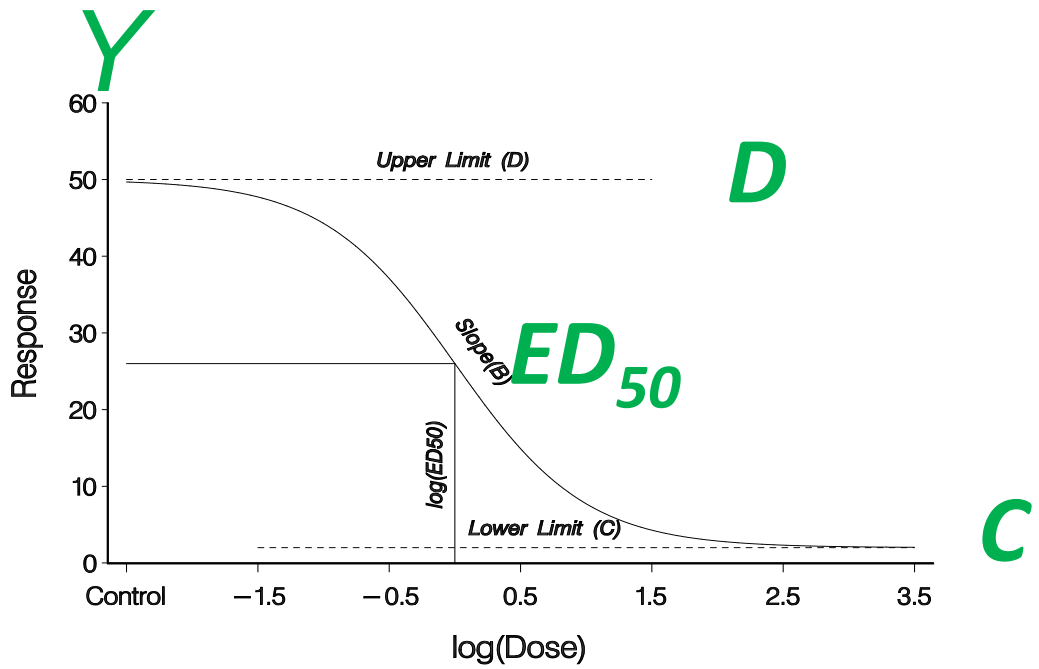
Log-Logistic Dose Response curve



The mathematic model

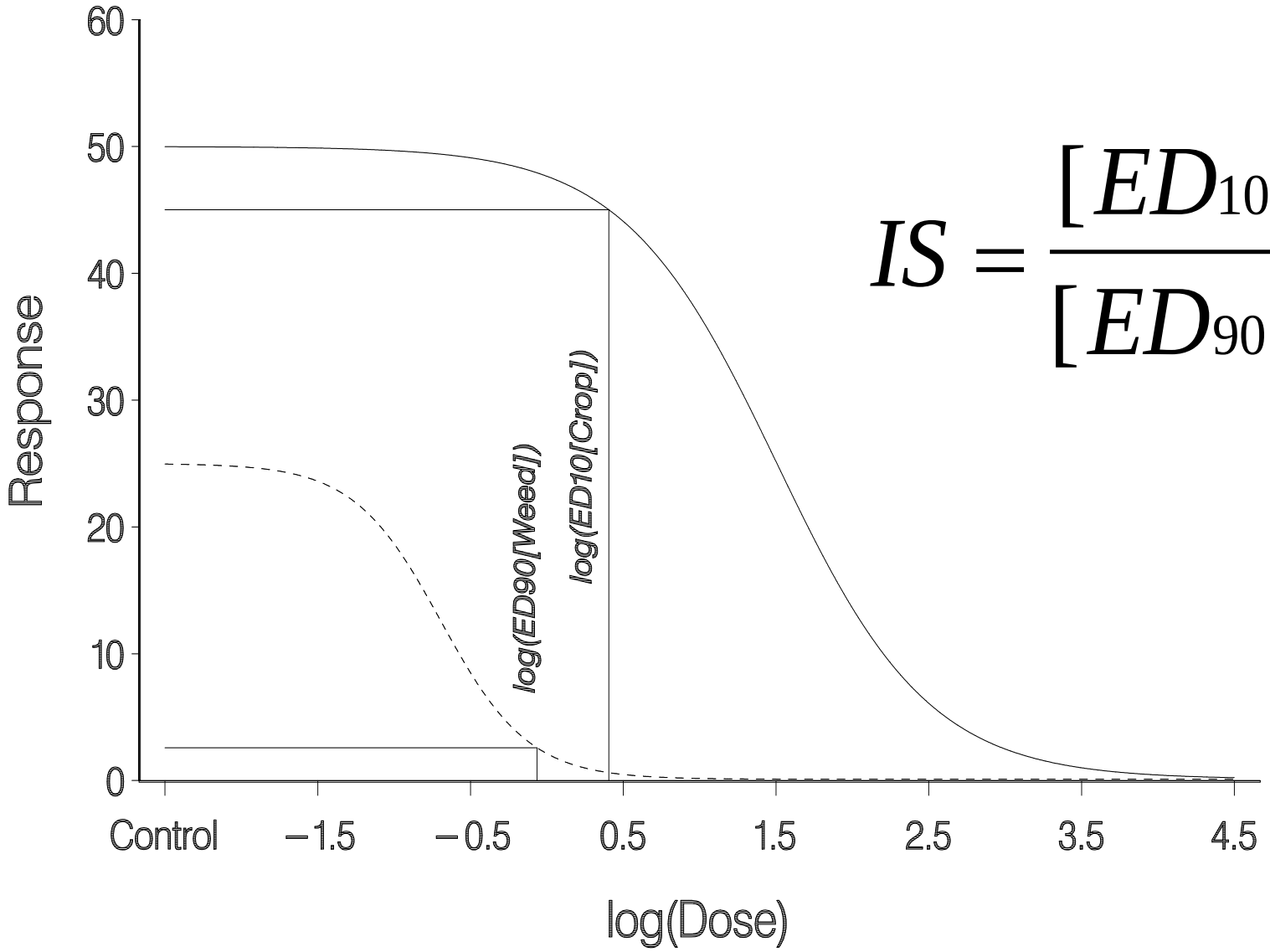
biomass, mortality, ect.

$$y = C + \frac{D - C}{1 + \exp\{b \cdot [\log(z) - \log(ED_{50})]\}}$$



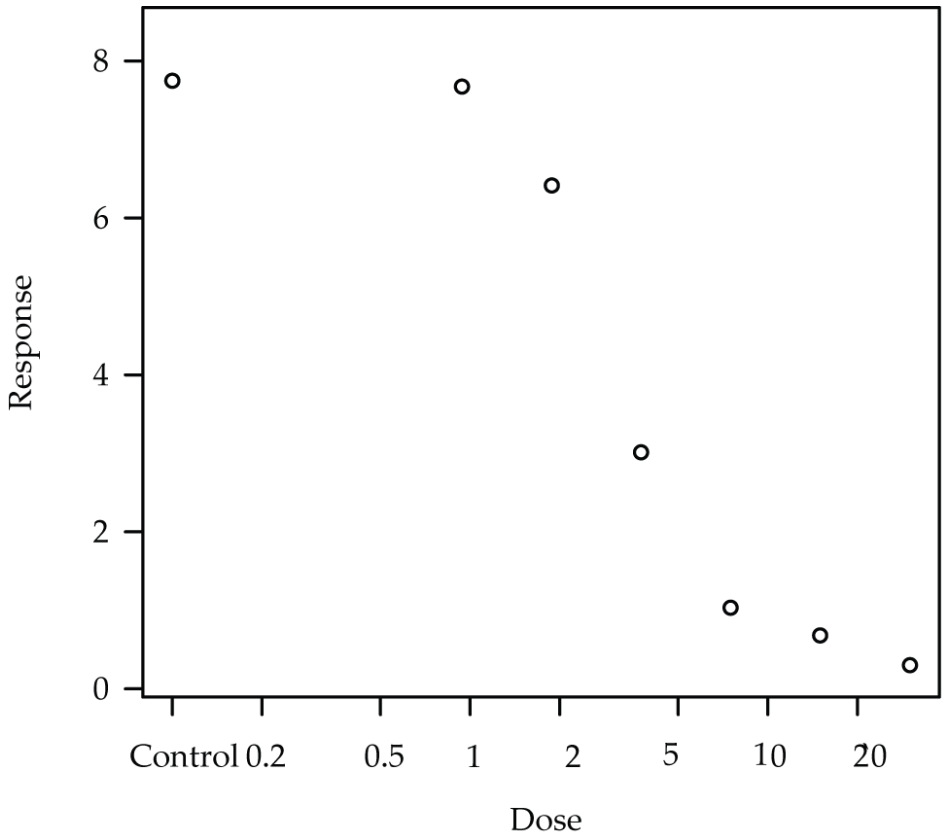
The effect of herbicides on the crop

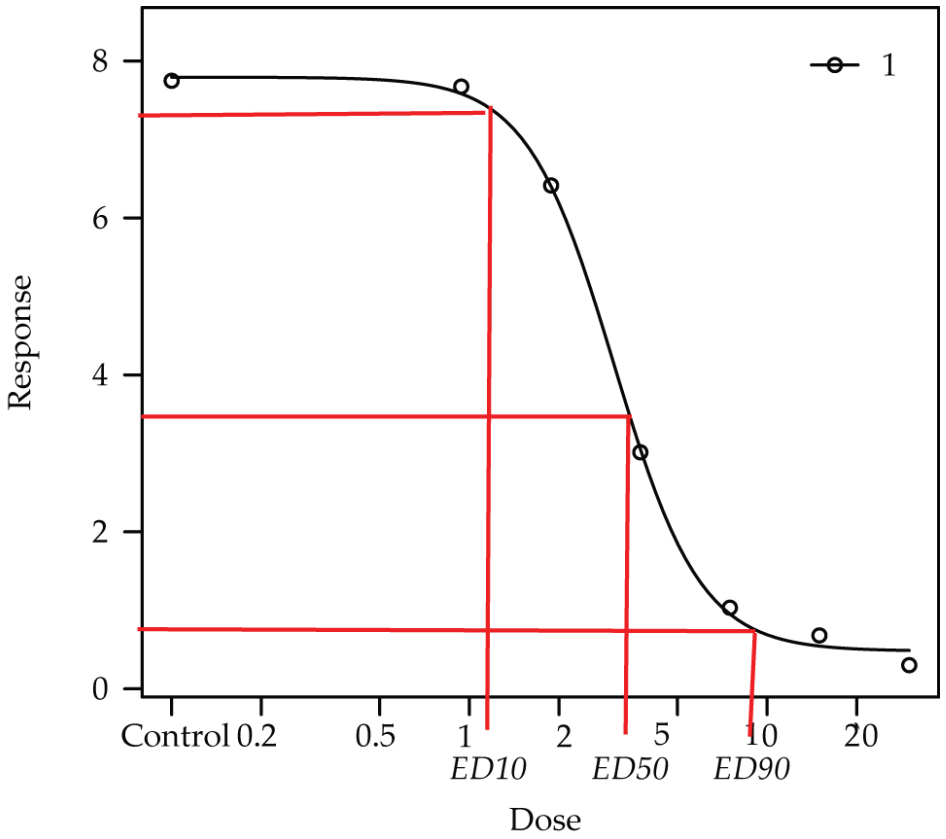
Selectivity Index



$$IS = \frac{[ED_{10}]_{Crop}}{[ED_{90}]_{Weed}}$$

Logistic Dose Response Curve

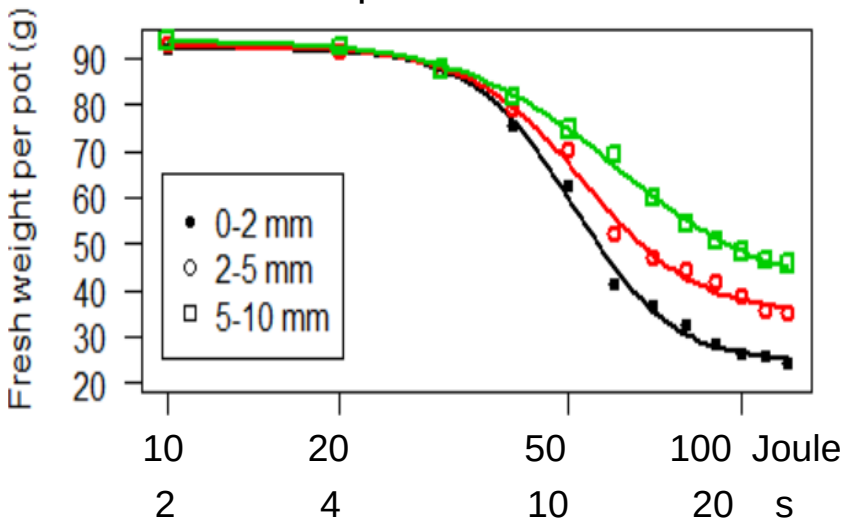




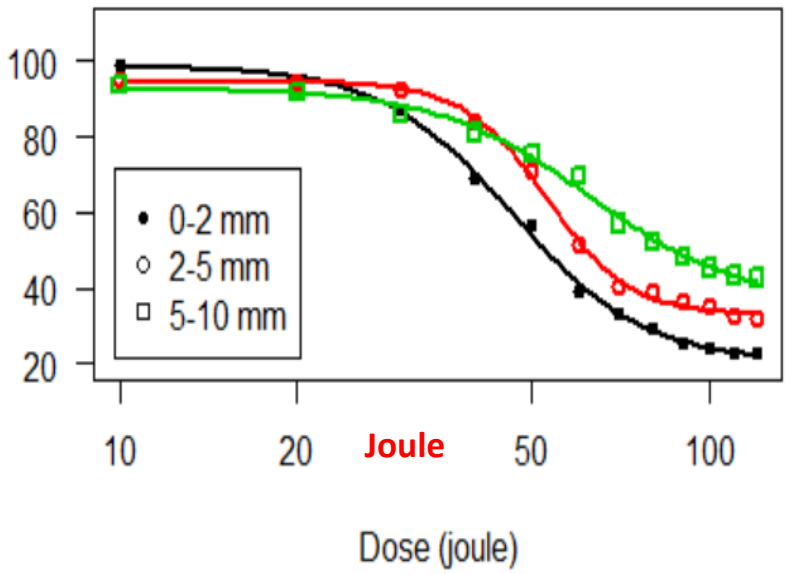
Beam diameter

Calculation of the energy = W x Second = Joule

Elymus repens exposed to **1 W** laser beams (435 nm) with different internal spot diameters



Elymus repens exposed to **5 W** laser beams (450 nm) with different internal spot diameters



(From Rakhmatulin and Andreasen, *Agronomy* **2020**, *10*(10), 1616)

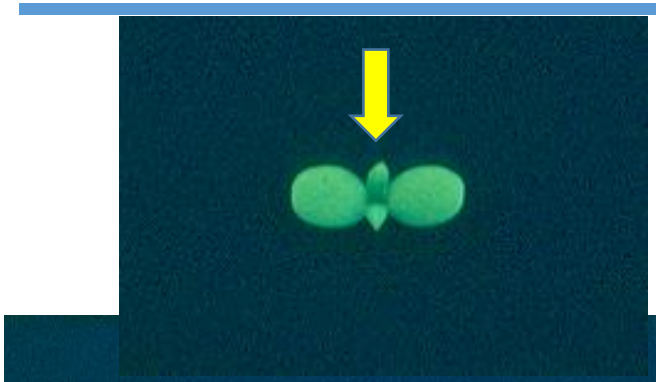
Living organisms

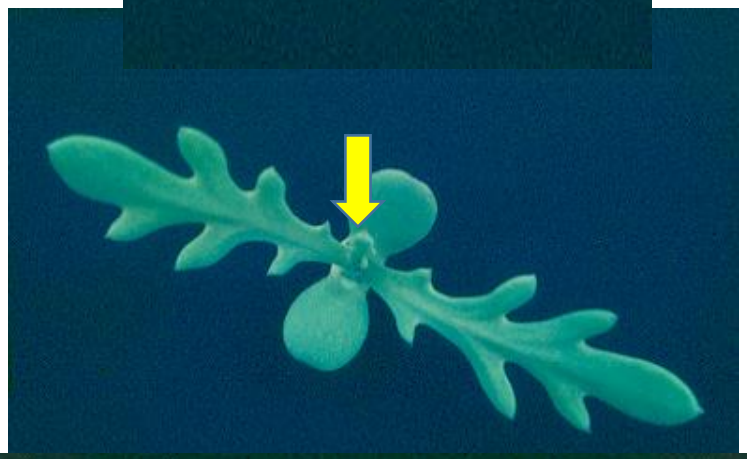
- Weeds: Dose-response exp.
- Crops : Dose-response exp.
- Insects: Dose-response exp.
- Worms: Dose-response exp.
- Large animals: Literature review
- Humans: literature review

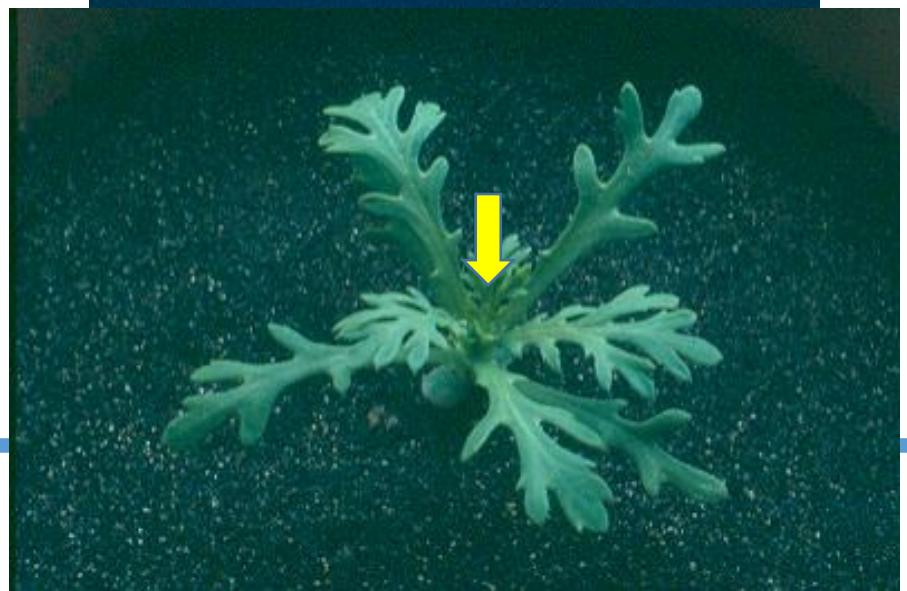


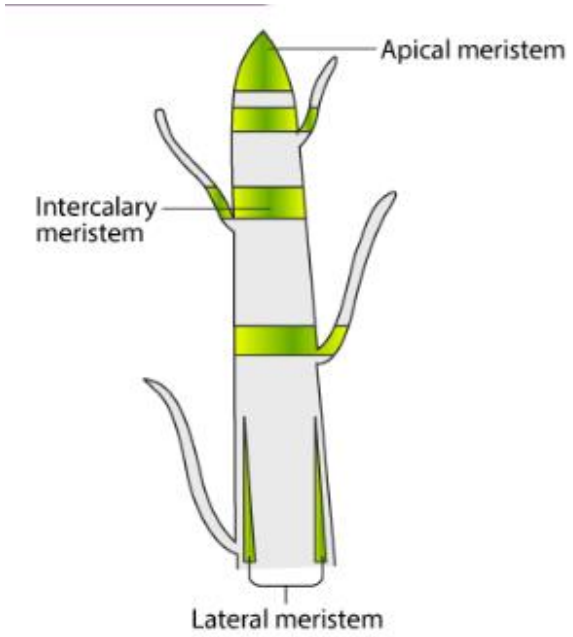


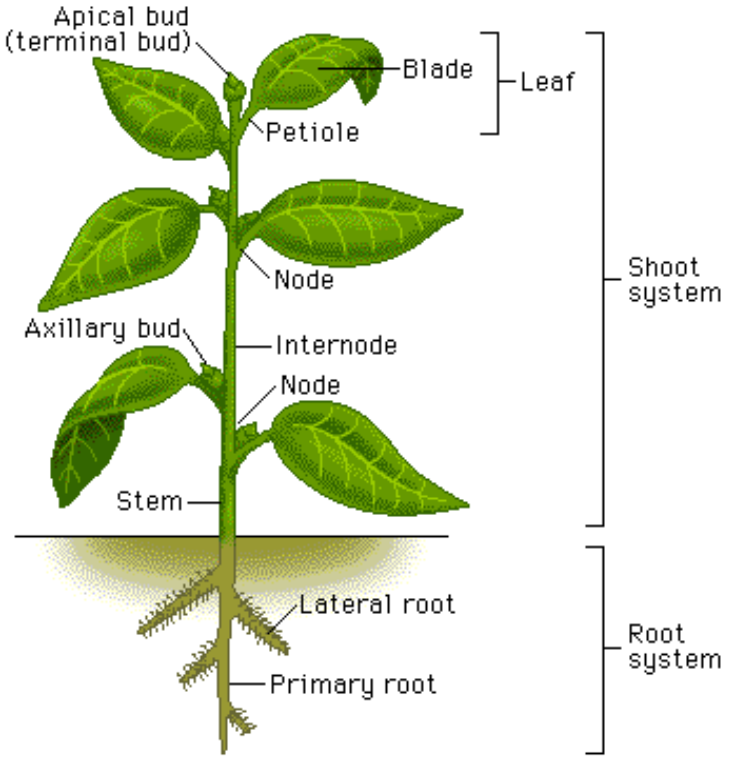

Chrysanthemum segetum





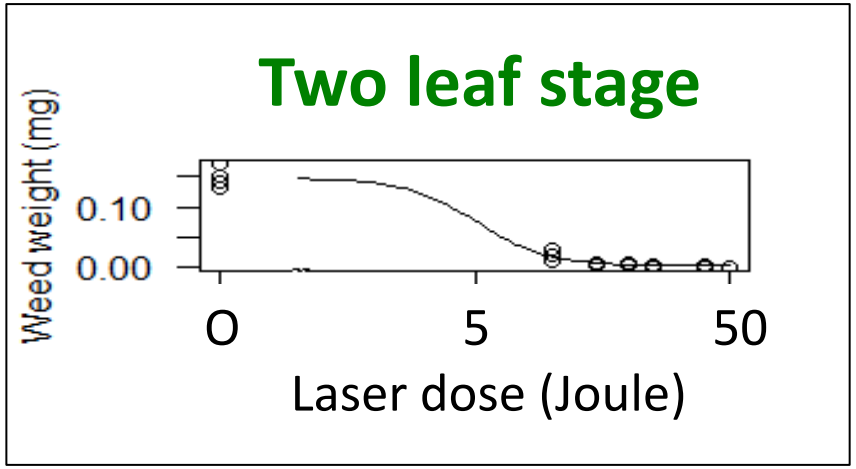


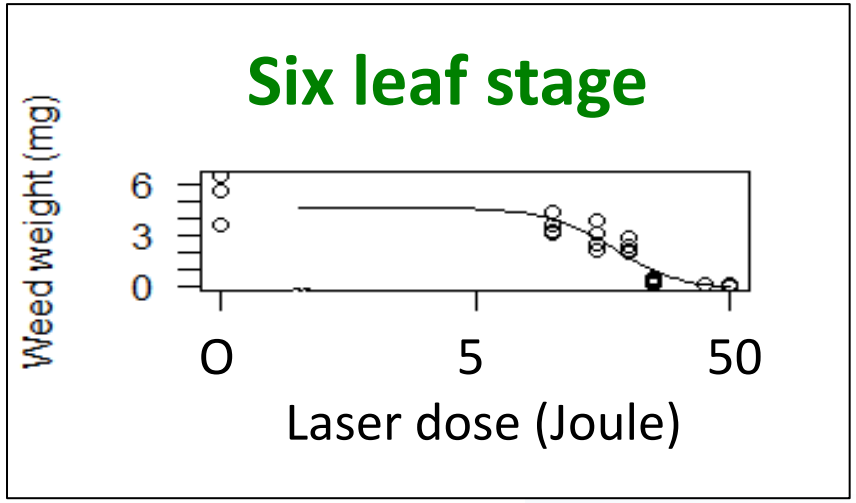




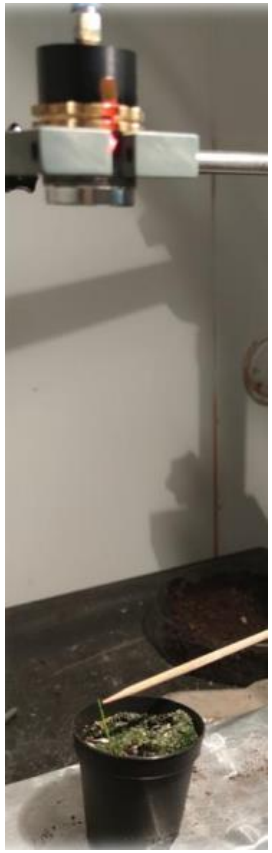
Dose-response - Annual weeds (50 W)

Dose-response experiment with the weed *Chenopodium album* (Fat Hen)

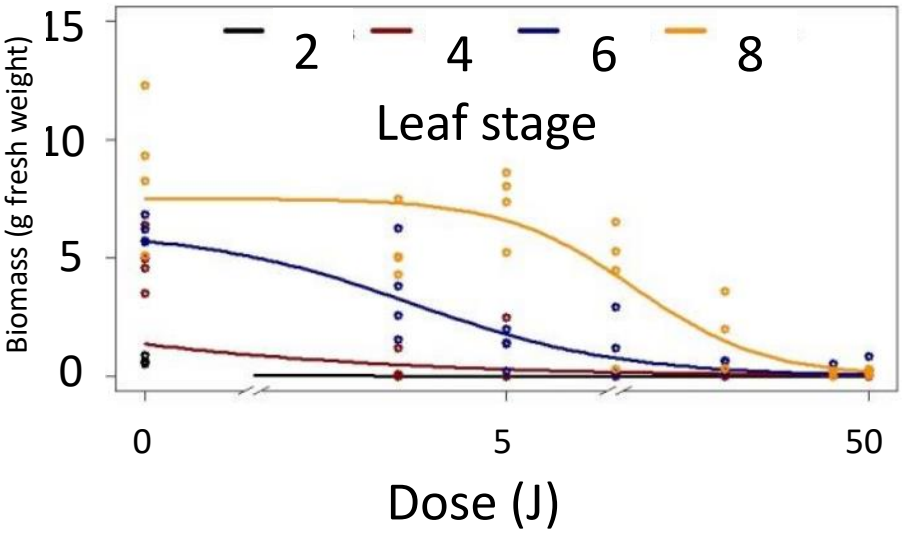




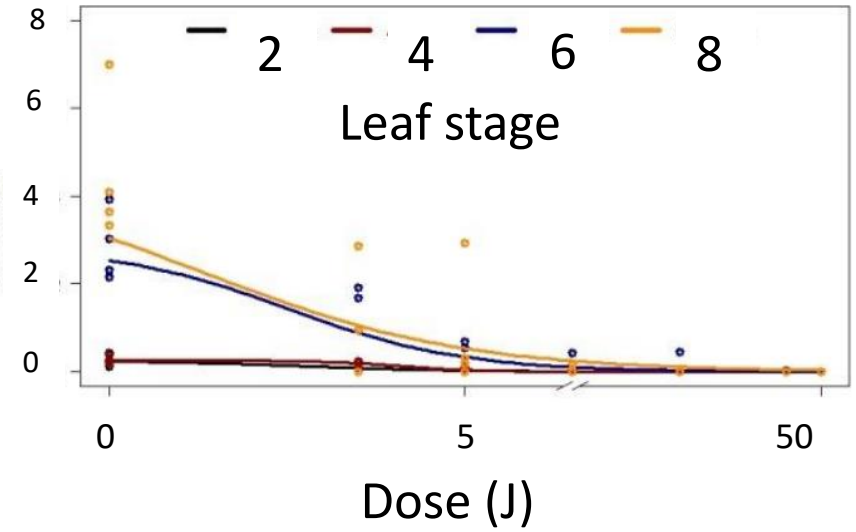
The effect on plants (50 W Laser)



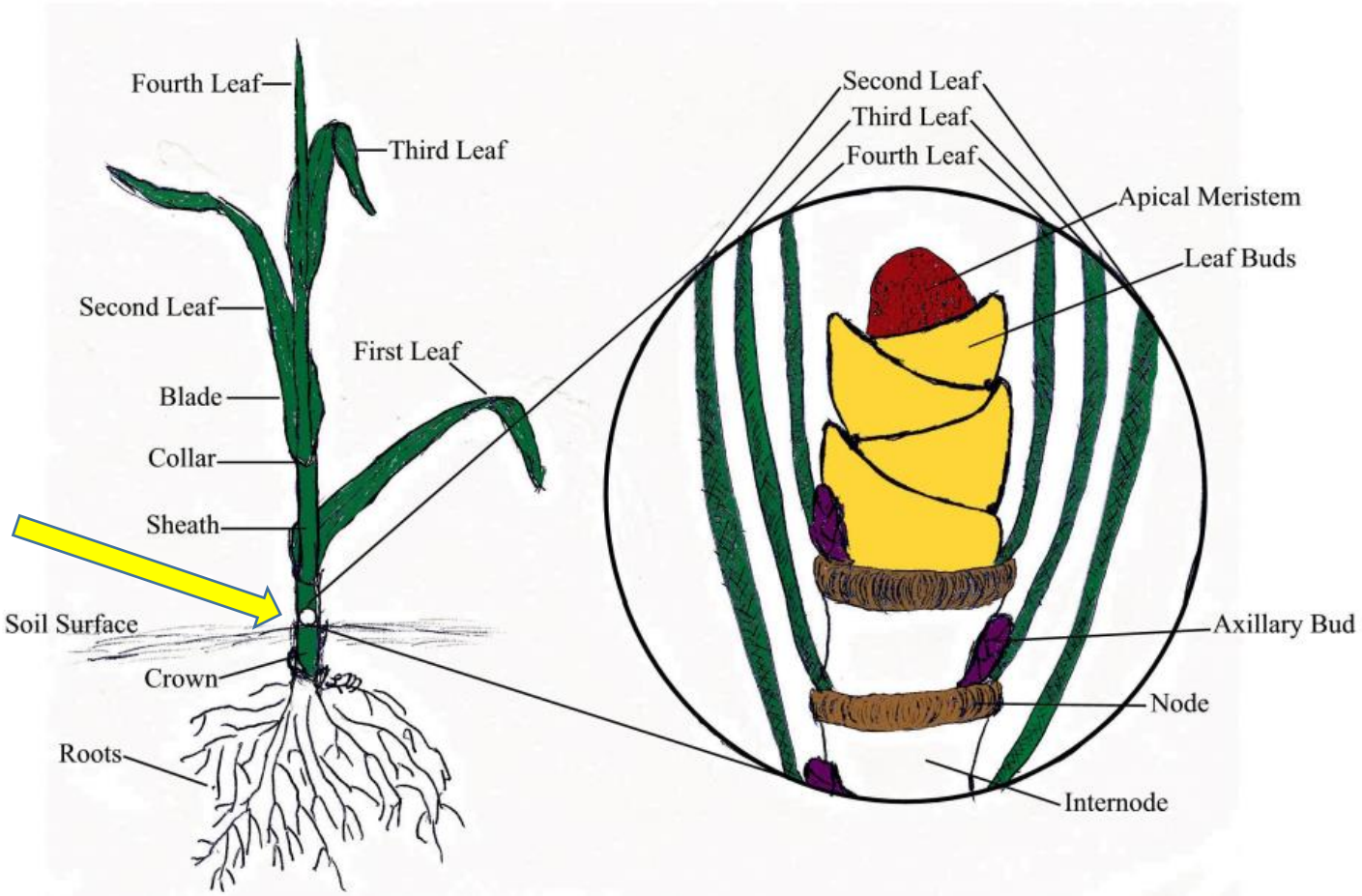
Centaurea cyanus



Capsella bursa-pastoris



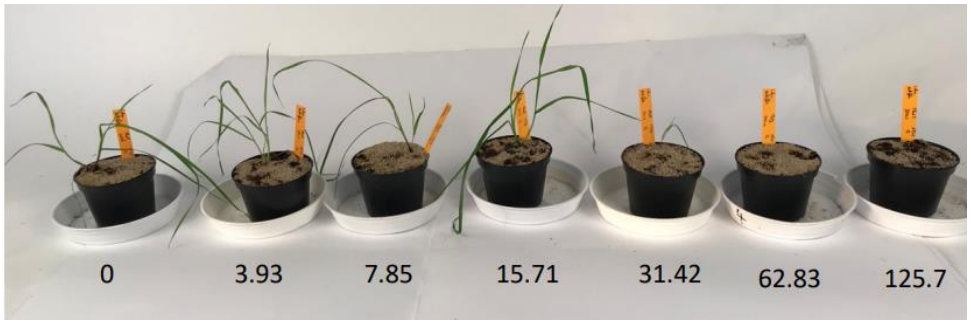
Grasses



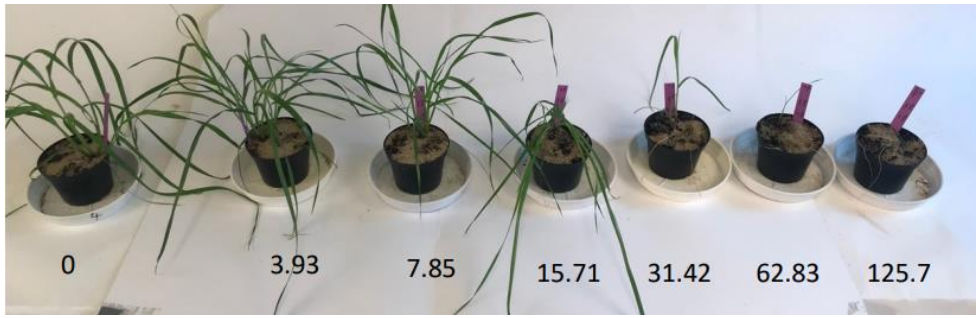
Grass Tiller at 3.5 Leaf Stage

From https://www.ndsu.edu/agriculture/sites/default/files/2022-10/topic1_volume2_report1.pdf

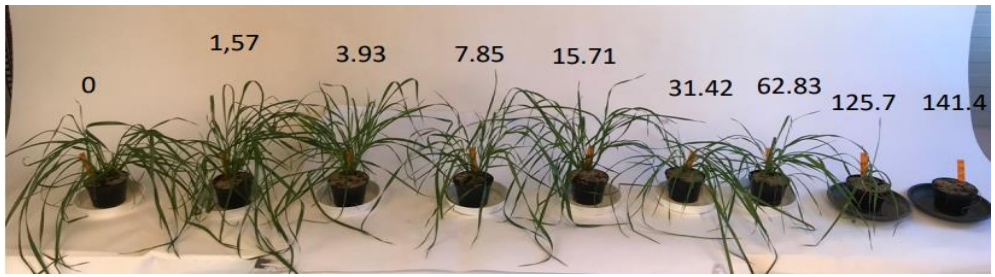
The effect on *Lolium multiflorum* (50 W Laser)



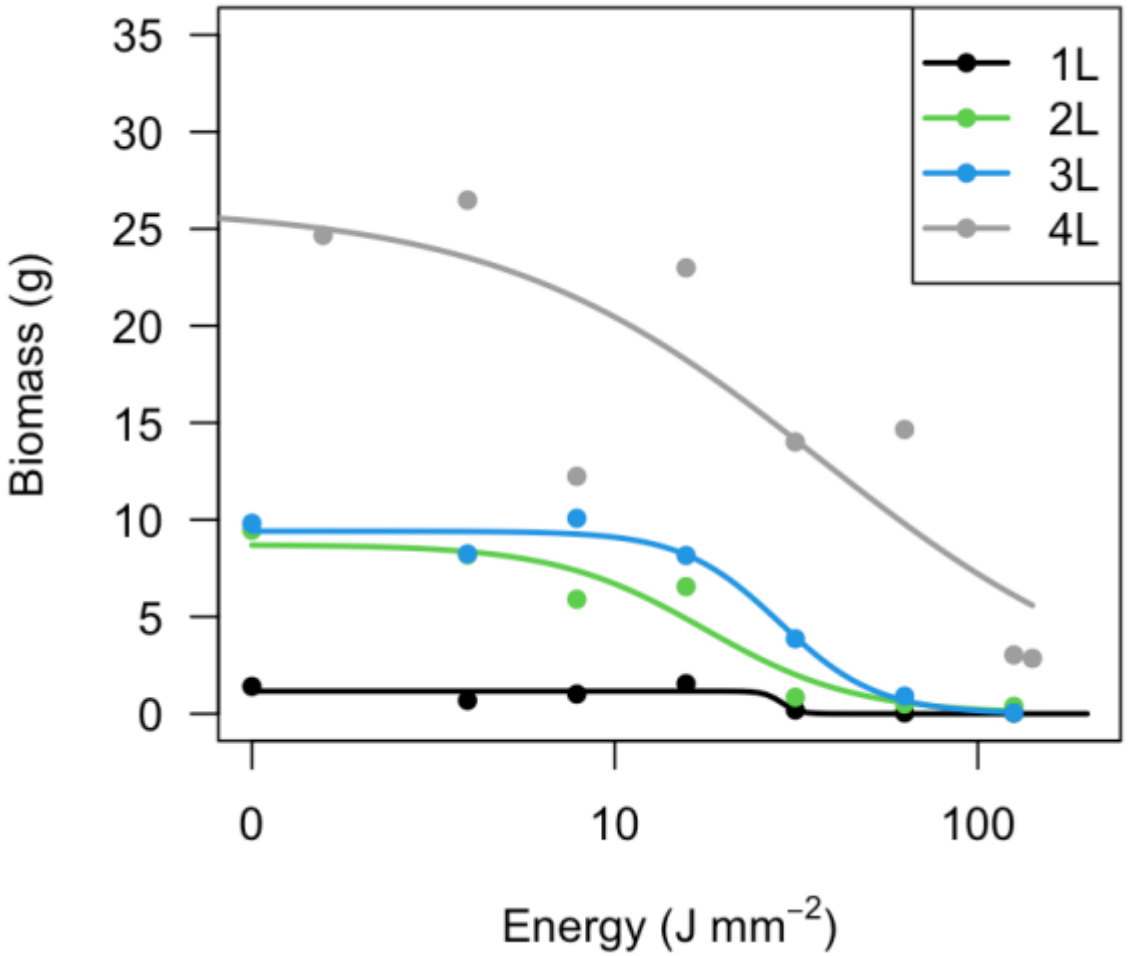
L. multiflorum one leaf stage 21 days after laser treatment.



L. multiflorum two leaf stage 21 days after laser treatment.



L. multiflorum four leaf stage 21 days after laser treatment. The doses are expressed in J mm^{-2}.



Perennial weed species with a taproot

Rumex crispus ***Rumex obtusifolius*** ***Taraxacum* sp.**

Perennial weeds

Sonchus arvensis *Cirsium arvense* *Equisetum arvense*

Elymus repens *Tussilago farfara*

Perennial weeds: *Cirsium arvense*

Cirsium arvense

Cirsium arvense

Growth stage 1

Growth stage 2

Growth stage 3

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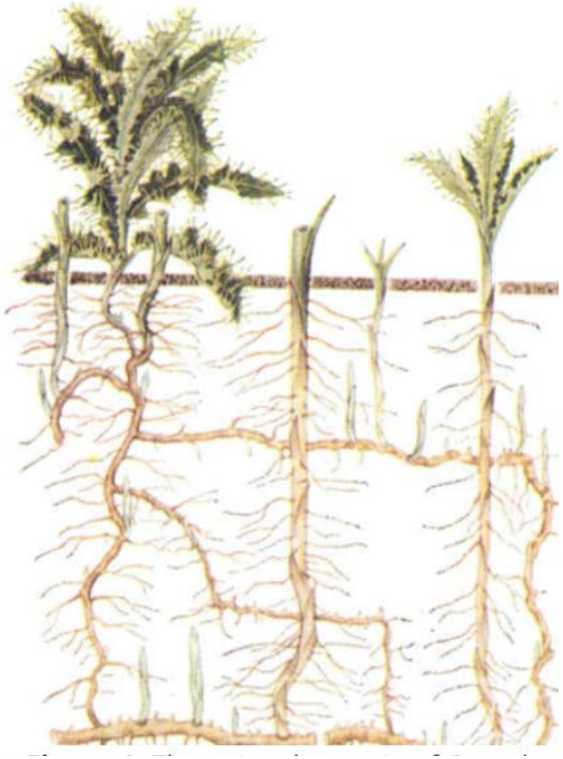
Two weeks after laser treatment

Growth stage 1

Growth stage 2

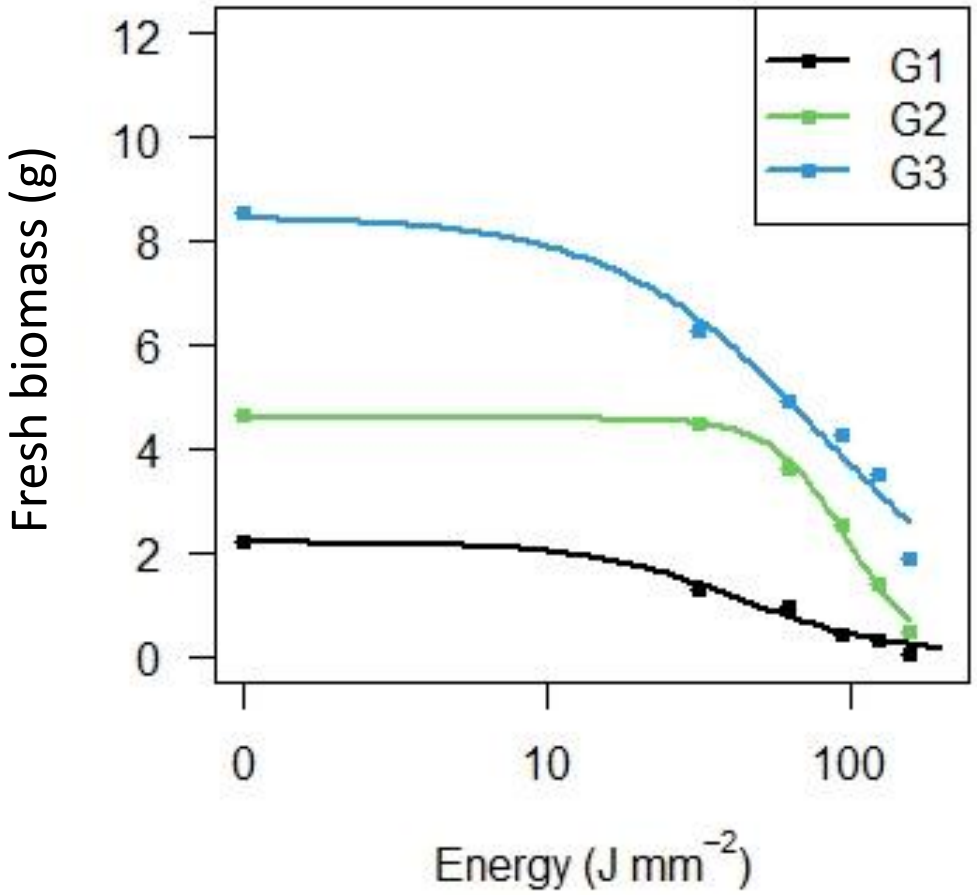
Growth stage 3

Cirsium arvense

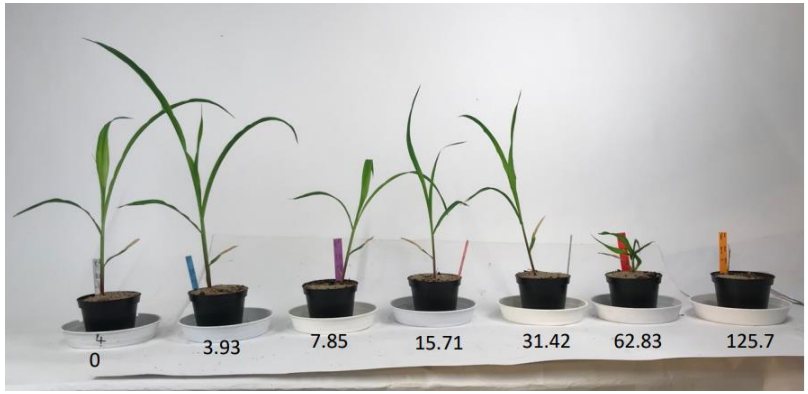


The extensive roots of Canadian thistle make it difficult to control

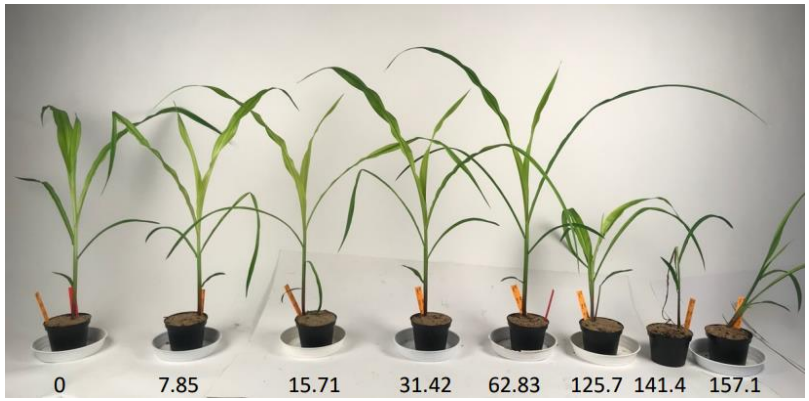
Cirsium arvense



Experiment with maize



Z. mays one leaf stage 15 days after laser treatment.
The doses are expressed in J mm^{-2}.



Z. mays four leaf stage 15 days after laser treatment.
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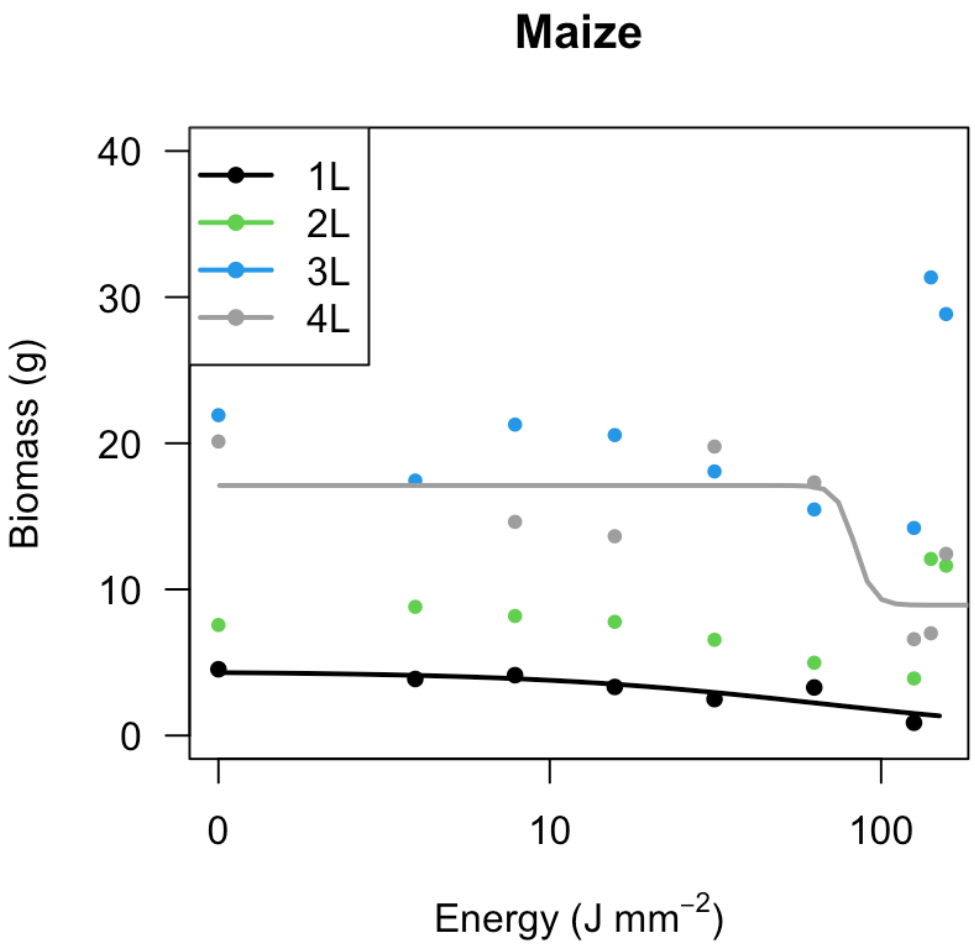
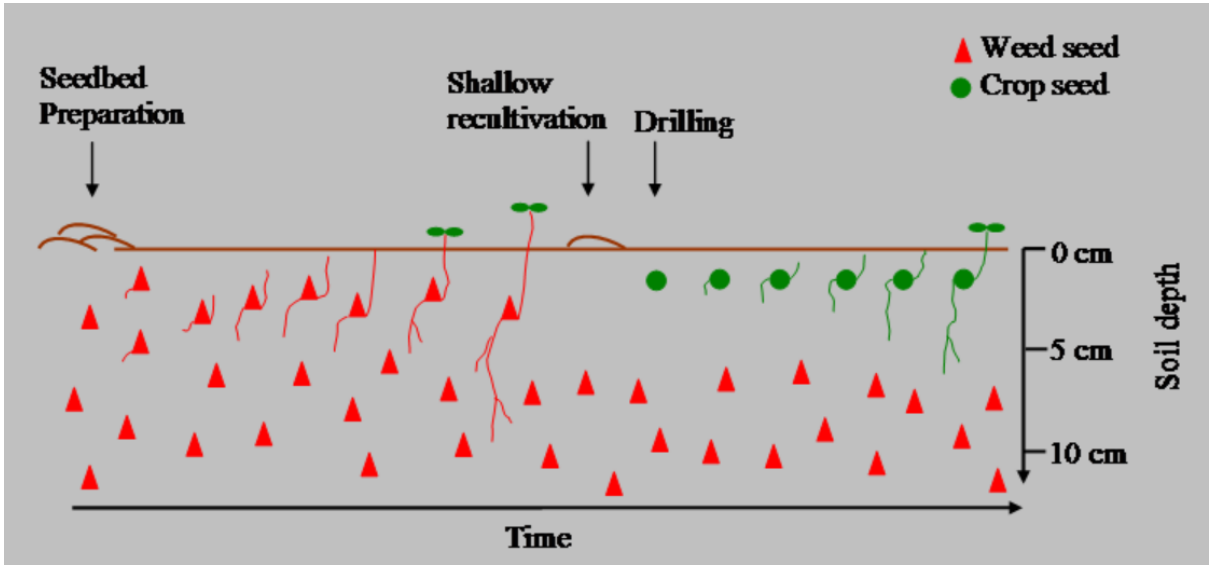
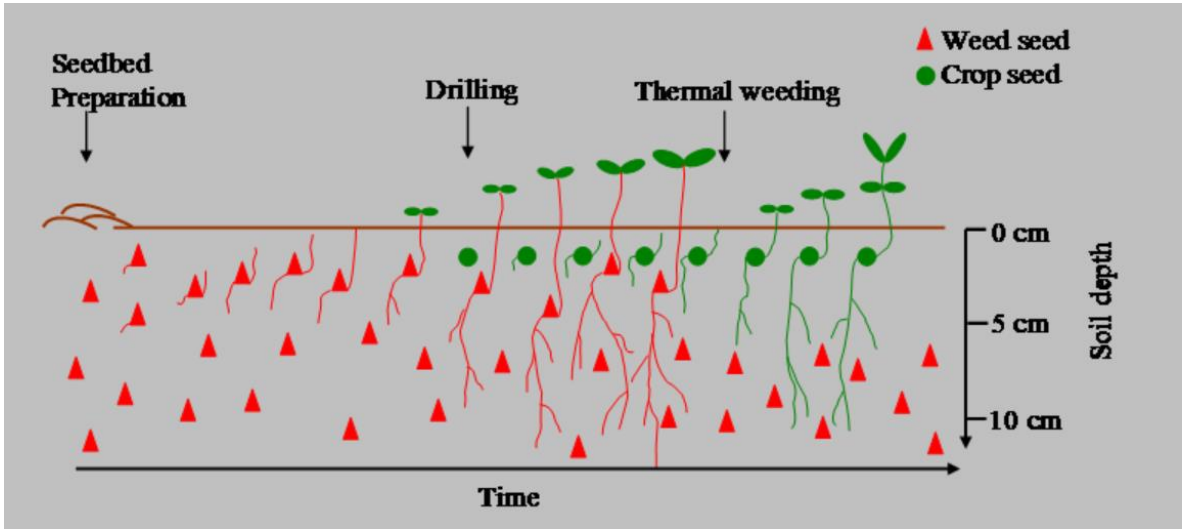


The effect on seeds



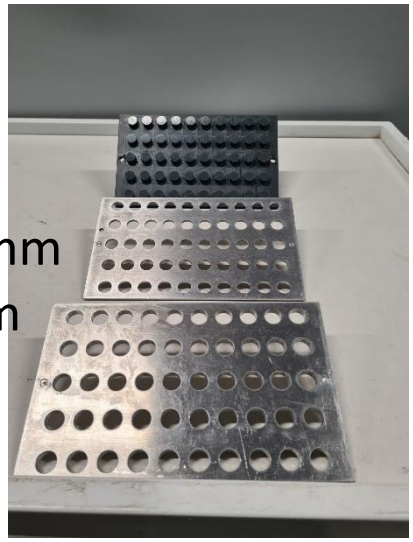


Partner logo

Dose-response experiments with seeds in different soil depths

Plates ensuring
The correct soil depth

2.5 mm
5 mm



Wheat and *Centaurea cyanus* germinated at 20 °C in climate boxes

Soil elevations correspond to that soil layer that covered the seed under irradiation

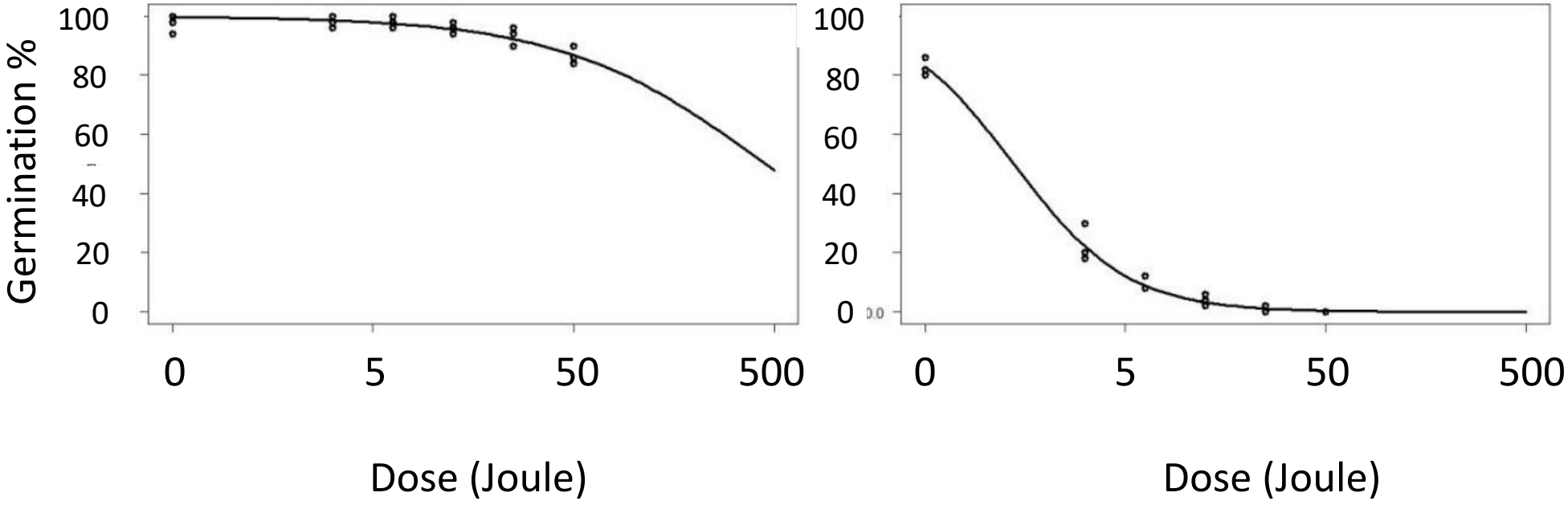
Dose-response experiments with seeds on the soil surface (50 W laser)

5 to 9 mm long

Wheat seeds

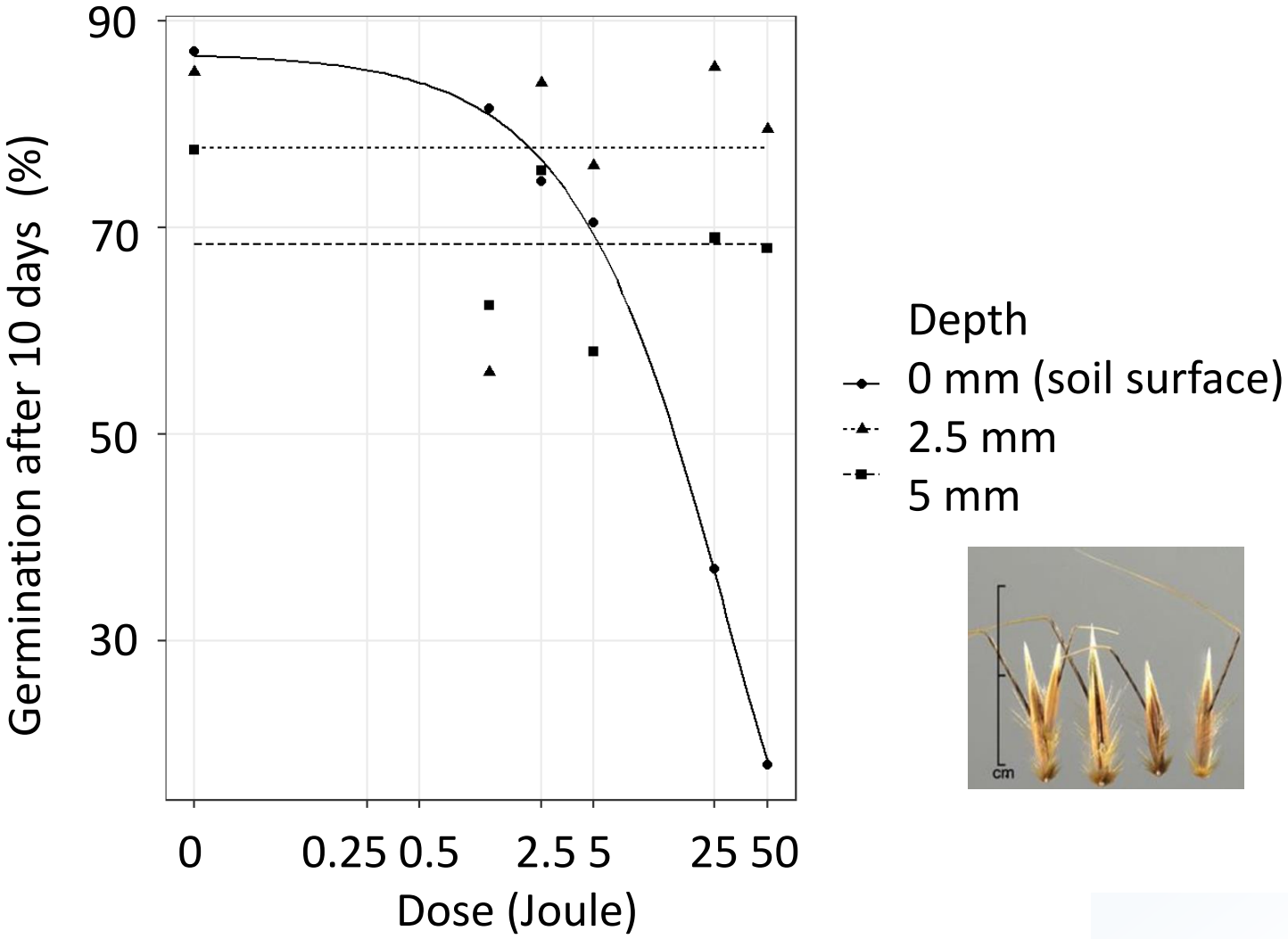
3.4 long

Centaurea cyanus seeds



From Zang (2022)

Dose-response experiment with *Avena fauta* seeds



The effect on worms

Enchytraeus albidus and *Enchytraeus crypticus* are often used in ecotoxicological studies

Enchytraeus albidus and *Enchytraeus crypticus* living in different soil types

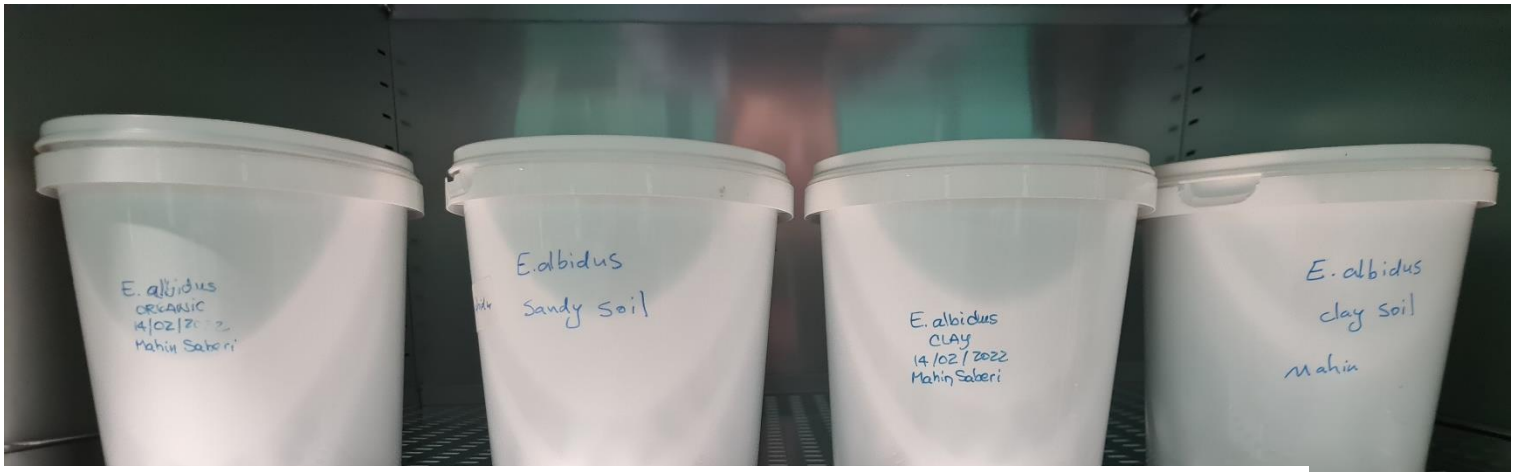
Enchytraeus

A colony

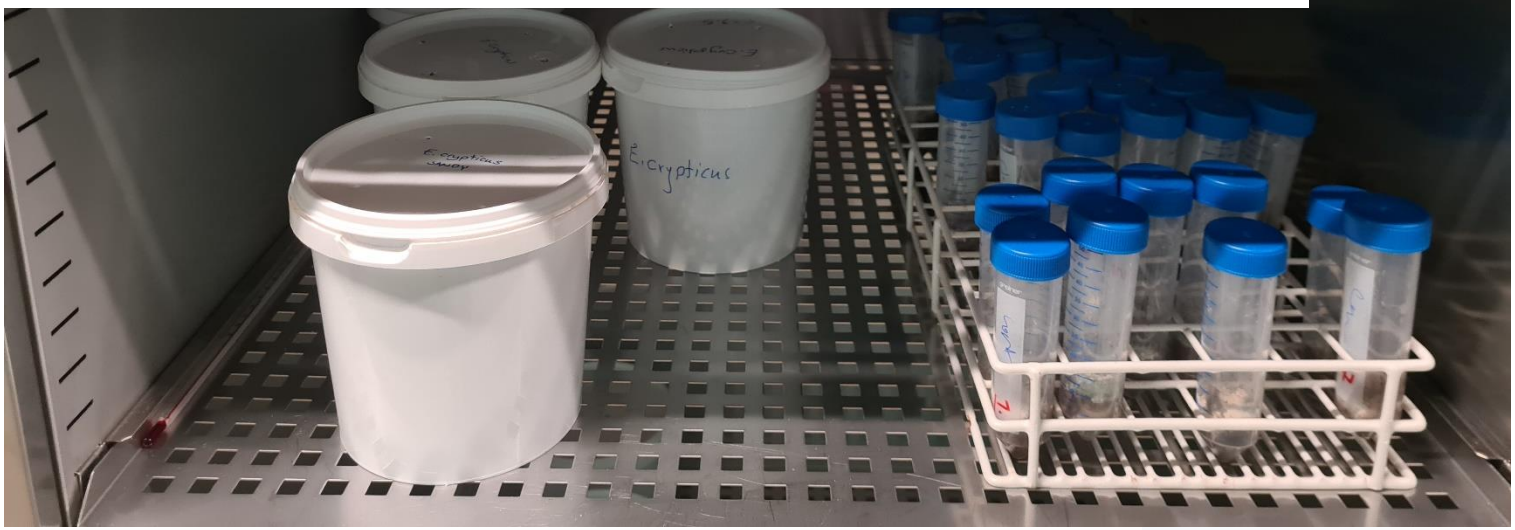
Scientific classification

Kingdom:	Animalia
Phylum:	Annelida
Class:	Clitellata
Order:	Tubificida
Family:	Enchytraeidae
Genus:	***Enchytraeus*** Henle, 1837

Species



NO EFECT OF LASER ON THE WORMS !



Life cycle of yellow mealworm (*Tenebrio molitor*)

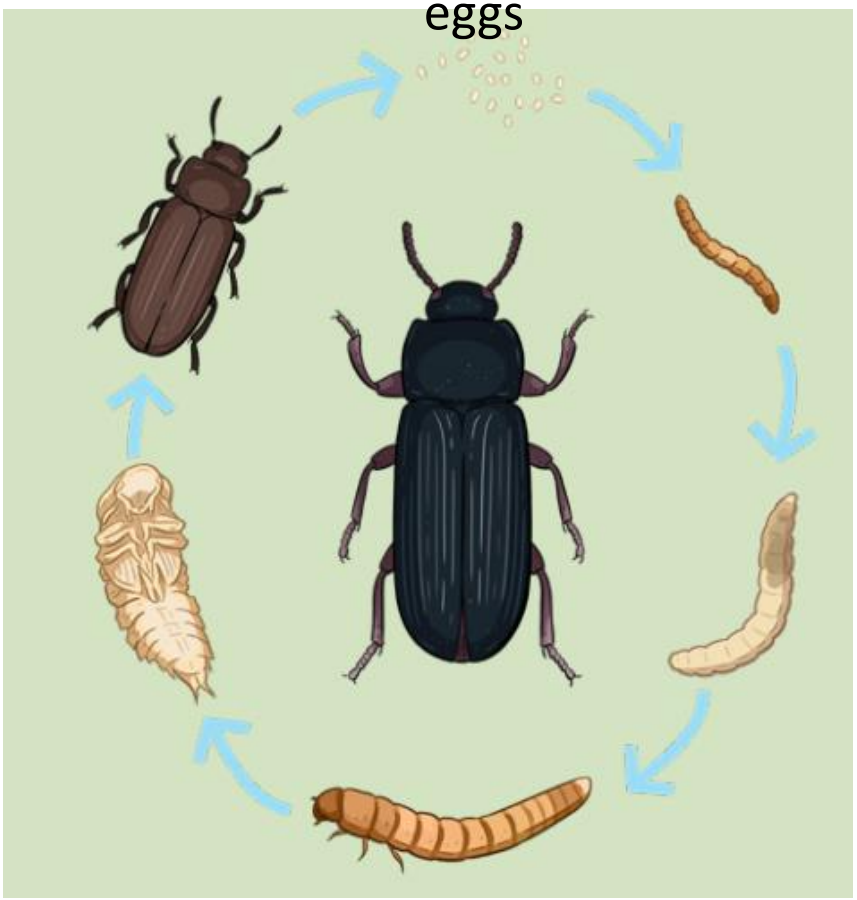
Model insect

1. 

2. 

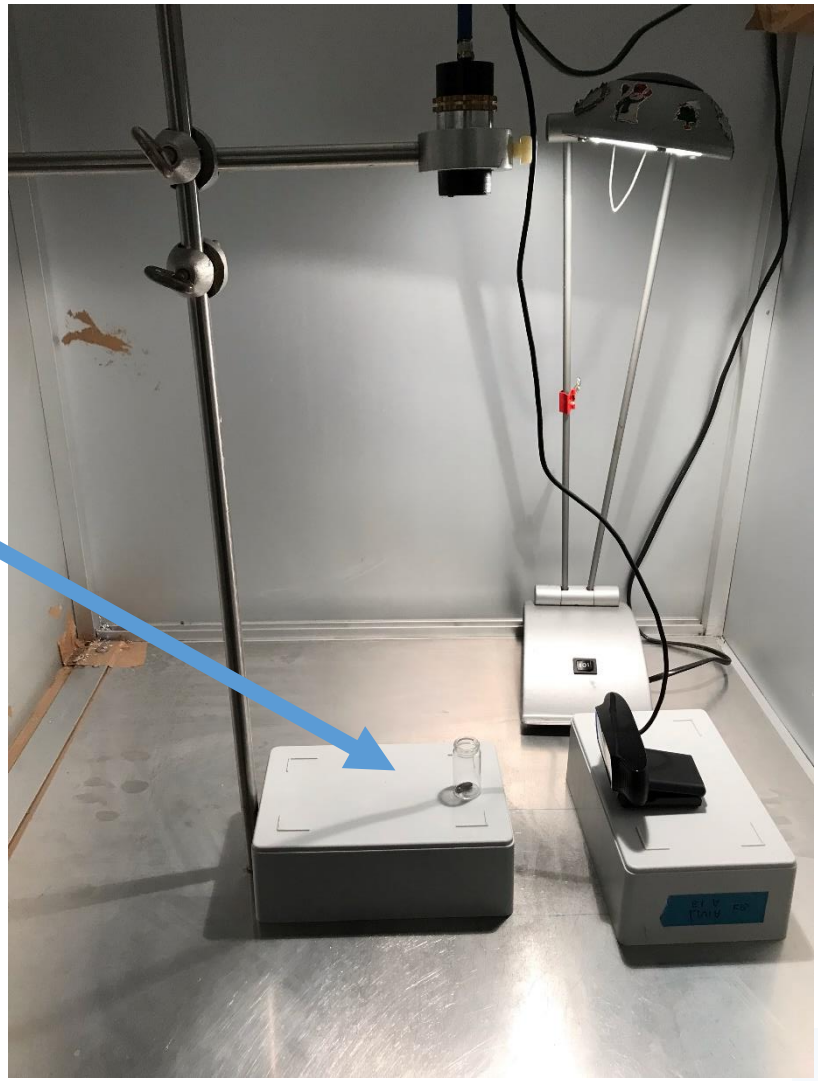
Pupa

3. 



Dose-response experiments with *Tenebrio molitor* beetles

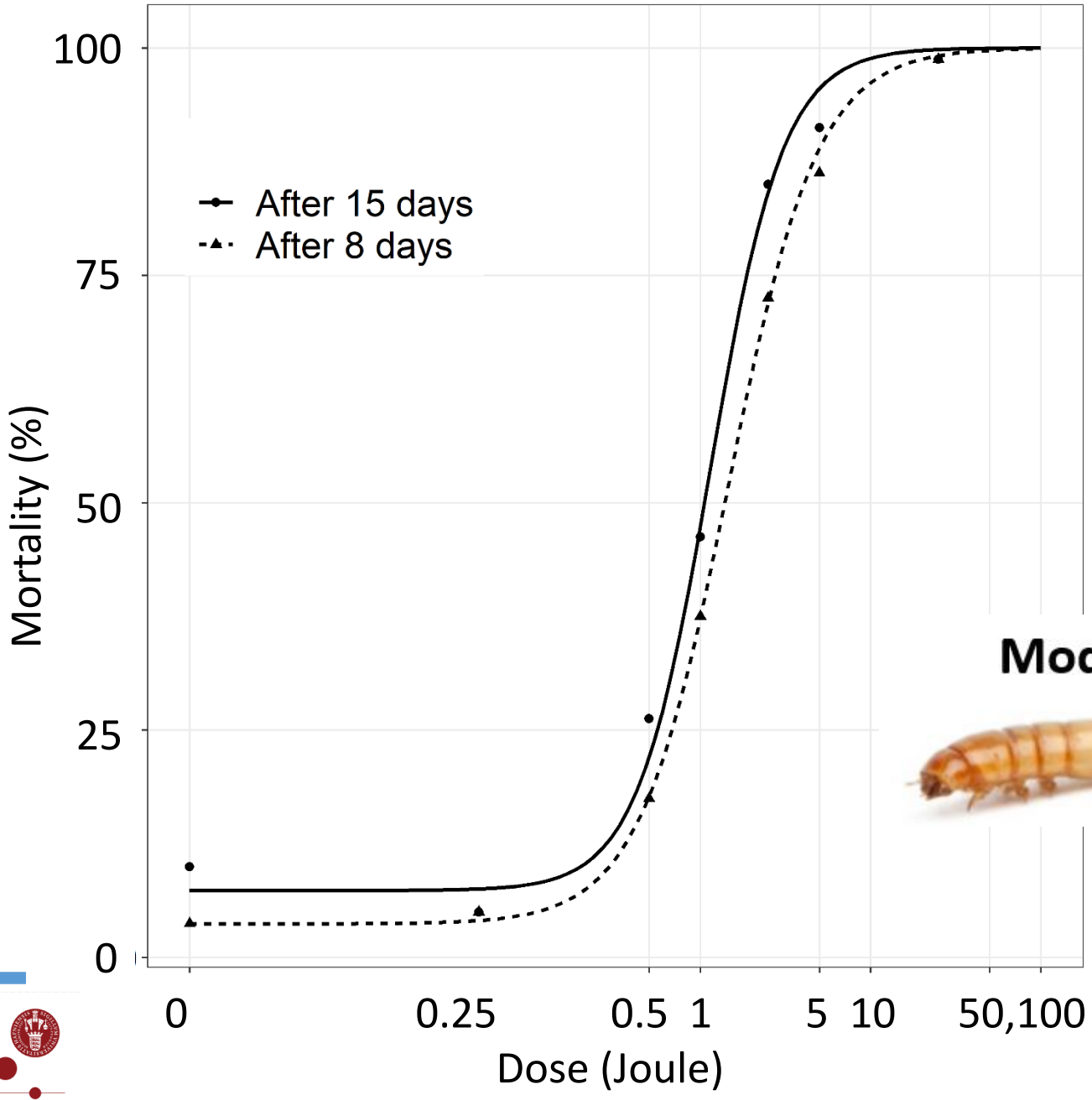
Beetle in glass tube



yellow mealworm (*Tenebrio molitor*) larva

Mealworms feeding
on oatmeal and potatoes

Dose – response experiment *with T. molitor larvae*



Mortality
after 15 days
after 8 days

Model insect

T. molitor larvae experiment

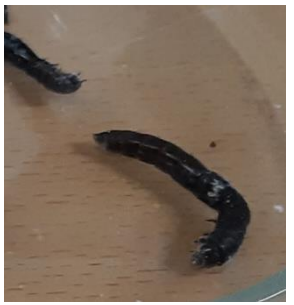
Examples of observed damages

Control
Larvae develop to adult at the end of the experiment (no physical deformities)

0.05 J (0.01 ms)
Larvae become a deformed alive adult

1.0 J (20 ms)
Larvae develop to deformed adults and die

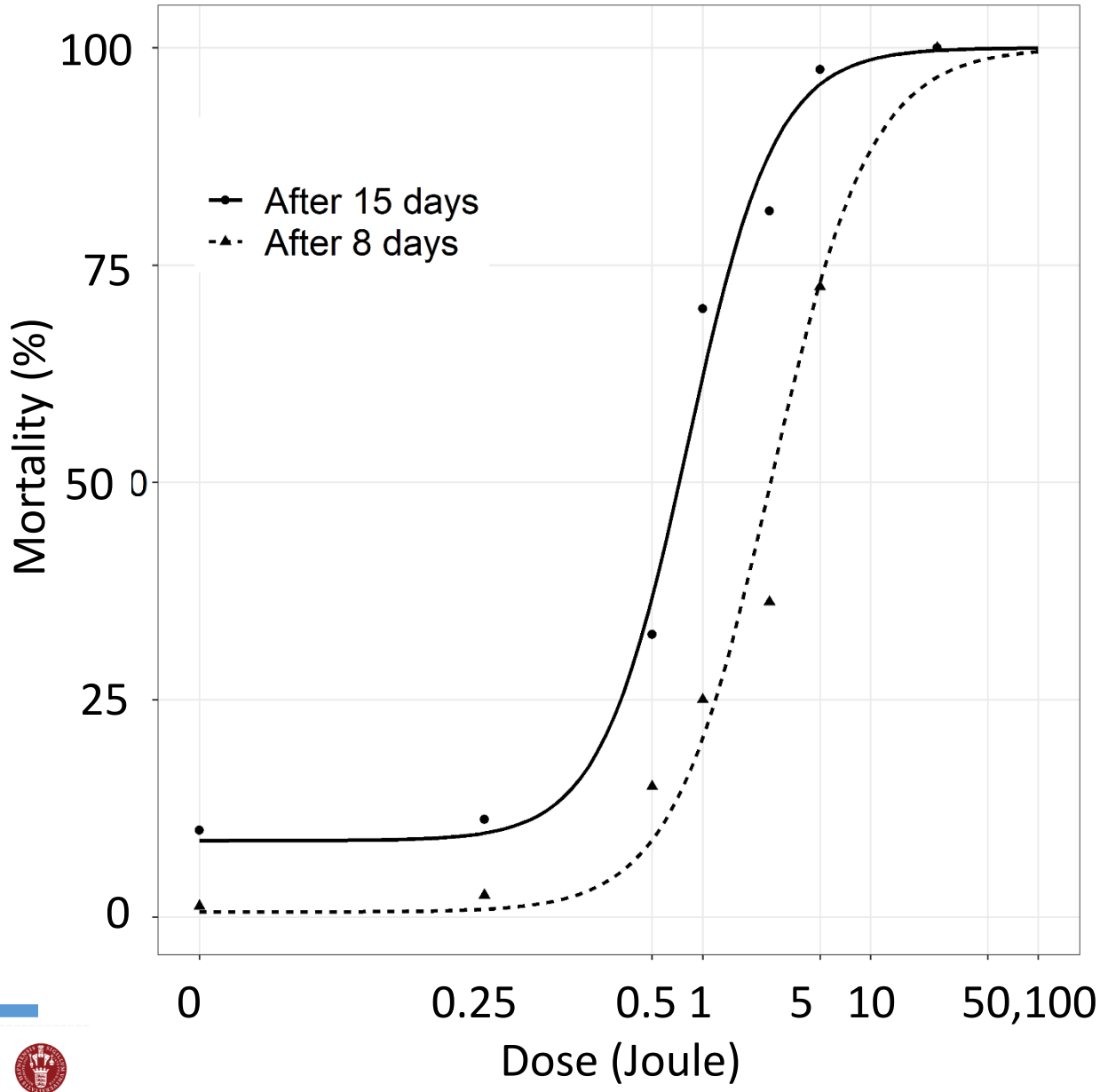
2.5 J (50 ms)
Larva does not complete Metamorphosis. (Severely deformed insect; half pupa, half adult)



5 J (100 ms)
Burnt larva

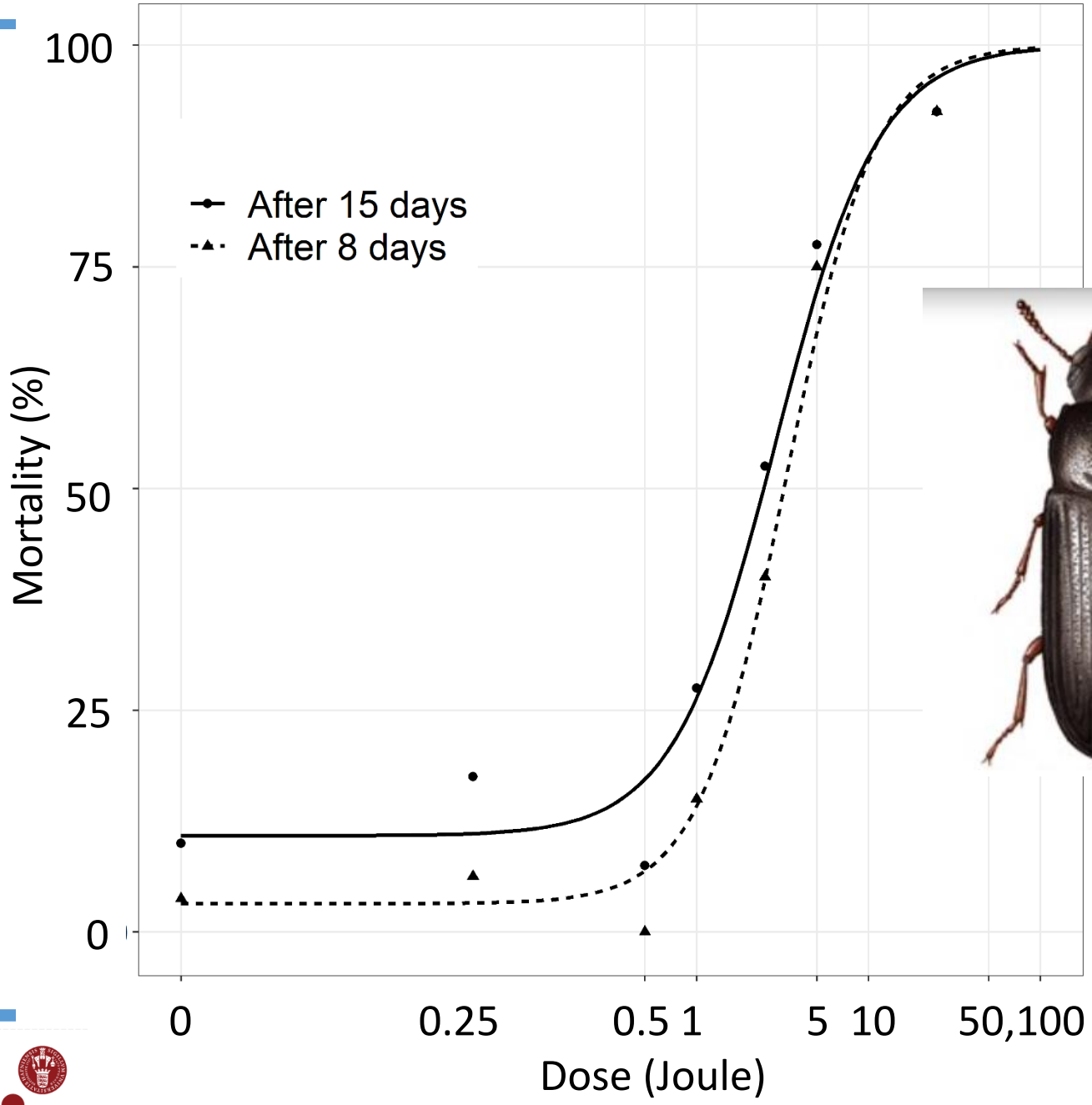
25 J (500 ms)
Larva was killed fast after the laser. pronounced damages: inability to develop into the next stage (haemolymph flowed out of the body due to a laser hole)

Dose – response experiment *with T. molitor pupae*



Mortality
after 15 days
after 8 days

Dose – response experiment *with T. molitor pupae*



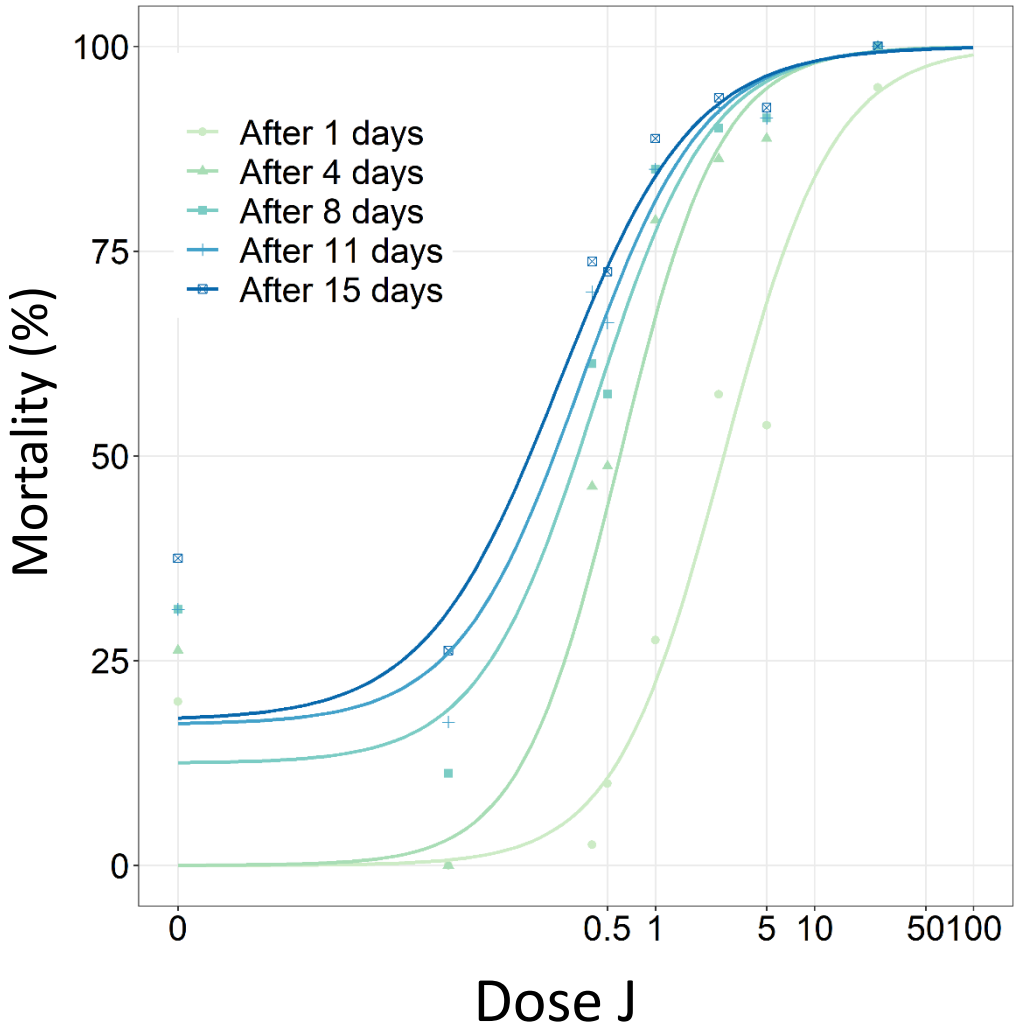
Mortality
after 15 days
after 8 days

Ladybug (*Adalia bipunctata*)

Beneficial insect

Life cycle

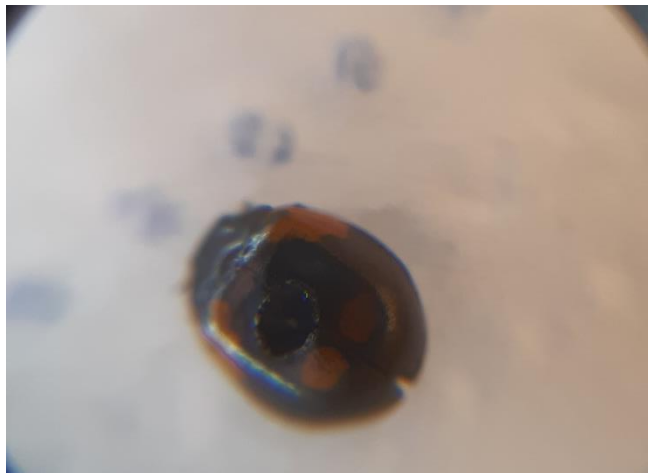
Dose-response experiments with ladybugs



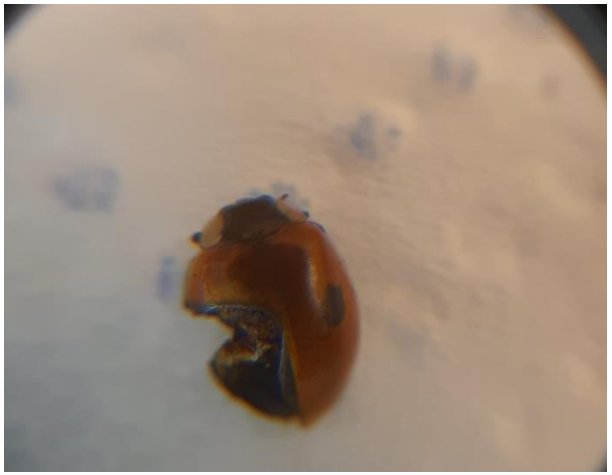
Dose-response experiments with ladybugs

0.05 J (1ms)
Brownish colour of the outer shell, alive insect

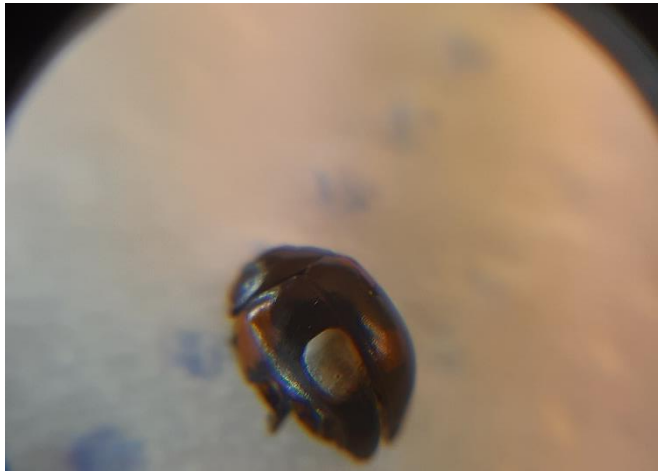
0.1 J (20ms)
Small damage, alive insect



2.5 J (50ms)
Severe damage, dead insect



25 J (500ms)
Acute damage, dead insect one day after shooting

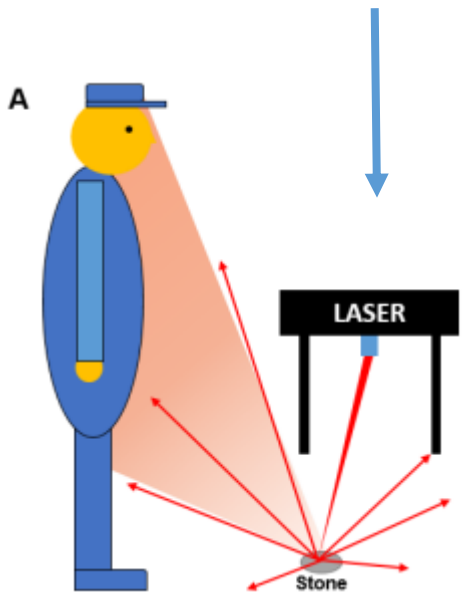


25 J (500ms)
Fungal infection, dead insect

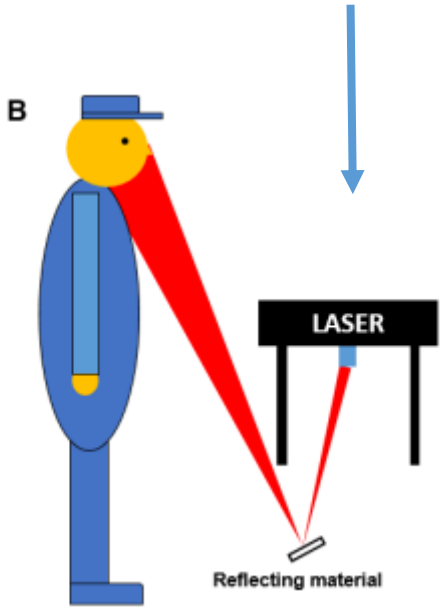
Humans and larger animals

If the applied laser radiation is divergent, i.e. expanded, the irradiance decreases with increasing distance from the laser beam focus.

Fiber laser for weed control with a wavelength of 2 µm (invisible)



A. If the laser beam hits a stone, it is reflected diffusely, and the laser energy is spread in all directions.



B. A reflected beam remains directed and expands as given by the laser optic. It may pose a serious risk for the person and the surroundings

Conclusion

- Good effect on small annual plants
- Perennial weeds require several treatments
- No effect on soil worms in the soil
- Insects at all life stages are sensitive to laser irradiation, but as only a very little area is exposed, the risk of hitting the fauna is very small.
- Human and larger animal can be blinded and burnt by the laser beam.

Laser safe goggles

Impact on larger organisms (animals and humans)

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Laser Weeding With Small Autonomous Vehicles: Friends or Foes?


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Safety

Laser beams can be harmful to humans and animals. Infrared cameras and sensors must be mounted on the vehicle to warn and stop it when it approaches humans, animals or any other obstacles ensuring an appropriate safety distance. Depending on the laser wavelength, the laser can be more or less harmful to the eyes and skin and cause irreversible damages (e.g., blindness). Visible and near-infrared (400–1,400 nm) laser light pose a critical hazard on the retina. Since the tissue structures of the retina are unable to undergo any repair, lesions caused by the focusing of visible or near-infrared light on the retina may be permanent. The most critical area of the retina is the central portion, the macula, and the fovea.

Laser light in the ultraviolet or far-infrared spectrum can cause damage to the cornea or the lens. Far infrared (1,400 nm – 1 mm; CO_2 lasers, 10,600 nm) can cause thermal damage by the heating of the tears and tissue water of the cornea. Excessive exposure to infrared radiation results in a loss of transparency of the cornea or surface irregularities (Occupational, Safety and Health Administration, 2022).

AI-Autonomous Robots for Agriculture – Weeding with Laser

WeLASER Summer School

Thank you for your attention!

Please find more information on

https://welaser-project.eu/

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CSIC Consejo Superior de Investigaciones Científicas · FUTONICS · LZH Laser Zentrum Hannover e.V. · University of Copenhagen

AGREENCULTURE Smart robots for smart farming · COAG · Alma Mater Studiorum Università di Bologna · IETU Instytut Ekologii Terenów Uprzemysłowionych · Ghent University · van den borne aardappelen