Physical weed control in protected leaf-beet in Central Italy

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Abstract

In Central Italy leaf-beat is a typical and very important protected cultivation. In leaf-beet protected cultivation weed control is one of the most important problems, because of it's quite long crop cycle (about 4-5 months).

The aim of this research was to set up an efficient non-chemical weed control strategy performed with innovative machines built and set up by the University of Pisa.

A two-year (2006-2007) "on-farm" experimental trials were carried out in Crespina (PI). A conventional weed management technique (consisting in one pre-transplanting chemical treatment) was compared to an innovative physical weed control strategy (consisting in stale seedbed technique, in some post emergence precision hoeing and in-row hand-weeding treatments). In the conventional technique the leaf-beat was manual transplanted, while in the innovative strategy it was sowed with a precision pneumatic planter. All the innovative machines for physical weed control were adjusted and set up for the protected cultivation. In the two year trials similar yields were recorded for the two systems in comparison. Total labour time (for weed management and crop planting) was appreciably lower in the conventional system in the first year of experiment (-67%), while, in the second year, some improvement in the innovative technique allowed to reach lower values with respect to the conventional technique (-40%). Weed dry biomass at harvest was significantly lower for innovative system (on average -50%).

Keywords: organic farming system, rolling harrow, precision hoe, flaming machine.

Introduction

Recently, integrated and organic vegetable production systems has gained a great deal of attention in agreement with EU agricultural policy reorientations, furthermore, this is in line with mounting public concern for environmental issue, workers safety and the growing consumer demand for high quality food products (Peruzzi *et al.*, 2007). One of the major technical problems that arise in vegetable cropping when decreasing use of agrochemicals is weed control (Bàrberi, 2002). This is a very important problem in protected cultivation in which an inevitable intensification of cultivation involves even more difficulties. Protected cultivation has many commercial advantages but it has many agronomic and crop protection problems, including weed control. This problem, very important for horticultural crops, can be tackled and solved in sustainable way using and optimising physical weed control.

Recently a series of techniques and purpose-designed operative machines have been devised to perform efficient and economically viable non chemical weed control in the open field. Numerous interesting trials have been carried out with promising results on spring-summer crops (Raffaelli *et al.*, 2004 e 2005), on winter cereals (Bàrberi *et al.*, 2000; Rasmussen, 2004) and on horticultural crops (Peruzzi *et al.*, 2007).

In contrast research on physical weed control in protected cultivations was not developed to the same extent. For this reason, technical and scientific knowledge available on this topic is lacking. Moreover, the specifically designed techniques and operative machines are not usable on different crops and operative conditions. Therefore, to obtain a sustainable weed control in protected cultivation it is needed to study with attention the problem, to have specific machines devised for the different operative conditions and to analyse into deep the interactions among operative parameters (crop typology and management practices, as well as weed density, developmental stage and competitiveness, soil conditions, protection typology, etc.) (Bàrberi *et al.*, 2000; Peruzzi *et al.*, 2007; Vanhala *et al.*, 2004).

With the aim to set up and evaluate strategies in order to reduce or eliminate herbicide use in protected cultivation an experiment was carried out on leaf-beat (*Beta vulgaris* L. var. *cycla* (L.) Ulrich). In Central Italy leaf-beat is a typical and very important protected cultivation and for this crop weed control is one of the most important problems, because of it's quite long crop cycle (about 4-5 months). In the experimental trials a conventional weed management technique was compared to innovative physical weed control strategies.

Materials and methods

A two-year (2006-2007) "on-farm" experimental trials were carried out in Crespina (PI). Two different farms, conventional and organic, with similar sandy soil (sand 67%, silt 26%, clay 7% and organic matter 2%) and climatic conditions were involved.

In organic farm sowing was performed with a precision planter, in August at a seeding rate of 30 seeds m^{-2} (20 X 12 cm), on ridges 1.4 m wide (with 5 rows $ridge^{-1}$). In conventional farm leaf-beet was sowed in seed-bed in August and after was manual transplanted in tunnel at the end of September at a rate of 12 plant m^{-2}, on ridges 1 m wide (with 3 rows $ridge^{-1}$).

<u>First year</u>

In the conventional strategy weed control was carried out with transplanting technique and with one pre-transplanting chemical treatment (8 kg ha^{-1} Kerb, a. p. propizamide).

In the non chemical strategy weed control was carried out with false seed bed technique (by means rolling harrow), three post-emergence precision hoeing and two in-row hand-weeding treatments performed between hoeing treatments. The machines used for physical weed control were studied, built and set up by Research Unit involved in this trial, over the years, to perform effective and efficient treatments.

The rolling harrow was realized to perform a very shallow tillage and an efficient weed control both in "false seedbed" technique and in precision hoeing treatments in post-emergence of the crop. The machine is modular, so it can be built with different working widths adapted to operative conditions (Fig. 1). Apart from working width, the rolling harrow is structured on a square draw piece frame bearing working tools and three points linkage. The tools are spike discs with diameter of 30-35 cm (placed in the front) and gage rolls with diameter of 27-33 cm (placed in the rear), that are inserted in two axles connected one another by means of a chain drive with a ratio easily adjustable. The discs and the rolls are placed differently on the axles and changed with elements of different sizes with a very simple blocking system. The discs and the rolls can be placed differently on the axles (Fig. 1): close arrangement in order to perform a very shallow tillage (till 3-4 cm) of the whole treated area for seed-bed preparation and non-selective mechanical weed control after false sowing and with spaced arrangement in order to perform efficient selective mechanical weed control treatments in post-emergence for precision inter row weeding. In precision weeding it is possible to work on very different inter row distances from a minimum value of 15 cm. The action of the rolling harrow is characterized by the passage of the spike discs that till the soil at 3-4 cm of depth followed by the passage of the gage rolls that work at high peripheral speed as the rear axle is powered by the front axle by means of an overdrive tilling and crumbling the soil till a depth of 1-2 cm. The rolling harrow can be equipped with couples of elastic tines (working as both vibrating teeth and torsion weeders) in order to perform a mechanical weed control also in the rows. For precision weeding a version of rolling harrow with a steering handle system was set up. In these trials a machine 1,4 m wide was used.

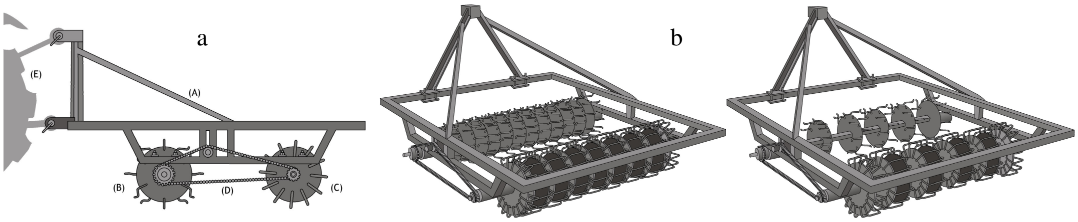

Figure 1. a) Scheme of the rolling harrow: (A) frame; (B) front axle with spike discs; (C) rear axle with cage rolls; (D) chain drive; (E) three points hitch. b) Arrangement for treatments on the whole surface (left) and of hoeing (right).

The precision hoe utilized in this experimental trial is a machine 2 m wide (Fig. 2), designed to perform selective weed control in the horticultural row crops with very low inter row distance (in this trial 20 cm). The precision hoe is structured on a square draw piece frame bearing working tools and three points linkage. The working tools can be 11 and each is placed on articulated parallelogram equipped with a small wheel for the working width adjustment. The machine was equipped with rigid elements bearing a 9 cm wide triangular horizontal blade and two kinds of elastic tines (torsion weeders and vibrating tines). The elastic tines are able to perform a selective weed control on the row crop. A back-seated operator can adjust the actual position of the working tools by operating a steering handle. This precision hoe is a very interesting innovation for the region trial because it is able to work on 5 rows on a "standard" ridge 1,4 m wide.

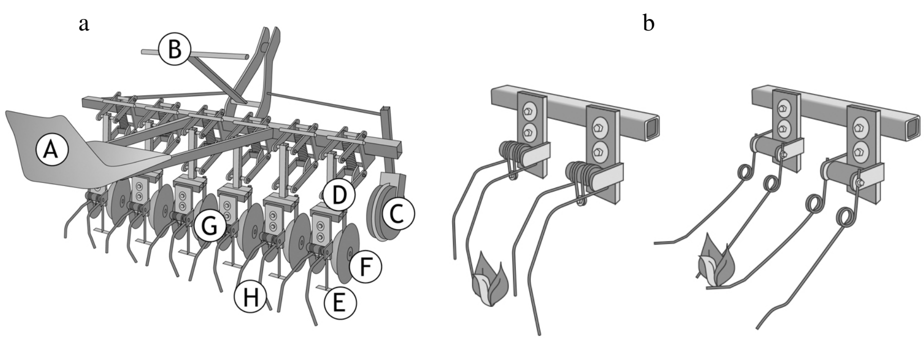

Figure 2. a) Scheme of precision hoe: A) hoe operator seat; B) steering handle; C) steering wheel D) articulated parallelogram; E) working tool; F) lateral disc; G) support wheel; H) elastic tines. b) Vibrating tines (left) and torsion weeders (right).

In conventional farm the machine utilized for chemical treatments was a sprayer of firm Projet srl, model sprayer mix, with a tank capacity of 300 dm^3. The treatments was performed with an hand lance equipped with a turbulence full cone spray nozzle and with manual valve for flow adjustment. The hand lance was equipped with a tube 100 m long that is reeled by an on purpose manual tube reel.

In the trials data concerning soil (physical and mechanical characteristics), machine operative characteristics (working width, depth, speed, capacity, time and fuel consumption), weeds (density before and after each weed control treatments and dry biomass at hand weedings and harvest) and crop production (total fresh yield) were measured or calculated.

<u>*Second year*</u>

In the conventional farm weed control was carried out with transplanting technique and with one pre-transplanting chemical treatment (3.5 kg ha^{-1} Kerb, a. p. phenmediphan) performed with the same machine of the first year.

In organic farm, in the light of the first year results, weed control was carried out with a modified strategy performed with false seed bed technique (by means rolling harrow), one pre-emergence of the crop flaming, two post-emergence hoeing (the first with rolling harrow, the second with precision hoe) and one final in-row hand-weeding treatments. For physical weed control, besides the machines used in the first year, a flaming machine realized and set up in previous experiment by Research Unit was used.

The implement allows to perform both pre-emergence and post-emergence flame weeding (Fig. 3). The flaming machine can be equipped with 8 rod burners 25 cm wide that have a good flame shape and with 4 LPG tanks. Any couple of burners is placed on a control board and is connected to a 25 kg LPG tank on which a pressure regulator and a manometer are placed. The LPG tanks are placed inside a hopper which contains warm water, thus allowing good heat exchange. The exhausted gas of the tractor engine are used to heat the water by means of a flexible pipe connected to both the exhaust head and a copper tube placed inside the hopper. Any couple of burners is connected to an articulated parallelogram in order to maintain the set out adjustments (height and inclination with respect to soil surface) when the flamer is working. Any burner is also equipped with one valve, one safety tap and an electronic control system which allows the tractor driver to adjust the LPG feed (high or low levels) and to control if the burners work appropriately directly from his seat.

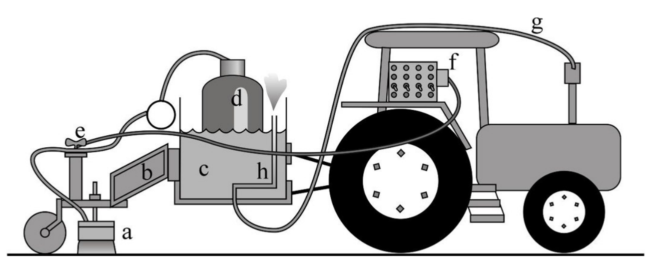

Figure 3. Scheme of the new flaming machine: (a) burner; (b) articulated parallelogram; (c) hopper containing water; (d) LPG tank; (e) shelf on which the inflow LPG control system is located; (f) control panel; (g) flexible pipe that pipes the exhausted gas of the tractor engine to the heat exchanger in the hopper; (h) heat exchanger.

During the trial assessments were the same of the first year with the addition of a final weed sampling carried out by means of the Braun-Blanquet ordinal scale that is able to give good informations on weed canopy assessment, biodiversity and aggressiveness.

Results

<u>*Operative characteristics*</u>

The operative characteristics of the machines used for physical weed control in the first year trial are presented in Table 1.

The rolling harrow, utilized only for pre sowing treatment, was used with high speed (about 6 km h^{-1}) and therefore its working time was low (1.47 h ha^{-1}). The precision hoe instead, given the more "gentleness" of intervention, was utilized on average with a working speed of 1.2 km h^{-1} and consequently the working time for each treatment was higher to 6 h ha^{-1}. The working depth was for all treatments lower to 4 cm in order to avoid soil disturbance, that could cause a new high level of infestation. Fuel consumption was about 3 kg ha^{-1} for false seed bed treatment and on average 13 kg ha^{-1} for each hoeing.

Table 1. Performances of the machines used for physical weed control in 2006.

Characteristics		Har	Hoe 1	Hoe 2	Hoe 3
Working depth	cm	3.6	2.6	2.7	2.8
Working speed	km h^{-1}	5.9	1.2	1.1	1.2
Working productivity	ha h^{-1}	0.68	0.16	0.15	0.16
Working time	h ha^{-1}	1.47	6.21	6.87	6.36
Operators		1	2	2	2
Fuel consumption	kg ha^{-1}	2.9	12.4	13.7	12.7

Har=harrowing, hoe=hoeing (1, 2, 3 first, second or third pass)

Total working time for physical weed control was 283.96 h ha^{-1}, (20.91 h ha^{-1} for physical weed control, 4.34 h ha^{-1} for sowing and 258.71 h $ha^{-1}$for hand weeding) that were necessary largely for two expensive treatments of hand weeding that required respectively more than 80 h ha^{-1} the first and more than 170 h ha^{-1} the second.

In conventional strategy for weed control the time for manual transplanting (that can be considered a technique giving an advantage to the crop with respect to weeds) was 84.51 h ha^{-1}, while working time for chemical treatment was 7.81 h ha^{-1} (total time was 92.32 h ha^{-1})

In the first year trial, in all, physical weed control strategy needed a total labour employed very higher than in conventional strategy (284 h ha^{-1} vs 92 h ha^{-1}).

The operative characteristics of the machines used for physical weed control in the second year trial are presented in Table 2.

Table 2. Performances of the machines used for physical weed control in 2007.

Characteristics		Har	Fla	Har	Hoe
Working depth	cm	3.5	-	2.7	2.8
Working speed	km h^{-1}	6.1	3.5	1.7	3.0
Working productivity	ha h^{-1}	0.73	0.42	0.22	0.37
Working time	h ha^{-1}	1.36	2.39	4.47	2.71
Operators		1	1	1	2
Fuel consumption	kg ha^{-1}	2.7	4.8	8.9	5.4

Har=harrowing, Fla=flaming, hoe=hoeing

For false seed bed treatment, the rolling harrow worked at very high speed and as consequence its working time was very low 1.36 h ha^{-1}. In the first hoeing treatment, for leaf beat small size, the rolling harrow was used with slow speed with consequent increasing in operative time (4.47 h ha^{-1}). This parameter, however, was lower than that recorded in previous year for precision hoeing; this result was possible for a better overall strategy in which a flaming treatment in pre emergence of the crop was carried out. The flaming treatment was performed with forward speed of 3.5 km h^{-1} (2.39 h ha^{-1}) and working pressure of 0.25 MPa with a LPG consumption of roughly 40 kg ha^{-1}. Total working time of the last hoeing too, carried out with precision hoe with static tools, was very lower than that recorded for the hoeings of the previous year. Together with working time reduction, fuel consumptions reduced decidedly; total fuel consumption was about half of first year. The working time reduction trend was even more evident, in consequence of higher values, for the final hand weeding (37 h ha^{-1}); this time was nearly seven times lower than first year.

In the second year the set up of strategy of physical weed control reduced heavily labour employed for an hard improvement of performances of all treatments, but specially for the reduction of hand weeding working times.

In conventional strategy for weed control the time for manual transplanting was nearly the same as that the previous year , while the time for chemical treatment was slightly lower.

For physical weed control in organic farm total working time was 52.31 h ha^{-1} (10.93 h ha^{-1} for physical weed control, 4.34 h ha^{-1} for sowing and 37.04 h $ha^{-1}$for final hand weeding), while in conventional farm 89.86 h ha^{-1} (83.56 h ha^{-1} for transplanting and 6.30 h ha^{-1} for spraying).

<u>*Weed control and yield*</u>

In the first year trial physical weed control allowed a progressive depletion of seed-bank in the first centimetres of soil layer. Weed flora was at first composed by *Picris echioides* L. (30% of relative density), *Veronica persica* Poiret (20%), *Rumex* spp. L. (20%) and winter annual and perennial grasses (17%). Weed density value was 350 plants m^{-2} before stale-seedbed technique realization, 250 plants m^{-2} before first hoeing intervention, 100 plants m^{-2} before second hoeing intervention and 120 plants m^{-2} before third hoeing pass. Weed control efficiency was 100% for rolling harrow intervention and over 90% for hoeing passes (taking into account in-row and inter-row space). Weed dry biomass value registered during the second hand-weeding intervention was triple with respect to each sampled during the first one (12 *vs* 4 g m^{-2}).

Weed density registered in the conventional farm before chemical treatment was about 150 plants m^{-2} and the most relevant species was *Stellaria media* (L.) Vill. (over 90% of relative density).

Weed dry biomass registered before the last crop leaf harvesting was 6 g m^{-2} and 13 g m^{-2} for the organic and the conventional farm respectively (Table 7). In this case, the most relevant species observed were *Rumex* spp. (13% of relative density), *P. echioides* (39%), *Conyza canadiensis* (L.) cronq. (19%), *V. persica* (7%), *Anagallis arvensis* L. (6%), *Cerastium holosteoides* Fries. ampl. Hylander (6%) for the organic farm and only *S. media* (almost 100% of relative density).

The two cropping systems didn't show significant differences, at the end of the first year of the experimental trial, concerning with total fresh yield (Table 3). However, conventional system yield was slightly higher with respect to the organic one (on average about 37 Mg ha^{-1} *vs* 33 Mg ha^{-1}).

Table 3. Yield and weed biomass at harvest determined in 2006.

Weed management system	Yield (Mg ha^{-1})	Weed dry biomass (g m^{-2})
Conventional system	36.9 ns	12.8 a
Organic system	33.4 ns	5.9 b

Different letters on the same column mean significant differences for p< 0,05 (LSD test)

Concerning with the second year of organic cropping system, weed density observed before stale-seedbed technique treatment was about 400 plants m^{-2}. Weed flora was mainly composed by *Solanum nigrum* L. (52% of relative density), *P. echioides* (22%), *C. canadiensis* (22%) and *Portulaca oleracea* L. (8%). However the rolling harrow intervention, carried out before crop sowing, was characterized by a total weed control effectiveness. Furthermore, very few weeds re-grew from this treatment to crop emergence (about 10 plants m^{-2}). Pre-emergence flaming treatment was carried out just in order to control few weed species (for example *Cyperus* spp.) that were fairly developed (4-6 true leaves) so that they could compromise crop emergence. Before the first hoeing intervention, carried out by means of the hoe conformed rolling harrow, weed density was about 200 plants m^{-2}. This treatment controlled about the 90% of weed in the inter-row space and the 30% in the in-row space. The second hoeing treatment, carried out by means of the precision hoe, was characterized by similar levels of weed presence reduction. Weed density before this intervention was about 100 plants m^{-2}. Moreover, one hand weeding intervention was carried out in order to reduce weed presence in the intra-row space. Weed dry biomass in that phase was about 4 g m^{-2} and *Amaranthus retroflexus* and *Chenopodium album* were the most widespread and developed weeds.

In the conventional farm, weed density before herbicide application was about 180 plants m^{-2}, and *Stellaria media* was almost the only species emerging in the field.

Weed dry biomass and weed canopy data collected before the last crop leaf harvest showed significant differences between the two cropping systems. Organic plots were characterized by a significantly lower weed biomass (-50%) and weed canopy percentage (-65%) values with respect to the conventional ones (Table 4). Concerning with weed canopy assessments, carried out by means of the Braun-Blanquet ordinal scale, 16 different weed species were observed in the organic farm and only three on the conventional plots. This probably means that chemical weed management could more easily bring to a sensible weed selection action with respect to organic weed management. Moreover, a strictly selected weed flora could be very aggressive. In this case the most widespread species was *Stellaria media* for both the cropping system. Its canopy percentage value was about 87% for the conventional farm and 57% for the organic one. Moreover, other two weed species reached relevant relative percentage values before the last harvest in the organic cropping system: *Conyza canadensis* and *Chenopodium album* (about 40% of relative density together).

Table 4. Yield, weed biomass and canopy at harvest determined in 2007.

Weed management system	Yield (Mg ha^{-1})	Weed dry biomass (g m^{-2})	Weed canopy (%)
Conventional system	30.6 ns	7.8 a	12.9 a
Organic system	30.8 ns	3.5 b	4.4 b

Different letters on the same column mean significant differences for p< 0,05 (LSD test)

Concerning with total crop fresh yield, no significant differences were registered during the second year too. The observed value was about 31 Mg ha^{-1} for both the cropping system and it was similar, even if slightly lower, with respect to the one observed in 2006 (Table 4).

Conclusions

These experimental trials show that the physical weed control strategy set up in the two year trials allowed an efficient cultivation of leaf-beat in protected cultivation. In particular in the first year the yield of the two compared cropping system was very similar but physical weed control strategy needed a total labour employed very higher than in conventional.

In the second year physical weed control strategy was improved and its working times reduced positively; in the two compared cropping system practically equal yields with similar working times were obtained. In a global evaluation of the different cropping systems must also take into account that physical weed control strategy, allows to obtain a produce with higher quality and price (on average in the two years the price on Central Italy market was 1.5 € kg^{-1} and 0.5 € kg^{-1} for organic and conventional leaf-beat respectively).

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