*J. Agr. Sci. Tech. (2019) Vol. 21(2): 235-248*

# Cost-Benefit Analysis of Tomato Crops under Different Greenhouse Covers

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## ABSTRACT

**The tomato (*Solanum lycopersicum* L.) is one of the most popular and widely consumed vegetables in the world, being also the most common vegetable within the Mediterranean diet. The last few years have seen the appearance on the market of several types of agricultural plastic developed to alter the spectrum of radiation that enters the greenhouse, sometimes filtering it and, in other cases, intensifying certain wavelength bands. The objective of this study was to evaluate the production of tomato cultivated under different covers and to analyze the profitability of the yield, under each of them. A study was carried out in six tunnel greenhouses, with an area of 100 m$^2$ each, to evaluate the effect of different types of plastic roof, with different radiation properties. The yield of tomatoes was recorded and valued economically as a function of the mean prices of the Consejería de Agricultura de la Región de Murcia (CARM) (Department of Agriculture of the Region of Murcia) of the last years and one survey of the wholesale markets network (Mercas) and farmers, in order to know the weekly prices according to the caliber. The production costs of each of the alternatives were determined and the net present value of the yield and the annualized value were obtained. The highest annualized value was obtained with the UVA100%e cover (€24,856.04 per year), followed by UV90%e and PeTc (€18,931.49 and €16,205.53 per year, respectively). The LDe and Anti NIR covers provided the poorest results (€3,954.93 and €10,480.40 per year, respectively).**

**Keywords:** Greenhouse tomato, Photoselective films, Roofing materials, UVA100%e cover.

## INTRODUCTION

Tomato is the most popular vegetable on a worldwide basis. Its demand has increased continuously and, hence, so have its cultivation, yield, and commerce. At present, the international tomato trade is located in two specific areas with high purchasing power: The European Union (EU) and the United States. The main countries supplying the European Union are Spain, The Netherlands, Turkey, and Morocco - with 1.004, 1.013, 0.547, and 0.457 million tons, respectively (FAOSTAT, 2016). The more competitive prices of countries like Morocco and Turkey mean that tomato cultivation in southeastern Spain is not as profitable as it was until a few years ago. Among other factors, cheaper labor, poor working conditions, and authorization by the EU of the use in external countries of certain pesticides that are banned within the EU are gradually tipping the balance in favor of these emerging countries.

It is therefore very important to reduce inputs and increase the economic yields of crops while producing high quality products (Pahlavan *et al*., 2012). It is worth noting the importance of the

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[ DOR: 20.1001.1.16807073.2019.21.2.16.7 ]

choice of the type of greenhouse and the technology and implements of cultivation used within the productive ecosystem, since these will influence not only the yield but also the levels of certain nutritional compounds in the fruit (López-Marín *et al*., 2013).

The quality and quantity of light radiation influence crop growth and productivity. Roofing materials make an essential contribution to the productivity of greenhouse crops, enabling the creation of a microclimate in which both temperature and relative humidity are modified. This, together with the introduction of other new cropping technologies, such as the use of photoselective cover materials, makes it possible to improve yields (Del Amor *et al*., 2008). These photoselective films are also used to achieve other aims - such as the reduction of pesticide requirements (Fenoll *et al*., 2007; Fenoll *et al*., 2008) through selective spectral absorption for pest control (Antignus *et al*., 1998), the elongation of flower stems (Mascarini *et al*., 2013), and the extension of the growth period and delayed fruit ripening (Möller *et al*., 2010; Raveh *et al*., 2003). In the spectrum of light, there are four types of radiation bands that, according to the wavelength range they occupy, have different effects on the protected crops. In increasing wavelength, they are: UltraViolet (UV), from 180 to 380 nm, Photosynthetically Active (PAR), from 400 to 700 mm, Near InfraRed (NIR), from 800 to 1,100 nm, and Far InfraRed (FIR), from 1,100 up to around 4,000 nm. Each of these radiation ranges, within a very generic consideration, has repercussions for the environment, harmful insects, photosynthesis in plants, fruit quality, etc., in different ways.

Another factor to consider when studying the influence of roofing materials is the diffusion of radiation, fundamental for a good distribution of solar radiation inside the greenhouse (Hemming *et al*., 2008; Abdel-Ghany and Al-Helal, 2010). It is also important to analyze the temperatures that can increase or decrease the quality of the fruit produced in greenhouses (López-Marín *et al*., 2016, 2017; Shamshiri *et al*., 2017). These are sometimes more important than the light spectrum itself, as demonstrated for tomato by Riga *et al*. (2008).

Therefore, the choice of the greenhouse cover can influence not only the nutritional quality of the fruits but also their number and size, and this will have an immediate effect on the economic performance of the crop, which can be calculated from the value of the investment necessary and the adequate discount of the net cash flows. The latter is obtained as the difference between expected income and costs.

Therefore, the objective of this study was to determine which plastic cover provides the highest economic yield in greenhouse-grown tomato. We aimed to evaluate the yield of tomato crops cultivated under different roofing covers and analyze the profitability of each one.

## MATERIALS AND METHODS

The trials was carried out on the experimental farm of the IMIDA at Torreblanca, located at 37º 45' north (longitude) and 0º 59' west (latitude), in the Campo de Cartagena area, about 4 km from the coast of the Mar Menor saltwater lagoon. The tomato plants used were of the variety 'Brenda' (Gautier seeds). The trial was performed over two years: in the first, the plants were transplanted on January 19, 2011, and in the second, on January 12, 2012. The planting density was 25,000 plants ha$^{-1}$, with 100 cm between lines and 40 cm between plants. The cultivation was carried out following the practices commonly used for this type of tomato crop.

The experiments were carried out in six Kyoto model tunnel greenhouses. Each unit of cultivation or greenhouse was 5.55 m wide, 18.00 m long, and 2.70 m high in the roof ridge, giving a usable area of 100 m$^2$. The greenhouses were independent, being 5 m apart.

The types of cover material used were:

- Long Duration, experimental (LDe)
- Thermal Polyethylene, commercial (PeTc)
- UltraViolet A, 100% experimental (UVA100%e)
- Antithermal (Anti NIR)
- Long Duration, commercial (LDc)
- UltraViolet A, 90% experimental (UVA90%e)

The covers were characterized by measurements of radiation and temperature. The Photosynthetically Active Radiation (PAR) and global radiation were measured





[ DOR: 20.1001.1.16807073.2019.21.2.16.7 ]

using Quantum model sensors (LI-COR Inc., Lincoln, Nebraska, USA), and the ultraviolet radiation A and B with Delta OHM sensors, model HD2102.2 (Padova, Italia). The temperature was followed using a datalogger (model 177-H1) with Testo probes (Onset, Massachusetts, USA).

In each unit, the experimental design was a randomized block design. Each treatment (cover) had three blocks and 15 plants. Nine harvests were carried out in the two years of study, beginning on 21/4 and 10/5 in the first and second years, respectively, and ending on 20/6 and 4/7, respectively. The tomatoes were harvested at their optimum collection time, weighed, and then classified as commercial and non-commercial (sun affected, tissue rot, etc.). The tomatoes were classified into different calibers: GG (≥ 82 mm), G (67-81 mm), M (57-66 mm), and MM (47-56 mm) (DOCE, 2000).

## Prices

Data from the CARM (2017) regarding average weekly prices for tomato for the seasons 2005 to 2015 were used. Keeping in mind that these were wholesale prices, and due to the fact that they were average prices, one survey was carried out with farmers and the people in charge of the wholesale markets network, in which the respondents had to indicate a price for each of the calibers, given the price of caliber G (the highest commercial value). With the results of the survey, several regressions were carried out to obtain the relationship between the prices of calibers MM, M, and GG (dependent variable) and G (independent variable).

The data provided by the CARM are average prices, and nothing is shown about the price of caliber G. The average price for a plot can be obtained from the yield of calibers GG, G, M, and MM, denoted by $x_{GG}, x_G, x_M, x_{MM}$, respectively, and $X_T$ as the total yield of the plot. The percentage represented by the price of each caliber, derived from the price of caliber G, is denoted by $\beta_{GG}, \beta_G, \beta_M, \beta_{MM}$. The average Price (PM) can be obtained as equation 1 (see the below).

Finally, the price of caliber G can be obtained from the average price provided by the CARM.

$$G = \frac{PM}{\frac{x_{GG}}{X_T}\cdot\beta_{GG} + \frac{x_G}{X_T}\cdot\beta_G + \frac{x_M}{X_T}\cdot\beta_M + \frac{x_{MM}}{X_T}\cdot\beta_{MM}} \quad (1)$$

Where, the percentage of each caliber *i* ($i = GG, G, M, MM$) with respect to the price of *G*, $\beta_i$, can be obtained by Equation (2), depending on the survey results.

$$Prec_i = \alpha_i + \beta_i \cdot Prec_G \quad (2)$$

## Yield Valuation

In order to make a correct cost-analysis benefit (Mishan, 1982; Mao, 1986; Ballestero, 2000), for each year, the weekly yield was registered. Incoming payments were obtained for each cover as the product of the weekly yield of each caliber and its price.

- Changes in the value of the yield for the two consecutive years were obtained according to three effects: changes in the average prices perceived by the farmer, changes in the yield, and changes in the composition of the calibers. The average price perceived by the farmer was obtained by dividing the income perceived by the farmer by the yield.
- Changes in the value due to changes in yield were obtained by comparing the yield of both years using the prices of the year 2011 and the percentage distribution of the calibres for 2011.
- Changes in the value due to changes in the average prices were obtained from the yield of the year 2011 and the percentage distribution of the calibers for 2011, but

$$PM = \frac{x_{GG}}{X_T}\cdot\beta_{GG}\cdot G + \frac{x_G}{X_T}\cdot\beta_G\cdot G + \frac{x_M}{X_T}\cdot\beta_M\cdot G + \frac{x_{MM}}{X_T}\cdot\beta_{MM}\cdot G \quad (3)$$





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considering two valuations: the first with the prices of 2011 and the second with the prices of 2012.

- Changes in the value due to changes in the percentage distribution of the calibers were obtained from the yield of the year 2011 valued at 2011 prices, but considering the observed percentage distributions of the calibers for years 2011 and 2012.

## Cost Estimation

The costs were estimated for one hectare and divided into overhead and annual costs (Hood and Snyder, 1999; Engindeniz and Tüzel, 2002). The former were classified into installation of the greenhouse, for which a lifetime of 24 years was considered, installation of the drip irrigation, with lifetime of 9 years, and cover plastic, 3 years. In the same way, the annual costs, that is, the generated cost during the planting season were divided into fixed and variable costs.
Fixed costs being classified into phytosanitary, supplies, labor costs (excluding harvesting) and hire of land, and the variable costs of seeds, seedbed, fertilizers, water, energy, and labor costs (harvesting). The harvesting costs were obtained from the harvest (kilograms) multiplied by the harvesting price per kilogram.

## Net Present Value (NPV)

This is obtained by updating all net cash flows generated by the investment. When choosing among alternatives, the one with the highest *NPV* is taken. Brealey and Myers (2001) stated that this method is the one most suitable for estimating the benefits of a project and it has been used in work like that of Grünwaldt and Guevara (2011), for the study of the profitability of the combined activity of post-weaning and feedlot of beef cattle, and in Guevara *et al*. (2010), for the profitability of finishing beef cattle in feedlots, both in Mendoza Province, Argentina. The *NPV* is calculated as follows:

$$\mathrm{NPV} = \sum_{r=0}^{R} \left(C_r - P_r\right)\cdot\left(1+i\right)^{-r} \qquad (4)$$

Where, $C_r$ represents the incoming payments received in year $r$, $P_r$ the outgoing Payments for year $r$, $i$ the applied discount rate, and $R$ the useful life.

The *NPV* is obtained from three variables: Net cash flows, measured as the difference between outgoing payments and incoming payments, the interest rate, and the life of the project. The first two of these were analyzed and correspond to the difference between the revenues and expenses. We considered a useful life of 25 years.

## Discount Rate

The discount rate applied is risk-free interest plus $\beta$ times the premium discount, which is the difference between the market yield $E(Rm)$ and the rate free of risk $i_{free}$ (Welch, 2009).

$$i = i_{free} + \beta\left(E\left(Rm\right) - i_{free}\right) \qquad (5)$$

## Annualized Net Yield (NY)

The *NY* is obtained from the *NPV* as follows (Welch, 2009):

$$\mathrm{NY} = \frac{\mathrm{NPV}\cdot i}{1-\left(1+i\right)^{-R}} \qquad (6)$$

Where, *NPV* is the Net Present Value, $i$ the applied discount rate, and $R$ the useful life of the greenhouse.

## Analysis of the Difference in Value of Yield in the Two Years

The values of the yield in the two years analyzed differed despite the fact that the average prices of ten years were used. These differences can be due to:

1. Differences in annual yield
2. Differences in the caliber distribution.

Greater yield of caliber G increases the value of the yield although the total yield remains constant

3. Differences in prices. The weekly price applied for this purpose was constant in both years, but harvesting did not occur in the same week. Hence, there were differences between seasons for this concept.

To sum up, the difference in the Value of the yield ( $\Delta VP$ ) can be split up in the equation7, (see below).

Where, *Prod* refers to average yield in kg, *Prec* to the Price in Euros, *%Cali* to the percentage of the total yield that Caliber *j* represents, and subindexes 11 and 12 to years 2011 and 2012, respectively.

## RESULTS AND DISCUSSION

### Characterization of the Covers

Table 1 shows the global, PAR, and UltraViolet A (UVA) and B (UVB) radiations, both as net values and as percentages of the transmission entering the interior of the crop with respect to the exterior. Differences can be observed between the different covers, the cover with the AntiNIR material causing the greatest reduction of the amount of radiation entering the interior, followed by the LDe cover material, while the two most radiation-permeable cover materials were UltraViolet A at 100% (UVA100% e) and 90% (UV90%e).

Regarding the average temperatures in the two years of study (Figures 1-a and -b), small differences can be observed, these being greater from week 16.

### Prices

Figure 2 shows the changes in price for the harvest weeks from April to June. Data were collected from the CARM and from a survey of farmers and the people in charge of the wholesale markets network. The aforementioned figure shows the changes for the calibers: caliber G was the one that had the highest prices, followed by calibers GG and M, with caliber MM showing the lowest prices.

The relationships between the prices obtained for each caliber and those of the caliber with the highest commercial value (G) are shown in Table 2. The price of caliber MM represents only 31.25% of the price of caliber G, while the price of caliber GG represents 93.75% of that of caliber G. For all the regressions analyzed, the independent term was not significant (P> 0.05)

### Yield

Figure 3 (a and b) shows the commercial yield classified into calibers MM, M, G, and GG for each of the studied years. The yield of caliber G was greatest in both years in most of the analyzed treatments.

With respect to the yield by caliber (Figure 3), caliber G stands out from the others in both years for most of the covers, except in 2012 for covers LDe and PeTc, for which caliber M had the greatest yield. This may be due to the loss of the quality of the film, due to the aging in the second year of utilization. The trend and the differences between calibers for each cover were similar to the total yield (Tables 3 and 4)

Tables 3 and 4 show the weekly yield in each season for each of the covers. As can be seen, in both seasons, the experimental cover UVA100%e gave the highest yield, followed by UVA90%e and PeTc. In a previous work, it was also demonstrated that the greatest yields were obtained with those treatments that gave a greater reduction of ultraviolet A radiation (Papaioannou *et al.*, 2012).The materials UVA100%e and UVA90%e gave higher PAR inside the greenhouse (Table 1), followed by PeTc. The UVA radiation varied most among the treatments due to the distinct optical properties of the materials evaluated, and excess UVA can damage the plants (Yarosh and Smiles, 2009). In both years, cover LDe gave the lowest values of

$$\Delta VP = \left(Prod_{12} - Prod_{11}\right) \cdot \sum_{j} \left(Prec_{12j} - Prec_{11j}\right) \cdot \left(\%Cali_{12j} - \%Cali_{11j}\right) \qquad (7)$$





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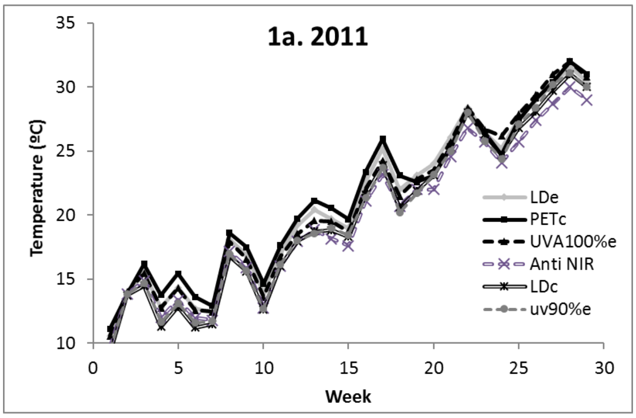
**Table 1.** Radiation transmission of different cover films.

| | GLOBAL ($W\ m^{-2}$) | | PAR ($\mu E\ m^{-2}\ s^{-1}$) | | UVA $10^{-3}$ ($W\ m^2$) | | UVB $10^{-3}$ ($W\ m^2$) | |
|---|---|---|---|---|---|---|---|---|
| | Net | % | Net | % | Net | % | Net | % |
| LDe | 961.9 | 77.41 | 1503 | 76.51 | 431.9 | 35.53 | 1161 | 74.56 |
| PETc | 1025 | 86.99 | 1809 | 85.78 | 35.8 | 5.92 | 1848 | 69.31 |
| UVA100%e | 1048 | 89.88 | 1836 | 90.65 | 0 | 0 | 2118 | 69.87 |
| Anti NIR | 705.6 | 64.38 | 1258 | 62.4 | 7.9 | 0.51 | 1219.4 | 34.1 |
| LDc | 1042 | 87.19 | 1786 | 88.22 | 13.9 | 1.29 | 2207 | 74.41 |
| UV90%e | 1060 | 89.09 | 1846 | 90.75 | 179.7 | 10.97 | 4921 | 77.65 |



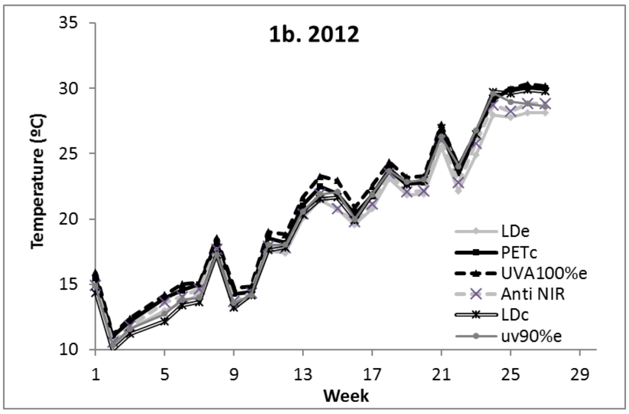




**Figure 1**. Average temperature inside the different greenhouses (2011).

**Table 2.** $\beta_i$ and $R^2$ for calibers MM, M, G, and GG.

| | MM | M | G | GG |
|---|---|---|---|---|
| $\beta_i$ | 0,3125 | 0,6250 | 1,0000 | 0,9375 |
| $R^2$ | 0,92 | 0,95 | 1,00 | 0,98 |

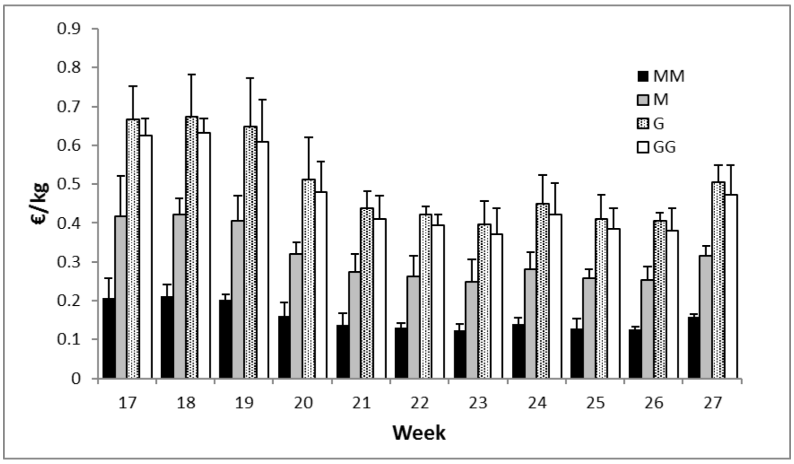



**Figure 2.** Weekly tomato prices by calibre. Data are means±*SE* of fifteen plants. Source: our own elaboration from the data provided by the CARM and the survey of the prices of the calibers.

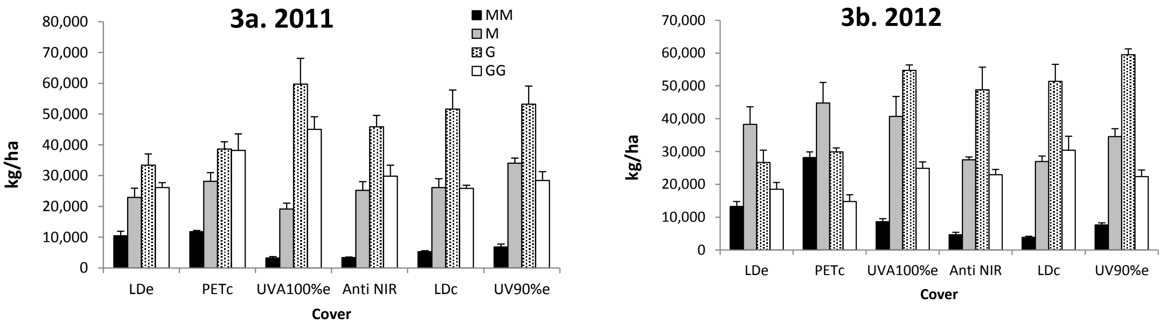



**Figure 3.** Total yield for each cover by caliber. Data are means±*SE* of fifteen plants.

**Table 3.** Yield of tomato under different covers in 2011 (kg ha$^{-1}$).[a]

| Date | LDe | PeTc | UVA100%e | Anti NIR | LDc | UV90%e |
|---|---|---|---|---|---|---|
| 21/04/2011 | 2.426±(97) | 7.680±(768) | 6.646±(531) | 0±(0) | 3.306±(396) | 6.646±(930) |
| 27/04/2011 | 2.653±(238) | 10.880±(1.740) | 11.410±(228) | 3.693±(590) | 3.210±(64) | 13.600±(1.224) |
| 11/05/2011 | 20.973±(1.887) | 30.466±(3.960) | 32.226±(3.544) | 18.126±(2.175) | 17.746±(1.597) | 21.146±(2.749) |
| 17/05/2011 | 3.266±(522) | 1.720±(292) | 3.166±(411) | 1.300±(104) | 993±(149) | 713±(85) |
| 23/05/2011 | 9.453±(283) | 11.400±(798) | 5.853±(117) | 22.540±(3.155) | 16.940±(677) | 21.766±(1.306) |
| 31/05/2011 | 29.280±(1.756) | 29.026±(3.773) | 35.957±(4.314) | 15.700±(2.041) | 15.820±(1.740) | 15.700±(785) |
| 06/06/2011 | 8.133±(488) | 9.833±(688) | 14.726±(2.061) | 19.306±(1.351) | 22.600±(1.356) | 19.306±(1.737) |
| 13/06/2011 | 7.506±(1.126) | 6.353±(444) | 9.380±(1.219) | 11.366±(1.477) | 12.226±(1.100) | 11.366±(909) |
| 20/06/2011 | 9.253±(647) | 9.453±(189) | 7.826±(547) | 12.253±(735) | 16.100±(2.093) | 12.253±(735) |
| Total | 92.947 | 116.814 | 127.194 | 104.286 | 108.943 | 122.500 |

[a] Data are means±*SE* of fifteen plants.

**Table 4.** Yield of tomato under different covers in 2012 (kg ha$^{-1}$).[a]

| Date | LDe | PeTc | UVA100%e | Anti NIR | LDc | UV90%e |
|---|---|---|---|---|---|---|
| 10/05/2012 | 32,38±(453) | 5,237±(576) | 5,804±(1,044) | 0±(0) | 4,933±(394) | 6,476±(194) |
| 17/05/2012 | 4,682±(468) | 11,719±(1,757) | 19,178±(1,534) | 4,682±(327) | 1,300±(130) | 12,229±(733) |
| 24/05/2012 | 11,298±(1,242) | 14,616±(1,315) | 8,896±(444) | 10,880±(1,632) | 10,784±(754) | 9,260±(555) |
| 31/05/2012 | 17,515±(1,576) | 15,866±(2,856) | 15,114±(2,569) | 5,934±(652) | 9,914±(991) | 9,563±(573) |
| 05/06/2012 | 5,934±(237) | 5,147±(411) | 9,390±(845) | 11,174±(223) | 21,146±(2,537) | 7,552±(906) |
| 12/06/2012 | 15,460±(927) | 20,098±(3,416) | 18,510±(3,146) | 14,601±(2,190) | 12,051±(482) | 35,716±(1,071) |
| 19/06/2012 | 6,834±(1,025) | 13,668±(956) | 13,350±(1,068) | 18,251±(2,555) | 15,064±(1,958) | 18,790±(2,442) |
| 26/06/2012 | 25,556±(3,577) | 22,196±(2,219) | 17,700±(1,593) | 20,383±(2,242) | 18,638±(2,236) | 17,693±(884) |
| 04/07/2012 | 6,266±(501) | 9,155±(457) | 20,986±(2,728) | 18,101±(1,629) | 18,873±(943) | 6,834±(546) |
| Total | 96,785 | 117,705 | 128,931 | 104,010 | 112,707 | 124,117 |

[a] Data are means±*SE* of fifteen plants.

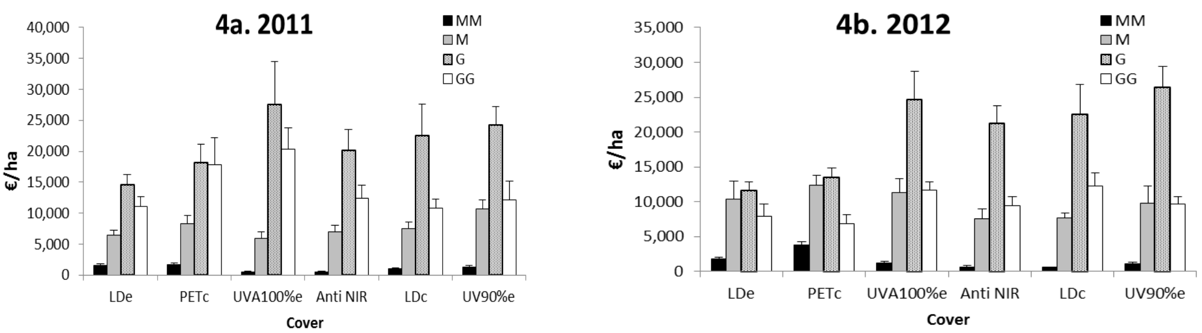



**Figure 4.** Value of the yield for each cover by calibre. Data are means±*SE* of fifteen plants.

yield. The fall in yield in this case may not be due to the radiation, but may have arisen to a greater degree because of the temperature, since under cover LDe the temperatures were higher than under AntiNIR (Figures 1-a and -b). The results obtained with AntiNIR reflect similar negative effects on pepper growth, where the radiations of formulations of experimental anti-thermal films invade other nearby radiation bands, such as PAR, affecting the precocity of production (López-Marín *et al*., 2011). In the greenhouse with LDe cover, a greater number of non-marketable fruits were obtained and, therefore, less commercial production. Although the materials LDc and LDe are similar in optical properties (Table 1), it can be seen that in the greenhouse with LDe cover the UVA input was 35.53% and in LDc 1.29%: this higher input of UVA radiation could be the cause of the poor production. The UVA radiation has to reach the plant at optimum levels, to obtain both high yield and good levels of the salutiferous principles in the tomato fruits (Rosales, 2008).

The product of the weekly prices of each caliber (Figure 4) multiplied by the weekly yield of each caliber gives the yield for each season, although only total weekly yield (kg ha$^{-1}$) for each cover and total yield by caliber (kg ha$^{-1}$) are shown.

Table 4 shows the total value of the yield by caliber for each cover. Firstly, we must point out that there were important differences between the two years. Most of the differences in income were due to price variations. Caliber GG provided slightly higher income than M, but always quite a bit lower than caliber G, except in 2011 with cover UVA100%e - where this caliber was the one with the highest income. Finally, the contribution of caliber MM was quite limited due to its small size and low price.

Tables 5 and 6 show the weekly changes of the accumulated value of the yield, according to the yield obtained and the recorded prices for each season. As shown, the cover with the highest yield was UVA100%e, followed by UV90%e, PETc, and LDc, with LDe giving the lowest yield.

The difference in the value of the yield between 2011 and 2012 was due to three factors: changes in the yield, changes in the weighted average prices perceived by the farmer (mainly from the different harvest data, although the average weekly prices used in both years were the same), and changes in the caliber distribution. Table 7 shows, in percentage terms, the rise in the value of the yield in 2012 compared to 2011 due to each of these factors, as well as the changes due to interactions between them. As can be checked, most of the differences were due to changes in caliber distribution (the others remained constant), which reached 17.60% for the PETc cover.

The second column of Table 7 indicates the increase in the value of the production from 2011 to 2012, considering that the prices remain constant as well as the percentage of each caliber. The third column shows the increase in the value of the production in 2012 considering the prices of 2012, but also that the production and the percentage of each caliber remains constant. In the fourth column, the production and the price remain constant, and only the percentage of each caliber is changed. In the fifth column, the percentage of each caliber remains constant and the production and the price change, and so on.

Changes in value due to yield variation (the weighted average price and caliber distribution remained constant) were very low, in all cases being less than 5%. Finally, with regard to the changes due to variation in weighted average prices, although the weekly prices used were the same, there were differences higher than 3% for PETc (20.81%), UVA100%e (9.94%), and LDe (5.91%). For the remainder, the fall was very slight. The other columns of Table 7 show the cross effects (changes in yield and prices at constant caliber distribution, changes in yield and caliber distribution at constant weighted average prices, etc.) and the last column shows the changes in the total value of the yield in 2012 compared to 2011.

Although the average prices used were the same for both years, it must be kept in mind that the changes in prices were different for each cover due to the fact that each cover gave a different weekly distribution of calibers and prices; as a result, the weighted average price was different for each cover.





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**Table 5.** Accumulated value of the yield in 2011 (€ $ha^{-1}$).

| | LDe | PeTc | UVA100%e | Anti NIR | LDc | UV90%e |
|---|---|---|---|---|---|---|
| 21/04/2011 | 936 | 3,663 | 3,327 | 0 | 971 | 3,435 |
| 27/04/2011 | 2,143 | 10,031 | 9,675 | 1,418 | 2,173 | 8,689 |
| 11/05/2011 | 11,728 | 24,714 | 25,895 | 9,983 | 10,417 | 18,812 |
| 17/05/2011 | 12,970 | 25,430 | 27,232 | 10,541 | 10,820 | 19,099 |
| 23/05/2011 | 16,686 | 29,847 | 29,612 | 19,659 | 17,738 | 27,942 |
| 31/05/2011 | 26,849 | 39,927 | 43,335 | 25,641 | 23,766 | 33,923 |
| 06/06/2011 | 29,310 | 42,576 | 48,948 | 33,008 | 32,522 | 41,290 |
| 13/06/2011 | 31,249 | 43,956 | 52,064 | 36,559 | 36,470 | 44,842 |
| 20/06/2011 | 33,724 | 46,117 | 54,285 | 40,129 | 41,716 | 48,412 |

**Table 6.** Accumulated value of the yield in 2012(€ $ha^{-1}$).

| | LDe | PeTc | UVA100%e | Anti NIR | LDc | UV90%e |
|---|---|---|---|---|---|---|
| 10/05/2012 | 1,653 | 2,571 | 3,073 | 0 | 2,517 | 3,306 |
| 17/05/2012 | 3,807 | 7,727 | 11,858 | 2,154 | 3,106 | 8,395 |
| 24/05/2012 | 8,364 | 12,972 | 15,584 | 6,287 | 7,226 | 11,935 |
| 31/05/2012 | 15,030 | 17,896 | 20,469 | 8,359 | 11,146 | 15,780 |
| 05/06/2012 | 16,981 | 18,957 | 23,861 | 12,544 | 18,978 | 18,620 |
| 12/06/2012 | 21,220 | 24,466 | 30,456 | 18,323 | 23,860 | 33,233 |
| 19/06/2012 | 23,119 | 28,264 | 34,729 | 24,909 | 29,424 | 39,437 |
| 26/06/2012 | 29,543 | 33,140 | 39,965 | 31,660 | 35,679 | 44,670 |
| 04/07/2012 | 31,732 | 36,522 | 48,890 | 38,933 | 43,101 | 47,003 |

**Table 7.** Analysis of the increased value of the yield in 2012 compared to 2011(%).[a]

| Cover | Production | Price | Calibre | Production× Price | Production ×Calibre | Price× Calibre | Production ×Price | Total variation |
|---|---|---|---|---|---|---|---|---|
| LDe | 4.13 | -1.06 | -8.06 | -0.04 | -0.33 | -0.51 | -0.02 | -5.91 |
| PETc | 0.76 | -3.65 | -17.60 | -0.03 | -0.13 | -0.15 | 0.00 | -20.81 |
| UVA100%e | 1.37 | -0.81 | -8.38 | -0.01 | -0.11 | -1.96 | -0.03 | -9.94 |
| Anti NIR | -0.26 | -1.21 | -1.47 | 0.00 | 0.00 | -0.04 | 0.00 | -2.98 |
| LDc | 3.46 | -0.91 | 0.81 | -0.03 | 0.03 | -0.04 | 0.00 | 3.32 |
| UV90%e | 1.32 | -3.86 | -0.06 | -0.05 | 0.00 | -0.26 | 0.00 | -2.91 |

[a] The heading of each column shows the changing factor, the others remaining constant

## Costs

The structure of the real costs of the assay is shown in Tables 8 (overhead costs) and 9 (annual costs). This structure is similar to that of other works such as López-Marín *et al*. (2016), although it differs from the one used, for example, by De Miguel (2009), which only refers to total costs, and that of Gázquez *et al.* (2012), where the yield analysis was made by introducing the overhead costs as depreciations.

Our analysis assumes the same costs for each cover, except the cover plastic for the overhead costs and the hand harvesting for the annual costs. No significant difference was found regarding the phytosanitary costs.

## Net Present Value

The net present value can be obtained now by updating, with a proper discount rate, all the cash flows generated during the useful life and





[ DOR: 20.1001.1.16807073.2019.21.2.16.7 ]

**Table 8.** Overhead costs of greenhouse-grown tomato (€ $ha^{-1}$).

| Concept | LDe | PeTc | UVA100%e | Anti NIR | LDc | UV90 %e |
|---|---|---|---|---|---|---|
| Greenhouse installation | 44,889 | 44,889 | 44,889 | 44,889 | 44,889 | 44,889 |
| Earth movement: 7,191 | | | | | | |
| Cement: 7,300 | | | | | | |
| Structure: 17,486 | | | | | | |
| Doors, locks, and carpentry: 12,031 | | | | | | |
| Health and safety: 881 | | | | | | |
| Drip irrigation, Installation of irrigation (self-compensating integrated drip irrigation line, 10 years) | 4,600 | 4,600 | 4,600 | 4,600 | 4,600 | 4,600 |
| Plastic cover (thermic, 36 months, 800 gg, 2,500 kg) | 5,250 | 6,000 | 5,750 | 5,500 | 5,250 | 5.750 |
| Total | 54,739 | 55,489 | 55,239 | 54,989 | 54,739 | 55,239 |

**Table 9.** Annual costs of greenhouse-grown tomato (€ $ha^{-1}$).

| | LDe | PeTc | UVA100%e | Anti NIR | LDc | UV90%e |
|---|---|---|---|---|---|---|
| Fixed costs | 13,435 | 13,435 | 13,435 | 13,435 | 13,435 | 13,435 |
| Phytosanitary (including auxiliary insects) | 5,600 | 5,600 | 5,600 | 5,600 | 5,600 | 5,600 |
| Supplies | 900 | 900 | 900 | 900 | 900 | 900 |
| Labor cost (not harvesting) | 6,435 | 6,435 | 6,435 | 6,435 | 6,435 | 6,435 |
| Hire of land | 500 | 500 | 500 | 500 | 500 | 500 |
| Variable cost | 13,060 | 13,210 | 13,670 | 13,182 | 13,376 | 13,514 |
| Seeds + trays (no grafting) | 3,100 | 3,100 | 3,100 | 3,100 | 3,100 | 3,100 |
| Fertilizer | 4,300 | 4,300 | 4,300 | 4,300 | 4,300 | 4,300 |
| Labor cost (harvesting) | 1,360 | 1,510 | 1,970 | 1,482 | 1,676 | 1,814 |
| Water | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 | 2,000 |
| Energy | 2,300 | 2,300 | 2,300 | 2,300 | 2,300 | 2,300 |
| Total | 26,495 | 26,645 | 27,105 | 26,617 | 26,811 | 26,949 |

subtracting the initial investment. That is why we need to determine in advance the discount rate, the useful life of the greenhouse, the irrigation equipment installation, and the plastic cover costs.

## Discount Rate

The return of the 10 years Spanish Bond from the 18th of September 2015, 2.83%, was used as the free interest rate (Banco de España, 2015). With reference to the risk premium, there is an extensive literature and we wish to highlight the work of Fernández *et al.* (2011), who interviewed managers, economic analysts, and university lecturers. They obtained a wide range of risk premium values; the median of the university lecturers and managers was 5.5%, while for the economic analysts it was 5.0%. Other studies - such as Dimson *et al.* (2007), Shiller (2000), Wilson and Jones (2002), Damodaran (2002), Brotons and Terceño (2010), Siegel (2005), and Fernández (2011) - estimated a risk premium between 4.2 and 8.5%.

To sum up, the free risk return is 2.83% and the risk premium (from the aforementioned bibliography) takes an average value of 6.35%. The β value for the food and drinks sector of the Spanish stock market (Bolsa de Madrid, 2013) is 0.3951. As a result, the discount rate used for the present work was 4.26%.

## Net Present Value

Table 10 shows the net present values obtained. Starting from the average yield in 2011 and 2012, and considering a useful life of 25 years for the greenhouse, 10 years for the irrigation





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equipment installed, and three years for the plastic cover, the *NPV* is obtained for each cover according to Expression (4), using the discount rate of 4.26% obtained from Expression (5) using average prices. As can be seen, all of the covers show positive results, the *NPV* being highest for the UVA100%e cover, followed by UV90%e. The others (PeTc and Anti NIR) show clearly lower values**.**

Once we have obtained the *NPV*, it is possible to determine the annualized net yield; that is, to distribute in a financial way the *NPV* over the useful life of the project. Although the preference order of the covers remains constant, the annual net yield (Table 10) shows that cover UVA100%e presents an annualized net yield of 23,247.20 €, higher than UV90%e (17,384.72 €)

## CONCLUSIONS

From the analysis of the yields, it is clear that, in both years, the cover with the experimental material UVA100%e was the one that gave the greatest yield, followed by UVA90%e and PeTc. This is consistent with the fact that these covers were the ones that led to higher levels of PAR inside the greenhouse.

The highest yield per caliber, in both years, corresponded to caliber G.

The survey of representative merchants and farmers allowed us to estimate the prices of the different calibers with a high level of reliability. Given that the market price is highest for caliber G, followed by GG, and lowest for calibers M and MM, the first two calibers are the ones that contribute most to the farmer's income due to their greater unit weight and higher price.

The most profitable covers for tomato cultivation, with production from January to June in the southeast of Spain, are UVA100%e and UVA90%e, having low permeability to UVA radiation, since they give the highest yields and net present values.

**Table 10.** Net present values (€ ha$^{-1}$).

| | NPV | Annualized net yield |
|---|---|---|
| LDe | 44,225.09 | 2,910.70 |
| PeTc | 227,964.97 | 15,003.67 |
| UVA100%e | 353,216.76 | 23,247.20 |
| Anti NIR | 139,772.34 | 9,199.21 |
| LDc | 165,441.27 | 10,888.63 |
| UV90%e | 264,142.64 | 17,384.72 |

The annualized net yield makes it possible to determine the average yield that a farmer would obtain each year during the useful life of the greenhouse. The covers UVA100%e and UV90%e gave the highest yields.

Finally, it should be noted that the greatest differences in the value of the yield between the two years analyzed occurred with the LDe and PETc covers, being higher than 20% and 5%, respectively. This was mainly due to the change in the calibers produced.

According to this study, the best option for greenhouse cultivation of tomatoes in the southeast of Spain, and in zones of similar climate around the world, is the use of covers containing additives that block at least 90% of the ultraviolet A radiation.

## ACKNOWLEDGEMENTS

Research project FEDER 14-20-08, financed by the European Regional Development Fund 80% **-** Región de Murcia.

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# تحلیل هزینه و منفعت گیاه گوجه فرنگی زیر پوشش های مختلف گلخانه

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## چکیده

گوجه فرنگی (*Solanum lycopersicum* L.)یکی از پرطرفدارترین و پر مصرفترین سبزیجات جهان است که در رژیم های غذایی مدیترانه ای هم بیشترین حضور را دارد. در سال های اخیر چند نوع پلاستیک مصرفی در کشاورزی در بازار عرضه شده است که طیف تابش ورودی به گلخانه را تغییر می دهد و در مواردی آن را فیلتر کرده و در مواردی باند بعضی طول موج ها را تشدید می کند. هدف پژوهش حاضر ارزیابی تولید گوجه فرنگی گلخانه ای زیر پوشش های مختلف و تجزیه و تحلیل سودمندی عملکرد زیر هر پوشش بود. به منظور ارزیابی اثر پوشش های سقفی از پلاستیک های مختلف که خواص تابشی متفاوتی داشتند، آزمایشی در ۶ گلخانه تونلی اجرا شد که مساحت هر کدام ۱۰۰ متر مربع بود. عملکرد گوجه فرنگی اندازه گیری و ثبت شد و ارزش اقتصادی آن به صورت تابعی از میانگین قیمت سال های اخیر از اداره کشاورزی منطقه Murcia (CARM) و نظر خواهی از شبکه بازارهای کلی فروشی( wholesale markets network) و کشاورزان به منظور تعیین قیمت هفتگی بر اساس کیفیت محصول (caliber) مشخص شد. هزینه تولید هر یک از گزینه ها تعیین شد و سپس ارزش خالص فعلی عملکرد و ارزش سالانه به دست آمد. بالاترین ارزش سالانه €24,856.04 در مورد پوشش UVA100%eبود و بعد از آن UV90%eو PeTc(به ترتیب €18,931.49و €16,205.53در سال) قرار داشتند. پوشش های LDe و Anti NIRضعیفترین نتایج را به دست دادند( به ترتیب €3,954.93و €10,480.40).



[ DOR: 20.1001.1.16807073.2019.21.2.16.7 ]