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ORIGINAL ARTICLE / ORIGINALBEITRAG

An Alternative Sucker Management Method in Hazelnut: Application of Nitrogen Fertilizer Solution

Ümit Serdar[1] · Coşkun Gülser[2] · Burak Akyüz[1] · Ayşegül Balta[3] · Yusuf Çil[4] · Fatma Yilmaz Figen[5]

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Abstract

The goal of this study was to determine the usability of nitrogen solution for hazelnut sucker management. This study was carried out from 2015 to 2016 at two hazelnut orchards; one established with the shrub (ocak) system in Atakum district and the other established with the multi-stemmed system in the Carsamba district, both in Samsun province. For sucker management, 21% ammonium sulphate (AS) and 26% calcium ammonium nitrate (CAN) fertilizer solutions were used. Doses of 0, 10, 15 and 20% of solutions for both fertilizers were tested. In the study, hazelnut suckers were removed by knife in July 2015 and March 2016. Nitrogen solution applications were started in September 2015 when suckers reached 20–30 cm length. In 2016 four applications were made from April to August. Fifteen days after the applications, the wilting ratio (starting from the tip) and newly emerged suckers per bush were determined. Nitrate, pH, and EC analyses were made with soil samples collected at the beginning of the experiment and compared to those taken 15 days after each application. As a result, a 10% dose of 21% ammonium sulphate fertilizer gave the best results for hazelnut sucker management. Nitrogen solution application should be started 1 to 1.5 months after removal of suckers by cutting with a knife. Suckers should be removed when they reach 15–20 cm length and before they are lignified. For effective sucker management, nitrogen solution application should be applied at least three times in a year.

Keywords Ammonium sulphate · Calcium ammonium nitrate · Corylus avellana · Desuckering · Lignification · Hazelnut

Eine alternative Methode zur Bekämpfung von Wurzelausläufern bei Haselnüssen: Applikation einer N-Düngerlösung

Schlüsselwörter Ammoniumsulfat · Kalkammonsalpeter · Corylus avellana · Bekämpfung von Wurzelausläufern · Verholzung · Haselnuss

Introduction

Hazelnut is one of the most important nut plants grown in the world. According to the latest data provided from FAOSTAT, in 2019 Turkey was a leader country with 776.046 tons production, followed by Italy (98.530 tons), Azerbaijan (53.793 tons), USA (39.920 tons) and Chile (35.000 tons) (FAOSTAT 2021). In hazelnut cultivation, sucker management, fertilizing, irrigation, pest/disease management, and pruning are the primary horticultural activities. Among these activities, classical sucker management requires the largest proportion of the labour force (42%) (Ilkyaz 1986; Tous et al. 1994; Kılıç and Demir 2004).

✉ Burak Akyüz
burak.akyuz@omu.edu.tr

1 Department of Horticulture, Faculty of Agriculture, Ondokuz Mayıs University, Samsun, Turkey

2 Department of Soil Science and Plant Nutrition, Faculty of Agriculture, Ondokuz Mayıs University, Samsun, Turkey

3 Samsun Province Directorate of Ministry of Agriculture and Rural Affairs, Çarşamba, Samsun, Turkey

4 Ferrero hazelnut company, Samsun, Turkey

5 Chamber of Agriculture, Salıpazarı, Samsun, Turkey

In Turkey, hazelnut orchards are mostly established with a multi-stemmed bush system. In this system, many shoots grow at the base of the trunk (Tomasone et al. 2010). These shoots can negatively affect the bush by competing with the main branches for nutrients and water. As a result, main branches slow their growth leading to a decrease in yield (Okay et al. 1986; Mehlenbacher and Smith 1992; Tous et al. 1994). Also, suckers can decrease the ventilation capacity of the bush which can increase the epidemic of some diseases like powdery mildew (*Erysiphe corylacearum*). On the other hand, in the multi-stemmed bush system suckers can be used to replace old branches. Researchers suggest performing sucker management at least twice a year (Okay et al. 1986; Yılmaz 2017). However, due to the high cost associated with this operation and absence of experienced people for this job, sucker management is only performed once a year or once every two years in Turkey (Kurnaz and Serdar 1993; Kılıç et al. 2009).

Topographic properties of the orchards are the key factors to choose the best sucker management method. For this aim, different sucker management methods are tested (Me et al. 1988; Dolci et al. 2001, 2005; Smith and Erdogan 2001; Tomasone et al. 2009, 2010). The traditional sucker management method is to remove suckers using sharp tools by hand (using special knives or pruning shears). This is the most environmentally friendly method, but it requires so much working hour and it is tiring for workers. Some farmers tested motor scythes to reduce labour time. Beyhan and Pınar (1996) reported that the use of motor scythes in hazelnut sucker management resulted in saving 54.5% of labour force and reduced the cost by 17.2%. However, in the bush system, it is extremely hard to control these kinds of machines. It can harm the main branches. As an alternative method, flame and steam machines were tested in Italy. These machines were found effective on herbaceous suckers (Tomasone et al. 2009). Also, both machines are suitable for organic farming. Nevertheless, these machines can only be used at orchards which were established with a single trunk growing system.

Most of the farmers prefer to use different chemicals to save time and money. Chlorthiamid, aminotriazole, bromacil, dichlobenil, krenite, paraquat, dinoseb, diquat, cypromid, cacodylic, 2,4,5-T, dicamba, and picloram active indigents were used for this purpose (Paglietta 1968; Reich and Lagerstedt 1971; Geraci and Baratta 1973; Germain 1973; Alberghina 1979; Rapparini 1986). However, herbicides can harm ecology and environment by remaining active for a long time. Herbicides also threaten the microbial activity in soil (Tucker et al. 1969; Dolci et al. 2001). Due to these negative effects of herbicides on ecology, new efficient and more environmentally friendly methods should be used.

Nitrogen is an important nutrient for plants. Plants cannot use or take nitrogen directly from the soil, plants can uptake nitrogen through nitrogen forms that include ammonium and nitrate. The dose of fertilizer is very important. Excessive fertilizing can harm plants by the salt effect. In this case, nitrogen solution applications can be used as an alternative chemical for hazelnut sucker management.

This study was aimed to determine the effects of different nitrogen fertilizer solutions on hazelnut sucker management.

Materials and Methods

The study was carried out in two hazelnut orchards (Atakum and Carsamba districts of Samsun) with two different training systems (multi-stemmed bush and row respectively) in 2015 and 2016. In row training system, plants are planted on a row with little spacing (Fig. 1). In this system, 15 branches were counted as one plant. Both orchards were established with 'Çakildak' cultivar (Köksal 2002; Serdar and Demir 2005; Özçağıran et al. 2007) (Table 1).

In the study, two different nitrogen fertilizers, ammonium sulphate (AS) (21% N) and calcium ammonium nitrate (CAN) (26% N), were used. To determine the suitable dose for sucker management, 0, 10, 15 and 20% of nitrogen solutions were tested. Solutions were sprayed to the suckers by using PALMERA OS 76 pulverizator. PALMERA OS 76 pulverizator has 15 L tank. Nitrogen fertilizer doses were calculated according to 15 L and tap water was used as a solvent (Table 2). Solutions were shaken well and then filtered into pulverizator tank.

In July 2015, all existed suckers were removed by hand in two orchards. First application was performed in September (Table 3). In Atakum orchard for each multi-stemmed bush and in Çarşamba orchard for 15 branches 1 L solution was applied. Solutions were applied to the sucker entirely, from apex to the base. Operators avoided to spray on to main branches.

Fig. 1 General appearance of the Çarşamba orchard

Table 1 Properties of experimental locations

General Characteristics								
Location	*Altitude (m)*			*Slope (%)*		*Age of the tree (year)*		*Orchard system*
Carsamba	20			0–1		15		Row
Atakum	500			12–15		15		Multi-stemmed bush
Soil Characteristics								
Location	*Clay (%)*	*Silt (%)*	*Sand (%)*	*pH (1:1)*	*Total salt (%)*	*P (mg/kg)*	*K (cmol/kg)*	*Organic material (%)*
Carsamba	63.2	24.7	12.1	7.30	0.04	24.2	0.54	2.20
Atakum	31.0	36.6	32.5	5.24	0.01	18.1	0.48	4.51

Table 2 Amount of the fertilizers to prepare 15 L solution

Doses (%)	Amount of the fertilizer
0	0 kg
10	1.5 kg
15	2.25 kg
20	3 kg

In March 2016, all existed suckers were removed by hand again. That application was performed to put the plants into same stage. In that year, nitrogen solution applications were applied four times (Table 3). The same nitrogen solutions were applied to the same multi-stemmed bush or 15 branches each time. Fifteen days after application, wilted sucker ratio (starting from tip) was determined by checking the cambium tissues. Suckers were cut vertically by knife and cambium tissue was examined. Suckers with straight brown cambium tissue counted as wilted. Also, fifteen-days after the applications newly emerged suckers for each application was counted in a 30 cm × 30 cm area.

To determine the changes in nitrate (NO_3), pH and EC values in soils due to nitrogen solution applications, surface soil samples (0–20 cm) were taken from each replication at the beginning of the experiment (September 2015) and 15 days after each nitrogen solution application. Soil characteristics of the orchards were determined as follows; particle size distribution by hydrometer method (Day 1965), soil pH in 1:1 (w:v) soil water suspension by pH meter (Mettler Toledo S400), electrical conductivity (EC25 °C) in the same soil suspension by EC meter, and exchangeable cations using ammonia acetate extraction method (Kacar 1994). Organic carbons (OC) were determined by the modified Walkley-Black method (Kacar 1994). Nitrates (NO_3) in soil samples were measured potentiometrically using a NO_3 electrode (EPA 1996). Available phosphorus was determined in acidic soil by the Bray method and in neutral soil by the Olsen method (Kacar 1994). According to the basic soil analysis results in Table 1, the soil of orchard located in Carsamba has clay textural class, neutral in pH, non-saline, moderate in available P, exchangeable K, and organic matter contents. The soil of orchard located in Atakum has clay loam textural class, strongly acid in pH, non-saline, moderate in available P and exchangeable K contents, and high in organic matter content (Hazelton and Murphy 2007).

This study was carried out at two orchards using 2 different nitrogen fertilizers (ammonium sulphate and calcium ammonium nitrate) with 4 doses (0, 10, 15 and 20%) and 3 replications including 3 hazelnut bushes (15 branches were counted as 1 bush in Çarşamba orchard) per replication. The experiment was designed by randomized block with 144 total number of bushes. Data were analyzed using the General Linear Models (GLM) procedure of SPSS (16.0). The means of data were compared using Duncan's multiple comparison test.

Table 3 Methods and periods between applications for sucker management

Method of sucker management	Experiment locations			
	Carsamba		Atakum	
	Date of application	Dates between applications	Date of application	Dates between applications
By knife	30 July 15	–	30 July 15	–
Nitrogen solutions	28 Sept. 15	60	29 Sept. 15	61
By knife	5 March 16	–	5 March 16	–
Nitrogen solutions	23 April 16	44	1 May16	57
	2 June 16	40	3 June 16	33
	7 July 16	35	7 July 16	34
	19 August 16	43	18 August 16	42

Table 4 Wilted sucker ratio 15 days after applications (%)

Applications	30.09.15	23.04.16	02.06.16	07.07.16	19.08.16
ÇARŞAMBA					
AS-0	0.00 c[a]	0.0 d	0.0 c	0.0 b	0.0 c
AS-10	11.8 b	45.1 c	61.0 b	99.5 a	94.9 ab
AS-15	12.9 b	44.8 c	86.6 a	99.8 a	94.2 ab
AS-20	14.1 b	68.5 b	97.6 a	89.3 a	99.2 a
CAN-0	0.00 c	0.0 d	0.0 c	0.0 b	0.0 c
CAN-10	11.1 b	61.9 b	90.5 a	90.7 a	81.1 b
CAN-15	15.7 b	82.6 a	92.2 a	98.7 a	95.7 a
CAN-20	25.9 a	91.6 a	91.5 a	99.1 a	97.9 ab
P	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01
ATAKUM					
AS-0	0.0 c	0.0 b	0.0 c	0.0 d	0.0 b
AS-10	4.7 b	63.1 a	91.2 a	69.7 bc	88.2 a
AS-15	8.1 ab	77.6 a	74.3 b	90.5 a	92.9 a
AS-20	6.4 ab	70.8 a	82.3 ab	84.7 ab	91.9 a
CAN-0	0.0 c	0.0 b	0.0 c	0.0 d	0.0 b
CAN-10	6.4 ab	62.0 a	83.8 ab	57.0 c	91.3 a
CAN-15	4.8 b	80.0 a	89.3 a	92.5 a	99.5 a
CAN-20	16.5 a	76.5 a	96.3 a	98.5 a	100.0 a
P	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01	≤ 0.01

[a]There is no difference between the means indicated by the same letter in the same column

Results and Discussion

In 2015, nitrogen solution application was applied at the end of September. The wilted sucker ratio ranged from 0% to 16.5% in Atakum orchard and 0% to 25.9% in Çarsamba orchard (Table 4). In both orchards, wilted sucker ratio was found low. The growth stage of the sucker is an important parameter for this application. In September, suckers were in lignification phase. So, the effectiveness of the applications was insufficient. According to the results, nitrogen solution application dates in 2016 were rescheduled and completed before September.

Fig. 2 The view of the AS-10 applied bush on 31.08.2016 in Atakum orchard

Nitrogen solution applications in 2016 were performed four times between April and August. The wilted sucker ratio ranged from 0% to 100.0% in Atakum orchard and 0% to 99.8% in Carsamba orchard. On 23.04.2016 and 02.06.2016 nitrogen solution applications were performed on shorter suckers (15–20 cm) compared to on 07.07.2016 and 19.08.2016 (35–45 cm) application dates. Nevertheless, the wilted sucker ratio was determined higher on 07.07.2016 and 19.08.2017. The best ratio was obtained from the 4th application in both orchards (Table 4) (Fig. 2). Fifteen days after the 4th application, there was no significant difference between fertilizers and the tested doses in sucker management at Atakum orchard. The same results were obtained from the Carsamba orchard except with 10% Calcium Ammonium Nitrate application.

Number of newly emerged suckers were differed according to the application times. It ranged from 1.8 to 23.3 in the Atakum orchard and 0.8 to 23.8 in the Carsamba orchard (Table 5). On the last application of the vegetation period (19.08.2016), nitrogen solution applications were decreased the newly emerged sucker numbers. However, it did not prevent all newly sucker growth. In multi-stemmed bush system, it is important to leave some suckers for replacing old branches (Tomasone et al. 2010).

The nitrate nitrogen values at the beginning of the field experiments varied between 11.40 and 13.22 ppm in

Table 5 Mean numbers of newly emerged suckers per bush (at 30 cm × 30 cm area) 15 days after application

Applications	30.09.15	23.04.16	02.06.16	07.07.16	19.08.16
ÇARŞAMBA					
AS-0	10.9 d[a]	10.5 a	8.2 b	12.3 ab	11.0 a
AS-10	11.5 d	7.7 ab	23.8 a	7.5 b–d	4.2 cd
AS-15	17.2 a–c	9.4 ab	23.0 a	7.0 b–d	2.9 d
AS-20	14.4 b–d	11.1 a	21.2 a	9.4 bc	1.5 d
CAN-0	21.4 a	6.2 ab	8.3 b	16.3 a	8.4 ab
CAN-10	19.6 a	9.4 ab	18.0 a	7.6 b–d	7.0 bc
CAN-15	17.7 ab	5.4 ab	9.0 b	4.6 cd	1.7 d
CAN-20	12.9 cd	4.6 b	3.8 b	3.0 d	0.8 d
P	≤ 0.01	≤ 0.05	≤ 0.01	≤ 0.01	≤ 0.01
ATAKUM					
AS-0	10.0 ab	13.7	13.3	10.0 cd	4.8 b
AS-10	8.0 ab	12.7	15.0	17.3 a–c	2.4 c
AS-15	7.0 b	10.7	13.0	15.3 b–d	1.8 c
AS-20	9.3 ab	10.0	16.0	21.8 ab	2.8 bc
CAN-0	12.9 a	14.0	15.0	12.3 cd	8.7 a
CAN-10	5.3 b	13.0	20.7	23.3 a	2.8 bc
CAN-15	9.7 ab	11.7	10.7	9.0 d	3.4 bc
CAN-20	6.0 b	10.3	11.0	13.3 cd	1.9 c
P	≤ 0.05	NS	NS	≤ 0.01	≤ 0.01

NS Not significant
[a]There is no difference between the means indicated by the same letter in the same column

Table 6 Nitrate changes at hazelnut orchards (NO_3-N ppm)

Applications	Before Application	Sampling Date					Mean
		15.10.15	08.05.16	17.06.16	22.07.16	03.09.16	
ÇARŞAMBA							
Control	12.13	10.00	2.43	12.01	5.22	8.02	8.30 b[a]
AS-10	11.40	9.16	5.93	13.79	5.01	7.96	8.88 b
AS-15	13.22	11.60	12.27	10.38	6.57	7.41	10.24 a
AS-20	11.63	11.70	6.31	10.00	7.69	7.40	9.12 ab
CAN-10	11.63	12.50	4.63	4.60	8.24	7.97	8.26 b
CAN-15	12.41	10.50	3.87	7.92	5.62	7.60	7.99 c
CAN-20	11.89	9.29	13.89	8.24	5.28	7.29	9.31 ab
P							≤ 0.01
ATAKUM							
Control	4.01	6.00	3.92	3.64	4.34	5.22	4.52 bc
AS-10	5.81	2.03	3.56	4.54	2.90	3.87	3.79 d
AS-15	6.00	6.09	3.51	3.28	2.84	4.68	4.40 c
AS-20	6.15	6.73	3.91	5.25	3.66	4.10	4.97 a–c
CAN-10	4.41	6.52	5.50	5.91	3.82	5.94	5.35 a
CAN-15	5.28	4.29	3.66	3.93	4.81	5.06	4.51 bc
CAN-20	6.19	7.62	3.75	2.94	4.73	5.13	5.06 ab
P							≤ 0.01

[a]There is no difference between the means indicated by the same letter in the same column

Table 7 pH (1:1) changes at hazelnut orchards

Applications	Before Application	Sampling Date					Mean
		15.10.15	08.05.16	17.06.16	22.07.16	03.09.16	
ÇARŞAMBA							
Control	7.51	7.75	6.73	7.38	7.17	7.42	7.33
AS-10	7.41	7.70	6.36	8.5	7.18	7.52	7.45
AS-15	7.29	7.62	6.38	7.35	6.8	7.16	7.10
AS-20	7.53	7.60	7.04	8.08	7.22	6.97	7.41
CAN-10	7.42	7.57	6.62	7.49	6.96	7.48	7.26
CAN-15	7.45	7.56	6.42	7.94	7.15	7.14	7.28
CAN-20	7.50	7.66	6.82	8.18	7.19	6.90	7.38
P							NS
ATAKUM							
Control	4.81	5.51	5.76	5.42	4.96	6.28	5.46
AS-10	5.34	5.10	5.7	5.4	4.92	4.83	5.22
AS-15	5.12	5.93	6.12	5.4	5.27	5.31	5.53
AS-20	5.84	5.35	6.56	4.83	4.33	5.77	5.45
CAN-10	5.03	5.60	5.76	6.02	5.54	6.33	5.71
CAN-15	5.11	5.65	4.82	5.51	5.45	5.36	5.32
CAN-20	5.47	5.54	5.88	5.33	5.71	5.71	5.61
P							NS

[a]*NS* Not significant

Table 8 Changes in EC (dS/m) values at the hazelnut orchards

Applications	Before Application	Sampling Date					Mean
		15.10.15	08.05.16	17.06.16	22.07.16	03.09.16	
ÇARŞAMBA							
Control	0.575	0.362	0.801	0.806	0.821	0.438	0.634 bc
AS-10	0.590	0.365	0.899	0.532	0.786	0.528	0.617 c
AS-15	0.691	0.469	0.851	0.906	0.849	0.665	0.739 a
AS-20	0.603	0.469	0.709	0.738	0.843	0.769	0.689 ab
CAN-10	0.603	0.469	0.778	0.510	0.912	0.499	0.629 bc
CAN-15	0.701	0.469	0.840	0.778	0.908	0.540	0.706 a
CAN-20	0.617	0.412	0.654	0.649	0.928	0.598	0.643 bc
P							≤ 0.01
ATAKUM							
Control	0.065	0.156	0.776	0.203	0.138	0.408	0.291 a
AS-10	0.166	0.083	0.304	0.390	0.258	0.203	0.234 bc
AS-15	0.176	0.156	0.212	0.231	0.345	0.176	0.216 bc
AS-20	0.240	0.120	0.582	0.084	0.126	0.505	0.276 a
CAN-10	0.087	0.213	0.47	0.561	0.205	0.183	0.287 a
CAN-15	0.136	0.156	0.272	0.317	0.223	0.094	0.200 c
CAN-20	0.187	0.156	0.564	0.237	0.158	0.212	0.252 ab
P							≤ 0.01

[a]There is no difference between the means indicated by the same letter in the same column

Carsamba and 4.01 and 6.19 ppm in Atakum (Table 6). The nitrate nitrogen values varied between 2.43 and 13.89 ppm in Carsamba, and 2.90 and 7.62 ppm in Atakum (Table 6). In both locations, nitrate nitrogen values during the sampling time significantly decreased compared with the values obtained before application ($p \leq 0.01$). Generally, the mean nitrate values of the fertilizer solution applications were not significantly different over the control application. These results indicated that nitrogen solution applications did not change the soil nitrate content. Simon and Le Corre (1992) reported that the critical drainage volume defined as the minimum volume necessary to leach completely the nitrate

nitrogen present in the soil profile is between 300 and 400 mm. Hazelnut cultivation is mostly done in Blacksea region. Blacksea region can be divided into 3 according to its ecological characteristics. Samsun is located in the middle Blacksea region which's mean annual precipitation is the lowest. However, mean annual precipitation in Samsun province is around 700 mm. It seems that this precipitation amount can cause enough drainage volume to leach nitrate from soil profile at both locations. Therefore, nitrate nitrogen values showed fluctuations with sampling dates during the experiment.

Nitrogen solution applications did not significantly change the pH values of soils in both locations (Table 7).

During the field experiments, EC values varied between 0.362 dS/m and 0.906 dS/m in Carsamba, and 0.064 dS/m and 0.582 dS/m in Atakum (Table 8). While the mean EC values of nitrogen solution applications in Çarşamba was not generally significantly different from the EC value in control treatment, that in Atakum was significantly lower than the EC value in control treatment (Table 8). The EC values in both locations significantly changed with the sampling date. These results indicated that EC values did not change among the nitrogen solution applications. At both locations, EC values of soils were lower than 2 dS/m, and there was no salinity problem in soils due to nitrogen solution applications.

Physical control methods, such as fire and steam were tested for hazelnut sucker management in Italy. However, these methods need special machines and flat orchards (Tomasone et al. 2009, 2010). Also, non-suckering plants, non-suckering rootstocks or disbudding of the hazelnut tree during its propagation by layering can be used for this aim (Smith and Erdogan 2001; Cerovic et al. 2007; Salvador et al. 2009). However, most of the hazelnut orchards in Turkey are located in sloping areas. Effect of ground mulching on suckers were tested by Dolci et al. (2001). Mulching was found effective on single trunk vase system, but it is not suitable for multi-stemmed bush system.

Sucker management methods in hazelnut should be selected according to the training system. Among these methods, chemical herbicides application may be a suitable method for multi-stemmed bush system. Beyhan et al. (1996) tested the effect of 500, 1000 and 1500 ppm paraquat concentrations on hazelnut suckers. The best wilting ratio was obtained from 1500 ppm paraquat application with 93%. Effect of nitrogen solution applications on hazelnut suckers were found similar with chemical herbicides. Applications of chemical herbicides are very useful on herbaceous suckers but they are associated with residue problems and a large environmental impact (Dolci et al. 2001; Tomasone et al. 2010). On the other hand, nitrogen solution applications are more environmentally friendly than herbicides. Also, sucker management with nitrogen solution application affects positively the productivity parameters of hazelnut (Serdar et al. 2017).

Conclusion

As a result of this study, a 10% dose of 21% ammonium sulphate fertilizer was advised for hazelnut sucker management. There were no harmful effects of nitrogen solutions on yield, nut quality, shoot development and soil characteristics in hazelnut. Nitrogen solution application should be started 1 to 1.5 months after removing suckers by knife when suckers reached 15–20 cm length and before lignification. For effective sucker management, nitrogen solution applications should be applied at least three times each year. Also, long term effect of this method on soil should be determined.

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Conflict of interest Ü. Serdar, C. Gülser, B. Akyüz, A. Balta, Y. Çil and F. Yilmaz Figen declare that they have no competing interests.

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