THESIS OF PhD DISSERTATION

COMPARATIVE EVALUATION OF MULCHING METHODS IN TOMATO PRODUCTION

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OBJECTIVES

The goal of the examination is to choose mulching methods for transplanted tomato production system that serve simultaneously weed management purposes and the production of healthy, marketable tomato fruits too. To determine the appropriate one, different soil covering methods have to be compared and examined parallelly with untreated, traditionally hand hoed and herbicide treated controls. Beside the effect of tested mulching methods on total weed cover, the cover of weeds of different life forms and species also has to be examined. It can be an important starting point or accomplished solution for tomato production to determine mulching methods which roll back weed populations with different species composition and farms with local weed problems.

During the examinations the following objectives were the most important ones:

1. Comparative evaluation of different mulching materials by their effect on tomato yield.
2. Comparative evaluation of different mulching materials by their effect on amount and rate of healthy tomato fruits.
3. Comparative evaluation of different mulching materials by their weed controlling effect in tomato production.
4. Comparison of examined mulching methods as parts of a management strategy of weeds of different life forms.
5. Comparison of different mulching methods as parts of a management strategy of various weed species.
6. Comparison of different mulching methods as compared to weed management with herbicide saving methods with respect to weed management effect and influence on yield apart and in a complex way.
7. Comparing mulching that avoids soil moving thus protects the soil and weed control done by hand hoeing according to yield quality of tomato (pest free fruits).

8. Complex evaluation of soil covering methods in organic tomato production, their effect on quality and quantity of yield of tomato and according to their weed management effect.
9. Comparing statistical analysis methods that act on the aims of the examination and choosing the most appropriate one in practice.

MATERIALS AND METHODS

The six-year long field experiment was executed at Soroksár, experimental area of Department of Ecological and Sustainable Production Systems of Corvinus University of Budapest from 2000 to 2005.

11 treatment combinations were compared with four replicates in each experimental year. Each of the 44 plots was 2 m x 5 m = 10 m^2 per plot and 440 m^2 for the whole experiment. Plots were divided by weed-free roads of 0,5 m width.

Soil tillage was done until preparing fine seed bed.

The tested tomato (*L. esculentum*) hybrid was Dual Early (1997). Tomato plants were planted into 60 x 70 cm plant-to-plant distance. Planting was done by hand.

Time of planting was the end of May in every year: 29 May 2000, 29 May 2001, 25 May 2002, 28 May 2003, 27 May 2004, 26 May 2005.

No plant protection treatments were used in the experiment. During the six year of the experiment only subsequent irrigation was used.

The experimental area is almost plane with forest belt around it.

The soil type was a mildly deep, slightly humic chernozem-like sandy soil.

The experimental plots were established in different places in every year to avoid tomato health problems.

Treatments of the experiment: untreated control (1), herbicide control (2), hoed control (3), straw mulch (4), straw mulch with Phylazonit (5), black plastic foil mulch (6), paper mulch (7), grass clippings mulch (8), legume clippings mulch (9), compost mulch (10),

weed clippings mulch (11).

Samples were taken in an identical way in every year. After weed survey and data recording, statistical analysis and evaluation of data were done by spreadsheet and statistical software.

Weed surveys were done according to the within named:

-survey of cover of weeds and tomato in June, July and August in every year on every plot

-weight measurement of pest free and infected tomato yield on every plot, many times a year according to the intensity of ripening

Weed survey was done after recording the code name of weed species of the current surveying area. The BALÁZS-UJVÁROSI method was chosen from all the available coenological survey methods. 3 times a year covering percentage of different weed species was estimated on a randomly allotted 1 m^2 survey area in every replication of every treatment.

Measuring fresh yield of tomato was done immediately after harvest on the field. Pest free and infected fruits were separated and weighted. Sum of them gave the total yield of tomato.

Weediness was analysed according to total weed cover, cover of different life forms and main weed species too, in average of six years and in each experimental year. Cover percentage of tomato was analysed with the same method as total weed cover.

Effect on yield and effectiveness in weed control, different mulching methods were evaluated also by rank numbers in a complex way. Results of analysis of examined factors were ranked by effectiveness and marked with rank numbers. During complex analysis rank numbers of different factors were summed so the final ranks show the mulching methods that are the most appropriate for the complex aim. Summarised rank

number was developed with accordance to the weight and ratio of total and pest free yield of tomato and weed cover percentage factors.

Collected data were analysed with SPSS 17.0 for Windows Copyright: SPSS Inc., and ROPSTAT statistical analysing software.

Weed covering percentage is an estimated, ordinal variable thus traditional analysis of variance does not give a clear picture. On the other hand ordinal variables can be compared regarding their rate. That is why two analysing methods were used to evaluate cover percentage of weeds and tomato.

These two analysing methods can demonstrate differences of the two methods and can point out practical importance of using the most accurate one.

RESULTS AND EVALUATION

There were no difference between yearly average and monthly data of weed and tomato cover percentage by treatments.

Average weed cover

According to the Bonferroni-method, average weed cover percentage of the six experimental years justified that untreated control (1) is the worst solution regarding weediness. Tomato does not cover the soil enough to withhold the spreading of weeds.
It is also justified that compost mulch (10) and its nutrient content has positive effect not only on tomato yield but on weeds development too. That is why any the less compost could enhance tomato growing, it could not reach such an increase in soil cover that it would be enough to suppress weeds effectively. It could cause more problems if compost contains many weed seeds that increases original weediness of the production area. As a result of these effects, compost mulch (10) treatment showed the second highest weed cover percentage.
Similarly poor effect of weed clippings was observable (11). The amount of chopped weeds did not reach the quantity which would be enough to give a thick mulching layer, so annual and perennial weeds could break it through.
According to covering percentage of weeds, the effect of herbicide control (2) was not significantly better than compost mulch (10) and weed clippings mulch (11). That is why we can conclude that if only these three mulching methods are available, any of them could be chosen with taking into account other factors, too. To consider the effect of herbicide treatment (2) compared to compost mulch (10) and weed clippings mulch (11) in a more accurate way, a targeted examination would be necessary.
Comparing the two types straw mulch, no significant difference was found in the average of the six years. This traditional mulching method - thanks to its good

tractability and structural stability - gave significantly better effect than the three worst treatments and herbicide control (2). Regular control of mulch layer is not to be failed neither in the case of straw mulch because as a consequence of packing, the mulch layer easily becomes too thin through which weeds can grow in the second part of the growing season. That is the explanation for the fact that plastic foil (6) and paper mulch (7) with their whole surface cover were significantly better than straw mulch in the average of more years.

The two treatments with the most effective weed suppressing ability were plastic foil (6) and paper mulch (7) in the average of the six years. Significant difference between these two treatments was not observable, except for each other, they had better weed controlling effect than all the other treatments.

In the case of black plastic mulch watering holes allowed weeds to break through to the light in many cases. With paper mulch there is no need for watering holes, therefore this problem occurs only when animals or farm workers steps on the paper surface and tore it or when the holes for transplants are too big.

Average soil cover of different life forms of weeds

During examination of the life forms of weeds, it was justified that weeds of T_4 life form were dominant on the experimental area. Average total cover of them was 24,84% during the six years irrespectively of treatments. Other observable life forms like G_3 weeds covered 1,28% while G_1 weeds only 0,66%.

Because of the above mentioned distribution of life forms of weeds, the cover of T_4 weeds can be characterised just the same way as total weed cover.

T_4 weeds gave the highest cover percentage on untreated plots (1), the two most effective treatments were plastic mulch (6) and paper mulch (7) in the average of the six years. Significant difference was not observable between these latter two.

Hoed control (3), straw mulch (4), straw mulch with Phylazonit (5) and grass clippings

mulch (8) were in a homogeneous group, which means that all of them were equally effective against T_4 weeds, only the most effective treatments were significantly better than these ones. That is why from this group, any of the mentioned treatments can be used with local conditions taken into account if annual weeds germinating in late summer are causing problems or plastic or paper mulch are not available.

Against G_3 weeds the most effective treatments were plastic (6) and paper (7) mulches. Significant differences were observable between paper mulch (7)with the lowest weeds cover and grass clippings mulch (8) with highest cover of G_3 weeds. Besides, according to the Bonferroni method, the untreated control (1) and plastic mulch (6) were significantly better than grass clippings mulch (8). Considering cover percentages this result shows the same differences as was observable during the surveys. The three treatments with the lowest G_3 weed cover were in a homogeneous group.

Low cover percentage of untreated control (1) refers to the root concurrence with which other weeds can compete and suppress weeds with rhizome. In the case of weed clippings (11) mowing of G_3 weeds can be effective in control of this life form.

Regarding weeds of G_1 life form outstanding effectiveness of plastic mulch (6) can be justified with Bonferroni method. Significantly better effect of this treatment was proved with analysis based on stochastic dominance except in the case of legume clippings mulch (9) and compost mulch (10).

Weeds of other life forms were not observable on the experimental area or only one plant occurred (T_1 and H_3 life forms).

Average soil cover of main weed species

Portulaca oleracea

From T_4 weeds *P. oleracea* gave a stable cover in almost every year of the examination, average total cover of this species was one of the highest in the average of the six

years. It is observable that mulching with weed clipping was the less effective treatment against *P. oleracea* in six years of the examination. Mowing is ineffective against this species of T_4 life form with laying stems. Cutting is thinning other species above the laying *P. oleracea*, but this species remained untouched so because of decreased concurrency it could spread more than in the other treatments.

Against *P. oleracea* straw mulch (4), straw mulch with Phylazonit (5), plastic mulch (6) and with little variance paper mulch (7) and grass clippings mulch (8) were similarly effective. Consequently comparing their effectiveness against T_4 weeds, listed treatments have a more square effect on *P. oleracea* and effect of straw mulches is not significantly different from the results of plastic (6) and paper mulch (7).

Treatments with imperfect soil cover and the chosen herbicide (2) with different target species did not give satisfactory result against *P. oleracea.* Hoed control (3) had better than moderate but not satisfactory effect, accordingly in the case of massive *P. oleracea* infection thoughtful mulching is better than traditional hoeing with moving of soil.

Amaranthus retroflexus

Significant differences of rank averages analysed by Bonferroni-method showed a heterogeneous picture. Every single treatment could be divided from at least four other treatments. Compared to untreated control (1) every treatment – except the ones with weak soil cover the compost mulch (10) and the weed clipping mulch (11) – was more effective against *A. retroflexus,* even the legume clipping mulch (9) too that gave bad results during many other analyses. Straw mulch (4) was justifiably more effective against *A. retroflexus* than legume clippings mulch (9), therefore straw mulch (4) with more stable soil cover gave better result than legume clippings mulch (9) again.

The best treatment was the paper mulch (7), thus in the case of high *A. retroflexus* infection it is good to chose paper mulch from the others, because only positive effect of plastic foil mulch (6) was not significantly different from the one of paper mulch.

A. retroflexus showed a surpassingly high cover even in the average of the six years,

that is why the treatments that were effective against this species could effectively decrease total weed cover too. Similarly to the other T_4 weed species *A. retroflexus* can be suppressed by the most thoughtful mulching methods, i.e. the methods with the highest soil cover. Worse effect of easily opening or tapering mulches refers to the necessity of supplying and thickening mulching material in the support of successful weed management or plastic foil and paper mulches should be chosen that are not susceptible to this and give continuous cover.

Echinochloa crus-galli

Against *E. crus-galli* herbicide control (2) showed better result than against T_4 weeds in general. Herbicide of the treatment was Dual Gold 960EC that is effective against seed born monocotyledons, so better effect can be explained with this. Better effect means in this case that herbicide control (2) were significantly better than untreated control (1) and weed clippings mulch (11). Hoed control (3), straw mulch with Phylazonit (5) and grass clippings mulch (8) belonged to a homogeneous group with herbicide control (2) according to the significant differences, therefore these four treatments can be considered equally effective and for the practice the best-fitting one should be advised for the local circumstances, where *E. crus-galli* is the problem. The most effective treatments against common barnyard grass are again plastic foil (6) and paper (7) mulches, although there is no significant difference between the effectiveness of these ones and herbicide control (2), hoed control (3), straw mulches and grass clippings mulch (8) in the case of *E. crus-galli.*

Ambrosia artemisiifolia

From treatments against common ragweed herbicide control (2) showed worse result than even untreated control (1) and this herbicide sparing method gave significantly worse result than weed clippings mulch (11). This can be explained by that ragweed does not belong to the direct effect range of Dual Gold 960EC, although it is sensitive to

this herbicide. According to the results mowing is more effective against *A. artemisiifolia* than the herbicide used in the experiment. It is worth considering the use of mulches with strong cover on areas infected by ragweed or combine them with mowing of ragweed and leave it there as a mulch in the crop stand too. Hoeing with moving the soil was equally effective against plastic foil mulch (6). These two treatments was not statistically different from straw mulch (4), straw mulch with Phylazonit (5), grass clippings mulch (8) and legume clippings mulch (9).

Elymus repens

Because of the patch-like spreading of *E. repens,* differences were so big among replications that statistical analysis showed few significant results in the average of the six years. The most effective treatment was plastic foil mulch (6), the least effective one was weed clippings mulch (11). This result could justify also with statistical analysis, that against *E. repens* with stolons only plastic foil mulch (6) of whole surface soil cover can be a possible solution from non-chemical or herbicide sparing weed management methods.

In the case of the other treatments, only conditional conclusions could be drawn. Mowing against monocotyledonous *E. repens* with stolons was not effective at all, therefore on areas infected by grass species another solution should be found to suppress weed cover percentage. Good result of plastic foil mulch (6) refers to unconditional usability of this treatment which could give acceptable result against either G_1 weeds.

Cirsium arvense

During examination of *C. arvense*, G_3 weed few significant differences of average cover were justifiable in the average of the six years although this species showed up in the treatments in every year. With comparing pairs positive effect of plastic foil mulch (6) and weed clippings mulch (11) was justifiable in contrast to all other treatments except

plastic foil (6) and paper (7) mulches.

Average yield of tomato

Comparing yield of tomato during the six years of the experiment it is ascertainable that the highest yield was from paper mulch (7) and plastic foil mulch (6) treatments. On the other hand this result did not differ significantly only from weed clippings mulch (11). Average results of the six years refer to that it is not particularly the yield by which appropriate treatment should be chosen.

Nevertheless, when only pest free yields are compared, hoed control (3) does not belong to the homogeneous group of the best treatments any more. Examining pest free yield, it is ascertainable that highest average pest free yield was on plastic foil mulch (6) in the average of the six years. As far as hoeing was not statistically different from any other treatments it means that it had heterogeneous effect on pest free yield and amount of this yield was medium, this treatment should be considered as a less effective one in respect of pest free yield of tomato. That is why rather soil cover should be chosen instead of hoeing to increase pest free yield. Lowest pest free yield was measured in untreated control (1) and on weed clippings mulch (11) where because of high weed concurrence total yield was also low.

A more accurate picture could be seen on pest free yield when the ratio of pest free and total yield is examined. In this case the best ratio was found in straw mulches. Positive effect of straw much on plant health is confirmed by other scientific examinations too. According to this, straw mulch should be kept in mind as an effective method against leaf-pests and insects in organic farming. Hoeing showed an unfavourable picture, which confirms the above mentioned conclusions.

Contracted effect of treatments according to tomato yield and weed management effect

Treatments were placed in order according to yearly average yield, pest free yield, ratio of pest free yield, and total weed cover. The most effective treatment got the highest number (11) and the least effective got the lowest (1).

One of the most effective treatment of the experiment was plastic foil mulch (6). Except for the ratio of pest free yield, it was on one of the two first places in the order of treatments. However according to the ratio of pest free yield, it was only the fourth , but there was no significant difference among the first four treatments.

Straw mulch with Phylazonit (5) did not differ from straw mulch (4). Utilization of this bacterial fertilizer did not improve tomato yield in a statistically verifiable amount compared to untreated straw mulch.

Straw mulch, as it is respective to literature, was an effective treatment. It was at one of the first four places according to all of the examined treatments. Only straw mulch with Phylazonit (5) could outrank it in the ratio of pest free yield but this difference was not significant either.

Regarding weed management effect, paper mulch (7) was the most effective treatment which is confirmed by literature sources, too. Otherwise very bad results were experienced with the ratio of pest free yield, that is why this type of mulch was on the fourth place in the summarised rank table. This result was even significantly worse than straw mulches. In the case of straw cover precipitation leaks through the mulch layer slowly and fungal infection is lower with lower lashing up too, because of the uneven surface. At the same time on paper mulch fine soil fragments can adhere to the surface and the danger of lashing up could be higher.

Contracted effect of grass clippings mulch (8) is barely worse than the one of the best treatment. On the other hand its effect is strongly altering, and shows high deviation. Utilisation of this type of mulch can be an alternative only on smaller areas beside straw,

plastic foil or paper mulches, because regular thickening of this mulch is necessary to keep its positive effect.

Legume clippings mulch (9) and grass clippings mulch (8) were competitive mulching methods regarding total yield of tomato but their weed management effect was weak, that is why in the contracted list these treatments were relegated. From legume clippings nitrogen could get into the soil and tomato could utilize it.

Among control treatments hoed control (3) was the most effective one regarding total yield of tomato and weed management effect too. In many cases it showed significantly better effect than the worst soil covering treatments (legume clippings mulch (9) and compost mulch (10)). Still its effect was regularly worse than the effect of the best treatments, moreover it was among the worst treatments regarding the amount and ratio of pest free yield of tomato.

Regarding total yield of tomato, compost mulch (10) got higher rank number than grass clippings mulch (8), but its total rank number was low. Nutrient content of compost was favourable not only for tomato but for weeds too, that is why it was one of the worst treatments regarding weed management effect.

Herbicide control (2) plots were treated by Dual Gold 960 EC herbicide that is effective against seed born monocotyledons on the first hand. Without any further examinations, this herbicide sparing solution can not be regarded as effective alternative of mulching.

Weed clippings mulch (11) belonged to the worst treatments in the case of all factors. Mulch layer made of weeds of inter-rows was not thick enough and resulted in heterogeneous mulching effect, that is why it gave notably higher total weed cover than the other treatments especially in years with low weed cover.

In tomato production leaving the production area alone (untreated control (1)) resulted in heavy weed cover, that apparently decreases total yield of tomato. This is not adequate either for economic production or further farming practice because weed infection of the area is appreciably worsening.

NEW SCIENTIFIC RESULTS

1. Effectiveness of straw mulch, straw mulch with Phylazonit, plastic foil mulch, paper mulch, grass clippings mulch, weed clippings mulch in weed management of tomato with respect to local circumstances is verified.
2. Competitiveness of straw mulch to plastic foil mulch regarding weed management effect and yield of tomato together is justified.
3. Against *Cirsium arvense,* the effectiveness of mowing inter-rows is demonstrated.
4. Positive effect on plant health of natural mulches, especially straw much is proved.
5. Statistical analysis of cover percentages based on rank averages gave more accurate results which are more usable for farming practice even in the case of higher deviations.

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