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Economic Viability of the Hydromulching in Artichokes

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Abstract: *Although its utility, excessive use of low-density polyethylene mulches is contributing to the accumulation of high amounts of plastic wastes and environmental problems for agricultural ecosystems. The objective of this work was to study the economic viability of the use of different hydromulches in an artichoke crop. Three blends were prepared by mixing paper pulp and cardboard with different additives: wheat straw (WS), rice hulls (RH), and substrate used for mushroom cultivation (MS). These were compared with low-density polyethylene (Pe), a treatment without mulching on bare soil where hand weeding was performed (HW), and treatment without mulching on bare soil where herbicide was applied (H). The results indicate that the use of hydromulch in an artichoke crop represents a good alternative for reducing plastic waste in agriculture. The net profits of the hydromulch treatments (MS, WS, RH) were higher than for HW and H, and slightly lower than for Pe.*

1. INTRODUCTION

Treatment of herbicides in agricultural areas can be a cause of soil and water contamination and their use have to decrease. The use of plastic mulching in horticultural crops is a very common practice due to its agronomic (Kader et al., 2017; Kannan, 2020), it is a good technology used to manipulate the crop environment to reduce weeds, it also increases the yield of the crop and improves the quality of the product, controlling the temperature and retaining the humidity of the soil. Plastic mulches provide higher performance and quality of products and, consequently, greater economic value for farmers, with linear low-density polyethylene being the most widely used material for growing vegetables in the southeast of Spain (López-Marín et al., 2012). Despite the multiple benefits of polyethylene in cultivation, the use of these materials carries long-term detrimental effects on soil quality and environmental contamination due to their removal (Steinmetz et al., 2016). The main disadvantage of using polyethylene is its disposal after use. Material that is not recycled or disposed of properly can break and cause soil degradation in the agroecosystem, with the consequent loss of crop yield (Scalenhge, 2018). Modern agriculture has to increase yields and product quality while reducing environmental impacts. An alternative could be liquid mulches or "hydromulches" consisting of a liquid mixture of recycled paper pulp in combination with different types of agricultural residues, which later solidify in the soil, simulating the effect of mulches on the crop. Hydromulch has been used in many land rehabilitation projects - for instance, to mitigate post-fire runoff and erosion (Warnick, 2006). Hydromulch is an innovative mulching technology in the horticultural area, which, in preliminary studies has proven to be an efficient strategy for increasing yield in horticultural crops (Romero et al., 2019).

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One of the most important crops in the Mediterranean area is the artichoke. The major production and consumption areas worldwide are located in Spain and Italy (FAOSTAT, 2021). However, the consumption of artichoke has also increased in other locations in the last few years, due to its organoleptic, nutritional, and nutraceutical properties (USDA, 2021).

This work aims to compare the economic outcomes of artichoke cultivation, with mulch (one plastic and three hydromulches), without mulch (with and without herbicide). For each of these, the yields of two consecutive years will be valued.

2. MATERIAL AND METHODS

Plants of artichoke (*Cynara candunculus* var. scolymus L.) cv. Symphony (Nunhens-BASF), grown from seed, were cultivated at the IMIDA agricultural experimental farm, located in Murcia (Spain) (latitude 37° 45'N, longitude 0° 59'W). They were transplanted on 8 August in the first year and on 1 August in the second, the final harvests taking place on 28 and 16 March, respectively. The crop density was 5,000 plants/ha. A standard nutrient solution for artichoke was used, applied through an underground drip irrigation system at a depth of 5 cm, with emitters of 4 L/h.

The hydromulches consisted of different mixtures (blends). Recycled paper pulp and paper pinus pulp were used as the basic components and sodium silicate was used as a matrix for the hydromulch samples. To prepare the blends, in addition to paper pulp, the following crop products were used: wheat straw (WH), used mushroom (Agaricus bisporus) substrate (MS), and rice husk (RH). Three random cultivation blocks were established, with five treatments each: two-color low-density Pe (white/black, top/bottom), the three hydromulches (WS, RH, and MS), a treatment without mulching on bare soil where hand weeding was carried out (HW), and treatment without mulching on bare soil where a herbicide was used (H). Each block comprised 25 plants.

Economic analysis. A cost-benefit has been carried out comparing incomes with costs for each treatment. Weekly production has been considered to obtain the income, multiplying it by the weekly average price, available on the web page of the Murcian Government (CARM, 2021). The average weekly prices of the latest 20 years have been considered. Regarding the costs, they have been classified into overhead costs and annual costs. For the first ones, annual depreciation has been considered, as the result of dividing the purchase price allocation of each element by its useful life, in particular, toolshed (with a useful life of 25 years), an irrigation pumping head (15 years), a localized irrigation network (10 years), a regulating reservoir (30 years), and various auxiliary materials (5 years). For the annual costs, the average cost of the two studied years has been considered. Keeping in mind the biennial character of the artichoke cultivation, costs of preparation and planting as well as of the mulching materials and their installation were distributed between the two years. For mulching costs, it has been assumed that the covering of one hectárea requires 4,600 m^2 of hydromulche. In order to better comprehend, costs were classified into common costs (not affected by the treatments) and specific treatment costs. On the other hand, each year, four treatments with herbicides and five with phytosanitary products were carried out where required. The considered harvesting cost has been 0.1 € kg^{-1} and the cost of the water 0.23 € m^{-3}. Regarding the cost of personnel, it has been considered that a worker could manage 20 ha with an hourly cost of 7.5 € h^{-1}. Finally, this paper considers an hourly cost of the tractor of 36 € h^{-1}

Statistical analysis. For the analysis of the yield and income of each treatment, the Levene test was used for the analysis of the homogeneity of variances. The non-existence of significant differences in the variance ($p>0.05$) allowed the application of a one-way ANOVA to determine the existence of significant differences in yield and income among the treatments. When a difference was significant ($P<0.05$), the treatment means were separated by Tukey's honestly significant difference (HSD) multiple-range test, using lowercase letters to indicate significant differences between treatments. The statistical package used was SPSS (Chicago, IL, USA).

3. RESULTS

Income. Figure 1 shows the weekly production of each treatment (2019). Production of the year 2019 (2020 is not shown) begins the second week of the year (mid-January) and increases from the fifth (early February), reaching the highest production from the seventh week (late September). Weekly changing production is very similar for all treatments. From the seventh week, prices decrease from 0.85 0.85 € kg-1 to 0.33 € kg-1. Such decreases are due mainly to the supply increase. According to Prestamburgo and Saccomandi (1995), the greater the offer, the faster the decline in agricultural prices. Production is similar for the Pe and organic mulches, being a bit lower in H (15%) and HW (29%). The three organic mulches give similar results. The product of the weekly prices for the productions allows obtaining the income, the summary of which is shown in Figure 3. As can be seen, H and HW treatments present similar incomes to Pe and can be used as their substitutes.

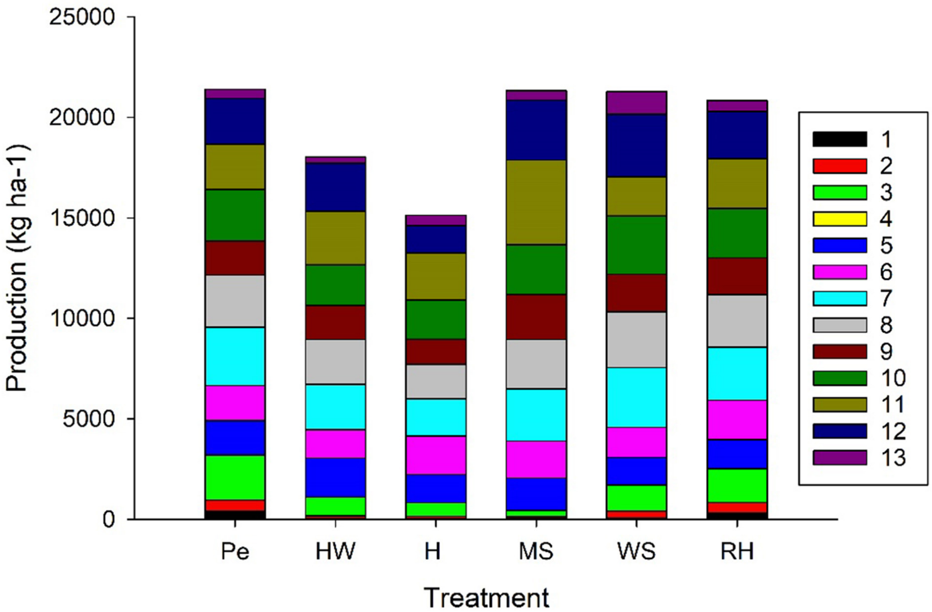

Figure 1. Weekly production (weeks 1 to 13 of the year 2019)

In order to analyze the possible differences between the productions of each treatment, the application of the Levene test has allowed verifying the homogeneity of the variances and the subsequent application of the ANOVA analysis that showed that there are significant differences between treatments ($p=0.000$). Finally, the application of the Tukey test showed that treatments H and HW gave significantly worse production, with no significant differences between the rest. The results were similar for the income analysis, which also showed that the H and HW treatments offered significantly lower results than the rest.

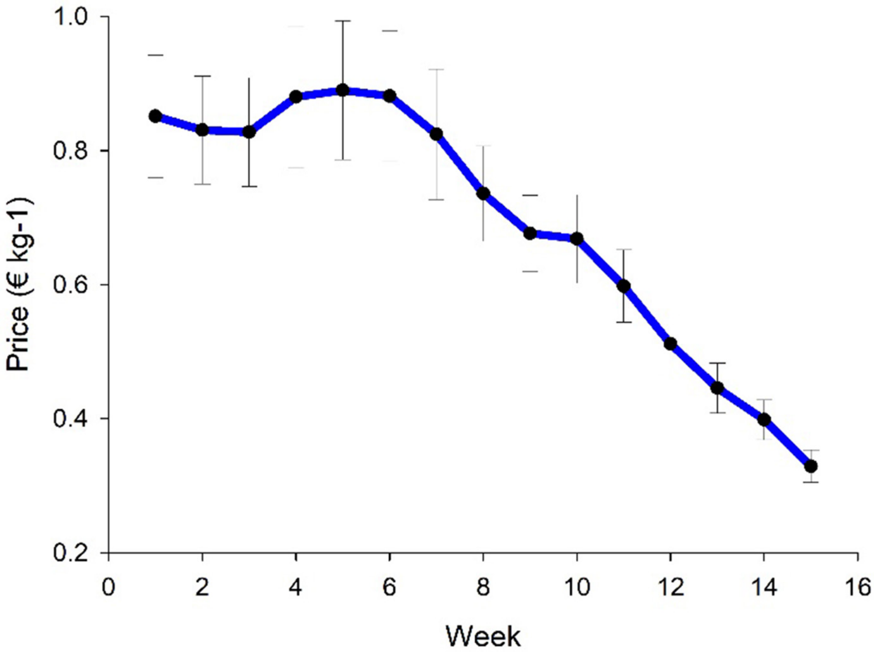

Figure 2. Weekly artichoke prices

Costs. The cost has been classified into overhead costs and annual costs. The overhead costs are shown in Figure 3. Localized irrigation networks are the largest with 302 € ha^{-1} with a useful life of 15 years.

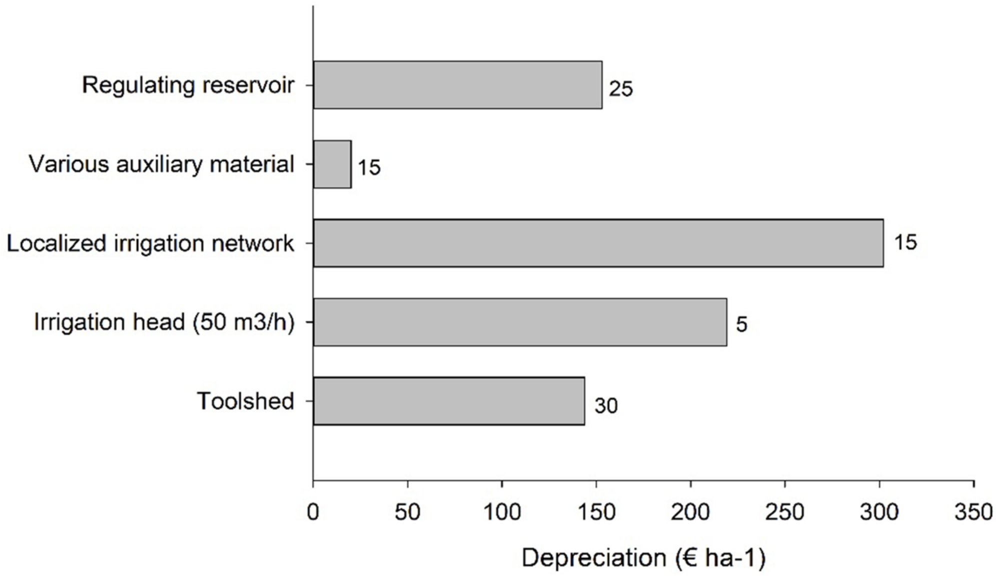

Figure 3. Overhead costs (€) and useful life (years)

Annual costs are summarized in Table 1, in which the specific costs analyzed in this work (mulching, mix, plastic Mechanical mulching, etc.) have been separated from the costs common to the six treatments (common cost). In this table, mix refers to recycled paper pulp, pinus paper pulp, and sodium silicate and self-production and installation of mulch (semi-mechanical). On the other hand, harvesting costs have been considered as a fixed cost of 0.1 € kg-1 regardless of the yield. In particular, the costs (without considering the structure costs) were lower for HW (8.60% lower than Pe) and H (25.07% lower than Pe) since mulch was not used. The treatments WS, RH, and MS had slightly higher costs than Pe (between 2.14 and 4.88%).

Table 1. Total costs per year

	Pe	HW	H	MS	WS	RH
Specific costs per treatment	4,600	3,624	1,756	5,154	4,843	4,878
Mulching material	610	0	0	553	219	259
Mix	0	0	0	2,475	2,475	2,475
Plastic mechanical mulching	570	0	0	0	0	0
Cost of removal of mulch	1,260	0	0	0	0	0
Hand weeding	0	1,800	0	0	0	0
Herbicides	0	0	232	0	0	0
Harvesting	2,160	1,824	1,524	2,126	2,149	2,144
Common costs	7,585					
Preparation and planting	1,853					
Machinery	749					
Personal cost (non-harvesting)	700					
Taxes	491					
Phytosanitiry products	636					
Fertilizers	719					
Maintenance	151					
Electrical energy	169					
Irrigation water	1,279					
Overhead costs	838					
Total Costs	12,185	11,210	9,341	12,739	12,428	12,463

Net profit. The highest net yield (Figure 4) has been obtained for Pe, followed by WS and RH (16.54 and 14.95% respectively lower than Pe), obtaining the lower values in HW and H (53.37 and 31.56% lower, respectively). The latter two, despite presenting lower costs than the rest, the net profit was lower because of the low income obtained. On the other hand, HW despite high revenues, did not obtain great net profit due to high costs. The MS treatment presents higher costs than the WS and RH due to the transport costs from the place where the substrate was obtained. This suggests the convenience of using the mulching in places close to its generation to avoid transport costs and externalities such as pollution.

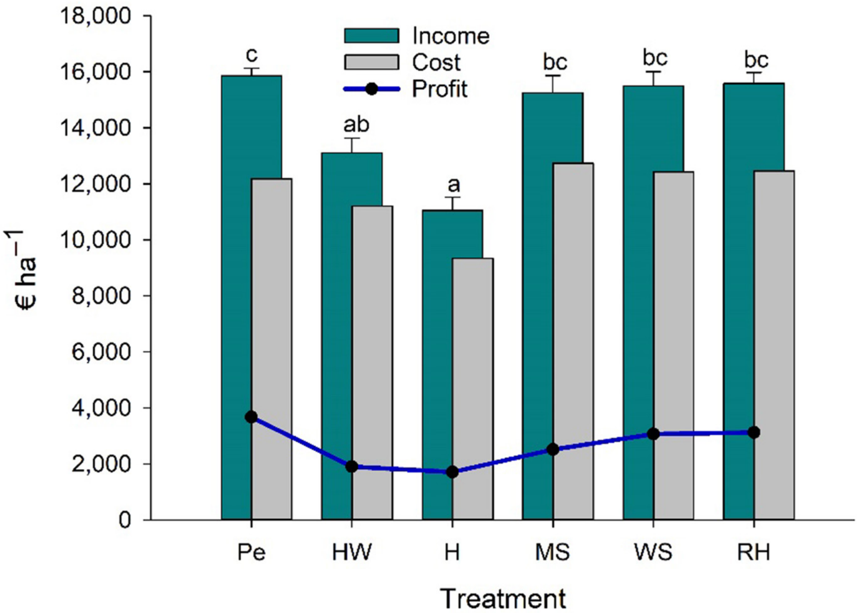

Figure 4. Income, cost and profit for each treatment

Mulching improves the soil moisture regime by limiting the evaporation rate of water at the surface; in general, mulching gives higher soil moisture contents compared to bare soil (Chakraborty, et al. 2008, Zaho et al, 2017), which means that the yields are lower in treatments without mulching, as happened in our work. The power of plastic mulches to retain soil moisture is greater than that of organic mulches (Chakraborty, R.C.; Sadhu, 1994). However, in our work, in both growing cycles, there were no statistical differences between the hydromulches and the treatment with plastic. This may have been because these organic mulches (hydromulches), with the intervention of the soil moisture and temperature, affected the dynamics of the soil organic matter, augmenting the contents of dissolved organic carbon (C) and nitrogen (N) through the decomposition of plant materials, as has been found with other organic mulches (Chantigny. 2003, Huang et al. 2008).

4. FUTURE RESEARCH DIRECTIONS

The environmental benefit of hydromulches is evident, and their production is very similar to polyethylene. However, its high costs prevent its commercial application, so future research must focus on reducing producer prices.

5. CONCLUSION

Hydromulches are a good alternative for artichoke cultivation, for the reduction of plastic waste. Their use can reduce the carbon footprint, and be more sustainable and profitable as well as being eco-friendly. The use of mulch increases the production in a similar way to polyethylene with regards to H (15% lower) and HW (29% lower), and, in addition, it gives environmental advantages. Organic mulching presents higher costs to Pe (up to 5% higher) and consequently, future research should be aimed at reducing these costs. It should be mentioned that their application must be carried out close to the generation of their components to avoid high transport costs. Profit of organic mulching (MS, WS, and RH) were higher to HW and H, but lower to Pe due to its higher costs. That's why, despite its undeniable environmental benefit, their implementation will not be effective till there is a cost cut.

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