Cost efficiency of different cropping systems encompassing the energy crop Helianthus annuus L.

E. Skoufogianni, K.D. Giannoulis*, D. Bartzialis and N.G. Danalatos

University of Thessaly, Department of Agriculture, Crop Production & Rural Environment, Fytokoy street, 38443, Volos, Greece

*Correspondence: kyriakos.giannoulis@gmail.com

Abstract. Crop rotation and green manure are the most ancient and popular cropping systems. This study sought to analyze the economic efficiency of sunflower where pea (Pisum sativum L.) either harvested or incorporated at the flowering stage in the soil before the sowing of sunflower in Europe and the final agricultural profit of such a cultivation system. Therefore, the main objective of this paper is to report the production costs and to find out which of the tested cultivation system gets sunflower cultivation economically viable in Greece and in Mediterranean region. To assess the economic efficiency, three-year field experiments were established in two contrasting environments in central Greece (Trikala and Larisa) and contained three different cultivation practices using legumes comprised the main-factor (T1: control, T2: legume incorporated at the flowering stage, T3: legume incorporated after seed harvest), while nitrogen fertilization comprised the sub-factor (N1:0, N2:50, N3:100 and N4:150 kgNha⁻¹). The results derived from this study revealed the positive effect of the legume incorporation treatment (T2: legume incorporated at the flowering stage) where the final yield increased up to 5 t ha⁻¹ regardless region. Moreover, depending on the year the T2 treatment increases the final yield 30–50% and a yield increase was also noticed to the treatment where the legume was harvested (T3: legume incorporated after seed harvest). Therefore the introduction of this scheme into future land use systems in Greece and more generally in Mediterranean basin should be seriously taken into consideration.

Key words: sunflower, pea, monocrop, rotation, green manure.

INTRODUCTION

A challenge for sustainable agriculture is to identify those plants which are most efficient in forming stable soil structure and to incorporate them into economic rotational management systems. Several organic materials have been reported as suitable soil amendments for increasing crop production and the most ancient and famous are crop rotation and green manure (Ruis & Blanco-Canqui, 2017).

It is generally accepted that rotation with cover crops is fundamental for yield increase, as well as for controlling soil erosion and degradation, ground water pollution, and maintaining acceptable organic matter levels in the topsoil (Ruis & Blanco-Canqui, 2017). Soil organic matter represents a major proportion of the organic carbon within a terrestrial biosphere which plays an important role in soil fertility and affects infiltration, water retention, crop growth and productivity (Stepięń et al., 2018). As a result, by conserving the soil its yield over time and generally agroecosystem sustainability are
ensured (Powlson et al., 2001; Brennan & Smith, 2005; Tonitto et al., 2006; Ordonez et al., 2007; Imogie et al., 2008; Cattanio 2012; Isbell et al., 2017).

Legumes are included in crop systems due to the atmospheric N fixation of nitrogen and are the finest external options that can be used to enhance the efficiency of nitrogen use (Thorup-Kristensen et al., 2003; Fageria & Baligar, 2005; Dorn et al., 2015). *Pisum sativum* has great potential among legume species that could be used as cover crops, as it is well adapted to Mediterranean-type crops with thriving cultivation techniques (Miller et al., 2003). Residue quality is usually associated with two factors: the time to preserve its physical characteristics, and the supply of carbon and mineral elements from its decomposition. These two aspects are affected by both the climate and the structure of the residue (Vergani & Graf, 2015; Bacq-Labreuil et al., 2018). It has been reported (Voroney et al., 1989) that the fixation of organic carbon from pea residue would sequester 212–318 kg of C ha\(^{-1}\).

Nitrogen (N) is one of the most important elements in the metabolic processes of plants such as protein synthesis and photosynthetic processes. Consequently its use is necessary in order to maximize yields and quality of crops worldwide (Ahmad et al., 2009; Massignam et al., 2009; Ullah et al., 2010).

Nitrogen is a limiting factor that prevents yield in many crops such as sunflower. Sunflower growth depends more on nitrogen than any other nutrient (FAO, 2010). Thus, meeting the needs of the plant in N is necessary for the crop to be profitable (Mortvedt et al., 2003). More specifically the requirements of the sunflower in nitrogen reach 100 kg N ha\(^{-1}\) in order to have a good yield (Malligawad et al., 2004). However, nitrogen fertilization is quite variable and depends largely on the soil type and the climate conditions of the area (Chapman et al., 1993; Lauretti et al., 2007). Sunflower has a mean rooting depth of 50 cm that varies with different cultivation management (e.g., tillage system) (Gajri et al., 1997). Water consumption of sunflower may range from 200 to over 900 mm per season, depending on many factors (like latitude, soil-climate conditions, sowing period and management (Gajri et al., 1997; Debaeke et al., 1998; Karam et al., 2007).

Moreover, it is well documented that sunflower is a crop with low water use efficiency (Rinaldi, 2001; Goskoy et al., 2004), while Mediterranean areas are characterized by mild temperatures and high water availability early in the season, but later on and especially during summer due to greater temperatures and minimum rainfalls, irrigation application seems inevitable (Soriano et al., 2004). In order to reach high seed yields, sunflower should be irrigated at least three times during its growing period, especially during heading, flowering and milking stage, with full or limited irrigation water (Goskoy et al., 2004). Responses to fertilization are also influenced by weather conditions and soil water availability (Lopez-Bellido, 2003). Studies have shown that the optimum amount of N-fertilization is found mainly in the range of 40–190 kg N ha\(^{-1}\), depending on soil type and previous crop (Sirbu et al., 1992; Glas, 1998).

Nitrogen is very essential for plant growth and makes up 1–4% of dry matter of the plants. Moreover, in the case of the comparison between a mono-crop system (industrial crop-industrial crop) and a crop-rotation system (industrial crop - leguminous crop rotation), N application averages 18% and 13% of the variable costs, respectively (Duvick & Cassman, 1999).

There are no data reported about the cost performance of *Pisum sativum*, either harvested or incorporated in the soil before the sowing of sunflower in Europe and the
the main objective of this paper is to report the production costs and to find out which of the tested cultivation system makes economically feasible sunflower cultivation in Greece and the Mediterranean region generally.

MATERIALS AND METHODS

Field experiment
Two field experiments were established in two different soils, e.g. in Trikala (West Thessaly; coordinates: 39032 mottle 17.08° ppl N, 21046 mottle 17.19° E, 120 m asl) and in Larisa (East Thessaly; coordinates: 39030 mottle 02.85° ppl N, 22042 mottle 50.37° E, 60 m asl), central Greece.

The soil in Larisa (plough layer) is a calcareous (pH: 8.0) clay (sand 2%, silt 35%, clay 63%), fertile (organic matter content 1.7% at 20 cm depth) and was classified as Vertisol (Soil Survey Staff, 1993), while the soil in Trikala area (plough layer) is deep, calcareous (pH: 7.4), sandy clay loam (sand 62%, silt 17%, clay 21%), fertile (1.25% organic matter content at 30 cm depth). The soil is characterized as Entisol (Aquic Xerofluvent; Soil Survey Staff, 1993).

For the purposes of the study sunflower (Hybrid Panter) was sown using a modern pneumatic seeding machine and the population was 7 plants m⁻² for both sites. The experimental used design was a factorial split plot with three replications (3 blocks) and 12 plots per block. Three different cultivation practices using legumes (Pisum sativum L., cv. caroubi) comprised the main-factor (T₁: control; T₂: legume incorporated at the flowering stage, average 6,000 kg ha⁻¹ dry yield; T₃: legume incorporated after seed harvest), while nitrogen fertilization comprised the sub-factor (N₁: 0, N₂: 50, N₃: 100 and N₄: 150 kg N ha⁻¹). The second dose (nitrate form) was applied on the onset vegetative phase of sunflower, at plant height approximately up to 60cm. Sowing dates and other relevant agronomic data are summarized in Table 1. Fertilization for pea was 60 kg Pha⁻¹
(superphosphate) as basal dressing. The amount of dry biomass of pea incorporated in the top soil was measured directly by means of destructive sampling upon full flowering each year.

During the harvest period (seed maturation) in both areas, a destructive sampling took place by hand, where 1 m\(^2\) in every plot was harvested.

It should be noticed that proper nutrient uptake determinations require at least one extra year of field experimentation, with the plots with same fertilization levels placed exactly at the same position to minimize any residual effect from previous fertilization. This was the case in both field experiments here. The presented data correspond to 2012 and 2013 experimental years, where the crops were sown in the same position for the 2\(^{nd}\) and 3\(^{rd}\) growing period.

**Economic Parameters - Trade off analysis**

Besides the agronomic aspects of a cultivation system, analysis of cost–benefit ratio mainly demonstrates farmer’s profitability. To assess this, on farm budgets were constructed including three scenarios: i. sunflower as a single crop (mono-crop system), ii. Sunflower as a second crop after legume incorporated at the flowering stage (rotational system), iii. Sunflower as a second crop after legume incorporated after pea seed harvest (rotational system).

The economic costs of the cultivation systems were land rent and establishment costs of each cultivation such as plowing, cheelering, harrowing, sowing, herbicide application, seeds, irrigation, fertilization, incorporation and labor costs for the preparation of the above practices (€ hour\(^{-1}\) multiplied with the sum of the needed hours per hectare; existing market prices in Greece were considered), and harvesting costs which depend on the crop (Table 2). Furthermore, to calculate economic returns (per hectare); for the each crop, existing market prices in Greece were considered (the prices refer to the average prices obtained from the survey carried out in the local area during the experimental period). To construct such databases, material and operation costs were considered as well as the local market prices (0.38 and 0.50 € kg\(^{-1}\) for sunflower seed and pea grain, respectively).

| Table 2. Pisum sativum and Helianthus annuus cultivation costs in central Greece |
|---------------------------------|----------------------------------|----------------------------------|----------------------------------|
|                                 | € ha\(^{-1}\)                    |                                  |                                  |
| Cultivation costs              |                                  |                                  |                                  |
| Weed management (labor)         | 15                               | 15                               | 15                               |
| Plowing                        | 90                               | 90                               | 90                               |
| Cheeler                        | 40                               | 40                               | 40                               |
| Harrowing                      | 60                               | 60                               | 60                               |
| Sowing                         | 20                               | 20                               | 30                               |
| Seeds                          | 170                              | 170                              | 50                               |
| Irrigation                     | 0                                | 0                                | 300                              |
| Fertilization                  | 15                               | 15                               | 15                               |
| Fertilizer (46-0-0)            | 150                              | 150                              | 0                                |
| Land Rent                      | 700                              | 700                              | 0                                |
| Harvest Cost                   | 200                              | 0                                | 150                              |

**Statistical analysis**

The statistical package GenStat (7\(^{th}\) Edition) was used for the analysis of variance (ANOVA) within sample timings for all measured and derived data. The LSD\(_{0.05}\) was used as the test criterion for assessing differences between means (Steel & Torrie, 1982).
RESULTS AND DISCUSSION

Sunflower Yield

The positive effect of nitrogen fertilization to the final seed yield of sunflower has been mentioned worldwide (Rinaldi et al., 2001; Zubillaga et al., 2002; Ruffo et al., 2003; Göksoy et al., 2004; Albrizio & Steduto, 2005). The same was also noticed in this study, where the two higher nitrogen fertilization applications (N₃, N₄; 4–4.2 t ha⁻¹) produced 1-1.2 t ha⁻¹ higher yield in comparison with the lower levels (N₁, N₂; 3 t ha⁻¹) for both years and areas (Table 3).

The most impressing finding was the positive effect of the legume incorporation treatment (T₂) where the final yield increased up to 5 t ha⁻¹ in 2012 for both areas, while in 2013 remained in lower levels 4.72 t ha⁻¹. The higher harvested yield in 2012 was noticed due to higher precipitation during the seed filling stage. Therefore, depending on the year the T₂ treatment will increase the final yield 30–50% which is in agreement with literature (Thorup-Kristensen & Dresboll, 2010).

This is due to the nitrogen-binding capacity of the pea, and in particular, during the flowering stage where the nitrogen (N), phosphorus (P) and potassium (K) contents are 10, 3.15, and 3%, respectively, for both sites (data not shown). Finally, it has to be mentioned that there was also found a yield increase to the treatment where the legume was harvested (T₃), which also agree with Stepien et al. (2017) where it is reported an influence of crop rotation on rapeseed seed yield.

It is really important to be mentioned that in sandy soils such as in Trikala, significant yields on seed can be achieved with only small nitrogen applications if the cultivation practice of crop rotation, and in particular that of green fertilization using legumes and in particular peas.

In higher fertility, clay soils such as Larisa, crop rotation has clear benefits in organic carbon and enzyme activities and is related to the percentage of the organic matter as well as the total percentage N. The deep, perennial root system of sunflower utilizes the maximum of the nutrients (Omay et al., 1997; Potter et al., 1998; Ashraf et al., 2004; Sainju et al., 2006; Lopez-Belido et al., 2010; Melero et al., 2011).

Table 3. Sunflower seed yield (kg ha⁻¹) as affected by three cultivation practices and four nitrogen fertilization levels

<table>
<thead>
<tr>
<th></th>
<th>Seed Yield</th>
<th>Seed Yield</th>
<th>Seed Yield</th>
<th>Seed Yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Larisa</td>
<td>1st year</td>
<td>2nd year</td>
<td>1st year</td>
<td>2nd year</td>
</tr>
<tr>
<td>N₁</td>
<td>2,537</td>
<td>3,295</td>
<td>3,019</td>
<td>3,895</td>
</tr>
<tr>
<td>N₂</td>
<td>4,165</td>
<td>5,197</td>
<td>5,288</td>
<td>5,123</td>
</tr>
<tr>
<td>N₃</td>
<td>3,415</td>
<td>4,116</td>
<td>3,844</td>
<td>3,956</td>
</tr>
<tr>
<td>N₄</td>
<td>3,597</td>
<td>4,376</td>
<td>4,432</td>
<td>3,633</td>
</tr>
<tr>
<td>T₁</td>
<td>3,663</td>
<td>4,154</td>
<td>4,576</td>
<td>3,784</td>
</tr>
<tr>
<td>LSD₀.₀₅</td>
<td>686.0</td>
<td>789.7</td>
<td>91.4</td>
<td>692.7</td>
</tr>
<tr>
<td>N₁</td>
<td>2,826</td>
<td>3,753</td>
<td>3,222</td>
<td>3,283</td>
</tr>
<tr>
<td>N₂</td>
<td>3,194</td>
<td>3,887</td>
<td>3,970</td>
<td>3,643</td>
</tr>
<tr>
<td>N₃</td>
<td>3,597</td>
<td>4,376</td>
<td>4,432</td>
<td>3,633</td>
</tr>
<tr>
<td>N₄</td>
<td>3,663</td>
<td>4,154</td>
<td>4,576</td>
<td>3,784</td>
</tr>
<tr>
<td>LSD₀.₀₅</td>
<td>209.0</td>
<td>103.8</td>
<td>302.5</td>
<td>536.4</td>
</tr>
<tr>
<td>CV(%)</td>
<td>5.5</td>
<td>14.5</td>
<td>12.3</td>
<td>12.0</td>
</tr>
</tbody>
</table>

*(T₁: control; T₂: legume incorporated at the flowering stage; T₃: legume incorporated after seed harvest; N₁: 0; N₂: 50; N₃: 100 and N₄: 150 kg N ha⁻¹).

Pea Yield

The blossom stage of pea begins at the Growing Degree Days of 350 °C-d while the seed maturation takes place at 820 °C-d in Larisa and at 947 °C-d in Trikala. The seed growing rate is 100–120 kg ha⁻¹ per day, while the final yield reaches the 2,180 kg ha⁻¹ in Larisa and the 1,930 kg ha⁻¹ in Trikala. The small no significant difference (data not
shown) to the final seed yield of the sites is due to the lower soil fertility of the sandy soil in Trikala. Finally, it must be mentioned that pea cultivation reaches the maximum dry yield at the Growing Degree days of 450 °C-d, which is the best period for the incorporation.

Production Costs
The total costs for the different cultivation practices of sunflower using legumes (T1: control, T2: legume incorporated at the flowering stage, T3: legume incorporated after seed harvest) and the different nitrogen fertilization levels (N1:0, N2: 50, N3: 100 and N4:150 kg N ha⁻¹) are summarized in Fig. 1.

As it was expected, higher average production costs were reported in the case of the T3N4 treatment (legume incorporated after seed harvest with 150 kg ha⁻¹ nitrogen fertilization), where costs are increased by the fertilization costs and the harvest costs of pea and totally agree with previous findings (Liebman et al., 2012). The required expenses for this case are 1,920 € ha⁻¹. On the other hand, the case with the lower average production costs was the T1N1 treatment (control) where the required expenses are 820 € ha⁻¹.

Cultivation Profit
Higher profit was found for the treatment where sunflower was harvested as a second crop where pea seed was harvested and the biomass of the legume was incorporated regardless area and year. The average profit for this treatment was 883 € ha⁻¹ having a significant difference with the cultivation practice of sunflower as mono-crop system (Table 4).

In the case of the nitrogen fertilization (Fig. 2; Table 4), there was found significant difference for the higher fertilization levels (N3, N4) comparing with the lower (N1, N2). Moreover, it was found that the cost of the used nitrogen had a negative effect for the treatment with the 150 kg N ha⁻¹ (Table 4).
As illustrated in Fig. 2, farmers’ profit 53 to 225 € ha\(^{-1}\) for the single culture of sunflower (cropping scenario monoculture \(T_1\)), from 273 to 609 € ha\(^{-1}\) and from 824 to 945 € ha\(^{-1}\) for the multiple cropping system of sunflower after legume (cropping scenarios \(T_2, T_3\)).

Therefore, the above results show a high dependence of sunflower cultivation as a second crop while the extra fertilization of 150 kg N ha\(^{-1}\) decreases farmers’ profit, with the scenario of incorporation the biomass of pea cultivation after seed harvest and sunflower as second cultivation being more feasible.

Based on the above scenarios, sunflower cultivation as monoculture seems to be not feasible due to the low profit (143 € ha\(^{-1}\)) if someone includes the fact of the fragmentation of rural land and therefore a farmer needs more than 100 hectares to ensure a sustainable annual income by taking into account the costs of the next year.

**Trade off analysis**

The economic analysis is for the 2\(^{nd}\) and 3\(^{rd}\) growing years (2012 and 2013). Finally, sensitivity analysis was used to estimate the effect of product price to crop income benefits for the most viable cultivation system (\(T_3N_3; 945 \text{ € ha}^{-1}\)) estimating that the yield is stable.

**Table 5.** 2-input table for the \(T_3N_3\) treatment and different seed yield price

<table>
<thead>
<tr>
<th>Seed Price € per ha</th>
<th>Pea</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Sunflower</strong></td>
<td></td>
</tr>
<tr>
<td>0.10</td>
<td>-</td>
</tr>
<tr>
<td>0.15</td>
<td>-</td>
</tr>
<tr>
<td>0.20</td>
<td>-</td>
</tr>
<tr>
<td>0.25</td>
<td>-</td>
</tr>
<tr>
<td>0.30</td>
<td>-</td>
</tr>
<tr>
<td>0.35</td>
<td>-</td>
</tr>
<tr>
<td>0.40</td>
<td>-</td>
</tr>
<tr>
<td>0.45</td>
<td>+</td>
</tr>
<tr>
<td>0.50</td>
<td>+</td>
</tr>
<tr>
<td>0.55</td>
<td>+</td>
</tr>
<tr>
<td>0.60</td>
<td>+</td>
</tr>
</tbody>
</table>

*(\(T_3\): legume incorporated after seed harvest; \(N_3\): 100 kg N ha\(^{-1}\)).

![Figure 2](image-url) Figure 2. Farmer’s profit from sunflower cultivation as observed in Thessaly plain during 2012 and 2013 and as affected by three cultivation practices and four nitrogen fertilization levels. (\(T_1\): control; \(T_2\): legume incorporated at the flowering stage; \(T_3\): legume incorporated after seed harvest; \(N_1\): 0; \(N_2\): 50; \(N_3\): 100 and \(N_4\): 150 kg N ha\(^{-1}\)).
Therefore, as it shown in Table 5, in case that sunflower seed price is stable at \(0.50 \, € \, kg^{-1}\), the lower price that pea seeds can get is \(0.10 \, € \, kg^{-1}\), while if the seed price of pea is stable the lower price that sunflower seed can get is \(0.30 \, € \, kg^{-1}\). In Table 5 are presented all the price combination for the scenario of pea harvest and the remaining biomass incorporated and the cultivation of sunflower as second crop with nitrogen fertilization of \(100 \, kg \, ha^{-1} \, (T_{3}N_{3})\).

**CONCLUSION**

Through the different tested cropping systems, single sunflower cropping and multiple cropping of legume followed by sunflower, it was found that the single crop scheme is not economically viable. There was a higher profit for the treatment where sunflower was harvested as a second crop after pea harvest and the remaining biomass is incorporated, irrespective of area and year. The most impressive finding was the positive effect of treatment with legume incorporation with an increase in yield up to \(5 \, t \, ha^{-1}\) regardless of region. Depending on the year the incorporation of legume may increases the yield by 30–50 percent while for the treatment where the previous cultivation was legume was also noticed a yield increase.

As a general conclusion, the sunflower cultivation system after pea cultivation appears to be a successful cropping scenario, characterized by high profit for farmers with a possible further rise in profit by enhancing the final yield or raising the seed selling price, and therefore, serious consideration should be given to the implementation of this system into future land use schemes in Greece and, more usually, in the Mediterranean basin.

ACKNOWLEDGEMENTS. The authors acknowledge the Department, Agriculture Crop Production and Rural Environment, University of Thessaly (Greece) for the economic support and access to the literature research database.

REFERENCES


