Development of tools for automated physical weed control

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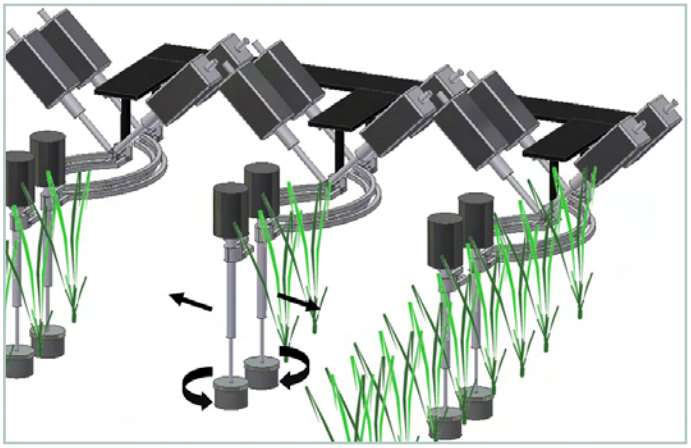
Tools are being developed for automated physical weed control in the close to crop area. The most promising weed control concepts are the so-called high precision tillage solutions and thermal weed control by pulsed lasers.



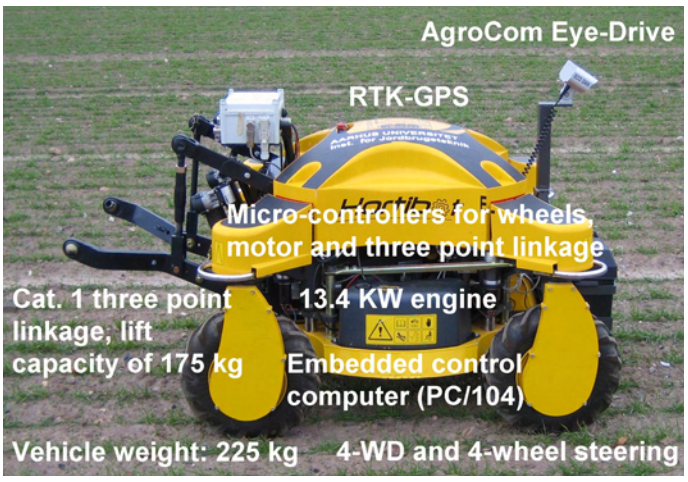
Three row steel brush conceptual tool for close to crop weed control (student project by Thomas Jensen and Anders Ø. Clausen, University of Southern Denmark).

Novel implements for intra-row flaming and mechanical weed control are commercialised (www.fp-engin.dk, www.garford.com). The demand to future technology is properties to control weeds in the near proximity of crop plants without reducing yield. In this study, 30 concepts for close to crop weed control were identified and evaluated by various aspects. The most promising weed control concepts were so-called high precision tillage solutions and thermal weed control by pulsed lasers.

Technology development with regard to organic principles

In organic crop production, weeds in the close to crop area are controlled by time consuming and monotone manual weeding in order to reach high crop yield. Consequently, there is a need for new technologies capable of carrying out effective physical weed control in near proximity to individual crop plants in order to assure the economics in organic crop production. Compared with traditional tractor pulled weed controlling implements, light weight and low speed autonomous vehicles equipped with advanced sensor and control systems provide opportunities for weed control operations close to crop. Consequently, novel weed control tools have to be identified and evaluated for those vehicles.

The aim of this study was to identify potential and conceptual tools for close to crop weed control in narrow intra-row spaced crops that can be carried and powered by an autonomous vehicle - HortiBot (www.hortibot.dk). The process of Pahl and Beitz's concept selection matrix (CSM) has in 2006, in the same context, been introduced to help adding structure to a development process for automatic intra-row weed control in sugar beet. This second study provides novelty to evaluation criteria, scenario, and conceptual tools. More evaluators with engineering, practical and agricultural machine manufacturing background are required to reach higher significance of the evaluation process.



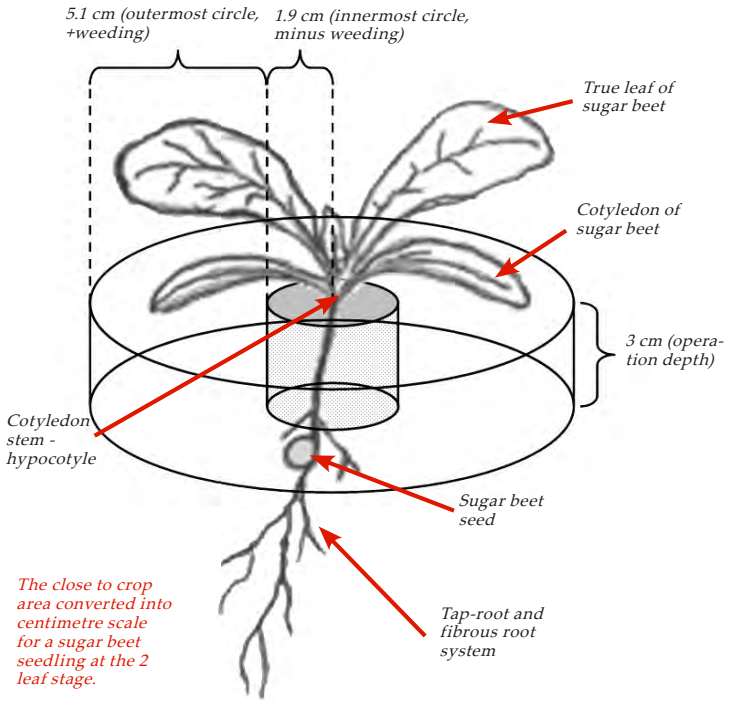
HortiBot - a research platform for developing novel control strategies and applications for agricultural robots.

Technologies for close to crop weed control

The technologies in selection counted 30 conceptual solutions and ranged from steered finger weeders and tines over mulching with biological material to lasers and air jets with abrasive powder (derived from patents, literature, product data sheets and personal inventions). Concepts facilitated high degree of selectivity, meaning that weeds are selected and crop yield reduction avoided. The list of tools is too long to present in this short communication but will be presented in a peer reviewed paper with additional line drawings of conceptual tools and electromechanical and control suggestions enabling the tools to navigate as close to crop as possible. High accuracy of the crop plant positioning is a prerequisite for all tools to operate. In the selected scenario, crop plants are first recognized and then positioned by a computer vision system (research on this topic is on-going in parallel to the development of tools).

Evaluation criteria

The concept selection matrix lists the evaluation criteria down the left side of the matrix. Tool concepts are listed across the top. Each evalua-



The close to crop area converted into centimetre scale for a sugar beet seedling at the 2 leaf stage.

Definition of "close to crop area"

The radii of the foliage cover, the vertical and horizontal root growth distribution and the strength of crop seedling establishment define the size of the close-to-crop area.

It is a circular area with center at the germinated stem of individual crop plants. Weeds germinating close to individual crop plants provide most negative impact on crop yield.

The timing of physical control of weeds in the close-to-crop area to minimize crop yield loss should be at the 2-4 leaf stage of weeds.

tion criteria have priority relative to each other, and a measurable target value. The evaluation criteria and measurable target values were defined by agronomic, engineering and feasibility specifications.
In the table to the right, the list of criteria sections, i.e. sections include many sub-criteria with related measurable target values.

The priority is multiplied by the assessed strength of the relationship between each evaluation criteria and the tool concept. A seven level scale for assessing the relationship was used for a finer scoring system. The derived values in each column were summed in the bottom row as a rating. The preferred concept(s) was the one(s) with the highest rating. The strength of relationship was based on data from literature or product data sheets, but in some cases the strength was based on assumptions only. Therefore due to the unknown overall performance of some concepts uncertainty was considered and included for each concept investigated giving a variation to the rating value.

Conclusion

From the CSM process clearly superior concepts emerged. High precision tillage solutions and thermal weed control by pulsed lasers for eradication of stem or main shoot were the most promising weed control concepts in this preliminary study. However, it should be noticed that this particular conclusion is only valid because the primary focus was on weed control efficiency, ability to target all weeds close to crop, and spatial resolution.

Advantages of the CSM process are; i) rather than simply list the positive and negative aspects of each concept, one by one, a matrix of weighted performance targets versus concepts helps address multiple factors simultaneously, ii) results can easily be reviewed and altered in a spreadsheet by many people either at the same time or separately, and perhaps most importantly iii) the history of the process is documented.

Resolution:	*Spatial resolution or ability to target individual weed plants or even plant parts*
Efficiency:	*Ability to control both annual and perennial weeds*
Accessibility:	*To target weeds underneath crop leaves and close to crop*
Energy consumption:	*Energy for the weed control operation including draft force*
Work rate:	*Treated weeds per unit of time or area*
Applicability:	*Ability to be carried and powered by the HortiBot*
Costs:	*Fixed and variable costs*
Auxiliary rate:	*Labour time allocated to assist the weeding tool*
Adaptation:	*Adaptation to various field and crop growing conditions*
Ease of construction:	*Level of difficulty concerning construction of electromechanically and control systems*