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Advanced Non-Chemical and Close to Plant Weed Control system for Organic Agriculture

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Abstract

Use of chemical has been reduced in agriculture for controlling weeds emergence. The use of alternative systems, such as cultural practices (mulching, flame, intercropping etc.) and mechanical system (hoe, tine etc.) has been introduced by various researchers. Automation technique based on sensors controlled system has enhanced the efficiency of the mechanical system for weed control. Mostly, low cost image acquisition sensors and optical sensor to detect the plant ensuring swift operation of vehicles close the crop plants to remove competitive weeds. The available system need to be evaluated to get best possible system for close to plant (CTP) weed removal. In the study various non-chemical weed control measures has been explored and 30 mechanical tools for CTP were evaluated. High precision tillage solutions and thermal weed control by pulsed lasers for eradication of stem or main shoot were found to be the most promising weed control concepts for CTP operation.

1. Introduction

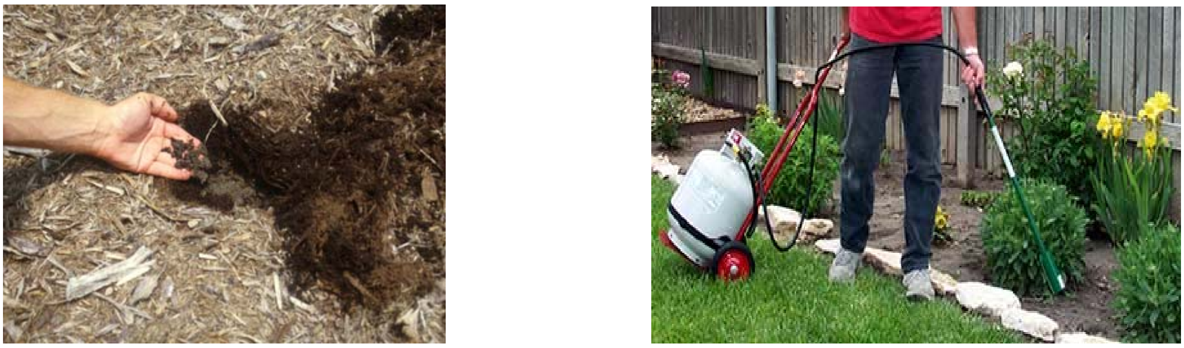
Agriculture has been evolved a lot within last couple of decades. Use of pesticides has been in agriculture since couple of century to control weeds, pests growing along the crop plant. With organic agriculture to produce chemical free agricultural crop is facing a huge challenge for researchers and farmers to control weeds. Ideally, growers would like to achieve zero weed level in their farms, which is beyond anybody's control. Reducing weeds substantially with least or no use of weedcides and chemicals might be welcomed by the growers. Researchers have been concentrating to reduce or optimized the application of pesticides amount in agriculture to crops and fruits with minimum chemical content and ensuring green environment releasing least amount of pollutants to the surroundings. Despite the serious threat which weeds offer to organic crop production, relatively little attention has so far been paid to research on weed management in organic agriculture, an issue that is often approached from a reductionist perspective (Barberi, 2002). Cereal cultivars conferring a high degree of crop competitive ability, especially against aggressive weeds, are highly beneficial in organic farming as well as other farming systems that aim to limit the use of herbicides (Hoad, 2008).

The aim of this study is to identify the potential and conceptual technique and tools for weed control in organic agricultural farms with special emphasis for 'close to plant' (CTP) weed control system.

2. Cultural Practices

2.1 Intercropping and mulching

Intercropping and undersowing offer scope for suppressing weeds in a rotation (Baumann et al., 2000). Cropping sequences that provide varying patterns of resource competition, allelopathic interference, soil disturbance and mechanical damage provide an unstable environment that prevents the proliferation and dominance of a particular weed (Liebman & Davis, 2000). Covering or mulching the soil surface can prevent weed seed germination or physically suppress seedling emergence, but is not effective against established perennial weeds. Mulch may take many forms: a living plant ground cover, loose particles of organic or inorganic matter spread over the soil or sheets of artificial or natural materials laid on the soil surface (Figure 1). For instance- A living mulch of Portulaca oleracea L. (purslane) from seed broadcast before transplanting broccoli (Brassica oleracea L. var. botrytis L.) suppressed weeds without affecting crop yield (Ellis et al., 2000). Fallowing has been shown to reduce perennial weeds within a rotation (Hintze & Wittmann, 1992). However, the economics of taking land out of production for a growing season together with undesirable effects on the soil and the environment make the use of a full fallow unlikely for weed control in the organic system (Lampkin, 1990).



(a) (b)

Figure 1: Cultural practices for weed control, a) Mulching, b) flame weeding

2.2 Intensive ploughing

Non-inversion tillage keeps fresh weed seeds near the soil surface where shallow cultivations can be directed to depleting seed numbers (Melander & Rasmussen, 2000). The merits of ploughing compared with reduced-tillage systems for weed management have been the subject of considerable research and debate (Forcella & Burnside, 1994). There are also conflicts about the intensity and timing of the cultivations needed to prepare a seedbed that best serves weed control purposes. The principle of flushing out germinable weed seeds before cropping forms the basis of the stale or false seedbed technique, in which soil cultivation may take place days or weeks before planting or transplanting a crop (Johnson & Mullinix, 1995). This depletes the seedbank in the surface layer of soil and reduces subsequent weed emergence. The weed plants uprooted and dried up in hot summer days. For many buried weed seeds, it is the exposure to light during soil cultivation that stimulates germination. The exclusion of light during seedbed preparation has been shown to reduce weed emergence (Hartmann & Nezadal, 1990). By covering the cultivated farms can reduce the germination of weed by 70% (Ascard, 1994). Improved soil sensors can be developed to evaluate the ploughing requirement and maintain depth and row spacing of ploughing in terms of weed density, moisture content to improve soil fertility and to cease weed emergence. Mechanical weeders, work as shallow and spaced-row cultivating tools such as hoes, harrows, tines and brush weeders, cutting tools like mowers and strimmers, and dual-purpose implements like thistle- bars can also be implement for weed reduction in different crops.

2.3 Using gas flame

Flame has been used for weed control in some part of the world. For instance, wild blueberry farming in Canada, where, after fruit harvesting the crop plants along with the weed were burnt just before the next cropping season. Along this process, it reduced the amount of blueberry maggot flies and insects in isolated fields (Drummond, 2008). Flame is also used to remove traces, dried leaves etc from the farms after crop harvesting.

Flame weeding uses the heat generated from one or more LPG (propane) burners to kill weeds. Flame-weeders can be either hand-held with the propane tank carried in a cart or in a backpack, or tractor-mounted. Intense heat sears the leaves of the weeds, causing the cell sap to expand, damaging cell walls. This causes leaves to wilt and prevents water from moving from the roots to the leaves. In a short period of time, the plant withers and dies. The plant is not actually burned completely. Different type of grasses is difficult to impossible to remove using flames as its growing roots are protected under the soil (Smith et al., 2008). However, the growth of the grasses can be ceased temporarily before able to compete with the crop plants. Flame weeders may be used for total vegetation control or for selective removal of unwanted plants, but are not suitable for crops with shallow or sensitive root systems (Mattsson et al., 1990).

3. Sensor-based Weed Detection and Control

Sophisticated guidance and weed detection systems have now been applied to mechanical weeding implements (Tillett et al., 1999; Tillett & Hague, 1999). Laser transmitters and receivers have been used to guide tractor mounted machinery in a straight line across a field (van Zuydam et al., 1995). With this system, seedbed preparation, mechanical or chemical weed control, or fertilizer operations could be carried out day or night. More complex guidance systems rely on finding and following the crop rows by identifying features of the row structure. A method of tracking row structures using image analysis allowed a machine to follow the crop row in cauliflower, wheat and sugar beet with reasonable accuracy (Marchant, 1996). These have lead to the development of tractor-mounted hoes with automatic guidance systems (Williams, 2001a; 2001b; 2003). Modified CCTV cameras take pictures ahead of the tractor and computer analysis of these maintains the position of the hoe in relation to the crop rows. The greater accuracy of the vision guidance system means it requires a only a 26.1 mm gap either side of the tine to avoid crop damage 99.7% of the time at a forward speed of 6.5 kph (Home et al., 2001). In the UK a prototype driverless system that uses image analysis for guidance has been developed that can operate completely automatically (Williams, 1996).

Plant detection systems have included image analysis (Miller et al., 1997) based on leaf shape (Woebbecke, 1995), or color (Perez, et al., 1997). Other systems use spectral sensing or light reflectance as a way of discriminating between crop and weeds (Hahn & Muir, 1994). These techniques could be further improved and used to detect weeds in non-chemical weed control systems. They could improve selectivity and allow faster operating speeds. An automatic guidance system is unlikely to be cheap but there could be reduced labor costs. In flaming systems in particular automatic guidance would give greater operator safety.

A Danish ‘Advanced Tool Control’ system has been developed comprising a vision system, guidance frame and a wheel sensor linked by computer. This automatic guidance system has been designed for mounted inter-row cultivators and band sprayers. The Dutch too have developed a vehicle that uses DGPS signals to hoe accurately between crop rows. It is said to be capable of working to an accuracy of 1 cm at speeds of 7 kph (Vale, 2002). A French mechanical intra-row hoe has been developed that uses an infra red sensor to detect crop plants (Vale, 2003). The signal is transmitted to a computer that triggers an air cylinder to push the hoe blade out of position before it reaches the crop plant. The blade then returns to the working position.

4. 'Close to Plant' (CTP) Weed Control System

4.1 CTP area

The 'close to plant' area is defined as the radii of the foliage cover, the vertical and horizontal root growth distribution and the strength of crop seedling establishment (Figure 2). 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 CTP area to minimize crop yield loss should be at the 2-4 leaf stage of weeds.

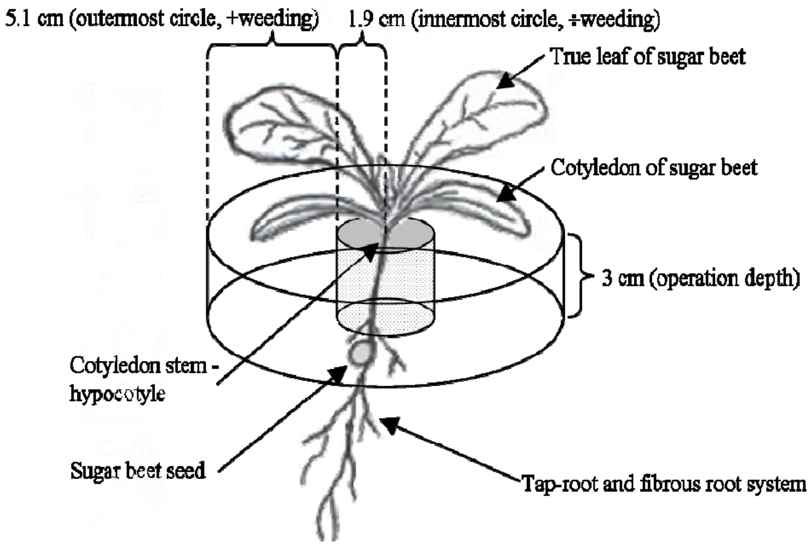


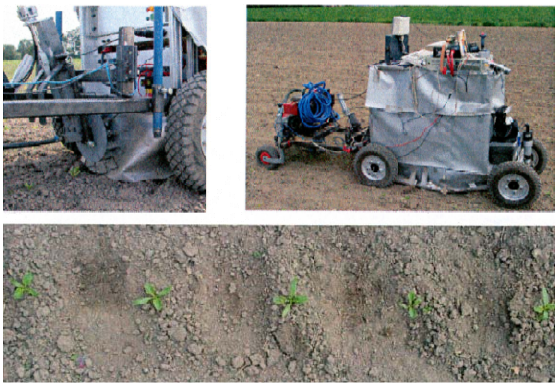
Figure 2: CTP area determination

4.2 Technologies for CTP weed control

The technologies in selection counted 30 conceptual solutions for CTP 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. High accuracy of the crop plant positioning is a prerequisite for all tools to operate. It has been maintained using image acquisition system for row-following. In the selected scenario, crop plants are first recognized and then the system is positioned as close as possible to the plants. The tools were mounted on tractors or small farm vehicles during the operation (Figure 3).

(a)

(b)



(c)

Figure 3: CTP systems for the experiment;
a) Rotating hoe optical sensors (Wisserodt et al., 1999); b) Flame weeder with computer vision; c) Basket weeder with computer vision (Aastrand, 2002)

4.3 Evaluation criteria for CTP

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

Table 1: Evaluation criteria for CTP weed control system

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

4.4 Results and Discussion

From the CTP experiment clearly superior concepts emerged for verifying the suitability of analyzing different weed control tools. High precision tillage solutions and thermal weed control by pulsed lasers (Mathiassen, 2006) 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 results is only valid because the primary focus was on weed control efficiency, ability to target all weeds close to crop, and spatial resolution. A matrix of weighted performance targets versus concepts helps address multiple factors and decide the best solution for CTP weeding system. The system will further mounted on an automated agricultural robot (HortiBot) vehicle to work through the intra-row crops for weed removal at initial stage of plant growth.

5. Conclusions

Controlling weed in organic agriculture remains a big challenge for the researchers and growers. Different cultural and mechanical practices can provide a sight of relief for the growers with no chemical application in agriculture. Mulching, intercropping, crop rotation, inter row mechanical and thermal weeding will be few of the techniques can be used for this purpose. CTP techniques can reduce the competitive weeds maintaining crop yield at early stage of plant growth. 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 CTP techniques. More research is required to implement the techniques and evaluate the crop specific best possible CTP tool.

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