Turk J Agric For
30 (2006) 137-144

Integrated Weed Control in Sugar Beet through Combinations of Tractor Hoeing and Reduced Dosages of a Herbicide Mixture

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Received: 28.04.2005

Abstract: Weed control is performed by hand in 83% of the sugar beet growing area in Turkey. Due to the movement of the labour force to industry recently, the lack of labour has led to a huge problem. Therefore, the completely mechanised alternative methods must be introduced into the weed control of sugar beet. In this study, the effects of alternative control methods, based on the use of a tractor hoe combined with post-emergence reduced herbicide dosages, on weeds and on the yield and quality of sugar beet were investigated. Our data indicated that tractor hoeing twice + thinning (96.2%) resulted in very good weed control, as good as the control treatment (i.e. hand hoeing twice + thinning) (98%). The other combinations differed significantly from the control. However, weed control via combinations of i) herbicide once + thinning + tractor hoeing once (86.6%), ii) herbicide 3 times + tractor hoeing once (86%), iii) herbicide 3 times (83.1%) and iv) herbicide twice + tractor hoeing once (76.8%) were satisfactory. In terms of root and sugar yields, following the control treatment (67.9 and 10.1 t ha^{-1}), these combinations were most effective: i) tractor hoeing twice + thinning (67 and 10 t ha^{-1}), ii) herbicide application 3 times (67 and 10 t ha^{-1}), iii) herbicide application 3 times + tractor hoeing once (64.3 and 9.7 t ha^{-1}), iv) herbicide application twice + tractor hoeing once (63.7 and 9.7 t ha^{-1}) and v) herbicide application once + thinning + tractor hoeing once (65 and 9.6 t ha^{-1}), although there was no significant difference among them. The other treatments produced significantly lower root and sugar yields compared to the control. One of the following alternatives, tractor hoeing twice + thinning, herbicide application 3 times, herbicide application twice + tractor hoeing once and herbicide application once + thinning + tractor hoeing once, may be applied to control weeds in a large proportion of land in which hand hoeing twice plus thinning is used.

Key Words: Sugar beet weed control, low-dose herbicide application, tractor hoeing

Şeker Pancarında Traktör Çapası ve Düşük Doz Herbisit Karışımı Kombinasyonları ile Entegre Yabancı Ot Kontrolü

Özet: Türkiye'de şeker pancarı ekim alanlarının % 83'ünde yabancı ot kontrolü, insan işgücü ile yapılmaktadır. Tarım nüfusunun sanayiye kaymasıyla işgücü sıkıntısı büyük bir problem olarak kendini hissettirmeye başlamıştır. Bu nedenle yabancı ot kontrolünde tam mekanize alternatif metotlara ihtiyaç duyulmaktadır. Bu çalışmada, şeker pancarının yabancı ot mücadelesinde çıkış sonrası düşük doz herbisit uygulamalarıyla traktör çapası kombinasyonlarına dayalı alternatif kontrol metotlarının yabancı ot etkinliği ile şeker pancarının verim ve kalitesi üzerindeki etkisi incelenmiştir. Sonuçlara göre, 2 kez traktör çapası + seyreltme uygulaması (% 96.2), 2 kez el çapası + seyreltme (% 98) (kontrol) ile aynı seviyede, iyi bir yabancı ot kontrolü sağlamıştır. Daha sonra sırasıyla, i) bir kez herbisit + seyreltme + bir kez traktör çapası (% 86.6), ii) 3 kez herbisit + bir kez traktör çapası (% 86), iii) 3 kez herbisit (% 83.1), iv) 2 kez herbisit + bir kez traktör çapası (% 76.8) uygulamaları, kontrol deneme konusundan istatistiki olarak düşük ama ona yakın bir yabancı ot kontrolü sağlamıştır. Pancar ve şeker verimi bakımından, Kontrol (67.9 ve 10.1 t ha^{-1}) ile kıyaslandığında aralarındaki farklar önemli olmamakla birlikte, en iyi sonuçlar sırasıyla, i) 2 kez traktör çapası + seyreltme (67 ve 10 t ha^{-1}), ii) 3 kez herbisit (67 ve 10 t ha^{-1}), iii) 3 kez herbisit + bir kez traktör çapası (64.3 ve 9.7 t ha^{-1}), iv) 2 kez herbisit + bir kez traktör çapası (63.7 ve 9.7 t ha^{-1}) ve v) bir kez herbisit + seyreltme + bir kez traktör çapası (65 ve 9.6 t ha^{-1}) uygulamalarından elde edilmiştir. Diğer deneme konularında ise kontrolden istatistiki olarak önemli seviyede düşük pancar ve şeker verimleri tespit edilmiştir. Türkiye'de büyük oranda el ile yapılan yabancı ot kontrolüne alternatif olarak, 2 kez traktör çapası + seyreltme, 3 kez herbisit, 2 kez herbisit + bir kez traktör çapası ve bir kez herbisit + seyreltme + bir kez traktör çapası uygulamalarından birisi tercih edilerek uygulanabilir.

Anahtar Sözcükler: Şeker pancarı yabancı ot kontrolü, düşük doz herbisit uygulaması, traktör çapası

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Introduction

Weed control in sugar beet is very important and the methods applied have been changing with the requirements of each time period. In previous times, weeds were controlled by hand, and then by hand hoeing (Schweizer and May, 1993). Coupled with decreases in the labour force, mechanisation began to be introduced into farming practices, which resulted in a replacement of hand hoeing by herbicide spraying and tractor hoeing.

The effectiveness of pre-emergence residual herbicides decreases with reductions in rainfall or soil wet content. Furthermore, they reduce the root yield of sugar beet under heavy rainfall due to phytotoxic action on the sugar beet as a result of their high effectiveness (Campagna et al., 2000). As a consequence, the application of post-emergence herbicides has become more and more important. Considering the insufficient effectiveness of one time high-dose herbicide applications on weeds, a low-dose technique of post-emergence for weed control was adopted in the 1980s (Schweizer and May, 1993; May, 1996; Schäufele, 2000). Several herbicide residues were found in soils (Eronen and Mutanen, 2000) The usage of low-dose herbicide twice or more not only increases their effectiveness on weeds but also decreases the amounts of their residues in soils. On the other hand, methods of mechanical weed control, especially tractor hoes, were also developed. After several new types of tractor hoes were developed, trials were carried out to make their usage widespread (Miller and Fornstrom, 1989; Tugnoli et al., 2002).

Efficient weed control in sugar beet could increase yield by 25%-40% in Turkey, where weed control is mainly performed by hand (Özgür 1980; Gürsoy, 1982). In 83% of the total sugar beet growing areas, weeds are controlled by implementing firstly hand hoeing between the rows, secondly thinning with hand hoeing within the rows and finally hand hoeing between the rows. Consequently, this method gives very good weed control. Tractor hoeing is used in 17% of the sugar beet growing area. However, when tractor hoeing only is employed, weeds over rows remain and additional hand hoeing is then needed (Özgür and Kaya, 2003).

In sugar beet cultivation, research has been done on weed control not only through the application of low-dose post-emergence herbicides but also by tractor hoe (Özgür and Kaya, 2000; Buzluk and Acar, 2002).

Relatively efficient weed control was achieved with low-dose herbicide mixtures applied 3 times (Özgür and Kaya, 2000). On the other hand, the results indicated that treatments with different tractor hoes also produced relatively satisfactory weed control (Buzluk and Acar, 2002). The disadvantage of using a low-dose herbicide is that it is more expensive than hand hoeing. However, the cost of hand labour is getting higher and higher. Tractor hoeing is efficient for the control of inter-row weeds but not within the rows, and this can be regarded as one of its disadvantages.

With the aim of obtaining satisfactory weed control and complete mechanisation in sugar beet, we tested the effects of an alternative method involving tractor hoeing combined with post-emergence reduced herbicide dosages on weed control, and on root yield and quality.

Materials and Methods

The study was carried out in Etimesgut trial field of the Sugar Institute during 2002-2004. The trials, including 54 plots, were established in an area of 3623 m^2 in a randomised complete block design with 6 replications. Plots were 2.25 m wide (5 rows) and 10 m long. Harvesting plots were 1.35 m wide (3 rows) and 7.4 m long.

The cultivar Leila, obtained from Kleinwanzlebener Saatzucht A.G. – Einbeck (Germany), treated with fungicides (hymexazol and thiram) and an insecticide (imidacloprid), was used in this study. In the soil preparation in autumn, stubble tillage was done at the tilt of shadow following the harvest of cereals. To allow volunteer cereals and other weed seeds to germinate, the trial sites were irrigated and then ploughed. After the recommended fertilisers were applied to the soil in a conventional way, the trial field was ploughed again. For seed bed preparation in spring, the remaining part of the fertilisers was applied to the soil, and then the trial field was drilled with Kombi-krüm. The sowing was then performed by mechanical precision drilling machine with 5 rows, in 45 cm row width and at 8 cm seed spacing. The other cultivation techniques were implemented in the conventional way.

A hand hoe with a sharpened blade of 15 cm and a handle of 140-150 cm was used in the control treatment. A tractor hoe having 6 rows, 2.5 cm working width, 6-goose foot, long-nosed 12 blades, 3-8 cm working depth,

4-5 km h^{-1} working speed, and 25 kW power was used in the required treatments.

The herbicide mixtures used in the trials consisted of Betanal Progress OF [Phenmedipham (9.2%) + Desmedipham (7.2%) + Ethofumesate (11.3%), 1.2 kg h^{-1}], Pyramine DF [Chloridazon (65%), 1.0 l h^{-1}], and Lontrel 100 [Clopyralid (12.6%), 0.5 l h^{-1}]. The herbicide mixes were applied post-emergence by a knapsack sprayer, which had flat fan nozzles with a distance of 45 cm between nozzles (nozzle number 11002, 220 l h^{-1} volume capacity).

All sprays were applied at the cotyledon stage of the weeds. Other implementations were carried out according to the growth stage of the sugar beet plants (Table 1).

After implementing all treatments, the weeds in all trial plots were counted in the area of 1 m^2 by a tool with the dimensions of 0.185 x 1.35 m (TKB, 1996). The weed species were identified according to Davis (1965-88) and the identified weed species and density are given in Table 2.

Effectiveness of weed control was determined by Abbott's formula after calculating the angle values of the weed density per plot. The data were tabulated and evaluated through analyses of variance using a statistics package, Mstats-C Version 1.42. Then Duncan's test was used to determine the differences among the means of the treatments.

Results

The results of the trials, presented as means of the years of 2002, 2003 and 2004, are shown in Figures 1-5. The treatments of hand hoeing twice plus thinning (control) and tractor hoeing twice plus thinning produced the lowest weed densities. All other treatments produced higher weed densities. In terms of effectiveness of weed control, the best results were obtained from the control and tractor hoeing twice plus thinning treatments. The differences between both treatments were not significant. The others, compared with the control, showed a lower effectiveness of weed control. Effectiveness of weed control was 98% in hand hoeing twice plus thinning, 96.2% in tractor hoeing twice plus thinning, 86.6% in herbicide once plus thinning plus tractor hoeing once, 86% in herbicide 3 times plus tractor hoeing once, 83.1% in herbicide 3 times, 76.8% in herbicide twice plus tractor hoeing once, 64% in herbicide once plus tractor hoeing once and 61% in herbicide twice. The differences between these treatments were statistically significant (Figure 1).

In the trial, the results of root yield were consistent with those of sugar yield. In terms of both root and sugar yield, tractor hoeing twice plus thinning, herbicide 3 times, herbicide twice plus tractor hoeing once, herbicide once plus thinning plus tractor hoeing once and herbicide 3 times plus tractor hoeing once treatments gave as good

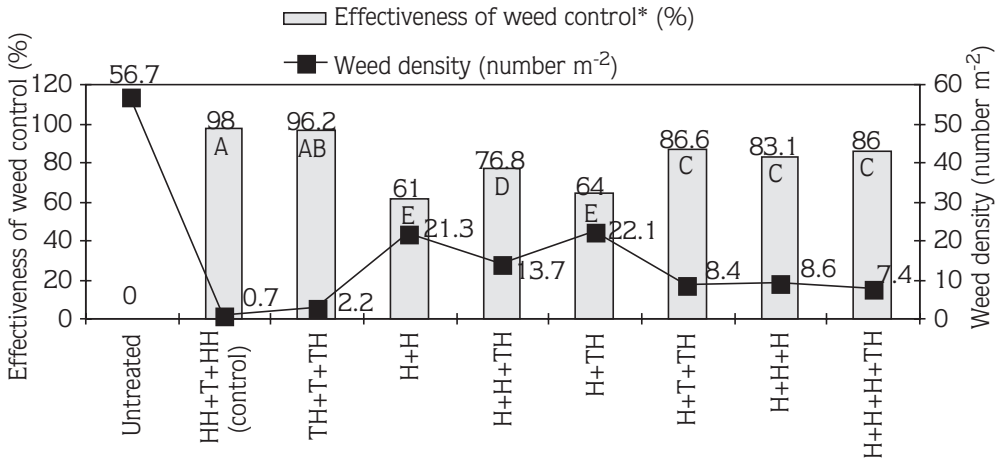
Table 1. The treatments and weed management order at sugar beet growth stages.

Treatments	Weed management order at sugar beet growth stages				
	Cotyledon	2-4 true leaves	4-6 true leaves		8-10 true leaves
1. Untreated				Thinning by hand	
2. 2x HH + T (control)		Hand hoeing		Thinning by hand hoe	Hand hoeing
3. 2x TH + T		Tractor hoeing		Thinning by hand hoe	Tractor hoeing
4. 2x H	BPO+P+L mix	BPO+P+L mix		Thinning by hand	
5. 2x H + 1x TH	BPO+P+L mix	BPO+P+L mix		Thinning by hand	Tractor hoeing
6. 1x H + 1x TH	BPO+P+L mix			Thinning by hand	Tractor hoeing
7. 1x H + T + 1x TH	BPO+P+L mix			Thinning by hand hoe	Tractor hoeing
8. 3x H	BPO+P+L mix	BPO+P+L mix	BPO+P+L mix	Thinning by hand	
9. 3x H + 1x TH	BPO+P+L mix	BPO+P+L mix	BPO+P+L mix	Thinning by hand	Tractor hoeing

BPO: Betanal Progress Of (1.2 kg ha^{-1}), P: Pyramine DF (1 kg ha^{-1}), L: Lontrel 100 (0.5 kg ha^{-1})
HH: Hand hoeing, T: Thinning, TH: Tractor hoeing, H: Herbicide mix

Table 2. Weed species and average density in the trial field in 2002-2004.

Weed species	Average weed density (number m^{-2})			
	2002	2003	2004	Average
Amaranthus blitoides S.Wats.	5.8	53.5	33.2	30.8
Amaranthus retroflexus L.	-	0.7	0.5	0.4
Atriplex nitens Schkuhr	-	-	0.2	0.1
Chenopodium album L.	4.5	9.7	8.8	7.7
Chenopodium vulvaria L.	1.3	1.3	2.7	1.8
Chenopodium urbicum L.	1.7	0.8	0.2	0.9
Convolvulus arvensis L.	-	-	1.3	0.4
Descurainia sophia (L.) Webb ex Prantl	-	0.5	0.3	0.3
Echinochloa crus-galli (L.) P.Beauv.	-	-	0.3	0.1
Euphorbia chamaesyce L.	0.7	0.2	0.2	0.4
Euphorbia sp.	0.2	-	0.8	0.3
Fumaria parviflora Lam.	-	-	0.8	0.3
Heliotropium europaeum L.	3.0	1.5	6.7	3.7
Lactuca serriola L.	-	0.3	0.7	0.3
Polygonum aviculare L.	-	-	0.2	0.1
Polygonum convolvulus L.	-	-	0.2	0.1
Senecio vulgaris L.	-	-	0.2	0.1
Solanum nigrum L.	13.2	1.3	11.7	8.6
Sonchus asper (L.) Hill	0.3	-	0.5	0.3
Total	30.7	69.8	69.5	56.7



HH: Hand hoeing, T: Thinning, TH: Tractor hoeing, H: Herbicide mix

* percentage reduction in the number of weeds vs. the untreated control set at 100

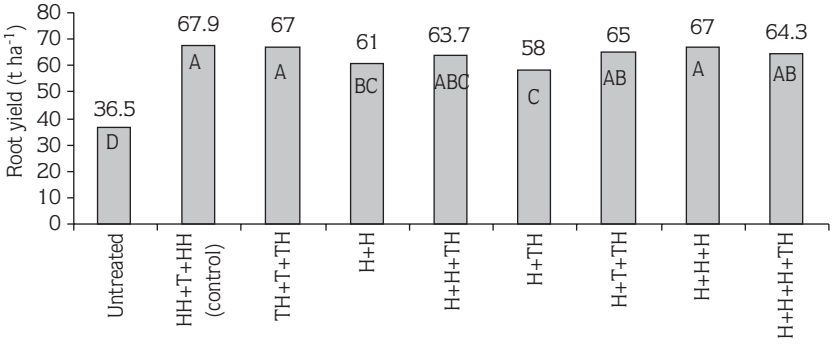
Figure 1. Mean effectiveness of weed control and weed density of the treatments in 2002-2004 ($P < 0.05$).

results as the control and the differences among the treatment means were not statistically significant.

Although higher root yields were obtained with tractor hoeing twice plus thinning and herbicide 3 times treatments, there was no significant difference when compared to the other treatments, i.e. tractor hoeing twice plus thinning (67 t ha^{-1}), herbicide 3 times (67 t ha^{-1}), herbicide once plus thinning plus tractor hoeing once (65 t ha^{-1}), herbicide 3 times plus tractor hoeing once (64.3 t ha^{-1}) and herbicide twice plus tractor hoeing once (63.7 t ha^{-1}) (Figure 2).

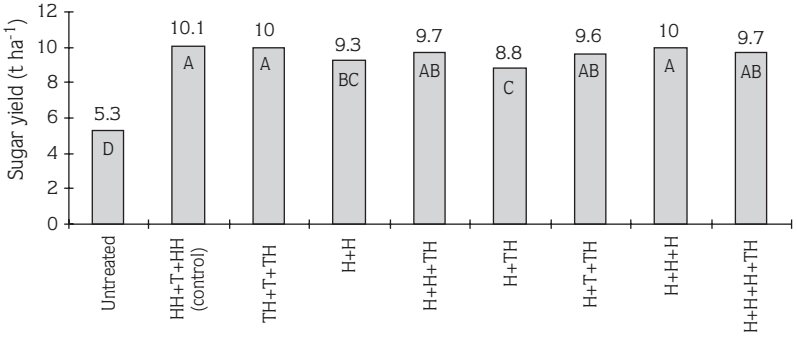
The differences among the mean sugar yields of these treatments were statistically the same as the control (10.1 t ha^{-1}): herbicide 3 times (10 t ha^{-1}), tractor hoeing twice plus thinning (10 t ha^{-1}), herbicide twice plus tractor hoeing once (9.7 t ha^{-1}), herbicide 3 times plus tractor hoeing once (9.7 t ha^{-1}) and herbicide once plus thinning plus tractor hoeing once (9.6 t ha^{-1}). While the highest sugar yields were obtained with the treatments involving herbicide 3 times and tractor hoeing twice plus thinning, no treatment resulted in a loss of 46% root yield and 48% sugar yield (Figures 2 and 3). There were no differences among the treatments in terms of quality parameters such as sugar content, extractable sugar content, and the contents of Na, K and α-amino N (Figures 4 and 5).

Even though the effectiveness of weed control by herbicide treatment 3 times was lower than that in the control and tractor hoeing twice plus thinning, the root and sugar yields of herbicide 3 times were similar to the yields of these treatments. On the other hand, while the effectiveness values of weed control by herbicide twice plus tractor hoeing once, herbicide once plus thinning plus tractor hoeing once, herbicide 3 times, and herbicide 3 times plus tractor hoeing once were comparably low, they produced as satisfactory root and sugar yield as the control treatment did.



HH: Hand hoeing, T: Thinning, TH: Tractor hoeing, H: Herbicide mix

Figure 2. Mean root yields of the treatments in 2002-2004 ($P < 0.05$).



HH: Hand hoeing, T: Thinning, TH: Tractor hoeing, H: Herbicide mix

Figure 3. Mean sugar yields of the treatments in 2002-2004 ($P < 0.05$).

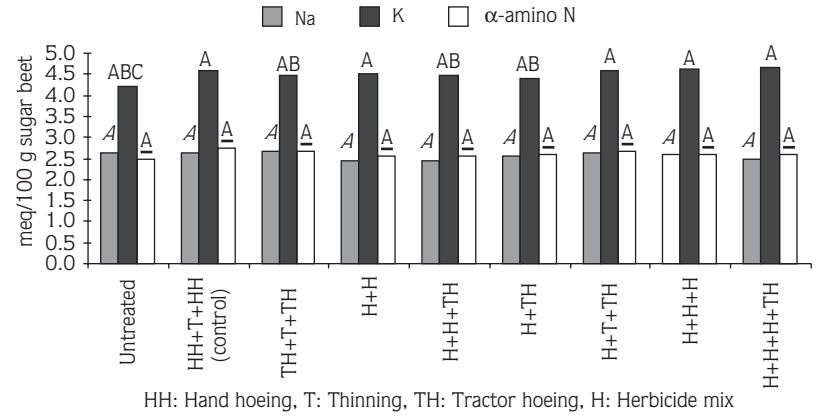


Figure 4. Mean contents of Na, K and α-amino N of the treatments in 2002-2004 ($P < 0.05$).

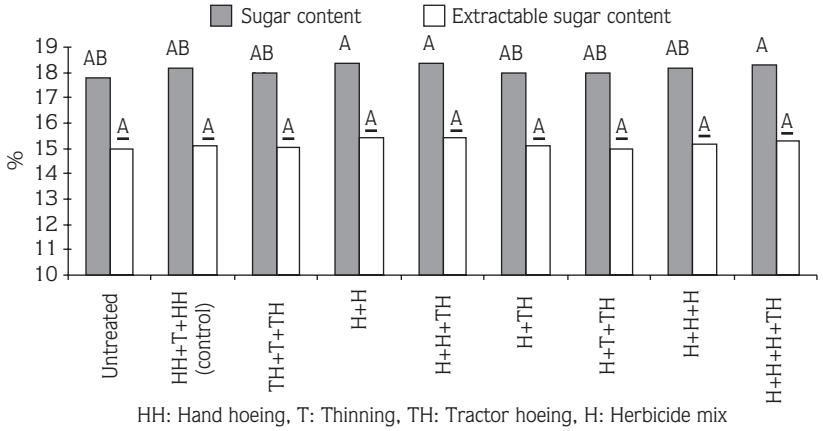


Figure 5. Mean sugar and extractable sugar contents of the treatments in 2002-2004 ($P < 0.05$).

Herbicide application twice plus tractor hoeing once was more satisfactory than herbicide application twice. On the other hand, the combination of herbicide once plus thinning (instead of herbicide once) plus tractor hoeing once with the root and sugar yield (65 and 9.6 t ha^{-1} respectively), changed from the treatment of herbicide twice plus tractor hoeing once with the root and sugar yield (63.7 and 9.7 t ha^{-1} respectively), was also satisfactory. Implementing tractor hoeing once combined with herbicide 3 times did not lead to any increase when compared to herbicide 3 times only.

The results also showed that uncontrolled weed density up to 21% did not bring about an economically significant loss of root and sugar yield, even though the control treatment differed statistically from the treatments of herbicide twice plus tractor hoeing once, herbicide once plus thinning plus tractor hoeing once, herbicide 3 times and herbicide 3 times plus tractor hoeing once in terms of effectiveness of weed control, but not in terms of root and sugar yield.

Discussion

After herbicide was applied 3 times, additional implementation of tractor hoeing once did not cause any increase. Herbicide twice and herbicide once plus tractor hoeing once were not enough for weed control. In the same way, their root and sugar yields were naturally not efficient and both treatments need one additional herbicide application for economically sufficient yields. In

contrast, the low-dose post-emergence applications were found to give a satisfactory result (Campagna et al., 2000).

Tugnoli et al. (2002) suggested that only mechanical implementations currently available do not appear to be capable of supplanting chemical methods entirely since a certain amount of manual work on the rows would be needed to stay on top of the weeds. Ollson (1996) also reported that good weed control and good sugar yield were obtained from tractor hoeing twice with harrowings plus herbicide twice. Considering these results, thinning with a hand hoe plus tractor hoeing twice produced a good result. On the other hand, low-dose post-emergence sprayings twice in combination with tractor hoeing and low dose spraying once plus thinning with a hand hoe in combination with tractor hoeing gave a satisfactory result.

Low-dose herbicide applied 3 times produced a good result again as suggested by Özgür and Kaya (2000).

Scott et al. (1979) stated that weeds that emerge after sugar beet plant have 8 or more leaves are less likely to affect yield, and sugar beet can tolerate the presence of weeds. Schweizer (1981) suggested that weed numbers were less well related to root yield losses when weeds had been treated with herbicides, and their growth had been suppressed during the growing season. Brandes et al. (1998) also reported that a certain infestation of weed could be tolerated. Likewise, the results in this study showed that an infestation of 21% weeds did not result in a significant loss of root and sugar yield.

Our results indicated that no treatment gave a 54% loss of root yield compared to hand hoeing twice plus thinning. As Schweizer and Dexter (1987) had stated, competition from uncontrolled annual weeds can reduce root yield by 26%-100%.

In contrast to Brandes et al.'s (1998) findings but consistent with Özgür and Kaya (2000), 2 sprayings were not efficient. In addition, our results suggested that one more spraying was necessary for effective weed control. In line with our results, May (1996) reported that 3 low-dose sprayings were expedient.

At the same time, our study showed that when weeds were not controlled at all, weed growth resulted in higher losses by 46% for beet yield and 48% for sugar yield than the losses (24%-40%) stated by Özgür (1980) and Gürsoy (1982). In terms of sugar content, extractable sugar content, and the contents of Na, K and α-amino N, our results are in line with those reported by Campagna et al. (2000).

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