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Use of a PSNM to Increase Precocity and Its Benefits in Greenhouse-Grown Sweet Pepper

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ABSTRACT

The types and varieties of peppers grown in Mediterranean areas are a response to the demand of European markets, although in each Autonomous Community local varieties are grown to satisfy the national demand. Nowadays, the range of shapes, colours, tastes and uses is wider than ever as a result of greenhouse cultivation, national and international tendencies and increased demand. In Murcia, the growing cycle runs from December to July or August, depending on the market and the growth of the crop. Sweet pepper is normally grown in greenhouses, using a variety of technologies: from simple shaded greenhouses, to the most-advanced multitunnels (large, in the form of a round arch or Gothic arch and with sophisticated ventilation). Due to the high cost of fuel, it is impossible to use heating during winter after transplanting, so alternative techniques are used to raise the temperature a few degrees and improve crop production. The aim of this work was to increase the precocity and productivity of sweet pepper grown in greenhouses. The effect of a Polypropylene Spunbonded Nonwoven Microtunnel (PSNM) was studied. The results show that, although the increase in production was not great (lower than 5% in both years of the study), precocity increased by 16% in both years. Since the increased cost of using this technology is not excessive, crop profitability increases if precocity is taken into account, as all our indicators show. The study suggests that the use of a PSNM raises the marketable production and brings forward the first harvests.

Keywords: Crop protection, Monte carlo, Profitability, Risk, Value at risk.

INTRODUCTION

Sweet pepper is one of the most important horticultural crops in Mediterranean areas. Southeast Spain is amongst the main production areas of sweet pepper in Europe (López-Marín *et al.,* 2013a); here, 7,000 ha of sweet pepper are grown in greenhouses in the province of Almería (López-Marín *et al.*, 2009) and 1,300 ha in the provinces of Murcia and southern Alicante (Lopez-Marin *et al.,* 2013). Spain is the sixth-greatest producer of peppers in the world (898,000 t in 2011) and the third-greatest exporter after Mexico and Holland. Due to overlapping production calendars, Turkey is Spain's main competitor (MAGRAMA, 2015).

Some sweet pepper crops in Murcia and southern Alicante are grown from late autumn to late summer (López-Marín *et al.*, 2008). Earliness is very important in this crop in this region because the first and second harvests are concentrated around the middle of April. However, the use of

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techniques such as heating can advance the first harvest by two to three weeks.

Heating can take two forms: hot air, to avoid momentary drops in temperature and avoid the risk of frost, and hot water, which maintains a stable temperature and enables the productive cycle to be brought forward (García-Martínez *et al.,* 2008). The main problems with heating are the cost, global warming and climate change (Bakker *et al.*, 2008; Attarod *et al.*, 2015). The absolute use of energy differs between specific locations; for example, for Finland the total energy consumption has been estimated at 1,900 MJ m^{-2} per year (Olofsson *et al.*, 2006), for The Netherlands 15,00 MJ m^{-2} (Van der Knijff *et al.*, 2004) and for southern France 500-1,600 MJ m^{-2} (Vesine *et al.*, 2007). The costs of maintaining appropriate conditions inside the greenhouse, in particular the energy used for heating, threaten the greenhouse industry and thus should be reduced.

Appropriate climatic conditions in mild-winter climates are the most important factor determining sustainability in passive greenhouses. In Mediterranean areas with a favourable climate, the available natural resources, together with the sensible use of well-selected technologies to overcome brief unfavourable weather conditions, are the key factors for achieving sustainability (Montero *et al.*, 2011).

In response to the increased cost of the most-frequently-used fuels (diesel, natural gas or propane), current trends, which demand lower unitary costs, are moving toward a greater consideration of alternatives - such as bio-fuels, to guard against low temperatures, moveable thermal screens and double-layered coverings (Buchholz *et al.*, 2005; Castilla, 2005; Boulard and Fatnassi, 2006). Another way of decreasing both the amount spent on energy and the emission levels for different greenhouse industries is the use of microtunnels inside the greenhouses. Such microtunnels are usually covered with plastic [Low Density Polyethylene (LDPE)] (Castilla, 2005); however, the use of Polypropylene Spunbonded Nonwoven Microtunnels (PSNMs) is not widespread. The use of direct covering with polypropylene is expanding as a simple, cheap and effective semi-protecting technique, also known as floating mulch, for horticultural crops. While the influence of direct covering on the productivity of various horticultural crops like tomato (Wolf *et al.*, 1989), melon (Hemphill and Mansour, 1986), watermelon (Soltani *et al.*, 1995) or cucumber (Wolf *et al.*, 1989) has been studied, information about the yields, costs and benefits for sweet pepper crops cultivated under PSNMs in greenhouse conditions is scarce.

Since cultivation in a PSNM allows the first harvest to be brought forward, growers can benefit from the higher prices at the beginning of the season. This will mean an increase in income and profit. However, it must not be forgotten that agricultural prices are very difficult to estimate because they are subject to high doses of uncertainty. Working with average values does not really help as prices are high some years, while in others they are not sufficient to cover variable costs.

Therefore, the objective of this article is to determine the possible economic benefits for growers of advancing production, based on the use of PSNMs and taking into consideration the costs involved. For this, the effect of price variations will be analysed by Monte Carlo methodology, using the value at risk of the different variables analysed to incorporate the variability of prices and discount rates used for assessment.

MATERIALS AND METHODS

The experiments were carried out over a two-year period at the IMIDA experimental farm, located close to the Mediterranean coast of southeast Spain (37º 45’ N, 0º 59’ W).

Sweet pepper plants (cv. Herminio) were transplanted on January 7th 2010 in the first year and on January 5th 2011 in the second year, in an unheated, arch-shaped multispan greenhouse covered with thermal polyethylene. The plant density was 2.5 plants m^{-2} and the growing techniques were the usual ones for greenhouse pepper in Spain. Cropping ended on August 11th (2010) in the first year and on August 16th (2011) in the second year.

The greenhouse was covered with a standard film. Immediately after transplanting, 10 microtunnel rows were covered with a PSNM fabric (thickness 20-25 µm, density 17 g m^{-2}) (Agryl Fiberweb, France) and the rest of the rows were kept uncovered (Standard).

The number of harvests in both years was eight. At each harvest, the fruits were weighed and graded into marketable and non-marketable. Marketable fruits were classified into commercial calibres (Table 1).

For the estimation of production in the PSNM and under standard conditions, we used the Net Present Value (NPV), the Net Yield (NY), the benefits/investment ratio and the Payback. For this, the average production costs and the average market prices for each of the above calibres were taken into account. The information on average costs was obtained from surveys of local farmers, while the average market prices were obtained from information provided by local market exchanges and the official website of the Ministry of Agriculture, Food and Environment (MAGRAMA, 2015).

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 net present value is taken. Brealey and Myers (2001) state that this method is the one most suitable for estimating the benefits of a project. The net present value is calculated as follows (Welch, 2009):

$$NPV = \sum_{r=0}^{R}\left(C_j - P_j\right)\cdot\left(1+i\right)^{-r} \qquad (0)$$

Where, C_j represents the incoming payments received in *year r*, P_j the outgoing payments for year *r*, *i* the applied discount rate and *R* the age of the project.

Table 1. Distribution of commercial calibres of pepper fruit.

Calibre	mm	Weight (g)
GG	80-110	170-250
G	70-90	135-170
M	60-80	95-135

Net Yield (NY)

This is obtained from the *NPV*. Although the payments received are supposed to be annual and constant, there are many payments that are made over a period of years, such as the assembly of the greenhouse (which occurs at the beginning), the cost of renewing the plastic (every three years) or the drip irrigation (every eight years). The *NY* is obtained from the *NPV* as follows (Welch, 2009):

$$NY = \frac{NPV\cdot i}{1-\left(1+i\right)^{-R}} \qquad (0)$$

Where, *NPV* is the net present value, *i* the applied discount rate and *R* the age of the project.

Net Benefit-Investment Ratio (N/K)

The ratio between benefit and investment indicates the net gain generated from the project for each monetary unit invested (Welch, 2009):

$$\frac{N}{K} = \frac{\sum_{r=1}^{R}\left(C_j - P_j\right)\cdot\left(1+i\right)^{-r}}{\sum_{r=0}^{R}K_r\cdot\left(1+i\right)^{-r}} \qquad (1)$$

Where, C_j represents the incoming payments for each period, P_j the annual outgoing payments and K_r the investment made during year *r* (the payments made for the construction of the greenhouse, the plastic, the drip irrigation system, etc.).

Payback

Defined as the time needed for the amortization of the investment made. This is calculated with an iterative system; that is, accumulating the net cash flows until the sum is at least equal to the initial investment (Welch, 2009).

Discount Rate

The applied discount rate is risk-free interest plus β times the premium discount, which is the difference between the market yield *E(Rm)* and the rate free of risk (Welch, 2009).

$$i = i_{free} + \beta\left(E\left(Rm\right) - i_{free}\right) \quad (2)$$

Monte Carlo Simulation

The Monte Carlo approach was used to evaluate the sensitivity of the inverse model and to provide a sound estimate of its uncertainty (Kroese *et al.,* 2011). The uncertain parameters were considered as variables that followed a normal distribution when possible, depending on the available data, or as evenly distributed variables if the above data were not available (for example, the risk premium). For this, an Excel worksheet was used and 20,000 iterations were made.

Value at Risk (VaR)

Let *X* be a random variable with a cumulative distribution function $F\left(X\right)$, and let *VaR* be a fixed value of *X* (Pruzzo *et al.*, 2003 or Saunders *et al.,* 2003),

$$\alpha = \Pr\left(X \le VaR\right) = F_X\left(VaR\right) \quad (3)$$

Then, using the inverse function of the cumulative distribution function, *VaR* is:

$$VaR = F_X^{-1}\left(\alpha\right) \quad (4)$$

VaR can be defined as the lowest value of a variable for a given level of confidence *α*, that is, a value for which *α*% of the possible values of the said variable are lower and 1-α % are higher.

If *X* is a normal distribution with μ_X the average and σ_X the standard deviation, its standardised value is (Pruzzo *et al.,* 2003; Saunders *et al.,* 2003):

$$x = \frac{X - \mu_X}{\sigma_X} \quad (5)$$

The *VaR* can be obtained parametrically. If VaR_α is the value of the standard normal distribution which corresponds to the *α*-quantile of the said distribution, *VaR* can be obtained as,

$$VaR = \left|VaR_\alpha\right| \cdot \sigma_X \quad (6)$$

The level of confidence for $NPV = 0$, NPV_α. The level of confidence for $NPV = 0$ can be obtained from the probability that *NPV* is lower than or equal to zero, $P\left(NPV \le 0\right)$.

$$NPV_\alpha = P\left(NPV \le 0\right) \quad (7)$$

Statistical Analysis

The SPSS 22.0.0.0 statistical package was used to calculate significant differences by ANOVA, and means were compared at probability $P \le 0.05$ according to the Student's *t*-test.

RESULTS

Income

Our references were the prices given by the price observatory of the Ministry of Agriculture, Food and Environment, covering 2004 to 2014, which are shown in Figure 1. Prices were high until week 15 (beginning of April), when they reached €1.20, after which they began to fall,

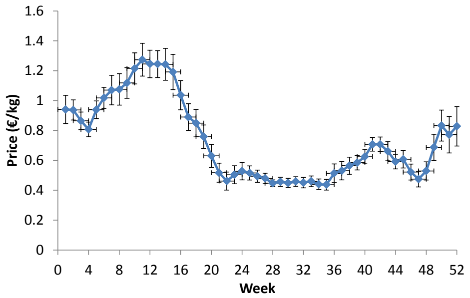

Figure 1. Weekly average prices and standard error 2004-2014 (MAGRAMA, 2015).

reaching €0.40-€0.50, their standard deviation also decreasing. The objective of the grower, therefore, would be to bring production forward in order to benefit from the higher prices.

For the correct valuation of production, the price was obtained for the wholesale markets of the available zones, to ascertain any statistical relationship between the prices of the different calibres. In this way, it was possible to construct a historic price series of the different calibres.

The weekly productions obtained with and without a PSNM in 2010 and 2011. The two treatments gave similar production; the difference did not exceed 2% in any case. The commercial production differed significantly between the treatments. However, no significant differences existed between the calibres of the different treatments, according to the Student's *t*-test (α= 0.05) (Table 2). Production was higher with the PSNMs in both years, especially for calibre GG. However, calibre G varied, its production being lower in the PSNM treatment in 2010 and higher in 2011, while the results for calibre M were the opposite. The most-important differences were in precocity, the use of a PSNM bringing production forward by two weeks in both years (harvesting being possible from 12/04 and 19/04 in 2010 and from 11/04 and 18/04 in 2011) and providing 20,188 and 23,310 kg, respectively.

Table 2 shows the kg ha^{-1} harvested on each date, the obtained income and the average price. As can be seen, the average price was superior for the PSNM because it was harvested earlier, taking advantage of the best prices.

The accumulated value of the production in 2010 and 2011, at the average prices of Figure 1, can be observed in Figure 2. As can be seen, early harvesting (in the first weeks of May) increased the total value of the crop when using a PSNM at the beginning of the season, the differences being maintained until nearly the end of the season.

Costs

The costs have been separated into pluriannual costs (Table 3), which include the costs of installation of the greenhouse (useful life 30 years), the drip irrigation system (useful life 10 years) and the plastic (useful life 3 years). The costs of whitewashing were not included, because the time of whitewashing depends on the weather. In the same way, the costs of the PSNM - which include the costs of labour (€200 annually) plus the cost of the covering with non-woven polypropylene (€369) - were included, assuming a useful life of three years.

In turn, the annual costs (Table 4) have been separated into variable (€34,896.35) and fixed (€2,680) costs. The former, in turn, have been sub-divided into: (i) Raw materials (€20,051.35), which include the

Table 2. Summary of the mean values of production. Values in the same column followed by different letters differ significantly.

	Total	GG	G	M	Total marketable	Non- marketable
PSNM^a	135244 ^{a}	35674 ^{a}	56065 ^{a}	28968 ^{a}	120707 ^{a}	14537 ^{a}
Standard	135335 ^{a}	32400 ^{a}	55407 ^{a}	29259 ^{a}	117065 ^{b}	18269 ^{a}

^{a} Polypropylene Spunbonded Nonwoven Microtunnel.

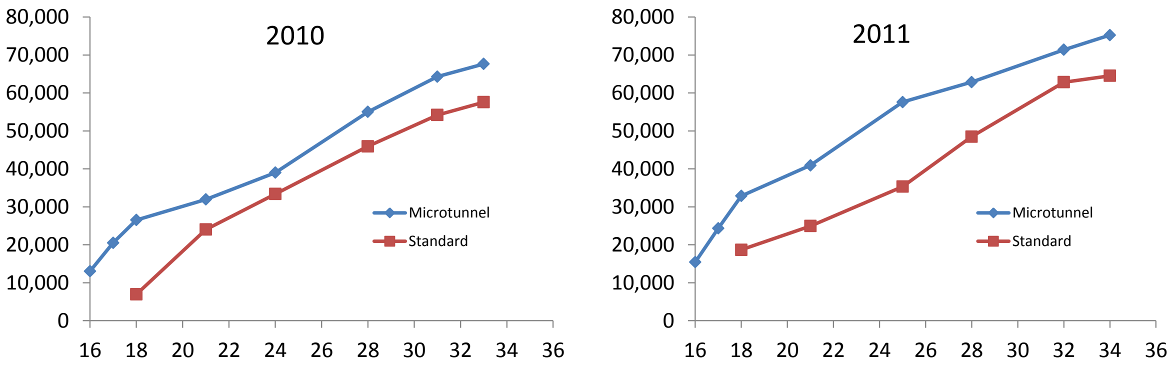

Figure 2. Accumulated value of the production in years 2010 and 2011, at average prices.

Table 3. Summary of the harvests by date (kg ha^{-1}), the average price (€ kg^{-1}) and the value of the production (€ ha^{-1}).

Year	2010				2011		
	kg ha^{-1}	Average price (€ ha^{-1})	€ ha^{-1}		kg ha^{-1}	Average price (€ ha^{-1})	€ ha^{-1}
PSNM	121673	0.56	67633	PSNM	119742	0.63	75228
12/04/2010	12113	1.07	13014	11/04/2011	13986	1.10	15417
19/04/2010	8075	0.93	7511	18/04/2011	9324	0.96	8914
28/04/2010	6729	0.89	5988	30/04/2011	9324	0.92	8533
18/05/2010	10267	0.53	5430	20/05/2011	16090	0.50	8050
07/06/2010	12473	0.57	7053	14/06/2011	30809	0.54	16681
06/07/2010	37700	0.42	16020	05/07/2011	11383	0.46	5271
29/07/2010	24100	0.38	9277	02/08/2011	19025	0.45	8512
11/08/2010	10217	0.33	3340	16/08/2011	9800	0.39	3850
Standard	116220	0.50	57568	Standard	117911	0.55	64506
28/04/2010	8300	0.84	6939	30/04/2011	23260	0.80	18675
18/05/2010	34150	0.50	17077	20/05/2011	11100	0.57	6274
07/06/2010	16862	0.55	9347	14/06/2011	18517	0.56	10369
06/07/2010	26779	0.47	12565	05/07/2011	29310	0.45	13159
29/07/2010	20489	0.40	8272	02/08/2011	30967	0.46	14343
11/08/2010	9640	0.35	3368	16/08/2011	4758	0.35	1687

costs of water, seeds, seedbeds, disinfectant, manure, fertiliser, etc.; (ii) Labour costs, including social security payments on behalf of the workers; and (iii) The variable costs of the machinery itself. The fixed costs refer to the costs of the machinery itself, social security payments made by the grower, the payment of taxes and other administrative costs and the rent payments for the land.

To obtain the discount rate, based on Equation (4), we used the average returns for the past 15 years as the risk free rate (17/9/1999 to 16/9/2014) of 10-year bonds (Bank of Spain, 2014). The average was 4.5% and the standard deviation was 0.82%. The average annual cash flow is obtained as the difference between the income and annual costs. The income is obtained by multiplying the weekly production by the average price (the product of the production of each calibre and its corresponding price). This process was carried out for both years to obtain the average for the PSNM and standard treatments (Table 5). The costs are shown in Tables 3 and 4.

Table 6 shows the annual income obtained with and without a PSNM, calculated from the values shown in Table 5. The PSNM

Table 4. Costs of the assembly of one hectare of greenhouse (Authors' calculation).

Concept		Cost (€)
Greenhouse installation		103895.19
Structure	76959.40	
Staking	1963.25	
Polycarbonate	1413.54	
Assembly	23559.00	
Drip irrigation system.		4600.00
Integrated drip emitter tube (Self-compensating)		
Cover film (Thermic 36 months 800 gg		7500.00
2,500 kg×3 € ha^{-1}		
Whitening		
Annual		260.00
Additional, every three years		260.00
PSNM[a]		
Labour		200.00
Non-woven polypropylene[b]		369.00

[a] Polypropylene Spunbonded Nonwoven Microtunnel. [b] We have considered a useful life of three years for the thermal cover.

Table 5. Annual costs for one hectare.

Concept		Cost (€)
1. Variable Costs		35946.35
1.1. Raw materials		20051.35
Water	8200 m^3×0.21 € m^{-3}= 1722	
Seed (Herminio)	25000×0.2 € plant^{-1}= 5000	
Seedbed	25000×0.037 € plant^{-1}= 925	
Disinfectant (Agrocelhone)	4495	
Pesticides	2640	
Auxiliary insects	2750	
Manure	40000 kg×0.03 € kg^{-1}= 1200	
Fertiliser	1319.35	
1.2. Labour		14195.00
Watering	540	
Phytosanitary application	246 h×5 € h^{-1}= 1230	
Varied labour	1330	
Staking	2120	
Maintenance and repairs	1200	
Plantation	45 h×5 € h^{-1}= 225	
Harvesting	1300 h×5 € h^{-1}= 6500	
Social security	1050	
1.3. Variable costs of the machinery itself		1700.00
2. Fixed costs		8660.00
2.1. Machinery		2680.00
2.2. Social security (Owner)		2040.00
2.3.Payments to public administrations (Land value t		3440.00
2.4 Land rent		500.00
Total cost		44.60635

Table 6. Production, average price and value of the production for the PSNM and standard treatment.

PSNM				Standard			
	kg ha^{-1}	Average price (€ kg^{-1})	€ ha^{-1}		kg ha^{-1}	Average price (€ kg^{-1})	€ ha^{-1}
2010	121673	0.56	67633	2010	116220	0.50	57568
12/04/2010	12113	1.07	13014	28/04/2010	8300	0.84	6939
19/04/2010	8075	0.93	7511	18/05/2010	34150	0.50	17077
28/04/2010	6729	0.89	5988	07/06/2010	16862	0.55	9347
18/05/2010	10267	0.53	5430	06/07/2010	26779	0.47	12565
07/06/2010	12473	0.57	7053	29/07/2010	20489	0.40	8272
06/07/2010	37700	0.42	16020	11/08/2010	9640	0.35	3,368
29/07/2010	24100	0.38	9277				
11/08/2010	10217	0.33	3340				
2011	119742	0.63	75228	2011	117911	0.55	64506
11/04/2011	13986	1.10	15417	30/04/2011	23260	0.80	18675
18/04/2011	9324	0.96	8914	20/05/2011	11100	0.57	6274
30/04/2011	9324	0.92	8533	14/06/2011	18517	0.56	10369
20/05/2011	16090	0.50	8050	05/07/2011	29310	0.45	13159
14/06/2011	30809	0.54	16681	02/08/2011	30967	0.46	14343
05/07/2011	11383	0.46	5271	16/08/2011	4758	0.35	1687
02/08/2011	19025	0.45	8512				
16/08/2011	9800	0.39	3850				
PSNM average	120707	0.35	71431	Standard average	117065	0.35	61037

costs are derived by adding the placement costs (€569) to the values obtained for the standard treatment. The annual cost column already includes the annual whitewashing. The updating of the NCF was made using a discount rate of 7%, obtained according to expression (4). The *NPV* was €51,880 for the standard treatment and €173,790 for the PSNM.

The Net Cash Flows (NCF) for standard are obtained as: NCFYear 0: - greenhouse (103,895) - drip irrigation (4,600) - cover film (7,500) NCFYears 1,...,30: Incomme (61,037) - drip irrigation (4,600, years 10 and 20) - cover film (7,500, years 3, 6, 9, ...) - annual cost plus whitening (45,366) - additional whitening (260, years 2, 5, 8, ...).

The NCF for PSNM are obtained as: NCFyear 0 = - greenhouse (103,895) - drip irrigation (4,600) - cover film (7,500) NCFYear 1,...,30 = Incomme (71,431) - drip irrigation (4,600, years 10 and 20) - cover film (7,500, years 3, 6, 9, ...) - annual cost plus whitening (45,366) - aditional whitening (260, years 2, 5, 8,...) - microtunnel (569).

Table 7 summarizes the results obtained. The installation of the PSNM improved the outcomes derived with the different methodologies. With the PSNM, the values of NPV and Net Yield were triple those achieved with the standard treatment, while the Payback was reduced by almost half.

Figure 3 shows the results obtained with the previous information and using the Monte Carlo simulation. Without the use of a PSNM, the average annual yield with Monte Carlo simulation is 4.204, with some negative values. With the PSNM, the average is 14.099, being positive in most cases.

The *NPV* values are 53,586 and 177,233 for the PSNM and standard treatments, respectively, with several negative values in the first case and mostly positive values in the second.

Regarding the ratio *NPV*/investment, it can be seen that the PSNMs provide a higher value in most situations. The average values are 0.36 and 1.20 with a PSNM and without, respectively, being mostly positive in the case of the PSNMs but with some negative values in their absence.

Lastly, the use of PSNMs gave a shorter Payback time, the average being 5.65 years, which increased to 9.85 years without the microtunnel.

To determine the maximum assumable risk, the $VaR_{5\%}$ was calculated for the four variables (Table 8).

This value indicates, for annualised values, the maximum annual loss which the producer assumes in 95% of cases; put another way, on 95% of occasions, the loss will not exceed these values (or the benefit will be higher).

For one hectare, with no microtunnel, 95% of the time, the annual value (including the annual costs, labour and part of the initial costs distributed over the useful life of the investment) of the loss is not greater than €2,328 (Table9); if no thermal blanket is

Table 7. Derivation of the Payback.

Year	NCF standard	NCF PSNM	NCF standard accumulated	NCF PSNM accumulated
0	-116255	-116255	-116255	-116255
1	16171	25995	-100084	-90260
2	15911	25735	-84173	-64525
3	8671	18495	-75503	-46030
4	16171	25995	-59332	-20034
5	15911	25735	-43421	5701
6	8671	18495	-34750	24196
7	16171	25995	-18579	50191
8	15911	25735	-2668	75926
9	8671	18495	6003	94421
10	11571	21395	17574	115817

Table 8. Summary of results for the Standard and PSNM treatments.

	Standard	PSNM
NPV	51845	173756
Net yield	4178	14002
Net benefit ratio	0.352	1.178
Pay back	9	5

Table 9. $VaR_{5\%}$ for the different variables studied.

	Standard	PSNM
Annual yield	-2328	7589
NPV/investment	-0.19	0.62
Pay back	15.19	7.25
NPV	-27719	89417

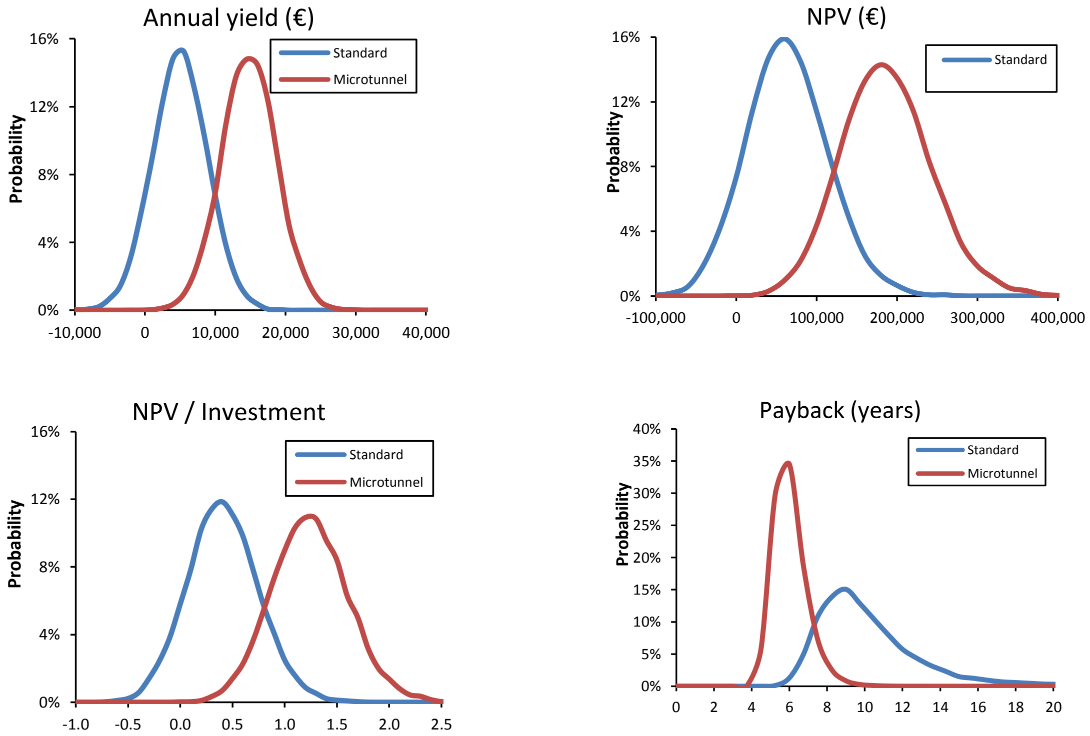

Figure 3. Monte Carlo simulation for the variables annual yield, payback time, benefit/investment ratio and NPV.

used, the benefit is positive in most cases and, in 95% of cases, it is higher than €7,589.

It can be stated that, in 95% of cases, the *NPV*/investment ratio is not lower than -0.19 without the use of a microtunnel and not lower than 0.62 with them.

The $VaR_{5\%}$ of the Payback time is 7.25 years in the case of the PSNM treatment and 15.19 years without the use of a PSNM. This means that, on 95% of occasions, the Payback time will be shorter than these values.

Lastly, when not using a microtunnel, the *NPV* is higher than -€27,719 in 95% of cases. This means that, for the range of prices considered, the actual value of the loss will not exceed that value. Meanwhile, with the use of a PSNM, the profit will exceed €89,417 in 95% of cases.

Lastly, determination of the confidence level of *NPV* (Figure 4) - that is, the probability that the *NPV* will be negative - gave a value of 0.14 when not using a microtunnel and 0.00 with a PSNM. Thus, it can be deduced that the performance will always be positive if using a PSNM, but the same cannot be said when not using a PSNM.

DISCUSSION

The profit obtained by an agricultural company depends, amongst other things, on

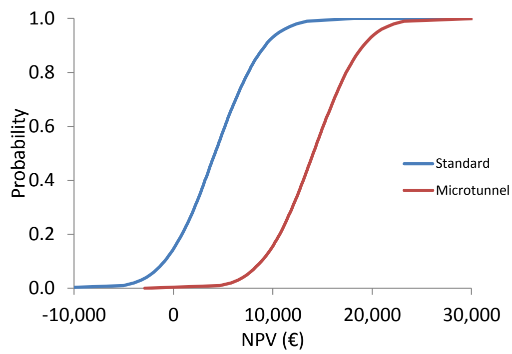

Figure 4. *NPV* accumulated probability.

the means of production used. However, it must not be forgotten that prices fluctuate, not only from year to year but also during the same year. Several studies have dealt with this question: for example, Ott (2014) analysed the cause of these variations in cereals, while Hwang and Ahn (2012) analysed them in fresh fruits, concluding that agricultural policies that stabilise the price of such products are needed. Meanwhile, Kang (2008) studied the relationship between the volatility of the offer and the volatility of corresponding wholesale prices using a GARCH-GJR model. According to the author, there are two kinds of source for the increase in volatility of daily supply: one is adverse weather and the other is the suppliers' controllability of daily carry-in, which makes the price less volatile.

As can be seen, these processes have been well studied, and it can only be concluded that the agricultural business must not only live with them, but must also try to benefit from them. Pisanu *et al.* (2012) studied the effect of the density of artichoke clones on precocity and economic yield. Higher density had a negative effect on earliness and the uniformity of artichoke heads. For their part, Dong *et al.* (2010) analysed the effects of an Unequal Salt Distribution (USD) in the root zone and concluded that yield and earliness increased 20.8% and 5.1%, respectively, as a result of furrow seeding rather than flat seeding. Csuvar *et al.* (2009) analysed the convenience of using CO_2 in greenhouses to improve different aspects of cultivation such as earliness.

In line with these studies and bearing in mind the record of pepper prices (Figure 1) and that the normal harvesting of peppers in a greenhouse starts in week 19 (the beginning of May), it is evident that bringing forward production will allow growers to benefit from higher prices. This is why cultivation methods such as the use of microtunnels, which allow harvesting to commence a few weeks earlier, should allow growers to enjoy higher prices.

The distribution of costs is similar to that which arises normally, as shown by Orús (2009). Fernández-Zamudio *et al.* (2006) provided very similar values for the variable costs of the California variety Quito: €3,482 ha^{-1} with underground heating, while the fixed costs rose to €1,298 ha^{-1} with opportunity costs of €0.303 ha^{-1}. Salas *et al.* (2003) found lower variable costs, of between 20,300 and 22,500€ ha^{-1}, depending on the treatment applied.

For the correct evaluation of investment and costs, a suitable discount rate must be used. We used Equation (4) and, as the risk-free rate, the average of the last 15 years (17/9/1999 to 16/9/2014) of 10-year bonds (Bank of Spain, 2014*)*. The average was 4.5% and the standard deviation was 0.82%.

To obtain the discount rate, we must add a risk premium to this value. The literature regarding this is abundant, and we only need to mention Fernández *et al.* (2011), who interviewed directors, analysts and university teachers, obtaining a wide range of replies. The mean for university teachers and directors was 5.5%, while for analysts it was 5.0%. On the other hand, authors such as Dimson *et al.* (2007), Ibbotson Associates (2006), Shiller (2000), Wilson and Jones (2002), Damodaran (2002), Brotons and Terceño (2010), Siegel (2005) and Fernández (2009) estimated the risk premium at between 4.2 and 8.5%. Because of this dispersion, we used a range between 4.2 and 8.5%. For its part, the β of the food and beverages sector of the Madrid Stock Exchange (2013) was 0.3951. In this way and according to expression (4), the Monte Carlo simulation allowed different values of the discount rate to be used.

To study sensitivity, we used the Monte Carlo simulation model, a tool which allows the distribution functions of the variables to be studied. This methodology has been used in other work: for example, in Quiroga *et al.* (2011) to evaluate the hydrological risk and water policy implications for food production. The use of the Monte Carlo simulation allows us to obtain not only one value but a distribution of performance probabilities. Hence, this article shows not only the evaluation of the agricultural holding, but of a range of values and distributions of probability.

The use of the Monte Carlo simulation model led to the following conclusions,

-The average annualised yield, according to Monte Carlo simulation, is 4,221 when not using a microtunnel and is negative for some values. If we do use a PSNM, the average is 14,057, and it is positive in most cases.

-The results for *NPV* are similar, with mean values of 53,876 and 177,006 with and without a PSNM, respectively, several values being negative in the first case and almost none in the second case.

-Regarding the *NPV*/investment ratio, use of a PSNM gave a higher value in most situations. The mean values reached are 0.36 and 1.19 with and without a PSNM, respectively, being mostly positive with a PSNM and occasionally negative without.

-Lastly, the Payback time is shorter when using a PSNM: an average of 5.66 years with and 9.88 years without.

In this sense, Popescu *et al.* (1995) made a study of the growth of sweet pepper plants in a soilless system that was supposed to solve some of the problems associated with traditional cultivation. The results highlight the superiority of substrate over soil cultivation since total yield doubled, harvesting was two weeks earlier and there was a drastic diminution of the number of phytosanitary treatments.

As an additional measure, to analyse the risk of the studied variables, we used the Value at Risk (VaR), a parameter frequently used in agricultural studies. Moreira *et al.* (2014) used *VaR* to evaluate three strategies for the management of risks in corn trading: simultaneous buying and selling, storage and short selling. In this sense, Dos Santos *et al.* (2013) determined the maximum loss acceptable on investments for a producer of 100/120-kg-calibre grey shrimps. Likewise, in our study, the maximum loss at 95% is 2,289 when not using a PSNM and is zero when one is used (as VaR is equal to €7,489).

CONCLUSIONS

The use of a PSNM raises the marketable production and brings forward the first harvests, so that the growers can benefit from the higher prices at the start of the season and boost their income significantly. The mean income was increased from 61.037 to 71.431 €/ha by the use of a PSNM. The values of all the indicators used (NPV, net yield, net benefit ratio and payback) were improved by the use of a PSNM. In particular, the net present value rose from 51,845 to 173,756 € ha^{-1} with the use of a PSNM. By contrast, the use of a PSNM cut the Payback from nine to five years, thus shortening significantly the time required for the grower to recover his investment. Analysis of the *VaR* shows that, in 95% of cases, the annual loss due to the application of the standard method of cultivation does not exceed €2,238, whereas with a PSNM it is always positive (the NPV and NPV/investment ratio give the identical interpretation). With the use of a PSNM, the payback, in 95% of cases, is less than 7.25 years.

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REFERENCES

1. Attarod, P., Kheirkhah, F., Khalighi Sigaroodi, Sh. and Sadeghi, S. M. M. 2015. Sensitivity of Reference Evapotranspiration to Global Warming in the Caspian Region, North of Iran. *J. Agr. Sci. Tech.,* **17:** 69-883-869.
2. Bakker, J.C., Adams, S.R., Boulard, T. and Montero, J. I. 2008. Innovative

Technologies for an Efficient Use of Energy. *Acta Hort.,* **801:** 49-62.

3. Bank of Spain. 2014. *Boletín del Mercado de Deuda Pública*. Number 6544. Year 26 Available at: http://www.bde.es/webbde/es/secciones/informes/banota/boleanf.html. Accessed February 2015.
4. Brealey, R. and Myers, S. 2001. *Principios de finanzas corporativas*. McGraw-Hill. Madrid.
5. Brotons, J. M. and Terceño, A. 2010. A Risk Premium in the Spanish Market: An Empirical Study. *Econ. Comput. Econ. Cyb.*, **1(44):** 81-99.
6. Buchholz M., Jochum P. and Zaragoza G. 2005. 'Basic Water, Heat and Food Supply from a Closed Greenhouse – The Watergy Project'. *Acta Hortic.*, **691**:509-516.
7. Boulard, T., Fatnassi, H., Roy, J.C., Lagier, J., Fargues, J., Smits, N., Rougier, M. and Jeannequin, B. 2004. Effect of Greenhouse Ventilation on Humidity of Inside Air and in Leaf Boundary-Layer. *Agr. Forest. Meteorol.*, **125**: 225-239.
8. Castilla, N. 2005. *Invernaderos de Plástico. Tecnología y Manejo*. Ed Mundi-Prensa, Madrid.
9. Csuvar, A., Krecz, A., Paksi, A. Kassai, T. and Dimeny, J. 2009. Effect of Atmospheric CO2 Enrichment on Tomato, Grown in Soil. *Cereal Res. Communicat.*, **37:** 201-204.
10. Damodaran, A. 2002. *Investment Valuation*. 2ª Edition, John Wiley and Sons.
11. Dimson, E., Marsh, P. and Staunton, M. 2007. The Worldwide Equity Premium: A Smaller Puzzle. In: "*Handbook of Investments: Equity Risk Premium*", (Ed.): Mehra, R. Elsevier.
12. Dong, H. Z., Kong, X. G., Luo, Z., Li, W. J. and Xin, C. S. 2010. Unequal Salt Distribution in the Root Zone Increases Growth and Yield of Cotton. *Eur. J. Agron.*, **33(4):** 285-292.
13. Dos Santos, I. J, Rezende, A. L. and De Souza, V. 2013. Evidences in the Projection of Value-at- Risk in Prices of Shrimp in Brazil using ARIMA Models with GARCH Errors. *Custos Agronegocio*, **9(3):** 49-78.
14. Fernández, P. 2009. La Prima de Riesgo del Mercado Según 100 Libros. IESE Business School–Navarra University. http://www.iese.edu/research/pdfs/di-0823.pdf Accessed December 15.
15. Fernández, P., Aguirreamalloa, J. and Corres, L. 2011. Prima de Riesgo Utilizada en el Mercado: Encuesta. Documento de Investigación DI-921, IESE Business School, Universidad de Navarra.
16. Fernández-Zamudio, M. A., Pérez, A. and Caballero, P. 2006. Costes de Tecnología en Invernaderos de Pimientos. *Hortic. Int*., **51:** 20-26.
17. García-Martínez, M., Caballero, C. and Fernández-Zamudio, P. 2008. Price Trends in Greenhouse Tomato and Pepper and Choice of Adoptable Technology. *Span. J. Agric. Res.*, **6(3):** 320-332.
18. Hemphill, J. D. D. and Mansour, N. S. 1986. Response of Muskmelon to Three Floating Row Covers. *J. Am. Soc. Hortic. Sci.,* **111:** 513–517
19. Hwang, E. S. and Ahn, B. 2012. Analysis on the Characteristics of the Trend and Volatility of the Major Fruits and Vegetables. *Korean J. Agron.,* **53(3):** 1-21.
20. Ibbotson Associates. 2006. *Stocks, Bonds, Bills, and Inflation.* Valuation Edition, Yearbook.
21. Kang, T. 2008. The Influences of Volume Volatilities on Wholesale Price Stabilities for Fresh Vegetables. *Korean J. Agron*., **49(1):** 21-38
22. Kroese, D. P., Taimre, T. and Botev, Z. I. 2011. *Handbook of Monte Carlo Methods*. Wiley Publication, A John Wiley and Sons, Inc., Hoboken, New Jersey.
23. López-Marín J., Egea-Gilabert, C., González, A., Pérez-Alfocea, F. and Fernández, J. A. 2013. Grafting is an Efficient Alternative to Shading Screens to Alleviate Thermal Stress in Greenhouse-Grown Sweet Pepper. *Sci. Hortic-Amsterdam*, **149:** 39-46.
24. López-Marín, J., Gálvez, A., González, A. and Fernández, J. A. 2009. Agronomic Behaviour of Grafted Sweet Pepper Grown in a Greenhouse in Mediterranean Area. *Acta Hortic.*, **807:** 655-660.
25. López-Marín, J., González, A., García-Alonso, Y., Espí, E., Salmerón, A., Fontecha, A. and Real, A. I. 2008. Use of Cool Plastic Films for Greenhouse Covering in Southern Spain. *Acta Hortic.*, **801:** 181-186.
26. Madrid Stock Exchange. 2013. Available at: http://www.bolsamadrid.es/docs/Sbolsas/InformesSB/anual.pdf, Accessed February 2015.

27. MAGRAMA. 2015. *Ministerio de Agricultura, Alimentación y Medio Ambiente.* Observatorio de precios de los alimentos. http://www.magrama.gob.es/es/estadistica/temas/estadisticas-alimentacion/observatorio-precios/. Access 15 January 2015.
28. Montero, J. I., Van Henten, E. J., Son, J. E. and Castilla, N. 2011. Greenhouse Engineering: New Technologies and Approaches. *Acta Hortic.*, **893**: 51-63.
29. Moreira, V. R., Souza, A. and Duclós, L. C. 2014. Avaliação de Retornos e Riscos na Comercialização de Milho: Estudo de Caso Usando Value-at-Risk. *Revista de Economia e Sociologia Rural*, **52(2):** 303-322.
30. Olofsson, T., Majabacka, A. and Engblom, S. 2006. Evaluation of Energy Performance for Greenhouses Based on Multivariate Analysis Methodology. *Acta Hortic.,* **718:** 211-218.
31. Orús F. 2009. Fertilización Agrícola y Producción Agraria Sostenible. *ITEA-Inf. Tec. Econ. Agr., 105(1):* 1-4
32. Ott, H. 2014. Volatility in Cereal Prices: Intra-Versus Inter-Annual Volatility. *J. Agr. Econ.,* **65(3):** 557-578.
33. Pisanu, A.B., Mallica, G., Baghino, L., Cadinu, M., Repetto, A., Tatti, A.M., Beneventi, S., Pilia, R. and Muntoni, M. 2012. Different Plant Densities of Micropropagated 'Spinoso Sardo' Artichokes. *VII International Symposium on Artichoke, Cardoon and Their Wild Relatives. Acta Hortic.,* **942:** 261-266.
34. Popescu, N., Lacatus, V. and Voican, V. 1995. Sweet Pepper Grown on Organic Substrates Compared to Soil under High Plastic Tunnels. First International Symposium on Solanacea for Fresh Market. *Book Series: Acta Hortic.,* **412:** 348-354.
35. Pruzzo, L., Cantet, R. J. C. and Fioretti, C. C. 2003. Risk-Adjusted Expected Return for Selection Decisions. *J. Anim. Sci.,* **81:** 2984–2988
36. Quiroga, S., Fernández-Haddad, Z. and Iglesias, A. 2011. Crop Yields Response to Water Pressures in the Ebro Basin in Spain: Risk and Water Policy Implications. *Hydrol. Earth. Syst. Sci.,* **15:** 505-518.
37. Salas M. C., Urrestarazu, M., Castillo, E. and Berenguer, J. J. 2003. Costos Variables en el Cultivo del Pimiento. *Horticultura,* **169:** 14-21.
38. Saunders, A., Boudoukh, A. and Allen, L. 2003. *Understanding Market, Credit, and Operational Risk. The Value at Risk Approach*. John Wiley and Sons.
39. Shiller, R. J. 2000. *Irrational Exuberance*. Princeton University Press, Princeton, New Jersey.
40. Siegel, J. J. 2005. Perspectives on the Equity Risk Premium. *Financ. Anal. J.,* **61(6):** 61-71.
41. Soltani, N., Anderson, J. L. and Hamson, A. R. 1995. Growth Analysis of Watermelon Plants Grown with Mulches and Row Covers. *J. Am. Soc. Hortic. Sci.,* **120:** 1001–1009.
42. Van der Knijff, A., Benninga, J., Reijnders C. and Nienhuis, J. 2004. *Energy in Greenhouse Horticulture in The Netherlands. Developments in the Sector and Individual Enterprises until 2004.* Report 3.06.02, LEI, Den Haag, 77 PP.
43. Vesine, E., Grisey, A., Pommier, F., Chantry, N., Plasenti, J. and Chassériaux, G. 2007. *Utilisation Rationelle de Lénergie Dans les Serres. Situation Technico-Economique et Leviers Diction Actuels et Futures*. Report Department DPIA, ADEME Angers, France. 134 PP.
44. Welch, I. 2009. *Corporate Finance: An Introduction*. Prentice Hall, New York.
45. Wilson, J. W. and Jones, C. P. 2002. An Analysis of the S&P500 Index and Cowles's Extensions: Price Indexes and Stock Returns, 1870-1999. *J. Bus*., **75(3):** 505-533.
46. Wolf, D. W., Albright, L. D. and Wyland, J. 1989. Modeling Row Cover Effects on Microclimate and Yield. I. Growth Response of Tomato and Cucumber. *J. Am. Soc. Hortic. Sci.,* **114(4):** 562–568.

استفاده از PSNM برای افزایش زودرسی و فواید آن در فلفل دلمه ای گلخانه ای

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چکیده

انواع و ارقام مختلفی از فلفل دلمه ای ها در حوضه مدیترانه در پاسخ به تقاضای بازارهای اروپایی کشت یافته اند، اگرچه در هر جامعه محلی، ارقام محلی برای براوردن تقاضای محلی استفاده می شود. امروزه، طیف وسیعی از اشکال و رنگ ها در گلخانه ها، به دلیل سلایق مختلف، تمایلات ملی و بین المللی و افزایش تقاضا به وجود آمده است. در مورسیا، چرخه رشد از دسامبر تا ماه ژوئیه یا اوت، با توجه به بازار و رشد محصول اجرا می شود. فلفل دلمه ای به طور معمول در گلخانه با استفاده از انواع فناوریها از گلخانه ساده سایه دارتا گلخانه های چند تونلی پیشرفته (بزرگ، در قالب یک قوس گرد یا قوس گوتیک و با تهویه پیچیده) تولید می شود. استفاده از حرارت در زمستان پس از نشاء، با توجه به هزینه های بالای سوخت، غیر ممکن است، از این رو روش های جایگزین برای بالا بردن درجه حرارت و بهبود تولید محصول استفاده می شود. هدف از این کار افزایش زودرسی و بهره وری فلفل دلمه ای رشد کرده در گلخانه بود. اثر(polypropylene spunbonded nonwoven microtunnel (PSNM مورد مطالعه قرار گرفت. نتایج نشان می دهد که اگرچه افزایش چندانی در محصول مشاهده نشد (کمتر از ۵٪ در هر دو سال) اما زودرسی ۱۶ درصدی در هر دو سال مشاهده شد. از آن جا که استفاده از این تکنولوژی هزنیه چندانی نداشت ، سودآوری محصول با توجه به در نظر گرفتن شاخص زودرسی افزایش یافت. این مطالعه نشان می دهد که استفاده از PSNM ، تولید برای بازار را افزایش و برداشت زودتر را به ارمغان می آورد.