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Yield of green mass, grain and other yield components of field pea (*Pisum sativum* L.) in dependence of agroecological conditions and seed maturity

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Summary

The goal of the research was to determine the influence of two locations (Osijek and Vinkovci) and seed age on field germination, vegetative mass and dry matter of vegetative mass yields, grain yield, 1000 grain weight and grain crude protein yield of foreign spring field pea cultivar (Timo) during two successive years (2004 and 2005). The year has significantly influenced the grain yield, and the location influenced the grain yield and 1000 grain weight. In the first year of research, the greater grain yield by 70 % was accomplished on Osijek location, and in the second year it almost doubled. 1000 grain weight was by 19 % greater in the second year of research on Osijek location in relation to Vinkovci location. The same cultivar seed stored for 9 and 21 months were sown on both locations in the second year of investigation. Field germination of 9 month old seed was for 12.1 % greater than 21 month old seed. Seed maturity and location interaction was significant (p=0.05) for vegetative mass yield, dry matter of vegetative mass yield, grain yield and grain crude protein yield.

Key words: field pea, agroecological conditions, yield, seed maturity

Introduction

Field pea green mass yield, which is used in domestic animal feeding, depends on the high number of genetic and agrooecological factors (Popović et al., 1997; Lecoeur and Sinclair, 2001; Egli, 2004). Page and Duc (1999) and Uher et al. (2008) state that the pea green mass and grain are important resources of proteins. In relation to soybean, pea has less concentration of grain proteins (20-30 %), as Uher et al. (2010) and Yamauchi and Minimikawa (1998) indicate. However, pea can accomplish grain yields from 4 t ha^{-1} or more, so it is a good replacement for soybean on soils which do not have economical justification for soybean cultivation (Popović et al., 1997). Furthermore, Marohnić (2006) claims some of the advantages of pea over soybean (simplest production, simplest storage of the grain which does not contain oils and direct consummation without any preliminary treatment). Because of its relatively high content of crude protein and starch, legume grain is a valuable food for any kind of cattle. Pea grain is remarkable concentrate of protein and energy for dairy cows feeding (Vander Pol et al., 2008) because of its higher energy value (1.2) than soybean flour. Quantity and distribution of precipitation during the vegetation period are of crucial significance for green mass and grain forming because this culture has great requests for moisture. Duthion and Pigeaire (1991) note that high temperatures during the summer from June to July,

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which is in stage of pod development in agroecological conditions in eastern Croatia have a negative effect. In that way the temperatures over 26 °C in the stage right after the flowering may significantly decrease grain yield because they cause flower deterioration (Popović et al., 2002). The quality of the seed used in sowing (Van Assche and Leuven, 1988) influences, beside environmental factors, the pea green mass and grain yield. The vigour of the pea seed is very variable and it depends on the range of factors, one of which is the seed age. Saxena et al. (1987) emphasize that the increase of pea storage period results in the decrease of the germination percent. The goal of this study was to determine the influence of agroecological conditions and seed age on the field germination, green mass and dry matter of vegetative mass yield, grain yield, 1000 seed weight and grain crude protein yield of field pea.

Materials and methods

In this research the Swedish spring cultivar "Timo", selected for the production of voluminous forage, which seed is available on the Croatian market, was used. The field experiment was conducted on two locations of eastern Croatia during 2004 and 2005. On Osijek location the soil was classified as eutric brown, and on Vinkovci location as semigley. The chemical characteristics of soils are represented in Table 1.

The weather conditions on both locations during vegetation for both years of research and the long-term averages (1984-2003) are displayed in Table 2. The experiment was placed according to the random block scheme in four repetitions. The size of basic plot was 25 m^2. The sowing was hand-made with 20 cm space between rows and 5 cm space in rows. The seed, which was produced in 2003, was sown on both locations in 2004.

Table 1. Chemical characteristics of soils
Tablica 1. Kemijska svojstva tla

Location/Lokacija	pH		AL (mg/100g)		Humus
	H_2O	KCl	P_2O_5	K_2O	(%)
Osijek	7.80	7.33	36.4	43.59	2.19
Vinkovci	7.55	6.83	42.9	36.70	1.69

Table 2. The monthly means of air temperatures (°C) and monthly precipitation (mm) over 2004 and 2005 vegetations and many years average (1984-2003) in Osijek and Vinkovci
Tablica 2: Srednje mjesečne temperature zraka (°C) i mjesečne količine oborina (mm) tijekom vegetacija 2004. i 2005. godine, te višegodišnji prosjeci (1984.-2003.) u Osijeku i Vinkovcima

Month/Mjesec	Montly means of air temperatures Srednje mjesečne temperature zraka (°C)			Monthly precipitation Mjesečne oborine (mm)		
	2004	2005	Average Prosjek	2004	2005	Average Prosjek
Osijek						
April/Travanj	11.7	11.5	11.6	137.1	55.3	51.0
May/Svibanj	14.6	17.0	17.1	65.0	46.1	62.6
June/Lipanj	19.2	19.5	19.9	78.6	112.0	84.0
July/Srpanj	21.5	21.5	21.7	43.3	170.8	57.9
Vinkovci						
April/Travanj	12.1	11.3	11.9	110.0	40.3	51.9
May/Svibanj	14.9	17.1	17.0	100.9	24.4	56.1
June/Lipanj	19.5	19.8	19.8	71.2	93.4	82.5
July/Srpanj	21.7	21.6	21.7	98.9	149.8	54.5

Table 3. Dates of sowing, field emergence, beginning of flowering and harvest of field pea seed at investigated locations in 2004 and 2005

Tablica 3. Datumi sjetve, nicanja, početka cvatnje i žetve sjemena stočnog graška na ispitivanim lokacijama za 2004. i 2005. godinu

Location/Lokacija	Osijek		Vinkovci	
Year/Godina	2004	2005	2004	2005
Sowing/Sjetva	1.04.	7.04.	2.04.	8.04.
Field emergence/Poljsko nicanje	21.04.	21.04.	22.04.	22.04.
Beginning of flowering/Početak cvatnje	4.06.	31.05.	5.06.	1.06.
Harvest/Žetva	21.07.	14.07.	22.07.	15.07.

The same seed was sown in 2005 (after 21 months of storage in air-dry storage) as the seed produced in 2004 (after 9 months in air-dry storage). The fertilization was not conducted on neither of the two locations during the research. The mechanical weed protection was implemented by requirement. The dates of sowing, field germination, the beginning of flowering and seed harvesting are shown in Table 3. The aboveground mass samples were taken in the flowering stage from the area of 2 m^2 from all repetitions. After weighting, the samples were dried to constant weight in the oven at 105 °C and the content of dry mass of samples (%) was determined. Green mass and dry mass yields were converted in t ha^{-1}.

Grain yield (t ha^{-1}) and 1000 grain weight (g) were qualified after the harvest. Crude protein content in grain of different age pea was defined according to Weende (Kjeltec autosampler 1035-Tecator) during 2005 and from the values of the protein content and grain yield, crude protein yield was calculated and converted in kg ha^{-1}. ANOVA and t-test were conducted in SAS 9.1 (SAS Institute Inc., 2002-2003).

Results and discussion

In agroecological conditions in eastern Croatia, spring pea could be sown already in February because the minimal temperature for seed germination is 1 to 2 °C. However, the pea is usually sown in March or as soon as the soil moisture allows because the soil moisture is the most common limiting factor. In both years of research the sowing was not conducted until the beginning of April because of the higher amount of precipitation in the period from January to March. The seed was sown in wet soil, but the oversized amount of precipitation in April, of the first year of cultivation, did not influence the field germination which was slightly greater than that in the second year of cultivation (Table 4). In the second year of research, the difference between the locations was barely 0,9 %, while the difference between locations was 3,0 % in average for both years of research. Generally, obtained values were mainly in accordance with the range (75.9 % to 85.5 %) which was quoted from the International Seed Testing Association (ISTA, 1993).

By the research of location influence and seed age on field germination in 2005 (Table 5), it was concluded that sowing of the 21 months old seed field germination on both location was lesser in relation to germination of the 9 month old seed. That confirmed the fact that the incensement of pea storage period results in the decrease of germination percent (Saxena et al., 1987; Rapčan et al., 2006). Forage cultivar "Timo" reaches the larger or lesser green mass yield in dependence of agroecological conditions of production. Borreani et al. (2007) notice that pea cultivation on dairy farms could improve self-sufficiency regarding the forage rich in proteins. Namely, by increasing the normative of the pea including, the content of crude protein portion is increased, so the pea silage could partly replace grass silage of intermediate-quality in dairy cow feeding (Salawu et al., 2002). In this experiment, green mass yield was from 46.19 to even 73.01 t ha^{-1}, in dependence of location and seed age (Table 5), which is somewhat higher than the values which other authors, have acquired for pea (Hoffman and Dér, 2003; Tekeli and Ates, 2003). Significant difference in green mass yield was not found by comparing both years of research. In the second year, significant interaction ($p=0.05$) between seed

age and location was determined, the largest green mass yield was obtained by sowing older seed on Vinkovci location. In climatic condition of 2005, field cultivar "Timo" had established more grain (p=0.01) and somewhat less green mass in relation to the first cultivation year. It can be concluded that somewhat lesser amount of precipitation and its adverse distribution have not specially damaged this cultivar. During the whole vegetation, pea has large demands towards moisture.

Coefficient of transpiration is from 300 to 600, in dependence of cultivar. In 2004 in the pea vegetation period (April - July) on Osijek location there was totally 324 mm of precipitation (long-term average 254 mm), and on Vinkovci location 381 mm (long-term average 245 mm). The second year of research was wet as well, when in Osijek there was totally 383.4 mm and in Vinkovci 307 mm of precipitation, but May was dry with only 46.1 mm in Osijek, and in Vinkovci 24.4 mm of precipitation. Green mass and dry mass yield of field pea, as well as 1000 grain weight, were not probably influenced by this dry period. By testing the seed age and location on green mass yield of field pea, the interaction of these two factors (p=0.05) can be seen, as shown in Table 5. The lesser green mass yield (for 13.65 t ha^{-1}) on both locations was obtained by sowing the 9 month old seed. Green mass yield was, in average, for seed age on Vinkovci for 4.1 t ha^{-1} larger than on Osijek location.

Table 4: Influence of year and location on tested traits of field pea
Tablica 4: Utjecaj godine i lokacije na istraživana svojstva stočnog graška

Location/Lokacija - B	Year of sowing/Godina sjetve - A		
	2004		2005
	Field germination/Poljsko nicanje, %		
Osijek	88.00		86.00
Vinkovci	83.75		85.25
LSD 0.05	A: ns	B: ns	AxB: ns
0.01	ns	ns	ns
	Vegetative mass yield/Prinos zelene mase, t/ha		
Osijek	56.20		55.26
Vinkovci	57.87		46.19
LSD 0.05	A: ns	B: ns	AxB: ns
0.01	ns	ns	ns
	Dry matter of vegetative mass yield/Prinos suhe tvari nadzemne mase, t/ha		
Osijek	9.52		9.36
Vinkovci	10.08		7.77
LSD 0.05	A: ns	B: ns	AxB: ns
0.01	ns	ns	ns
	Grain yield/Prinos zrna, t/ha		
Osijek	0.93		3.42
Vinkovci	1.58		1.78
LSD 0.05	A: 0.5027	B: 0.2991	AxB: 0.5556
0.01	0.9228	0.4532	0.9345
	1000 seed weight/Masa 1000 zrna, g		
Osijek	128.25		132.25
Vinkovci	131.25		111.00
LSD 0.05	A: ns	B: 6.2261	AxB: 12.7282
0.01	ns	ns	21.6539

Table 5: Influence of seed age and location on tested traits of field pea in year 2005
Tablica 5: Utjecaj starosti sjemena i lokacije na istraživana svojstva stočnog graška u 2005. godini

Location /Lokacija - B	Seed age/Starost sjemena - A	
	21 months/21 mjesec	9 months/9 mjeseci
	Field germination (Poljsko nicanje), %	
Osijek	76.75	86.00
Vinkovci	76.00	85.25
LSD 0.05	A: 0.4326	B: ns AxB: ns
0.01	0.6553	ns ns
	Vegetative mass yield/Prinos zelene mase, t/ha	
Osijek	55.74	55.26
Vinkovci	73.01	46.19
LSD 0.05	A: ns	B: ns AxB: 22.5628
0.01	ns	ns ns
	Dry matter of vegetative mass yield/Prinos suhe tvari nadzemne mase, t/ha	
Osijek	9.30	9.36
Vinkovci	12.50	7.77
LSD 0.05	A: ns	B: ns AxB: 3.7007
0.01	ns	ns ns
	Grain yield/Prinos zrna, t/ha	
Osijek	3.42	3.42
Vinkovci	2.82	1.78
LSD 0.05	A: ns	B: 0.4420 AxB: 0.9364
0.01	ns	0.6696 ns
	1000 seed weight/Masa 1000 zrna, g	
Osijek	140.00	132.25
Vinkovci	128.75	111.00
LSD 0.05	A: ns	B: 8.6334 AxB: ns
0.01	ns	13.0789 ns
	Grain crude protein yield/Prinos sirovih bjelančevina zrna, kg/ha	
Osijek	827.92	887.26
Vinkovci	734.68	478.44
LSD 0.05	A: ns	B: 115.5760 AxB: 244.3142
0.01	ns	175.0879 ns
	Milk quantity/Količina mlijeka, kg/ha	
Osijek	11314.9	12125.9
Vinkovci	10006.9	6538.7
LSD 0.05	A: 358.8002	B: 104.8124 AxB: 363.9595
0.01	658.6273	158.7820 646.8972

Obtained pea grain yields (Table 5) were in range from 0.93 to 3.42 t ha^{-1}, which is, in dependant of cultivar and weather, common during the pea vegetation in eastern Croatia (Popović et al., 2002). Al-karaki (1999) reported similar range (1.95 to 3.24 t ha^{-1}) while Rapčan et al. (2006), Uher (2006) and Uher et al. (2010) state somewhat larger yields.

Significantly (p=0.01) lager grain yields (for 1.34 t ha^{-1}), which is in synchrony with the reference in literature (McPhee and Muehlerbauer, 1999) were made, because the weather conditions in the second year of study were on both locations more favourable for grain production of this culture. On Osijek location, in average for both years of research, the green yield of 2.18 t ha^{-1} was obtained, which is for 29.76 % greater than that on Vinkovci location. Significant influence of location and year on this property, as well as interaction between tested factors (p=0.01), is represented in Table 4. The air temperature is, with sufficient amounts and favourable distribution of precipitation, of special significance for obtaining the high grain yield, particularly during pea flowering. Optimal average day air temperature for pea flowering is in range from 15 to 18 °C. Temperatures above 26 °C in stage immediately after flowering decrease grain yield because of the flower falling. In first 10 days after flowering in 2004 sum of the average day air temperatures on Osijek location was 198.2 °C (maximum temperature sum 249.7 °C), and on Vinkovci location 153.4 °C (maximum temperature sum 200 °C). It can be concluded that the high air temperatures in 2004 have additionally decreased grain yield, based on this temperature sums, which is more considerable on Vinkovci location. High temperature as an environmental factor, on which pea is sensible, is stated by other authors (Salter, 1963; Ridge and Pye, 1985; Jeuffroy et al., 1990).

During 2005 (Table 5), grain yield of different aged seed was not distinguished on Osijek location, while the older seed produced 1.04 t ha^{-1} more grain than the younger on Vinkovci location. The interaction between the seed age and the location was significant on probability level p=0.05 because the seed age did not cause the yield change in Osijek, while in Vinkovci it did. However, by comparing the grain yields obtained by sowing seed produced in 2003, seed sowed in 2005, thus after 21 moths of storage (Table 5), gave more than two times greater yield than in 2004 (sowed after 9 months of storage). It could be concluded that the genetic potential of fertility of cultivar "Timo" in favourable agroclimatic condition of production is still considerably accomplished even after longer storage period.

Dry matter of vegetative mass yield was not significantly different between years or between locations (Table 4). As older seed (21 months of storage) produce more vegetative aboveground mass (Table 5), so was the quantity of dry matter of the same mass larger (for 2.33 t ha^{-1}) in relation to younger seed (9 months of storage). Interaction between location and seed age was found by analysis of this property on significant level p=0.05 because older seed had produced for 4.73 t ha^{-1} more than younger seed on Vinkovci location.

Different cultivars of pea have a 1000 grain weight in range of 130 to 350 g, but the cultivars for green mass have a smaller seed and those for grain have a bigger seed (Rapčan, 2002; Tawaha and Turk, 2004). According to some researches, the seed size is the most stable component of the yield (Ayaz et al., 2004). The location has significant influence on this property (p=0.05), while the year and location interaction were of high significance (Table 4), because the 1000 grain weight was for 20.25 g smaller in 2005 than in 2004 on Vinkovci location. In dependence of agroecological conditions of cultivation and seed age, the 1000 grain weight of field cultivar "Timo" was from 111.0 to 140.0 g (Table 5), with significant difference between locations (p=0.05). Uher et al. (2006b) found somewhat smaller 1000 grain weight (109.8 to 110.5 g). Based on the recent researches it can be concluded that pea could be used like an alternative resource of protein and energy in dairy cow feeding (Melicharova et al., 2008). As pea contains more than 20 % of crude proteins in grain, for high-producing cow feeding, they are being used in amount of 2 to 3 kg per day in form of concentrated ingredient as a replacement for protein supplement or barley grain (Christensen and Mustafa, 2000; Masoero et al., 2006), soybean flour and corn grain (Vander Pol et al., 2008) or soybean (Corbett et al., 1995; Liponi et al., 2007). Petit et al. (1997.) claim that disregarding of pea in meals for cows in early lactation did not have a useful effect on milk production. Grain protein yield of field pea was very significant influenced by the loca-

tion (p=0.01) in the second year of research (Table 5). Older seed had a bigger protein yield for 98.45 kg ha^{-1}, which confirms that the duration of storage period did not significantly influence the genetic potential of this cultivar. In numerous researches, it was confirmed that nitrogen concentration, thus protein concentration, in grain varies in independence on year and location between and within pea genotypes (Igbasan et al., 1996; Lecoeur and Sinclair, 2001; Atta et al., 2004; Wang and Daun, 2004). Protein yield was in range from 478.44 to 887.26 kg ha^{-1} during 2005 in dependence of seed age and location. On Vinkovci location, significantly (p=0.01) lesser amounts of proteins were obtained (606.56 kg ha^{-1}) in relation to Osijek (857.59 kg ha^{-1}). Significant interaction between seed age and location on significance level p=0.05 was found by analysis of this property. Seed age did not significantly influence crude protein yields on Osijek location, while the older seed was richer with proteins for 256.24 kg ha^{-1} in relation to younger on Vinkovci location. Determined grain yields of pea cv. "Timo" potentially satisfies demands for production of milk with 4 % of milk fat and 3.4 % of protein in kg ha^{-1}. Namely, obtained grain yields satisfy demands for production of 6538.7 to 12125.9 kg ha^{-1} of milk. Uher et al. (2010) found similar range of potential milk quantity. Milk production would be significantly different (p=0.01) between crops obtained with sowing of different aged seed and between crops sowed on different locations. Potentially the largest milk production would give the 9 month old seed on Osijek location, and the smallest the seed of the same age on Vinkovci location.

Conclusions

Based on obtained results of field research during two years on two locations, it could be concluded that climate conditions do not in large proportion influence all tested parameters of the field pea grain yield and quality. In the second year of research, only the grain yield was significantly larger, while the grain yield and 1000 grain weight were larger on Osijek location in average for two years. By the examination of influences of seed age and location during 2005, significantly larger values for field germination and somewhat smaller for grain yield by sowing 9 month old seed were obtained. Grain yield, 1000 grain weight and protein yield were significantly larger on Osijek location in the same year in average for seed age. Seed of cultivar "Timo" in age of 9 months would satisfy demands for the largest milk production on Osijek location.

Prinos zelene mase, sjemena i ostalih komponenata uroda stočnog graška (Pisum sativum L.) u zavisnosti od agroekoloških uvjeta i starosti sjemena

Sažetak

Tijekom 2004. i 2005. godine istraživan je utjecaj agroekoloških uvjeta i starosti sjemena na poljsko nicanje, prinos zelene mase i suhe tvari nadzemne vegetativne mase, prinos zrna, masu 1000 zrna i prinos sirovih bjelančevina zrna inozemnog jarog stočnog kultivara graška (Timo) na dvije lokacije istočne Hrvatske (Osijek i Vinkovci). Godina je značajno utjecala na prinos zrna, a lokacija na prinos i masu 1000 zrna. U prvoj godini istraživanja ostvaren je za 70 % viši prinos zrna na lokaciji Vinkovci, dok je u drugoj godini gotovo dvostruko viši prinos zrna ostvaren na lokaciji Osijek. Masa 1000 zrna u drugoj godini istraživanja bila je za 19 % veća na lokaciji Osijek, a interakcija godine i lokacije značajna. Sjeme istog kultivara skladišteno 9 i 21 mjesec posijano je na obje lokacije u drugoj godini istraživanja. Poljsko nicanje sjemena starog 9 mjeseci bilo je za 12,1 % više od poljskog nicanja sjemena starog 21 mjesec na obje lokacije. Interakcija starosti sjemena i lokacije bila je značajna (p=0,05) za prinos zelene mase i suhe tvari nadzemne vegetativne mase, prinos zrna, te prinos sirovih bjelančevina zrna.

Ključne riječi: stočni grašak, agroekološki uvjeti, prinos, starost sjemena

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