Rapid communication

Effect of soil type on pyrethrum seed germination

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Abstract: Pyrethrum (*Tanacetum cinerariifolium* (Trevir.) Sch. Bip.) is an autochthonous insecticidal plant from Dalmatia (Croatia). It is commercially grown worldwide with a particularly fast expansion in Africa and Australia (Tasmania) and used as a natural insecticide. The study was conducted in Istria, Croatia, in a greenhouse, to determine the effect of soil type on the germination of pyrethrum seeds. The effect of different soil types on the germination of pyrethrum was found to be highly significant. The highest percentage of germination was found on white clay loam (soil type 2), and the lowest on red clay Terra Rossa (soil types 1 and 6). Seed germination was greatly influenced by soil texture, foremost silt percentage, and soil pH. The present study suggests that pyrethrum seed germination is best on slightly alkaline clayey loams with moderate nutrients. Positive correlation was confirmed among germination percentage and silt content and soil pH.

Key words: Croatia, germination, pyrethrum, soil characteristics, *Tanacetum cinerariifolium* (Trevir.) Sch. Bip.

Introduction

Pyrethrum (*Tanacetum cinerariifolium* (Trevir.) Sch. Bip.) is a perennial plant of the Asteraceae family native to the Dalmatian coast of Croatia. This plant is cultivated worldwide for the extraction of the natural insecticide pyrethrin (Casida and Quistad 1995; Benić Penava 2012). Pyrethrum is a highly effective insecticide, environmentally sensitive, effective, and in ready supply; it is considered as a 21st century insecticide. Today the principal producers of pyrethrum flowers in the world are Kenya and Tasmania (Li *et al*. 2011). The development of alternative methods that are not chemical applications is necessary in pest management for the sake of human health and for the safety of the environment (Jafarbeigi *et al.* 2012). The demand for natural insecticides (Ertürk *et al*. 2004; Ebadollahi 2013) as well as the demand for pyrethrum as a botanical insecticide is rising rapidly in the world market (Andreev 2008; Li 2011). Its powder is prepared from dried flower heads. This powder has been used as a natural insecticide for centuries in traditional Croatian farming systems (Biankini 1881; Kolak *et al*. 1999). Pyrethrum is endemic to the East coast of the Adriatic Sea (Grdiša *et al.* 2009) and there are wild populations both in North (Istria) and South (Dalmatia) Adriatic. This indigenous Dalmatian plant was the leading export article in the interwar (First and Second World Wars) period in coastal Croatia (Benić Penava 2012). Although originally from Dalmatia and showing great productive potential (Benić Penava 2012), pyrethrum is not exploited commercially today in Croatia. Recent attempts to encourage commercial pyrethrum production in Croatia are ongoing, especially in the light of the development of organic farming (Benić Penava 2012). Evidence that pyrethrum has been studied and cultivated in Istria for about a hundred years (Rossi 1924; Gioseffi 1929) points to its natural production potential. In the paper Rossi (1924) published in one of the first world journals of agriculture, "Istria Agricola" (published from 1907), it is documented that pyrethrum was commercially cultivated in the North Adriatic islands (Lošinj and Cres) and the first attempts to cultivate it in Istria were promising. In the same journal, in 1929, Gioseffi describes the results of cultivation in Poreč, Western Istria, and highlights the potential for an increase in production. Moreover, in an old 1924 map found in the Institute's archives in Poreč, it is recorded that pyrethrum was planted as a trial field. Istria is a peninsula with a 3,476 km^2 surface and great soil type diversity (Lončar 2005). Based on geomorphology, Istria can be divided into three zones: red Istria (western and southern coasts with a red-brown soil type), Grey Istria (Central Istria with grey soils) and White Istria (eastern coast, and Učka mountain slopes with rocky soils) (Gluhić 2005; Lončar 2005). So far, pyrethrum in Istria has been grown on the red clay soil, Terra Rossa, typically found in the Mediterranean, developing on $CaCO_3$ rocks with good drainage properties (Irmak and Aydemir 2008). The influence of different soil types on the germination and growth of pyrethrum has never been investigated. Therefore, this study intends to determine the effect of soil types in Istria, on the germination of pyrethrum.

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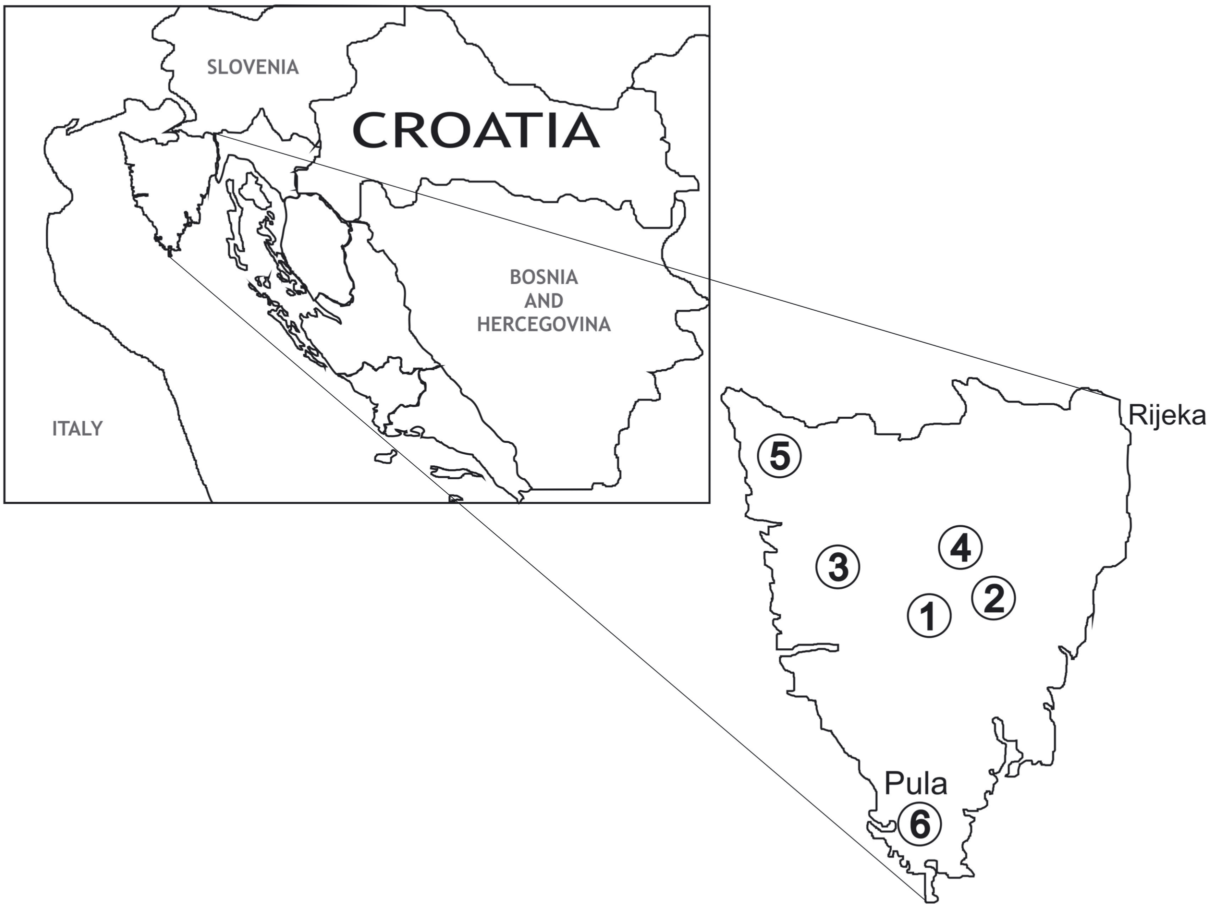

Fig. 1. Sampling locations in Istria (Croatia)

Germination efficacy is generally related to specific ecological conditions. The key to successfully growing pyrethrum lies in having adequate climate, soil, and propagation material (Benić Penava 2012). It is reported that seed quality and germination are variable and are a determining factor for successful production (Li 2011). A pyrethrum crop is established by direct seeding or by planting in the fields as seedlings. Direct seed sowing is not very successful for a number of reasons including the very small size of the seeds with low and uneven germination and the slow growth of the seedlings (Vasisht 2001). Previous studies reported that pyrethrum germination is influenced by light, hydro priming, and abiotic stress, but few studies about soil-type-effect on pyrethrum have been performed (Salardini 2001; Kulkarni 2005; Ahmed and Khan 2010; Li 2011). Most of these studies have been carried out on the nutritional requirements and their adequate amount for optimal plant growth (Vasisht 2001). However, there is a scarcity of information dealing with the effects of soil texture, pH, and the amounts of gravel and calcium carbonate in the soil on pyrethrum seed germination (Wandahwa and van Ranst 1995).

Materials and Methods

Freshly matured seeds of pyrethrum collected in June 2012 from an experimental field in Poreč, Croatia (4°13′N 13°37′E, 20 m ASL), and originally from wild populations in Dalmatia (Ban *et al*. 2010) were used in this study. The seeds had no impurities and were stored in paper bags at room temperature, in darkness. Six-month-old seeds were used in the experiments.

Soil samples used were collected at six locations in Istria representing the typical soil types (three locations on red clay (Terra Rossa soil), two clayey loam soils, and one sandy clayey loam soil) (Fig. 1). Sampling was done according to a zigzag layout (Pennock *et al.* 2006) on the surface soil layer (depth 0–15 cm). One composite sample was obtained by mixing five individual soil samples taken from the zigzag layout. Approximately 1 kg of composite sample was dried in the air and used for the further mechanical and chemical soil analyses. Mechanical soil analysis, total carbonates, $CaCO_3$ and CaO determination, physiologically active lime, pH value and percentage of organic matter analyses were performed according to Škorić (1982) at the Soil Laboratory of the Institute of Agriculture and Tourism in Poreč using the mechanical analysis method.

One hundred pyrethrum seeds for each soil type were seeded singularly in multiple containers in controlled conditions in three replicates. The control was seeded in the potting media usually used in greenhouses (contents: 20% white and 80% black moss, 1,600 g of mineral fertiliser NPK/m^3, 200g/m^3 of microelement for common greenhouse production). Germination was recorded 14 days after seeding. The percentage of germination was recorded for each treatment. The experiment was carried out in the greenhouse in Central Istria under conditions

Table 1. Mechanical composition and chemical characteristics of six soils representing six soil types

Sample no.	Soil type	Clay [%]	Silt [%]	Sand [%]	pH in water	pH in KCl	N total [%]	P accessible [mg P_2O_5/100 g soil]	K accessible [mg K_2O/100 g soil]	Organic matter [%]	Total carbonate	CaO [%]
1	Red clay	35	28	36	6.34	6.14	0.28	7.31	45	2.74	0	0
2	Clayey loam	37	41	21	7.72	7.59	0.08	4.5	11.4	0.84	37	26.05
3	Clayey loam	35	28	34	7.4	7.4	0.33	3.65	23	4.44	2.9	3.8
4	Sandy clay loam	30	22	47	7.44	7.29	0.27	10.74	40	2.56	11.3	5
5	Red clay	50	14	36	6.68	5.03	0.16	3.8	27.5	1.32	0	0
6	Red clay	48	13	38	6.99	6.61	0.11	1	7.6	0.67	0	0

of natural photoperiod, and at a temperature of 21–22°C. This greenhouse is commercially used for seedlings production and the experiment was carried out under the usual propagation conditions.

The final germination percentage (FGP**)** was calculated as follows:

$$FGP = N_i/N \times 100,$$

where: N_i – number of germinated seed till i-th day, N – total number of seeds.

A completely randomised design with three replications was used in the experiments. All data was analysed by SPSS v.17.0. Analysis of variance (ANOVA) was used to compare treatment effects, and the Tukey test ($p < 0.05$) was used for the significant differences of the means. The correlation analysis among germination percentage and soil parameter was used to determine the correlation and to calculate coefficients; their significance was calculated by analysis of variance (F-test), and the t-test. The strength of the correlation based on the calculated coefficients was determined by the Roemer Orphal scale (Vasilj 2000).

Results and Discussion

Six soil samples represented the typical Istrian soil types. Three of the soil samples represented the most widespread soil in Istria – Terra Rossa or red clays (Soils 1, 5, and 6), two clayey loams (Soils 2 and 3), and one sandy clay loam (Soil 4). Soil characteristics are presented in table 1.

The study revealed that pyrethrum germinated on all samples. The percentage of germinations were not very high and varied significantly ($p < 0.05$) in different soil types (Fig. 2). Breeding programmes have obtained pyrethrum seeds with a germination capacity of 80% (Fulton *et al.* 2001), while wild population seeds have a lower germination capacity. Generally, breeding programs are primarily directed at increasing the concentration of active compounds (Singh and Sharma 1989). So far, experiments have shown that total pyrethrins content of natural Dalmatian pyrethrum are lower than those obtained from commercial selected varieties (Ban *et al*. 2010; Grdiša 2013). Still, those natural populations have benefits such as increased production, and also widen the genetic base for breeding efforts, and fight genetic uniformity and vulnerability (Rauf *et al.* 2010). Maximum germination in our investigation occurred in one of two clayey loams (Soil 2).

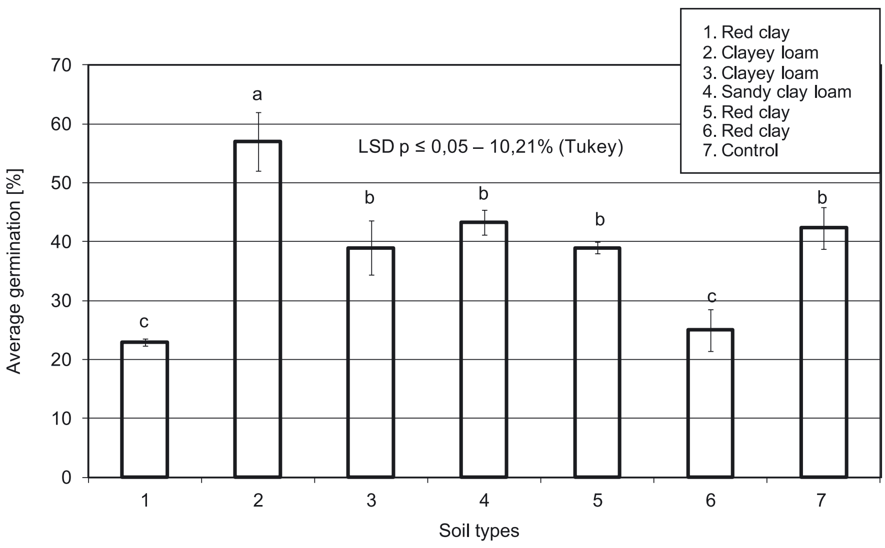

Fig. 2. The percentage of germinations in different soil types

Table 2. Correlation analysis of the pyrethrum germination and soil parameters

Pearson's correlation	*Sig. p ≤ 5%	R^2 (Correlation coefficient)	t (Model)	T (Tabelar value)	*Sig. p ≤ 5%
Clay [%]	0.118	–0.571	–1.392	3.173	0.236
Silt [%]	0.020*	0.831*	2.992	2.530	0.040*
Sand [%]	0.166	–0.484	–1.105	3.038	0.331
pH	0.017*	0.966*	6.500	6.425	0.008*
N total	0.439	0.082	0.164	3.214	0.878
P accessible [mg P_2O_5/100 g soil]	0.145	0.520	1.218	3.833	0.290
K accessible [mg K_2O/100 g soil]	0.217	0.389	0.869	3.370	0.434
Organic matter [%]	0.439	0.108	0.218	4.140	0.838
Total carbonate	0.226	0.549	0.929	7.667	0.451
CaO [%]	0.225	0.551	0.933	7.810	0.449

*Significant difference for p ≤ 5%

On the other hand, red clays (Soils 1 and 6) showed lower germination percentages than other soils and the control (Fig. 2).

Correlation analysis showed that soil texture, especially silt percentage, is linearly correlated to the germination of pyrethrum (Table 2). From chemical soil parameters, the pH value significantly influenced germination of pyrethrum. Soil acidity proved to be relevant with a preference for slightly alkaline soils. This was also found by Wandahwa and Van Ranst (1995), and the Pyrethrum Board of Kenya recommends soils with a pH above 5.6 for pyrethrum.

Australia and Tasmania are currently one of the most developing pyrethrum production areas in the world. In Australia and Tasmania, the best soils for pyrethrum production are volcanic loams (Red Ferrosol) and clay loams (Dermosols) (Gray and Murphy 2002) which are similar in some properties to Istrian soils: well drained, clay loams (Soil 2) with the presence of free iron oxide (Soils 1, 5, and 6). The difference is in the pH and carbonates; volcanic soils tend to be slightly acidic, while Terra Rossa is calcareous and thus with a neutral pH (Durn 2003). In Croatia, natural populations of pyrethrum are found on hard limestone substrate (Mihovilović 2005; Grdiša *et al.* 2013). Traditionally pyrethrum was grown in Croatia on karstic soils, well drained and with moderate fertility (Kolak *et al*. 1999). Our investigation proved that the most suitable soils for pyrethrum germination in Istria are white clay loams which are similar to Dermosols. Karstic light soil is usually described as the preferred soil type for pyrethrum (Kolak *et al*. 1999), but this is not in accordance with this study.

Moderate nutrients contents are preferred. Further research is needed to investigate the possible influence of free iron oxides on pyrethrum, present both in Istrian Terra Rossa and Australian Ferrosol.

Salardini (2001) states that phosphorus is very important for pyrethrum growth. Present experiments show that nutrient quantity and organic matter are not among the most relevant soil parameters for germination.

Conclusions

In conclusion, the present study suggests that pyrethrum seeds germinate best on slightly alkaline clayey loams with moderate nutrients. Positive correlation was confirmed among the germination percentage and silt content and soil pH.

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