Innovative operative machines for physical weed control on processing tomato in the Serchio Valley (Central Italy)

Peruzzi A.[1], Raffaelli M.[1], Ginanni M.[2], Lulli L.[2], Frasconi C.[1], Fontanelli M.[1]
[1] *MAMA - DAGA, University of Pisa. Via del Borghetto 80, 56124 Pisa, Italy, tel. +39050599263, fax +39050599264, mail address: aperuzzi@agr.unipi.it*
[2] *CIRAA "Enrico Avanzi", University of Pisa. Via Vecchia di Marina, 6, 56122 San Piero a Grado (PI), Italy, tel. +390502210505, fax +390502210503, mail address: ginanni@tiscali.it*

Abstract

Processing tomato is the first Italian vegetable crop for harvested area (about 94000 ha) weed control represent one of the most serious problem for tomato producers.
A two year "on-farm" open field research on processing tomato weed control was carried out in 2006 and 2007 in a conventional farm in the Serchio Valley (Pisa, Central Italy). The aim of the experiment was to test innovative strategies and operative machines for non-chemical (physical) weed control in order to reduce agrochemical input and improve crop quality.
The innovative strategy was compared with the farm traditional technique. The innovative strategy consisted in the application of the stale-seedbed technique (by means of a rolling harrow and a flaming machine in pre-transplanting) and precision hoeing interventions in post-transplanting (with an innovative machine equipped with rigid elements, for inter-row weed control, and elastic tines for selective intra-row weed control). Traditional technique consisted in two chemical pre-transplanting interventions and two post-transplanting PTO powered rotary hoe treatments.
Innovative operative machines performances, weed density during the crop cycle, dry weed biomass at harvest and crop fresh yield were recorded.
The innovative strategy allowed reaching significantly higher yield values (from 15 to 20%), a good weed control and a relevant increase of gross marketable production with respect to conventional management (from 400 up to 700 € ha^{-1} of increase as net value of weed management costs)
The experiment is still on-going and it will finish in 2008.

Keywords: processing tomato, physical weed control, rolling harrow, flame weeder, precision hoe.

Introduction

Processing tomato is the most important Italian vegetable crop, although a significant reduction of tomato harvested area was observed in Italy in the last two years (-20%, from 113000 to 91000 ha). This trend is mostly due to political (uncertainty of CMO reform) and economical (high cultural fixed costs) reasons (Bazzana, 2007).

The production valorisation (for example by organic cultivation) could be a good strategy in order to follow the new policy trends and to guarantee high income to the farmers. This aim could be easily reached by means of cultural practices that respect environment and consumers health safety.

The development of new strategies and operative machines for physical weed control (one of the most serious problems in organic farming), could represent a good way to reach the aims previously mentioned.

Actually physical weed control is mostly studied in Northern Europe (Denmark, Sweden, Germany, the Netherlands, etc.), where strict pesticide action plans are commonly launched in order to reduce agrochemicals (about the 50% of which are herbicides) use in agriculture (Melander, 2007). In fact the use of pesticides can cause water contamination and the impoverishment of the flora and fauna in the agricultural landscape and the exposition to chemicals can be dangerous for human health. Moreover, consumers are often concerned about the possible presence of pesticide residues in food (Melander, 2007).

Otherwise processing tomato is a typical Mediterranean crop. Thus, with the exception of some recent Spanish field trials (Cirujeda et al., 2007), no scientific papers are at the moment available concerning with the physical weed control methods application on this crop.

Furthermore, paired-rows transplanting is at the moment one of the most utilized spatial crop arrangement for processing tomato cultivation in Italy, and it's the system adopted in the Serchio Valley (Tei *et al.*, 2008). This system is surely characterized by some advantages with respect to the single row cultivation (a more contemporaneous fruit maturation, an easier field accessibility with operative machines, the use of one irrigation line per paired-row instead of one irrigation line per row) (Tei *et al.*, 2008) but, at the same time, it is very difficult to control weeds into the pair space. The presence of the irrigation line in the middle of the pair make the intervention even more difficult. For this reason conventional farmers usually carry out post-transplanting mechanical intervention (usually with PTO powered rotary hoes) just in the inter-pair space.

In this work, the first two years results of a three year (2006-2008) "on-farm" open field research are reported. The experiment is still on-going and it is being carried out by the University of Pisa with the aim to develop and improve innovative strategies and innovative operative machines for an effective physical weed control on processing tomato.

Materials and methods

The experimental trial

The experiment was carried out during two growing seasons (2006 and 2007) on processing tomato in a conventional farm placed near Pisa. The tomato varieties utilized were two hybrids: "Leader" the first year and "Reflex" the second year. The crop was mechanically transplanted on paired rows at the density of 33000 plants ha^{-1} (1.10 m of inter-pair space; 0.4 m of intra-pair space and 0.25-0.30 m of intra-row space) (Figure 1). Crop was irrigated by drip hoses placed in the middle of the intra-pair space. Organic-mineral fertilizer was applied before crop-planting while fertirrigation was carried out in post-emergence. Soil was sandy-loam and a four year rotation was adopted (tomato, wheat, maize, sunflower).

The experiment consisted in the comparison between the traditional farm weed management system (FS) and an innovative physical weed control system (PWCS). FS was carried out by means of three different chemical treatments: one before crop planting (1 kg ha^{-1} of "Stomp" – a.i. Pendimetalin – and 1 kg ha^{-1} of "Ronstar" – a.i. Oxadiazon) and two after crop establishment (250 g ha^{-1} of "Sencor" – a.i. Metribuzin – and 40 g ha^{-1} of "Titus" – a.i. Rimsulfuron"). FS consisted also in two post-transplanting PTO powered rotary hoe interventions (not able to till the soil in the intra-pair space). PWCS was carried out applying the innovative strategies and machines developed by the University of Pisa.

Hand weeding was also performed when necessary in both the two different systems, in order to control well developed weeds in the in-row space that survived to the treatments.

Figure 1. Pair-rows transplanted processing tomato experimental field during the second year of trials. The irrigation line is placed in the middle of the pair.

<u>*The innovative physical weed control strategy*</u>

PWCS consisted in the application of stale seedbed technique as preventive weed control method and post-transplanting precision hoe interventions.

The stale seedbed technique consists in one or more shallow tillage interventions carried out, by means of an on purpose made operative machine, before crop planting. These interventions have substantially two main issues: actual flora control and weed emergence stimulation. This technique is also characterized by the application of flame weeding before crop planting. The aim of this strategy is to reduce sensibly the surface weed seed-bank and consequently to low weed emergence during the crop cycle.

Precision hoeing interventions were performed in order to low weed presence during the crop cycle in the inter-pair space, intra-pair space and selectively in the in-row space.

<u>*The innovative operative machine for physical weed control*</u>

Three different innovative operative machines were used for physical weed management: a rolling harrow, a flaming machine and a precision hoe.

The rolling harrow was projected, built, tested and patented by Pisa University. It was set up both for pre-sowing (or pre-transplanting) and post-emergence hoeing (for inter-row and intra-row selective weed control) interventions (Figure 2). Working tools are spike disks (placed in the front) and cage rolls (placed at the rear), respectively mounted on two different parallel axles. The axles are connected by an overdrive with a ratio equal to 2. Spike discs till the soil very shallowly while cage rolls (rotating with a double peripheral speed) allow to separate weed seedling roots from soil (Peruzzi *et al.*, 2007). This tools also allows to brake efficiently soil crusts and to effectively separate weed seedlings roots from soil, in order to avoid seedlings re-growth after the intervention. Moreover, this operative machine was also equipped with a manual guidance system (with a back-seated operator) and elastic tines for selective in-row weed control, in order to improve the hoeing performances. However, in this case the treatment was carried out just before crop trans-planting with a working speed of about 7 km h^{-1} and a working depth of about 4 cm.

Figure 2. The rolling harrow at work during the pre-transplanting intervention in 2007.

The flaming machine controls weeds by the use of an open flame. In this experiment it was equipped with three 50 cm wide rod burners, for a total working width equal to 1,5 m. This treatment has the advantage of eliminating weeds without stimulating new emergence because the soil remains undisturbed (Figure 3).

Figure 3. The flame weeder at work before tomato transplanting in 2006.

The machine was equipped with three common 15 kg weight LPG thanks placed into an on purpose made hopper. Furthermore this machine was also equipped with an innovative heat exchange system, in order to avoid thanks cooling during the flaming treatment (due to the LPG passage from liquid into gaseous phase). It consists in heating the water contained into the hopper utilizing the exhaust emission coming from the tractor exhaust head. A security system, characterized by one electromagnetic valve per burner, stops the LPG flow in case of burner flame extinguishing. A minimum-maximum valve per burner allows to reduce LPG working pressure (just leaving a pilot light) during tractor turning operations, in order to reduce LPG consumption and fire risk. The treatment was performed just in the pre-transplanting phase, but if necessary, tomato may tolerate post-emergence selective flaming interventions (with the flame directed to the crop collar) (Peruzzi *et al.*, 2007). Working speed was about 3 km h^{-1} and LPG consumption was about 35 kg ha^{-1}.

The precision hoe is characterized by a 3 m wide frame. It is equipped with rigid elements for inter-row cultivation (a control "foot-goose" tool and two side "L" shaped sweeps) and elastic elements for intra-row selective weed control (torsion weeders and vibrating tines) and a seat, steering handles and directional wheels (Peruzzi *et al.*, 2007). Thus it was possible to till soil and control weeds even inside the crop pairs, without removing the drip irrigation hoses (Figure 4a). Furthermore, the precision hoe was equipped with on purpose made "V" shaped elements, that allowed to "gently-open" crop vegetation during late hoeing interventions (Figure 4b). Average working speed was about 2 km h^{-1} and working depth was about 4 cm.


a)

b)

Figure 4. The precision hoe during an early intervention on processing tomato in 2007 (a). Detail of the "V" shaped tool utilized for the late hoeing intervention carried out in 2006 (b).

<u>*Experimental assessments, experimental desing and data analysis*</u>

During the trials, all data concerning the operative performance of the operative machines used for physical weed control were recorded: working depth, working speed, working capacity, working time, engine load, LPG working pressure, fuel and LPG consumption.

Furthermore, numerous weed parameters were recorded at repeated intervals. Weed density was measured before and after each physical weed control treatments on three 25 x 30 cm sampling areas $plot^{-1}$. At harvest, weed and fruit samples were collected from a 1,2 m^2 area $plot^{-1}$ (corresponding to the surface covered by four tomato plants). Weed samples were then oven dried until constant weight, in order to assess dry biomass.

Some economic parameters were also considered. The gross marketable production as weed control costs net value was calculated for both the weed management systems compared

The experimental design was a randomized block with four replicates. Data were analyzed by ANOVA.

Results

<u>*Innovative machine operative performances*</u>

Innovative machines performance are shown in table 1.

All the machines operated with a working width equal to 1.5 m, in accordance with the traditional controlled traffic lines system adopted in the Serchio Valley and in most of the vegetable production contexts in Central and Southern Italy.

Tractor engine power ranged from 44 up to 55 kW, but it was absolutely an excess value considering the real operative machine traction requirement. In fact engine load was only 20%.

Both the machines for soil tillage reached very few working depths, with a maximum value of about 4 cm.

The rolling harrow was characterized by the best operative performances, reaching the highest working speed and working capacity values (about 7 km h^{-1} and 1 ha h^{-1} respectively), while precision hoeing (that is surely a more difficult operation) appeared the most expensive treatment because of its low working speed (about 2 km h^{-1}) and the presence of a second back seated operator.

Flaming was performed only in 2006. Working speed value was in this case about 3,5 km h^{-1} and LPG consumption was about 35 kg ha^{-1}.

Fuel consumption was very low for all the tested machine. However, precision hoe, as a result of its low working speed, showed sensibly higher fuel consumption values with respect to flamer (+100%) and rolling harrow (+300%).

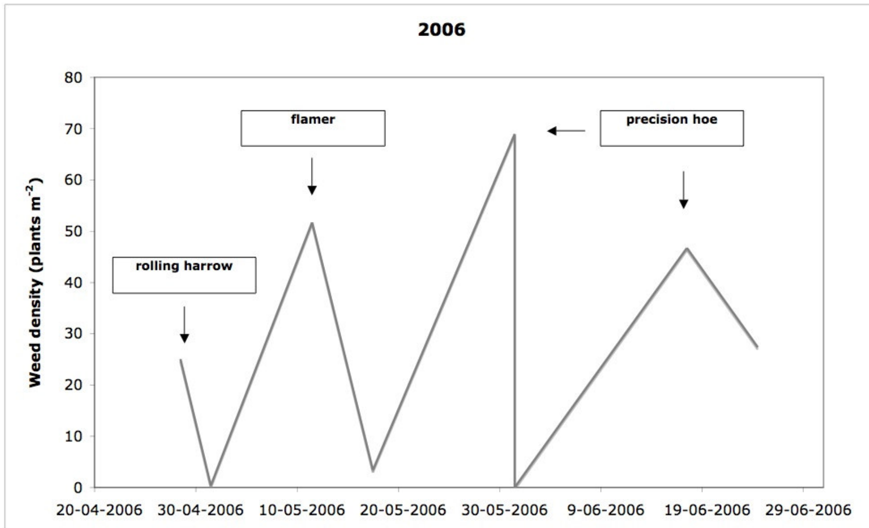
Table 1. Mean operative performances of the innovative machines for physical weed control during the two year of experiment.

Characteristics		2006			2007	
		Rolling harrow	Flamer	Hoe	Rolling harrow	Hoe
Working width	(m)	1.5	1.5	1.5	1.5	1.5
Working depth	(cm)	3.5	-	3.8	2.8	3.1
Working speed	(km h^{-1})	6.8	3.4	1.9	6.4	1.3
Working capacity	(ha h^{-1})	0.9	0.5	0.3	0.8	0.2
Working time	(h ha^{-1})	1.1	2.2	3.9	1.3	5.7
Operators	(No.)	1.0	1.0	2.0	1.0	2.0
Tractor engine capacity	(kW)	55.0	55.0	55.0	44.2	44.2
Engine load	(%)	20.0	20.0	20.0	20.0	20.0
Fuel consumption	(kg ha^{-1})	3.3	6.5	11.6	3.1	13.6
LPG pressure	(MPa)	-	0.2	-	-	-
LPG consumption	(kg ha^{-1})	-	35.9	-	-	-

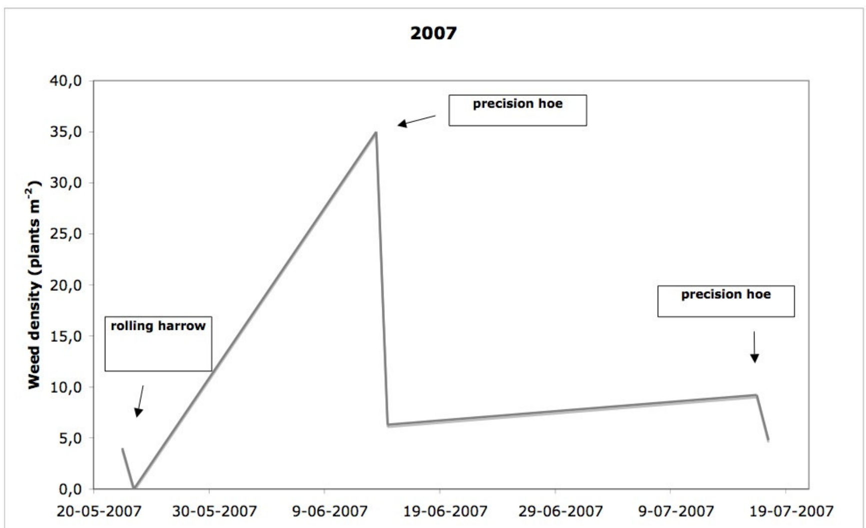
<u>*Weed control*</u>

Weed density trend for the PWCS in the two years of experiment is shown in Figure 5. Innovative machines always controlled weeds very well, reaching the 100% of effectiveness in the case of rolling harrow and flamer, while precision hoe efficiency varied from 50% up to 100% depending on tomato and weeds development stage.

FS weed average density registered during the two years ranged from 2 up to 10 plants m^{-2} (data not shown in the graph), thus physical weed control interventions guaranteed the maintenance of similar levels of infestation also in the PWCS.



a)



b)

Figure 5. Weed density trend during the crop cycle in 2006 (a) and 2007 (b) for the innovative weed control system (arrows indicate physical weed control treatments).

<u>*Yield, weed dry biomass at harvest, labour time and crop economy*</u>

The innovative strategy allowed to reach significantly higher yield values (from 15 to 20%), a good weed control and a relevant increase of gross marketable production with respect to conventional management (from 400 up to 700 € ha^{-1} increase as net value of weed management costs) (Table 2). Yield increas could be probably due to the positive agronomical effects of the intra-pair hoeing (crust breaking, soil oxygenation, etc.).

Furthermore PWCS was characterized by sensibly higher total labour time values (+260% in 2006 and +110% in 2007) caused by the higher need of working time for in-row hand weeding, but the gross marketable production increase completely justify the adoption of this innovative technique.

Table 2. Yield, weed biomass at harvest, total labour time requirement and gross marketable production weed management costs net value (GMP w.n.v.) registered during the two years of activity.

Weed management system	Yield ($t\ ha^{-1}$)	Weed biomass ($g\ m^{-2}$)	Total labour time* ($h\ ha^{-1}$)	GMP w.n.v.* (€ ha^{-1})
		2006		
Conventional system	59.4 b	102.9 ns	15.0	3748
Innovative system	72.1 a	126.1 ns	54.1	4185
		2007		
Conventional system	54.1 b	2.1 ns	11.3	4106
Innovative system	61.9 a	21.9 ns	24.0	4830

Different letters on the same column and for the same year mean significant differences for $P \leq 0,05$ (LSD test).
*Data were not analyzed by ANOVA.

Conclusions

The innovative physical weed control strategy allowed to reach higher yields and gross marketable production values in both the two years of experiment.

Furthermore, innovative operative machines for physical weed control appeared very versatile, suitable and adaptable to the processing tomato crop. Moreover, these machines can be easily utilized for weed control in organic farming, where herbicides use is not permitted. The results of this two years experiment showed that the alternative cultural strategy could be convenient not only for environment and consumers health but also for farmers gross income. However, a further year of experimental work is obviously required in order to verify and improve the effectiveness of innovative strategies and machines for physical weed control on processing tomato.

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