Apple Burrknots Involved in Trunk Canker Initiation and Dying of Young Trees

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Abstract

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Conditions associated with an unusually high occurrence of burrknots in two young commercial apple orchards at two locations, Těšetice and Stošíkovice, South Moravia, the Czech Republic, were analysed. In the first orchard, planted in spring 2003, the occurrence of burrknot on trees of cvs. Early Smith, Jonagold and Gala on M.9 rootstock was evaluated. In the second orchard, planted in autumn 2002, cv. Gala on M.9 rootstock was assessed. Planting material used at each location was obtained from the same commercial propagator and had been established from the same propagation stock materials. Of 60 trees per cultivar surveyed in the first orchard, incidence of burrknots in cvs. Early Smith, Jonagold and Gala trees was 98, 97 and 92%, respectively. The burrknot severity (mean number of burrknots on above portion of rootstock) was significantly higher on Jonagold trees, i.e. 3.65, than on the other two cultivars. Of 60 Gala trees in the second orchard, symptoms of burrknot appeared on 73.3% of trees planted on a slight slope and 70.0% of trees planted on a plane. The burrknot severity was significantly higher on the Gala trees planted in the Těšetice orchard than in the Stošíkovice location. Burrknot incidence and incidence of root-suckers were the highest on Jonagold trees at Těšetice. However, correlations between burrknot number and number of root-suckers were not statistically significant. Five years after the tree planting, increased dying of Jonagold trees was recorded at Těšetice. Of 290 trees examined, 5.5% had died. On the rootstock portion of trunk, each dead tree exhibited burrknots associated with bark cankers that more or less girdled the trunks. Only sporadic occurrence of canker symptoms and no premature dying of young trees were observed at Stošíkovice. Attempts at isolation of the fire blight bacterium, *Erwinia amylovora,* and oomycete *Phytophthora* spp. from necrotic tissue surrounding burrknots on rootstocks were not successful. The stem associated apple tree viruses *Apple stem pitting virus* (ASPV) and *Apple stem grooving virus* (ASGV) were detected frequently in the rootstock and scion parts of cvs. Jonagold and Early Smith and less frequently in Gala cultivar. The virus positive trees included individuals both with various burrknot severity and without symptoms of burrknots. There were no correlations between the incidence of burrknots and the presence of ASPV and ASGV.

Keywords: burrknot; apple tree; M.9 rootstock; root-suckers; trunk canker; ASPV; ASGV

Burrknot is a swelling or rough knot that is composed of partially developed adventitious roots on trunks above the soil line, limbs or branches (Swingle 1925a, b, 1927; Rom & Brown 1979; Perry & Cummins 1990). Fusing of adjacent burrknots and increase in burrknot size, occurring

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faster than an increase in trunks, limbs or branch circumference, can lead to girdling. Although a few burrknots will not hurt the tree, trees with excessive numbers of burrknots can be weakened, stunted or can suffer from branch breakage.

The burrknot problem has been comprehensively reviewed by Rom (1970) and by Perry and Cummins (1990). Brown (1924) demonstrated that typical burrknots are not caused by rhizogenic strains of the crown gall bacterium, *Agrobacterium tumefaciens*, having the Ri plasmid and causing hairy roots. The non-pathological nature of growths was reconfirmed by Swingle (1925a), who checked nearly 500 apple cultivars and stressed that occurrence of burrknots is entirely a cultivar characteristic. At present, burrknot is ranked among non-infectious (genetic or physiological) disorders. Certain apple cultivars and rootstocks, such as Malling clonal rootstocks, are genetically predisposed to burrknot. In these genotypes, burrknot symptoms can be induced by low light intensity, warm temperatures (in the 20–35°C range) and high humidity (Perry & Cummins 1990). Many recent rootstocks from the Geneva series have been selected for low predisposition to burrknots (Kain & Robinson 2005).

Burrknots are thought to be sites for insect borer infestations (e.g. *Synanthedon myopaeformis* in Europe and *Synanthedon scitula* in the North America) as well as for infection by the fire blight bacterium (*Erwinia amylovora*), fungal or oomycetal pathogen (e.g. *Phytophthora* spp., etc.) (Brown 1924; van der Zwet & Beer 1995; Leskey & Berg 2005).

In past years, burrknots were sporadically observed on some clonal apple dwarfing rootstocks in the Czech Lands. However, to the best of our knowledge, no published records indicate that Czech growers had serious problems with burrknot disorder in the past. In 2005, an unusually high occurrence of burrknots was recorded in two young commercial apple orchards in South Moravia, the Czech Republic.

The objectives of this paper are to: (*i*) identify conditions associated with the unusually high occurrence of burrknot disorder in two young commercial apple orchards; (*ii*) specify burrknot incidence on apple cvs. Early Smith, Jonagold, and Gala on M.9 roostock; (*iii*) find out if there was any relationship between burrknot incidence and the development of root-suckers; (*iv*) compare formation of burrknots in apple trees of Gala cultivar on M.9 rootstock at two locations on planting material that had been established from the same propagation stock materials; and (*v*) assess the possibility of association between burrknot incidence and the occurrence of ASPV and ASGV in the rootstock and scion parts of apple trees.

MATERIALS AND METHODS

Plants and location

Apple trees of cvs. Early Smith, Jonagold, and Gala on M.9 rootstock were planted (at spacing of 1.1 m within rows and 3.6 m between rows) at orchard Těšetice in the South Moravian Region in spring 2003. In Stošíkovice orchard, adjacent to Těšetice, trees of cv. Gala on M.9 rootstock were planted (at spacing the same as that at Těšetice) in autumn 2002. Planting material used at the two locations was obtained from the same commercial propagator and had been established from the same propagation stock materials. At Stošíkovice, one block of Gala trees in the orchard was planted on a gentle north-east-facing slope and another block on the adjoining flatland.

After planting, similar management practices for intensive fruit production were applied annually in both orchards. Plastic trunk guards were used. The herbicide diquat (Reglone) was applied for root-sucker killing. Supplementary irrigation was supplied as needed using drip irrigation.

Sixty trees of each of three cultivars were examined for burrknots in May or June and October 2007 and 2008. Parameters measured were: (*i*) incidence (%) of trees with symptoms of burrknot; (*ii*) burrknot severity (number of burrknots on above-ground portion of rootstock per tree; (*iii*) trunk diameter (cm); (*iv*) height of graft junction above the soil line; and (*v*) mean number of root-suckers per tree.

The frequency of dead Jonagold trees and the proportion of necrotic bark tissue on above-ground portion of the rootstock trunk circumference of dead trees (i.e. 1/3, 1/2, 2/3 and 2/2, respectively) were recorded during 2007.

The differences between various parameters were analysed using the analysis variance and Pearson correlation. The UNISTAT 5.0 package (UNISTAT Ltd., London, UK) was used for statistical analyses of the data.

Searching for infectious agents

Erwinia amylovora ***and*** *Phytophthora* spp.

Because some symptoms observed on apple trees attacked by burrknot (i.e. cankers formed

Table 1. Primers used in this study

Virus	Primer	Sequence (5'–3')	Nucleotides	Product size (bp)	Reference
ASPV	ASP-C (sense) ASP-A (anti-sense)	CTCTTGAACCAGCTGATGGC ATAGCCGCCCCGGTTAGGTT	8993–9012 9237–9256	264	Jelkmann and Kein-Konrad (1997)
ASGV	ASGV-U (sense) ASGV-2 (anti-sense)	CCCGCTGTTGGATTTGATACACCTC GGAATTTCACACGACTCCTAACCCTCC	5873–5897 6345–6371	499	James (1999)

around burknots) were similar to those caused by *Erwinia amylovora* and *Phytophthora* spp., an examination for these pathogen was carried out according to methods of Schaad *et al.* (2001) and Tsao (1987), respectively. Attempts to isolate fire blight bacterium from necrotic rootstock trunk tissues were carried out using King's B medium and nutrient agar. Apple fruits were used as bait material for isolation of *Phytophthora* spp.

Pome fruit tree viruses

Stem associated pome fruit tree viruses can cause a decline in young plants. Therefore, the presence of *Apple stem growing virus* (ASGV) and *Apple stem pitting virus* (ASPV) was assessed in 32 trees of cvs. Gala, Early Smith, and Jonagold with various burrknot severity using one-step-RT-PCR (Kundu 2003a). Four samples were usually tested from a single tree (leaves and bark tissue both from rootstocks or suckers and apple scions). Tissues were ground in a mortar and pestled in liquid nitrogen. One hundred mg of ground tissue were used for total RNA extraction using the RNeasy Plant mini kit (Qiagen, Hilden, Germany) according to the manufacturer's description.

Primers used in this study are shown in Table 1. Pome fruit tree viruses were detected using one-step-RT-PCR kit (Qiagen, Hilden, Germany) (Kundu 2003a). The one-step-RT-PCR reaction contained 5 μl of the 5× one-step RT-PCR buffer, 1 μl dNTP mixture (10 mmol/1 dNTPs), 0.7 μl of the RT-PCR enzyme mixture, 1 μl Q solution, 10 pmoles forward and reverse primers and 2 μl of total RNA, and was carried out in microtubes. The reaction mixture was adjusted to 25 μl with RNase-free water. The reaction was carried out in a thermocycler (MJ Research, Waltham, USA) as follows: an RT step at 50°C for 30 min and an initial PCR activation step at 95°C for 15 min, then 31 cycles of 94°C for 30 s (denaturation), 55°C for 45 s (annealing), and 72°C for 1 min (extension). After the last cycle, a final extension step at 72°C for 10 min was added.

RESULTS

Symptoms

The roughened, warty-looking circular or spherical growths or swellings of the gall-like appearance occurred primarily on the rootstock portion of trunks, between the soil line and the graft junction and predominantly near the graft union. The growths were formed by many partially developed adventitious roots as is typical for burrknot. The size of individual burrknots ranged from 5 mm to 25 mm in diameter (Figure 1). In the area immediately above some burrknots, the trunk diameter was depressed (Figure 2). Not infrequently, cankers were formed around burrknots. The canker tissue appeared as sunken, orange-to-brown areas in the bark (Figure 3). A crack eventually developed between diseased and healthy tissue. Some older cankers had a zonate appearance (Figure 4). When cankers encircled the greater part of the trunk circumference, tree vitality was clearly lowered as determined by the greater incidence of necrotic lesions, especially anthracnose cankers with typical fiddlestring appearance (caused by the fungus *Neofabraea malicorticis*) on the limbs and branches in the tree-top (Figure 5). No burrknots were noticed on the scion part of the trunk, limbs and branches of trees evaluated. A strong tendency to produce root-suckers was observed in many roots of trees surveyed (Figure 6).

The graft junction was, on average, 19 cm (in the range from 7 cm to 30 cm) above the soil line. In most trees evaluated, the swelling around the graft junction was pronounced. Removal of bark above and below the place where scion and rootstock was joined revealed markedly thick and spongy bark tissue. In addition, symptoms that suggested the presence of some viral pathogens were observed,

Figure 1. Burrknots on the rootstock trunk of an apple tree located at the base, in the middle and near the graft union (Photo V. Krejzar)

Figure 2. Trunk fluting (see arrow) above developed burrknots on the rootstock trunk of an apple tree (Photo V. Krejzar)

Figure 3. Canker formed around burrknots on the rootstock trunk of an apple tree (Photo V. Krejzar)

Figure 4. Zonate appearance of canker developed on the rootstock truck of a heavy bearing apple tree (Photo V. Krejzar)

Figure 5. An anthracnose canker on the branch of an apple tree associated with heavy burring and cankering on the rootstock trunk (Photo V. Krejzar)

Figure 7. Slight pitting and grooving in the wood on the rootstock trunk of an apple tree (Photo V. Krejzar)

such as slight pitting and grooving in the wood on the rootstock part of the trunk (Figure 7).

Burrknot incidence and severity

Těšetice planting. Incidence of burrknots in cvs. Early Smith, Jonagold and Gala was 98%, 97%, and 92%, respectively. Burrknots were localised on the rootstock part of the trunk between the soil line and the graft junction. The mean severity of burrknots was the highest on cv. Jonagold (3.65), whereas on cvs. Early Smith and Gala severity was about 23% lower (Table 2). The number of burrknots per tree was not related to trunk diameter.

Figure 6. High number of root-suckers produced by tree with burrknots (Photo V. Krejzar)

Table 2. Formation of burrknot and root-suckers in apple trees of three cultivars on M.9 roostock and correlations between burrknots number and number of root-suckers

Cultivar	Incidence of trees with burrknots (%)	Burrknot number per tree		Number of root-suckers per tree		Correlations between burrknots number and number of root-suckers (Pearson correlation test)	
		mean[y]	(%)	mean[y]	(%)	r	correlation
Jonagold	91.66	3.65[a]	100.00	5.90[a]	100.00	0.3355	middle
Gala	96.66	2.83[b]	77.53	5.63[a]	95.42	0.1789	weak
Early Smith	98.33	2.86[b]	78.35	5.25[a]	88.98	0.0156	very weak

[y]the same letters are not significantly different from each other at P = 0.05 of LSD test

Stošíkovice planting. Symptoms of burrknot were exhibited on 73.3% of cv. Gala trees planted on the gentle slope and 70.0% of trees planted on a level site. Burrknot severity on trees planted on the gentle slope (1.85) was not significantly different than on the flatland (1.37) (Table 3).

Relationships between burrknot incidence and development of root-suckers

Burrknot incidence and the incidence of root-suckers were the highest in Jonagold trees (Table 2). However, correlations between the incidence of burrknot and incidence of root-suckers were not significant.

Dying of trees

Five years after planting, increasing dying of cv. Jonagold trees was recorded at the Těšetice orchard. Of 290 trees examined, 5.5% died. Each dead tree exhibited burrknots on the rootstock, associated with cankers which more or less girdled the trunk. Of the evaluated trees, 43% showed a complete

Table 3. Formation of burrknot and root-suckers in apple trees of Gala cultivar on M.9 rootstock at two locations at different times of planting and correlations between burrknots number and number of root-suckers

Location	Time of planting	Incidence of trees with burrknots (%)	Burrknot number per tree		Number of root-suckers per tree		Correlations between burrknots number and number of root-suckers (Pearson correlation test)	
			mean[y]	(%)	mean[y]	(%)	r	correlation
Těšetice	spring 2003	96.66	2.83[a]	100.00	5.63[a]	100.00	0.1787	weak
Stošíkovice (on the gentle slope)	autumn 2002	73.33	1.85[b]	65.37	3.12[b]	55.48	0.4156	middle
Stošíkovice (on the flatland)	autumn 2002	70.00	1.37[b]	48.40	3.48[b]	61.81	0.4542	middle

[y]the same letters are not significantly different from each other at P = 0.05 of LSD test

Table 4. Relationship of dying of Jonagold trees to the percentage of necrotised bark tissue surrounding burrknots on rootstock part of the trunk and encircling trunk circumference

Percentage of dead trees (n = 290)	Percentage of trees with necrotised bark tissue (n = 16)				
	part of trunk circumference encircled by necrotised bark				total
	1/3	1/2	2/3	3/3	
5.51	6.25	31.25	18.75	43.75	100.00

Table 5. Incidence of *Apple stem pitting virus* (ASPV) and *Apple stem grooving virus* (ASGV) in comparison with the burrknot incidence in apple trees of tree cultivars

Cultivar	Number of trees tested	Number of burrknots per tree	Number of positives for ASPV		Number of positives for ASGV	
			rootstock	scion	rootstock	scion
Jonagold	10	3.65	10	10	10	10
Early Smith	10	2.80	10	10	10	10
Gala	12	2.81	2	2	5	8

girdling canker, 50% exhibited necroses encircling one-half to two-thirds of the trunk circumference, and 6% revealed necroses encircling at least one third of the trunk circumference (Table 4). No abnormal premature dying of young tress was observed at the Stošíkovice orchard.

Infective agents and insects on trees with burrknots

Atempts to isolate *Erwinia amylovora,* and *Phytophthora* spp. from necrotised tissues surrounding burrknots on rootstock trunk tissues were not successful.

Apple stem pitting virus (ASPV) and *Apple stem grooving virus* (ASGV) were detected in all of 10 tested trees of cultivar Jonagold and in 10 trees of cultivar Early Smith. The incidence of ASPV and ASGV in 12 trees of cv. Gala was lower. The virus positive trees included individuals both with various burrknot severity and without symptoms of burrknots. From data shown in Tables 5 and 6 it is evident that there is no relationship between burrknot severity and the occurrence of ASPV and ASGV in the rootstock and scion parts of apple trees.

Some burrknots infested with larvae of the red-belted clearing wing, *Synanthedon myopaerformis,* were noticed during surveying the orchard at Těšetice at the beginning of June 2008.

DISCUSSION

Initiation and development of apple burrknots in nurseries and orchards

After the reporting of an unusually high occurrence of burrknots in commercial apple orchards in South Moravia, the question arises if the disorder of trees was initiated before or after their planting in the orchards.

In agreement with statements from growers, no burrknot symptoms were noticed on trees before planting. Therefore, it is highly probable that development of burrknots had already been initiated in the nursery. Burrknots arise from root initials, which originate from root primordia. Most often they are initiated at a node. A bud gap is the most common point of burrknot origin (Rom & Brown 1979). Development of root initials occurs consecutively as the stem elongates (Wolfe

Table 6. Relationship between the incidence of *Apple stem pitting virus* (ASPV) and *Apple stem grooving virus* (ASGV) and the incidence of burrknot in apple trees

Burrknot number per tree	Number of trees tested	Number of positives for ASPV	Number of positives for ASGV
0	5	4	5
1	8	3	8
2–4	4	3	3
5	7	6	6
6	4	4	3
7	4	2	2
Sum	32	22	29

1935). The scion/clonal rootstock apple trees are frequently developed under conditions that are conductive to the formation of preformed root initials, i.e., low light intensity, high humidity, and temperature in stool bed and propagation row, resulting from shading in these high planting density situations. The primordium may or may not continue development. It may lie dormant for months or even years and it usually takes several years for burrknot to develop visually apparent symptoms (Perry & Cummins 1990).

When the trees are planted in the orchard, these preformed root initials may develop into burrknots on exposed portions of the clonal rootstock if low light intensity persists as a result of shallow planting, weed growth, use of opaque trunk protectors or shading by low limbs. Furthermore, temperature and humidity is increased under these trunk protectors (Rom & Brown 1979; Howitt 1993).

Factors that might have contributed to an outbreak of burrknots in the surveyed commercial apple orchards in South Moravia after tree planting include shading (as a result of root-sucker and weed growth) and drip irrigation. It seems to be probable that plastic trunk guards, used both in Těšetice and Stošíkovice orchards, could not have worsened the burrknots in these locations.

Apple genotypes genetically predisposed to burrknot

Our results demonstrate that of three apple cultivars on the same rootstock, i.e., Early Smith, Jonagold and Gala on M.9, burrknot severity was the highest on Jonagold tree (Table 2). This finding probably reflects a higher inherent predisposition of Jonagold cultivars to burrknot development because all three cultivars come from the same nursery.

Generally, the problem of burrknots has arisen after size-controlling rootstocks have been introduced into fruit growing and a number of rootstock-cultivar combinations were grown using different cultivar practices throughout world. With the trend to bud or graft high and plant with unions well above the soil line, burrknots are more frequently observed (Rom 1970; Leskey & Berg 2005).

In most cases, the burrknots were observed on clonal apple dwarfing rootstocks. They occur less frequently on scion cultivars. It is likely that cultivars showing the highest occurrence of burrknots had been discarded by nurserymen at the beginning of the last century because of the difficulty of producing trees free of bacterial hairy-root (Swingle 1925a). On the other hand, clones that are inherently predisposed to produce burrknots were often chosen as rootstocks in preference to those that do not produce them, because clones with this tendency root much more easily (Perry & Cummins 1990).

Plant pathogens and pests associated with burrknots

Burrknots located at or about the level of the soil surface are considered to be sites where infections of two pathogens injurious to apple can be started, namely fire blight bacterium, *Erwinia amylovora*, that can cause so-called collar blight (Deckers 1994; van der Zwet & Beer 1995) and oomycete *Phytophthora* spp., the causal agent of crown, collar and root rots (Jeffers & Wilcox 1990). Two different types of rootstock infections with *E. amylovora* are distinguished: root-sucker infection and burrknot infection. Large scale burrknot infection was observed on M.26 apple rootstock just under the graft union with cv. Braeburn, an apple cultivar susceptible to fireblight.

Some burrknots infested with larvae of the red-belted clearwing, *Synanthedon myopaerformis*, were noticed during our survey at Těšetice. Burrknots are thought to be sites for insect borer infestations (e.g. *Synanthedon myopaeformis* in Europe and *Synanthedon scitula* in the North America). The moth is native to Europe, from southern Scandinavia through Central Europe to North Africa and Asia Minor. The host range includes important horticultural and landscape trees in the *Rosaceae* family, including members of stone fruit as well as apple, pear, hawthorn, quince and mountain ash. The larvae feed primarily in burrknot tissue on clonal rootstocks. As the burrknot tissue is consumed, the larvae move outward and cut into adjacent phloem and cambium tissues. In Europe, until the 1960s, *S. myopaeformis* was regarded as one of the secondary pests of apple trees weakened by other factors. It has since become a significant pest and this can be attributed to changes in apple production technology. Intensive plantations were established using rootstocks with low growing capacity and this may result in the early death of young trees under unfavourable environmental conditions (Balasz *et al.* 1996). According with Kain and Robinson (2005), if burrknots do not develop in the first place, there will be no problem with borers.

In our study, increasing dying of Jonagold trees was recorded in the Těšetice orchard. Of 290 trees examined, 5.5% died. No abnormal premature dying of young trees was observed in the Stošíkovice orchard in spite of the burrknot occurrence (although in lower severity). Each of dead trees in Těšetice exhibited burrknots on the rootstock part of trunk associated with bark necroses or cankers that more or less girdled the trunk. On the other hand, the occurrence of trunk cankers in the Stošíkovice orchard was only sporadic. Not only parasitic but also facultative parasitic fungi or weekly pathogenic fungi (members of Ascomycetes and Anamorfic fungi) are most commonly responsible for canker development in apple trunks. Canker development is usually the result of predispositional wounding or tissue stress in the susceptible host plant (Barnes 2001). We can, therefore, speculate that spring planting promoted a stronger transplant shock for planted trees in the Těšetice orchard, which has weakened trees, and provided better conditions for entry of canker pathogens into basal trunk tissues than autumn planting in the Stošíkovice orchard.

Our attempts to isolate fire blight bacterium and oomycetes *Phytophthora* spp. from diseased rootstock trunk tissues were not successful. In this connection it should be noted that M.9 rootstock is susceptible to *E. amylovora* (van der Zwet & Beer 1995) but it appears to be the most resistant to *Phytophthora* spp. (Jeffers & Wilcox 1990).

The association of pome fruit tree viruses with burrknot formation in apple trees has not yet been studied. ASPV and ASGV alone may cause plant death when they attack trees that comprise a combination of susceptible rootstocks and cultivars (Kundu & Yoshikawa 2008).

ASPV and ASGV were frequently detected both in apple orchards and nurseries in the Czech Republic. According to a recent survey, as many as 27.86% ASPV-infected and 44% ASGV-infected trees were recorded (Kundu 2003b). Therefore, our detection of viruses in tested apple trees with and without symptoms of burrknot is not surprising. Nevertheless, no association between burrknot incidence and the occurrence of ASPV and ASGV in the rootstock and scion parts of apple trees tested were found. However, the presence of ASPV and ASGV in young apple trees in the Těšetice orchard could have contributed to premature dying of trees.

Control measures

An exclusion of rootstocks with genetic predisposition to produce burrknots is recommended to minimise the risk associated with insect borer infestations and infections of the basal trunk of apple trees with canker pathogens.

Burrknots have long been a serious problem with the clonal apple rootstocks Malling (M.7, M.9, M.26), Malling-Merton 106 and 111 (MM 106, MM 111), Mark and B.9 (Fugatt & Rom 1969 – cit. Rom & Brown 1975; Rom & Brown 1975; Perry & Cummins 1990; Kain & Robinson 2005). Burrknots occur rarely on certain rootstocks, such as Novole, Maruba, and Ottawa 3, (Perry & Cummis 1990), M.27, G.11, G.16, G.41, G.956, and G.30 (Kain & Robinson 2005), and infrequently on P-2 and P-22, Budagovsky 9, and Bemali. Burrknots occur less frequently on scion cultivars such as Empire, Gala, and Springdale (Perry & Cummins 1990). When burrknot development was evaluated on 10-year-old Gala scions growing on 8 dwarfing roostocks, trees on P.1 and O.3 produced the most burrknots, while trees on M.27 produced the fewest burrknots (Marini *et al.* 2003).

Development of burrknots in apple cultivars is influenced by rootstocks. A trial was conducted with apple cv. Golden Smoothee on the rootstocks Pajam 1, Pajam 2, Mark, J9, B9, M.26, M.9/19, M.9/29, and M.9/T337. Burrknot formation was affected by rootstock, being by far the greatest on J9, followed by M.9/29 (Mantinger & Stainer 1996). Likewise, the data presented by Marini *et al.* (2003) clearly show that rootstock can influence burrknot development on apple scions. Leskey and Berg (2005) found that cv. Idared on M.26 had more burrknots than cvs. Burkekez and Gala on the same rootstock at the same site.

It is unreasonable to expect farmers to abandon planting apple cultivars on dwarfing clonal rootstocks for their predisposition to burrknot. Therefore, planting with the scion union as close to the ground line as possible is a practical way to reduce burrknot numbers and problems associated with them (Rom & Brown 1979). According to Perry and Cummins (1990), keeping the area around the trunk free of weeds and trash and avoiding opaque rodent guards may reduce the development of burrknots. Opening up the tree to better sunlight penetration and less humidity will help prevent formation of new burrknots. Often the problem can be rectified by mounding soil on the trunk to encourage rooting of the burrknots. However, if mounding extends above the graft union, scion rooting and loss of dwarfing can occur.

Kain and Robinson (2005) point out that burrknots develop to a greater extent when trees are planted so that the graft union is high above the soil surface. Trees that are planted with the graft union at or within a couple of inches of the soil surface may not develop above ground burrknots but may develop scion rooting. In addition, tree vigour is decreased with increasing distance of graft union above the soil.

During the survey of orchards in South Moravia, rootstock parts of trunks were relatively long and the graft junction was approximately 20 cm above the soil line. It could be one of the factors responsible for the unusually high occurrence of burrknots and subsequently canker symptoms and premature tree death in the commercial apple orchards.

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