Volodymyr Nadykto
Editor

Modern Development Paths of Agricultural Production

Trends and Innovations

Springer

Editor
Volodymyr Nadykto
Tavria State Agrotechnological University
Melitopol, Ukraine

ISBN 978-3-030-14917-8 ISBN 978-3-030-14918-5 (eBook)
https://doi.org/10.1007/978-3-030-14918-5

Library of Congress Control Number: 2019935551

This Springer imprint is published by the registered company Springer Nature Switzerland AG
The registered company address is: Gewerbestrasse 11, 6330 Cham, Switzerland

Effect of Living Mulch on Chlorophyll Index, Leaf Moisture Content and Leaf Area of Sweet Cherry (*Prunus avium* L.)

Tatyana Gerasko, Lyudmila Velcheva, Liudmyla Todorova, Lyubov Pokoptseva and Iryna Ivanova

1 Introduction

Achieving future of safe environment depends on conserving soil, water, and biological resources. Soil is a key component of sustainability. Mulching is one of the methods to protect and enhance the productivity of the soil. Different mulches are widely used in agriculture due to the countless advantages they have [1–4]. There is an increasing interest for use of living mulches in orchards. Based on reports in the literature, we conclude that living mulches increase humification and reduce denitrification and runoff, thus enhancing soil nitrogen availability and water regulation [5–10]. Natural grass cover can act as a living mulch: It is shown that spontaneous vegetation cover enhanced the physical quality of orchard soil [11], improved AM fungal propagules, soil organic carbon, and soil enzyme activities more effectively than did sod culture [12]. Spontaneous grass does not require sowing and irrigation, generates a large biomass, which can remain in place for replenish the soil with organic matter, prevents soil erosion [13], increases biodiversity [14], and provides pollination services [15]. However, it was reported that living mulches decreased soil water availability, impairing apple yields [16], decreased apricot yield, fruit weight, and economic output [17]. That is, trees compete with herbs for water [18, 19] and nutrients [20]. Thus, in an organic orchard, to support the natural biocenosis and to create optimal conditions for the reproduction of the soil fertility, it is necessary to keep soil under living mulch. But the effects of living mulch on the physiological parameters of fruit trees have not been fully explored. To fill this gap, this work aimed at examining the effects of living mulch in the organic orchard on the chlorophyll

T. Gerasko (✉) · L. Velcheva · I. Ivanova
Department of Fruit, Vegetable and Biochemistry, Tavria State Agrotechnological University, B. Khmelnitsky Av., 18, Melitopol, Zaporizhia Region 72312, Ukraine
e-mail: tetiana.herasko@tsatu.edu.ua

L. Todorova · L. Pokoptseva
Department of Plant Production, Tavria State Agrotechnological University, B. Khmelnitsky Av., 18, Melitopol, Zaporizhia Region 72312, Ukraine

V. Nadykto (ed.), *Modern Development Paths of Agricultural Production*,
https://doi.org/10.1007/978-3-030-14918-5_66

index, leaf moisture content, and leaf area of sweet cherry (*Prunus avium* L.) in the conditions of the southern Steppe of Ukraine.

2 Materials and Methods

2.1 Site Description

The work was conducted from 2017 to 2018 in the southern steppe of Ukraine (Melitopol district, Zaporozhye region) in the experimental orchards of Taurian State Agrotechnological University, which is intended for research purposes. The soil cover of the investigated area is the chestnut soils, which are very low humus. Soils have a weakly alkaline reaction of soil solution (pH varies within 7.1–7.4). On the background of a light granulometric composition, the humus content in the upper humus horizon is 0.6%. The analysis of aqueous extraction revealed that the total content of water-soluble salts does not exceed 0.015–0.024%. Analyzing all physical and agrochemical properties, we can conclude that the soils are suitable for growing sweet cherries. The long-term mean air temperature is +9.6 °C. The summer months (June, July, August) have an average daily air temperature of 20–22 °C. Winters are warm with frequent thaws. The coldest months are January and February. During these months, mean annual air temperature ranges minus 3.7–4.3 °C, but the minimum temperature is reduced to minus 33 °C. Mean annual precipitation for the last 10 years was approximately 350–450 mm.

2.2 Orchard Floor Management

Plant material for research was sweet cherry (*Prunus avium* L.) cultivars "Valery Chkalov"/Prunus mahaleb and "Dilemma"/Prunus mahaleb planted in 2011 at 7 m × 5 m. The experiment was designed as a randomized complete block with two treatments, in triplicate. Each experimental plot had an area of 210 m^2 (7 m × 30 m). Each plot contained 10 sweet cherry trees. The experiment included two different orchard floor management systems (OFMS): Standard mechanical cultivation—one discing at a 15-cm depth followed by harrowing + manual weeding during the growing season (MC) was compared with living mulch—spontaneous vegetation cover (LM). The natural vegetation of grasses was mowed four times during the growing season, and the clippings were left on the ground for decomposition. Any other management was identical in each treatment. Synthetic fertilizers and chemical plant protection products were not used.

tetiana.herasko@tsatu.edu.ua

2.3 Sampling Measurements and Data Calculation

Leaves for analysis were collected in the first decade of August, with the full development of the leaf surface. The leaf area was determined by the method of cuttings: Ten leaves of each tree were harvested from the middle of the annual shoots on the southern side of the crown and transported to the laboratory for analysis. The leaves were weighed, punched with punch (the area of the cutting was 1 cm^2). Cuttings were weighed, and the area of the leaves was calculated by the ratio of the mass of leaves and the mass of the cuttings. The parameters of the water regime of the leaves were determined ravimetrically, as described by G. K. Karpenchuk and A. V. Melnyk: The total moisture content was determined by oven drying (105 °C) until constant weight; the relative turgrescence was calculated as the ratio of the total moisture content to the moisture content after the 24-h saturation in a wet chamber; the moisture deficit—the ratio of moisture absorbed by the leaves (after a 24-h saturation in a wet chamber) to the total moisture content after a 24-h saturation in a humid chamber; the water-retaining ability—the ratio of lost moisture (after a 24-h wilting) to the total moisture content [21]. The content of photosynthetic pigments (chlorophylls *a*, *b* and carotenoids) in the leaves was estimated by determination of visible and near UV light absorption capacity of leaf acetone extracts spectrophotometrically in the biochemical laboratory of the Taurian State Agrotechnological University according to generally accepted methods [22]. Biochemical analyses were conducted in three biological replicates. Means for the treatments were compared using the least significant differences (LSD) and Student's criterion, and significant differences were determined at $P < 0.05$ probability level. All data were analyzed using the Microsoft Excel 2010 [23].

3 Results and Discussions

Tables 1 and 2 show data on the content of photosynthetic pigments in sweet cherry leaves. The content of chlorophylls and the sum of chlorophylls *a* and *b* in the leaves of both studied cultivars in the experimental variants did not differ significantly in 2017 or 2018. But it should be noted significantly more carotenoid content in the leaves of the cultivar "Valery Chkalov" in 2017 in LM. The enhanced synthesis of carotenoids is a nonspecific response of plants to stress [24]. Due to the increase in the carotenoid content, the chlorophyll index of this cultivar in LM conditions was significantly lower compared to MC in 2017. At same time (in 2017), for the cultivar "Dilemma," on the contrary, it was noted the increase of the chlorophyll index in LM and a significantly higher content of carotenoids in MC. Further studies of cultivars characteristics are needed to find out the reason for this revealed trend. We hypothesize that this is due to the activity of soil microorganisms, symbiotic mycorrhiza. It is known that LM creates optimal conditions for the development of

Table 1 The content of photosynthetic pigments in sweet cherry leaves cultivar "Valery Chkalov"

OFMS	Chlorophyll a content (%)	Chlorophyll b content (%)	Carotenoids content (%)	Sum of chlorophylls $(a + b)$, %	Chlorophyll index $(a + b)/\kappa$
2017 Year					
MC	1.77 ± 0.16	1.73 ± 0.13	0.17 ± 0.01	3.49 ± 0.31	20.4 ± 0.06
LM	2.09 ± 0.17	1.51 ± 0.13	0.24 ± 0.02*	3.59 ± 0.16	14.7 ± 0.05*
2018 Year					
MC	1.19 ± 0.12	0.48 ± 0.05	0.30 ± 0.02	1.67 ± 0.17	5.5 ± 0.04
LM	1.12 ± 0.10	0.52 ± 0.05	0.27 ± 0.02	1.65 ± 0.16	6.2 ± 0.05*

Note *—The difference is significant at $P \leq 0.05$

Table 2 The content of photosynthetic pigments in sweet cherry leaves cultivar "Dilemma"

OFMS	Chlorophyll a content,%	Chlorophyll b content (%)	Carotenoids content (%)	Sum of chlorophylls $(a + b)$, %	Chlorophyll index $(a + b)/\kappa$
2017 Year					
MC	1.86 ± 0.12	1.39 ± 0.11	0.25 ± 0.04*	3.25 ± 0.32	13.3 ± 0.02
LM	1.81 ± 0.16	1.46 ± 0.14	0.14 ± 0.04	3.27 ± 0.33	24.1 ± 0.03*
2018 Year					
MC	0.88 ± 0.12	0.31 ± 0.05	0.25 ± 0.02	1.20 ± 0.12	4.86 ± 0.23
LM	1.22 ± 0.11	0.80 ± 0.14	0.25 ± 0.02	2.02 ± 0.12	8.21 ± 0.16*

Note *—The difference is significant at $P \leq 0.05$

soil symbiotic mycorrhiza [12], but different cultivars may have their own specific features regarding the formation of symbiosis with soil microorganisms.

It should be noted that the weather conditions of 2017 were relatively satisfactory with respect to moisture supply, especially in June, as opposed to 2018, when drought lasted throughout all summer months. Drought was reflected on the physiological state of leaves, which contained significantly less photosynthetic pigment. The content of chlorophylls under such severe conditions in 2018 was lower, and the carotenoids content was higher in both cultivars in both OFMS. It should be noted that the chlorophyll index was higher in LM in both cultivars in 2018, which indicates the positive effect of LM on the physiological state of sweet cherry trees.

Tables 3 and 4 show the parameters of the water regime of sweet cherry leaves. For the cultivar "Valery Chkalov," there was no significant difference between the MC and LM on the total moisture content, relative turgrescence, and moisture deficit. But under hiding conditions, we observed a significant increase in the water-retaining ability of leaves in 2017. This can be associated with an increase in the content of colloids in the tissues of leaves, which is an adaptive plants response to water deficit. Naturally, the deficit of moisture in the leaves was closely negative linked with the relative turgrescence ($r = -0.9$).

tetiana.herasko@tsatu.edu.ua

Table 3 Water regime in leaves of sweet cherry cultivar "Valery Chkalov"

OFMS	Total moisture content (%)	Relative turgrescence (%)	Moisture deficit (%)	Water-retaining ability (%)
2017 Year				
MC	58.7 ± 0.19	23.4 ± 1.38	76.6 ± 1.39	94.3 ± 0.61
LM	58.2 ± 0.65	21.3 ± 1.36	78.7 ± 1.37	96.5 ± 0.45*
2018 Year				
MC	54.3 ± 0.29	31.6 ± 0.35	68.4 ± 0.55	95.8 ± 0.79
LM	53.6 ± 0.47	30.7 ± 0.33	69.3 ± 0.42	95.2 ± 0.75

Note *—The difference is significant at $P \leq 0.05$

Table 4 Water regime in leaves of sweet cherry cultivar "Dilemma"

OFMS	Total moisture content (%)	Relative turgrescence (%)	Moisture deficit (%)	Water-retaining ability (%)
2017 Year				
MC	62.1 ± 0.22	25.7 ± 2.07	74.3 ± 3.08	93.3 ± 1.47
LM	54.8 ± 0.12*	27.5 ± 1.79	72.5 ± 1.79	91.7 ± 0.25
2018 Year				
MC	55.7 ± 0.35	30.9 ± 1.55	69.1 ± 1.99	94.5 ± 1.41
LM	51.6 ± 0.43*	26.6 ± 1.67*	73.4 ± 1.25*	97.7 ± 1.44*

Note *—The difference is significant at $P \leq 0.05$

The sweet cherry cultivar "Dilemma" was characterized by a significantly lower total moisture content in the leaves in LM during two years of research; the water-retaining capacity of leaves was increased in 2018. Since the decrease in the total moisture content and relative turgrescence in LM and severe drought in 2018 in the cultivar "Dilemma" was significant (unlike the cultivar "Valery Chkalov"), it could be noted that cultivar "Dilemma" is more vulnerable to drought conditions and competition with herbs. But in the scientific literature, there is a message that an increase in the dysfunction of the hydraulic system in the most vulnerable cultivars may represent a signal for enhancing the delivery of water to fruits, and in this case, water instead of moving into the leaves is delivered to the fruits [25].

To better explain the obtained data, we will analyze the results of determining the sweet cherry leaf area, presented in Table 5.

The leaf area was significantly less in LM for both studied cultivars in 2017. In 2018, there was no significant difference with MC, but the cultivar "Valery Chkalov" showed a tendency to decrease the leaf area in LM, and the cultivar "Dilemma," on the contrary—increased.

Table 5 Sweet cherry leaf area, m^2/tree

OFMS	Cultivar "Valery Chkalov"	Cultivar "Dilemma"
2017 Year		
MC	38.2	46.8
LM	29.0	32.4
$LSD_{0.5}$	3.05	3.74
2018 Year		
MC	60.8	51.7
LM	52.8	59.3
$LSD_{0.5}$	5.17	5.04

4 Conclusions

The content of carotinoids in 2017 was significantly higher in the leaves of the cultivar "Valery Chkalov" in LM and in the leaves of the cultivar "Dilemma" in MC and in 2018 was no significant difference in both cultivars.

The chlorophyll index in LM (compared to MC) was higher in the cultivar "Dilemma" in 2017 and in both cultivars under severe drought in 2018.

The water-retaining ability in 2017 (satisfactory moisture supply) was greater in LM in the leaves of the cultivar "Valery Chkalov," in 2018 (drought)—in the cultivar "Dilemma."

The leaf area was significantly less in LM for both studied cultivars in 2017. In 2018, a significant difference with MC was not noted.

The disadvantage of our study is the lack of data on the state of soil microorganisms, namely the symbiotic mycorrhiza in the rhizosphere of cherry trees, which could explain the revealed trends in the physiological state of the leaves.

References

1. Chen, Y., Wen, X., Sun, Y., et al.: Mulching practices altered soil bacterial community structure and improved orchard productivity and apple quality after five growing seasons. Sci. Hort. **172**, 248–257 (2014). https://doi.org/10.1016/j.scienta.2014.04.010
2. Granatstein, D., Sanchez, E.: Research knowledge and needs for orchard floor management in organic tree fruit systems. Int. J. Fruit Sci. **9**(3), 257–281 (2009). https://doi.org/10.1080/15538360903245212
3. Bakshi, P., Wali, V.K., Iqbal, M., et al.: Sustainable fruit production by soil moisture conservation with different mulches: a review. Afr. J. Agric. Res. **10**(52), 4718–4729 (2015). https://doi.org/10.5897/ajar
4. Oliveira, M.T., Merwin, I.A.: Soil physical conditions in a New York orchard after eight years under different groundcover management systems. Plant Soil **234**, 233–237 (2001). https://doi.org/10.1023/a:1017992810626

5. Qian, X., Gu, J., Pan, H.-J.: Effects of living mulches on the soil nutrient contents, enzyme activities, and bacterial community diversities of apple orchard soils. Eur. J. Soil Biol **70**, 23–30 (2015). https://doi.org/10.1016/j.ejsobi.2015.06.005
6. Yao, S.R., Merwin, I.A., Bird, G.W., Abawi, G.S., Thies, J.E.: Orchard floor management practices that maintain vegetative or biomass groundcover stimulate soil microbial activity and alter soil microbial community composition. Plant Soil **271**(1/2), 377–389 (2005). https://doi.org/10.1007/s11104-004-3610-0
7. Nikiema, P., Nzokou, P., Rothstein, D.E. et al.: Soil microbial biomass as affected by groundcover management in a Fraser fir (*Abies fraseri* [Pursh] Poir) plantation after 1 year. Biol. Fertil. Soils **48**, 727. https://doi.org/10.1007/s00374-012-0666-5
8. Turrini, A., Caruso, G., Avio, L., et al.: Protective green cover enhances soil respiration and native mycorrhizal potential compared with soil tillage in a high-density olive orchard in a long term study. Appl. Soil. Ecol. **116**, 70–78 (2017). https://doi.org/10.1016/j.apsoil.2017.04.001
9. Huang, J., Wang, J., Zhao, X., et al.: Effects of permanent ground cover on soil moisture in jujube orchards under sloping ground: a simulation study. Agric. Water Manage. **138**, 68–77 (2014). https://doi.org/10.1016/j.agwat.2014.03.002
10. Atucha, A., Merwin, I.A., Brown, M.G., et al.: Soil erosion, runoff and nutrient losses in an avocado (Persea americana Mill) hillside orchard under different groundcover management systems. Plant Soil **368**(1–2), 393–406 (2013). https://doi.org/10.1007/s11104-012-1520-0
11. Fidalski, J., Tormena, C.A., da Silva, A.P.: Least limiting water range and physical quality of soil under groundcover management systems in citrus. Sci. Agric. (Piracicaba, Braz.) **67**(4), 448–453 (2010). https://doi.org/10.1590/s0103-90162010000400012
12. Wang, P., Wang, Y., Wu, Q.S.: Effects of soil tillage and planting grass on arbuscular mycorrhizal fungal propagules and soil properties in citrus orchards in southeast. China Soil Till. Res. **155**, 54–61 (2016). https://doi.org/10.1016/j.still.2015.07.009
13. Garcia-Diaz, A., Bienes, R., Sastre, B.: Nitrogen losses in vineyards under different types of soil groundcover. A field runoff simulator approach in central Spain. Agric. Ecosyst. Environ. **236**, 256–267 (2017). https://doi.org/10.1016/j.agee.2016.12.013
14. Juarez-Escario, A., Conesa, J.A., Sole-Senan, X.O.: Management as a driver of functional patterns and alien species prominence in weed communities of irrigated orchards in Mediterranean areas. Agric. Ecosyst. Environ. **249**, 247–255 (2017). https://doi.org/10.1016/j.agee.2017.07.042
15. Saunders, M.E., Luck, G.W., Mayfield, M.M.: Almond orchards with living ground cover host more wild insect pollinators. J. Insect. Conserv. **17**, 1011–1025 (2013). https://doi.org/10.1007/s10841-013-9584-6
16. Zelazny, W.R., Licznar-Malanczuk, M.: Soil quality and tree status in a twelve-year-old apple orchard under three mulch-based floor management systems. Soil Till. Res. **180**, 250–258 (2018). https://doi.org/10.1016/j.still.2018.03.010
17. Du, S., Bai, G., Yu, J.: Soil properties and apricot growth under intercropping and mulching with erect milk vetch in the loess hilly-gully region. Plant Soil **390**, 431 (2015). https://doi.org/10.1007/s11104-014-2363-7
18. Forey, O., Metay, A., Wery, J.: Differential effect of regulated deficit irrigation on growth and photosynthesis in young peach trees intercropped with grass. Eur. J. Agron. **81**, 106–116 (2016). https://doi.org/10.1016/j.eja.2016.09.006
19. Hammermeister, A M.: Organic weed management in perennial fruits. Sci. Hort. **208**, 28–42 (2016). https://doi.org/10.1016/j.scienta.2016.02.004
20. Ni, X., Song, W., Zhang, H., Yang, X., Wang, L.: Effects of mulching on soil properties and growth of tea olive (*Osmanthus fragrans*). PLoS ONE **11**(8), e0158228 (2016). https://doi.org/10.1371/journal.pone.0158228
21. Karpenchuk, G.K., Melnyk, A.V.: Uchety, nabliudenyia, analyzy, obrabotka dannykh v opytakh s plodovymy i yahodnymy rastenyiamy: Metodycheskye rekomendatsyy. Uman. s.-kh. yn-t, Uman (in Russian) (1987)
22. Pochynok, H.N.: Metody biokhymycheskoho analyza rastenyi. Nauk, Dumka, Kiev (in Russian) (1976)

23. Lakyn, H.F.: Biometryia. Vysshaia shkola, Moscow (in Russian) (1990)
24. Gross, J.: Carotenoids. In: Pigments in Vegetables. Springer, Boston, MA (1991). https://doi.org/10.1007/978-1-4615-2033-7_3
25. Peschiutta, M.L., Bucci, S.J., Scholz, F.G., et al.: Leaf and stem hydraulic traits in relation to growth, water use and fruit yield in *Prunus avium* L. cultivars. Trees-Struct. Funct. 27(6), 1559–1569 (2013). https://doi.org/10.1007/s00468-013-0904-y