Turk J Agric For
29 (2005) 173-177

Economic Threshold for Wild Radish (*Raphanus raphanistrum* L.) Control in Wheat Fields

Özhan BOZ*
Adnan Menderes University, Faculty of Agriculture, Plant Protection Department, 09970 Aydın - TURKEY

Received: 16.03.2004

Abstract: Field experiments were conducted in Aydın province in 1998 and 1999 to determine the economic threshold (ET) using florasulam + flumetsulam, 2,4-D amine, thifensulfuron methyl + tribenuron-methyl, and tribenuron-methyl for wild radish (*Raphanus raphanistrum* L.) in wheat. The effect of wild radish density (1, 2, 4, 8 and 16 plants m^{-2}) on wheat yield was investigated using an adjacent plot design with 4 fields. For each weed density, yield was compared with that in the adjacent weed-free control plot. The grain yield in wild radish-free wheat was 4079 kg ha^{-1} in 1998, 4369 kg ha^{-1} in 1999 and 4224 kg ha^{-1} averaged over the 2 years. Results over the 2 years showed that the ET of wild radish in wheat varied from 1.8 to 2.0 plants m^{-2} depending on the herbicide applied. The lowest ET value was calculated for 2,4-D amine and the highest for florasulam + flumetsulam. It is therefore concluded that wild radish in wheat should be controlled by herbicides if the density is between 1.8 and 2.0 plants m^{-2}. Below this level, a certain amount of damage and the presence of weeds can be tolerated, thus minimizing herbicide use.

Key Words: Wild radish (*Raphanus raphanistrum*), economic threshold, wheat (*Triticum aestivum*), florasulam + flumetsulam, 2,4-D amine, thifensulfuron methyl + tribenuron-methyl, tribenuron-methyl

Buğday Alanında Yabani Turpun (*Raphanus raphanistrum* L.) Ekonomik Zarar Eşiği

Özet: Çalışma, florasulam + flumetsulam, 2,4-D amine, thifensulfuron methyl + tribenuron-methyl, ve tribenuron-methyl kullanılarak yabani turpun buğdaydaki ekonomik zarar eşiğini saptamak amacıyla 1998 ve 1999 yıllarında Aydın'da gerçekleştirilmiştir. Bu amaçla farklı yabancı ot yoğunluğunun (1, 2, 4, 8 ve 16 bitki m^{-2}) buğday verimine etkisi yabancı otsuz parseller oluşturularak 4 ayrı tarlada belirlenmiştir. Her bir yabancı ot yoğunluğunda verim, yabancı otun bulunmadığı kontrol parseliyle kıyaslanmıştır. Yabani turpun olmadığı parsellerde buğday verimi 1998 yılında 4079 kg ha^{-1} iken, 1999 yılında 4369 kg ha^{-1} olmuş, iki yılın ortalaması ise 4224 kg ha^{-1} olarak belirlenmiştir. İki yıllık çalışma sonuçlarına göre, buğdaydaki yabani turpun ekonomik zarar eşiğinin herbisit fiyatına bağlı olarak 1.8-2.0 bitki m^{-2} arasında değiştiği belirlenmiştir. En düşük ekonomik zarar eşiği değeri 2,4-D amine, en yükseği ise florasulam + flumetsulam uygulandığında elde edilmiştir. Bu çalışma sonuçlarına göre, yabani turp yoğunluğu 1.8-2.0 bitki m^{-2} olduğunda kontrol edilmelidir. Bu seviyenin altı kabul edilebilir zarar ve yabancı ot yoğunluğunun olduğu seviyedir.

Anahtar Sözcükler: Yabani turp, ekonomik zarar eşiği, buğday, florasulam + flumetsulam, 2,4-D amine, thifensulfuron methyl + tribenuron-methyl, tribenuron-methyl

Introduction

Wheat (*Triticum aestivum* L.) is the main winter crop in Turkey and is sown in November and December. Wild radish (*Raphanus raphanistrum* L.) is one of the most important weeds in the Aegean region in Turkey (Öngen et al., 1996) being found in 55% of fields surveyed in wheat growing areas in Aydın province (Boz, 2000). Florasulam + flumetsulam, 2,4-D amine, thifensulfuron methyl + tribenuron-methyl, and tribenuron-methyl are used to control broad leaved weeds in wheat, such as wild radish.

The use of pesticides is being limited in many countries because they are harmful to users, contaminate the soil, water and foods, and change the flora and fauna. Numerous agronomic studies have therefore been conducted to investigate options for reducing their use. One approach to minimize the use of pesticides is integrated pest management. The economic threshold

* Correspondence to: ozhanboz@yahoo.com

(ET), i.e. the density of a pest at which the benefit of taking action is greater than the cost of taking action is an important concept in integrated pest management (Daxl et al., 1994). The use of herbicides may thus be justified when the economic damage caused by the weed population is greater than the cost of the treatment (Labrada and Parker, 1994). Below the ET, a certain amount of damage and the presence of weeds can be tolerated.

Studies conducted in Turkey have measured the ET of some important weeds in wheat as follows: 0.1-0.3 plants m^{-2} for wild mustard (*Sinapis arvensis* L.), 1.8-2.2 plants m^{-2} for vetch (*Vicia* spp.) (Boz and Uygur, 1997), 2-3 plants m^{-2} for wild bishop (*Bifora radians* Bieb), 0.5-1.2 plants m^{-2} for catchweed bedstraw (*Galium aparine* L.) (Mennan, 1998), 4-20 plants m^{-2} for wild oat (*Avena sterilis* L.) (Kadıoğlu et al., 1998; Mennan et al., 2002), and 23-39 plants m^{-2} for blackgrass (*Alopecurus myosuroides* Huds.) (Mennan et al., 2002).

In other countries, ET values for important weeds in wheat have also been calculated: 7-12 plants m^{-2} for winter wild oat (*Avena ludoviciana* Durieu), 37 plants m^{-2} for sterile brome (*Bromus sterilis* L.), 5-10 plants m^{-2} for common vetch (*Vicia sativa* L.), 20-35 plants m^{-2} for Italian ryegrass (*Lolium multiflorum* Lam.) (Zanin et al., 1993), 20 plants m^{-2} for loose silky bent (*Apera spica-venti* (L.) Beauv.) (Heitefuss et al., 1987), 0.5-2 plants m^{-2} for catchweed bedstraw (*Galium aparine* L.) and 25-30 plants m^{-2} for blackgrass (*Alopecurus myosuroides* Huds.) (Heitefuss et al., 1987; Zanin et al., 1993).

Hashem et al. (2001) investigated the yield losses in wheat due to wild radish competition at different densities. They found that wheat yield was reduced by wild radish competition by 7%, 20%, 37% and 56% at 10, 25, 50 and 75 wild radish m^{-2}, respectively. They did not, however, determine the ET of wild radish in wheat in their study.

The aim of the present study was therefore to determine the ET of wild radish in wheat in Turkey.

Materials and Methods

Field experiments were conducted in 1998 and 1999 in 4 fields in Aydın province in Turkey.

An adjacent plot design was used with 4 replicates; plots were 1 m^2. One of each adjacent plot was left infested with wild radish at a range of densities (1, 2, 4, 8, and 16 wild radish plants m^{-2}), and the other served as a weed-free control. All other weed species were removed biweekly by hand.

Wheat seed was sown in rows at 180 kg ha^{-1}. All plots were fertilized with diammonium phosphate (DAP, 80 kg ha^{-1} phosphorus) and ammonium sulfate (180 kg ha^{-1} N) before sowing. Additional fertilizer (ammonium nitrate, 33% N, at 600 kg ha^{-1}) was applied to all experimental plots before the beginning of tillering (BBCH Code21) and at the beginning of stem elongation (BBCH Code30) of wheat (Stauss, 1994). Plots were observed from the 2- to 4-leaf stage of wheat until harvest. All plots were harvested separately using a reaphook and grain yield per plot was recorded.

For each weed density, yield was compared with that in the adjacent weed-free control plot. Percentage yield loss was calculated and correlated to the weed density using a linear regression model. The ET, representing the weed density at which the cost of treatment was equal to the economic benefit obtained from that treatment, was calculated using the cost of herbicide applied at the recommended dose, application costs, average yield and grain price. The cost of application of different herbicides (2,4-D amine, florasulam + flumetsulam, thifensulfuron methyl + tribenuron-methyl, and tribenuron-methyl) for control of wild radish was calculated. The theoretical income was then estimated from the average income of the control plots. The prices were calculated in Euros (€). The ET, representing the weed density at which the cost of treatment was equal to the economic benefit obtained from that treatment, was calculated in 2 steps:

Step 1: Determination of the level of yield loss at which it was economically beneficial to control wild radish, using equation 1 (Uygur et al., 1999):

$$y = \frac{HM+UM}{OV*ÜF} \times 100 \qquad [1]$$

where y = % loss of yield associated with weed density in m^2

OV = average of expected maximum grain yield in weed-free plots (kg ha^{-1})

ÜF = price of grain (€ kg^{-1})

HM = cost of herbicide (€ ha^{-1})

UM = application costs (€ ha^{-1})

Step 2: Determination of the weed density that was associated with the level of yield loss calculated in Step 1, using regression equation [2]:

y = coefficient*x + coefficient [2]

y = % loss of yield according to density in m^2

x = number of weeds in m^2 (economic threshold)

The ET for use of 2,4-D amine, florasulam + flumetsulam, thifensulfuron methyl + tribenuron-methyl, and tribenuron-methyl was thus calculated for wild radish in wheat.

Results and Discussion

Figure 1 shows the linear regression equations calculated using the yield data obtained in 1998 and 1999 and those for the average of the 2 years. The results showed that wheat yield decreased as wild radish density increased.

In the second stage of the study, ET of wild radish in wheat for 2,4-D amine, florasulam + flumetsulam, thifensulfuron methyl + tribenuron-methyl, and tribenuron-methyl were calculated. ET calculations were based on the cost of herbicide applied at the recommended dose, application costs, average yield and grain price. The grain yield in wild radish-free wheat was 4079 kg ha^{-1} in 1998, 4369 kg ha^{-1} in 1999 and 4224 kg ha^{-1} averaged over the 2 years.

An example with 2,4-D amine in 1998 is given below:

Step 1: Determination of the level of yield loss at which it was economically beneficial to control wild radish:

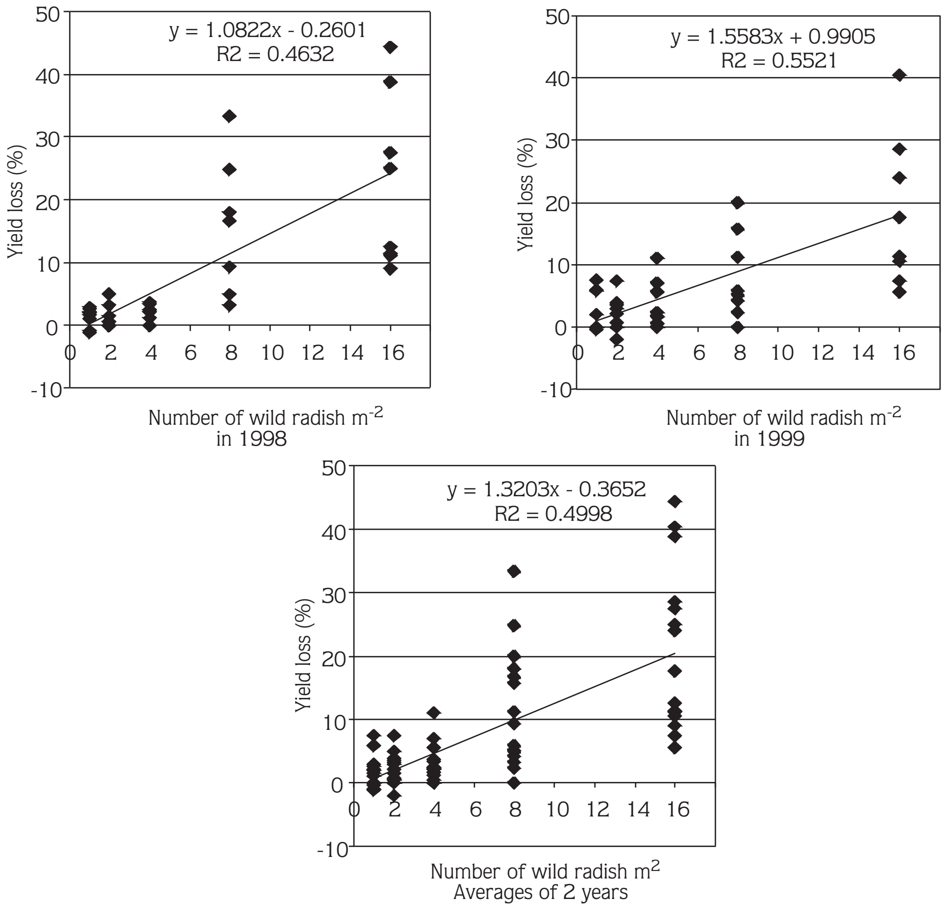

Figure 1. Yield losses in wheat due to wild radish (*Raphanus raphanistrum*) competition in 1998, 1999, and the average of both years.

$$\text{Loss of grain for application (\%) (y)} = \frac{\text{Cost of herbicide (5.5 € ha}^{-1}\text{) + Application cost (5.5 € ha}^{-1}\text{)}}{\text{Average yield (4079 kg ha}^{-1}\text{) * Price of grain (0.13 € kg}^{-1}\text{)}} *100$$

y = 2.1%

This result indicates that if the yield loss caused by wild radish competition exceeds 2.1%, the benefits of weed control will outweigh the costs. In order to determine the density of wild radish causing a 2.1% yield loss, the regression equation derived from the field data (Figure 1) was used as follows:

Step 2: Calculation of the wild radish density causing 2.1% grain loss:

Regression equation: y = 1.0822 x + 0.2601 (Figure 1)

2.1 = 1.0822 x + 0.2601

x = 1.7 wild radish per m^{-2} (ET for 2,4-D amine in 1998)

ET for the other herbicides were also calculated (Table 1). The differences between the ET values obtained are explained by the cost of the herbicides because all other expenses, such as cost of application, grain yield, and grain price, were constant. The lowest ET value was calculated for 2,4-D amine and the highest for florasulam + flumetsulam. Averaging across the herbicides examined, the ET for control of wild radish was 1.7 to 1.9 plants m^{-2} in 1998, 1.9 to 2.0 plants m^{-2} in 1999 and 1.8 to 2.0 plants m^{-2} on average. The results of this study therefore suggest that wild radish should be controlled by herbicides if the density is between 1.8 and 2.0 plants m^{-2}.

Since wild radish is one of the most abundant weed species in wheat growing areas in Aydın province, with a 55% frequency, its density was determined as 0.55 plants m^{-2} (Boz, 2000). Based on the survey results, it seems that no herbicide treatment is necessary for wild radish control in general, but it is necessary in some locations because of the higher density of this weed, which was over the ET value determined in this study. However, herbicide treatments could be still necessary in fields to control other weed species. Therefore such ET studies should be carried out with many other important weed species, which would be the aim of further studies.

Although wild radish is an important invasive weed in cereal fields, there are no studies concerning the ET for wild radish in the literature. Hashem et al. (2001) reported that wild radish caused yield losses of 7%, 20%, 37% and 56% in wheat at densities of 10, 25, 50 and 75 plants m^{-2}, respectively, but they did not calculate the ET level for wild radish in that study. However, their results showed that increased wild radish density resulted in higher yield losses, which was also observed in this study. In a similar study conducted in the Çukurova region Boz and Uygur (1997) investigated the ET for another Brassicaceae member weed (wild mustard; *Sinapis arvensis* L.) and found that this weed caused economically significant yield loss in wheat at a 0.1-0.3 plants m^{-2} density. In some other studies, ET for some important grass weeds, such as *Avena sterilis* L. (Kadıoğlu et al., 1998; Mennan et al., 2002) and *Alopecurus myosuroides* Huds. (Mennan et al., 2002), were higher compared with the broad leaved weeds investigated (4-

Table 1. Economic threshold of wild radish (*Raphanus raphanistrum* L.) in wheat in terms of some herbicides, their application rate and price.

Herbicides (active ingredient, formulation and rate)	Appl. rate (prep. ha^{-1})	Price € ha^{-1}	Economic Threshold		
			1998	1999	Average
2,4-D amine (50) SL	2000 ml	5.5	1.7	1.9	1.8
Tribenuron-methyl (75) DF	10 g	6.0	1.8	1.9	1.9
Thifensulfuron methyl +tribenuron-methyl (50+25) DF	20 g	6.5	1.9	2.0	1.9
Florasulam + flumetsulam (7.5 +10.0) SC	60 ml	7.0	1.9	2.0	2.0

SL: Soluble concentrate; DF: Dry flowable; SC: Suspension concentrate

20 plants m^{-2} for *A. sterilis* and 23-39 plants m^{-2} for *A. myosuroides*). The results of these studies show that the ET for broad leaved weeds are lower than those for grass weeds, which can be attributed to the lower costs of herbicides applied against broad leaved weeds.

The herbicides considered in the present study are commonly applied in wheat and their use can be the most important factor in obtaining acceptable grain yields. However, farmers sometimes apply herbicides at the wrong time or unnecessarily, resulting in higher production costs, as well as in other side effects. However, ET are important components of integrated weed management strategies that help farmers in deciding whether or not to spray herbicides (Daxl et al., 1994; Kudsk and Streibig, 2003). Therefore, knowledge about ET for weeds provides an opportunity to control them at the right time, serving to save an production costs and to prevent the side effects of incorrect herbicide applications.

For the practical application of these findings farmers should monitor their fields regularly, starting from the 2-4 leaf stage of wheat until the tillering stage and determine the occurring weed species and their densities. Herbicide treatments should be then applied only in those cases in which wild radishes exceed the ET (1.8-2.0 plants m^{-2}). To accurately determine the practical application of the ET concept, ET values for different weeds and also for mixed weed populations should be determined in further studies.

Acknowledgments

The author thanks the Adnan Menderes University Research Foundation for its support of this project. Project code: ZRF-98002. He also thanks Dr. M.N. DOGAN, Dr. Z. DALKILIC, and Dr. Hüsrev MENNAN for their comments, and Dr. J.K. TOWNSON for language editing.

References

Boz, Ö. and F.N. Uygur. 1997. Çukurova bölgesi buğday ekim alanlarındaki yabani hardal (*Sinapis arvensis* L.) ve yabani fiğin (*Vicia* spp.) zarar seviyelerinin saptanması ve ekonomik zarar eşiğinin hesaplanması. Türkiye II. Herboloji Kongresi. 1-4 Eylül 1997-İzmir ve Ayvalık/Türkiye, 15-24.

Boz, Ö. 2000. Aydın ili buğday ekim alanlarında bulunan yabancı otlar ile rastlama sıklıkları ve yoğunluklarının saptanması. Türkiye Herboloji Dergisi. 3(2): 1-11.

Daxl, R.N., C.K. von Kayserlingk, R.L. Koch and H. Waibel. 1994. Integrated Pest Management Guidelines. GTZ im TZ-Verlag. Germany. p. 119

Hashem, A., N. Wilkins and T. Piper. 2001. Competitiveness of wild radish in a wheat-lupin rotation. Department of Agriculture Western Australia. http://www.agric.wa.gov.au/cropupdates/2001/lupins/Hashem-Wilkins-Piper.htm

Heitefuss, R., B. Gerowitt and W. Wahmhoff. 1987. Development and implementation of weed economic thresholds in F.R. Germany. Proc. Brighton Crop Prot. Conf.-Weeds. Fornhom UK British Crop Protection Council, 1025-1034.

Kadıoğlu, İ., İ. Üremiş, E. Uluğ, Ö. Boz and F.N. Uygur. 1998. Researches on the economic thresholds of wild oat (*Avena sterilis* L.) in wheat fields in Çukurova Region of Turkey. Turkish Weed Sci. 1(2): 18-25.

Kudsk, P and J.C. Streibig. 2003. Herbicides–a two-edged sword. Weed Res. 43: 90-102.

Labrada R. and C. Parker. 1994. Weed control in the context of integrated pest management. In: Weed Management for Developing Countries (Eds., R. Labrada, J.C. Caseley and C. Parker). p. 383.

Mennan, H. 1998. Samsun ili Buğday Ekim Alanlarında Önemli Zarara Neden Olan Kokarot (*Bifora radians* Bieb.) ve Yapışkanotu (*Galium aparine* L.)'nun Ekonomik Zarar Eşiklerinin ve Bazı Biyolojik Özelliklerinin Araştırılması. Ç. Ü. Fen Bilimleri Enstitüsü Doktora Tezi. p. 137

Mennan, H., D. Işık, M. Bozoğlu and F.N. Uygur. 2002. Economic thresholds of *Avena* spp. and *Alopecurus myosuroides* Huds. in winter wheat. In: Proceedings 21st German Conference on Weed Biology and Weed Control (Eds., K. Hurle, R. Belz and F.M. Dux), 5-7 March 2002, Stuttgart-Hohenheim. 375-381.

Öngen, K.N., I. Serim and A. Uzun. 1996. Weed flora of crops in West Anatolia. IVth Plant Life in Southwest Asia Symposium. 21-28 May, 1995. İzmir-Turkey. 921-937.

Stauss, R. 1994. Compendium of Growth Stage Identification Keys for Mono and Dicotyledoneus Plants, Extended BBCH Scale. Ciba-Geigy AG. p.47

Uygur, F.N., İ, Kadıoğlu, Ö. Boz and H. Mennan. 1999. Yabancı Otların Ekonomik Zarar Eşiği ve Dünya ile Türkiye'deki Uygulamaları (Economic threshold of weeds and application in the world and Turkey). Bitki Korumada Ekonomik Zarar Eşiği Modelleri ve Uygulaması (Workshop), 8-9 September 1999. Samsun/Turkey. 170-225.

Zanin G., A. Berti and L. Toniolo. 1993. Estimation of economic thresholds for weed control in winter wheat. Weed Res. 33: 459-467.