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INFLUENCE OF HARVESTER TYPE AND HARVESTING TIME ON QUALITY OF HARVESTED CHAMOMILE

Miloš B. Pajić[*], Vesna S. Pajić, Sanjin M. Ivanović, Mićo V. Oljača, Kosta B. Gligorević, Dušan R. Radojičić, Milan S. Dražić and Ivan J. Zlatanović

University of Belgrade, Faculty of Agriculture,
Nemanjina 6, 11080 Belgrade-Zemun, Serbia

Abstract: This paper is the result of studying effects of mechanical chamomile harvesting on yield and quality of harvested chamomile. Chamomile (*Chamomilla recutita* (L) Rausch.) was harvested at three time intervals (T1 – 240 days, T2 – 250 days and T3 – 260 days after sowing) by three conceptually different harvesters. The results achieved indicate that the harvester type significantly influences quality of harvested chamomile, whereas it is not influenced by chamomile harvesting time. Quality of harvested chamomile was classified into four categories, and it was observed that the greater number of rotations of a picking device increased the content of the first category of quality. The harvester A achieved 54.79% of the first category of quality in respect to the harvester B achieving 50.26% and the harvester C with 42.93%.

Key words: chamomile, harvester, harvesting time, harvest quality, picking device.

Introduction

For more than two thousand years, chamomile (*Chamomilla recutita* (L) Rausch.) has been known and appreciated as a medicinal plant. In the beginning, the necessary chamomile quantities were obtained by hand gathering of self-sown chamomile. However, due to wide use of this herb in the pharmaceutical, cosmetic and food industries, needs for this herb species today are much greater and demand plantation production (Oravec et al., 1993; Salamon, 1994). Harvesting of cultivated chamomile is to be the same as for the wild population, i.e. when most of the flowers are already open. Essential oil content constantly increases starting from the period when flowers are formed and reaches its maximum when the white flowers are in a horizontal position (Rohticht et al., 1997).

[*]Corresponding author: e-mail: paja@agrif.bg.ac.rs

Harvesting of cultivated chamomile depends on a large number of parameters, such as sowing time, temperature and air humidity, harvesting time and harvesting method (Dražić, 2004). For chamomile harvesting to be as efficient as possible, it is necessary to conduct various researches investigating the influence of these parameters on particular aspects of harvested chamomile, such as yield, quality, losses, and others. This paper is focused on analyzing the influence of harvesting time and harvesting method on quality of harvested chamomile. Studies performed so far observed the harvested chamomile quality mainly in respect to the content of essential oil (Emongor and Chweya, 1989; Falzari and Menary, 2003; Franz et al., 1986; Gašić and Lukić, 1990; Hadi et al., 2004; Mirshekari, 2011). However, chamomile is very often classified into different quality groups based on morphological characteristics (Hecht et al., 1992; Martinov et al., 1992; Mohr et al., 1996a; Radojević et al., 2000), so such a classification (Standard SRB.E.B3.015:1963, 2010) was used in this study, too.

Multi-year studies point to the fact that cultivated chamomile gives higher yields and quantities of essential oil in comparison to wild, self-sown chamomile (Blažek and Stary, 1961; Milojević-Janaćković, 1965). For plantation production whose yield is higher than 700 kg·ha^{-1} of the fresh mass, hand harvesting is not an acceptable method of harvesting (Franke and Schilcher, 2005; Kirsch, 1990). Nowadays, chamomile harvesting from larger areas is performed by harvesters of 200 to 300 kg·ha^{-1} capacity and productibility of 3 to 5 ha per day (Franke and Schilcher, 2005; Mohr et al. 1996b; Salamon, 1992).

Harvesting time is important in respect to the content of chamomile essential oil (Kišgeci and Adamović, 1994; Rohricht et al., 1997). Flowering index (IC) is used for deciding on harvesting time, and it is confirmed that flowering index of -0.3 to -0.2 is the best time for the first harvest (Ebert, 1982; Frany et al., 1978). A later harvest can cause flower head damage and massive dispersal of harvested chamomile (Dechler and Pelzmann, 1999; Pirzada et al., 2011a, b). Chamomile blooms several times a year, while in agroecological conditions of Serbia it is harvested once, twice or maximum three times (Kojić, 1997). The first harvest (performed in May) gives the highest yield and content of essential oil, while the quantity and quality of essential oil from subsequent harvests severely decrease (Dražić, 2004).

The first harvest period in agroecological conditions of Serbia lasts for about 30 days. In our study, chamomile was harvested three times during this period in order to investigate the influence of harvesting time on quality, too, and thus to determine the optimum time for mechanized chamomile harvesting. Harvesting was performed by three conceptually different harvesters that are most often used in Serbia. Monitoring the yield and quality of harvested chamomile can help with the choice of an appropriate harvester type and chamomile harvesting time in order to rationalize plantation production of chamomile from the aspect of quality and quantity of harvested mass. The aim of this paper is to underline the significance of various harvester technical solutions and chamomile harvesting time on quality of the obtained raw material.

Material and Methods

Investigations were performed during three years of production 2005/2006, 2006/2007 and 2008/2009 on production fields of the Institute for Medicinal Plant Research "Dr Josif Pančić" in Pančevo, Serbia (Latitude 44.876202, Longitude 20.698457). Production year 2007/2008 was omitted from these investigations since several chamomile cultivars were mixed in the production process, which would significantly influence comparative researches, and the obtained results would not be relevant. Basic climate data for the research period, as well as multi-year averages (20 years) are presented in Table 1.

Table 1. Monthly precipitation and average temperature data, Pančevo, Serbia.

	2005		2006		2007		2008		2009		(1990–2010)	
	P*	T*	P*	T*	P*	T*	P*	T*	P*	T*	P*	T*
Jan.	33.9	0.9	31.9	-1.1	49.1	4.6	26.1	1.3	47.4	-1.3	34.0	0.6
Feb.	64.0	-3.5	32.0	0.8	36.3	6.0	9.8	4.3	53.5	1.4	29.5	2
Mar.	24.7	4.0	52.0	5.3	51.4	8.4	61.4	7.6	43.6	6.9	30.8	6.4
Apr.	73.2	11.7	92.5	12.6	15.6	11.5	70.9	12.4	12.5	14.9	51.8	11.9
May	54.1	17.3	26.6	16.9	80.0	17.0	40.0	17.6	112.9	18.8	53.7	17.5
Jun.	70.8	19.4	90.0	19.3	71.4	20.5	67.2	21.2	69.9	20.2	85.6	20.6
Jul.	63.7	21.6	15.3	23.0	4.8	22.7	24.1	21.7	89.1	22.5	78.1	22.2
Aug.	150.4	20.3	98.1	19.7	56.9	21.1	18.3	22.6	13.2	22.5	56.8	21.9
Sep.	66.9	17.2	13.4	17.2	95.0	14.3	83.4	15.8	3.1	19.1	57.0	16.8
Oct.	32.8	11.5	21.4	13.1	111.6	9.8	19.6	12.9	72.7	11.8	51.6	11.8
Nov.	19.1	5.4	16.8	7.3	81.1	3.4	49.3	7.4	82.1	8.3	48.4	6.6
Dec.	87.5	2.3	41.2	2.6	49.3	-0.2	60.7	3.6	90.0	3.5	53.1	1.5
Total P*	741.1	-	531.2	-	702.5	-	530.8	-	690.2	-	630.4	-
Mean T*	-	10.8	-	11.5	-	11.6	-	12.4	-	12.4	-	11.7

* P – Precipitation, T – Temperature.

The diploid autochthonous cultivar of chamomile ‘Banatska’ was used in the researches (Maksimović et al., 1997; Ristić et al., 2007). It was sown in optimal agrotechnical terms (from 1 September to 10 September) at a seeding rate of 1.5 $kg \cdot ha^{-1}$, and seed purity was 97%. The forecrop was winter wheat, grown in a conventional production system. Field studies were carried out on chernozem soil type by the method of split-plot design with three replications. The total experiment ground surface was 10,800 m^2. Basic chemical properties of the soil (Radanović et al., 2003) are presented in Table 2.

Table 2. Basic chemical properties of profile samples.

Soil horizons	Depth (cm)	pH		$CaCO_3$ %	Humus %	AL-P_2O_5 $mg \cdot 10^{-2}g$	AL-K_2O $mg \cdot 10^{-2}g$
		in KCl	in H_2O				
Amo,p	0–26	5.81	7.1	0.16	2.67	4.0	32.3
Amo,p	26–75	6.39	7.56	0.25	1.66	2.6	19.1
AC	75–108	7.29	8.45	23.57	1.01	1.2	12.7
Cgso	108–150	7.36	8.56	28.62	0.86	8.0	11.8

Three conceptually different harvesters were used for chamomile harvesting and all the treatments were under the same harvester working regime (the moving speed and number of rotations of a picking device). The harvester A is a self-propelled harvester, an adapted version of Zmaj “Univerzal” grain harvester (Brkić et al., 1998). The harvester working width is 3.6 m, number of picking rotor rotations is 230 min^{-1}, and the harvester moving speed is 0.43 $m \cdot s^{-1}$. The harvester B is a tractor mounted harvester “NB 2004” (Pajić et al., 2007), powered by tractor (IMT 560). The harvester working width is 2 m, number of picking rotor rotations is 220 min^{-1}, and the harvester moving speed is 0.52 $m \cdot s^{-1}$. The harvester C is a semi-mounted harvester “VB 2002” (Pajić et al., 2009), powered by tractor (MTZ 82.1). The harvester working width is 2 m, number of picking rotor rotations is 205 min^{-1}, and the harvester moving speed is 0.54 $m \cdot s^{-1}$.

A detailed field study and laboratory research show that soils at the investigated localities are middle deep, belonging to automorphous, humus-accumulative soil of chernozem type. It is a variety of calcerous-clay soils (Škorić et al., 1985).

Herbal composition analysis was performed for three times from the surface of 1 m^2 by the method of trial surfaces (Oljača and Dolijanović, 2003), and it is presented in Table 3. Indicators of chamomile yield were later calculated under 12% humidity. The power of tearing flower heads was established by a mechanic dynamometer “GRAMMES - Carpano et Pons”.

Table 3. Biological and physicomechanical properties of chamomile.

Year	HC*	Plant height (cm)			Number of flowers per plant			Power of tearing flowers (N)			Biological yield ($kg \cdot ha^{-1}$)	
		max	min	mean	max	min	mean	max	min	mean	fresh	dry**
2005/06	342	82	52	59	25	3	9	7.5	1.2	3.6	5,520	890
2006/07	518	74	56	66	30	5	12	8.6	1.8	4.6	6,370	1,010
2008/09	411	93	48	71	24	1	14	7.5	4.3	4.9	9,510	1,620

* HC – Herbal composition (number of plants per m^2).
** Dry (12% humidity).

The optimum chamomile harvesting period in agroecological conditions of Serbia is from 1 May to 30 May, and chamomile was harvested during this period in the research. The first harvest was 240 days after sowing, and the two follow up harvests were at intervals of 10 days after the previous one (T1 – 240 days after chamomile sowing date, T2 – 250 days, T3 – 260 days). Flowering index (IC) was used for deciding on the time for harvest (Franz et al., 1978), and it is presented in Table 4, according to the Eq. (1).

$$IC = \frac{V - Kn}{Kn + eB + V} \tag{1}$$

IC – flowering index,
Kn – buds which have not bloomed (%),
eB – flowers to be harvested (%),
V – flowers near the end of blooming (%).

Table 4. Chamomile flowering index parameters depending on harvesting time.

Sowing date	Harvesting date		Vegetative period	Kn (%)	eB (%)	V (%)	IC (%)
05.09.2005	T1	03.05.2006	240	32.28	58.66	9.06	-0.232
	T2	13.05.2006	250	25.47	61.29	13.24	-0.122
	T3	23.05.2006	260	12.53	72.33	15.14	+0.026
08.09.2006	T1	06.05.2007	240	23.83	62.49	13.68	-0.102
	T2	16.05.2007	250	18.14	67.34	14.52	-0.036
	T3	26.05.2007	260	11.06	74.42	14.52	+0.035
03.09.2008	T1	01.05.2009	240	31.18	61.03	7.79	-0.234
	T2	11.05.2009	250	25.56	64.22	10.22	-0.153
	T3	21.05.2009	260	19.30	70.53	10.17	-0.091

Quality of harvested chamomile was defined according to the regulations of SRPS E.B3.015:1963 Standard, and it was divided into 4 categories according to the market value, respectively.

Percentage of particular categories was established by collecting three samples from the harvested mass per each treatment and separating particular categories, thereby establishing weight percentage of each category of the harvested chamomile relative to the total sample. Average values of particular categories were established in weight percentages. The sample size was 81.9 measurements per each treatment. Four dependent variables (category I, category II, category III and category IV) were used for description, as well as two independent variables (harvester and harvesting time).

The results obtained during research were statistically calculated with the use of two-factor multivariate analysis of variance (MANOVA) so as to verify the influence of harvesting time and harvester type on the obtained quality of harvested chamomile. All the statistical analyses were done in "SPSS Statistics" program, version 17.0.

Results and discussion

Two-factor multivariate analysis was performed to investigate the influence of harvester type and harvesting time on the obtained quality. The acquired data were described by statistical indicators presented in Tables 5, 6 and 7. Hypotheses on normality, linearity, atypical points and homogeneity of variance were tested by a preliminary investigation, whereby no significant violation of these assumptions was discovered.

Table 5. Average values and deviations of harvested chamomile quality categories obtained by the harvester A (%).

Harvesting time	DV	Mean ± Std. error	Range (x_{min}–x_{max})	Standard deviation
T1	category I	54.8 ± 3.5	41.2–71.7	10.45
	category II	26.4 ± 1.5	20.2–32.6	4.57
	category III	15.4 ± 2.9	1.0–29.1	8.76
	category IV	3.3 ± 0.7	0.3–5.6	1.99
T2	category I	51.0 ± 2.7	38.1–62.8	7.99
	category II	28.5 ± 1.2	24.1–36.0	3.65
	category III	17.0 ± 3.3	5.5–33.7	9.88
	category IV	3.4 ± 0.6	1.6–5.9	1.66
T3	category I	47.5 ± 2.5	37.6–58.1	7.42
	category II	32.2 ± 1.8	24.8–40.6	5.52
	category III	17.5 ± 3.0	5.2–34.9	8.87
	category IV	2.6 ± 0.5	0.4–4.2	1.36

Table 6. Average values and deviations of harvested chamomile quality categories obtained by the harvester B (%).

Harvesting time	DV	Mean ± Std. error	Range (x_{min}–x_{max})	Standard deviation
T1	category I	50.3 ± 3.1	39.6–67.1	9.3
	category II	29.5 ± 1.9	20.1–38.2	5.8
	category III	16.4 ± 3.4	1.0–33.1	10.1
	category IV	3.7 ± 0.6	0.8–6.4	1.7
T2	category I	47.3 ± 1.6	40.1–54.6	4.7
	category II	29.3 ± 1.2	24.2–33.4	3.5
	category III	19.8 ± 2.4	7.1–31.9	7.2
	category IV	3.8 ± 0.8	1.0–7.5	2.4
T3	category I	48.1 ± 2.4	37.2–59.6	7.3
	category II	34.8 ± 2.5	26.7–48.7	7.6
	category III	12.8 ± 2.5	1.6–23.5	7.4
	category IV	4.2 ± 0.7	2.1–8.9	2.1

Regarding all three types of harvesters, high values of standard deviation can be noticed, which indicates a great dispersion of the obtained data values. These high deviations are caused by unequal conditions of chamomile growing at the microlocality (Frany et al., 1983; Franz et al., 1983; Radanović et al., 2003; Tomić et al., 2004).

Table 7. Average values and deviations of harvested chamomile quality categories obtained by the harvester C (%).

Harvesting time	DV	Mean ± Std. error	Range (x_{min}–x_{max})	Standard deviation
T1	category I	41.2 ± 2.8	30.1–56.4	8.3
	category II	34.6 ± 2.9	22.0–49.0	8.6
	category III	18.3 ± 4.4	1.9–40.2	13.2
	category IV	5.7 ± 1.3	1.1–13.4	3.8
T2	category I	38.6 ± 1.5	32.2–44.7	4.4
	category II	37.8 ± 2.4	29.0–47.3	7.1
	category III	18.3 ± 3.5	7.6–32.9	10.6
	category IV	5.1 ± 0.6	3.6–9.3	1.9
T3	category I	42.9 ± 1.7	36.2–51.6	5.1
	category II	32.9 ± 3.0	20.9–44.6	9.1
	category III	18.1 ± 4.2	4.0–36.4	12.4
	category IV	5.8 ± 1.1	3.2–11.5	3.3

Multivariate analysis presented in Table 8 does not show a statistically significant influence of interaction of the two observed factors (F=1.583, p=0.075), so the analysis of the separate influence of each independent variable (factor) was done. A statistically significant difference was noticed among samples obtained by different types of harvesters (F=5.536, p<0.001, Wilks' lambda=0.573). Since the obtained partial Eta squared indicator of the influence of harvester type was equal to 0.243, and based on the directions presented in Cohen (1988), we are of the opinion that harvester type had a very significant influence on the quality of harvested chamomile. On the other hand, the influence of harvesting time on quality of the harvested chamomile was not statistically significant (F=1.631, p=0.121).

Table 8. Results of MANOVA analysis of harvester type and harvesting time on quality of harvested chamomile.

Factor	Wilks' lambda	F	Hypoth-esis df	Error df	Sig.	Partial eta squared
harvester	0.573	5.536	8.000	138.000	0.000	0.243
harvesting time	0.835	1.631	8.000	138.000	0.121	0.086
harvester × harvesting time	0.708	1.583	16.000	211.436	0.075	0.083

Indicators like these provide significant practical knowledge, such as information that there is no influence of chamomile harvesting time on quality of the harvested chamomile. In agroecological conditions of Serbia, the period of chamomile harvesting (the first harvest) lasts for 30 days, which means that from the perspective of harvested chamomile quality, harvesting can take place anytime within the prescribed agrotechnical period. This result greatly simplifies the optimization of using technical systems in the course of harvesting and processing of chamomile. On the other hand, the choice of harvester and working regime greatly influences the yield and quality of harvested chamomile, which indicates that there is need for a comprehensive study on the influence of harvester work parameters on the components of chamomile yield.

More detailed analyses on the influence of harvester type on particular dependent variables are presented in Table 9, which leads to the conclusion that harvester type had a statistically significant influence on the quantities of category I (F=13.548, p<0,001), category II (F=6.131, p=0.003) and category IV (F=7.818, p=0.001). This influence was not significant for the category III (F=0.282, p=0.755).

Table 9. Influence of harvester type on chamomile quality category – Tests of BSE*.

Source	Dependent variable	Sum of squares	df	Mean square	F	Sig.	Partial eta squared
harvester	I cat	1,522.656	2	761.328	13.548	0.000	0.273
	II cat	510.995	2	255.498	6.131	0.003	0.146
	III cat	56.597	2	28.299	0.282	0.755	0.008
	IV cat	88.657	2	44.328	7.818	0.001	0.178

* Tests of BSE – Tests of Between-Subjects Effects.

Comparison of data groups from harvesters A, B and C with LSD test showed that quality of chamomile harvested by the harvester C was statistically significantly different from the quality of chamomile harvested by the harvesters A and B, while between data collections on the harvesters A and B, there was no statistically significant difference, as shown in Table 10. Figure 1 graphically presents the content of each category of harvested chamomile per harvester.

Table 10. LSD comparisons of data for harvesters A, B and C.

		category I			category II			category IV		
(X)**	(Y)**	Mean difference (X-Y)	Std. error	Sig.	Mean difference (X-Y)	Std. error	Sig.	Mean difference (X-Y)	Std. error	Sig.
A	B	2.547	2.040	0.216	-2.149	1.756	0.225	-0.698	0.648	0.285
	C	10.203*	2.040	0.000	-6.067*	1.756	0.001	-2.484*	0.648	0.000
B	A	-2.547	2.040	0.216	2.149	1.756	0.225	0.698	0.648	0.285
	C	7.655*	2.040	0.000	-3.918*	1.756	0.029	-1.786*	0.648	0.007
C	A	-10.203*	2.040	0.000	6.067*		1.756	2.484*	0.648	0.000
	B	-7.655*	2.040	0.000	3.918*	1.756	0.029	1.786*	0.648	0.007

*statistically significant difference.
**(X), (Y) – Type of harvester.

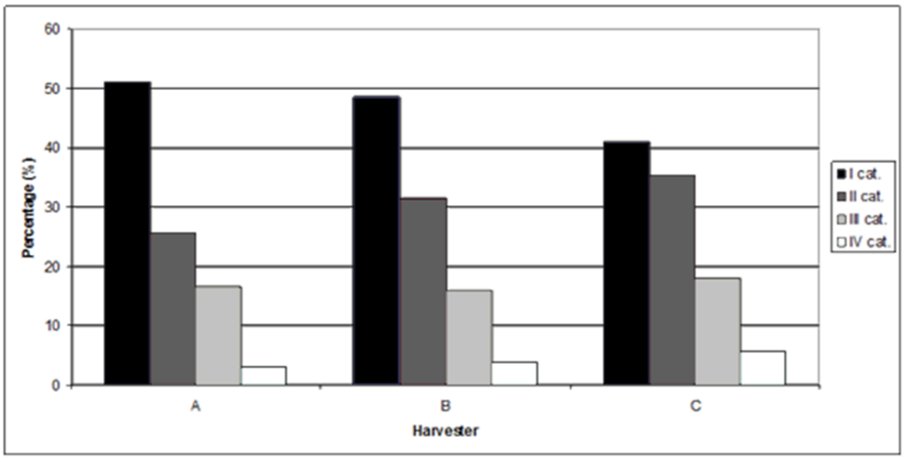

Figure 1. Mean values of categories of harvested chamomille.

These results indicate the significance and influence of exploitation parameters of harvester operation. This refers primarily to the number of rotations of the picking device which is different in the harvesters A and B (230 and 220 min^{-1}) relative to the harvester C (205 min^{-1}). The influence of the number of rotations of a picking rotor on quality of harvested chamomile has been confirmed by studies, too (Martinov, 1992).

Conclusion

In agroecological conditions of Serbia, the period of chamomile harvesting lasts for 30 days. The exact time of mechanized harvesting within this period has no significant influence on the quality of harvested chamomile. This conclusion is very important from the perspective of organization of chamomile production since it simplifies the process of optimization of using technical systems in the process of chamomile harvesting and processing. This refers primarily to interharmonization of processes of harvesting, processing and drying of harvested chamomile, as well as using some technical systems in those activities.

Quality of harvested chamomile was classified into four categories, and it was observed that the greater number of rotations of the picking device increased the content of category I chamomile. The harvester A achieved 54.79% of category I in respect to the harvester B with 50.26% and the harvester C with 42.93%.

On the other hand, the choice of harvester type for chamomile harvesting, as well as exploitation characteristics of it, are among the crucial decisions when it comes to production of chamomile due to the great influence on the yield and quality of harvested chamomile.

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UTICAJ TIPA KOMBAJNA I VREMENA UBIRANJA NA KVALITET UBRANE KAMILICE

Miloš B. Pajić*, Vesna S. Pajić, Sanjin M. Ivanović, Mićo V. Oljača, Kosta B. Gligorević, Dušan R. Radojičić, Milan S. Dražić i Ivan J. Zlatanović

Univerzitet u Beogradu, Poljoprivredni fakultet,
Nemanjina 6, 11080 Beograd - Zemun, Srbija

R e z i m e

Ovaj rad predstavlja rezultat istraživanja u okviru koga su praćeni efekti mehanizovanog ubiranja na prinos i kvalitet ubrane kamilice. Kamilica je ubirana u tri različita vremenska intervala (T1 – 240 dana, T2 – 250 dana i T3 – 260 dana nakon setve) sa tri koncepcijski različita kombajna. Ostvareni rezultati ukazuju da tip kombajna ima značajan uticaj na kvalitet ubrane kamilice, dok takav uticaj nije izražen kada se posmatra termin ubiranja kamilice. Kvalitet ubrane kamilice je klasifikovan u 4 kategorije, gde je uočeno da veći broj obrtaja beračkog uređaja povećava učešće I kategorije kvaliteta. Kombajn A ostvaruje 54,79% I kategorije kvaliteta ubrane kamilice u odnosu na kombajn B sa 50,26% i kombajn C sa 42,93%.

Ključne reči: kamilica, kombajn, vreme ubiranja, kvalitet ubiranja, berački uređaj.

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*Autor za kontakt: e-mail: paja@agrif.bg.ac.rs