



Distribution of Rhizomania Disease in Sugar Beet Growing Areas of Turkey

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Abstract: Rhizomania is one of the most destructive diseases affecting sugar beet. It leads to a severe loss in terms of root yield and sugar content up to 90 % and up to 70 % respectively, depending on the disease severity. It was reported in some regions of Marmara, Central Black Sea, and Central Anatolia and tends to spread in other regions in Turkey. The disease is caused by Beet Necrotic Yellow Vein Benyvirus (BNYVV) and transmitted by a fungus, *Polymyxa betae*. The primary source of its spread is through the movement of infested soils or beets. Only cultural control methods are employed to control this disease. At present, the most effective control measure is to use of partially resistant sugar beet cultivars. The other additional measures like planting early into cool soils, minimizing watering, avoiding soil compaction, and employing crop rotations can reduce levels of the virus in the soil. Therefore, it is essential to determine the infested areas and take cultural measures before the disease causes economically important yield losses. Based on a three-year crop rotation, surveys were conducted and sugar beet root samples were collected from the growing areas in 102 regions of 17 sugar factory boundaries and in three periods including 1996-1998, 1999-2001 and 2002-2004. These root samples were tested by means of DAS-ELISA and distribution of BNYVV was determined. Rhizomania was detected in the sugar beet production areas of 4, 9 and 15 sugar factories in 1996-1998 1999-2001, and 2002-2004 at the rates of 19.30% (46200 ha), 31.42% (94140 ha), and 48.66% (203640 ha), respectively.

Key Words: BNYVV, rhizomania, beet necrotic yellow vein benyvirus, sugar beet

Türkiye’de Şeker Pancarı Ekim Alanlarında Rhizomania Hastalığının Yayılma Durumu

Öz: Rhizomania, şeker pancarının en zararlı hastalıklarından biridir. Hastalık, enfeksiyon şiddetine bağlı olarak, şeker pancarında % 90'a varan kök verimi ve % 70'e varan şeker verimi kayıplarına yol açmaktadır. Türkiye’de Marmara, Orta Karadeniz ve İç Anadolu’nun bazı bölgelerinde hastalığın varlığı rapor edilmiş ve hastalık, dünyada olduğu gibi diğer bölgelere giderek yayılmaktadır. Bu hastalığa pancar nekrotik sarı damar virüsü (BNYVV) yol açmakta ve *Polymyxa betae* fungusu vektörlük etmektedir. Yayılma esas olarak, bulaşık toprak veya şeker pancarının taşınmasıyla olmaktadır. Hastalığın mücadelesi, bulaşık ekim alanlarında yalnızca kültürel tedbirler alınarak yapılmaktadır. Günümüzde, en etkili kontrol tedbiri, kısmen dayanıklı şeker pancarı çeşitlerini kullanmaktır. Soğuk topraklara erken ekim, aşırı sulamanın azaltılması, toprak sıkışmasından kaçınılması ve münavebe uygulaması gibi yardımcı tedbirler topraktaki virus seviyesini düşürebilmektedir. Bu nedenle, bulaşık alanların büyük ekonomik kayıplara yol açmadan tespit edilmesi ve kültürel tedbirlerin alınması büyük önem taşımaktadır. Üç yıllık münavebe uygulamasına göre, 1996-1998, 1999-2001 ve 2002-2004 yıllarında olmak üzere, üçer yıllık üç dönem halinde 17 şeker fabrikasının 102 bölgesinin şeker pancarı ekim alanlarında surveyler yapılarak, şeker pancarı kök örnekleri toplanmıştır. Bu örnekler DAS-ELISA ile test edilmiş ve BNYVV’nin yaygınlığı belirlenmiştir. Buna göre, 1996-1998 döneminde 4 fabrikada toplam % 19.30 (46200 ha), 1999-2001 döneminde 9 fabrikada % 31.42 (94140 ha) ve 2002-2004 döneminde 15 fabrikada % 48.66 (203640 ha) Rhizomania yaygınlığı tespit edilmiştir.

Anahtar Kelimeler: BNYVV, rhizomania, pancar nekrotik sarı damar virüsü, şeker pancarı

Introduction

Sugar beet (*Beta vulgaris* var. *altissima* Döll), a member of Chenopodiaceae family, is a plant that contains very high concentration of sucrose, and is grown commercially for sugar production. In Turkey, sugar beet was grown in 422500 ha and 335800 ha in 1996 and 2005, respectively (Anonymous 2006).

Rhizomania is a very damaging disease leading to a major reduction in root yield and quality of sugar beet. The disease was first recorded from Po Valley in Italy in the mid-1950s (Canova 1959). At present, it is widely distributed in a large sugar beet growing area in Asia, Europe, and America continents. It still continues

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to spread to the other areas (Putz et al. 1990, Suarez et al. 1999).

Rhizomania disease is caused by *Beet necrotic yellow vein benyvirus* (BNYVV) (Tamada et al. 1975). The virus is transmitted by zoospores of the soil-borne plasmodiophorid *Polymyxa betae* (Keskin 1964). BNYVV is a positive-strand RNA virus with rigid rod-shaped having different clear predominate lengths with a length of 390 nm; 265 nm; 100 nm; 70 nm; width of about 20 nm. It was found that RNA-1, 2, 3 and 4 are always present in naturally infected sugar beet roots. In addition, some BNYVV isolates from Japan (Tamada et al. 1989), Europe (Koenig et al. 1997) Kazakhstan (Koenig and Lennfors 2000) and Turkey (Ilhan 2004), contain 5 RNA types.

RNA-1 and RNA-2 are required for replication, transmission and cell-to-cell movement; RNA-2 is also involved in cell-to-cell movement and vector transmission (Bouzoubaa et al. 1986, 1987). RNA-3 is responsible for the yellow local and severe lesion of leaf symptoms and systemic movement of the virus in sugar beet (Tamada et al. 1989). RNA-4 is needed for vector transmission of the virus (Richards and Tamada 1992). RNA-5 can influence symptom severity in a synergistic fashion with RNA-3 (Tamada et al. 1996). Virus isolates have been classified into three strain groups (A, B or P). The A and B types are found in most European countries. The third type P, which seems to be more aggressive than the others, has been found only in France, Kazakhstan and the UK (Koenig and Lennfors 2000, Harju et al. 2002).

P. betae, widely distributed in almost all sugar beet growing areas worldwide, was first identified by Keskin (1964). This fungus, a member of Plasmodiophoromycetes, survives as an obligate parasite on Chenopodiaceae family. The fungus has an important role on transmission, and distribution of rhizomania (Blunt et al. 1991). The disease is spread by means of water, wind, waste plant material, cultivation machines, transplanted vegetable seedlings (Asher 1994), and movement of contaminated soil and manure directly (Heijbroek 1987). It is also spread by waste substances and waste water from sugar factories (Cariolle 1987). The cysts of *Polymyxa betae* remain in the form of cystosory (resting spore) under field conditions (Ertunç 1998). The virus within the resting spores can persist in soil for at least 15 years and it is found that the fungus transmits the virus a very long time after uptaking it (Abe and Tamada 1986, Duffus 1991, Rush and Heidel 1995).

The typical root symptoms following early infection include a mass of fine, hairy secondary roots, mostly dead, that give the taproot a beard-like

appearance. Therefore, the name of rhizomania was given. With slightly later infection, the storage root often is rotted and constricted, becoming much broader near the crown, thus resembling the shape of a wine glass. Longitudinal sections of infected roots reveal vascular tissue that is visibly darkened. Infected roots occasionally are rotten. Very late infections may result in no obvious symptoms. Leaves may become flabby and wilt without discoloration. A general yellowing of foliage commonly occurs. Because infected roots are inefficient in water and nutrient uptake, general foliar symptoms are similar to water stress or nitrogen deficiency. Rarely, vein yellowing with associated dead (necrotic) areas of leaf tissue can be seen. This rare symptom occurs when infection becomes systemic. Because of this type of leaf symptoms, the name of *Beet necrotic yellow vein benyvirus* was given. Diseased plants usually occur in patches or areas of the field and not as scattered individual plants dispersed throughout the field. Because the fungus vector thrives on moist areas, disease severity usually is greatest in depressions or compacted, poorly drained portions of the field that tend to collect water and remain wet. Reduced water uptake by infected roots increases the tendency for soil around diseased plants to remain waterlogged.

Depending on the disease severity, rhizomania cause a decrease in root yield of 30-90 % (Asher 1993, Asher and Kerr 1996) and it reduces sugar yield up to 70 % (Putz et al. 1990, Whitney and Duffus 1991, Rush and Heidel 1995). It also impairs purity by increasing in the content of the substances forming molasses (Kajiyama et al. 1990).

In Turkey, rhizomania was first detected in the beet samples sent from Alpullu (Keşan, Uzunköprü) and Amasya (Erbaa, Taşova) to Germany in 1987 (Koch 1987). Later the presence of the disease was reported in different beet growing areas of Turkey (Vardar and Erkan 1992).

It was reported that the disease spread in some sugar beet growing areas of, especially Marmara, West and Central Black Sea and Central Anatolian Regions (Erdiller and Özgür 1994, Kıymaz and Ertunç 1996, Ertunç et al. 1998, Kaya and Erdiller 1998). The disease usually occurs in poorly drained soils with high clay content (Kaya and Erdiller 2001). Consequently, it infects sugar beet roots in close proximity and continues to spread.

Evidence of BNYVV in sugar beet plants is detected by Enzyme-Linked Immunosorbent Assay (DAS-ELISA, TAS-ELISA), Western Blot, Dot-Blot and Reverse Transcriptase Polymerase Chain Reaction (RT-PCR). Although Dot-Blot and RT-PCR is very

specific and sensitive test when compared to DAS-ELISA, they are not convenient for routine tests with lots of samples. DAS-ELISA is suitable for analyzing more samples in epidemiological studies (Wisler et al., 1994, Rush and Heidel 1995).

Chemical control methods against the vector are either too expensive (methyl bromide soil disinfection) or ineffective. The only useful control measure is the growing of tolerant varieties (Richard-Molard 1996). The search for tolerant or resistant cultivars has been actively carried out since 1978. Progress is made each year and the best new cultivars limit losses on heavily infested soils. The other additional control measures such as extended rotation, good drainage, improving soil aeration and early sowing are recommended. They have a limited effect, except sowing tolerant cultivars (Tosic et al. 1985).

Sugar beet yield in the infested areas will decrease more and more as the disease spreading rapidly. Consequently, the profit of farmers from sugar beet will decline. As a result of sugar beet being sown on the same field for years despite a three year rotation, farmers' production costs per hectare will be higher than their income. Finally farmers will give up growing sugar beet. Due to the limitation in sugar beet quota and decrease in quality, factories will not process sugar beet economically and sugar production will be less than expected. In order not to impede the quota of beet and sugar production in Turkey it is necessary to determine the infested areas and take measures to minimize yield loss.

The objectives of the present study was to detect rhizomania disease in the sugar beet growing areas of sugar factories in order to estimate the infection risk and manage the disease by using resistant varieties and the other cultural practices.

Materials and Methods

The study was carried out in the 102 sugar beet growing regions of 17 sugar beet factories in Turkey; Ağrı, Ankara, Eskişehir, Iğın, Turhal, Ereğli, Kırşehir, Malatya, Susurluk, Uşak, Çarşamba, Afyon, Bor, Burdur, Çorum, Elazığ, Elbistan, Kütahya and Yozgat in 1996-2004 (Table 1).

In accordance with a three-year crop rotation, the growing areas of all sugar factories were surveyed in three periods. The survey periods in different sugar beet growing areas are given in Table 1. Surveys were

first conducted in the sugar beet growing areas adjacent to the areas infested by BNYVV and show similar climatic conditions with the diseased regions. Investigations were conducted in next three-year period in the areas in which BNYVV was not detected before.

Sugar beet root samples were collected in fields without considering whether they were infested or not by rhizomania disease during July and August every year. After sugar beet growing areas of sugar factories were investigated, a field of one hectare to represent every 500 ha area in the regions of the sugar factories was determined. Five beet root samples were taken from the selected 1 hectare area by walking in the field shaped as "W" and they were placed in paper bags and transported to the laboratory (Barnet 1986). Since sugar beet growing areas change every year based on a three-year rotation, the numbers and places of representative root samples were determined and same samplings were done again.

After cutting the beet roots in diameter of 0.5-1 cm from each sample, they were put in a sterile polyethylene bag. These samples were frozen in deepfreeze at a temperature of -27 °C and pressed. Sap of 0.2 ml from each root sample was added to a sample buffer of 1.3 ml and diluted homogenous extracts were obtained at the ratio of 1/7.5 (Bürcky 1994).

BNYVV in the root extracts were detected by using Das-ELISA method of Clark and Adams (1977), which was modified by Büttner and Bürcky (1987). Based on the Das-ELISA results, rate of sugar beet growing areas infested by rhizomania were determined (Table 2). The sugar beet growing areas matches for BNYVV-infected samples were calculated and total infested areas and their ratio, based on factories, were determined (Table 3).

During the surveys it was observed that sugar beet varieties such as Anadolmono, KWSTR-239, Loretta, Tiara, Evita, Arosa, Aura, Ansa, Fiona, Sonja, Hülya and Cassandra, which are not resistant to rhizomania, were still sown in sugar beet growing areas.

DAS-ELISA reagents for the detection of BNYVV, anti BNYVV IgG, Anti BNYVV IgG conjugated w/AP and positive/negative controls, were obtained from BIOREBA AG (Chr. Merian Ring 7 CH-4153 Reinach BL 1, Switzerland).

Table 1. Factories and their areas surveyed according to years.

Factories	Areas	Years
1. Ağrı	İğdir	1996-1998
2. Ankara	Ankara, Bala, Beypazarı, Çubuk, Haymana, Kırıkkale, Polatlı, Temelli	1996-2004
3. Eskişehir	Alpu, Beylikova, Çifteler, Eskişehir, İnönü, Seyitgazi, Sivrihisar, Yunusemre	
4. Iğın	Akşehir, Çeltik, Iğın, Kadınhanı, Yunak	
5. Ereğli	Ereğli, Karaman, Karapınar	1999-2004
6. Kırşehir	Gülşehir, Kaman, Kırşehir, Kozaklı, Mucur, Ş.Koçhisar	
7. Malatya	Akçadağ, Doğanşehir, Gölbaşı, Kahramanmaraş, Kangal, Malatya,	
8. Susurluk	Balıkesir, Biga, Burhaniye, Bursa, Karacabey, Manyas, M.Kemalpaşa, Soma, Susurluk, Yenişehir	
9. Uşak	Uşak, Banaz, Çivril, Dumlupınar, Gediz, Simav	1999-2001
10. Çarşamba	Bafra, Çarşamba, Kavak, Ladik	
11. Afyon	Afyon, Çay, Emirdağ, Fabrika Merkez, Sandıklı, Sinanpaşa, Şuhut	2002-2004
12. Bor	Aksaray, Bor, Eskil, Niğde, Sultanhanı, Yeşilova	
13. Burdur	Burdur, Dazkırı, Dinar, Elmalı, Gölhisar, Senirkent, Tefenni, Yeşilova	
14. Elazığ	Yurtbaşı, Kovancılar	
15. Elbistan	Afşin, Elbistan, Göksun, Tufanbeyli	
16. Kütahya	Altıntaş, Aslanapa, Emet, Kütahya,	
17. Yozgat	Akdağmadeni, Çekerek, Fakılı, Kadışehri, Sarıkaya, Sorgun, Şefaati	

Table 2. The rates of BNYVV infections according to the Das-ELISA results of sugar beet root samples collected from sugar beet growing regions of factories in different three-year periods, 1996-1998, 1999-2001 and 2002-2004.

Factories and number of regions surveyed			Number and ratio (%) of positive sugar beet root samples to tested samples						
			1996-1998		1999-2001		2002-2004		
1.	Ağrı-İğdir	1	37/40	92,58					
2.	Ankara	8	33/92	35,87	9/42	21,43	5/25	20,00	
3.	Eskişehir	8	16/175	9,14	43/125	34,40	29/70	41,42	
4.	Iğın	5	2/149	1,34	33/125	26,40	22/69	31,88	
5.	Ereğli	3			0/76	0	12/71	16,90	
6.	Kırşehir	6			20/81	24,69	29/42	69,05	
7.	Malatya	6			21/32	65,63	5/18	27,78	
8.	Susurluk	10			21/30	70,00	4/7	57,14	
9.	Uşak	6			5/31	16,13	11/24	45,83	
10.	Çarşamba	4			29/34	85,29			
11.	Afyon	7					31/68	45,59	
12.	Bor	6					79/109	72,48	
13.	Burdur	8					27/79	34,18	
14.	Elazığ	2					23/28	82,14	
15.	Elbistan	4					25/45	55,55	
16.	Kütahya	4					11/35	31,43	
17.	Yozgat	7					49/54	90,74	
Total			102	88/456	19,30	181/576	31,42	362/744	48,66

Table 3. Investigated, infested and percent infested areas of sugar beet growing areas of 17 factories in three-year periods, 1996-1998, 1999-2001 and 2002-2004.

Factories	1996-1998			1999-2001			2002-2004		
	Investigated area (1000 ha)	Infested area (1000 ha)	Percent infested area	Investigated area (1000 ha)	Infested area (1000 ha)	Percent infested area	Investigated area (1000 ha)	Infested area (1000 ha)	Percent infested area
1. Ağrı-İğdır	21,0	20,1	95,71						
2. Ankara	47,3	18,0	38,05	24,0	4,80	20,00	14,4	2,07	13,15
3. Eskişehir	90,0	7,5	8,33	66,8	22,50	33,68	36,3	17,55	48,35
4. Iğın	76,1	0,6	0,79	64,9	18,00	27,73	36,6	12,99	35,49
5. Ereğli				39,0	-	0,00	38,7	7,50	19,38
6. Kırşehir				43,1	12,00	27,84	23,3	16,50	70,82
7. Malatya				15,3	6,00	39,22	8,7	2,10	24,14
8. Susurluk				16,8	12,00	71,43	4,1	1,89	46,10
9. Uşak				17,1	2,04	11,93	12,5	6,30	50,40
10. Çarşamba				18,2	16,80	92,31			
11. Afyon							35,3	17,40	49,29
12. Bor							56,6	45,60	80,57
13. Burdur							40,4	14,34	35,49
14. Elazığ							14,4	13,80	95,80
15. Elbistan							24,2	14,10	58,26
16. Kütahya							18,0	4,50	25,00
17. Yozgat							29,4	27,00	93,42
Total	234,4	46,2	19,71	305,2	94,14	30,85	392,9	203,64	51,83
Infested areas matched for one year in a three-year rotation		46,2/3=15,4			94,14/3=31,38			203,64/3=67,88	

Results

DAS-ELISA results of sugar beet root samples collected from the growing areas of Ağrı, Ankara, Eskişehir and Iğın factories in the first three-year period of 1996-1998 showed that total ratio of BNYVV positive sugar beet samples was 19.3 %. The rate of infested areas in the sugar beet growing regions of Ankara, Eskişehir, Iğın, Ereğli, Kırşehir, Malatya, Susurluk, Uşak and Çarşamba factories was 31.42 % in the second three-year period (1999-2001). Rhizomania infested areas of Ankara, Eskişehir, Iğın, Ereğli, Kırşehir, Malatya, Susurluk, Uşak, Afyon, Bor, Burdur, Elazığ, Elbistan, Kütahya and Yozgat factories were found as 48.66 % in the third three-year period (2002-2004) (Table 2).

The highest rate of infested areas by rhizomania was found as 92.58% in the region İğdır of Ağrı Sugar Factory in 1996-1998 and 85.29 % in Çarşamba Sugar Factory in 1999-2001. The highest rate of infested areas was determined in Yozgat sugar factory at the rate of 90.74 % and it was followed by Elazığ

(82.14%), Bor (72.48 %), Elbistan (55.55 %), Afyon (45.59 %), Burdur (34.18 %) and Kütahya (31.43 %) sugar beet growing areas when surveys were first conducted in the period of 2002-2004 (Table 2).

Rhizomania was detected in the sugar beet regions of Kırşehir, Malatya, Susurluk and Uşak at the rates of 24.69, 65.63, 70 and 16.13 %, respectively, in the period of 1999-2001. BNYVV was not detected in some regions of these factories. Because of this, uninfested regions of these factories were investigated again in the period of 2002-2004 and BNYVV was determined at the rates of 69.05, 27.78, 57.14 and 45.83 %, respectively. Test results of root samples, taken from the regions of Ereğli Sugar Factory in the period of 1999-2001, were negative for BNYVV. When the surveys were repeated in the same area in 2002-2004, it was found that the rate was 16.90 % (Table 2).

The rate of rhizomania infested areas in the sugar beet growing regions of Ankara, Eskişehir and Iğın factories were 35.87, 9.14 and 1.34 %, respectively, in the period of 1996-1998. The

investigations were continued in the uninfested sugar beet growing regions of these factories in the next period, 1999-2001. BNYVV was detected at the rates of 21.43 % in Ankara, 34.40 % in Eskişehir and 26.40 % in Iğın. BNYVV was not found in some regions of these factories again. After surveys were conducted in these uninfested regions of Ankara, Eskişehir and Iğın factories in the next period (2002-2004), the tests of root samples were positive at the rates of 20 % in Ankara, 41.42 % in Eskişehir and 31.88 % in Iğın (Table 2).

The samples infected by BNYVV were matched for the growing areas in which a three-year crop rotation applied. Then, infested areas were calculated. In conclusion, rhizomania-infested areas in the regions of 4 factories (Ağrı, Ankara, Eskişehir and Iğın) were determined as 46200 ha in the period of 1996-1998, the diseased areas in the regions of 9 factories (Ankara, Eskişehir, Iğın, Ereğli, Kırşehir, Malatya, Susurluk, Uşak and Çarşamba) were 94140 ha in the period of 1999-2001 and rhizomania-infested areas in the regions of 15 factories (Ankara, Eskişehir, Iğın, Ereğli, Kırşehir, Malatya, Susurluk, Uşak, Afyon, Bor, Burdur, Elazığ, Elbistan, Kütahya and Yozgat) were 203640 ha in the period of 2002-2004 (Table 3).

Discussion

Rhizomania disease was first identified by Koch (1987) and Vardar and Erkan (1992) in Turkey. The first studies of rhizomania outbreak in Turkey were done in some regions of Alpullu, Adapazarı and Amasya factories (Erdiller and Özgür 1994, Kaya and Erdiller 1998). Later the disease was detected in the regions of Çorum, Kastamonu and Turhal sugar factories (Ertunç et al. 1998, Kutluk and Yanar 2001). Although the disease was determined in several regions of Amasya Sugar Factory (Erdiller and Özgür 1994), later all the regions of the same factory were found as infested by BNYVV (Özer and Ertunç 2005). This study comprised the sugar beet growing regions of 17 sugar factories and indicated that rhizomania disease was spread quickly to large areas (Figure 1).

The evaluations made in places where successive three year periods of rotation are applied (1996-1998, 1999-2001 and 2002-2004) indicated that the disease was only present in some regions of Ankara, Eskişehir and Iğın sugar factory boundaries in 1996-1998. Later on, rhizomania was detected in some of the previously uninfested areas in the same factory areas in 1999-2001 and in 2002-2004. Similarly, the disease was determined in some regions of Kırşehir, Malatya, Susurluk and Uşak in 1999-2001 and in the other regions of these factories in 2002-2004. The disease was also found in the adjacent locations of the

infested areas of Ankara, Eskişehir, Iğın, Afyon sugar factories. This shows that the disease spreads quickly to adjacent fields where *Polymyxa betae* is present, which was shown by Ertunç et al. (1998). On the other hand, infested areas in Malatya and Susurluk in the period of 1999-2001 were higher than in the period of 2002-2004, although infested areas in the other factories increased higher in the same periods. The rate of rhizomania-infested areas in Ağrı-Iğdır, Susurluk, Çarşamba, Kırşehir, Bor, Burdur, Yozgat factories were higher than in the other factories. The reason for the high rates of infested areas is that the areas of these factories have many more fields with moist soils at the side of rivers, streams, creeks and puddles than those of the other factories during vegetation period. Soil moisture promotes *Polymyxa betae* growth and thus transmission of BNYVV. Heavy field soils are generally wet for a long time. Because of this, the disease is encouraged and spread. Lack of such areas in Malatya and Susurluk factories might be the reason for low rate of infestation in both areas. Some regions of Ankara, Burdur, Iğın, Ereğli, Malatya, Uşak and Kütahya factories will probably be infested later since they are far from infested areas and soil conditions are less appropriate for *Polymyxa betae* life cycle. In this study, it was observed that the disease will quickly spread to the uninfested areas of all factories, where the ground water is near the surface and which remain wet for a long time.

Erdiller and Özgür (1994), Kaya and Erdiller (1998), Kutluk and Yanar (2001, 2002), Özer and Ertunç (2005) determined the disease in the regions of Adapazarı, Alpullu, Kastamonu, Amasya, Çorum and Turhal. In this study, numbers of sugar factories, which have infested areas by rhizomania, reached to 23. Serious measures must be taken since the disease was spread to sugar beet growing areas of 23 sugar factories out of 32.

Campbell (1996) reported that surface flow, resulted from heavy rainfall and flood irrigation, ease and speed up the spread of the vector fungus from one field to the others. Erdiller and Özgür (1994), Kaya and Erdiller (1998), and Özer and Ertunç (2005) determined the disease generally in the fields where ground water was near the surface. In the same way, the disease was detected in the fields, where excess water is not removed from heavy soils for a long time, in the near stream, river, creek and puddle in this study.

Diseased areas in the periods of 1996-1998, 1999-2001 and 2002-2004 were 15400, 31380 and 67880 ha, respectively. According to these figures, resistant sugar beet varieties to rhizomania must be sown in total areas of 114660 ha every year (Table 3).

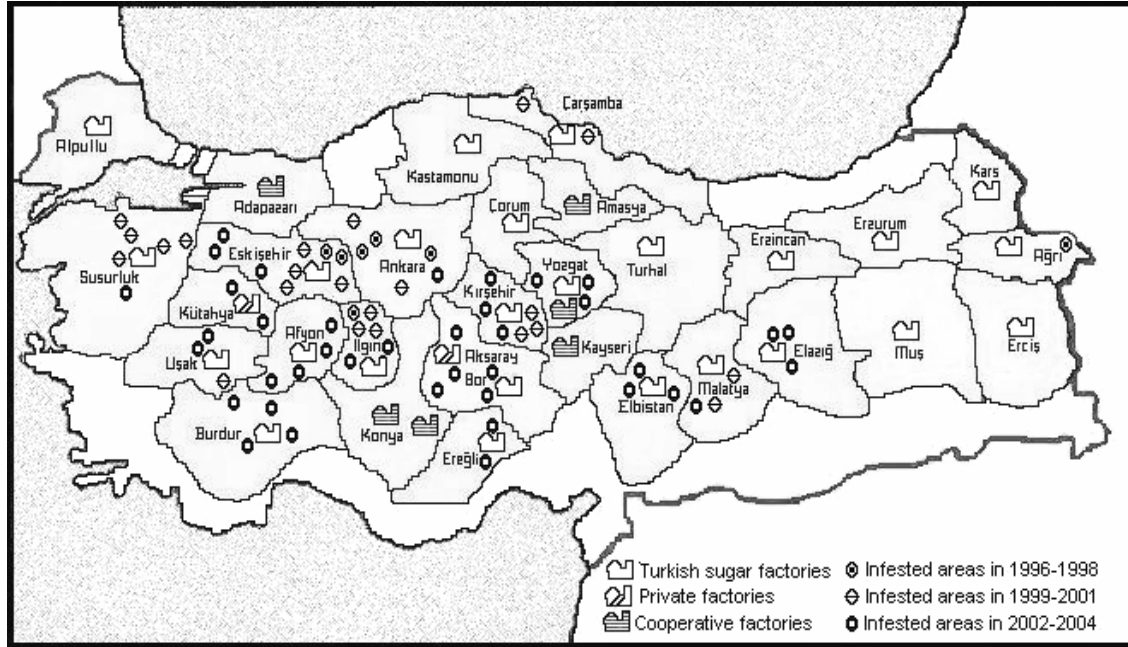


Figure 1. Infested areas of 17 factories in three-year periods, 1996-1998, 1999-2001 and 2002-2004.

Resistant sugar beet varieties such as Esperanza, Isella, Valentina, Coyote, Leila, Evelina, Lolita, Felicita and Visa, which have been tested in field trials for yield and quality and registered officially by The Seed Registration and Certification Center in Turkey, have been recommended (Anonymous 1996, 2006).

The measures to suppress the vector *Polymyxa betae*, which is not controlled by chemicals, must also be taken. First of them is to apply a four-year crop rotation instead of a three-year in seen practice. Hofmeester and Tuitert (1989) and Tuitert and Hofmeester (1992) explained that there was an effect of irrigation for sugar beet on soil moisture content. Since waterlogged soils form a good condition for the vector fungus, sugar beet must be irrigated in adequate water on time. As Asher and Thomson (1987), Asher and Blunt (1987) and Kaya and Erdiller (2001) stated, soils which is exposed to excess water promote the disease infection. Because formation of plough pan or soil compaction constitutes a non permanent soil layer in depth of tillage, water remains in this layer for a long time. As a result, the growth of the fungus is encouraged. By breaking the plough pan by a subsoiler at least once for 3-4 years, excessive water will drain from the soil in a short time. This will limit the growth of the vector *Polymyxa betae* in the sugar beet growing season.

Conclusion

Rhizomania disease was spread quickly to large areas. The number of sugar factories having rhizomania infestation reached to 23 in Turkey. The disease was generally determined in the fields where the level of ground water was very shallow and not well drained near the valleys of streams and rivers.

Resistant sugar beet varieties to rhizomania disease must be sown in total sugar beet growing areas of 114660 ha every year. To prevent the spread of the disease, it is recommended that vegetable seedlings grown in infested fields, waste plant materials and manure should not be allowed to move from infested fields into uninfested ones. To increase the suppression of the vector *Polymyxa betae*, it is also recommended that sugar beet plants should not be irrigated excessively in vegetation period.

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References

- Abe, H and T. Tamada. 1986. Association of beet necrotic yellow vein virus with isolates of *Polymyxa betae* Keskin. Annals of the Phytopathological Society of Japan 52: 235-247.
- Anonymous. 2006. TÜİK Tarım istatistikleri özeti. <http://www.tuik.gov.tr/VeriBilgi> (15 Temmuz 2008).
- Anonymous. 1996. Türkiye Şeker Fabrikaları A.Ş. Cercospora ve Rhizomania'ya dayanıklı şeker pancarı çeşitleri verim kontrol ve tescil deneme sonuçları. Ankara.
- Anonymous. 2006. Türkiye Şeker Fabrikaları A.Ş. Cercospora ve Rhizomania'ya dayanıklı şeker pancarı çeşitleri verim kontrol ve tescil deneme sonuçları. Ankara.
- Asher, M.J.C. and S.J. Blunt. 1987. The ecological requirements of *Polymyxa betae*. Proceedings of 50th International Institute Sugar Beet Research Winter Congress. 45-55. 11-12 February 1987, Brussels.
- Asher, M. and K. Thompson. 1987. Rhizomania in Europe. An article based on the July meeting of the SBREC. British Sugar Beet Review 55 (3): 24-28.
- Asher, M.C.J. 1993. Rhizomania. p:312-346. Editors: D.A. Cooke and R.K. Scott. The Sugar Beet Crop. Chapman and Hall, London, U.K.
- Asher, M.C.J. 1994. Rhizomania: Recent development. British Sugar Beet Review 62 (4): 10-12.
- Asher, M.C.J. and S. Kerr. 1996. Rhizomania: Progress with resistant varieties. British Sugar Beet Review 64 (2): 19-22.
- Barnet, O. W. 1986. Surveying for plant viruses: Design and consideration in plant virus epidemics: Monitoring, modeling and predicting outbreaks. p: 147-166. Editors: G.R. Meleon, G. Garrett and G. Ruesink. Sydney, Orlando.
- Blunt, S. J., M. J. C. Asher and C A. Gilligan. 1991. Infection of sugar beet by *P.betae* in relation to soil temperature. Plant Pathology 40: 257-267.
- Bouzoubaa, S., V. Ziegler, D. Beck, , H. Guilley, K. Richards and G. Jonard. 1986. Nucleotide sequence of beet necrotic yellow vein virus RNA-2. Journal of General Virology 67: 1689-1700.
- Bouzoubaa, S., L. Quillet, H. Guilley, G. Jonard and K. Richards. 1987. Nucleotide sequence of beet necrotic yellow vein virus RNA-1. Journal of General Virology 68: 615-626.
- Bürcky, K. 1994. Rhizomania-diagnose 1994, Deutsche Zuckerrübenzeitung 4.
- Büttner, G. and K. Bürcky. 1987. Verbesserung der nachweisempfindlichkeit von ELISA beim test auf BNYVV. Proceedings of 50th International Institute Sugar Beet Research Winter Congress. 289-294. 11-12 February 1987, Bruxelles.
- Campbell, R.N. 1996. Fungal transmission of plant viruses. Annual Review of Phytopathology 34: 87-108.
- Canova, A. 1959. Appunti di patologia della barbabietola. Informatore Fitopatologico 9: 390-396.
- Cariolle, M. 1987. Rhizomanie - mesures de prophylaxie en france et dans d'autres pays. Proceedings of 50th International Institute Sugar Beet Research Winter Congress. 63-79. 11-12 February 1987, Bruxelles.
- Clark, M.F. and A.N. Adams. 1977. Characteristic of the microplate method of enzyme - linked immunosorbent assay for the detection of plant viruses. Journal of General Virology 33: 475-483.
- Duffus, I.E. 1991. Rhizomania. p: 29-30. Editors: E.D. Whitney and C.E. Duffus. Compendium of Beet Diseases and Insects. APS Press, USA.
- Erdiller, G. and O. Özgür. 1994. Distribution of rhizomania in sugar beet growing areas of Turkey. Journal of Turkish Phytopathology 23 (1): 53-55.
- Ertunç, F. 1998. *Polymyxa betae* (Keskin)'nin şeker pancarı kılcal köklerindeki biyolojik dönemleri üzerinde araştırmalar. Ankara Üniv. Ziraat Fak. Yayınları: 1495, Ankara, 17 s.
- Ertunç, F., K. Erzurum, A. Karakaya, D. İlhan and S. Maden. 1998. Incidence of rhizomania disease on sugar beet in Çorum, Kastamonu and Turhal sugar refinery regions. Journal of Turkish Phytopathology 27 (1): 39-46.
- Harju, V.A., R. A. Mumford, A. Blockley, N. Boonham, G. R. G. Clover, R. Weekes and C. M. Henry. 2002. Occurrence in the United Kingdom of *beet necrotic yellow vein virus* isolates which contain RNA 5. Plant Pathology 51 (6): 811.
- Heijbroek, W. 1987. Dissemination of rhizomania by water, soil and manure. Proceedings of 50th International Institute Sugar Beet Research Winter Congress. 35-43. 11-12 February 1987, Bruxelles.
- Hofmeester, Y. and G. Tuitert. 1989. Development of rhizomania in an artificially infested field. Med. Fac. Landbouww. Rijksuniv. Gent 54/2b.
- İlhan, D. 2004. Şeker pancarı nekrotik sarı damar virüsü (*beet necrotic yellow vein benyvirus-BNYVV*)'nün moleküler olarak tanılanması (Doktora Tezi, 75s). Ankara Üniversitesi Fen Bilimleri Enstitüsü Bitki Koruma Anabilim Dalı.
- Kaya, R. and G. Erdiller. 1998. Alpullu Şeker Fabrikası'nın ekim alanlarında rhizomania hastalığının yayılma durumu. Türkiye Fitopatoloji Kongresi. Bildirileri. 79-83. 21-25 Eylül 1998, Ankara.
- Kaya, R. and G. Erdiller. 2001. Alpullu Şeker Fabrikası'nın ekim alanlarında rhizomania hastalığının toprak özellikleri ile ilişkisi. Türkiye Fitopatoloji Kongresi Bildirileri. 168-180. 3-8 Eylül 2001, Tekirdağ.

- Kajiyama, T., A. Yoshizawa, T. Yoshida, A. Yanagisawa, Y. Yoshimura, K. Ohtsuchi, H. Abe and T. Niura. 1990. Response of sugar beet varieties to rhizomania disease of sugar beet. I. The yield and quality of sugar beet. Proceedings of Japanese Society of Sugar Beet Technologists 32: 53-58
- Keskin, B. 1964. *Polymyxa betae* n.sp., ein parasit in den wurzeln von *Beta vulgaris* Tournefort, besonders weahrend der jungendentwicklung der zuckerrübe. Archiv für Microbiologie 49: 348-378.
- Kıymaz, B. and F. Ertunç. 1996. Research on the detection of virus diseases in sugar beet in Ankara. Journal of Turkish Phytopathology 25 (1-2): 55-63.
- Koch, F. 1987. Bericht über eine reise in verschiedene zuckerrübenanbaugebiete der Türkşeker in Anatolien und Thrazien zum studium von wurzelerkrankungen, KWS Kleinwanzlebener Saatzucht AG, Einbeck / Germany.
- Koenig, R., A.M. Haerberle and U. Commendeur. 1997. Detection and characterization of a distinct type of beet necrotic yellow vein benyvirus RNA-5 in a sugar beet growing area in Europe. Archives of Virology 142 (7): 1499-1504.
- Koenig R. and B.L. Lennefors. 2000. Molecular analyses of European A, B and P type sources of beet necrotic yellow vein virus and detection of the rare P type in Kazakhstan. Archives of Virology 145: 1561-1570.
- Kutluk, N.D. and Y. Yanar. 2001. Study on the distribution of *beet necrotic yellow vein virus* (BNYVV) in sugar beet growing area of Tokat-Turkey. Journal of Turkish Phytopathology 30: 21-25.
- Kutluk, N.D. and Y. Yanar. 2002. Kastamonu ili şeker pancarı üretim alanlarında şeker pancarı nekrotik sarı damar virüsü (BNYVV) ve şeker pancarı toprak kaynaklı virüs (BSBV-2) hastalığının yaygınlığının belirlenmesi. Gaziosmanpaşa Üniv., Ziraat Fakültesi Dergisi 19 (1): 1-4.
- Özer, G. and F. Ertunç. 2005. Amasya Şeker Fabrikası şekerpancarı ekim alanlarında rhizomania hastalığının belirlenmesi. Tarım Bilimleri Dergisi 11 (3): 339-343.
- Putz, C., D. Merdinoglu, O. Lemaire, B. Stocky, P. Valentin and S. Wiedemann. 1990. Beet necrotic yellow vein benyvirus, causal agent of rhizomania. Review of Plant Pathology 69 (5): 247-254.
- Richards, K. and T. Tamada. 1992. Mapping functions on the multipartite genome of beet necrotic yellow vein benyvirus. Annual Review of Phytopathology 30: 291-313.
- Richard-Molard, M. 1996. Enquete rhizomanie 1996. Groupe de travail IIRB - Parasites et Maladies, Suede - 3-5 juillet.
- Rush, C.M. and O.B. Heidel. 1995. Furovirus diseases of sugar beet in the United States. Plant Disease 79 (9): 868-875.
- Suarez, M.B., I. Grondona, P. Garcia-Benavides, E. Monte and I. Garcia-Acha. 1999. Characterization of beet necrotic yellow vein furovirus from Spanish sugar beet. Int. Microbiology 2 (2): 87-92.
- Tamada, T. 1975. Beet necrotic yellow vein virus. CMI/AAB. Description of Plant Viruses 144.
- Tamada, T., Y. Shirako, H. Abe, M. Saito, T. Kiguchi and T. Harada. 1989. Production and pathogenicity of isolates of beet necrotic yellow vein virus with different numbers of RNA components. Journal of General Virology 70: 3399-3409.
- Tamada, T., T. Kusume, H. Uchino, T. Kiguchi and M. Saito. 1996. Evidence that beet necrotic yellow vein virus RNA 5 is involved in symptom development of sugar beet roots. Proceedings of 3rd Symposium of International Working Group Plant Viruses Fungal Vectors, 49-52.
- Tosic, M., D. Sutic and M. Milovanovic. 1985. Investigations of sugar-beet rhizomania in Yugoslavia. Proceedings of 48th International Institute Sugar Beet Research Winter Congress. 431-445. 13-14 February 1985, Bruxelles.
- Tuitert, G. and Y. Hofmeester. 1992. Epidemiology of beet necrotic yellow vein virus in sugar beet at different initial inoculum levels in the presence or absence of irrigation: Dynamics of inoculum. Netherlands Journal of Plant Pathology 98: 343-360.
- Vardar, B. and S. Erkan. 1992. The first studies on detection of beet necrotic yellow vein benyvirus in sugar beet in Turkey. Journal of Turkish Phytopathology 21 (2-3): 74-76.
- Whitney, E.D. and J.E. Duffus. 1991. Compendium of Beet Diseases and Insects. APS Press, USA.
- Wisler, G.C., H.Y. Liu and J.E. Duffus. 1994. Beet necrotic yellow vein benyvirus and its relationship eight sugar beet furo-like viruses from the United States. Plant Disease 78 (10): 995-1001.

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