An autonomous ground mobile unit for the precision physical weed control

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Abstract

In this paper the design, the main characteristics and the automation systems of innovative autonomous ground mobile units (GMU) for physical weed control (PWC) in maize are described. The machine will be created within the activities of the European Project RHEA (Robot fleets for Highly Effective Agriculture and forestry management), that aims to produce different prototypes of autonomous terrestrial and aerial robot able to perform several activities related to the general crop protection in different agricultural scenarios. The first autonomous ground unit machine was designed in order to perform a mechanical and thermal treatment removing weeds from the inter-row crop space and applying in-row selective and precision flaming by means of two crossed LPG rod burners. By means of some modifications of the tools it will be possible to realize also an autonomous unit for the precision broadcast flaming application. In this case the design involves a replacement of the mechanical tools working in the inter-row space with 50 cm wide burners able to perform flaming at different intensities according to weed cover detected by the perception system of the robot. The working width of both the PWC machines will be of 4.5 m, thus covering five entire maize inter-row spaces of 0.75 m each and 2 half inter-row space of 0.375 m each. The correct position of the tools (mechanical and thermal) will be guaranteed by an automatic precision guidance system connected and supervised to an image based row detection system. Each working elements will be provided by two crossed 0.25 m wide rod burners, hitting one side of each crop row. The flame should hit the weeds growing in the "in-row" space (a 0.25 m wide strip of soil with the maize plant in the middle). Regarding the control of the weed emerged in the "inter-row" space each working unit of the will be provided with rigid tools (one central foot-goose and two side "L" shaped sweeps). The mechanical treatment will be performed, independently from the weed presence, as hoeing is a very important agronomical practice. On the contrary, broadcast flaming in the inter-row space will be performed after weed detection, using three different LPG pressures and doses according to weed cover (no weed cover-no treatment, weed cover between 0 and 25%-flaming at 0.3 MPa, weed cover higher than 25%-flaming at 0.4 MPa). This very innovative application of precision PWC in maize could represent not only a good opportunity for farmers in term of herbicide use reduction, but also an environmental friendly and energy saving application of flaming in organic farming.

Key words: physical weed control, hoeing, flaming

1. Introduction

Controlling effectively weed flora has always been one of the fundamental conditions for adequate crops production (Barberi, 2002). In this respect, between the different agricultural

sectors, two of the most sensitive to such adversity are the horticultural and the herbaceous crops (Barberi, 2002). The current European Union guidelines, highlight how it is absolutely necessary for the future of the agriculture, a rational and "sustainable" use of chemicals (including herbicides) in crop protection, (Directive 2009/128/EC). Thanks to the modern sensor and robotic technologies, nowadays several equipment for the “intelligent” physical weed control were designed and realized, in particular for vegetable crops (Cloutier et al., 2007; van der Weide et al., 2008; Slaughter et al. 2008). These modern technologies and equipments associated with precision farming, are sinergic to a sustainable agroecosystem management. In fact, they can reduce the use of herbicides, and deliver them with precision in small quantities only where it is needed (Åstrand & Baerveldt, 2005). Moreover fully automated systems for physical weed control, could achieve the complete abandonement of the use of chemical herbicides (Åstrand & Baerveldt, 2005). In this context, in 2010, began a four-year research project called RHEA (Robot Fleets frames Higly Effective Agriculture and forestry management), funded by the Seventh Framework Programme of the European Union. The aim is to design and provide a fleet of autonomous robots for chemical or physical weed control on herbaceous crops and for phytosanitary treatment in olive orchard. In this work are described the main characteristic and the automations systems of a machine that wil work linked to an autonomous ground mobile unit, able to perform mechanical and thermal weed control on maize.

2. The autonomous unit for physical weed control (PWC)

This devices was designed in order to perform hoeing in the inter-row of the crop and precision apllication of crossed flaming in the row of the crop. The machine for mechanical and thermal weed control is 4.5 m wide, this measure cover 5 entire inter-row crop spaces of 0.75 m each and 2 lateral half inter-row crop spaces of 0.375 (Fig 1).

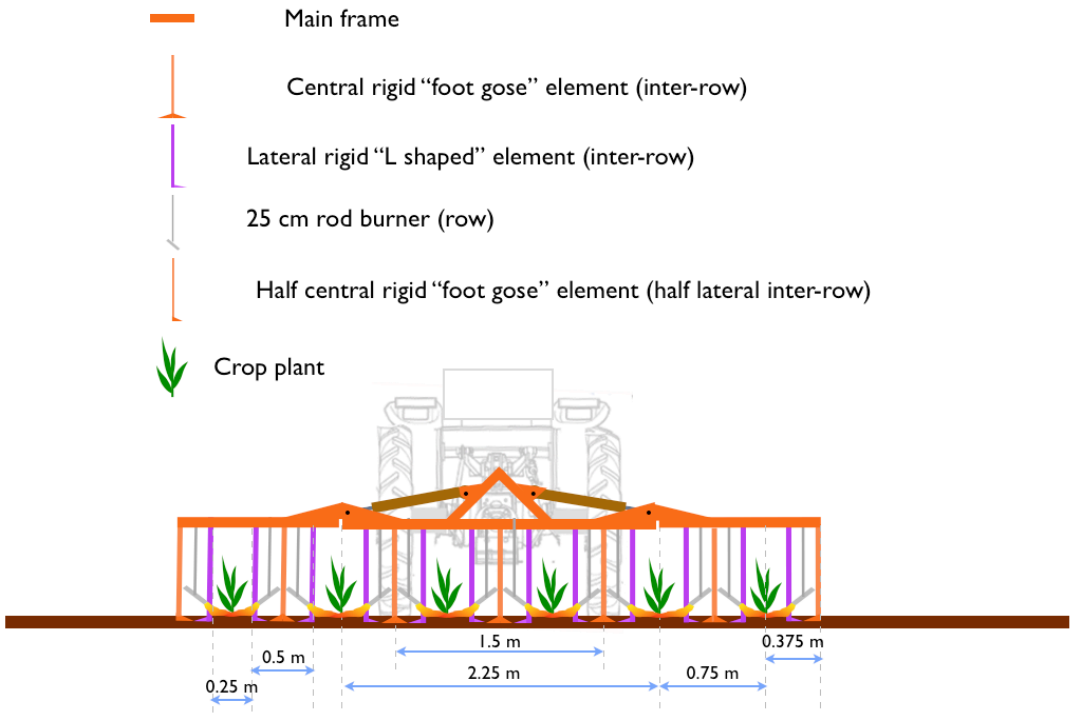

FIGURE 1: Simplified scheme of the operative machines linked at the autonomous ground mobile unit

The main frame of the machine is modular and divided into 3 parts. The central part of the frame is provided with a three point inch, in order to connect the equipment with an autonomous ground mobile unit. Each lateral part of the frame is provided by a folding system driven by 1 hydraulic cylinder (Fig. 2).

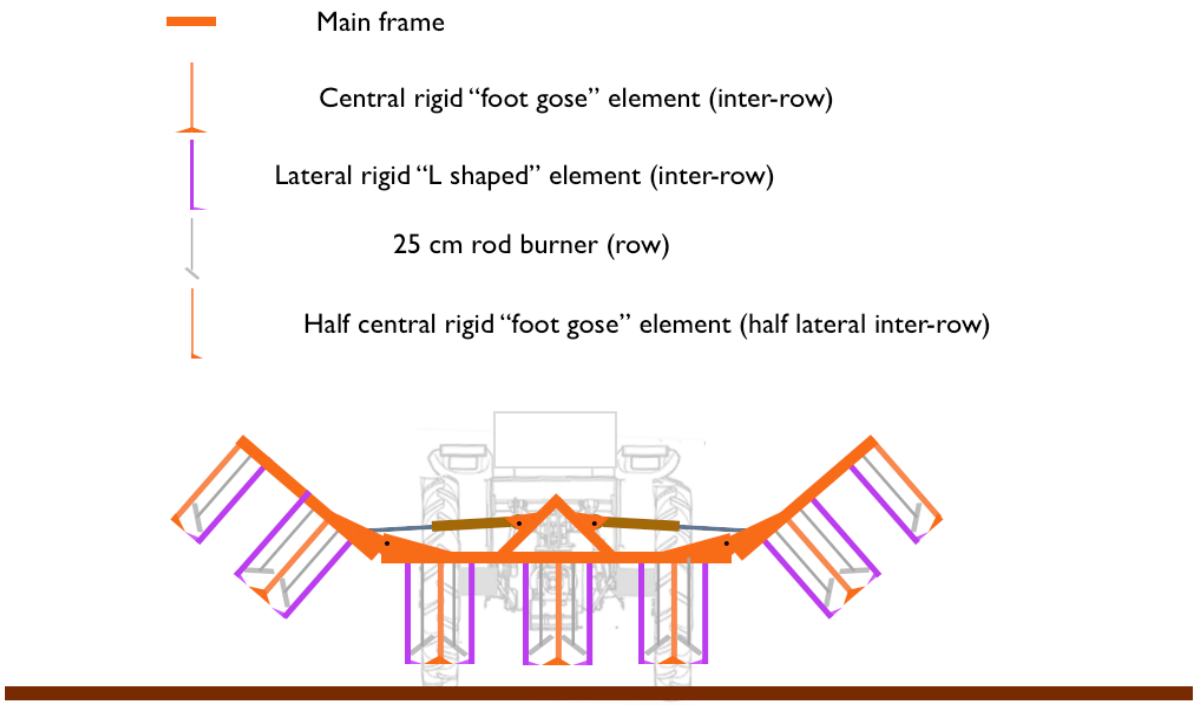

FIGURE 2: Simplified scheme of the folding system of the automatic operative machines for mechanical and thermal weed control.

Each complete working unit, connected to the main frame with an articulated parallelogram is provided with: one rigid foot-goose element, two "L" shaped adjustable rigid side sweeps, two 0.25 m wide rod burner fed with liquefied petroleum gas (LPG) (Fig. 3).

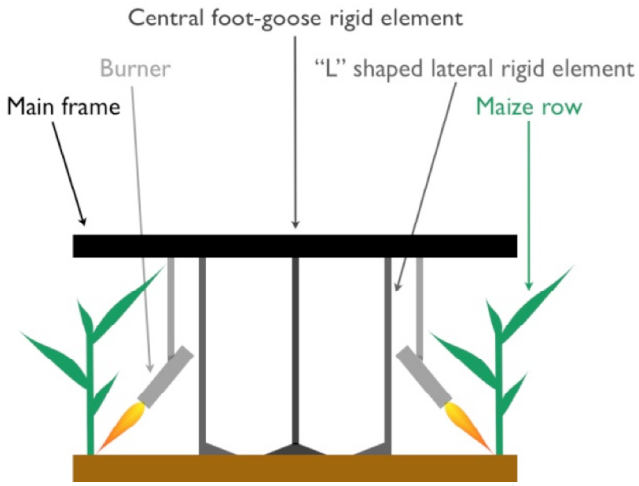

FIGURE 3: Scheme of a single complete mechanical and thermal working unit.

All the rigid hoeing tools were designed in order to till a strip of soil 0.5 m wide in the inter-row of the crop, performing the mechanical removal of the weeds. This mechanical treatment will be provided independently from weed presence, as matter of fact, hoeing not only performs weed control but the shallow tillage improves soil conditions for the roots of the crop and increase water availability. The uniformity of the working depth is guaranteed by a wheeled articulated parallelogram connected to the frame and mounting both mechanical and thermal weed control tools (Fig. 4)

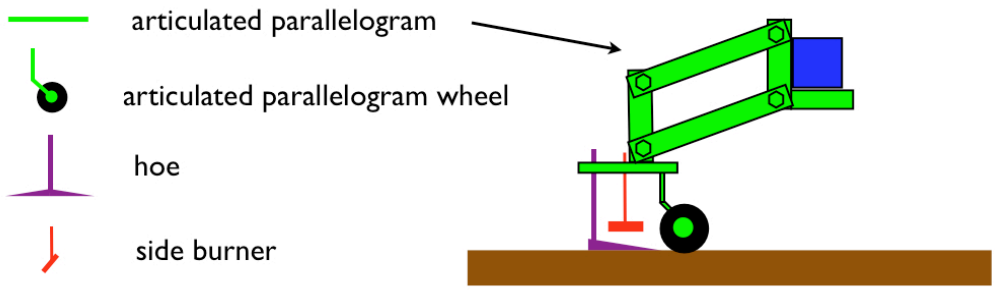

FIGURE 4: Scheme of a the wheeled articulated parallelogram provided for each working unit.

The two burner are placed in order to perform a cross flaming treatment in the row of the crop. Each burner will be set at an angle of 45° (with respect to the soil surface) and a distance of 10 cm from the soil. This thermal treatment will cover a 0.25 m wide strip of soil including the crop plant in the middle, so the flame will hit just the weeds growing in the "in-row" space and the lower, heat-tolerant part of the crop plant. Then the operative machine for mechanical and thermal treatments is provided with 6 couples of 0.25 m rod burners working 6 entire rows of the maize, placed in order to hit each sides of the crop. The working of LPG pressure (the fuel source for the burners), will be adjusted according to weed cover. Two pressure levels will be adopted, 0.3 MPa and 0.4 MPa, according to a threshold of 25% of weed cover level as reported in table 1.

TABLE 1: Different LPG working pressures values according with different level of weed cover detected by the perception system

Weed cover (wc) thresholds (%)	Working Pressure (MPa)
wc=0	0 (no treatment)
0<wc≤25	0.3
wc>25	0.4

A detection system, mounted on the GMU, able to discriminate the crop and spontaneous plants in a strip of 0.25 cm with the crop in the middle will send information that will be processed by the high level decision making system, that will manage the different LPG working pressure according with the perceived level of weed cover. This will allow a precise flaming application. The correct position of the tools (mechanical and thermal) will be guaranteed by a precision guidance system driven by an hydraulic piston connected with the

hydraulic system of the GMU and managed by a row detection system. Two steering wheels mounted on the frame of the machines will maintain the correct position of the tools following the real alignment of the crop row. The LPG feeding system is composed by 6 LPG tanks. Each LPG bottle containing 11 kg of liquefied gas (main component propane) and having a tare of 13 kg will feed two burners. The operative machines is also provided with a heat exchanger in order to avoid the cooling of the LPG tanks. This equipments consists in a hopper containing water that will be heated by the exhaust gases of the endothermic GMU engine. The gas feeding system present for each tanks 3 normally closed solenoid valves and 3 automatic pressure regulator, controlling three different LPG feeding pipelines: the first set on very low pressure for the pilot flame of the burner, the second set on a value of 0.3 MPa for treatment with low weed cover (<25%), the third set on a value of 0.4 MPa for treatment for high weed cover (>25%), according with the information provided by the weed cover perception system. Each tank is also provided whit a pressure transmitter that will send a signal when the gas pressure decrease under value of 0.4 MPa, indicating in this way the exhaustion of the LPG in the cylinder. The ignition system of the burners consists in an electric transformer, transferring hi voltage to specific electrode producing sparkle continuously. The flame presence will be supervised by thermocouples, in case of accidental shut down of the flame, the lack of the thermocouple signal, will cause the stop of the LPG efflux managed by automatic solenoid valves.

Taking into account that flaming can be used on maize (and eventually in other crops such as onion or garlic) in any stage of development (as these crops are tolerant to exposure to open flame) without determining relevant crop damage, it is possible to perform broadcast flaming from the stage of crop emergence to the stage of 6-8 leaves. On this regard, replacing the complete hoeing units with 0.5 m wide burners (working in the inter-row space of the crop) and subsequently the two half lateral unit with 0.25 m rod burners (working in the inter-row lateral spaces) it will be possible to obtain an autonomous operative machine for precision broadcast flaming application. In this case the weed detection system should cover the entire width of the operative machine.

3. Conclusion

The autonomous equipment for mechanical and thermal weed control could be an important innovation for the farmers, providing a concrete alternative to the chemical herbicide use. The machines is currently in the implementation phase and will be completed by the end of 2012, the first preliminary field trial test will be set in 2013 and the final demo test for the RHEA project is planned for 2014.

Acknowledgements

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