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Strokovni članek
Professional report

Organization of fine root data obtained from minirhizotrons and ingrowth soil cores (how to construct an operational database using MS Access)

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Abstract

Root observation with minirhizotrons is a useful technique to study root system dynamics by means of a transparent tube and a root image acquisition device. It has been in use in root studies for a few decades. The method is best complemented by sequential soil coring for studying root growth in defined soil volume in a time sequence of sampling, or by use of ingrowth soil cores method, which allows measurement of fine root biomass and growth in the exposed soil (substrate) cores during a defined time interval. Most fine root studies techniques are based on picture taking and computerized image analysis. From such analyses, enormous amount of raw data is derived, which is hard to control and manipulate. To enable a friendly and reliable data organization, two MS Access databases were designed, using data from minirhizotron pictures and ingrowth soil cores. These MS Access databases enable the data user to save time and reduce the amount of errors made during data handling (such as extensive copy-paste data routines in and out of numerous Excel files). Our aim was to improve data quality control and allow an easy, friendly and efficient way of manipulation of fine root growth data without a high level of knowledge on database construction. Therefore, in this study, we present an efficient way of handling a large amount of minirhizotron and ingrowth soil cores data, by using MS Access database. To better present the protocols some results and experience on improving data quality are presented.

Key words: fine root growth, minirhizotrons, ingrowth soil cores, database, Microsoft Access

Organiziranje podatkov o drobnih koreninah, dobljenih iz minirizotronov in vrastnih mrežic (kako ustvariti operativno podatkovno bazo z uporabo MS Accessa)

Povzetek

Opazovanje korenin z minirizotroni je uporabna metoda za študij dinamike rasti drobnih korenin s pomočjo prozorne cevi in naprave za zajemanje slik. V uporabi so že nekaj desetletij. Metodo je najbolje dopolniti z zaporednim vzorčenjem znanega volumna tal v določenem časovnem zaporedju ali z uporabo vrastnih mrežic, ki nam omogočajo merjenje koreninske biomase in rasti drobnih korenin v določenih časovnih intervalih. Večina metod študija korenin sloni na zajemanju slik in računalniško analizo le-teh. Z analizo slik dobimo ogromno količino neobdelanih podatkov, ki jih je težko nadzorovati in obdelovati. Da bi olajšali organiziranje podatkov in natančnost prenosov, smo pripravili dve podatkovni bazi MS Access, ki vsebujeta podatke o koreninah iz minirizotronov in vrastnih mrežic. Ti podatkovni bazi MS Access omogočata prihranek časa in zmanjšanje števila napak, nastalih med obdelavo podatkov (npr. obsežne operacije »copy-paste« v in iz številnih datotek Excel). Cilj je izboljšati nadzor kakovosti podatkov ter omogočiti enostaven, prijazen in učinkovit način za manipulacijo podatkov iz minirizotronov in vrastnih mrežic brez visoke stopnje poznavanja dela z bazami podatkov. V prispevku predstavljamo učinkovit način za obdelavo velike količine podatkov iz minirizotronov in vrastnih mrežic z uporabo baze podatkov MS Access. Zaradi lažje predstave je pristop podprt s prikazom izbranih rezultatov in izkušenj pri izboljšanju kakovosti podatkov.

Ključne besede: *drobne korenine, minirizotroni, vrastne mrežice, podatkovna baza, Microsoft Access*

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1 Introduction
1 Uvod

Root observation with minirhizotrons is a useful technique to study root system dynamics by means of a transparent tube and a root image acquisition device (Figure 1). It has been in use in root studies for a few decades. Minirhizotrons provide insight into the ground and enable direct root observation (UPCHURCH, RITCHIE 1984). According to the type of the experiment, several parameters can be observed, which usually include root status (alive versus dead or non-turgescent), root length and number of root tips.

The method is best complemented by use of the ingrowth soil cores method, which allows measurement of root biomass and growth of the fine roots during a defined time interval (MAJDI *et al.* 2005). Ingrowth soil cores is a method in which an intact soil core, removed from the ground, is replaced by a mesh bag of equal size, filled usually with an equivalent volume of root free soil from the site (Figure 2). Sometimes sand is also used to fill the cores (VOGT *et al.* 1998). The size of mesh openings is chosen according to research goals and can allow fine roots to grow in cores or prevent the ingrowth of roots and let in just fungi mycelia (PERSSON 1979; MAKKONEN, HELMISAARI 1999; NEUMANN *et al.* 2009).

Most improvements of root studies techniques in the last decades have been in picture taking equipment and computerized image analysis. Video optics has been replaced by different digital optical scanners and CCD devices (DANNOURA *et al.* 2008). Trends in development of picture analysis software is oriented towards a completely automated analysis of root pictures, although a substantial breakthrough has still not been achieved (LE BOT *et al.* 2010).

This kind of analysis results in enormous amount of raw data, which is hard to control and manipulate. Programs like Excel, Open Office, etc. are widely used for raw data manipulation, but unfortunately do not provide a good data control and the user can be easily lost in the large amount of data. Currently there is no software, which would enable handling of enormous amounts of raw minirhizotrons data placed in multiple files.

Inspired by the current situation, two MS Access databases were designed, using data from minirhizotron pictures and ingrowth soil cores. These MS Access databases enable the researcher to save time and reduce the amount of errors made during data handling (such as extensive copy-paste data routines in and out of numerous Excel files). Our aim was to improve data quality control and allow an easy, friendly and efficient way of manipulation minirhizotrons data without a high level of database knowledge.

Therefore, in this study, we present an efficient way of handling a large amount of minirhizotrons data, by using MS Access database (GROH *et al.* 2007). To better present the protocols some results from our research plots and our experience on improving data quality is presented.

2 Data description
2 Opis podatkov

2.1 Minirhizotrons
2.1 Minirizotroni

Fine root growth data obtained from minirhizotron pictures represent field conditions at research plots and provide information on fine roots living status at the time of each picture taking session. During the observations, roots are marked as alive, dead or disappeared. At the end of the experimental process, the living status of all roots is analysed and the lifespan of roots can be estimated with various statistical methods.

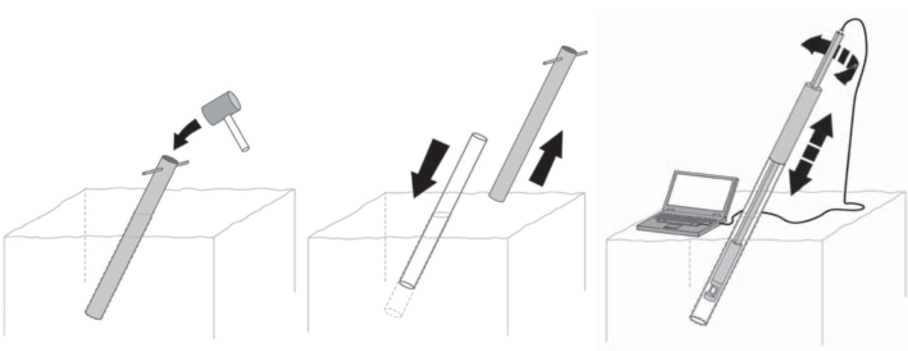


Figure 1. Minirhizotrons are inserted in two steps: corer is used to remove soil and transparent minirhizotron tube is inserted; minirhizotron camera is used to take pictures (drawing by M. Bajc)

Slika 1. Minirizotroni se vstavljajo v dveh korakih: s tal na sondo odstranimo zemljo in v luknjo vstavimo prozorno minirizotronsko cev; za zajemanje slik se uporablja minirizotronska kamera (ilustracije: M.Bajc)

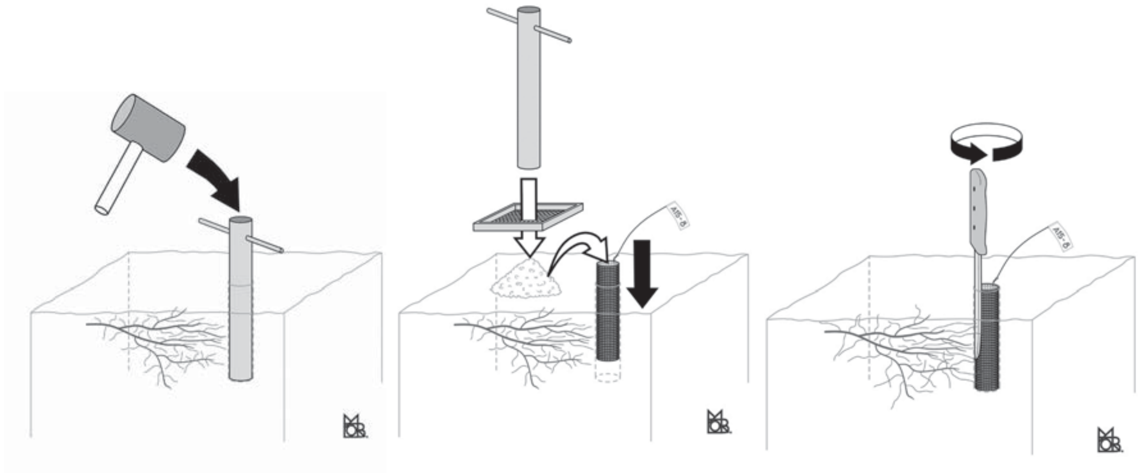


Figure 2: Ingrowth soil cores are installed with the help of soil corer; soil from the plot is sieved through sieve to remove the roots and filled in ingrowth soil core; core is left in the ground for chosen period of time and after that removed and new ingrown roots analyzed (drawing by M. Bajc).

Slika 2: Vrastne mrežice se vstavijo s pomočjo talne sonde; zemlja s ploskve je presejana, s čimer iz nje odstranimo korenine; s presejano zemljo napolnemo vrastne mrežice in jih vstavimo v tla ter vzorčimo v določnem časovnem intervalu (ilustracija M. Bajc)

In most studies, the Kaplan-Meier (KM) method (KAPLAN, MEIER 1958) is used for estimation of root lifespan. This method computes the root longevity by using a product limit formula. Root longevity is presented by a survival curve (Figure 3), where the mean (average) root longevity is defined to occur at the moment when 50% of all roots are dead (KLEINBAUM, KLEIN 2005). The outcome variable of interest of the KM method is the time until an event occurs (the event in this case is the death of a root). At the end of the experimental period, during analysis, roots are divided in two groups – the ones for which it is not possible to ascertain survival time and the ones for which the survival time can be ascertained. This process is called censoring, and the first group of roots is called censored roots. Roots for which the time of their birth (sprouting) is not known are left censored, and roots that are still alive at the end of the experiment are called right censored. The group, which is not censored, results in a known lifespan of individual roots.

To illustrate the problem of root censoring, data from a research plot at an international beech provenance trial in Slovenia is presented. In this, minirhizotrons were installed in the autumn 2006 nearby three different beech provenances, with picture taking sessions starting in June 2007 (for description see ŽELEZNIK 2010). Censored data for growth of roots from 2007 till 2009 are presented in Figure 3.

Pictures from minirhizotrons were acquired with BTC 100X Minirhizotron Camera system (Bartz Technology Corp., USA). The BTC 100X Minirhizotron Camera system consists of a camera handle with attached video optics. A cable connects the camera head to the camera control box, which consists of a digitizer of video signal and a notebook. Pictures are saved in special picture capture software, which accompanies the camera system.

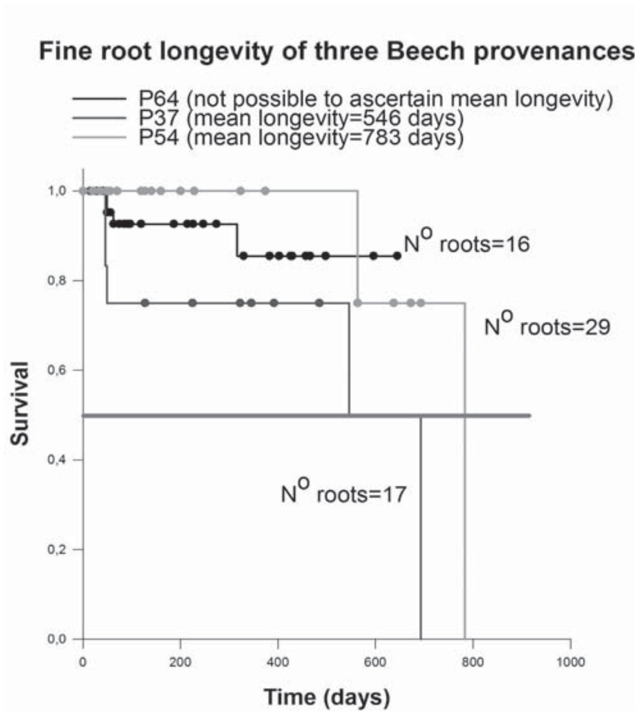


Figure 3. Survival curve for three beech provenances. Red line represents 50% root mortality.

Slika 3: Preživitvena krivulja za tri provenience bukve. Rdeča črta ponazarja trenutek, v katerem odmre 50 % korenin.

The acquired pictures are then analyzed by using WinRhizoTron MF® (v2003c; Regent Instruments, Canada).WinRhizoTron is software for manual analysis of minirhizotron pictures. Data is later prearranged using a special MS Excel macro, XLRhizo TRON (v2005; Regent Instruments, Canada), which transforms the WinRhizo output file (a simple text file) to an Excel file having one or more worksheets.

2.2 Ingrowth soil cores

2.2 Vrastne mrežice

Ingrowth soil cores (dimensions: diameter 5 cm, length 20 cm; mesh opening size 2 and 5 mm, substrate: sieved soil at research plot) were installed at the same research plot in May 2010 and removed after approximately 365 days. Roots grown into the cores were cut with a knife on the outside of cores, which were then pulled out from the ground and kept in plastic bags at 40C until analysis was carried out. Individual samples were soaked in water and roots separated from soil particles manually, first using water, running through different sieves and at the end under a stereo microscope for fine classification of roots. Roots were sorted into three categories: vital roots of woody plants, non-turgescent roots of woody plants and roots of non-woody plants. Roots from the first two groups were then scanned, while immersed in water, with an optical scanner (Epson Perfection V700 Photo). After scanning, all roots were dried at room temperature and weighed. The acquired images were analysed using WinRHIZO® (v2002c, Régent Instruments Inc., Canada). WinRHIZO is software that enables a completely automated analysis of pictures of scanned roots. The role of the system operator is to set the diameter classes, in which root data will be organized, and to correct any mistakes in detecting roots (or dirt), made by the software. The output files are then imported in MS Excel. An additional pre-processing step that changes the stop dots into comas is applied in order to avoid misinterpretation of decimal numbers by Excel (ŽELEZNIK 2004).

3 Database construction and manipulation methods

3 Metode izgradnje in upravljanja podatkovne baze

3.1. Database creation

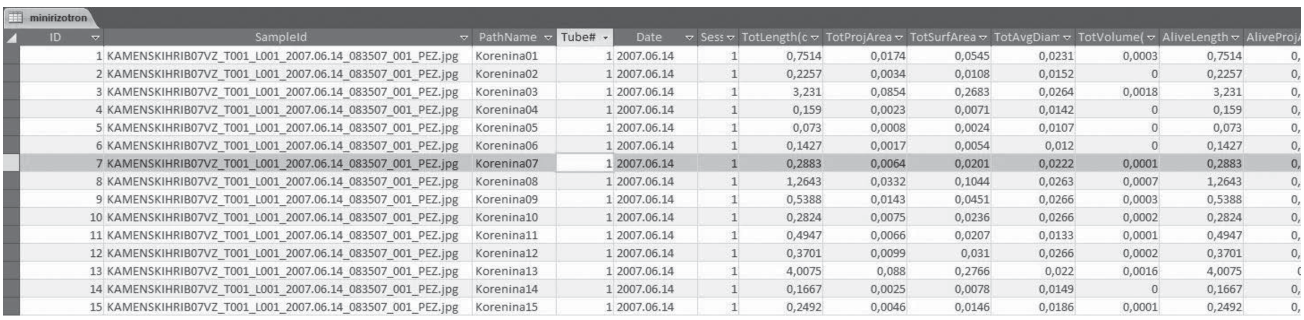
3.1 Ustvarjanje podatkovne baze

Data from minirhizotron pictures and ingrowth soil cores were organized in two databases. The minirhizotrons database includes data gathered in a 4-year period, obtained from 15 minirhizotron tubes. The ingrowth soil cores data includes values from 3 samplings. As a result of the analysis of the methods described above, the output data on the estimated root parameters is sorted in 30 MS Excel files and can reach dimensions of 27 columns per 20,000 lines and more.

Data for each root, observed in a specific tube at different sessions, is imported in MS Access. The structure of the MS Access database is prepared according to the MS Access documentation. The structure of each table in the database is generated according to the structure of the original data files (files processed by the XLRhizoTRON program).

The import process is simple and follows a user guided procedure for import data from different file formats, including MS Excel. The data can be imported in columns, arranged in a user-chosen way. During the import process, the consistency of the data is automatically checked. At any inconsistencies, import is stopped and the user is informed about such an event. An example of the result of an import process of the root data from MS Excel is presented in Figure 4.

After data are imported from Excel files, there is a minimal possibility left for user errors, since the compiler is asked to confirm each process, even an accidental attempt to delete data from the database. The import procedure can be saved and repeated every time data are imported, making the import process efficient in practice.



minirizotron

ID	SampleId	PathName	Tube#	Date	Sess	TotLength(c	TotProjArea	TotSurfArea	TotAvgDiam	TotVolume(	AliveLength	AliveProj
1	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina01	1	2007.06.14	1	0,7514	0,0174	0,0545	0,0231	0,0003	0,7514	0,
2	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina02	1	2007.06.14	1	0,2257	0,0034	0,0108	0,0152	0	0,2257	0,
3	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina03	1	2007.06.14	1	3,231	0,0854	0,2683	0,0264	0,0018	3,231	0,
4	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina04	1	2007.06.14	1	0,159	0,0023	0,0071	0,0142	0	0,159	0,
5	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina05	1	2007.06.14	1	0,073	0,0008	0,0024	0,0107	0	0,073	0,
6	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina06	1	2007.06.14	1	0,1427	0,0017	0,0054	0,012	0	0,1427	0,
7	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina07	1	2007.06.14	1	0,2883	0,0064	0,0201	0,0222	0,0001	0,2883	0,
8	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina08	1	2007.06.14	1	1,2643	0,0332	0,1044	0,0263	0,0007	1,2643	0,
9	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina09	1	2007.06.14	1	0,5388	0,0143	0,0451	0,0266	0,0003	0,5388	0,
10	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina10	1	2007.06.14	1	0,2824	0,0075	0,0236	0,0266	0,0002	0,2824	0,
11	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina11	1	2007.06.14	1	0,4947	0,0066	0,0207	0,0133	0,0001	0,4947	0,
12	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina12	1	2007.06.14	1	0,3701	0,0099	0,031	0,0266	0,0002	0,3701	0,
13	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina13	1	2007.06.14	1	4,0075	0,088	0,2766	0,022	0,0016	4,0075	(
14	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina14	1	2007.06.14	1	0,1667	0,0025	0,0078	0,0149	0	0,1667	0,
15	KAMENSKIHRIB07VZ_T001_L001_2007.06.14_083507_001_PEZ.jpg	Korenina15	1	2007.06.14	1	0,2492	0,0046	0,0146	0,0186	0,0001	0,2492	0,

Figure 4. Root data are imported in MS Access and at the same time checked for consistency

Slika 4. Ob vnosu podatkov za korenine v MS Access se preverijo še napake glede na izvirne podatke

In addition, errors found and corrected in queried data are automatically corrected in the original Ms Access data set. Thus, a constant control over data quality is assured.

3.2 Data manipulation

3.2 Upravljanje s podatki

A selected subset of data stored in the database can be filtered out and exported to external software for selected further statistical analysis. On the one hand, the filtering process is usually done by using database queries, where the user specifies the root's parameters and their values to be selected or queries on different criteria such as plot name, subplot name, date of gathering etc. On the other hand, the export process is simple because MS Access supports several export formats like MS Word, MS Excel, Open Office, csv format, etc.

In order to illustrate the operations that can be performed over the data organized in an MS Access database, we present several tasks of the data manipulation process executed over our databases. An example of a filtered left censored data where the filtering process was done by using database query on the session dates is presented in Figure 5.

An example of the longevity of the dead roots calculation is presented in Figure 6. First, a filtering task is done by using database query on the session dates and then a sorting task performed in order to better organize the results. At the end, the longevity of the dead roots is calculated in external statistical software.

An example of filtered right censored data is presented in Figure 7. The filtering process was also done by using database query on the session dates, as in the previous examples.

The ingrowth soil cores database was constructed in a similar way as the minirhizotron database and the data were organized in the same way as well. The main difference between these two databases is the time scale. The data included in the ingrowth soil cores database are sampled a few times per year whereas the minirhizotrons are visited and sampled on monthly basis. The differences in timescale prevent direct connection and joining of data between the two databases, whereas a research plot code or date of sampling can be selected as reference information in the linking process between the two databases. A part of the ingrowth soil cores, database is presented in Figure 8.

Time needed to arrange data in a way suitable for analysis, is considerably shortened as data extraction (queries) is made by a few clicks on mouse and keyboard. All queries can be saved and repeated when needed.

At last, the queries can also serve as error detection mechanism inside the database and enable tasks like detection and removal of duplicate or missing information among the data. This may be a very important step and sometimes an essential task of the data handling process that assures data integrations and quality.

minirizotron_Tube3

ID	SampleId	PathName	Tube#	Date	Session#	TipLivStatus
505	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina32	3	2007.06.14	1	A
506	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina33	3	2007.06.14	1	A
507	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina34	3	2007.06.14	1	A
508	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina35	3	2007.06.14	1	A
509	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina36	3	2007.06.14	1	A
510	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina37	3	2007.06.14	1	A
511	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina38	3	2007.06.14	1	A
512	KAMENSKIHRIB07VZ_T003_L001_2007.06.14_085123_001_PEZ.jpg	Korenina39	3	2007.06.14	1	A
(New)						

Figure 5. Left censored data are filtered from the database

Slika 5. Levo cenzurirani podatki so izločeni iz baze

minirizotron_Tube3 minirizotron_Tube2

ID	SampleId	PathName	Tube#	Date	Session#	TipLivStatus
5534	KAMENSKIHRIB08_T002_L001_2009.11.25_100024_012_PEZ.jpg	Korenina13	2	2009.11.25	12	D
5536	KAMENSKIHRIB08_T002_L001_2009.11.25_100024_012_PEZ.jpg	Korenina15	2	2009.11.25	12	D
5539	KAMENSKIHRIB08_T002_L001_2009.11.25_100024_012_PEZ.jpg	Korenina18	2	2009.11.25	12	D
5550	KAMENSKIHRIB08_T002_L001_2009.11.25_100024_012_PEZ.jpg	Korenina28	2	2009.11.25	12	D
5551	KAMENSKIHRIB08_T002_L001_2009.11.25_100024_012_PEZ.jpg	Korenina29	2	2009.11.25	12	D
(New)						

Figure 6. Dead roots are filtered out and longevity for each one ascertained from session dates

Slika 6. Mrtve korenine so izločene iz baze in za vsako posebej se ugotovi dolgoživost glede na datume snemanj

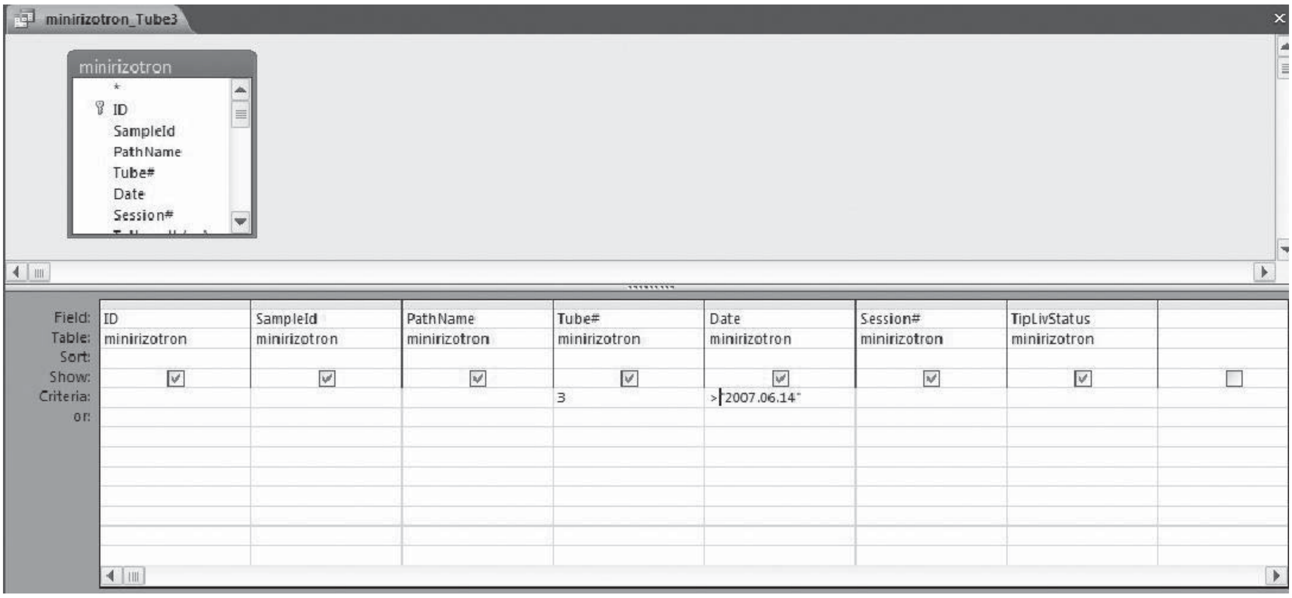


Figure 7. Right censored data is filtered from database

Slika 7. Desno cenzurirani podatki so izločeni iz podatkovne baze

Mrežica	Vstavljanje	Exposure (days	Mesh opening	Volumen vz	Masa (g)	Length(cm)	ProjArea(cn	SurfArea(cn	AvgDiam(m	RootVolum
KH31	11.11.2008	127	2	0,0003925	0,14	194,7254	10,9014	34,2477	0,5598	0,479
KH32	11.11.2008	127	2	0,0003925	0,01	26,635	0,4695	1,4749	0,1763	0,006
KH33	11.11.2008	127	2	0,0003925	0,03	90,7494	3,3519	10,5303	0,3694	0,097
KH31	6.5.2009	176	2	0,0003925	0,31	1043,8561	31,6284	99,3635	0,9563	0,764
KH32	6.5.2009	176	2	0,0003925	0,82	1083,8065	56,4299	177,2798	1,0808	2,308
KH33	6.5.2009	176	2	0,0003925	0,6	1437,7691	63,6046	199,8199	1,5236	2,229
KH121	6.5.2009	303	2	0,0003925	0,03	104,2041	5,1305	16,1178	0,796	0,2
KH122	6.5.2009	303	2	0,0003925	0,13	217,8041	10,4145	32,7179	0,9586	0,407
KH123	6.5.2009	303	2	0,0003925	0,11	189,7616	10,3866	32,6304	1,0679	0,447
KH181	6.5.2009	303	2	0,0003925	0,23	465,5878	24,7391	77,7204	1,0041	1,035
KH182	6.5.2009	303	2	0,0003925	0,11	271,4296	12,3858	38,9112	1,0418	0,462
KH183	6.5.2009	303	2	0,0003925	0,06	174,8524	8,7559	27,5077	1,0535	0,347
KH61	6.5.2009	303	2	0,0003925	0,04	137,4418	5,9773	18,7782	0,773	0,211
KH62	6.5.2009	303	2	0,0003925	0,05	107,9042	4,0688	12,7824	0,7768	0,121
KH63	6.5.2009	303	2	0,0003925	0,02	171,5111	5,8783	18,4672	0,7277	0,159
KH241	6.5.2009	303	2	0,0003925	0,08	86,0709	4,1833	13,1421	1,0292	0,16
KH242	6.5.2009	303	2	0,0003925	0,03	78,8367	3,9386	12,3735	0,9832	0,157
KH243	6.5.2009	303	2	0,0003925	0,22	339,649	19,1258	60,0856	1,2127	0,854
KH31	18.5.2010	377	2	0,0003925	0,41	501,2665	26,4876	83,2134	0,5284	1,099
KH32	18.5.2010	377	2	0,0003925	0,36	1302,858	54,8415	172,2899	0,7901	1,839
KH33	18.5.2010	377	2	0,0003925	0,31	547,7547	27,0197	84,885	0,4933	1,047
KH61	18.5.2010	377	2	0,0003925	0,14	919,2229	31,8814	100,1583	0,3468	0,868
KH62	18.5.2010	377	2	0,0003925	0,24	1070,4371	41,2178	129,4896	0,3851	1,247
KH63	18.5.2010	377	2	0,0003925	0,32	2667,2784	92,2443	289,7941	0,3458	2,506
KH121	18.5.2010	377	2	0,0003925	0,09	540,6073	18,0942	56,8447	0,3347	0,476
KH122	18.5.2010	377	2	0,0003925	0,39	1008,2697	44,6781	140,3605	0,4431	1,555
KH123	18.5.2010	377	2	0,0003925	0,33	2190,5414	78,9331	247,9758	0,3603	2,234
KH181	18.5.2010	377	2	0,0003925	0,41	938,2787	44,3988	139,483	0,4732	1,65
KH182	18.5.2010	377	2	0,0003925	0,57	2085,3222	99,1973	311,6377	0,9292	3,715
KH183	18.5.2010	377	2	0,0003925	0,73	4244,0185	145,6436	457,553	1,0284	3,929
kh241	18.5.2010	377	2	0,0003925	0,27	1165,104	39,0844	122,7874	0,3355	1,03
KH242	18.5.2010	377	2	0,0003925	0,29	1780,4649	61,4339	193,0003	0,6846	1,665
KH243	18.5.2010	377	2	0,0003925	0,19	555,095	23,0751	72,4925	0,4157	0,753

Figure 8. Ingrowth soil cores database

Slika 8. Podatkovna baza za vrastne mrežice

4 Conclusion

Data quality and time efficiency are two most important factors in any work concerning studies of root system dynamics. If a research project operates over 90 minirhizotron tubes, the extent of data is far over the capabilities of an MS Excel. Therefore, the minirhizotron data manipulation in Excel is time and labor expensive, and other statistical software provides only partial opportunities for data manipulation, sorting and extraction. Moreover, handling large amounts of data involves extensive copying procedures and compiling of root parameters in and out of various files, which produces a number of human errors.

In this study, an efficient way of handling large amounts of fine root growth data, by using an MS Access database, is presented using results from a sample research plot. The results can be summarized in the following conclusions:

- Time needed to arrange and rearrange large amounts of minirhizotron data in a way suitable for analysis is considerably shortened by using MS Access.

- The possibility of user errors is minimal and finding errors (if present) is more likely.

- Data extraction (queries) is made by a few clicks on mouse and keyboard only.

- Once queries are saved, process can be automated and repeated when needed.

- Errors found in queried data are automatically corrected in the original data set in Ms Access as well.

- A constant control over data quality is assured.

- Minirhizotron data can be easily connected with other databases like ingrowth soil cores data from the same research plots or data from a different analysis in order to obtain a better understanding of root biology, as presented by combination with the database on root growth in ingrowth soil cores.

The obtained results, knowledge and experience will be of great advantage in further work concerning root parameters analysis and handling large amounts of data.

Zaključek

Kakovost podatkov in časovna učinkovitost sta dva najpomembnejša dejavnika pri obdelavi podatkov dinamike rasti drobnih korenin. Trenutno opravljamo poskus v 90 minirizotronskih ceveh na raziskovalnih ploskvah in obseg podatkov presega zmožnosti programa MS Excel. Obdelava podatkov iz minirizotronov je zamudna in draga. Obdelava podatkov velikega obsega vključuje pogosto kopiranje in urejanje koreninskih parametrov v in iz različnih datotek, s tem pa lahko nastajajo napake.

V prikazani študiji predstavljamo učinkovit način upravljanja z velikimi količinami podatkov iz minirizotronov in vrastnih mrežic z uporabo podatkovnih zbirk MS Access. Poročamo tudi o dobljenih rezultatih, znanju in izkušnjah pri izboljšanju kakovosti podatkov. Naši rezultati so lahko povzeti v naslednjih zaključkih:

- Čas, potreben za urejanje velikih količin podatkov iz minirizotronov v obliko, uporabno za analizo, je znatno skrajšan z uporabo MS Accessa.

- Možnosti pojavljanja napak zaradi uporabnika so močno zmanjšane in njihovo odkrivanje je bolj verjetno.

- Pridobivanje želenih podatkov s poizvedbami je mogoče z nekaj kliki na miško in tipkovnico.

- Ko poizvedbe shranimo, jih lahko poljubno avtomatizirano ponavljamo.

- Zagotovljen je stalen nadzor nad kvaliteto podatkov.

- Baza s podatki iz minirizotronov se lahko enostavno poveže z drugimi podatkovnimi bazami iz iste raziskovalne ploskve ali s podatki iz drugih raziskovalnih ploskve z namenom pridobivanja boljšega vpogleda in razumevanja biologije korenin.

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