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ORAL PRESENTATION

Physical weed control in protected leaf-beet in Central Italy

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Abstract

In Central Italy leaf-beet is a typical and very important protected cultivation. In leaf-beet protected cultivation weed control is one of the most important problems, because of its 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-beet 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-beet (*Beta vulgaris* L. var. *cycla* (L.) Ulrich). In Central Italy leaf-beet is a typical and very important protected cultivation and for this crop weed control is one of the most important problems, because of its 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).

First year

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.

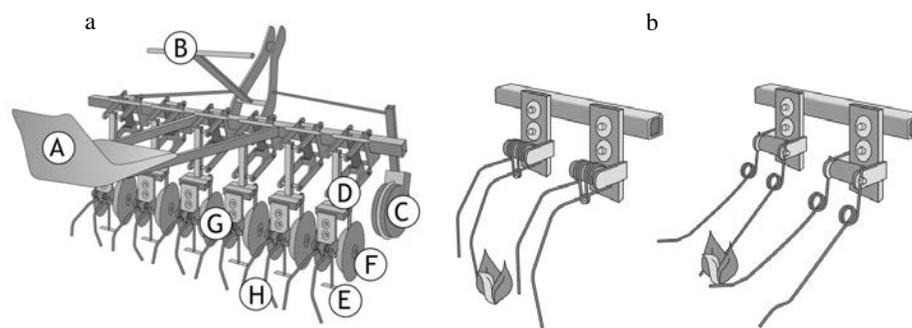


Figure 2. a) Scheme of precision hoe: A) hoe operator seat; B) steering handle; C) steering wheel D) articulated parallelogram; E) working tool; F) lateral disc; G) support wheel; H) elastic tines. b) Vibrating tines (left) and torsion weeders (right).

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 dm³. 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 weeding and harvest) and crop production (total fresh yield) were measured or calculated.

Second year

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.

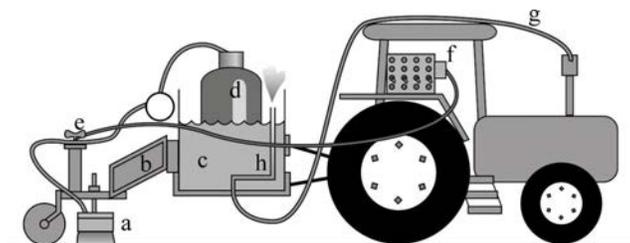


Figure 3. Scheme of the new flaming machine: (a) burner; (b) articulated parallelogram; (c) hopper containing water; (d) LPG tank; (e) shelf on which the inflow LPG control system is located; (f) control panel; (g) flexible pipe that pipes the exhausted gas of the tractor engine to the heat exchanger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

Operative characteristics

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).

Weed control and yield

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. echinoides* (22%), *C. canadensis* (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-beet respectively).

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

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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.

The innovative physical weed control strategy

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.

The innovative operative machine for physical weed control

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 tanks placed into an on purpose made hopper. Furthermore this machine was also equipped with an innovative heat exchange system, in order to avoid tanks 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.

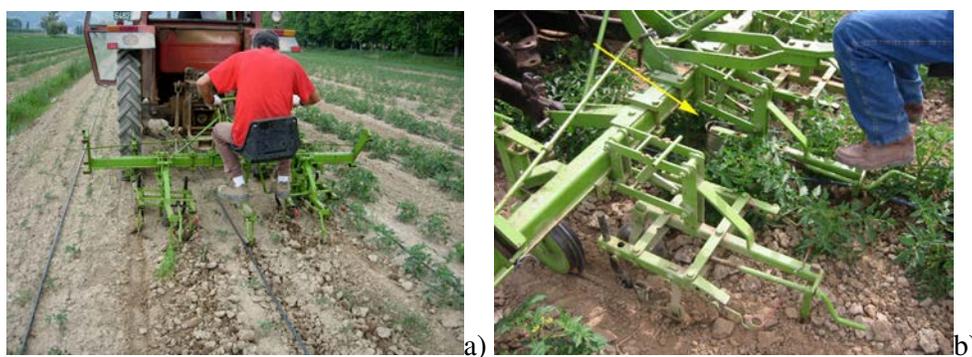


Figure 4. The precision hoe during an early intervention on processing tomato in 2007 (a). Detail of the “V” shaped tool utilized for the late hoeing intervention carried out in 2006 (b).

Experimental assessments, experimental desing and data analysis

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 m² 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

Innovative machine operative performances

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	-	-	-

Weed control

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.

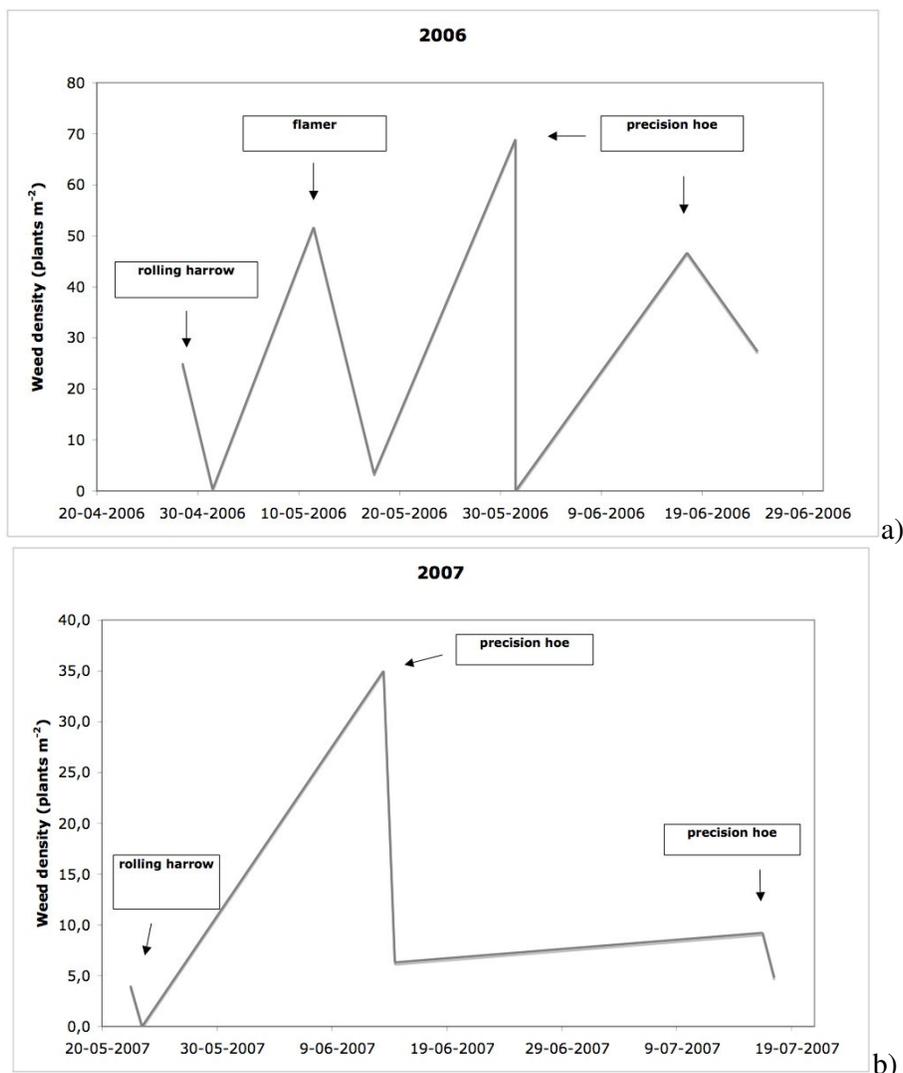


Figure 5. Weed density trend during the crop cycle in 2006 (a) and 2007 (b) for the innovative weed control system (arrows indicate physical weed control treatments).

Yield, weed dry biomass at harvest, labour time and crop economy

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 increases 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≤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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Self-moved ladder for date palm cultivation

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Abstract

Difficulty in accessing the productive zone is one of the common characteristics of adult palms that are cultivated for their fruits (*Elaeis guineensis*, *Cocos nucifera*, *Phoenix dactilifera* etc.); in most Countries where palms are grown, especially where cultivation is carried out with traditional techniques, workers have to apply tiring and risky techniques to reach the top of the trunks.

A self-moved ladder, consisting of 15 m extendable sliding ladder mounted on a mini tracked dumper has been developed to make access to the top of palm trees easier: positioning and transport of the ladder is controlled by the hydraulic system of the dumper, while the extension is done with a manual winch. Operating this equipment is simple and requires no effort for the worker who can then climb the trunk up to a height of 15 m tacking advantage of all the security accessories developed for ladder borne operations. Setting and extending the ladder to its maximum length takes about 60 s.

Keywords: mechanization, palm tree, harvesting, climbing, mini dumper.

Introduction

Date palm (*Phoenix dactilifera* L.) cultivation is widespread in North Africa, Near and Middle East where it has historically constituted a precious source of food and protection for desert dwellers. More recently, because of the qualities of the fruits that are appreciated worldwide, the cultivation of dates has become more rational and intensive and has expanded to new geographical areas (i.e. America, Australia, India, etc.).

Date palm cultivation requires several interventions during the year, among these the most important ones are carried out at the stem level (Figure 1) that in older plants can be 10 m and more above the ground. In some cases productive palm trees can reach up to 20 m, although in most cases more than 15 m is considered a discouraging height (Ali et al, 1998).

These operations, among which harvesting is obviously the major one, require that the worker reaches the stem of the plant and carries out his task holding himself at the trunk at the same time. Difficulty in accessing the productive zone is, as a matter of fact, one of the common characteristics of adult palms that are cultivated for their fruits (*Elaeis guineensis*, *Cocos nucifera*, *Phoenix dactilifera* etc.); this makes harvesting and other operations very difficult if carried out with ladders or poles or other manual aids, specially when palm height is over 8-10 m. In most Countries where palms are cultivated, especially where cultivation is carried on with traditional techniques (Abounajmi, 2004), workers have to climb up the trunk alone or with the help of belts or straps (Figure 2) or of other people piled up on each other's shoulders. These techniques are tiring and risky (Opara et al., 2003) and cause yearly many victims and only a small number of people, mostly elders, are still available for practicing it, making it difficult to harvest within the ideal period and causing the higher palms to be abandoned.

In most industrialized Countries and where date palm cultivation provides high revenues, self-moved aerial platforms are used to access to higher palms: these can rise one or two operators up to 20 m or more in only a few seconds but are very expensive. Even smaller elevating platforms, such as those mounted on tracked mini dumpers, are too expensive for those areas where date cultivation doesn't provide high incomes to farmers.

Where these machines are not affordable manual climbing is the most common technique, but rarely this is done with the use of adequate devices such as solid leather boots with steel shank, crampons, belt and gloves, and indeed sometimes worker climb the trunks without any aid at all (Figure 3).

Portable ladders are seldom used (Figure 4), mainly because of their limited length and because the longer ones are heavy to transport and to set and allow to reach only one side of the fruit bearing area. In some cases these aids are used to reach the top of the palm while the subsequent work is done in the traditional way, with the use of belts or other devices (Figure 5). In other cases ladders can be used to speed up the first part of the climbing.

In European Countries portable ladders are built according to specific regulations that limit height to about 15 m, however this is a considerable height and these ladders are built in 3 parts that can slide one into the other to form a shorter piece for handling and transportation. When the ladders are very long their mass can reach 80 and more kg so the extension is done with the help of a winch. All this makes it difficult to transport, set, open and close these ladders in a repetitive way, as required during field operations in specialized plantations.

Aiming to contribute to the improvement of safety, productivity and ergonomics of the operations that are carried on at the stem level of date palms, the author has developed a self-moved ladder where the heaviest operations are automatized.

This work therefore analyses the possibility of using long extendable aluminum ladders for climbing up the palm trunks since they are inexpensive, if compared to elevating platforms, and very reliable. However longer ones are heavy and difficult to handle so the possibility of mounting a ladder on a low cost mini dumper has been thoroughly examined in order to allow the carrier to bear the effort of moving and placing the ladder and to provide a reliable anchorage without the use of extendable stabilizers.

Materials and methods

A tracked mini dumper (Figure 6) of 300 kg with 500 kg of loading capacity, powered with a 4 stroke Honda GX200 4.5 kW petrol engine was used to hold an aluminum extensible ladder.

This ladder consists of 3 parts that can slide telescopically one in another. The ladder is 5.91 m long when closed and 15.15 m long when completely open. A professional hand winch with safety clutch is used to extend and shorten the ladder, an automatic safety catch assures stability as soon as winching is stopped. The mass is 76 kg. The ladder is provided with a special device for leaning on poles that assures improved stability and has been fitted with a banister on the last part. A pivoting hoisting pulley has also been installed at the end for raising and lowering tools and date bunches.

The dumper's tipping bed was removed by simply disconnecting it from the holding pins and from the hydraulic tipping ram and replaced with the ladder.

The ladder was connected to the same retaining system of the bed so it can pivot on the pins while the ram varies its inclination (Figure 7). For transport the ladder has an inclination of about 0.52 rad with the ground, while, when standing, the inclination can vary from 1.32 rad to 1.44 rad: this tolerance is allowed by the ladder's adjustable feet. The inclination of the ladder has been calculated according to the rule that for ladder heights up to 8 m the feet of

the ladder must be placed at a distance from the base of the vertical leaning plane of about 25% of the height, while for higher ladders the distance should be about 2 m. Figure 8 shows a draft of the equipment set in front of a palm tree.

Results

The machine takes all its movements from the tracked dumper so it is very easy to manoeuvre also in narrow or winding paths and to set it under a tree or a pole at a distance that varies from 1.5 and 2.5 m. Being the ladder much lighter than the maximum weight the mini dumper can transport no stress is set on it. Once the carrier has been positioned it takes about 10 s to place the ladder and regulate its feet and about 45 s to extend it comfortably to its maximum length. An operator can climb up to the top of the extended ladder in about 60 s while the bunch can be safely lowered to the ground in 15 s. The equipment can be moved to the next position in about 60 s after the operator has descended. Theoretically one operator is enough for operating the equipment and climbing the tree, but in some operations, such as harvesting, an assistant is needed for lowering the bunches.

The self-moved ladder, that cost altogether around 5.000 euro and consumes a maximum of 1.5 kg of petrol for 1 hour of continuous running of the engine, was tested on palm trees in Italy and then shipped to Iraq for in the field trials: there its performances will be compared to those of traditional harvesting techniques.

Conclusions

Safety and productivity can be improved in date palm cultivations with the use of an extensible self-moved ladder. The mini tracked dumper easily transports the ladder and sets it under the palm trees, improves its stability and allows operators to climb fast and safely up to 15 m height without the need for aids such as belt rigs or gaff hooks and without the help of other people. The mini dumper can also be used, once the bed has been reinstalled, for other transport operations even in different fields besides agriculture, so it has the potentialities for becoming an interesting tool for date palm cultivation.

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Figure 1. Cleaning the trunk is one of the operations that require climbing up to the top of the palm tree



Figure 2. Collection of dates in an uncomfortable position with the use of a simple belt (Scozzari, 2007)



Figure 3. Climbing with bear foot without straps or other safety devices (Scozzari, 2007)



Figure 4. Climbing up a palm about 7 m high with an extensible ladder (<http://www.jupiterimages.fr>)



Figure 5. Correct gear for working at the stem level of a tall palm tree (<http://tour.airstreamlife.com/weblog/Tucson%20palm%20trim.jpg>)

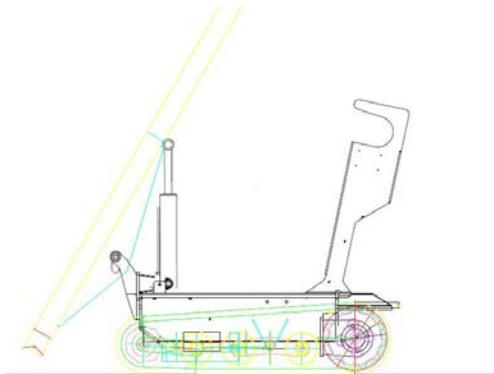


Figure 7. Scheme of the linkage between the dumper and the ladder



Figure 6. The minidumper used for mounting the ladder



Figure 8. Draft of the equipment positioned to service a date palm bearing fruits at a height of about 10 m. The figure shows the proportions within the sizes of the different components

Four machines for sod-seeding in comparison: first results of operational and technical tests in Basilicata

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Abstract

Our study was carried out to evaluate four different seeders for sod-seeding by a qualitative and quantitative comparison of their performances on cereal crops in Basilicata.

The application of sod-seeding, alias no tillage, it may represent a valid alternative to traditional seeding in areas with high cereal vocation, as a guarantee against production costs, safeguarding the productive and environmentalists aspects in the south of Italy, where there is a great crop specialization and higher environmental risk resulting from intensive farming operations.

So, were organized tests with four different seeders: Gaspardo-Directa, Amazone AD 300, Alpego ASI 303 and Laseminasodo. Relating to this study, the most important difference, between these machines we considered, was the coulter body.

We analysed the technical and operational characteristics of the seeders, the distribution regularity of the seed and the parameters concerning the harvesting.

The results were interesting for all machines, the operational capabilities have been certified on values equal to 1,8 ha/h, satisfactory values regularity of longitudinal and transverse distribution of the seed considering that the value of plants emergency was close to 90%. About yield obtained, some data collected showed a higher value compared with that obtained with the traditional seeding in the same soil conditions.

The results of our trials confirmed that with sod-seeding is possible to guarantee sustainability, energy saving, ability to establish the time of execution and therefore more timely intervention, so we can conclude that the qualitative and quantitative standards can be achieved satisfactory provided if there is a better choice of the machine depending on the physical characteristics of the soil, in particular a better choice of coulter body which is the essential element of a successful plants emergency.

Keywords: sod-seeding, seeders, sustainability.

Introduction

Lately the intensive farming caused sea changes in the ecosystems if we think to the gradual, but unstoppable, impoverishment of organic substance and to the alteration of soil structure, resulting from its ponderous exploitation. We refer to operations previous the traditional sowing, carried out by equipments reaching high depths and causing changes in the equilibrium of soil system.

Studies done by Bonari et al (1992) underlined as the adoption of cultivation methods can help along the correct equilibrium among solid, liquid and gaseous phase, illustrating traditional cultivation and sod-seeding.

Subsequently Hakansson et al. (1996) compared the methods of conventional cultivation with minimum tillage, analysing the characteristics of seedbed, fundamentally clay.

It resulted a considerable influence by reduced cultivation as superficial ploughing to 20 cm of depth and sod cutter to 13 cm, on the physical characteristics (volumic apparent mass)

as well as permeability and aeration characteristics, resilience to penetration. The latter is helpful to valuate the effect of reduced cultivations on the roots development.

Last decades it assisted to an increasing diffusion of new cultivation methods grounded on reduction intensity and number of interventions. An example can be provided by sod-seeding application, that consists in a valid alternative to methods of conventional cultivation especially in those areas, as that object of our investigation, known as a cereal vocated, because assures a reduction of production costs and safeguard of productive and environment aspects.

With this new method the preparation techniques are only harrowing, thanks to peculiar compliance of the seeders which compared to traditional seeders are gifted by lister discs, that penetrate some centimetres (4-10 cm), releasing subsequently the seed by adductor organs.

The aim of our study was to evaluate four different seeders for sod-seeding by a qualitative and quantitative comparison of them performances of cereals culture in Basilicata, relating the data obtained with those of traditional planting.

Moreover we verified the possibility to obtain production greater or comparable to that earned by traditional planting.

Materials and methods

The trials have been done by four different seeders: Laseminasodo, Gasparido-Directa, Amazone AD 303 and Alpego ASI 300. The tests included:

- the estimated amount of technical parameters associated with the use of planters;
- evaluation of the regularity of longitudinal and transverse distribution of the seed;
- analysis of operational parameters for the harvest and quality of the final product.

The place of the investigation correspond to an hilly zone in Basilicata, on a soil with an inclination between 8 and 10%, whose granulometry and physical-chemical characteristics at time of the research are reported in the following tables.

Table 1. Granulometry components and physical-chemical characteristics

COMPONENTS	%	CHARACTERISTICS	VALUE
Coars sand	35,9	ph	8,5
Fine sand	23,9	CaCO3	12,0
Coars silt	5,4	Humidity	4,5
Fine silt	15,0	CO	1,0
Clay	19,8	O.S.	1,8

In order to obtain a direct comparison with traditional planting, which submitted the area over the last few years, and sod-seeding, subsequently we reported two tables (tab.3 and 4), containing all operations executed before and after the planting. In both cases it sowed the species *Triticum durum*, variety *simeto*.

Table 3. Cultivation operations executed by traditional tilling of soil

OPERATIONS	PERIOD	EMPLOIED MACHINE
<i>Ploughing</i>	August-September	Nardi trivomere 163 T QZ/A
<i>First harrowing</i>	26 September - 26 October	Gherardi DRS 7P
<i>Second harrowing</i>	27 October - 21 December	Gherardi DRS 7P
<i>Planting</i>	27 October - 21 December	Accord pneumatic DL 32
<i>Manuring with Urea</i>	Genuary	Leley 1250 6 q
<i>Manuring with Niter</i>	20 February-20 March	Leley 1250 6 q
<i>Chemical weeding</i>	April	Nobili J600 P
<i>Harvesting</i>	6 June-20 July	John Deere 1177AL
<i>Straw Baling</i>	July-August	Class roulant 68

Table 4. Cultivation operations executed by sod-seeding

OPERATIONS	PERIOD	EMPLOIED MACHINE
<i>Harrowing</i>	26 September- 26 October	Nardi trivomere 163 TQZ/A
<i>Planting</i>	27 October- 21 December	Amazone AD3 Super
<i>Manuring with Urea</i>	Genuary	Leley 1250 6 q
<i>Manuring with Niter</i>	20 February- 20 March	Leley 1250 6 q
<i>Chemical weeding</i>	April	Nobili J600 P
<i>Harvesting</i>	6 June-20 July	John Deere 1177AL
<i>Straw Baling</i>	July-August	Class roulant 68

In this summarizing scheme are enumerated the operations to follow before and after planting, by different cultivation techniques. It is clearly visible as in the direct planting it obtains a drastic reduction of operations previous planting. The harrow is the only processing necessary to place the seed to the correct depth and therefore allows the sprout from the seedling.

Table 5. Summarized description of cultivation operations with conventional planting and sod-seeding

<i>CONVENTIONAL PLANTING</i>	<i>SOD-SEEDING</i>
<i>Ploughing</i> <i>First harrowing</i> <i>Second harrowing</i> <i>Planting</i> <i>Manuring with Urea</i> <i>Manuring with Niter</i> <i>Chemical weeding</i> <i>Harvesting</i> <i>Straw Baling</i>	- <i>Harrowing</i> <i>Planting</i> <i>Manuring with Urea</i> <i>Manuring with Niter</i> <i>Chemical weeding</i> <i>Harvesting</i> <i>Straw Baling</i>

For each seeders have been reported the technical characteristics such as the number of lister discs, the effective working width, the weight etcetera. On the parcels of one hectare these machines have been submitted to the evaluation of some operational parameters (planting depth, operational capacity, fuel consumption of the tractor). The longitudinal distribution has been determined counting the seedlings outcropped on a line of 5 cm, obtaining this value 200 times. The data have been reunited in classes correspondent to the seeds newfound and calculated the frequency, expressed in percentage of each class on the totality of surveys. So it is possible to verify and quantify potential failed release of seed or to the contrary releases of an excessive number of them.

For the evaluation of the transverse distribution has been adopted the variation coefficient (CV), calculated analytically by the application of this equation (Sartori et al.1999):

$$CV = \sqrt{\frac{\sum (x_i - (X))^2}{N - 1}} \cdot \frac{100}{X}$$

where:

X = arithmetic mean of the seed released by all unities (g)

X_i = quantity of seed released by each element adductor (g)

N = number of unities of planting evaluated.

Consequently before the trials we estimated the quantity of seed released singularly by each adductor pipe, after some turns of the distributor. This trial was tested several times analysing the differences owing to the variation of the seed velocity in the hopper and the rotation velocity of roller distributor. Also the harvesting phase has been the subject of our study, estimating the operational capacity of harvester and the evaluation of unit productions.

Results

It has been reported the planting and harvesting results, in order to evaluate the size of the production obtained with the different cultivation techniques.

The first aspect analysed concerned the execution modalities of planting, as the depth, important because from it depends the good germination and the adequate development of seedlings. The values registered was practically similar for all machines with exception of the Laseminasodo which puts the seed to a lower depth, equal to 4 cm. This is due to the

characteristics of lister discs; being hay-cutters of lower weight, the pressure applied on the soil is insufficient to guarantee high depth, which we obtained with the Gaspardo and Amazone, thanks to lister discs and in the Gaspardo to the compliance of the adductor organs.



Figure 1. Hay-cutters in the Laseminasodo



Figure 2. Lister discs in the Gaspardo



Figure 3. Lister discs in the Amazone



Figure 4. Organs adductor

The operational capacity of seeders is on average 1,8ha/h, while for the Laseminasodo it is no lower of 1,3ha/h (tab.6). The most interesting results was those relative to regularity of the transverse and longitudinal distribution of the seed, expressed analytically by the Variation Coefficient (VC) and the mean emergency (tab. 7-8).

The first parameter, in the Amazone and Alpego, reached a value equal to 1,4%, very below of the maximum limit (2%) to express an optimal judgment for cereals and forages. For the other two seeders the VC, although more high, doesn't exceeded the maximum threshold.

The mean emergency was satisfying, varying between a minimum of 80 and a maximum of 90%. The values no lower are due not much to the characteristics of seeders as the lack in precipitations in the period subsequent to the planting and to the soil tenacity, that induced the prevarication of some seedlings over the other. This situation influenced on the results of the trials until the harvesting and, as it was simple to foresee, the production no lower were those obtained by the Alpego and the Laseminasodo, as showed in the table 9. With these machines the mean emergency were low, although whatever goods.

Comparing the entity of productions emerged that the production obtained by sod-seeding are not much lower to that obtained by the conventional planting. Further the trend of productions was very similar, in fact where the productiveness with the sod-seeding was lower, the same result it reached by the conventional techniques.

All machines highlight a high level of trustworthiness. During trials, in fact it doesn't verified breaks or other problems connected to the machine, such as to cause the stopping and consequently the increase of times necessary to the operation. The Gaspardo and Amazone provided the better results. The Laseminasodo resulted the seeders less valid because of some characteristics: in particular the lower weight and the presence of the hay-cutters instead the disks, prejudicing the placement of the seed to a greater depth, because it doesn't reaching a sufficient pressure on the soil. In some cases the hay-cutter was not up to pierce in the soil.

Table 6. Operational data of planting

Seeders	Depth of planting (m)	Working width (m)	Operational capacity (ha/h)	Fuel consumer (l/ha)
Laseminasodo	0,04	2,60	1,3	18
Directa-Gaspardo	0,07	3,00	1,8	20
Amazone AD 303	0,10	3,00	2,1	21
Alpego ASI 300	0,10	3,00	1,9	40

Table 7. Regularity of transverse distribution

Seeders	Dose of planting (q/ha)	Weight of 1000 seeds (g)	Velocity of advancing (Km/h)	Inclination machine (%)	Variation coefficient (%)
Laseminasodo	2,5	42,5	7,5	8-10	1,90
Directa-Gaspardo	2,20	45,7	7,5	8-10	1,84
Amazone AD 303	2,5	50,5	8	8-10	1,40
Alpego ASI 300	2,3	40	8	8-10	1,40

Table 8. Regularity of longitudinal distribution

Seeders	Number percentage of plants for segment										Medium number of plants	Mean emergency (%)
	0	1	2	3	4	5	6	7	8			
Laseminasodo	18	30	25	15	5,5	3	2	1	0,5	1,53	83	
Directa-Gaspardo	19	32	26	15	5,9	1,5	0,5	0,1	0	1,65	90	
Amazone AD 303	19	32	26	15	5,9	1,5	0,5	0,1	0	1,65	90	
Alpego ASI 300	18	30	25	15	5,5	3	2	1	0,5	1,83	80	

Table 9. Operational and qualitative data of harvesting

Seeders	Productions (q/ha)	Weight of grains (Kg/m ²)	Hectoliter weight (Kg/hl)	Working width (m)	Operational capacity (ha/h)	Production of conventional planting (q/ha)
Laseminasodo	15	0,25	83	4,80	1,15	22,5
Directa-Gaspardo	26	0,35	83	4,80	1,25	27
Amazone AD 303	31	0,44	83	4,80	2,2	32,5
Alpego ASI 300	25	0,30	83	4,80	1,3	27

Conclusions

The results emerged from our analysis confirmed that by the sod-seeding it is possible to guarantee:

- ✓ ecocompatibility, preserving the soil structure;
- ✓ energy saving, thanks to drastic reduction of the operations previous the planting;
- ✓ possibility to establish the period of operating, executing tilling when the soil presents the optimal conditions, avoiding damages to the structure and consequently
- ✓ interventions more timely.

The qualitative and quantitative satisfying standards can be reached on condition that is an optimal choice of the machine to employ, on the ground of the physical characteristics of the soil. In particular it is necessary an adequate choice of the lister discs that are the essential elements in order to a good apical emergency. The machine firms diverted their attention in this direction and recently are able to offer a wide set of operational organs on the ground of the operational conditions required.

The greater limit is the excessive cost of seeders, in fact the most part of firms resort to third party, because they haven't always the plot of land enough extended to let the gradual amortization. Besides we are unacquainted with the numbers of years that it is possible execute the sod-seeding without the conventional planting, because are insufficient the trials realized until today. Overstay the distrust of the owner for a practice still not much known, although it is spreading some decade ago.

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POSTER PRESENTATION

First contribute to the mechanization string of saffron flowers (*Crocus Sativus L*)

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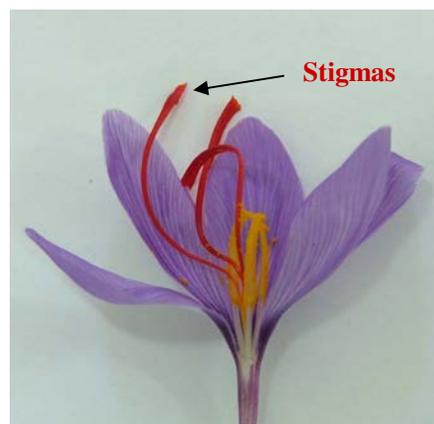
Abstract

In this work the some preliminary results of tests to mechanical string of the saffron stigmas in air current are shown. In particular have been compared, three models of air separation which some structural difference: duct diameter, air speed and the separation surface. For the flower disarticulation by cut and three system of cut are compared. The force applied for the cut, was relatively low (0,21 N) if the extraction stigmas by the hand was simulated; but increased if the operating conditions was expecting to simulated the cut reaching values included between the 7,39 N and the 21,37. Between the three cyclone system there was the following differences: a) Cyclone type 1: at the 3,5 m/sec maximum speed, the 49,3% of stigmas underwent the loss of one or two filaments; b) Cyclone type 2: reduction of the 25% of the duct diameter, does not complete the separation; c) Type 3: reduction of the 14% of the duct diameter and speed of the air included between 0,69 m/sec and 1,5 m/sec, the separation is completed (96% of separate stigmas) does not highlight stigmas damage. In definitive, the system arranged with the cyclone of type 3 is able to obtain a high percent of separation of stigmas which constitutes the beginning for the realization of a prototype for the experimentation in full field.

Keywords: saffron, stigmas, mechanical string.

Introduction

Sardinia has the national supremacy of the cultivated surface to saffron (70%) and of the production (80%). Today the separation of stigmas (fig. 1) still took 55% to 66% on the total work time because made exclusively to hand. The mechanization string of the saffron flower, is an important factor because gives an economic opportunity to the farmers to change the saffron cultivation from a secondary income in a primary income, with an increase in the amount of product obtained for hectare. Actually, without this chance stigmas production remains located strongly in an border role which not increase the economic importance of the product (spice).



the

Figure 1. Saffron stigmas

Material and method

The study, carried out in laboratory, was the beginning of study at last to arrive to the building of a prototype for the mechanical string of the saffron flower after the separation, by cut, of its components. The cut simulation was made with one texture analyzer (Low Force Plus, LFP, Nexygen, LTd). The dimensional flowers parameters were taken on a sample of 100 flowers with three repetitions, taken accidentally; this taken ones were: the diameters, longitudinal (lt), transversal (t) and intermediate (w), by an electronic caliper model s 225

(Wurth) with resolution of 0,001mm; the average geometrical diameter (D_g); the sphericity (Φ) expressed in per cent; and the superficial area (S) of the three parts of the flower calculate using the Mohsenin (1), (2) and Baryeh (3) formulas. The separation of stigmas was tested and obtained with three different types of cyclone (fig.2, fig. 3 and fig 4), in which we have modified air speed the diameter of the duct and the area of the separation surface. The data of air speed was collected by a thermo anemometer (DO 2003, HVACRI, Salmoiraghi, Inc). All the data, were statistically analysed with the software Statgraphics, XV-Centurion (StatPoint.Inc, 2005) by the analysis of the simple variance (ANOVA).

$$D_g = (LWT)^{\frac{1}{3}} \dots\dots\dots(Mohsenin ,1970)\dots\dots\dots(1)$$

$$\Phi = \frac{(LWT)^{\frac{1}{3}}}{L} * 100 \dots\dots(Mohsenin ,1970)\dots\dots\dots(2)$$

$$S = \pi * D_g^2 \dots\dots\dots(Bryeh ,2001)\dots\dots\dots(3)$$



Figure 2. Cyclone type 1



Figure 3. Cyclone type 2



Figure 4. Cyclone type 3

Results and discussion

Cut strength

As was shown in table 1 can be observe that the detachment strength to be applied, assuming an direct work of the farmer finger on the stigmas, was rather low 0,21 N, and this value proves the extreme accuracy which is necessary to proceed at the harvest of saffron stigmas. The choice to traditional blades which simultaneously cut the flower and stigmas needs the application of strengths included among the 7,39 N and the 21,37 N (0,7 kg and 2,1 kg). Between the groups (table 1) the cut simulated with ferrule to 0,5 mm and with cutter blade showed a low significant difference level, instead the others remaining groups are between them highly different.

Such application, suitable after the harvest, can be arrange the flower parts at the harvest: leaves, petals, anthers and stigmas. These can be separated independently by the use of airflows which remove the other parts not necessary by the differences between the specific weight of the same ones.

Table 1. Comparison between the different cut systems (ferrule, cutter blade and scissor)

Blade utilized	Number of samples (n)	Strength average (N)	Homogenous group
Detachment ⁽¹⁾	25	0.21	X
Cut simulated with ferrule to 0,5 mm ⁽²⁾	25	21.37	X
Cut simulated with cutter blade ⁽³⁾	20	15.28	X
Cut simulated with scissor ⁽⁴⁾	20	7.39	X
Comparison between groups		significant differences	
2 - 3		*6.0877	
2 - 4		*13.9792	
3 - 4		*7.8915	

Multiple Range Tests, Method: 95.0 Multiple Tests, Method range: 95.0 confidence percent averages were separated with the Duncan Test; Average * reveal a significant statistical difference (p < 0,05).

(1)detachment of the stigmas; (2),(3),(4) positioning and cutting of the whole flower.

Dimensional parameters of the saffron flowers in the two experimental fields.

The flowers analyze in the two experimental field (A and B) showed differences for the sites and between the parts petals, anthers and stigmas, (table 2). For the average geometrical diameter of the three parts its varied from 18,36 mm to 21,00 mm for the petals; from 4,04 mm to 4,98 mm of the anthers and from 2,66 mm to 4,84 mm in the field A and B respectively. Between all these parameters the two most important was the superficial area and the weight of the component. For all the part of the saffron flower harvested in the two fields, there was differences in the superficial area and in the weight. For effect of the variability observed on these two parameters, it was possible therefore to lead the various separation tests and obtain an high or low separation between the components of the flowers. The Superficial area exposed to the air varied from 0.22 mm² to the stigmas in field the B and

the 12,82 mm² of the petals in field A. The weight of the three parts varied from the 0,01 g to the stigmas in the field B and the 0,05g of the stigmas and the petals in the field A.

Table 2. Average geometrical diameter, sphericity, surface area and weight to the parts of saffron flowers harvest in two experimental fields (A and B)

Experimental field (A and B)	Average geometrical diameter (Dg)	Sphericity (Φ)	Superficial area of the flowers parts exposed to the air (S)	Weight
	(mm)	(%)	(mm ²)	(g)
Petals				
A	21,00 ± 3,25	50,66 ± 1,14	13,82 ± 0,53	0,05 ± 0,01
B	18,36 ± 1,40	39,92 ± 0,34	10,58 ± 0,22	0,02 ± 0,03
Anthers				
A	4,98 ± 0,58	23,18 ± 1,50	0,78 ± 0,17	0,02 ± 0,01
B	4,04 ± 0,72	20,92 ± 0,12	0,51 ± 0,11	0,02 ± 0,02
Stigmas				
A	4,84 ± 1,02	10,77 ± 0,09	0,54 ± 0,60	0,05 ± 0,02
B	2,66 ± 0,23	9,13 ± 0,13	0,22 ± 0,04	0,01 ± 0,02

Results of the airflow separation of the saffron flowers.

Results obtained with the Cyclone to type 1.

The separation of the various components takes place in conditions of growing speed passing from 0 m/sec at 4,2 m/sec (table 3), limit, beyond which the air speed determines the expulsion also of stigmas.

In consequence of the contact with the grained surface of the metal of which the separation duct is however constituted, some losses of filaments (breaks) of stigmas and the formation of a compact composed floral product mass from stigmas, anthers and petals are determined to the sides of the net of what the fan separates from the duct.

This behavior previously registers the disjointed flowers for effect of the vibrations transmitted by the fan of the wide surface of separation (40 cm) on which are deposited with the scissors from the operators engaged in the test. Experimentations led with speeds included among the 2,5 m/sec, 3,0 m/sec and 3,5m/s, the anthers and the petals of the saffron flower did not separate for expulsion from the duct or produce the break of one or two filaments in consequence of the collisions with the duct borders for the 50% of the saffron stigmas. The operating cyclone capacity ranges from 19,2 g/h to 168,0 g/h if the variability of the weight of the harvest stigmas was considered.

Results obtained with the Cyclone to type 2.

In this type of cyclone the surface of separation was reduced to the 25% of the diameter from 40 cm to 35 cm, and in consideration to the damage produced by the collision with rigid and

grained walls, the metal was replaced with of the pyrex glass to high resistance and smooth walls.

Table 3. Air speed, surface separation, flowers capacity (for minutes and for hour), saffron products and final quality of the stigmas in cyclone type 1

Air speed (m/s)	Area of separation (m ²)	Flowers separated (n°/min)	Capacity operating (Co) (flowers/h)	Saffron product (g/h)	Quality of the stigmas after separation		
					thre filaments 50 % (g)	two filaments 37 % (g)	one filament 13 % (g)
2,5	0,12	32	1920	96,0* 19,2**	48,0 9,6	33,6 6,72	17,4 7,1
3,0	0,12	44	2620	131,0* 26,2**	65,5 13,1	45,9 9,2	19,6 3,9
3,5	0,12	56	3360	168,0* 33,6**	84,0 16,8	58,8 11,8	25,2 5,0

*stigmas (weigh 0,05g relate flower weight/weigh stigma; 41% on the total weight)

** stigmas (weigh 0,01g relate flower weight/weigh stigma; 20% on the total weight)

Tests were made to the same conditions of speed of the preceding test passing from 0 m/sec at 4,2 m/sec (table 4). In these operating conditions even if a separation surface reduction was there the operating fan conditions turned out unfit to enliven an amount of sufficient air to separate the three flower components. The petal separation was obtained but the anthers and stigmas remained inside the separation duct. The speed and the door of the air which cross the duct raised of a height equal at 15 cm, 17 cm stigmas and the anthers but a complete separation of the two components was not determined. Ruptures of the stigmas in consequence of the contact with the duct surface were high from 13% to 37% of the filaments was breaking and however determined the formation of a compact mass of floral product composed by stigmas, anthers and petals to the sides of the net of what separates the fan from the duct. The operating cyclone capacity ranges from 18,0 g/h to 153,0 g/h if the variability of the weight of the harvest stigmas was considered. Also in this type of cyclone, this behaviour registers the disjointed flowers for effect of the vibrations transmitted by the fan to the separation surface up which are deposited.

Results obtained with the Cyclone to type 3.

In this type of cyclone the diameter of the duct (surface of separation) was reduced to another 14% from 35 cm to 30 cm and the pyrex glass was replaced by plastic and transparent PVC with smooth walls for a 120 cm height. To increase the speeds of the air inside the duct a snail fan was suitable for the same one while test execution conditions were modified with a speed reduction (about 50% of the other tests) passing from 0,69 m/sec to 1,5 m/sec (table 5).

Table 4. Air speed, surface separation, flowers capacity (for minutes and for hour), saffron products and final quality of the stigmas in cyclone type 2

Air speed (m/s)	Area of separation (m ²)	Flowers separated (n°/min)	Capacity operating (Co) (flowers/h)	Saffron product (g/h)	Quality of the stigmas after separation		
					Stigmas damage		
					three filaments 50 % (g)	two filaments 37 % (g)	One filament 13 % (g)
2,5	0,09	30	1800	90,0* 18,0**	45,0 9,0	33,3 6,66	11,7 2,3
3,0	0,09	42	2520	126,0* 25,2**	63,0 12,6	46,6 9,3	16,4 3,7
3,5	0,09	51	3060	153,0* 30,6**	76,5 15,4	56,6 11,3	19,9 3,9

*stigmas (weigh 0,05g relate flower weight/weigh stigma; 41% on the total weight)

** stigmas (weigh 0,01g relate flower weight/weigh stigma; 20% on the total weight)

Table 5. Air speed, surface separation, flowers capacity (for minutes and for hour), saffron products and final quality of the stigmas in cyclone type 2

Air speed (m/s)	Area of separation (m ²)	Flowers separated (n°/min)	Capacity operating (Co) (flowers/h)	Saffron product (g/h)	Quality of the stigmas after separation		
					Stigmas damage		
					three filaments 96 % (g)	two filaments 3,5 % (g)	one filament 0,5 (%) (g)
0,69	0,08	30	1800	90,0* 18,0**	86,4 9,0	3,1 6,6	0,5 2,3
0,92	0,08	36	2160	108,0* 21,6**	103,7 20,7	3,7 0,7	1,2 0,2
1,50	0,08	44	2640	132,0* 26,4**	126,7 25,4	4,6 0,9	0,7 0,1

*stigmas (weigh 0,05g relate flower weight/weigh stigma; 41% on the total weight)

** stigmas (weigh 0,01g relate flower weight/weigh stigma; 20% on the total weight)

In these operating conditions even if a separation surface reduction was there the operating fan conditions turned out suitable for the following reasons:

1) with air speed included between 0,69 m/sec and 0,92 m/sec was separated further on the 96% of stigmas of the 100 flowers with which we began the test and enlivened an amount of sufficient air to separate the three flower components.

2) the petals and anthers separation was obtained and the stigmas remained inside the separation duct floating at a height of about 30 cm to the separation surface and the operating cyclone capacity ranges from 18,0 g/h to 132,0 g/h if the variability of the weight of the harvest stigmas was considered. .

3) damages observed on stigmas were relatively low (stigmas with two or a single filament equal to 3,5% and 0,5% respectively).

4) wasn't determinate in this cyclone the formation of a compact mass of floral product formed by stigmas, anthers and petals inside the duct.

5) vibrations transmitted by the fan to the surface on which the disjointed flowers are deposited did not produce any anthers and petals store to the separation surface borders.

Conclusions

The saffron cultivation, in reason to the observations made and to the results obtained, is susceptible to an rational and effective mechanization which would give the same one a considerable decrease of the production costs. In the short run operations which could benefit from a mechanization level raising are all, except for the harvest and for the flower string. The introduction of the mechanical harvest and string of the flowers is bound to the adjustment, also minimize, the regularity and the dimensions (hectares) of the cultivation farm to allow the harvest machine participation. If for a few agricultural operations it was possible proceed in associated, like that form to increase sensitively the business dimensions, the advantage would be still more tangible. Of safe benefit, for the entrepreneurs engaged in this cultivation, it could be represented by the availability of a reference surface, managed by several producers with the experts' contribution, on which make the cultivation applying the last technologies in order to be compared and be conformed the knowledge. They still remain in to the traditional condition the harvest and the flowers string which are at the present (handmade). Experimental tests on the harvest and flowers string must be stretched connected, because the first must receive some of the technical-operative demands of the second. At last, to attribute at the saffron development an important economic role it is necessary go beyond the traditional method of production, principally harvest and flower string by hand arranging a single experimental project, in order to implement a mechanical system to flower string able to execute the intervention respecting the quality of the final product.

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Optimized design of a simplified interceptor for olive harvesting

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Abstract

It was been designed and realized a simplified interceptor system with olives harvest nets, to use during the olives harvesting phase for existing olives tree-plant on small surfaces. Such equipment complied to the design requirements of: inexpensiveness for investment and operative use, machine working in continuous, with possibility to use it for other similar crops, minimum employment of workman (an operator). The machine was constituted by a rectangular base climbed on wheels and hauled. It was surmounted by a grate that allowed the sieve of the olives and by a cage of nets, with form of trunk of inverted pyramid that, sustained by mechanically driven bars, succeeded in surrounding the tree locks. The machine tangentially worked to the trees trunks along the convenience order of the olive-tree-plant. By mean a pneumatic command, two telescopic bars that sustained the nets, escaped, so that they surrounded the whole tree trunk, in few second. At this point the shaking phase began. The olives harvested, by mean the inclination of the planes formed by the base nets, they went in the grate impending the tank of the considered machine, and therefore they were collected in the vain underlying. During the performed experimental tests, the detected losses on soil have practically almost been void. Finished such phase, reversing the pneumatic command, the return in initial condition of the nets was had, that is, they were displaced on the right broadside of the considered machine, and it was ready to be reallocated, under the following tree.

Keywords: nets for olive harvesting, olive interceptor, olive mechanical harvest.

Introduction

Today it is very important the interest to have agricultural productions on marginal soils located in particular sites, where the typical products obtained, by mean particular crops, can be exalted (Montedoro F., Servili M., Baldioli M., Pannelli G. 1991); (Vieri M., 2000). Among all, they result of notable importance the revaluations of agricultural sectors and the cultivation of soils until now uncultivated, able to assure an alternative source of income (Tombesi A., Guelfi P., Nottiano G.,1998), (Tombesi A.,2001).

A case of this type is represented by the cultivation of the olives tree plant, also whereas such tree plants are located in parks and therefore they represent, for law, an irreplaceable crop, and therefore they constitute, by a determined point of view, a "forced crop". Besides, such crop in some zones is in "way of abandonment", because of manpower high cost, that is besides in continuous increase, and of the little dimensions of the fields and their high slopes, that have not allowed any sort of agricultural mechanization.

Whereas it continues to be performed, the problem of the mechanical harvest of the olives has to be faces, (Formato A., Romano F.,2003); (Giametta G.,1975);(Giametta G.,2001); (Liguori A., Formato A., Amirante M.,2000); (Parchomchuc P.,Cooke J.R.,1972); (Tsatsarelis C.A., Akritidis C.B., Siatras A.,1990); and it is more and more pressing because of the reduction of the available manpower, with exorbitant costs and the too much long times

required for the harvest phase, that negatively engrave on the inexpensiveness of the production as well as on the quality of the final product. The diffusion, in this last ten years, of machineries that aid the olive harvest, it has in part solved these problems (Stefanelli G.,1971); (Vieri M., Bazzanti N., Toma M. ,2001); (Vitali G. ,1967).

Unfortunately, there is still now, the critical phase of collecting the product mechanically removed by the trees, that involves long and fatiguing times for the use of the nets on the soil to complete the olives harvest. An alternative is constituted by enough simple and not expensive machineries that facilitate the manual layout and the pick-up of the nets from the soil, but it remains the necessity of manual operations for the layout and the rewinding of the nets, with relative increase of the operative times. Moreover, in the case (the most frequent) to use machineries aiding the harvest, it is not avoided the risk to stamp on the olives falls, and to damage the quality of the obtained product.

Finally, since the nets are positioned on the soil, however wide, they offer scarce interception to the olives tangentially bounced by the vibrating machines. Besides the interception can result difficult under numerous conditions with the nets not in plain, when, the nets are positioned on soils with high slope. More recently, machineries able to spool the tree locks with a special inverted umbrella, are available on the market and able to carry the product harvested in containers. But the complexity and technological sophistication of such machineries make them rather expensive for small or medium farms, indeed it remains exclusive appanage, because of the high cost, of great farms or of specialized operators.

With the scope to contribute to solve the problem above mentioned during the olives harvest for crop on small surface, an optimized design has been performed , (Pahl G., Beitz W.,1996) (Ulrich, K., Eppinger, S.,2003), to realize a prototype that complied to the following requirements:

- 1) inexpensiveness of investment and operative costs;
- 2) machineries working in continuous, with possibility to use the equipment also for other similar crops;
- 3) minimum use of manpower (an operator);
- 4) increasing of profitable for the picked product in comparison to that obtained with manual harvest.

To comply to such design requirements, it has been proposed as solution, a very simple equipment inexpensiveness to be realized, as well as simple to use, that eliminated the manipulation of the nets on the soil, that was able to perform the positioning, intercepting, stowing and transporting of the picked product in rapid times.

Materials and methods

The equipment was formed by a system of interception constituted by harvesting nets moved by mean pneumatic pistons. The machinery was constituted by a rectangular basis, with a stake body, climbed on wheels and hauled. It was surmounted by a grate that allowed the sieve of the olives and by cage of nets, with a form of trunk of inverted pyramid, that, sustained by mean bars driven mechanically, succeeded in surrounding the tree locks.

The left side of the machine acted as static support for the nets; the right one, was instead an asset, and it was the peculiar nucleus of the considered equipment. The machine tangentially worked to the trees trunks along the most convenience order of the olive-tree plant. It was parallelly hauled to the tree rows, and it already resulted in position when the central part of its right side coincided with the tree trunk axis considered. At this point, by mean a command, was activated an air-compressed distributor, and two telescopic bars that sustained the nets were moved.

Contemporarily, by mean the same mechanical movement, two supports moved and they arranged in vertical position. They were hinged at the extremity of the telescopic bars, that supported the nets cage, in way that, they surrounded the whole trunk. The whole phase developed in few second and therefore the machine immediately can work. (fig.1,2,3)



Figure 1. Machine with nets rewinded



Figure 2. Machine with nets in operative conditions



Figure 3. Machine during the working phase

At this point the olives shaking and harvesting phases began. By mean the slope of the nets, they were carried in the grate, above the stake body, and therefore collected in the volume underlying. Completed such phase, reversing the pneumatic command, the unfolding of the nets is had, and they were rewinded in the right broadside of the machine. Indeed the considered machine was ready to be transferred, under the following tree.

The considered equipment is composed by:

- A base with a stake dump body, with hydraulic hoist, in plate placed on the loom with two wheels and a rudder with hooking device to allow the towing,
- a system of elastic connecting rods and 3 nets for the olive interception,
- two pneumatic pistons (pneumatic jack), jointed in parallel with a small compressor, with voltage of 12Volt, installed on the tractor
- hydraulic jack for the stake dump body turnover.

The loom has been designed by mean the aid of the computational codes pro/E 3.0 and ANSYS 10.0, that have allowed to perform an optimized design of such equipment, and they have also furnished the quoted constructive sketches for the considered equipment.

Geometry was similar to that of a common agricultural wagon with some changing ones:

- it was formed by 3 steel longerons (two longitudinal and one in cross direction).
- absence of the wheels axle, that were located on independent supports.

Further there was a longeron for the reinforcement of the loom, between the wheels supports to decrease the encumbrances under the stake dump body. The dynamic analysis of such design artifice was been verified by mean the computational code ANSYS 10.0

- the drawbar had a telescopic device and it was fixed on the loom with an hinge that allowed to rotate it so that to allow the off- set towing. This shrewdness allowed tractors with high outline to move in the center, between two trees rows, while the machine is hauled under the trees locks.

- the oleo-dynamic jack for the overturn of the stake body is in foreword position and that it avoided encumbrances in the centre of the loom so that to allow the use of the large stake body with regular fund. It was opportunely been designed and verified by mean the computational code ANSYS 10.0.

Stake body, with suitable ribs, it is set up on the loom by mean spherical joints that allow the back overturn. It has rectangular parallelepiped form, with three closed sides and only the back side it is possible to open it during the overturn and loading / unloading operations. The dimensions of the stake body were such, to be content inside the loom and its depth it was been calculated by mean the program code ANSYS 10.0 so that it did not form too many olive layers in overlap. It succeeded in containing about 35 boxes on a single plane.

The dimensions of longitudinal and transversal encumbrance of the considered machine have been verified by mean the computational code pro/E 3.0 that it allowed a management optimized of the considered volumes involved in this design. On the upper perimeter there were, on the fixed sides and on the hatch, plate shelves tilted upward. On the hatch, they were been shaped so that to contain a rectangular longitudinal hollow in which a grating plane was inserted, opportunely designed to sustain a workman weight. Every vertical bar had fixed at its extremity a tubular support with square section, in which a bar long 1 m was installed, tilted of 45° respect the vertical. In this tubular bar was inserted a bar long 1,50 m.

These bars acted as supports for the nets and they were suited, "una tantum", for the height of the trees locks of every specific tree plant. On the stake body, telescopic bars with square cross section of 4 x 4 cm were fixed (long around 2 m), tilted of around 15° in comparison to the horizontal plane and with the mobile part jointed to pneumatic pistons at "double effect" that moved them. At the extremity of the telescopic bars two horizontal

supports were settled in orthogonal way, within which were allocated the support bars for the nets. The nets for the base of the trees locks were three, with trapezoidal form and, situated in the centre, they resulted partly overlapped.

This overlap allowed to connect them on the shelf of the side right of the stake body, on off-set planes of around 10 cm, realizing three floors for the olives interception, tilted and separated. If the planes were not off sets, the picked olives in the uncovered triangle of the lower net, they were stopped, by the welding of the nets.

The three nets realized a "modellable tray" with three crossing nets that, as soon as they were positioned, they surrounded the tree trunk, and they close it more and more, intercepting the considered trunk with an angle that became more little. Insofar by mean this particular conformation it was possible to perform the automatic occlusion of the under locks nets, enveloping – as a scarf - the tree trunk, and contemporarily it allowed the carriage of the olives in the stake body.

This was been possible to realize since the sides of the three nets were bounded at rigid supports. Insofar this device with three overlapped nets allowed to form a carriage plane for the olives, after they were been occluded around the tree trunk.

Working phases

During the working operation of this equipment there are two phases:

1. the positioning of the machine,
2. the unfolding of the interception nets.

a) Positioning. The machine is towed along the tree plants rows , and it resulted in correct position when the median part of the stake body coincided with the tree trunk axis. The movements under tree locks were possible in how much, retracting the telescopic bars, the nets were compacted along the machine broadside.

b) Unfolding of the nets. The device for the unfolding of the nets was performed by mean the use of an air compressor, (with $p_{max}=10 \times 10^5$ Pa.), fed with 12 Volts (storage battery of the tractor), connected to a distributor that fed in parallel two pneumatic pistons that, they operated the telescopic bars.

The compressor and the distributor were installed on the tractor. The machine was connected to the tractor, over that with the draw bar, also by two small flexible pipes for the compressed air to allow the "double way" operations of the pistons. The system need not of reservoir for the compressed air. When the telescopic bars moved, they drag in their motion the three trapezoidal nets that "enveloped" the trunk.

Contemporarily, with the same movement they put on in tension the steel ropes that moved the bars that drag upward the nets. The necessary time for the unfolding of the nets was equal to that was necessary for the translation of the bars (few seconds). At this point the machine was in operative condition.

There was a small passage on the left side of the net overlooking the tractor by which the user quickly entered on the stake body. The passage was obtained cutting out a rectangle of nets with suitable dimensions and overlapping them, a wider edge sewn aloft to the inside and, heaved on the base by mean an iron rod.

At the end of the harvest operation, it was performed the reversing of the command for the telescopic bars, to activate the retraction of the bars to compact the 3 nets: the base nets were displaced as a packet, the vertical nets were withdraw for gravity effect, because of the rotation toward the machine of the bars, that were not held back by the constraint.

Constructive choices

The machine was designed to be simple and with constructive and maintenance inexpensiveness as well as it had to have operative versatility. The choice to use compressed air for pneumatic movement instead of oleo-dynamic systems involves notable advantages: The pneumatic pistons were very lighter (aluminium), not expensive. To overturn the stake body, in lack of hydraulic distributors, it was possible to use an oil reservoir with a manual pump, it was a less expensive solution.

As for the overturn of the stake body, it was to specify that it was not essential to the goals of the operative machine in how much it had 3 options of loading:

- on the fund of the stake body it was possible to locate the boxes - more than 35 - that they were automatically filled and that then it was possible to remove them making to flow them through the back hatch or transferring them upward removing the grating;
- on the fund of the stake body, the plastic large cases, for industrial use, were prepared, but in this case it was necessary to use the mechanical forks ;
- direct harvest in the large case: the hydraulic overturn was essential.

The pneumatic pipes were less expensive than those hydraulic, they were smaller (with diameter of 10 mm) and flexible, easily replaceable. A mini pneumatic compressor, fed with 12Volt, with consumptions of 30-50 A/h allowed to connect the machine to a simple tractor battery and, considered its intermittent use for few second, the load for the accumulator it was very low. The connection of the compressor to a pressure switch, it automated the ignition of it avoiding the manual operations.

The use of the only electric energy with 12 Volt, over that to be sure from the point of view of the safety, it allowed a great versatility of use in how much, by mean the due mechanical adjustments , it can be hauled by whatever machinery without hydraulic plant. This last characteristic allowed the considered machine a notable mobility in tree plant with inter spaces irregular or with little manoeuvre spaces, even if with scarce ability of loading.

The nets used were the same in use for the olive harvest from the soil; besides they were divided (one for side and two for the component under locks) in how much more comfortable and easy resulted the dismantlement for the stocking of them or replacement. The elastic ropes to pull the nets were those available on the market.

This machine was easily transformable in a wagon with double fund. Removed the nets by mean the unhook of the elastic ropes, and removing all the bars, it resulted in a wagon with double fund and a grating platform.

Results

Some experimental tests was been performed during the olives harvests in a tree plant situated near Salerno city. During the tests it has been noticed that the olives losses on the soil have been almost void, with operative time very low (about 1 minute) besides the following constructive and functional advantages for the considered machine have been found:

- it was built with a very simple components ,
- constructive simplicity made it economically very competitive in comparison to more complex machineries,
- the rapids convertibility in wagon it increased enormously the value of it and therefore the investment is more profitable,
- it allowed the olives harvest with a single workman,
- it eliminated the use of soil nets and the times necessary for the layout and unfolding of the nets,
- it annulled the times to pick up the olives from the nets and to put them in the boxes,

- it excluded the use of staircases,
- it improved the quality of the olives harvested in how much it eliminated the accidental stamping of the olives in the soil caused by the workman,
- it automatically eliminated branches and sprigs from the picked olives,
- it was operative in few second,
- it can circulate on road removing the encumbrances,
- for its use need not specialization,
- it need not any specific maintenance.

Conclusions

A machine was been designed and realized, able to comply at all the project requirements that were been preset, with satisfactory results. Such project requirements are typical for "niche" products harvest machines. Such machine had the following characteristic merits:

- 1) the machine was able to automatically form a complete cage with olives harvest nets with contemporary formation of base and external collecting planes;
- 2) the particular geometry of the bars and rods allowed to exclusively create with linear motion a triple plan tilted with under locks nets, so that don't hold back the olives harvested, but they allowed directly to carry the olive drupes in the containers;
- 3) the assemblage peculiar geometry for the elastic ropes, rods and crossed nets, realized an occlusive contact with the trees trunk;
- 4) the machine allowed the harvest with harvest facilitators and it automatically stowed the product in containers;
- 5) the machine, during the harvest phase, avoided that the olives harvested were stamped on the soil by the operators;
- 6) the machine, during the harvest phase, automatically performed a pre-selection of the olives drupes from the sprigs, that inevitably they detach during the phase of mechanical harvest;
- 7) the machine utilized only linear motion to form a system with flowing tray and not with "umbrella" that is notoriously more complex in the construction and in the maintenance and more expensive;
- 8) the machine can easily be turned into wagon and profitably used for the whole year and not only for the olives harvest period.

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A New Version of Prototype for Mechanical Distribution of Natural Enemies

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Abstract

The aim of this research is to assess the performances of a new version of the device patented by University of Catania and already used in natural enemy distribution trials on greenhouse vegetable crops. The prototype has been designed and constructed by Mechanics Section of DIA in order both to increase the work capacity and to promote a low impact pest control, which respects the environment and consumers' and farmers' health.

This version has the same working principle of the former prototype, but materials and dimension of the hopper, the distributor and the rotating disc have been changed. Moreover it has a handle directly carried by the worker.

From the laboratory trials, the dosage and distribution mechanism of the prototype seem well suited to biological pest control strategies. Negligible or absent impact on natural enemies proves prototype efficacy and enables its usage both with technical and economic advantages on manual distribution.

With this model the device performance is improved in manoeuvrability. Consequently, greater work capacity and higher work quality will be achieved in greenhouses and in field.

Keywords: plant protection machines, sustainable pest management, natural enemies.

Introduction

In the last years the orientation of consumers, who prefer more and more products obtained by biological crop, is encouraging the adoption of the biological control of agricultural pests also between the Italian farmers. This technique involves seasonal inoculative or inundative releases of natural enemies, as the predatory mite *Phytoseiulus persimilis* Athias-Henriot (Acari: Phytoseiidae) and the bug *Orius laevigatus* (Fieber) (Hemiptera: Anthicoridae) in the horticultural crops. In fact, it is demonstrated in several experiments (Morse and Trumble, 1991; Trumble and Morse, 1993), that these two arthropods are valid instruments to keep the two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae) and the western flower thrips *Frankliniella occidentalis* (Pergande) (Thysanoptera: Thripidae) and they are reared and distributed by commercial insectaries (Tropea Garzia et al., 2006).

At present, in Italy the predators are realised manually in the protected crops. On one hand this method of distribution allows to reduce the number of treatments effected with chemical products, and so the risks for environmental pollution and for workers' safety; on the other hand it requires long time and high costs and does not guarantee an uniform distribution. In order to solve these difficulties it is necessary to mechanise the distribution of predators; with this aim a prototype was designed and built by the Mechanics Section of the Agricultural Engineering Department of the University of Catania (Blandini *et al.*, 2006; Blandini *et al.*, 2007). This prototype uses operating principles which are different from those of other equipment on the market (Giles *et al.*, 1995; Morisawa e Giles, 1995; Gardner e

Giles, 1997; Wunderlich e Giles, 1999; Pezzi *et al.*, 2001; Pezzi *et al.*, 2002; Van Driesche *et al.*, 2002; Opit *et al.*, 2005; Baraldi *et al.*, 2006).

The results obtained with the prototype were excellent, nevertheless a new version of the prototype was built to improve its performances in terms both manoeuvrability and range of action reducing the distribution time. Therefore, this study refers about the laboratory tests effected to assess the performance of the last version of the prototype.

Materials and Methods

The distribution of the arthropods with the prototype came by means of centrifugal force developed by the rotation of a finned distributor disc (fig. 1). The arthropods, together with the substrate they are sold, are poured into a hopper placed above the distributor disc and are released down through a calibrated hole. On the axis of the hopper there is a rotating measuring device with flexible fins to guarantee continuous flow. Both the distributor disc and the measuring device are moved by means two direct-drive electric motor each one connected to the corresponding device. The two devices are fixed to the same frame which can be attached to a portable structure, tractor driven or in greenhouses carried on mechanically driven frames over the crop rows. However, it is possible regulate the position of the hopper with respect to the distributor disk in order to change the throw direction.

The modifies carried out on the prototype do not have changed its working principle. They have been involved the frame, the distributor disk, the hopper and the measuring device (fig. 2).

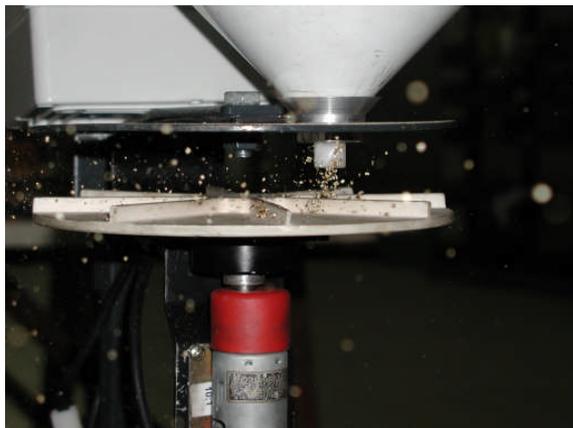


Figure 1. The finned distributor disk



Figure 2. The last version of prototype

In particular:

- a cylindrical articulation has been attached to the frame so it is possible regulate its inclination with respect to the portable structure and keep it parallel to the ground;
- the distributor disk has been built with aluminium and greater than the first version (300 mm diameter vs. 200 mm) so to improve the centrifugal force at the same rotation velocity and the range of the action;
- the hopper has been built with aluminium too, but its volume has been reduced with respect the first version (1.5 dm³ vs. 2 dm³) in order to lighten it; the exit hole has been increased in order to insert bush with different internal diameter (16, 17, 19, 21, 23, 25 mm) to regulate the amount of product released in the time, taking into account of the

granulometry of the substrate; however, the new capacity of the hopper still allows the treatment of 1000 m² without refill;

- the measuring device now has a simplified shape to reduce the production costs; it is a cylinder 190 mm high with 15 mm diameter without the helicoidal profile of the first version; the end of the device, which is inserted into the bush, has been symmetrically milled to have 10 mm thick; in order to remove the product from the inner side of the hopper and to help regulate product flow, two flexible plastic fins are applied along vertical axis of the measuring device.

Despite the modifies carried out to the prototype, do not found great difference in dimension (38 cm long, 30 cm large and 42 cm height) and in weight (4.3 kg) with respect the first one version.

In order to improve the manoeuvrability of the prototype along the inter-rows of the horticultural crops in greenhouses, it is applied to a rod carried by a worker (fig. 3). In fact, the first structure, which keeps constant the height of the prototype from the ground, showed some difficulty during the manoeuvres to turn back along an inter-row. To help the worker to support the prototype a shoulder-strap is applied to the rod. Furthermore, at the same rod it is applied an accumulator battery (6 V – 7.2 Ah) and a button to operate the electric motors which move the distributor disk and the measuring device.



Figure 3. The old and new portable versions

In order to assess the performance of the new version of the prototype several laboratory tests have been carried out to evaluate some machine parameters: the throw direction, the quantity distributed, the uniformity of throw in time (fig. 4), the vertical distribution of product at different distributor heights (90 and 130 cm from the ground) as well as at different distances (40 and 70 cm) from the test bench: 150 cm high, 100 cm wide and made up of 10 vessels to recover product at 15 cm separation (fig. 5). The tests were run with inert material commonly used for marketing bottles of predators: humid vermiculite and buckwheat husks mixed with humid vermiculite.

Moreover, experienced entomologists have evaluated throw effects on natural enemies vitality, with samples both from the hopper and from the rotating disc throw.



Figure 4. Laboratory tests: uniformity of throw in time



Figure 5. Laboratory tests: the vertical test bench

Results

Several laboratory tests were carried out in order to determine the working parameters of the prototype according to the distributing product and to optimise some components for later greenhouse tests.

The overall results of numerous tests, with only the hopper and measuring device, varying the measuring device diameter and its shape, the hopper's hole (16-17-19 mm) and using the same power supplied (6 V) already defined in previous tests (Blandini *et al.*, 2007), helped define the product quantity for distribution in greenhouse. Particular attention was paid on length and orientation of the flexible fins situated in the measuring device, in order to guarantee continuous flow.

In particular, 6 V was chosen to power both the measuring device and disc distributor which rotated at about 30 and 600 rpm, and to use the same measuring device with a hopper hole of 16 mm for *Phytoseiulus persimilis* (with humid vermiculite) and 19 mm for *Orius laevigatus* (with buckwheat husks mixed with humid vermiculite). In these configurations a 1000 m² greenhouse needs 4-5 bottles (35 g each one) of *P. persimilis* (about 9 g/min) and 2 bottles (60 g each one) of *O. laevigatus* (about 6 g/min).

The tests carried out on the uniformity distribution in time with buckwheat husks mixed with humid vermiculite show (fig. 6) the quantities of samples varied between about 7 – 2 g without extreme values and between 11 – 1 g including extreme values. In the first case the data processing show a 33% CV, in the other a 43% CV. The distributed product is subject to a sharp decrease to the 11th sample, while the next samples are quite constant. Further tests are necessary to verify if the prototype is able to keep the regulation constant in time and even for several treatments.

The results of vertical distribution (Figures 7 and 8) show significant differences between the test types (90 cm height and 40-70 cm from the test bench; 130 cm height and 40-70 cm from the test bench) both as regards product quantity monitored at different heights of the test bench as well as product type (HV = humid vermiculite; DV= dry vermiculite; BV= buckwheat husks mixed with humid vermiculite). The tests show the humid vermiculite is able to hit the target in greater quantity while the dry vermiculite in lower quantities. But in any tests the product dispersion is greater than previous tests carried out with old version of prototype (Blandini *et al.*, 2007).

In general, comparing the two tests at 40 cm from the test bench and then the two tests at 70 cm, more material is recovered (less dispersion) in both cases fixing the prototype at 90 cm from the ground irrespective of the product used.

It should be highlighted that, the results show good agreement between prototype and target height with most concentration of distributed product.

Conclusions

From the laboratory trials, the dosage and distribution mechanism of the prototype seem well suited to biological pest control strategies. Negligible or absent impact on natural enemies proves prototype efficacy and enables its usage both with technical and economic advantages on manual distribution. Further tests to verify the capability of maintaining over time the same product quantities should be carried out.

The tests carried out to assess the vertical distribution of product at different distributor heights as well as at different distances from the test bench, have shown a good agreement between prototype and target height with most concentration of distributed product.

With this new version, set on a handle directly carried by the operator, the device performance is improved in manoeuvrability. Consequently, greater work capacity and higher work quality will be achieved in greenhouses and in field.

Even the possible use of small battery-run electrical motors thanks to the limited power usage, can reduce costs and environmental impact.

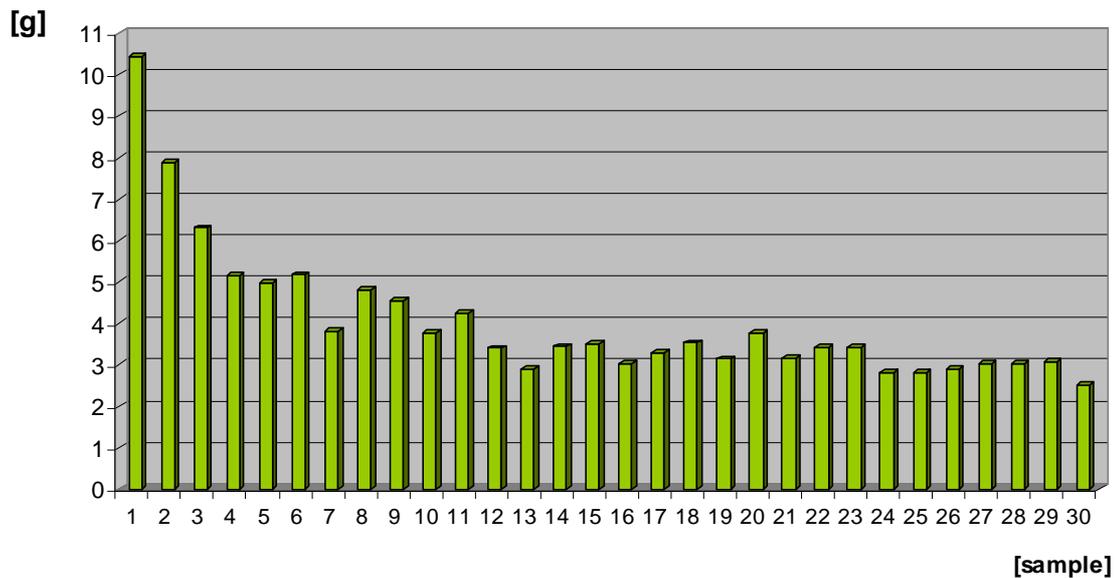


Figure 6. Mean values of buckwheat husks mixed with humid vermiculite and *O. laevigatus* delivered [g] every 30 s

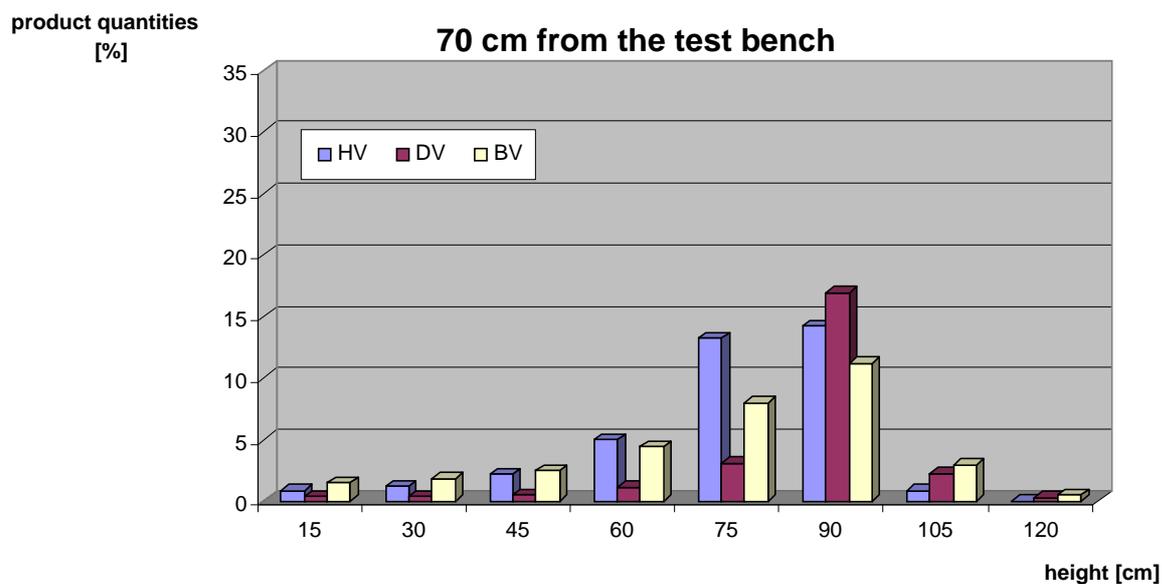
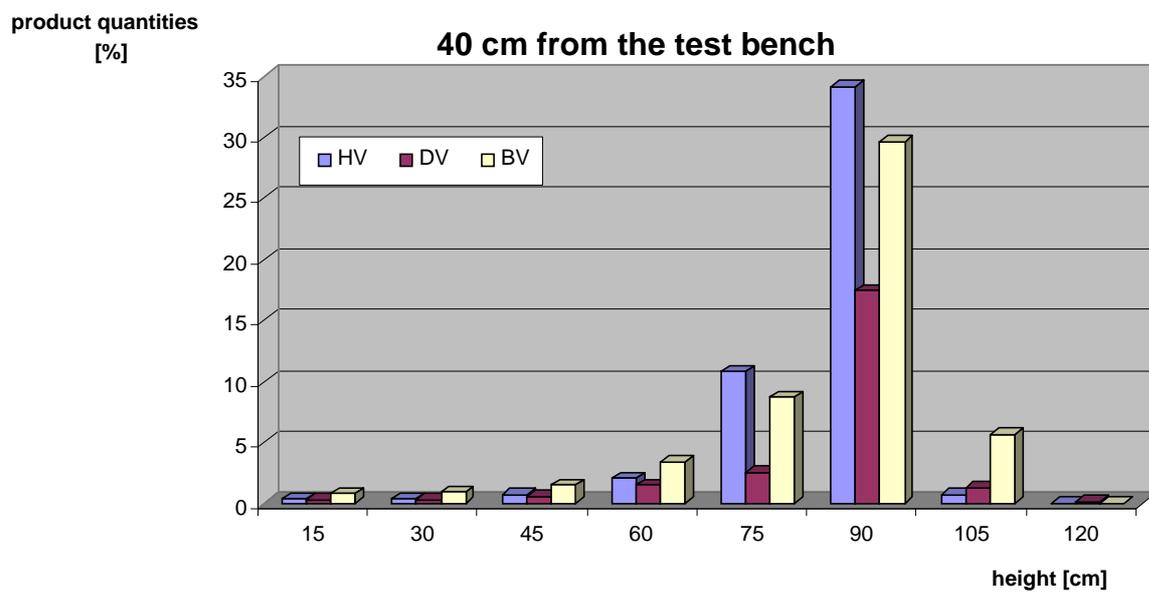


Figure 7. Product quantities collected [%] in the tests with the prototype 90 cm from the ground

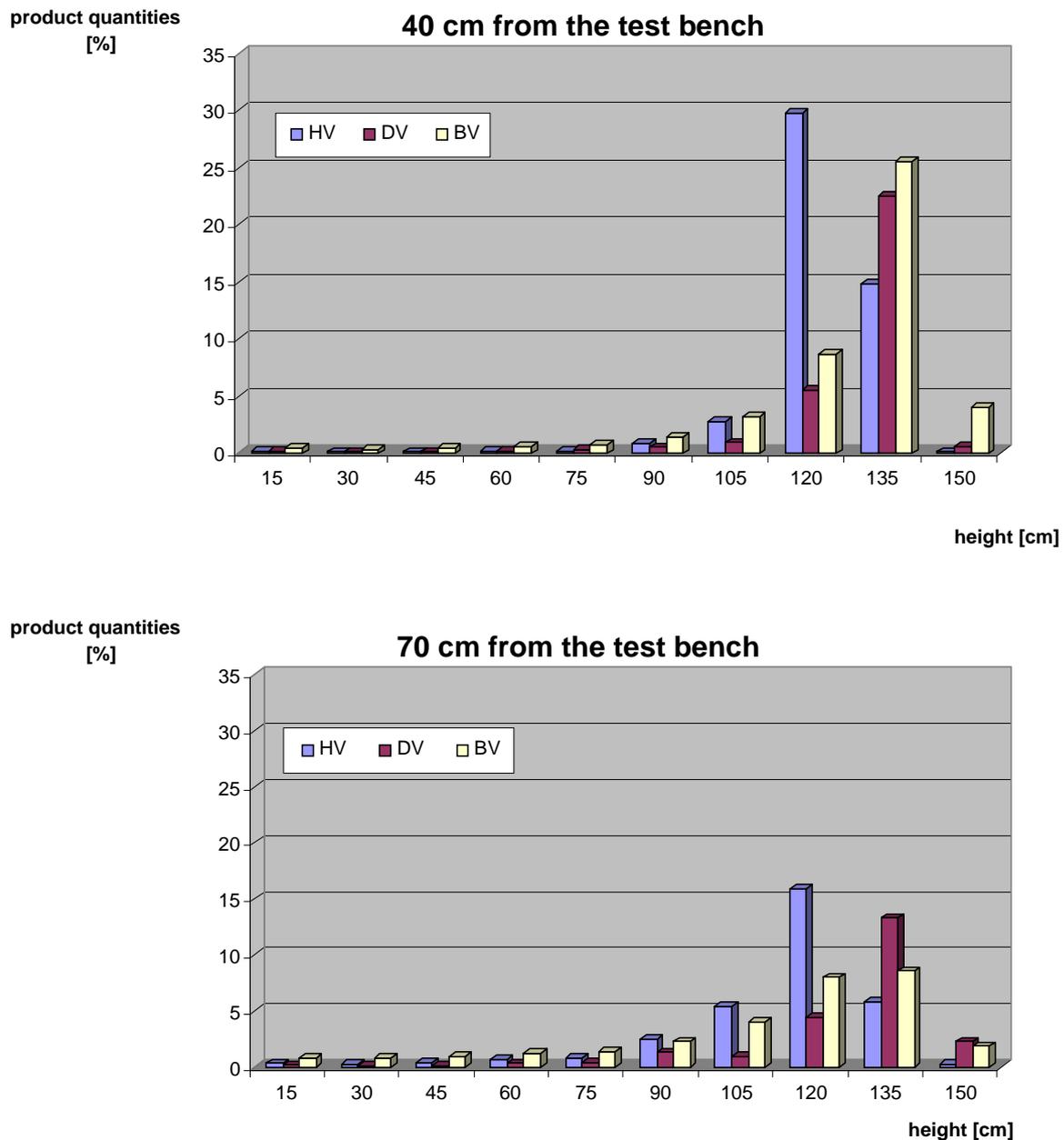


Figure 8. Product quantities collected [%] in the tests with the prototype 130 cm from the ground

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Influence of tree's structure on the efficiency of the mechanical harvest of olives

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Abstract

This study represents an analysis about the influence of the structure of the plant and the drupes' position on the efficiency of the mechanical harvest of olives. The aim is to study the eventual correlations between some geometrical characteristics of the plants and the harvest efficiency.

The experimental tests were carried out in an olive grove sited in Castelvetro, province of Trapani; the variety was Nocellara del Belice, the plants “globe” shaped.

Some morphological surveys were carried out on a sample of trees. The mechanical harvest was performed with a trunk shaker provided with an upside down umbrella. After the harvest, the residual production was quantified for each bud in order to evaluate the harvest efficiency.

The results showed that, in order to have a harvest efficiency higher than 80%, the geometric and morphologic parameters of the plants have to be: length of the main branch from 2 to 3 m, distance of the bud from the central axe of the tree from 1.30 to 2.30 m, height of the bud from the ground from 1.90 to 2.85 m, length of the fructiferous bud from 0.25 to 0.40 m. The above mentioned values are certainly to be referred to orchard having a regular lay out of planting of 6.00 x 7.00 m and mean circumference of the canopy about 10 m.

Keywords: mechanical harvest, olives, efficiency.

Introduction

In the modern olive growing the mechanization of the harvest is very important both to reduce the costs of production and to assure the quality of the oil.

Till today it's very difficult in Italy to mechanize the harvest of olives because a great number of orchards doesn't allow the use of the machines for several reasons: the irregular positioning of the plants, the slope of the plots, the large dimensions of the trees [Antognozzi E., Cartechini A., Tombesi A., Paliotti A. (1990), Paschino F., Mura R. (1997)].

Today the mechanical harvest of olives is greatly developing in the new orchards also due to their gradual modernization allowing the introduction of more and more efficient machines able to increase work capacity and productivity and considerably decrease the use of manpower [Amirante P., Pipitone F. (2000)].

Then, the design of new machines is not sufficient in order to improve the harvest efficiency, but it's fundamental that the orchard would be suitable for the best use of the machines and the structure of the plants would optimize the final result.

This study represents an analysis about the influence of the structure of the plant and the drupes' position on the efficiency of the mechanical harvest of olives.

The morphology of the tree is very important in the harvest with trunk shakers because it considerably influences the transmission of vibrations from the machine to the fruit in order to cause its detachment [Altieri G. (2001)]. Moreover, the geometry of the plants considerably varies inside the orchard and every tree has its characteristic frequency depending on its morphological, mechanical and dynamical properties [Formato F., Romano (2003)].

The aim of the study is to study the eventual correlations between some geometrical characteristics of the plants and the harvest efficiency.

Materials and methods

The experimental tests were carried out in an olive grove sited in Castelvetrano, province of Trapani, western Sicily, about 10 ha large, 200 m above sea level, with plants 10 years old having a lay out of planting 6.00 x 7.00 m. The variety was Nocellara del Belice, the plants “globe” shaped, planted at 0.65-0.85 m from the ground level, 4.00 m high on average, having mean circumference of the canopy about 10 m (fig.1).



Figure 1. Typical plant of the site test

Fifty plants morphologically representative of the orchard were casually chosen and some morphological surveys were carried out. Taking into account that the distribution of the stresses to detach the drupes depends on the dimensions of the fructiferous buds and particularly on its point of insertion on the main branch, the following parameters were defined and surveyed (fig.2):

- length of the main branch (*parameter A*) as the sum of the length of the internodes ($L_{1,2} \dots L_{n-1, n}$);
- distance (*D*) of the point of insertion of the bud from the central axe of the tree (*parameter B*);

- height (H) from the ground of the point of insertion of the bud (*parameter C*);
- length of the fructiferous bud (*parameter D*).

Then, the number of drupes was quantified for each bud.

The mechanical harvest was performed with a trunk shaker provided with an upside down umbrella (table 1).

Table 1. Technical characteristics of the machines used during the tests

Diameter of the holding member on the trunk [mm]	Machine total weight [kg]	Head weight [kg]	Diameter of the intercepting member [m]
50 – 550	1540	320	7.00

The following parameters were fixed during the tests: the height of the hooking point of the vibrating head (0.6 m from the ground), the direction of the arm bringing the pliers (orthogonal to the direction of the row), the rotation speed of the eccentric masses and, then, the vibration intensity.

After the harvest, the residual production was quantified for each bud in order to evaluate the harvest efficiency.

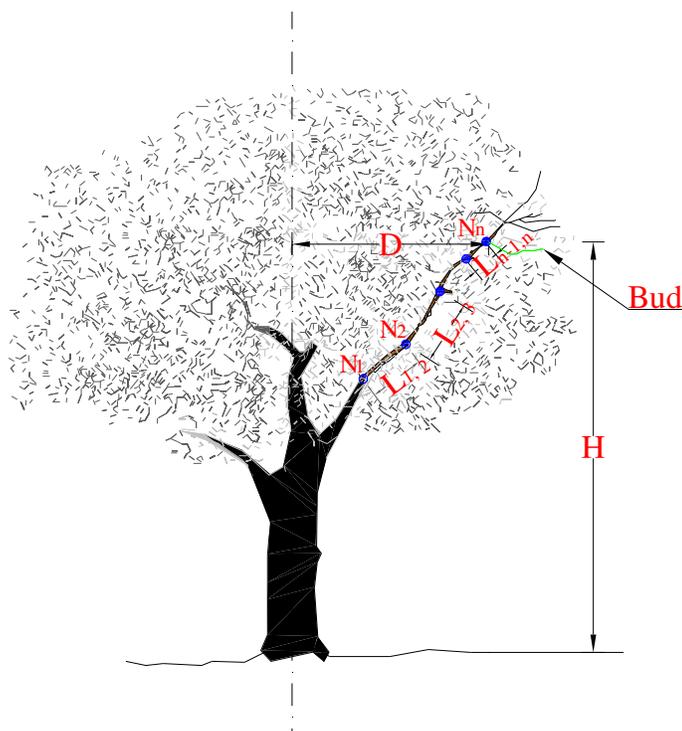


Figure 2. Surveys performed on the plant

The data were arranged in classes homogeneous in range and number of surveys (table 2, 3, 4 and 5) that were statistically analysed and the mean compared with

Duncan’s multiple comparison procedure ($p = 0.05$) using the software Statgraphics Plus, Manugistics.

Table 2. Classes of the parameter A

Class	Main branch length [m]
1	0.60 – 1.50
2	1.51 – 1.84
3	1.85 – 2.08
4	2.10 – 3.00

Table 3. Classes of the parameter B

Class	Distance from the axe [m]
1	0.10 – 0.90
2	0.95 – 1.15
3	1.16 – 1.35
4	1.36 – 2.35

Table 4. Classes of the parameter C

Class	Height from the ground [m]
1	1.00 – 1.70
2	1.71 – 1.90
3	1.91 – 2.15
4	2.16 – 2.85

Table 5. Classes of the parameter D

Class	Bud length [m]
1	0.25 – 0.40
2	0.41 – 0.50
3	0.51 – 0.60
4	0.61 – 0.90

Results

Table 6 shows the mean values of the harvest efficiency obtained for the classes of the *parameter A*. It emerges that the highest values were found in the classes 3 (83.2%) and 4 (96.4%) and statistically significant differences among all the classes; moreover, the efficiency increases going from class 1 to class 4.

Table 6. Results of Duncan’s multiple comparison procedure for the main branch length

Class	Harvest efficiency [%]		
	Mean	Standard deviation	Coefficient of variation
1	45.7 a	17.68	38.68%
2	70.8 b	11.12	15.70%
3	83.2 c	8.70	10.45%
4	96.4 d	6.08	6.30%

Note: different letters in the column denote statistically significant differences at the 95% confidence level.

In particular, the main branch (*parameter A*) determines an higher value of harvest efficiency with length more that 2 m; in fact, the harvest efficiency shows a 13% increase going from 2 to 3 m length. The lowest efficiency (45.7%) was obtained for length going from 0.60 to 1.50 m.

In table 7 the mean values of the harvest efficiency for the *parameter B* are reported; it shows that the efficiency increases going from class 1 (61.2%) to class 4 (82.9%); statistically significant differences were found between the classes 1-2, 1-3, 1-4, 2-3 and 2-4.

Table 7. Results of Duncan’s multiple comparison procedure for the distance of the bud from the central axe of the tree

Class	Harvest efficiency [%]		
	Mean	Standard deviation	Coefficient of variation
1	61.2 a	23.73	38.80%
2	70.5 b	16.20	22.97%
3	79.7 c	20.87	26.19%
4	82.9 cd	21.67	26.13%

Note: different letters in the column denote statistically significant differences at the 95% confidence level.

The distance of the fructiferous bud from the central axe of the tree influences the harvest efficiency; the highest values were obtained with distances more than 1 m. In fact, the efficiency shows a 25% increase going from distances lower than 1 m to distances higher than 1 m. The lowest value (61.2%) was found in class 1.

Table 8 shows the mean values of the harvest efficiency for the *parameter C*. It comes out that the highest values were obtained in class 3 (82.4%) and class 4 (79.9%); statistically significant differences were found between the classes 1-3, 1-4, 2-3 and 2-4.

The height of the fructiferous bud from the ground influences the harvest efficiency that shows the highest value with a height more than 1.90 m; in fact, the efficiency has a 12% increase going from 1.90 to 2.85 m. The lowest efficiency (66.1%) was found in class 1.

Table 8. Results of Duncan's multiple comparison procedure for the height from the ground of the bud

Class	Harvest efficiency [%]		
	Mean	Standard deviation	Coefficient of variation
1	66.1 a	24.67	37.31%
2	67.1 a	19.59	29.18%
3	82.4 b	17.53	21.29%
4	79.9 b	21.56	27.00%

Note: different letters in the column denote statistically significant differences at the 95% confidence level.

In table 9 the mean values of the harvest efficiency for the *parameter D* are reported; it shows statistically significant differences between the classes 1 (mean efficiency 81.2%) and 3 (70.2%) and 1 and 4 (69.9%).

Table 9. Results of Duncan's multiple comparison procedure for the length of the fructiferous bud

Class	Harvest efficiency [%]		
	Mean	Standard deviation	Coefficient of variation
1	81.2 a	21.14	26.05%
2	76.7 ab	22.95	29.92%
3	70.2 b	21.31	30.35%
4	69.9 b	21.30	30.47%

Note: different letters in the column denote statistically significant differences at the 95% confidence level.

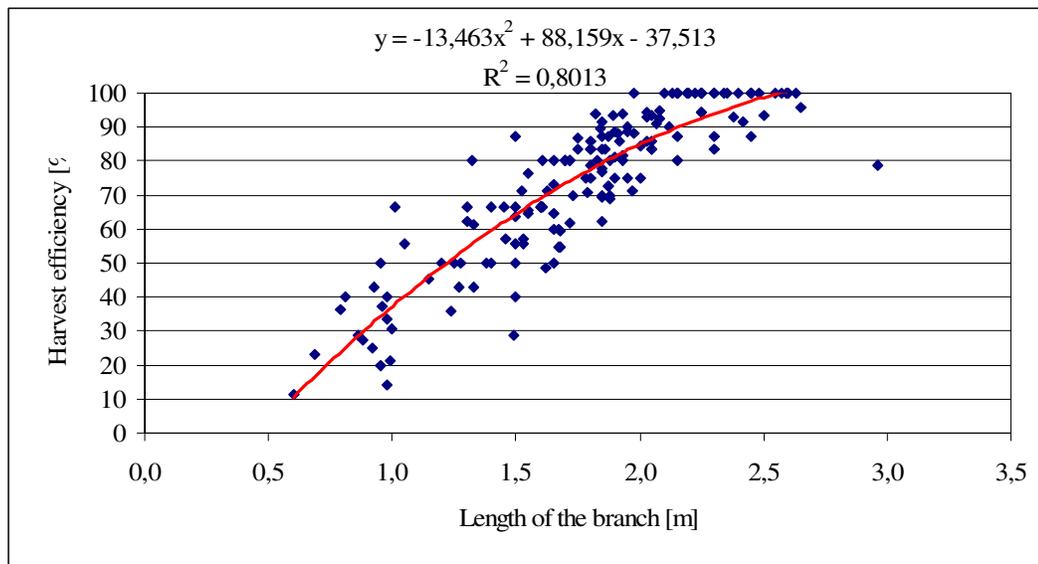


Figure 3. Correlation between the harvest efficiency and the length of the branch

The lower the bud length, the higher the efficiency; in fact, there is a 10% decrease of the efficiency going from 0.50 to 0.90 m. The lowest value of the efficiency was found in class 4.

Relating the values of the above mentioned *parameters* with the harvest efficiency, it was found a correlation only for the *parameter A* (fig. 3). The data are interpolated by an equation of the second order described, for the considered interval, by an increasing parabola having R^2 equal to 0.80.

Conclusions

The paper is a first contribution to the study of the influence of the geometric and morphologic characteristics of the olive tree on the mechanical harvest efficiency performed with trunk shaker.

Some interesting remarks can be drawn. The four parameters taken into account influence the harvest efficiency for the variety Nocellara del Belice. In particular, in order to have a harvest efficiency higher than 80% it can be asserted that the geometric and morphologic parameters of the plants have to be:

- length of the main branch (*parameter A*) from 2 to 3 m;
- distance of the bud from the central axe of the tree (*parameter B*) from 1.30 to 2.30 m;
- height of the bud from the ground (*parameter C*) from 1.90 to 2.85 m;
- length of the fructiferous bud (*parameter D*) from 0.25 to 0.40 m.

The above mentioned values are certainly to be referred to orchard having a regular lay out of planting of 6.00 x 7.00 m and mean circumference of the canopy about 10 m.

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