Original Research

Effect of Mulch on Soil Moisture Depletion and Strawberry Yield in Sub-Humid Area

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Abstract

In sub-humid areas supplementary irrigation is a rather important precondition for the commercial cultivation of berries. But due to the high price of irrigation systems and low incomes, some farmers prefer alternative approaches to irrigation systems. Mulching is considered the most important cultural practice as it plays an essential role in soil moisture conservation. In order to clarify and evaluate the influence of mulching in sub-humid areas on active soil water amounts, depletion during vegetation, our the investigation was conducted in a strawberry field (54º88'N, 23º09'E) on light loam (*IDg4-k*) soils. Chopped wheat straw and black plastic were used as organic and non-organic mulches. The present study revealed that the soil moisture content differed significantly and appropriate mulching of top soil layer was quite useful in the field to accelerate growth and get high fruit yield. The highest average weight-based soil moisture content of the active soil layer (0-40) within three years was 18.0% in the field mulched with straw, while the lowest one, 16.2%, was in the field without mulching; in the plot mulched with black polyethylene it was 16.5%. The yield of two years gained from the field mulched with the black polyethylene layer was higher by 60% than that in the non-mulched field and by 56% in comparison to the yield in the plot mulched with straw.

Keywords: soil water, straw, mulch, polyethylene layer, yield

Introduction

An effective adaptation to the changing climate on farms at the sector and policy levels is a prerequisite for reducing negative impacts and obtaining possible benefits [1], and includes land use and land management as well as changes in inputs of water, nutrients, and pesticides [2]. Some of the most wide-ranging adaptations involve changes in water management and water conservation that involve issues such as changing irrigation, adoption of drought-tolerant crops, and water-saving methods (e.g. mulching and minimum tillage) [2].

Research and practical experience have shown that lack of water at critical stages of crop development is a very important yield-affecting factor. Soil moisture deficit has a negative impact on strawberry growth, development, yield, berry size, and persistency in winter [3]. Irrigation has a significant influence on total yield, berry weight, runner production, and leaf area [4]. The results of strawberry research obtained in foreign countries, even in northern European states, show the positive effect of irrigation as well. In sub-humid areas supplementary irrigation is a rather important precondition for the commercial cultivation of fruit and berries; still, due to the high price of irrigation systems and low incomes, farmers prefer alternative approaches to irrigation systems. According to [5], the water conserving effect of mulch can have an increasingly tangible beneficial effect in terms of increasing the length of the growing season and reducing drought/productive risk and yield oscillations. Mulching of soil ensured better

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Table 1. Soil properties of 0-40 cm depth.

Soil depth (cm)	Particle size mm and quantity (%)						Particle <0.01 mm quantity (%)	Bulk density (g/cm³)	Porosity (%)	Field capacity (%)	Wilting point (%)	Hydroscopic soil moisture content %
	1-0.25	0.25-0.05	0.05-0.01	0.01-0.005	0.005-0.001	<0.001						
0-10	2.2	47.7	23.9	5.3	6.1	14.8	26.2	1.41	46.1	24.7	3.2	2.4
10-20	0.8	59.4	19.7	4.9	4.8	10.4	20.1	1.48	41.7	23.7	3.3	2.4
20-30	0.8	60.2	14.2	3.9	6.4	14.5	24.8	1.58	38.9	22.9	3.7	2.6
30-40	3.9	50.3	15.2	4.6	6.2	19.8	30.6	1.62	36.6	22.6	3.8	2.8

thermal conditions early in the morning and protected against rapid loss of heat accumulated in the soil during the day [6].

Among different strawberry production practices, mulching is considered the most important cultural practice as it plays an essential role in soil moisture conservation, weed control, and regulation of soil-hydrothermal regime, besides keeping the delicate fruit neat and clean [7]. Johnson and Fennimore [8] investigated the dependence of berry crop yield on plastic mulch of different colors, and reported that black-color mulch yielded the most marketable berries. In addition, mulching also improves strawberry plant growth, berry weight, fruit yield, and quality [9]. Mulching of the soil surface is an effective soil conservation practice [10, 11]. According to [12], mulching can be used as a means of successful crop production mainly in place, where irrigation facilities are scanty. Mulches greatly retard the loss of moisture from the soil and as a result, higher and uniform soil moisture regime is maintained, reducing irrigation frequency [13]. Mulch can contribute to a considerable reduction in the evaporation of water from the soil surface. This means better water utilization by plants. Mulch can also be used to alleviate the negative effects of a long-term draught [14]. Mulching increases soil moisture 1.7 times [15]. Sharma and Acharya [16] reported that seed zone (0-7.5 cm) as well as root-zone (0-45 cm) moisture contents at the time of sowing of wheat crop were significantly higher in mulched than in unmulched plots. Increased water intake and slower evaporation are observed in the surface covered plots [17]. Besides, soil moisture in mulched plots is not only higher, but also more stable during the entire vegetation period [18]. In different parts of the world various materials are used for mulching, but black polyethylene is the most widely used [9]. This material is frequently used in raised-bed cultures of strawberries to conserve water, control weeds with less herbicides, and keep fruit clean [19]. Locally available mulch materials can be applied on soils to reduce soil moisture loss from the profile [20]. The combination of different strawberry cultivars and mulches in one plantation enables the grower to be flexible in extending ripening time to an early as well as a late season [21].

This work is an attempt to clarify the effects of straw and black polyethylene mulches on soil moisture regime and productivity of strawberries in sub-humid areas.

Materials and Methods

Field Experimental Site

The investigation was carried out in the Water Balance Experimental Research station of Aleksandras Stulginskis University (54º88'N, 23º09'E) in 2006-08. The investigation was conducted in calcareous deeper gleyish leached soil, *IDg4-k*, (*Sod Podzolic JPlv*), mechanical composition – light loam on clay loam; medium-phosphorous and medium-potassium, pH_{KCl} – 6.3 (Table 1).

All experiments were conducted in randomized complete block designs. Individual plot size was 20 m^2 and each plot was replicated 4 times. The scheme of strawberry is planting in rows of 0.8×0.3 m (plant number per 1 ha – 41,666 units). Treatments of the experiment include: no mulching (A), wheat straw (B), black polyethylene layer (C). Chopped wheat straw mulch was applied in a 10 cm thick layer (as the relatively small amounts of straw are not effective in conserving soil moisture) [11], and plastic mulch (black polyethylene of 100 microns) was stretched out evenly on the soil surface with holes for strawberry sprouts.

Soil moisture content was measured by thermostatic method in three repetitions. Soil samples were taken every 10 days and after heavy precipitation (more 20 mm) at four depths (every 10 cm). Yield was determined in each treatment by direct weight method in three repetitions. The strawberry was harvested at the same day from all variants every two-three days. Single berry weight was determined as an average of 100 random berries. Determination of berry size considered the distribution of big (>10 g), average (5-10 g), and small (< 5 g) berries.

Climatic Conditions

The humidity of the vegetation period was evaluated according to Seleninov hydrothermal coefficient (HTK). Values of HTK < 0.3 – very dry, 0.4-0.5 – dry, 0.6-0.7 – middle dry, 0.8-1.0 – not humid enough, 1.0-1.5 – humid enough, > 1.5 – wet.

In 2006 and 2007 the investigation was wet, in 2008 it was humid enough (Table 2).

In 2006 very wet decades were changed by drought and after that wet weather conditions followed. Spring in 2006

Table 2. Air temperature (ºC) and precipitation (mm), in May-September 2006-08, and their long-term averages at the experimental site.

Month/year	Precipitation (mm)				Temperature (°C)				*HTK*		
	1961-90*	2006	2007	2008	1961-90*	2006	2007	2008	2006	2007	2008
May	55	74.5	96.5	35.5	12.4	12.5	13.6	12.3	2.2	2.8	0.9
June	69	18.0	70.7	83.2	15.8	16.5	17.8	16.0	0.4	1.3	1.7
July	80	70.7	148.7	43.0	16.9	20.9	17.1	18.1	0.8	1.4	0.8
August	78	165.6	78.6	99.3	16.4	17.8	18.5	17.9	3.0	1.4	1.8
September	56	89.8	41.5	27.0	11.9	14.6	12.8	12.2	2.1	1.1	0.7
Total (mm)	338	418.7	436.0	288.0	-	-	-	-	1.7	1.8	1.2
Average (ºC)	-	-	-	-	14.7	16.5	16.0	15.3	-	-	-

*Average of 1961-90 period according to Lithuanian Hydrometeorological Service.

was late and rainy. Due to cool and rainy weather the plants grew slowly, only in the third decade did warmer than usual weather accelerate the growth and development of plants. In June precipitation was just 26% of the norm and in July – 88% of long-term norm. However, in August the quantity of precipitation was more than twice the long-term norm.

During 2007 weather conditions as well as distribution of precipitation were stable. The air temperature was lower by 0.5ºC in comparison to that in 2006, but higher by 1.3ºC than the long-term average. The year was very wet: the quantity of precipitation was more than 29% of the long-term norm. Precipitation exceeded the long-term average of a month 1.75 times in May and 1.86 times in July. In August the quantity of precipitation was close to long-term average and in September – 74% of long-term norm of this month.

The year of 2008 was cooler and less humid than 2006 and 2007, though during the entire growing season, except May, air temperature exceeded the long-term average by 0.6ºC. In May, July, and September the quantity of precipitation was lower (approximately 55% of long-term norm), and in June and August – higher (20.6% and 27.3%, respectively) than the long-term rates. During the aforementioned period the amount of precipitation was equal to 85% of long-term norm of a growing season and to 66% of precipitation norm of the growing season in 2007.

The results obtained were subjected to statistical analysis (LSD, program ANOVA) and consequently compared using the least significant difference test at the probability level of 95% (LSD_{05}, $p = 0.05$) and 99% (LSD_{01}, $p = 0.01$).

Results and Discussion

During the period of vegetation in 2006-08 the general soil moisture content depended on meteorological conditions; the annual differences of soil moisture content at the 0-40 cm layer in the fields mulched with straw and in non-mulched fields were statistically significant ($p = 0.01$) (Table 3). Significant annual differences ($p = 0.05$) of soil moisture content were established in the plots mulched with straw and the polyethylene layer. There was no statistically significant difference between annual soil moisture content in the field mulched with polyethylene and in the non-mulched field.

Table 3. Soil moisture content at 0-40 cm and 0-10 cm layers in strawberry field during 2006-08.

Year	Treatment	Soil moisture at 0-40 cm layer, (%)	Soil moisture at 0-10 cm layer, (%)
2006-08	Control (A)	16.2 a	16.4 a
2006-08	Straw (B)	18.0 b	19.9 b
2006-08	Black layer (C)	16.5 a	17.1 a
2006	Control (A)	17.1 a	16.4 a
2006	Straw (B)	18.9 b	19.2 b
2006	Black layer (C)	17.0 a	16.3 a
2007	Control (A)	17.2 a	18.2 a
2007	Straw (B)	18.5 b	21.3 b
2007	Black layer (C)	16.9 a	18.2 a
2008	Control (A)	14.5 a	14.7 a
2008	Straw (B)	16.9 b	18.99 b
2008	Black layer (C)	15.6 ab	16.61 a

*for the same period of investigation within the same column, the values with different letters are significantly different at $p< 0.05$

Fluctuation of the soil moisture at 40 cm depth is depicted in Fig. 1 to give some insight on the soil moisture depletion pattern in mulched and non-mulched plots. The soil moisture of the active soil layer (0-40) varied from 10.0% to 22.6%. The highest average soil moisture content within three years was 18.0% in the plot mulched with straw (B), while the lowest one – 16.2% – in the plot without mulching (A). Average soil moisture content in the plot mulched with black polyethylene was 16.5% (C) and this confirms the findings of former researchers stating that mulch increases soil moisture content. The results showed that straw mulch of 10 cm thickness significantly reduces evaporation from the 0-15 cm depth during the hot, rainless 10-day period at the same time, allowing moisture to remain in the soil longer for plant use. Mulch reduces evaporation where the soil moisture content at the surface is maintained at a high level, but has little influence on evaporation in less humid regions.

The biggest variation of soil moisture content was at the top (0-10) soil layer – from 8.9 to 27.5%, and the difference between averages of soil moisture content in treatments varied from 14.7% (non-mulched in 2008) to 21.3% (mulched with straw in 2007) (Table 2). In the soil layers of 10-20, 20-30, and 30-40 cm depth soil moisture content differed about 2%. The straw mulch increased soil water storage. Every year average soil moisture content was higher in the layers of 0-10, 10-20, and 30-40 cm in the field mulched with straw, and only in the field mulched with black polyethylene was the highest soil moisture content in the 20-30 cm layer (Fig. 1).

Detailed soil moisture dynamics in every soil layer during 2006-08 are presented in Fig. 2.

Greater soil moisture content of surface covered plots was a result of increased water intake and reduced rate of evaporation. However, it should be considered that depletion and variation of soil moisture content in the top soil layer depend a lot on climatic conditions during the vegetation period. During humid periods of 2006 and 2007 the top soil layer moisture was similar and not significant in the plot mulched with polyethylene layer and without mulch, and only in the plot mulched with straw was it significantly higher ($p = 0.01$) in comparison to that in the plots mulched with the polyethylene layer and in the non-mulched plot. During 2008 the difference of average soil moisture content in mulched and non-mulched plots reached 2% (Table 3).

The present study has revealed that appropriate mulching of top soil layer is quite useful in strawberry fields, and helps to increase significantly ($p = 0.05$) the total strawberry yield of two years. The maximum yield of two years is obtained in the field mulched with black polyethylene layer, at 1,805 g/plant; the field mulched with straw produced the minimum yield of 1,036 g/plant; yield in the strawberry field without mulches was 1,115 g/plant. The obtained results indicate that mulching with black polyethylene layer results in significantly higher total yield per plant than in the case of non-mulching. The two-year yield harvested from the field mulched with black polyethylene layer was higher by 60% than that in non-mulched field and by 56% than that in the field mulched with straw (Table 4). No significant difference has been established between yields of non-mulched strawberries and the ones mulched with straw. The difference between averages of one berry weight varies during the period of investigation as it depends on meteorological conditions and biological features of plants (the first and the second growing season). Total weight of one berry is statistically significant in comparison of mulched and non-mulched variants. The total number of berries per plant increases 1.4 times in the field mulched with black polyethylene layer and the lowest number of berries is produced in the plot mulched with straw if compared to the control (no-mulching).

Table 4. Strawberry yield per plant.

Year	Field of investigation	Total strawberry yield per plant (g)	Average individual berry weight (g)	Fruit number per plant
2007-08	Control (A)	1,114.65 a	8.48 a	63.1
2007-08	Straw (B)	1,035.61 a	9.32 b	60.9
2007-08	Black layer (C)	1,850.57 b	9.74 b	85.9
2007	Control (A)	465.23 a	9.33 a	44.9
2007	Straw (B)	284.93 a	11.04 b	31.2
2007	Black layer (C)	829.83 b	9.23 ab	82.0
2008	Control (A)	649.42 a	7.92 a	81.2
2008	Straw (B)	750.68 a	8.23 a	90.6
2008	Black layer (C)	1,020.74 b	10.07 b	89.8

*for the same period of investigation within the same column, the values with different letters are significantly different at $p < 0.05$.

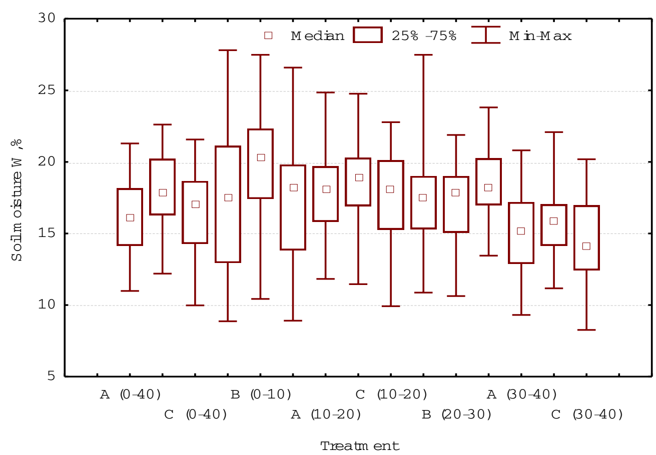

Fig. 1. Effects of mulches on soil moisture content in different soil layers during 2006-08: A – without mulch, B – straw mulch, C – black polyethylene layer.

Though the highest soil moisture content was in the field mulched with straw, the fruit number decreased 1.4 times, individual berry size and yield per plant was lower by 56% as those obtained in the field mulched with black polyethylene layer (Table 4). Such a difference could be determined by too high levels of soil moisture and different thermal regime of the soil. It is known that soil temperature influences horticultural crop production. Soil temperatures under black plastic mulch during the daytime are generally 2.8ºC higher at 5 cm depth and 1.7ºC higher at 10 cm depth as compared to those of bare soil [7, 22]. So some effects of black polyethylene layer mulch might be

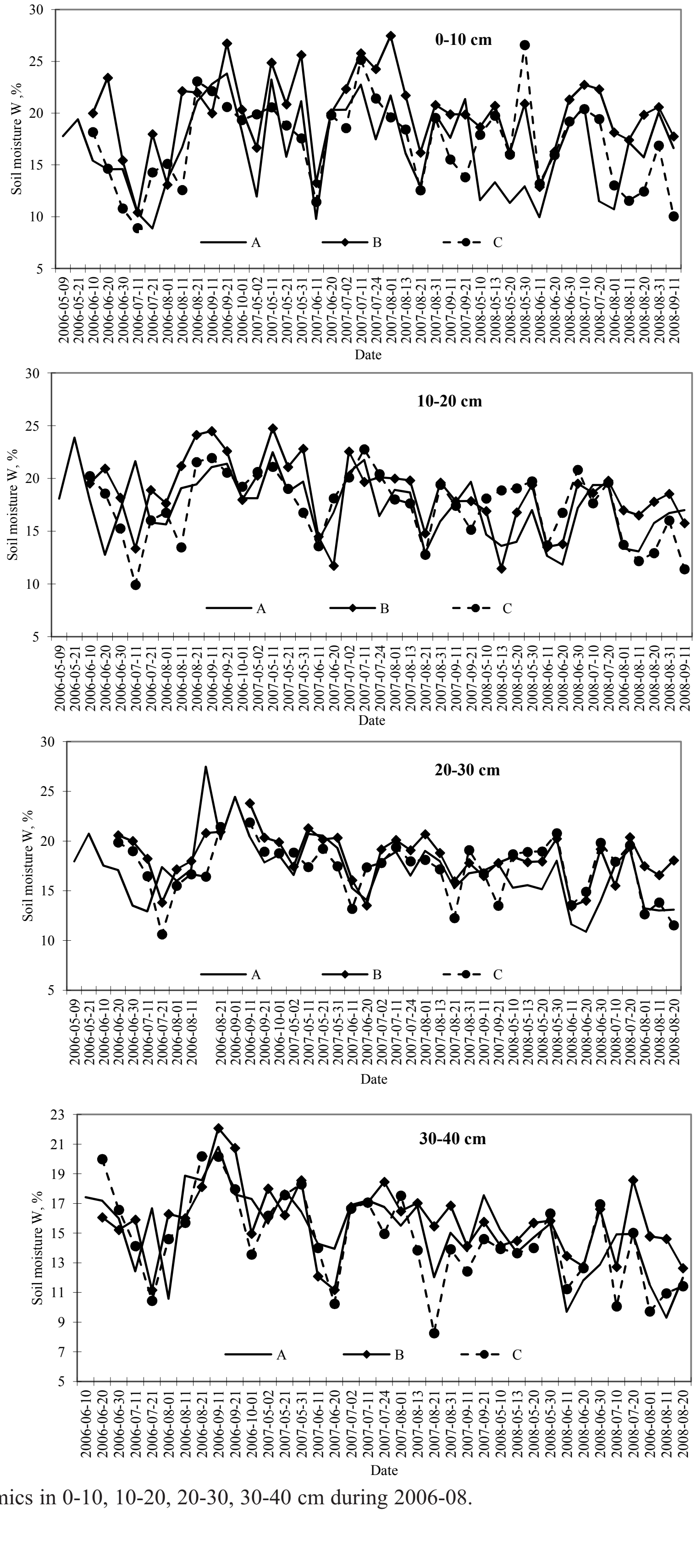

Fig. 2. Soil moisture dynamics in 0-10, 10-20, 20-30, 30-40 cm during 2006-08.

attributed to the fact that higher soil temperature results in better growth of plants, which might have favored higher total fruit yield and bigger berries than those mulched with straw or non-mulched ones. Additionally, during dry periods plastic mulch reduces soil evaporation and usually is covered with condensed water droplets. This water is transparent to incoming short-wave radiation, but is opaque to outgoing long-wave infrared radiation, so that much of the heat lost to the atmosphere from bare soil by infrared radiation is retained by plastic mulch. And in contrast – the lower soil temperature and higher soil moisture result in lower strawberry yield under straw mulch. According to [20], the maximum soil temperature in the surface layer is 4-6ºC lower when mulched with rice straw rather than in the non-mulched plots. The low transmissivity of the mulch results in a larger fraction of solar radiation absorbed at the top of the mulch layer. At 30 cm depth soil is 2-3ºC cooler in the mulched than in the non-mulched plots [7, 20]. Such results are confirmed by [23]. According to their research, different mulches can lead to differences in canopy temperature, soil temperature, and moisture content, and the quantity and quality of light transmitted, reflected, or absorbed. These differences, in turn, might have affected plant growth, development, fruit quality, and carbohydrate metabolism in strawberry plants during the present investigation.

The increased strawberry fruit yield in the present study could not be explained on the basis of availability of nutrients as the nutrient content was equalized at the time of planting, and analysis of soil samples after planting confirmed that the concentrations of macronutrients in all plots were statistically the same (data not presented). The investigation of soil nutrient content was done in 2008 – the third season of strawberry growing. The concentrations of nitrogen, phosphorus, and potassium in 2008 are presented in Fig. 3.

As expected, the lowest pH was under straw mulches, but in all fields was between 6.3-6.8. The level of potassium was middle, but mulching increased the amount of potassium during the vegetation period. The straw has

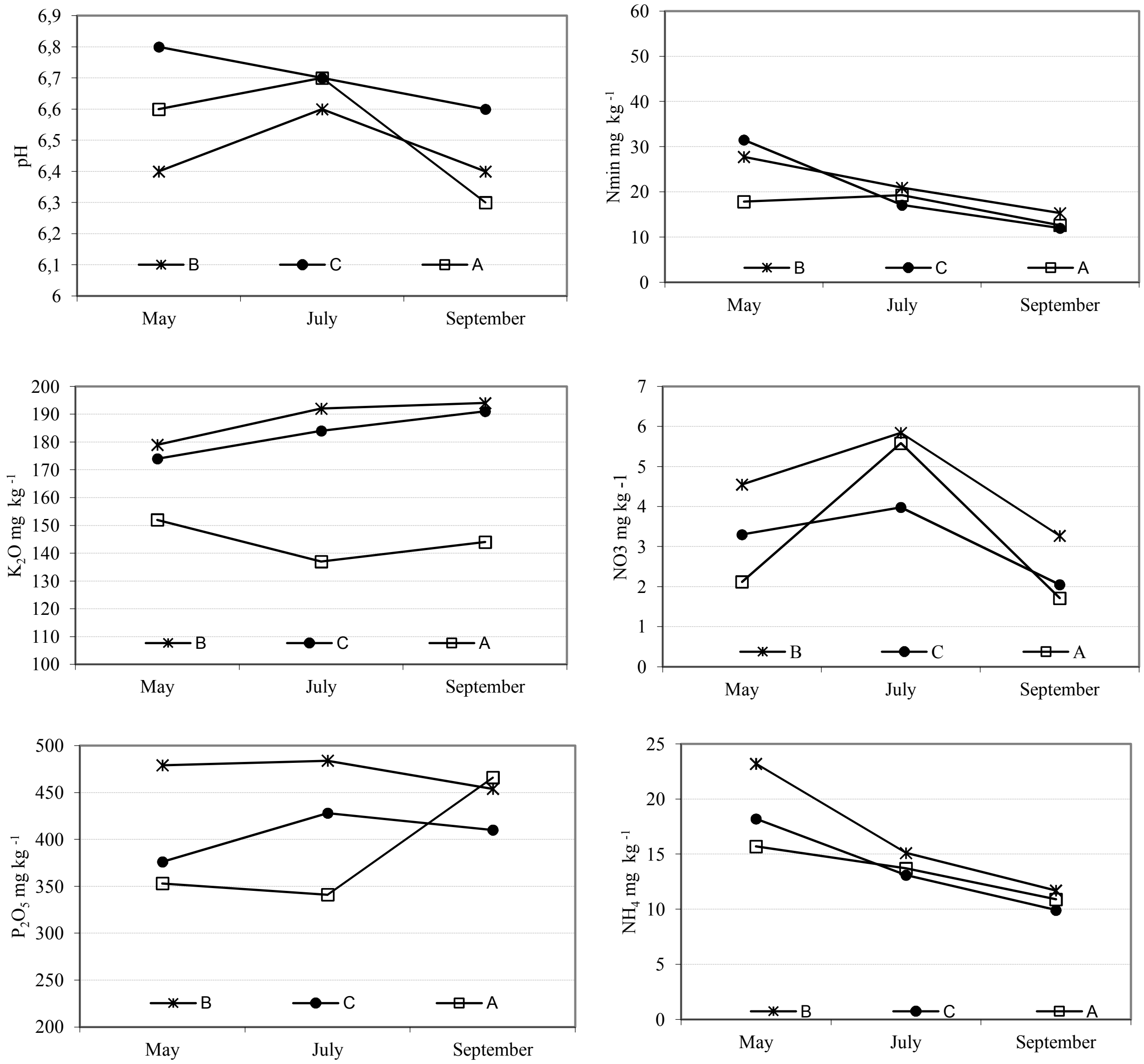

Fig. 3. Concentrations of macronutrients in 2008.

tendency to restore the major content of potassium as well as a small amount of nitrogen and phosphorus [24]. The amount of phosphorus was very high during all experimental time and did not change a lot during the vegetation period. In all fields the tendency of nitrogen dynamics was similar and tended to decrease during the vegetation period.

The obtained results clearly indicate that appropriate mulching is very important and during humid periods the polyethylene layer is preferred to straw mulches. Having completed this study, it can be assumed that during dry periods mulching of strawberries could be more beneficial as the water-conserving effect of mulch may not be discernible in water during sufficient years, but can still be particularly beneficial in dry years. And in occasional contrast, the water-conserving effect can be detrimental when it exacerbates poor drainage and water logging conditions.

Conclusions

From the above-mentioned results and discussion the following conclusions can be drawn:

1. The appropriate mulching of the top soil layer in a sub-humid area is quite useful as one of the components of integrated soil and water management system. Even during wet and humid periods of 2006-08, appropriate mulches helped keep a more favourable soil moisture regime for strawberries, getting higher fruit yield. The best results were obtained from the plots mulched with black polyethylene.
2. Soil moisture of the active soil layer (0-40) in the strawberry field during 2006-08 varied from 10.0% to 22.6%. The highest average soil moisture content within three years was 18.0% in the field mulched with straw, the lowest one – 16.2% in the field without mulching, and 16.5% in the plot mulched with black polyethylene. The soil moisture content differences in the 0-40 cm layer were significant in the field mulched with straw and in the non-mulched field. There was no statistically significant difference of soil moisture content in the field mulched with polyethylene and in the non-mulched field.
3. Mulching with straw increased soil moisture content during a humid period and can lead to a decrease of total strawberry yield. The two-year yield gained from the field mulched with black polyethylene layer was higher by 60% than that in non-mulched, and by 56% when mulched with straw field. The maximum – 1,805 g/plant two-year yield was obtained in the field mulched with black polyethylene layer, mulching with straw produced minimum yield – 1,036 g/plant, strawberries without mulches produced 1,115 g/plant.
4. The average differences of one berry weight were significant between mulched and non-mulched plants. The total number of berries per plant was 1.4 times bigger in the field mulched with black polyethylene layer and lower in the field mulched with straw in comparison to the non-mulched field.

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