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Production potential and economic viability of Croatian pyrethrum ecotypes

Proizvodni potencijal i ekonomska održivost proizvodnje hrvatskih ekotipova buhača

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ABSTRACT

Croatia is pyrethrums indigenous growing zone and among rare places in the world where wild populations are found intact in nature. Aim of this research was to explore production potential of Croatian wild pyrethrum ecotypes, and its use in breeding programs. Three wild ecotypes were tested for morphological traits and yield parameters. Plant height, number of flowers per plant, lodging, fresh and dry flower yield were not affected by ecotype in productive seasons (second and third). However, ecotypes differed in plant diameter and mass of 100 flowers. Positive linear regression among plant height, plant diameter, and number of flowers per plant with flower yield per plant (fresh and dry) was found, but these traits did not correlate with lodging. Even thought no significant differences were found between ecotype yields, financial analysis revealed the difference between ecotype profitability. Positive financial result was obtained in third season of growing with ecotypes 2 and 3. High costs of labour could be the main constraint in commercial pyrethrum production. Tested wild ecotypes, showed good productive characteristics and profitability potential, but there is a need for high yield breeding, and selection for traits adjusted to the use of agro-mechanization.

Keywords: financial traits, plant morphology, pyrethrum (*Tanacetum cinerariifolium*), wild ecotypes, yield components

SAŽETAK

Hrvatska je originalna zona uzgoja buhača i među rijetkim zemljama na svijetu gdje je još moguće pronaći divlje populacije netaknute u prirodi. Cilj ovog rada bio je istražiti proizvodni potencijal i korištenje u oplemenjivačkim programima divljih ekotipova buhača. Testirana su tri divlja ekotipa iz Hrvatske na morfološka svojstva i parametre. Visina biljke, broj cvjetova po biljci, polijeganje, prinos svježeg i suhog cvata, nisu ovisili o ekotipu u drugoj i trećoj proizvodnoj sezoni. S druge strane, ekotipovi su se razlikovali u promjeru biljke i masi 100 cvjetova. Pronađena je pozitivna linearna regresija između visine biljaka, promjera biljaka, broja cvjetova po biljci te prinosa. S druge strane, navedeni parametri nisu bili u korelaciji sa polijeganjem. Iako između ekotipova nije bilo razlike u prinosima, financijska analiza upućuje na razlike u profitabilnosti. Pozitivni financijski rezultat postignut je u trećoj proizvodnoj sezoni sa ekotipovima 2 i 3. Najvažniji ograničavajući faktor komercijalne proizvodnje buhača mogla bi biti visoka cijena rada. Testirani ekotipovi pokazali su dobre proizvodne karakteristike i potencijalno su profitabilni, ali postoji potreba za oplemenjivanjem u svrhu stvaranja kultivara viših prinosa te prilagođenih upotrebi mehanizacije.

Ključne riječi: buhač (*Tanacetum cinerariifolium*), divlji ekotipovi, financijske značajke, morfologija biljke, značajke prinosa

INTRODUCTION

Pyrethrum (*Tanacetum cinerariifolium* /Trevir./ Sch. Bip.) is a perennial plant known for its insecticidal use against pests. Environmentally sensitive, effective, and in ready supply, pyrethrum is used as one of the major insecticides in organic farming, especially aphid control (Ledieu et al., 1989; Isman, 2006). Today, pyrethrum is extensively used as a natural pesticide.

The first historical records of pyrethrum date to some 2000 years ago in China, as it was traded along the Silk Route into Europe, today's Croatia (Dalmatia region) (Greenhill, 2007). The species was identified and named as *Chrysanthemum cinerariaefolium* Vis., for the first time in Dalmatia (Visiani, 1847). The Dalmatian region was the predominant pyrethrum-producing region from the late 19th century till 1930. From Dalmatia it was exported all around the world. In 1885 pyrethrum was exported to USA (Grdiša et al., 2009), in 1928 it was introduced to the British Colony of Kenya (Grdiša et al., 2009), and Japan became the major supplier after 1918 (Greenhill, 2007). In the 1980s, the Tasmanian government sought high-value crops to improve the standard of living of farmers in Tasmania, and today Tasmania is one of the major world pyrethrum producers (Gullickson, 1995; Greenhill, 2007; Grdiša et al., 2009). Over the time, there has been periodical production in many parts of the world (Asia, Africa, Europe and South America), and currently the world's most important pyrethrum producing country is Kenya (Tóth et al., 2012).

In Europe, there have been several attempts to develop the production of pyrethrum and valorize the product. In the Mediterranean region, some regions of France and Spain have been determined as particularly suitable for the growth of pyrethrum. Continental European countries such as Slovakia and Czech Republic are also making efforts in pyrethrum production development (Tóth et al., 2012).

Croatian production has declined in time, particularly due to the fact that the price of imported pyrethrum extract was much lower than production costs in Croatia and because of expensive labour, particularly important for the labour intensive processes of harvesting (Ban et al., 2003). There have been efforts of many research institutes and commercial companies to revitalize the cultivation and processing of pyrethrum in agricultural production in Croatia (Ožanić, 1955; Ban et al., 2003; Crmarić and Jelaska, 2003; Grdiša et al., 2009; Penava, 2012) unfortunately with no success, and today there is only a sporadic individual pyrethrum production. However, tradition, origin, and climate are good predispositions for successful commercial pyrethrum production.

In the past the most extensive pyrethrum production in Croatia was on Dalmatian coast and islands, but there are also early records of experimental studies and trial field of pyrethrum in Istria (North Coastal Croatia).

Croatia was the leader country in world production of pyrethrum in 1914 (Oplanić et al., 2005) and evidence of pyrethrums studies and cultivation in Istria from almost hundred years ago (Tromba, 1924; Gioseffi, 1929) indicate at its natural production potential. It is documented in the paper Tromba (1924), published in one of the first worlds agriculture journals, Istria Agricola (published from 1907), how pyrethrum was commercially cultivated on the North Adriatic islands (Lošinj and Cres) and how the first attempts to cultivate pyrethrum in Istria were promising. In the same journal from 1929, Gioseffi describes the results of cultivation in Western Istria, Poreč, and highlights the potential for the increase of production. Moreover, old map found in the Institute's archives in Poreč, Croatia from 1924, contains records that pyrethrum trial field was planted at the experimental fields of the Austro Hungarian Research Agricultural Station (Figure 1).

Varieties widely used in commercial production are a result of international breeding programs initiated in countries like Australia, India, Japan, Kenya, New Zealand and the United States (Bhat, 1995). Those programs used different initial plant materials and have, over the time, selected highly productive varieties which showed a decrease in pyrethrins yield and quality as a consequence of genetic uniformity and disease-susceptibility. Recently, population improvement was carried out in the commercial

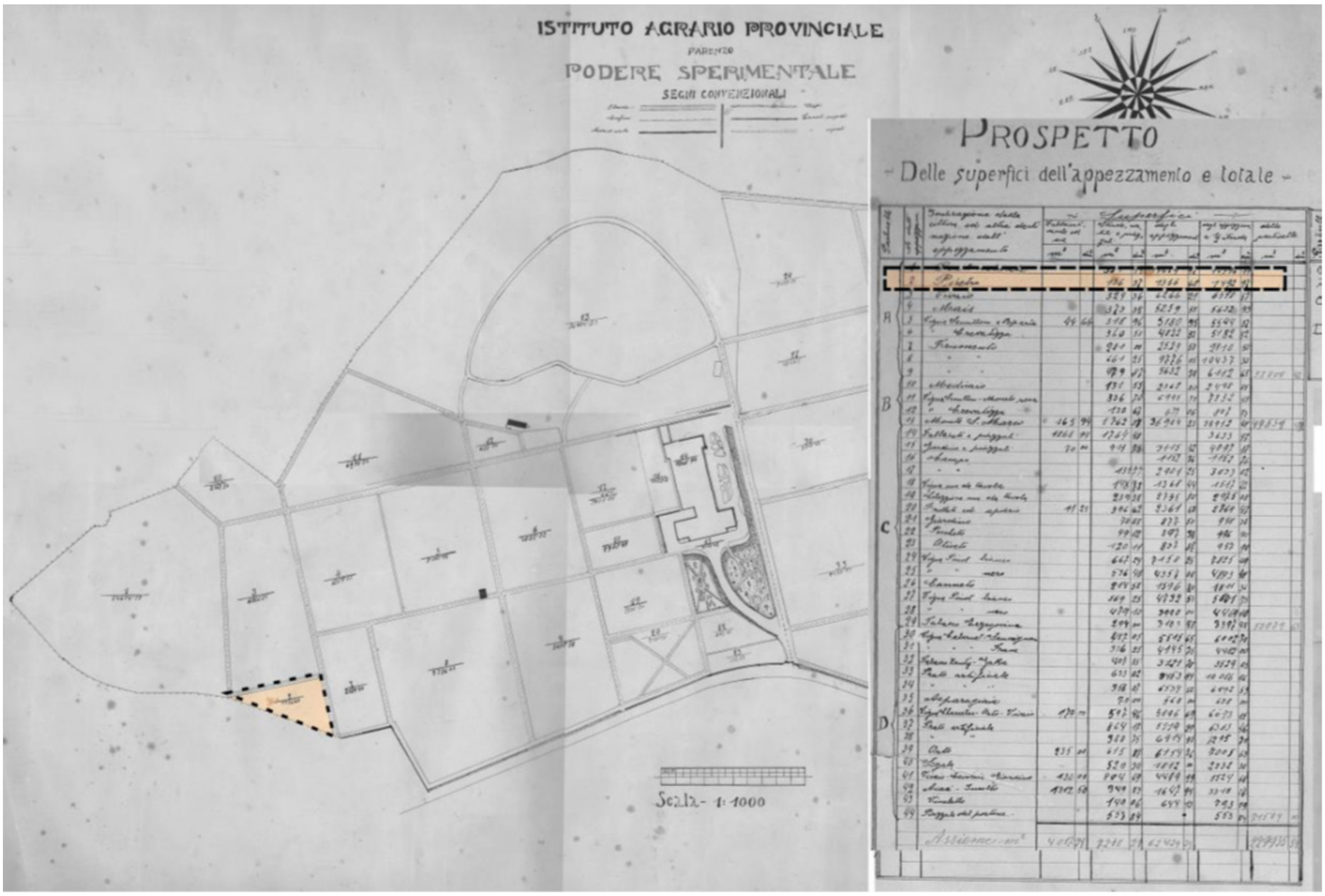

Figure 1. Institute's experimental holding map from 1924

bulk population using mass selection, family selection and polycross (Li et al., 2014). New research programs aimed at the increase of pyrethrins concentrations are oriented at the production of tetraploid pyrethrum plants with high productivity. Croatian wild pyrethrum populations with a wide genetic variability, represent a good source for breeding of novel, more robust and productive varieties.

Several wild populations still can be found in Croatia distributed along the Dalmatian coast, and in South Istria (Premantura) (Grdiša et al., 2009). Indigenous Dalmatian populations, have been screened so far, for its chemical diversity (Grdiša et al., 2009), pyrethrins content (Ban et al., 2010), and genetic diversity (Grdiša et al., 2014).

Production potential is measured through pyrethrins yield and quality, which are determined by pyrethrins content, flower yield, and the pyrethrin I: pyrethrin II ratio (Bhat, 1995). According to Zieg et al. (1983) and Morris et al. (2006), pyrethrin content depends on several factors: genotype, flower maturity, harvesting interval climate, drying method and storage conditions. Some of the most important traits in pyrethrum breeding are morphological traits such as bush size, flower shape and size and plant height, resistance to lodging and synchronous flowering (Bhat, 1995). Parlevliet and Contant (1970) stated that main selection criteria for pyrethrum are fresh flower yield and pyrethrins content; important secondary criteria are flower size and resistance to lodging.

Economic profitability of pyrethrum production has been previously evaluated for production in Slovakia (Toth et al., 2012) and in Istria (Croatia) (Oplanić et al., 2005) and it highlighted the importance of harvesting method and labour expenses. Harvesting method and efficiency are also dependent on lodging which itself is dependent on flower yield, plant height and growth density (Parlevliet, 1969; Grdiša et al., 2009).

Three ecotypes that were used in this study have shown high pyrethrins content (Ban et al. 2010), but no study has been performed so far in order to assess the production potential of wild pyrethrum populations.

The aim of the present paper was to evaluate the production potential and economic feasibility of three Croatian indigenous ecotypes as a potential material in future plant breeding programs. Traits determined as the most important for production evaluation have been investigated on three wild ecotypes during three-year field experiment.

MATERIALS AND METHODS

Field experiments

Three pyrethrum ecotypes were studied during three seasons (2001-2004) at the experimental field of the Institute of Agriculture and Tourism in Poreč (Croatia) (Lat. (N) 45°13'17.26", Long. (E) 13°36'9.00"). Experiment with three ecotypes (ecotype 1, ecotype 2, and ecotype 3) was set up as randomized block design in 3 repetitions. Basic plot size was 10 m x 4.5 m. In the spring of the first vegetative season, the soil has been ploughed at 30 cm depth and disk-harrowed, with no fertilizers.

Propagation material used in this study, originated from wild Dalmatian populations. Populations of interest have previously been studied for pyrethrins content (Ban et al., 2010). Ecotype transplants were obtained by vegetative apical meristem in vitro micro-propagation of the three genetically different mother-plants, according to Crmarić and Jelaska (2003) method, at the laboratory of the "Vitroplant" company (Solin, Croatia). After acclimatization, the transplants were grown in a greenhouse, in polystyrene containers with 54 pots, each pot having 75 ml volume.

Pyrethrum transplants, 100 plants per ecotype, were planted in the field at 6-8 leaf phase on April 30th. Planting was done manually, in three double-rowed stripes per each plot. Transplants planted in the middle stripe were taken for the measurements during experiment. Crop has been repeatedly cultivated during the first and the second vegetative season. During the two year-period pesticides and fertilizers were not applied.

After the planting, in the summer of the first cultivation year, the plants of ecotype 1 and 2 flowered insignificantly, starting July 17th, while the plants of the ecotype 3 did not flower at all. Opened flowers were picked manually to avoid limitations on the flowering shrub development. In autumn, flower shrubs were well rooted and developed.

In the second year of growing, after the wintering season, plants were developing normally. Beginning of flowering (more than 10% of opened flowers) was observed on May 19th, while the beginning of full flowering was documented on May 27th when flowers were picked manually, without staples. Begging of full flowering in third season was observed on June 1st.

Following parameters were measured during the harvest: plant height, plant diameter, bent-over according to scale 1 (90°) to 10 (0°), mass of 100 fresh flowers and fresh flower yield and number of flowers per each plant was counted. Plant height was measured as the length of the central plant staple from the soil surface to the highest flower (Ardelean et al., 2011a).

Flowers were dried in the shade during the summer and in September the mass of 100 dry flowers was calculated as well as the dry flower yield for each plot. Pyrethrin yield per ha was calculated by multiplying the yield of dry flowers with average pyrethrin content of tested ecotypes (Ban et al., 2010).

Financial analyses

Since there is no commercial pyrethrum production in the area, costs were based on experience gained in this experiment conducted at the Institute of Agriculture and Tourism in Poreč. All three ecotypes were cultivated with the same technology. In order to estimate costs and incomes, the period of plantation establishment, and the period of regular production can be distinguished. Establishing period lasts one year and includes land preparation, planting and young plantation maintenance during the first year.

All expenses are reported as specific costs on land area basis and are grouped in four main groups: labour with mechanization, human labour, input costs and amortization. Within these expenses singular working operations were specified, as well as acquired materials, together with all expenses and prices. The value of plantation annual amortization was calculated by the plantation establishment value and annual amortization rate of 11.1%, because the life expectance of pyrethrum plantation is 9 years. In the first year the focus was set on plant rooting and shaping without the harvest. The first harvest year was the second production year. Full flower yield is expected from the third until the tenth year. Selling price of dry pyrethrum flower was the same for all three ecotypes 2.20 €/g of dry flower. This was the actual price of dry flower on Croatian market in analyzed production years and it was slightly lower than the price on the world market (2.78 €/kg) (Tóth et al., 2012).

To determine annual crop revenue, crop yield data for each year were multiplied by the average price per gram of pyrethrum. The principal financial parameters were compared to Slovakian pyrethrum production analyses.

Statistical analyses

Data was tested for normal distribution and homogeneity of variance and transformed when necessary. Analysis of variance (ANOVA) was conducted using proc GLM of the SAS software, and mean separation was done by the LSD test at $P<0.05$. Linear regression among vegetative growth parameters and yield components of pyrethrum clones was calculated as well.

RESULTS AND DISCUSSION

Population production potential

It was indicated that for pyrethrum plants the peak harvest occurs during the second growing year. Păun et al. (1988) showed that in the first growing year, young plants are very weak, having a slow growth and forming a thick rosette of leaves, while in the second and the following years, the plants have a rapid rhythm of development. This trend is visible also in this investigation (Table 1).

Plant height

Vegetative traits measured in this study are presented in Table 1. The significant difference in height of the plants

Table 1. Plant height and diameter, number of flowers and lodging of three pyrethrum ecotypes grown during three seasons

Ecotype	Plant height (cm)	Plant diameter (cm)	Number of flowers per plant	Lodging (1-10)*
		Season 1		
1	28.4^{a}	21.6^{a}	5.2^{a}	1.55^{a}
2	26.8^{a}	23.2^{a}	6^{a}	1.49^{a}
3	12.6^{b}	19.43^{a}	0^{b}	1^{a}
		Season 2		
1	61.4^{a}	59.5^{b}	125^{a}	2^{a}
2	66.6^{a}	68.2^{ab}	153^{a}	2.8^{a}
3	63.6^{a}	69.1^{a}	136^{a}	2.5^{a}
		Season 3		
1	75.9^{a}	83.9^{b}	180^{a}	1^{a}
2	78^{a}	91.7^{ab}	174^{a}	1.67^{a}
3	77.6^{a}	97.7^{a}	232^{a}	2.5^{a}

*In the scale 1-10, 1 corresponds to 90° lodging and 10 to 0° lodging. ^{a,b} Means of the ecotypes in each season followed by the same letter are not significantly different at $P<0.05$

between ecotypes was found only in the first vegetative season where ecotype 3 was smaller comparing to ecotypes 1 and 2. According to literature, the plant height of pyrethrum varies in the range of 30 to 100 cm, depending on the genotype and production conditions (Kolak and Rozić, 1997; Kolak et al., 1999) and results of this research confirmed those findings. The height of the plant is an important factor influencing planning and construction of the mechanization for cultivation and mechanical flower picking (Kolak et al., 1999; Ardelean et al., 2011b). Obtained plant height in this study makes them suitable for cultivation and mechanical picking. The taller plants do bent-over often, thus not being suitable for mechanical cultivation and picking.

Plant diameter

Tested ecotypes significantly differed in plant diameter, and plants of ecotype 3 were wider than plants of ecotype 1 in the second and third season (Table 1). Obtained plant diameter data in the second and third vegetative years varied between 59 and 98 cm which is in accordance to other studies (Greenhill, 2007; Grdiša et al., 2009). Diameters of planted bushes suited the distance between the rows, plants were straight and they were not interfering with its mutual development.

Pyrethrum is a bushy plant and the bush size affects the planting distance between the rows (Kušan, 1969). Bush diameter is affected by genetic factors but also shows a strong interaction with environmental factors such as temperature, soil type and moisture (Ardelean et al., 2011a).

Number of flowers

Number of flowers per plant is an important yield component. In this study, number of flowers in second and third season ranged from 125 to 232, but no significant difference was found between ecotypes (Table 1). According to Kolak et al. (1999), the two-year old plant can develop from 200 to 400 flowers. The smaller number of developed flowers per plant in studied ecotypes is most likely the consequence of a drought period during the flower generation.

Lodging

No significant difference was found between ecotypes in lodging (Table 1). The lowest level of lodging was between 70° and 80° (found in ecotype 2 in the second vegetative season) in relation to the soil surface, although the ideal level is 90° (Table 1). An important success factor for mechanical picking is the level of plant lodging because there is a high loss of flowers during mechanical picking if the plant is heavily bent over. Therefore, mechanical production preference is for the plants which do not lodge or only slightly bend over (Kolak and Rozic, 1997; Kolak et al., 1999). The level of lodging for all 3 ecotypes tested satisfied the requirements for mechanical production.

Yield components

Mass of 100 fresh flowers was higher for ecotype 2 compared to ecotype 1 and 3 in both seasons, however, for ecotype 1 and 2 dry mass of 100 flowers was higher when compared to ecotype 3 (Table 2). Larger flowers are not preferable in Dalmatian pyrethrum production because of how their weight affects bending and causes losses in mechanical harvest (Kolak et al., 1999). In this experiment the weight of flowers did not significantly influence the plant lodging. Summer during the second season of growing was extremely dry so the plants were hibernating. After the rain, new vegetation started in mid-September, so flowering started at the end of October. Due to early autumn frost, harvest was not significant.

The yield of flowers per plant is an important component influencing the total flower yield per area. Fresh flower weight per plant was between 59.2 g to 77.67 g; while dry flower weight was between 11.78 g to 14.78 g (Table 2). The differences in yield of fresh and dry flowers per plant between the ecotypes were not significant in the experiment. The difference between ecotypes for the yield of fresh and dry flowers per hectare was not significant as well. Yield of dry flowers was within the range mentioned in the literature (Filipaj, 1997; Kolak et al., 1999; Ban et al., 2004). Pyrethrum yields, measured in kilograms of pyrethrins per hectare at harvest, have more than doubled since 1994 (Greenhill,

Table 2. Plant height and diameter, number of flowers and lodging of three pyrethrum ecotypes grown during three seasons

Ecotype	Mass of 100 flowers (g)		Yield (g/plant)		Yield (kg/ha)		Pyrethrin* yield (kg/ha)
	Fresh	Dry	Fresh	Dry	Fresh	Dry	
			Season 2				
1	63.3[b]	14.8[a]	72.6[a]	18[a]	3,192.7[a]	792.1[a]	9.9
2	77.7[a]	15[a]	72.4[a]	16.8[a]	3,187.1[a]	740.5[a]	8.6
3	59.2[b]	11.8[b]	50.7[a]	12.4[a]	2,232.7[a]	546.2[a]	7.1
			Season 3				
1	82.8[b]	19.9[a]	78.8[a]	20.2[a]	3,467.6[a]	887.2[a]	11.1
2	100.1[a]	21.7[a]	91.1[a]	21.4[a]	4,007.3[a]	943.3[a]	10.9
3	70.5[b]	16.3[b]	117[a]	29.2[a]	5,145.6[a]	1,284.2[a]	16.7

*Pyrethrin yield per ha was calculated by multiplying the yield of dry flowers with average pyrethrin content of tested ecotypes (Ban et al., 2010). [a,b] Means of the ecotypes in each season followed by the same letter are not significantly different at P<0.05.

2007). In Tasmania pyrethrum is typically retained for a period of 3-4 harvests (Greenhill, 2007).

In our climatic conditions the second harvest usually occurring in October is not significant due to possible autumn frosts. The average dry flower yield of the most productive ecotypes of pyrethrum tested in Slovakia was 1,056.3 kg/ha (Tóth et al., 2012) exceeding the world's average best harvest (619.7 kg/ha of dry flower) (Tóth et al., 2012). All ecotypes tested in the present study also exceeded this values being very close to the high productive value in Slovakia (Table 2).

Regression analysis performed with vegetative measurements data showed that plant height and plant diameter are strongly positively correlated (0.938), but weak correlation of both parameters was found with lodging (Table 3). In addition, plant height and diameter showed strong correlation with number of flowers per plant. The coefficient of determination between plant height and yield per plant (fresh and dry) was higher than for plant diameter, and a good connection between yield and number of flowers per plant was found as well.

Table 3. Coefficient of determination (r^2) among vegetative growth parameters and yield components of pyrethrum ecotypes grown during two seasons. The data are presented in Tables 1 and 2

	Plant height	Plant diameter	No. of flowers	Lodging	Mass of 100 flowers (fresh)	Mass of 100 flowers (dry)	Yield per plant (fresh)	Yield per plant (dry)
Plant height	1	0.938***	0.876***	0.177*	0.382**	0.361**	0.504***	0.480**
Plant diameter		1	0.898***	0.128*	0.245*	0.303*	0.344**	0.319**
No. of flowers			1	0.139*	0.015[ns]	0.018[ns]	0.55***	0.587***
Lodging				1	0.035[ns]	0.255*	0.035[ns]	0.01[ns]
Mass of 100 flowers (fresh)					1	0.693***	0.024[ns]	0.001[ns]
Mass of 100 flowers (dry)						1	0.030[ns]	0.014[ns]
Yield per plant (fresh)							1	0.939**

[ns], *, **, *** Linear regressions nonsignificant or significant at P<0.05, 0.01, 0.001, respectively.

Larger bushes usually yield more flowers (Grdiša et al., 2009), and according to data from this study, it seems that more vigorous plants yielded more and at the same time, they did not reach the size that could lead to significant lodging.

The values of morphological traits and yield obtained in this study showed that natural Dalmatian pyrethrum population could be used as a reproduction material for commercial growing but also it has a potential as a source of breeding material.

Financial analyses

Pyrethrum production costs are not presented separately for each ecotype because the technology and material consumption were uniform. Total expenses for pyrethrum plantation establishment for all three ecotypes are presented in the Table 4 and the expenses of regular production in the Table 5.

In the first establishment phase the major expense reaching 50% of total expenses is for seedlings acquirement (0.04 €/seedling). Next input is a value of organic fertilizer. Labour expenses with mechanization cover 35%, and human labour 9% of total establishment expenses (Table 4).

From total expenses in a year of regular production, the majority is accounted to labour with mechanization which is expected considering the mechanized harvesting. In the human labour cost structure, the major share is accounted to crop maintenance (92%), while from material inputs, the highest value is for organic fertilizer (51% of all input costs). Amortization of the plantation shared 21% of total annual costs (Table 5). Financial analyses based on costs of plantation establishment as well as of regular expenses, and considering the realized income for dry pyrethrum flowers was performed. Calculated production costs were similar to those calculated by Tóth et al. (2012) for Slovakian production. Their total production costs varied for different ecotypes from 1,520 to 2,473 €/ha.

In the second year of pyrethrum production, in which the first harvesting occurred, the lowest yield of dry flowers was achieved for the ecotype 3 (546.2 kg/ha), while the ecotype 1 achieved the highest yield (792.1 kg/ha) as seen in Table 2. Production price in that year was 2.32-3.36 €/kg (Table 6). Considering the market price of

Table 4. Expenses of pyrethrum plantation establishment

Costs	Unit	Quantity	Price (€/unit)	Value (€)
1. Labour with mechanization				1,227.91
1.1. Fertilisation	hours	9	22.67	204.03
1.2. Tillage	hours	16	20.00	320.00
1.3. Plantation	hours	20	17. 33	346.60
1.4. Crop maintenance	hours	22	16.24	357.28
2. Human labour				312.42
2.1. Plantation	hours	40	4.67	186.80
2.2. Crop maintenance	hours	26.9	4.67	125.62
3. Input costs				2,005.83
3.1. Seedlings	hours	44,444	0.04	1,777.76
3.2. Organic fertilizer	t	10	20.00	200.00
3.3. Pesticides	kg	15	1.87	28.05
Total expenses				3,546.16

Table 5. Production costs in a year of regular production

Costs	Unit	Quantity	Price (€/unit)	Value (€)
1. Labour with mechanization				756.25
1.1. Fertilization and tillage	hours	12.8	16.00	204.80
1.2. Crop maintenance	hours	8.8	17.21	151.45
1.3. Harvesting	hours	10	40	400.00
2. Hand labour costs				517.90
2.1. Crop maintenance	hours	101.7	4.67	474.94
2.2. Flowers processing	hours	9.2	4.67	42.96
3. Input costs				169.00
3.1. Organic fertilizer	kg	300	0.29	87.00
3.2. Pesticides	kg	30	1.87	56.10
3.3. Packaging	piece	50	0.53	26.50
4. Amortization	ha	1	394.02	394.02
Total expenses				1,837.17

2.2 €/kg in both production years, for dry flower in the second production year all three ecotypes of pyrethrum operated with loss (from 94.64 €/ha for the ecotype 1 to 635.62 €/ha for the ecotype 3) (Table 6).

In the third production year, or the second harvesting year, higher yields were realized in respect with the previous year, especially for the ecotypes 2 and 3, therefore for all three ecotypes a positive financial result was realized. The highest yield of 1,284.2 kg/ha was realized for the ecotype 3 which resulted with the profit of 987.98 €/ha (Table 6). The positive financial threshold yield of dry pyrethrum flower was 836 kg/ha.

Table 6. Revenue and net returns per hectare for three pyrethrum ecotypes

	Year	Ecotype		
		1	2	3
Production price of dry flowers (€/kg)				
	2003	2.32	2.48	3.36
	2004	2.07	1.95	1.43
Price of dry flowers on the Croaotian market (€/kg)		2.20	2.20	2.20
Revenue respecting the price on the Croatian market (€/ha)				
	2003	1,742.62	1,629.10	1,201.64
	2004	1,951.84	2,075.26	2,825.24
Profit or loss (€/ha)				
	2003	-94.64	-208.16	-635.62
	2004	114.58	238.00	987.98

Given the relatively high cost of hand labour operations (crop maintenance and flowers processing) compared with general maintenance and harvesting operations, one way of substantial increase in profit would be to reduce the need for hand labour. Perhaps more emphasis in research should be placed on this area rather than on the enhancement of crop yields as a mean of increasing pyrethrum production efficiency. Labour cost was the principal item also in the economic analysis of pyrethrum production in Slovakia (Tóth et al., 2012) and they concluded that innovative solutions for agricultural engineering elements, including harvesting, pyrethrum drug content and breeding are needed in order to achieve profitable intensive production.

CONCLUSIONS

This study provides information about possible use of Croatian pyrethrum ecotypes in production and for future plant-breeding programs for agricultural utilization. There were no significant differences in yield between the three tested wild pyrethrum ecotypes and the measured values of studied plant attributes are not a limiting factor for mechanical cultivation and picking. Vegetative propagation leads to genetic uniformity, which can offer many advantages in agricultural practices, but over the time, clonal populations become more susceptible to diseases, pathogens, and unexpected environmental stresses due to exhaustion of genetic variability (Grdiša et al., 2013). Contrary to existing cultivars, the natural Dalmatian pyrethrum populations maintain a broad genetic variability, an important factor for the adaptability to diverse environmental conditions, and resistance to diseases and pathogens resistance. These plant genetic resources could be used to expand the genetic base of the commercial varieties and alleviate their genetic vulnerability risk to biotic and abiotic stresses, and ensure their sustainability (Grdiša et al., 2013). Three ecotypes used in this study represent valuable biological resources, and there are prospects for its use in production of novel, more robust genotypes as well as in polyploidisation processes.

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