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ECONOMIC ANALYSIS OF PESTICIDE USE IN WHEAT PRODUCTION FOR SUSTAINABLE RURAL DEVELOPMENT

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Abstract. The objective of this research is to do the economic analysis of pesticide application practices and level of pesticides used by the farmers in wheat production for sustainable rural development in Turkey. The primary data were collected from 84 wheat producers. Results of this research show that the average area of wheat production was 3.91 ha with 3 461.90 kg ha^{-1}. The average cost of wheat production was EUR 549.94 ha^{-1}. It was calculated that the average usage of pesticides was 1 103.50 g per hectare as an active ingredient in the wheat production. The average usages per hectare of active ingredient of insecticides, fungicides and herbicides were determined to be 48.00 g, 146.60 g and 908.90 g, respectively. Herbicides are the biggest pesticide group used in wheat production. They accounted for 82.37 % of total weight of active ingredients, followed by fungicides (13.28 %) and insecticides (4.35 %). The study revealed that the farmers were using herbicides more than the recommended, fungicides and insecticides less than the recommended dosages. It was calculated that the average plant protection costs was EUR 50.25 ha^{-1} which was 9.14 % of wheat production costs. The percentages of average plant protection costs were 85.03 %, 9.24 % and 5.73 % herbicides, insecticides and fungicides, respectively. The gain threshold was calculated to be 228.39 kg ha^{-1}. As a result, government should be promoting research into application technologies that mitigate risk and cost and maximize gain from pesticide used. Also, pest management and farmer training programmes in all crops should be developed to ensure sustainable food security, food safety, farmers' income, and rural development.

Key words: wheat, pesticide use, economic analysis, environmental, sustainable rural development, Turkey.
JEL code: R1, Q5, Q180, Q160, Q120

Introduction

Pesticides have been a major contributor to the growth of crop productivity and food supply. Crops yields strongly depend on crop protection measures. The main purpose of pesticide use is to increase food security, with a secondary goal being increased standard of living (Delcour et al., 2015). Food productivity soared due to new technologies, mechanization, increased chemical use, specialization and government policies that favoured maximizing production. Sustainable agriculture integrates three main goals; environmental health, economic profitability, and social and economic equity. Most specialists agree upon the fact that organic, biological, or ecological agriculture is a component of the sustainable agriculture system, as well as an alternative to intensive, industrial, and conventional farming, which increasingly proves its limits and drawbacks with regard to the quality of the obtained products and the negative impact upon the environment, through the use of significant amounts of chemicals for the control of pests, weed and diseases (Sima, 2009). Sustainable approaches are least toxic and least energy intensive, and yet maintain productivity and profitability (Dimitri et al., 2005).

Sustainable rural development implies improving the quality of life for the rural poor by developing capacities that promote community participation, health and education, food security, environmental protection and sustainable economic growth, thereby, enabling community members to leave the cycle of poverty and achieve their full potential (Martin and Gertrud, 2007). Pesticides used in agriculture to protect crops and pest control have been accompanied with environmental pollution, human health issues and reduced agricultural sustainability around the world (Pimentel and Greiner, 1997). Excessive uses of chemical pesticides have many consequences on agriculture and environment, such as increased production costs, pest resistance to pesticides, and dangerous diseases to human. For reducing disease and pests and increase income from crop activities, farmers resorted using more pesticides (Wilson and Tisdell, 2001; Nazarian et al., 2013).

Insects, pests, diseases and weeds are the major source of crop damage, yield and quality reduction in Turkey and elsewhere in the world. Also insect infestation problem has become quite serious in

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cereals, badly affecting the production and the quality of the produce. Consequently, the use of pesticide in agriculture has become extremely essential. Pesticides are used to overcome the pest problem in various crops. When the pest problem is managed at the proper time it improves the crop productivity. Therefore, pesticide use definitely helps in improving the crop productivity and quality if right type of pesticide is used at right time with the right dose (Khan et al., 2010).

Pesticide use in Turkey increased substantially over the years. Although the overall intensity of pesticide use is low by comparison with many developed and developing countries and the European Union countries, there are concerns over adverse impacts on human health and the environment in some regions (OECD, 2008). Pesticides will continue to play an important role in food security in Turkey due to the limited arable land resources and the increase of future population. Therefore, the only way to improve food security is to increase crop yields through the scientific use of pesticides with an emphasis on protecting the environment (Yilmaz, 2015). Pesticides used are the most important elements in determining productivity and the level of cereal production.

Wheat is an important basic food consumed mostly as bread in Turkey. It provides a substantial component of the human diet. Wheat is also consumed as animal food and used to make various processed foods in the industry (Mutlu et al., 2014). Nutritional problem is a rapidly increasing issue more and more all around the world. The most plausible solution is to increase the crop and livestock production. Wheat is grown on about 7.9 million ha area annually with the production of approximately 19 million tons in Turkey for wheat; it occupies the prime position both in area and production among the cereal crops in Turkey. In Turkey, total cereal production was 32.7 million tons produced on 11.7 million ha, which was 58.08% of total cereal production was wheat (TURKSTAT, 2014). In some years, Turkey has been able to make small wheat exports, balanced in other years by small imports. In other words, it would appear that supply and demand are currently in rough balance (TUSAF, 2014).

The aim of this research was to evaluate the economics of pesticide use in wheat production for sustainable rural development. Furthermore, this study also attempts to determine the farm-level economic cost and amount of pesticides used in wheat production. Also, farmers' attitudes toward their use of pesticides, their pesticide used practices and problems were determined. There is limited available information about the economic evaluation of pesticide use in wheat production in Turkey. In order to fill this information gap, there is a need for this study.

Methodology

Data collection

The total wheat production in 2014 was 96 030 tons in Isparta province. Total cereals production was 212 986 tons produced on 99 512 ha. About 45.09 % of total cereals produced was wheat (TURKSTAT, 2014). Wheat, occupies the prime position in area and the second in production among the cereal crops in the Isparta Province.

Data for the study were obtained from primary sources. The primary data were collected using a set of structured and pre-tested questionnaires, which were administered to the wheat farmers of the study area. This study was conducted using a face to face interview with 84 wheat farmers from Egirdir, Gelendost and Yalvac districts of the Isparta province in West Mediterranean region of Turkey and their villages were chosen as the study area where there is intensive wheat production. Wheat is the most important crop grown in farms in these villages. The farms were chosen by simple random sampling method (Yamane, 2001).

Data Analysis

All data were analyzed using SPSS software and procedures. Descriptive and inferential statistics were used to analyze the data collected. Demographic characteristics of farmers were analyzed using percentages and frequencies. For the economic cost of pesticide the formula below was used (Eq. 1):

$$EC = APAIU * PPUPT, \quad (1)$$

where:

EC: Economic cost (EUR ha^{-1});

APAIU: Amount of pesticide active ingredient used (g ha^{-1});

PPUPT: Price of pesticide used by pesticides type (l/EUR).

Additionally, the gain threshold can be calculated with the following formula (Eq. 2);

$$\text{Gain threshold } (\text{kg ha}^{-1}) = \frac{\text{pesticide and pesticide application costs (EUR ha}^{-1})}{\text{average wheat price (EUR kg}^{-1})} \quad (2)$$

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Furthermore, pesticides were grouped by their toxicity classification and their chemical family in based on the WHO criteria (WHO, 2010).

Research results and discussion

1. General characteristics of the farms

The average age of the farmers was 51.1 years and the average experience of farmers in wheat was 27.6 years. The average household size was 4.7 people. Farmers' average years of education was 7.6 (Table 1). The percentage of farmers who used agricultural credit for wheat production was 36.9 %. The percentage of farmers who are members in agricultural cooperative was calculated as 77.4 %. The average farm size and cultivated area were 12.11 ha and 10.50 ha, respectively. It was found that farms who were under irrigation were 14.5 % of farm size and fallow land 13.3 %. The average cultivated area of the farms was 10.50 ha of which 32.3 % was devoted to wheat (3.91 ha) production (Table 1). In the study area, 63.1 % farmers rely only on wheat production as they do not have any other occupation, while the rest of the farmers were engaged in some other professions.

Table 1.

Farmers' socio-economic characteristics, environmental attitudes and extension practices

Variable	Mean	SD*	%
Personal characteristics			
Farmer's age (years)	51.1	12.89	-
Farmer's education(years)	7.6	3.04	-
Farmer's experience (years)	27.6	13.09	-
Number of people in family	4.7	2.38	-
The rate of the farmer membership of agricultural cooperative (%)	-	-	77.4
The number of the people working on crop production in family	2.9	1.57	-
The number of farmer dealing with non-agricultural activity	-	-	36.9
The rate of farmer use agricultural credit	-	-	41.7
Farm characteristics			
Average farm size (hectare)	12.11	13.27	100.0
Cultivated area (ha)	10.50	12.85	86.7
Fallowing area(ha)	1.61	3.25	13.3
Irrigated area(ha)	1.75	2.58	14.5
Non-irrigated area(ha)	10.36	12.54	85.5
Owned land(ha)	8.68	7.20	71.7
Rented land(ha)	3.43	11.08	28.3
Wheat area(ha)	3.91	5.90	32.3
Other crops production area(ha)	6.59	7.96	54.4
Farmers' environmental attitudes and extension practices			
The rate of farmers wants to produce by using the techniques environmentally friendly	-	-	85.7
The rate of farmers watches TV programmes related agriculture	-	-	95.2
The rate of farmers use internet for agricultural purposes	-	-	26.2
The rate of farmers subscribe for a farming magazine	-	-	3.6
The rate of farmers participated any meeting about wheat production	-	-	51.2
The rate of farmers participated any extension programmes related with plant protection	-	-	38.1
The rate of farmers knows about biological control in agricultural combat	-	-	22.6
The rate of farmers knows useful insects	-	-	36.9
The rate of farmers use protector pesticide against pests and diseases	-	-	69.1

**Standard Deviation*

Source: author's calculations based on farmer survey data.

The rate of farmers who watched the agricultural related programmes on television was calculated as 95.20 % and used the internet for agricultural purposes was 26.20 %. Farmers' that used modern information sources as mainly information sources for deciding to pesticide application time were 55.95 %, deciding to pesticide choice 90.48 % and deciding on pesticide application dosage 75.00 %. This means that farmers

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used more information from extension agents, farmer cooperatives, input dealers, pesticide label and mass media. Most of the farmers had contact with the public and private extension agents with 33.33 %, while 23.81 % indicated non-contact with extension agent. The rate of farmers who read pesticide labels was 96.43 %. Information on the label about when and how to use the pesticide was the most important source of information that affected farmer's knowledge, safety in pesticides and particularly training to improve the application of pesticides (Waichman et al., 2007). The rate of farmers who want to produce by using the environmentally friendly techniques was 85.70 %. It was determined that 51.20 % of the farmers participated in related with wheat production extension programme. The percentage of farmers who participated in related with plant protection extension programme was 38.1 %. It was determined that 69.10 % of the farmers used protector pesticide against pests and diseases. The rate of farmers who know about biological control in agricultural combat and known useful insects were 22.6 % and 36.9 %, respectively (Table 1).

2. Pests and diseases encountered by farmers in wheat production

Plant protection problems such as pests, weeds and diseases are the major factors decreasing wheat production. Table 2 shows the major pests and diseases encountered by farmers in wheat production in the study area. The research results showed that the majority of these farmers faced with pests, weeds and diseases include; weed seeds, sunn pest (*Eurygaster integriceps Put*), covered and semi loose smut of wheat, orthoptera, *zabrus sp.*, and *pactytyclus hordei*, respectively. These pests, weeds and diseases, cause economical losses in some wheat fields in the study area. The most important applications in controlling pests, weeds and diseases of wheat are cultural and mechanical controls. Chemical control is the other method used to suppress wheat pests, weeds and diseases, due to its rapid effect.

Table 2.

The major pests, weeds and diseases encountered by farmers in wheat production in research area

Pests, Diseases and Weeds	N*	%	Rank
Weed seed control	62	73.81	I
Sunn pest (Eurygaster integriceps Put)	23	27.38	II
Covered and semi loose smut of wheat	41	48.81	III
Orthoptera	8	9.52	IV
Zabrus sp.	6	7.14	V
Pactytyclus hordei	5	5.95	VI

Source: author's calculations based on farmer survey data. *Multiple responses

3. Classification and types of the pesticides used by the farmers in wheat production

Pesticides have been a major contributor to the growth of crop productivity and food supply. Yet, they are a source of concern because of human and environmental health side effects (Sexton et al., 2007). Table 3 shows an overview of all types of pesticides used by the farmers in wheat production in the research area. Pesticides were grouped by their toxicity classification and their chemical family (WHO, 2010). Among the 84 wheat farmers, 6 different types of pesticides were used. Among the 84 wheat farmers, 3 different types of insecticides were used. The insecticides commonly used by the farmers were identified as Deltamethrin (5.95 %), Chlorpyrifos ethyl (1.19 %) and Lambda-cyhalothrin used by 2.38 % of the farmers.

Among the 84 wheat farmers, single types of fungicides were used. The fungicide commonly used by the farmers was identified as Tebuconazole used by 27.38 % of the farmers as protection from fungal diseases in wheat production.

The most common herbicides in wheat production are 2.4-D Isooctylester (52.38 %) and Tribenuron-methyl (19.05 %). The study revealed that, the most common pesticides used by the farmers in wheat production were moderately hazardous categories (class II).

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Table 3.

Type of pesticides used in wheat production in the research area, classified using the WHO hazard classifications*

Trade Name	Chemical family	Toxicity class a	Number of farmersc	%
Insecticides				
Decis ulv 1,5	Deltamethrın	II	5	5.95
Fulrik 4	Chlorpyrifos ethyl	Not listed	1	1.19
Karate zeon	Lambda-cyhalothrın	II	2	2.38
Fungicides				
Izolexıl 2 DS	Tebuconazole	II	23	27.38
Raxil 2 DS	Tebuconazole			
Herbicides				
Ester EXT	2,4-D Isooctylester	Not listed	44	52.38
Ester H	2,4-D Isooctylester	Not listed		
Granstar	Trıbenuron-methyl	Not listed	16	19.05

Source: author's calculations based on farmer survey data. [a] WHO 2010 *The WHO recommended classification of pesticides by hazard. Index. Classification of active pesticide ingredients (Ia = Extremely hazardous; Ib = Highly hazardous; II = Moderately hazardous; III = slightly hazardous; U = Unlikely to present acute hazard in normal use; FM = Fumigant, not classified; O = Obsolete as pesticide, not classified). [c] Multiple responses were possible as there were no limitations set up for farmers' choices

The economic costs of pesticide and amounts of pesticides used on wheat production

According to literature weather is the most important factor in pesticide use for crop production, which has a major influence on the spread of plant diseases, fungi and insects. Other significant factors have been the prices, biological factors, damage per pest, pesticide effectiveness, and other random variables affect pesticide productivity and profits. When deciding whether to treat his crop, a farmer will weigh up the cost of the potential crop loss against the cost of applying pesticides; thus, pesticide prices are also influence sales. Another significant factor has been the introduction of new, highly active, lower dose pesticides in recent years (Tisdell 1986; Lucas and Vall, 1999; Sexton et al., 2007).

There exist today options damage control tools at the farmer's disposal. These include biological control, which makes use of natural predators of pests and other natural phenomena like the weather; mechanical control, which includes the use of specific tilling and cultivation techniques; and chemical control-the application of pesticides, herbicides, and fungicides (Sexton et al., 2007). Results of this research show that, the average usage of pesticides are 1 103.50 g per hectare as an active ingredient in the wheat production. The average usages per hectare of active ingredient of insecticides, fungicides and herbicides were determined to be 48.00 g, 146.60 g and 908.90 g, respectively. In a similar study done by TEAE (2001) founds that the average usage per hectare as active ingredient of herbicides were 762 g (in Tekirdag, Turkey), 520 g (in Adıyaman, Turkey), 595.90 g (in Polatlı, Ankara, Turkey) and 887.30 g (in Konya, Turkey). In the same study done by TEAE (2001) found that the average usage per hectare as active ingredients of fungicides were 78.30 g (in Polatlı, Ankara, Turkey) and 40.60 g (in Konya, Turkey). Care should be taken in making comparisons as the scope of the dose might vary from one province to another. A number of factors could affect figures from one year to the next: the weather and the seasons, pest pressure, pesticide prices, land set-aside and policy changes (Lucas and Wall, 1999). Herbicides are the biggest pesticide group used in wheat production. They accounted for 82.37 % of total weight of active ingredients, followed by fungicides (13.28 %) and insecticides (4.35 %). It was determined that farmers use herbicides more than the recommended, fungicides and insecticides less than the recommended dosages of private pesticide dealers and extension staff and pesticide labels. Increased or decreased use of pesticides can lead to inefficient, crop and economic losses and environmental hazards. It was calculated that economic cost was EUR 50.25 per hectare. The percentages of these costs are 85.03 %, 9.24 % and 5.73 % for herbicides, insecticides and fungicides, respectively.

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Table 4.

Economic costs of pesticide and amounts of pesticides used on wheat production

Type of Pesticides	Used amount		Recommended Amount	Pesticides+ Pesticide application costs	
	(g-ml-cc)/ha	%	(g-ml-cc)/ha	(€ /ha)	%
Insecticides	48.00	4.35	53.48	4.64	9.24
Fungicides	146.60	13.28	168.80	2.88	5.73
Herbicides	908.90	82.37	831.88	42.73	85.03
Total pesticides	1 103.50	100.00	1 054.16	50.25	100.00

Source: author's calculations based on farmer survey data.

Production and plant protection costs in wheat production

Table 5 shows plant protection costs in wheat production in the study area. Plant protection costs of items such as wages, uniforms, equipment of personnel engaged in plant protection and pesticides. In this study, the average costs of wheat production were determined to be EUR 549.94 ha^{-1}. According to this study, the cost of plant protection (pesticide and pesticide application costs) per hectare was determined as EUR 50.25 having the portion of 9.14 % of average production cost. In this study, the average yield for wheat was determined to be 3 461.90 kg ha^{-1}. It was calculated that pesticide and pesticide application costs and production costs were determined to be EUR 0.01 kg^{-1} and EUR 0.16 kg^{-1}, respectively.

Table 5.

Cost of plant protection applications and production cost in wheat production

Indicators	Mean	SD*
A. Average yield (Kg/hectare)	3 461.90	1 025.45
B. Average Pesticides+ Pesticide application costs (€ /ha)	50.25	28.59
C. Average Pesticides+ Pesticide application costs (€/kg) (C= B/A)	0.01	0.01
D. Average production costs (€ /ha)	549.94	138.90
E. Average wheat production costs(€/kg) (E= D/A)	0.16	0.04
F. The proportion of plant protection costs in average production costs (%) (F=(B/D)*100))	9.14	-

Source: author's calculations based on farmer survey data. *Standard Deviation

Gain threshold of pesticide use on wheat production

Gain thresholds levels of pest population that, if left untreated, would result in reductions in revenue that exceed treatment costs. Gain thresholds are used to decide if pesticide treatments or other pest management practices are economically justified. The decision generally requires information on pest infestation levels from scouting or monitoring (Pedigo and Higley, 1996). In this study, the gain threshold was also estimated for wheat production. Gain thresholds are a simple way to determine the relationship between the pesticide and pesticide application costs and the value of the harvested crop. Gain thresholds are simply the pesticide and pesticide costs per area divided by the value per unit of harvested wheat.

Average pesticide and pesticide application costs and average wheat price were EUR 50.25 ha^{-1} and EUR 0.22 kg^{-1}, respectively. The gain threshold was calculated to be 228.39 kg ha^{-1} and it was 6.60 % of wheat production per hectare. This means that the increase in yield, or gain, has to be 228.39 kg ha^{-1} (6.60 % of wheat production ha^{-1}) for this pesticide use to be economic.

Conclusions, proposals and recommendations

This study was aimed to analyse the farm level of economic analysis of pesticide use in wheat production in West Mediterranean Region of Turkey. Results of this research show that average area of wheat production was 3.91 ha with 3 461.90 kg ha^{-1}. The average cost of wheat production was EUR 549.94 ha^{-1}. Results of this research show that the average usage of pesticides was 1 103.50 g per hectare as an active ingredient in wheat production. Herbicides are the biggest pesticide group used in wheat production. It was calculated that the average plant protection cost was EUR 50.25 ha^{-1} and

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this represents 9.14 % of wheat production costs. According to this research's findings, there are some problems related to the use of pesticides in the study area.

6) The farmers' desire to grow wheat has to be cost effective, sustainable and environment-friendly.

7) Most of farmers use modern information sources (extension agents, farmer cooperatives, input dealers, pesticide label and mass media) as mainly information sources for deciding to pesticide application time, pesticide choice and pesticide application dosage.

8) The study revealed that the farmers were using herbicides more than the recommended, fungicides and insecticides less than the recommended dosages. Using herbicides more than the recommended dosages and using less than the recommended rate of fungicides and insecticides will aggravate the efficacy problems. This leads to crop losses, cost increase, economic loss and undesirable environmental effects.

The results of this research suggest that:

1) Agricultural policy makers should design and implement training interventions to promote knowledge, attitude and safety behaviour of wheat farmers in application of pesticides.

2) The effective training and extension activities which provide farmers research results related to pesticide application should be performed.

3) To decrease unnecessary pesticide use, training programmes should be implemented to increase information and consciousness level of farmer.

4) Extension and training programmes about production techniques environmentally friendly and Integrated Pest Management (IPM) should be developed in order to follow the new approaches.

5) To maximize the benefits of pesticide use at minimum human, environmental and economic cost, pesticides must be strictly regulated and used judiciously by properly trained and appropriately equipped personnel, ideally in tight integration with other complementary technologies.

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