SZENT ISTVÁN UNIVERSITY

DEVELOPMENT OF OPEN FIELD SWEET PEPPER PRODUCTION TECHNOLOGY

Ph.D. Thesis

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1. Research background and the main objectives

Compared to earlier years, sweet pepper is grown in Hungary on much smaller area in the open, while the area of forcing is increasing. The advantage of forcing can be explained with higher yield, better quality and mainly higher profitability. The main reason for the decline of open field crop land is the more and more obsolescent growing technology. In order to make open field crop competitive again, cropping safety, average yield and quality have to be increased.

This can't be realised with conventional technology; therefore use of intensive technology is needed. By the help of this technology, longer growing period, smaller danger of infection and safer production can be achieved. The main elements of intensive sweet pepper production systems are hybrid cultivar, tray seedlings of good quality, raised bed covered with plastic mulch, drip irrigation, fertigation and controlled release fertilizers.

In my research, from the intensive technological elements of open field sweet pepper production, I examined the effect of plastic soil mulches, raised bed and controlled realise fertilizers. Plastic mulches provide many positive advantages for the user; they improve water, heat and nutritive material household of soil. Further benefits can include increased yields, better quality, earlier-maturing crops, reduced soil compaction and inhibition of weeds. The effect of plastic mulch on soil temperature is determined primarily by the optical properties (reflectance, transmittance, absorbance) of the material, thus the different coloured mulches warm the soil to a different degree.

The use of raised bed covered with plastic mulches is especially important when warm season crops are being grown in areas with short growing season. Because Hungary is situated on the northern border of the open field sweet pepper production zone, the use of this technology could be of great importance.

Fertigation means a great advance in open field cultivation, because many disadvantages of conventional fertilization can be eliminated with the use of this method. Using controlled-release fertilizers (CRF) is another fertilization method applicable in intensive open field vegetable production. The most important advantage of these fertilizers is that they release gradually (in stages), so, for instance in the case of salt-sensitive plants all nutrients required in the growing season can be dosed at one occasion in one dose, even without a dose of water. Besides higher costs, the most important disadvantage of this method is its inflexibility. Ideally, with the parallel use of this two methods – fertigation and controlled-release fertilizers –, the disadvantages can be eliminated and the advantages can be integrated.

Objectives

In close connection with this possibility, the objective of this study was on the one hand to determine the effect of raised bed, black plastic mulch and different coloured mulches on soil temperature, as well as on yield, growth and flowering of a kapia-type and a tomato shaped sweet pepper cultivar. Also, I focused on determining which plastic film is the best for sweet pepper under Hungarian climatic circumstances.

The other objective of this study was, on the other hand, to examine the availability of controlled release fertilizers and to compare it with fertigation and with the combined use of fertigation and CRF.

2. Materials and methods

Experiments were conducted in northern Hungary at Gödöllő (47°61`N, 19°32`E; Gödöllői Agrár Központ Kht.) during 2001, 2002 and 2003, with soil classified as Cambisol (loamy sand soil).

The experiments can be divided into three groups:

1. The examination of the effects of raised bed and flat cultivation method combined with black plastic mulch
2. The examination of the effects of mulch film colour in case of raised bed covering
3. The examination of the effects of controlled release fertilizers

2.1. The examination of the effect of raised bed and flat cultivation method combined with black plastic mulch

In the first two years (2001, 2002) of the experiments examining the effects of raised bed and flat cultivation methods were grown the tomato shaped Pritavit F_1 and the kapia-type Kárpia F_1, while in 2003 only one hybrid, the Pritavit F_1 was used. Choice was made from this two types of cultivars because this types are grown in the open field for a longer term and they are harvested in a stage of full ripening. Thus, the prolongation of growing season, connected to increase of soil temperature, could be of special importance.

The following treatments were carried out in all the three years:

1. raised bed covered with black plastic mulch,
2. uncovered raised bed,
3. flat cultivation method covered with black plastic mulch,
4. uncovered flat cultivation method (control treatment).

The black polyethylene mulch was 0,12 mm thick. Raised beds were 0,25 m high and 0,5 m wide, and were situated in north-south direction.

Treatments were replicated four times. In all plots there were 40 plants. Pepper seedlings were transplanted in two rows per bed, with 0,3 m between rows and 0,25 m between plants in the case of flat and raised bed treatments, too. Transplanting took place during the 3rd week of May in all the three years.

In the experiments intensive technological elements were used: tray seedlings (4x4 cm), drip irrigation, fertigation. The times of irrigation and fertigation were determined by soil metric potential monitored by tensiometers in 15 cm depth.

2.2. The examination of the effects of mulch film colour

The experiments were conducted in 2002 and 2003; the kapia-type Kárpia F_1 was grown both years.

The treatments were made up in both years of mulch films of different colours and the control treatment.

Treatments in 2002:

1. light green
2. violet
3. dark green
4. red
5. black
6. un-mulched control

Treatments in 2003:

1. clear
2. violet
3. dark green
4. red
5. black
6. un-mulched control

The forming of raised beds, the conditions of the experiment and the production technology corresponded to those of the previous experiment.

2.3. The examination of the effects of controlled release fertilizers

The tomato shaped Pritavit F_1 was grown in all the three years (2001-2003) of the experiment.

The treatments in all the three years consisted of different fertilization methods. Three treatments were carried out in all the three three years, and treatments were repeated four times. Treatments differed in the ratio of nitrogen given by compound controlled release fertilizers (CRF) and by fertigation.

In the first treatment 0% CRF (fertigation), in the second treatment 50% CRF (combined method), and in the third treatment 90% CRF were applied, while the remaining 10% – since CRF does not contain Ca – was reserved for Ca-release in the form of calcite-nitrate.

During the growing season in 2001 and 2002, 30 g N/m^2 nutrients were dosed in all treatments. Since in this two years there were no significant differences between the treatments, the amount of N was reduced to 20 g/m^2. After all, the surplus of nutrient supply did not show any difference.

Plants were grown on raised beds covered by black plastic mulch. Irrigation and fertigation were supplied through a drip irrigation system. In the 0% CRF treatment in average two fertigations were applied weekly. If the soil water content was sufficient according to tensiometer readings, the actual irrigation was omitted in the 50% and 90% CRF treatments. In all plots there were 20 plants. The production technology corresponded to that of the first group of experiment.

2.4. Measurings and observations

Measuring soil temperature

In the experiments examining the effects of raised bed and black plastic mulch (2001-2003) and of different coloured mulches (2002-2003), the effects of the treatments on soil temperature were followed with close attention.

The measure was done with thermo recorders of TR-71S (T and D Corporation, Japan) and Tinytag Plus (Gemini Data Loggers Ltd., England) of type. Temperature sensors were placed at 10 cm depth under the plant row on the west side of the raised beds, and they recorded temperatures hourly. The measurement was done in one replication in 2001 because of the lack of thermo recorders, and in four replications in 2002 and 2003.

Measuring vegetative characteristics

In order to describe the growth, the changes in stem diameter and plant height were followed with close attention in all the three groups of experiments. Stem diameter was measured by digital sliding calliper 1 cm above the cotyledon. Plant height was measured from the soil surface to the highest point of the plant.

Observation of blooming time

In order to describe the generative growth in 2002 and 2003, the blooming time of the first flower was recorded in all plots and at all plants in all the three groups of the experiments, from which we can draw conclusions about earliness to a certain degree.

Yield and fruit quality

At every harvest time, fruits were sorted according to quality categories (fancy, first-rate, second-rate, third-rate, unmarketable). Weight and number of the fruits per categories were recorded, and the average fruit weight, as the most important quality characteristic in Hungary, was calculated.

During processing the results in the first two groups of experiments, early yield (harvests in August) and total yield were determined.

Statistical analysis

For statistical evaluation of the experimental results data processing and evaluating module of software MS Excel was used. To determine significant differences among the treatments, I used analysis of variance with LSD test at $p<0.05$ for mean separation.

The type of correlation between average soil temperature and average yield, as well as that of optimal soil temperature rate and average yield were assessed by regression-analysis determined. Furthermore, the closeness of correlations was assessed by correlation-analysis.

3. Results

3.1. The examination of the effects of raised bed and flat cultivation method combined with black plastic mulch

Soil temperature

Average soil temperature of the whole growing season was determined in respect of all treatments (Table 1). Soil warmed up to the highest degree using covered raised beds in all the three years, this rate was followed by covered flat treatment. Uncovered raised bed did not cause considerable soil temperature increase compared to the control treatment. In average of the three years, the uncovered raised bed caused 0,2°C, the covered flat treatment 0,8°C, the covered raised bed 2,1°C soil temperature increase compared to the control treatment.

Table 1. Effect of raised bed and plastic mulch on soil temperature 10 cm below the soil surface in the average of the whole growing season (Gödöllő, 2001-2003)

	Average soil temperature (°C)			Average of three years (°C)
	2001	2002	2003	
Covered raised bed	21,9	22,1	23,1	22,4
Uncovered raised bed	19,8	20,1	21,5	20,5
Covered flat ground	20,3	20,9	22,1	21,1
Uncovered flat ground (control)	19,9	19,8	21,1	20,3
LSD 0.05	-	0,4	0,4	-

On the basis of hourly data, we calculated that how many percent of the measured data belonged to the optimal temperature range of sweet pepper in the particular treatments. Based on data from the literature, we set the optimal soil temperature range between 20 and 30°C.

The ratio of optimal soil temperature values was similar in the first two years; it was the highest using the covered treatments (52-62%). Whilst in 2003, at uncovered flat treatment, compared to the two covered treatment (63-68%), a similarly high value occurred (64%), which can be explained with warmer weather. The rate of infra-optimal values was in all the three years the highest without covering (34-50%); the most supra-optimal values occurred at covered raised bed (7-10%).

On the basis of data of the whole growing season, diurnal trends in soil temperature were defined; results of 2002 are shown in Figure 1. Considerable differences developed among the treatments mainly during daytime. At raised beds – because of their bigger surface –the soil warmed up better during daytime, than at flat treatments. However, during night-time, the raised bed treatments lost more heat-energy. Treatments covered with black plastic mulch could then ensure higher soil temperature than treatments without covering, because PE mulch film retained outgoing long-wave radiation emitted from the soil.

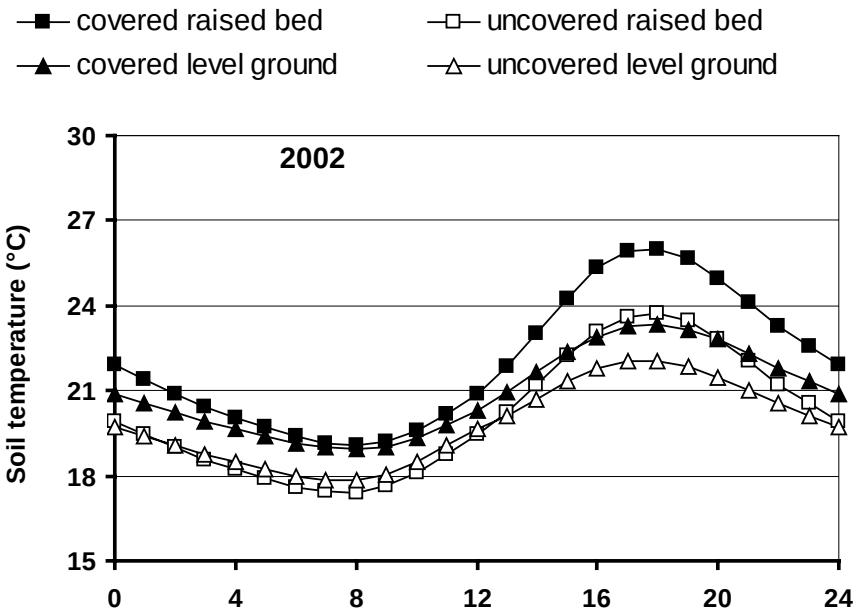

Figure 1. Effects of raised bed and plastic mulch on diurnal trends in soil temperature 10 cm below the soil surface in the average of the whole growing season. Each symbol represents the hourly mean soil temperature for the whole season (Gödöllő, 2002).

In order to be able to better analyse the tendency of soil temperature, weekly averages were determined. At the beginning of the growing season, when the plants did not cover the mulches considerably, the soil warmed up to a higher degree compared to the air temperature than later in the growing season, when plants shaded the mulches to a large extent. On the basis of the average weekly soil temperature, the soil warmed up to the highest degree on the 8^{th}, 9^{th} and 11^{st} weeks after transplanting in 2001, on the 5^{th} and 6^{th} weeks after transplanting in 2002 and on the 3-4^{th} weeks after transplanting in 2003. The different trends of the years can be explained with the different weather conditions.

Yield

In 2001 there were no significant differences in yield of Pritavit F_1. Covered raised bed resulted in the highest yield, with 13% higher than using uncovered flat treatment. In 2002 both covered treatments produced significantly higher yield than uncovered treatments. We observed a different trend in 2003. Covered level ground treatment produced more than 1kg/m^2 more than the covered raised bed, which produced similar yield to uncovered treatments. A possible reason for the lesser yield at raised bed can be that the soil may have warmed up too much under mulch covering.

In 2001 Kárpia F_1 produced significantly higher yield at raised bed than at the other treatments. In 2002 raised bed also produced significantly higher yield compared to the other treatments, and the yield of plants on covered flat ground was significantly higher only than the yield of plants on uncovered raised bed.

Comparing the results of the three years and the two cultivars, it can be established that the treatments, which ensured the most optimal soil temperature for sweet pepper in the growing season, produced higher yield.

3.2. The examination of the effects of mulch film colour

Soil temperature

Average soil temperatures of the whole growing season in 2002 and 2003 are shown in Table 2. Mulched treatments increased soil temperature in both years significantly, compared to the uncovered treatment. The colour of the soil mulch determined the degree of soil warming. Light coloured mulches (clear, light green, violet) maintained the highest values of soil temperature. Dark coloured mulches (black, dark green, black) warmed the soil at a lower rate than the light ones. In average of the two years, the dark coloured mulches caused 1,3°C, while the light coloured mulches brought 2,3°C soil temperature increase compared to the uncovered control.

Table 2. Effect of coloured mulches on soil temperature 10 cm below the soil surface in the average of the whole growing season (Gödöllő, 2002-2003)

	Average soil temperature (°C)	
	2002	**2003**
clear	-	24,3
light green	22,6	-
violet	22,9	24,0
dark green	21,8	23,5
red	22,0	23,1
black	21,5	22,8
uncovered control	20,1	21,4
LSD 0.05	0,5	0,6

In this experiment, I also defined that how many percent of the measured data belonged to the optimal temperature range of sweet pepper in the particular treatments. The rate of optimal soil temperature for sweet pepper was the highest in 2002 and in 2003 in the case of dark coloured mulches (60-68%). The most infra-optimal data (36-47%) occurred in both years at uncovered treatments, and the most supra-optimal values (12-17%) were measured at light coloured mulches.

From Figure 2, which demonstrates the diurnal trends in soil temperature in 2002, it can be concluded that uncovered treatment cooled down better at night and warmed up less during daytime than mulched treatments. Among the mulched treatments considerable difference occurred during daytime. The cooling of soil temperature during night-time was not influenced by the colour of the mulches.

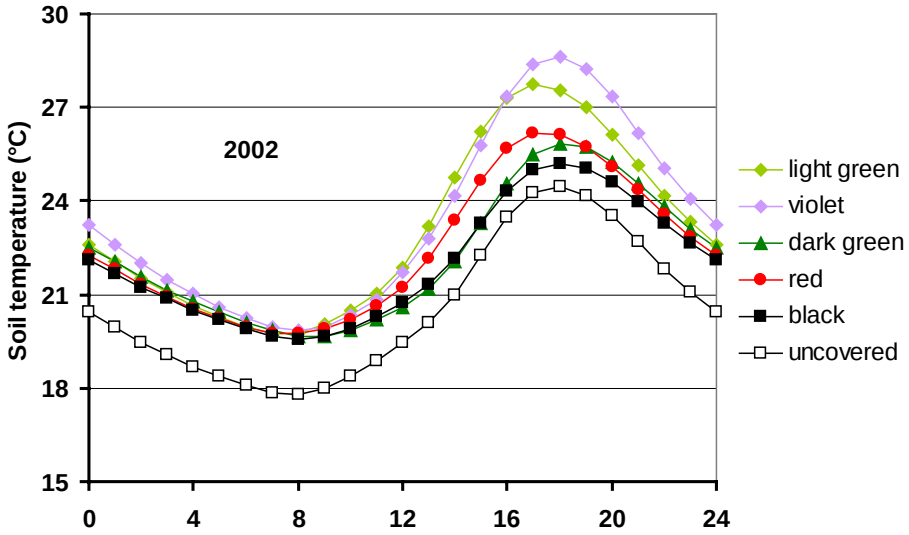

Figure 2. Effects of coloured mulches on diurnal trends in soil temperature 10 cm below the soil surface in the average of the whole growing season. Each symbol represents the hourly mean soil temperature for the whole season (Gödöllő, 2002)

On the basis of the average weekly soil temperature, the soil warmed up to the highest degree on the 5-6th weeks after transplanting in 2002, and on the 3-4th weeks after transplanting in 2003. The tendency in connection with shading effect of the plants was the same as in the experiment which examined the effects of raised bed and black mulch.

Yield

In 2002, mulched treatments produced significantly higher yields than the uncovered treatment. The yield difference among the mulched treatments was negligible. We observed a different trend in 2003. Dark mulches again produced significantly higher yield than the uncovered treatment. Clear mulch produced the lowest yield and the violet mulch also produced lower yield compared to dark mulches.

The different trends of the two years can be explained by different weather conditions, therefore with different soil temperature. In 2003, high soil temperature may have resulted in weaker vegetative growth by light coloured, mainly by clear mulch, and the weaker early development led to lesser yield.

3.3. Connection analyses between soil temperature and average yield, as well as optimum temperatures and average yield

Examining the two groups of experiments, our results show that the relationship between average soil temperature and yield is not linear, but it can be described with polynomial relationship. However, between the rate of optimal temperature values for sweet pepper and yield the relationship is nearly linear. Quadratic equations of the functions were used to compute the optimum average soil temperature (22,77°C) for yield, in respect of the whole growing season.

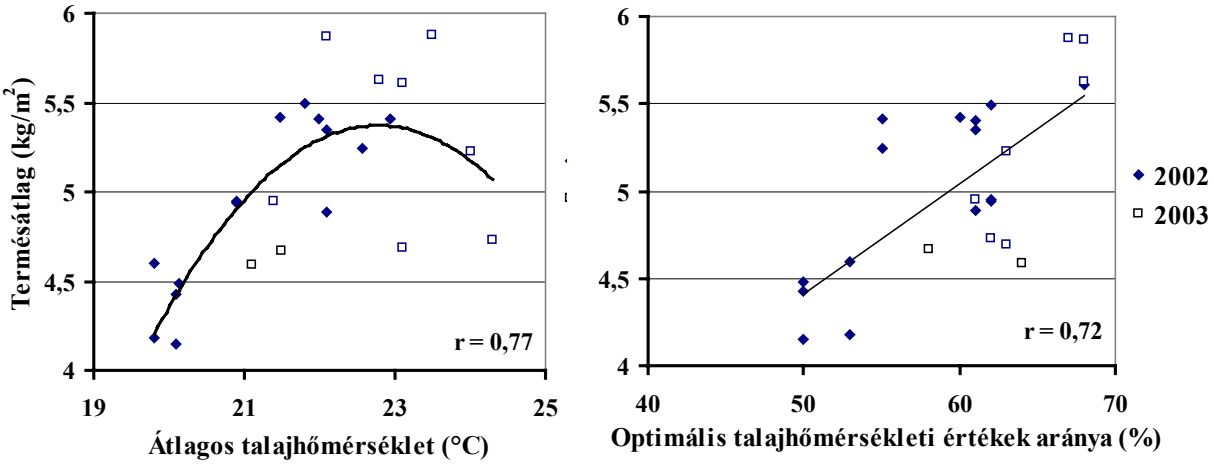

Figure 3. Effects of soil temperature on sweet pepper yield (Gödöllő, 2002-2003)

3.4. The examination of the effects of controlled release fertilizers

The amount of used water

In 2001 and 2002 the amount of irrigation water could be reduced by using CRF. The ratio of the reduction depended on the weather conditions of the given year. In the colder and more humid year of 2001, in the 50% and 90% CRF treatments, 29% and 48% less irrigation water was used respectively than in the control 0% CRF treatment (141 mm). While during the dryer and warmer year of 2002, this saving was just 14% and 21% in the 50 and 90% CRF treatments, respectively, compared to the 0% CRF treatment (252 mm). In the warmest and driest year 2003, in used water amount there was no difference between the treatments.

Yield

There were no significant differences in yield on any of the years, either. In 2001 and 2003, the 50% CRF treatment produced the highest yield, while in 2002 the 0% CRF treatment was the best. In all the three years the 90% CRF treatment produced the fewest.

Comparing the results of the three years, it can be established that the warmer the weather was, the higher yield the treatments produced. However, in 2003 the amount of N was reduced from 30 g m^{-2} to 20 g m^{-2} yields and fruit weight was the highest in this year.

3.5. New scientific achievements

1. In average of the three years and the whole growing season, in the experiments on the effects of raised bed and plastic mulches on open field sweet pepper production, the different treatments resulted in the following soil temperature increase in the depth of 10 cm:
   - uncovered raised bed compared to the uncovered flat treatment: 0,2°C
   - flat cultivation system covered with black plastic mulch compared to the uncovered flat treatment: 0,8°C
   - raised bed covered with black plastic mulch compared to uncovered raised bed: 1,9°C
   - raised bed covered with black plastic mulch compared to the uncovered flat treatment: 2,1°C

2. In average of two years and the whole growing season, in the experiments on the effects of coloured mulches on open field sweet pepper production, the light (clear, light green, violet) and dark (black, dark green, red) coloured mulches caused the following soil temperature increase in the depth of 10 cm:

- light coloured mulches, compared to the uncovered treatment: 2,3°C
- dark coloured mulches, compared to the uncovered treatment: 1,3°C

The soil can warm up under light coloured mulches to on extremely high temperature and can have a harmful effect on growth and yield of sweet pepper.

3. Higher rate of optimal soil temperature values for sweet pepper resulted in stronger vegetative growth and, through this, in higher yield.

Raised bed covered with black plastic mulch caused, depending on weather conditions and on cultivar, 2-24% higher yield than the uncovered flat control treatment.

Dark coloured mulches produced 15-21%, light coloured mulches brought 1-19% higher yield, depending on weather conditions, than the uncovered control treatment.

4. The relationship between average soil temperature and yield can be described with polynomial relationship. Quadratic equations of the functions were used to compute the optimum average soil temperature (22,77°C) for yield, in respect of the whole growing season.

5. The use of CRFs was not compared to fertigation in any of the previous experiments. Regarding yield, there were not significant differences among the treatments, but to a smaller degree, the 90% CRF treatment produced the lesser yield in all years. Comparing the two basic methods, it can be concluded that using only fertigation the results were better than using CRF. With the combined use of fertigation and CRF, similar or better yield could be achieved, compared to the usual fertigation technique; even though the number of fertigations was the half using combined methods, which, naturally required half the effort.

4. Conclusions and recommendations

4.1. The effects of raised bed and flat cultivation method

The results of the experiments show that raised bed and black plastic mulch had an effect on soil temperature and through this on growth and yield of the plants.

In average of three years and the growing season, the uncovered raised bed increased the soil temperature with 0,3-0,4°C compared with the uncovered treatment. The reason for this result is that raised beds warmed up better during daytime, because their bigger surface could absorb more incoming solar radiation, whilst during night-time – also because of the bigger surface – cooled down better than flat ground. The flat ground covered with black mulch caused 0,4-1,1°C soil temperature increase compared to the control treatment. This can be explained by the fact that black plastic mulch absorbs the most of incoming solar radiation and transfers absorbed energy to the soil by conduction. Covered soil cools down at night not as much as uncovered soil, because mulch film retains long-wave radiation. The raised bed covered with black mulch caused 1,6-2,1°C increase in soil temperature, compared to the uncovered raised bed. This can explained by the bigger surface, and by the soil warming effect and, at night, the heath-retaining effect of raised beds. The highest soil temperature increase and the most optimum soil temperature for sweet pepper can be achieved by the combined use of raised bed and black plastic mulch.

Due to the more favourable soil temperature, the plants showed stronger vegetative growth and earlier blooming than at uncovered treatments.

Regarding yield, it can be concluded that in the cool year of 2001 and in the less warm year of 2002, both cultivars produced the highest yield with covered raised bed, which treatment warmed up the soil to the highest degree. We observed in the warmest year of 2003 a different trend: the yield was with covered flat treatment significantly higher compared to the other treatments, however, the covered raised bed produced similar yield to the uncovered treatments. It may be explained by the fact that the soil may have warmed up too much for Pritavit F_1 in the case of raised bed combined with black mulch, since it produced than 1kg/m^2 less yield than the covered flat treatment.

4.2. The effects of different coloured mulches

The results of the experiments show that coloured mulches had an effect on soil temperature, which influenced the yield through the vegetative growth of the plants.

The degree of soil temperature increase was determined by the colour of the mulches and in relation to this, by the amount of light they transmitted. Soil mulches used in the experiment were divided into two groups on the basis of soil-warming ability: light coloured (clear, light green, violet) and dark coloured (black, dark green, red) mulches. The highest soil temperature occurred under light coloured mulches, in average of two years and the whole growing season they caused 2,3°C soil temperature increase, compared to the uncovered treatment. The reason for it is that clear mulch transmits 85-95% of solar radiation. The inner surface of clear mulch is usually covered with condensed water droplets. This water is transparent to incoming short-wave radiation, but it retains outgoing long-wave radiation emitted from the soil. In the case of light coloured mulches, the rate of soil temperature values optimal for sweet pepper, depending on weather conditions, was 1-5% higher than in the uncovered treatment, since the proportion between values over the optimum ranged between 12 and 17%.

Dark coloured mulches had a lower soil-warming ability than light coloured ones. In average of two years and the whole growing season, they caused 1,3°C soil temperature increase, compared to the uncovered treatment. Black mulch absorbs most of incoming solar

radiation and the absorbed energy can be transferred to the soil by conduction. Although the dark green and the red mulch transmit a portion of incoming solar radiation, their soil warming ability is similar to that of the black mulch. In the case of dark coloured mulches, the rate of soil temperature values optimal for sweet pepper, depending on weather conditions, was 6-12% higher than in the uncovered treatment, since the proportion between values over the optimum was smaller (7-9%) than at light coloured mulches.

In yield, no considerable difference occurred between the mulched treatments in 2002. However, in 2003 the use of clear and violet mulches with the highest soil-warming ability resulted in lower yield, than in the case of dark mulches.

We considered that due to the warmer weather in 2003, the soil warmed up under the clear mulch to a harmful extent and also to a certain degree under the violet mulch. This extremely high soil temperature was reached at the beginning of the growing season when the plants did not cover the mulches and the roots of the plants were located in the upper layer of the soil. High soil temperature can have a drastic effect on vegetative growth, fruiting, water and nutrient uptake and root respiration.

In the examined region, the use of clear and light coloured mulches can not be suggested in warmer years, because under these mulches the soil can warms up to an extremely high degree, which can result, compared to dark mulches which cause smaller temperature increase, in worse average yield, quite the same as, or even less amount than in the case of uncovered treatments. The use of dark coloured mulches is the safest solution, because even in case of high air temperature and higher solar radiation, the soil does not warm to a harmful degree. Therefore, among the mulches examined, they can meet the soil temperature demands of sweet pepper to the highest degree.

Examining the two groups of experiments, our results show that the relationship between average soil temperature and yield is not linear, but it can be described with polynomial relationship. However, between the rate of optimal temperature values for sweet pepper and yield the relationship is nearly linear. Quadratic equations of the functions were used to compute the optimum average soil temperature (22,77°C) for yield, in respect of the whole growing season.

4.3. The effects of controlled release fertilizers

Regarding yield, there were no significant differences among the treatments, but to a small degree the 90% CRF treatment produced the lesser yield in all years. Comparing the two basic methods, it can be concluded that using only fertigation the results were better than using CRF. With the combined use of fertigation and CRF, similar or better yield could be achieved, compared to the usual fertigation technique; even though the number of fertigations was in this case the half, which, obviously, required also half the effort.

The ratio of the saved irrigation water in case of different treatments depended to a high degree on the weather conditions of the given year. The advantage of CRFs, is that to dose nutrients there is no need to give irrigation water, which largely predominates in years with higher precipitation.

Although there were some differences between the treatments – not only in type of fertilizers, but also in ratio of nutrients, too –, these were of no significance. Also, it did not lead to significant differences that in 2003 20 g N/m^2 were dosed instead of 30 g. It may be explained by the fact that in intensive open field production fertilization has – to a certain extent – no influential effect. Weather conditions have a more important role, since the limiting factor in Hungary is mainly the temperature.

Where technological conditions are provided, fertigation is suggested because of greater flexibility and possibility of change in the ratio of nutrients while growing. Controlled

release fertilizers are of greater importance where drip irrigation can not be realized because of inappropriate water quality or because of the configuration of the soil. However, because of the last few summers with much precipitation, the use of controlled release fertilizers should be reconsidered, since over-irrigation can be avoided by their help.

5. Publications related to the topics of the thesis

Revised publications in English:

1. **Locher, J.,** A. Ombódi, T. Kassai and J. Dimény (2005)**:** Influence of coloured mulches on soil temperature and yield of sweet pepper. European Journal of Horticultural Science. 70(3):135-141.
2. **Locher, J.,** Ombódi, A., Kassai, T., Tornyai, T. and Dimény, J. (2003): Effect of black plastic mulch and raised bed on soil temperature and yield of sweet pepper. International Journal of Horticultural Science 9:107-110.
3. Ombódi, A., **J. Locher** and J. Dimény: Combined use of fertigation and controlled-release fertilizer in intensive open field sweet pepper cultivation. Acta Horticulturae. [ACCEPTED]

Revised publications in Hungarian:

4. **Locher J**., Ombódi A., Kassai T. és Dimény J. (2002): Kápia típusú paprika intenzív szabadföldi termesztése, különös tekintettel a talaj takarására és bakhát alkalmazására. Hajtatás Korai Termesztés 33(2):22-25.
5. **Locher J**., Ombódi A., Tornyai T., Deákvári J., Jakovác F., Dimény J. (2002): Különböző színű talajtakaró fóliák hatása a talaj hőmérsékletére és a paprika termésmennyiségére. Kertgazdaság 34(4):25-29.
6. **Locher J.**, Ombódi A., Kassai T., Dimény J. (2003): Fekete polietilénfóliás talajtakarás és bakhát alkalmazásának hatása a paprikára. Hajtatás, korai termesztés 34 (2):17-20.

Proceedings in English:

7. Ombódi A., **J. Locher** and J. Dimény (2004): Combined use of fertigation and controlled-release fertilizer in intensive open field sweet pepper cultivation. Italicus Hortus 11(3):38-39. ISHS Symposium, Towards ecologically sound fertilisation strategies for field vegetable production. Perugia, Italy, 7-10. June 2004.

Other appreciable publications:

8. **Locher J.**, Dr. Ombódi A. (2002): A talajtakarás és a bakhát alkalmazásának lehetséges előnyei szabadföldi paprikatermesztésben. Agrárágazat, 10:26-28.
9. Ombódi A., **Locher J.**, Helyes L., Dimény J. (2002): A combined fertilization method for field grown sweet pepper. J. Agric. Res. Tanta Univ. Vol(28): 3/II, 590-595.
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