Productivity Indicators of Five Safflower Cultivars (*Carthamus tinctorius* L.) Grown Under Lushnja, Albania, Climatic Conditions

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Abstract

The study on the productivity indicators of five safflower cultivars was conducted during two consecutive years, 2011-2012, in Lushnja, Albania. A randomized complete block design with five safflower cultivars, 3 replications and plot size of 5 m^2/variant in each replication, were used. Flower heads were harvested on full seed maturity, and from seeds there were determined the protein content (%), fatty acid content (%), moisture content (%), and fibre content (%). There were observed significant differences on total yield (kv/ha) and in biochemical indicators (protein, fatty acid, and fibre content). The highest yield was measured for "Espheau" (20.87 kv/ha), while the lowest yield was measured for "Guaimaro" (15.08 kv/ha). Protein content varied from 15.41 to 17.19%, fatty acid content varied from 28.11 to 22.77%, fibre content varied from 25.01 to 29.24%, and moisture and volatile substances content varied from 6.31 to 7.1%. The highest protein content was measured for "Ruggero" (17.19%), the highest fatty acid content was measured for "Guaimaro" (32.77%), and the highest fibre content was measured for "Espheau" (29.24%). There were not observed significant differences between cultivars on the moisture content. "Bellisario", "Ruggero" and "Espheau" can be recommended for cultivation in lowland of Albania.

KEYWORDS: fatty acid content, fibre content, indicator, protein content, safflower, yield.

INTRODUCTION

Safflower (*Carthamus tincttiorius* L.) is one of the world's oldest crops, highly branched, herbaceous, thistle like annual herb. It belongs to the *Asteraceae* Family of the *Composites* broad group. The safflower is a warm temperature crop, originated from Southern Asia, cultivated all over the world (Knowles, 1969), from tropical Asia, Africa (Oyen & Umali, 2007) and Australia (Knights *et al*., 2001), to Europe (Çamaş *et al*., 2007) and USA (Oelke *et al*., 1992). In Albania, there is grown as a native plant the species *Carthamus lanatus* L. (Demiri, 1971; Bardhi *et al*., 2007). The color of flower varies from white, light yellow, yellow to red orange. It is known as *alazor*, *American saffron*, *bastard saffron*, *benibana*, *benibana flower*, *cártamo*, *carthame*, *false saffron*, *hing hua*, *honghua*, *huile de carthame*, *kusumbha*, *kardi*, k*ussum*, etc. The color of flower varies from whitish yellow to red orange, the most common being deep yellow. Safflower flowers contain two pigments, red (*carthamin*), which is insoluble in water, and yellow (*carthamidin*), which is soluble in water and mainly used as a dye and as a natural food colorant (Machewad *et al.*, 2012). The alkaline extracts were used for dyeing silk, wool, cotton and paper, to make the pigment in the state of the precipitate and ancient Chinese manufactured and produced it as red paint for cosmetics (Wouters *et al*., 2010). Two parts of the safflower are primarily used: the flower itself and safflower seeds. Safflower (*Carthamus tinctorius* L.) has been grown for centuries, primarily for its colorful petals to use as a food coloring and flavoring agent, for vegetable oils and also for preparing textile dye in the Far East, Central and Northern Asia and European Caucasian. There is a growing interest in the use of natural dyes in textile coloration. On the other hand, the stringent environmental standards are imposed by many countries. Eco-friendly and biodegradable dyes derived from natural resources have emerged as important alternative to synthetic dyes. Safflower petals contain about 30% yellow pigment and 0.83% red pigment (Nagaraj, *et al*., 2001; Kulkarni *et al*., 2001). Safflower pigments are widely used as stain, additive in beverages, desserts, and cosmetics, printing and dyeing (Wang & Lijie, 2001). Traditionally safflower was grown for its flowers, which were used as a fabric dye, a food dye and medicinal purposes. A wide range of colors, expensive dyes were used to dye the analyzed silk yarns, coccid dyestuffs, madder, weld, young fustic, tannins and an indigoid dye were identified in a 16th century tapestry. Moreover, the use of safflower has been assessed for the first time in a European fabric (Degano *et al*., 2011). Today, mainly seeds are used for different purposes: as a high quality edible, for receiving an industrial and domestic oil, as a bird feed, fish feed, pig feed, as a forage for ruminants, etc (Knowles, 1989; Mayntz, 2013; Corleto et al., 1997; Guangwei & Dayue, 1999). Safflower seeds contain 35-45% oil, 15-20% protein and 35-45% hull fraction. Vegetable oil is one of the fundamental components in foods and has important functions regarding human health and its nutritional physiology. The demand for vegetable oils for food purposes has entailed a considerable expansion of oilseed crops all over the world (Corleto *et al*., 1997; GRDC, 2010). Particularly, consumers have demanded healthier oils, naturally low in saturated fat such as olive, safflower, canola and sunflower oils. Safflower has been received a lot of publicity recently, not so much for its colorful petals, but because it is hailed as one of the most important sources of vegetable oils. In the US diet, safflower oil has been frequently substituted for oils with higher saturated fat content, as monounsaturated fat may have a beneficial effect on the risk of coronary heart diseases. Some clinical studies have shown that safflower oil supplementation may be helpful in patients with cystic fibrosis, Friedreich's ataxia, and neurotoxicity from lithium. In traditional Chinese medicine, safflower is used for promoting blood circulation, removing blood stasis, amenorrhea (absence of mensturation), cardio vascular diseases pain, and traumatic injuries. It is also used to "calm" a live fetus and abort a dead fetus, and is therefore used cautiously during pregnacy (Healthline, 2013). Many Chinese medicines are prepared by using dried flowers and extract of flowers. Now-a-days the medicinal uses of flowers in China have become known to the rest of the world. These medicinal preparations have been widely accepted which helps in increasing the demand for the safflower petals. Choi *et al*. (2004) have found that safflower polyphenols have the effect of improving blood lipid status via increasing HDL-cholesterol formation and

cholesterol excretion without significant uterotropic action in estrogen-deficient animals, while Moon *et al*. (2001) have found that supplementation of SSE or SSW is very effective in improving the atherogenic risk factors in high-cholesterol fed rats. Herbel *et al.* (1998) have shown that addition of safflower oil to the diet significantly reduced the plasma total cholesterol and LDL-cholesterol concentrations. Safflower pigments are safe for food and have curative effects on diseases such as lack of oxygen coronary heart diseases, myocardial infarction, cerebral thrombosis and renal thrombosis etc (Shouchun et al., 1993).
Safflower has attracted significant interest as an alternative oil seed due to its high adaptability for dry climatic conditions with little precipitation and saline soils (Bassil & Kaffka, 2002). This plant is considered as a drought tolerant crop which is capable of obtaining moisture from levels not available to the majority of crops (Oelke *et al.*, 1992; Çamaş *et al*., 2007). Safflower can also be grown successfully on soil with poor fertility and in areas with relatively low temperatures, but the introduction of a new crop to a regional cropping system requires information concerning its performance under local environmental conditions. In Albania, the safflower cultivation has just started with a small area under cultivation, but there is a perspective, especially in hilly and dry areas, as spring or winter plants, since there are very suitable climate conditions (Bardhi *et al*., 2007). Among the biomass resources, vegetable oils seem to have the highest potential to be used as fuel alternatives for diesel engines (Isiĝigür et al., 1993).

MATERIAL AND METHODS

Experimental design. The study was conducted during two consecutive years, 2011-2012, in Lushnja, in the central part of Albania. The plot was situated in a plane land with a sloping gradient from 1% to 2%, and a planting density of 133330 plants ha^{-1} (50 cm x 15 cm). A randomized complete block design (RCBD) with five safflower cultivars, 3 replications and plot size of 5 m^2, containing 67 safflower plants for variant in each replication, were used. The total experiment size was 75 m^2. No irrigation possibilities existed in the plot and no irrigation was conducted throughout the whole experimental period. The climate in Lushnja and all over Albania was dry in the summer with a typical Mediterranean distribution of precipitation from autumn to spring. The mean climatic data for the period January 2011-December 2012 were collected in the field by the researchers (Table 1).

Table 1. Climatic data for Lushnja, Albania, for the period January-December 2012

Climatic data	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Temperature (^oC)												
Ist decade	8.8	8.2	9.6	13.2	16.8	21.0	23.5	25.8	23.2	19.1	14.5	10.2
IInd decade	8.2	9.1	10.6	14.0	18.4	22.1	24.7	25.3	21.2	17.6	14.1	9.8
IIIrd decade	8.0	9.4	12.4	15.4	19.47	23.8	25.2	23.8	20.4	16.1	11.4	9.4
Rainfall (mm)												
Ist decade	43.8	23.7	31.2	22.7	19.3	15.2	12.1	6.4	13.8	31.8	48.6	40.6
IInd decade	46.5	52.8	30.8	33.9	18.4	16.1	11.2	14.1	23.5	29.4	50.5	38.7
IIIrd decade	28.1	27.9	32.7	27.8	27.2	8.4	9.1	14.9	18.6	29.3	35.1	47.8
Humidity (%)												
Ist decade	58	53	55	53	56	49	44	41	47	48	59	60
IInd decade	57	58	56	57	53	48	43	41	47	51	61	61
IIIrd decade	51	54	56	57	51	45	44	43	47	49	57	61

Plant material. Five safflower cultivars originated from Italy, "Bacum", "Ruggero", "Espheau", "Belisario", and "Guaimaro", were used. Sowing was performed on March 15 with a sowing rate of 15 kg ha^{-1}, while the heads harvest was performed on July 30, at the full seed maturity. Samples of each cultivar, containing ten safflower plants, chosen randomly, for each cultivar on each replication, were measured and monitored to collect experimental data, such as plant height (cm), number of branches per plant, number of heads per plant, 1000 seeds weight (g), and total seed yield (kv ha^{-1}). Flower heads were harvested on full seed maturity and, from seeds of each cultivar on each replication, there were determined the protein content (PC) (%), fatty acid content (FAC) (%), moisture and volatile substances content (MVSC) (%), and fibre content (FC) (%).

Biochemical analyses

The seeds of each cultivar and replication were oven-dried at 40°C for 4 hours, using a ventilated oven, up to a moisture content of about 5%, and were then ground with a Waring blender. The safflower powder was used for protein and fatty acid content determination.

Protein content (PC) ***(%).*** Protein purification was performed using non-ionic detergents (0.2-0.5 M NaOH), as it is described by Roger *et al.* (2004) and Ersson *et al.* (2011), since NAOH is a good storage agent that combines solubilizing activity with prevention of endotoxin formation. A sample of 1 g of safflower powder was poured in the digestion apparatus, was added 15 g potassium sulphate, 1 g $CuSO_4$ * $5H_2O$ and 25 ml concentrated H_2SO_4. After two heating sessions in 120°C, solution was left in room temperature for 2 hours, taking care not to be hardened. Later, the solution was poured into the distiller tube test, using distilled water in minimal amount. Add into the expectant Erlenmeyer 25 ml H_2SO_4 0.1N, 100 ml distilled water and 2-3 drops red methyl. Pass through the test tube 100-110 ml NaOH 32% for 10-11 seconds and gurgle water steam until in the Erlenmeyer will be 250 ml solution. Erlenmeyer solution will be titrated with NaOH 0.1 N, until the solution will get straw color. Protein content (%) was calculated by formula:

$$PC\ (\%) = \frac{[(V_1 \times N_1) - (V_2 \times N_2) \times 0.014 \times 100 \times 6.25]}{m}$$

Where: V_1 = H_2SO_4 0.1N volume (ml), N_1= normality factor for H_2SO_4, V_2 = NaOH solution used for titration (ml), N_2 = normality factor of NaOH used for titration, and m = sample weight (g).

Fatty acid content (FAC) ***(%).*** Fatty acid content was determined according to the AOCS method (AOCS, 2009; Barthet & Dawn, 2004). A sample of 4 g of dried safflower seeds was superfine crashed, was poured in a filter bag and was extracted with petroleum ether for 6 hours in a Soxhlet system (B.Chi Universal Extraction System B-811, Germany). The oil extract was evaporated by distillation at a reduced pressure in a rotary evaporator at 40°C until the solvent was totally removed. The oil was extracted 3 times from a 2 g of air-dried seed sample by homogenization with hexane/isopropanol, 3:2 (v/v).

Moisture and volatiles content (MVC) ***(%).*** Moisture content was determined as it is described by ISTA (2007) and MoAFCP (1988). A sample of 10 g safflower seed powder was put in oven and heated at 130°C for 90 minutes, and was left in room temperature. After cooling, the sample was re-weighted. The difference between the first weight and the second one, expressed in %, was the sample moisture content.

Fibre content (FC) ***(%).*** Fibre content was determined according to the AOCS method (AOCS, 2009). A sample of 1 g from the sample used previously for moisture content determination was poured in a filter bag and was treated as above for fatty acid extraction. Then was treated with 360 ml H_2SO_4 0.26N and was boiled for 30 min. After that, the solution was rinsed 2-3 times with hot distilled water and was re-boiled for 30 min, after adding KOH 0.23N. Solution was rinsed again with hot distilled water until in the presence of some drops phenylphtaleine will get pink color. Rinsed filters were dry for 2 hours at 130^{o}C, were re-weighted, were poured into porcelain container and were put in the oven for 4 hours more at 600^{o}C. After cooling, filter bags were re-weighted and was calculated fibre content according to the formula:

$$FC\ (\%) = \frac{[(f' - f) - (k' - k)]}{m} \times 100$$

Where: f' = weight of filter with the residue, f = empty filter weight, k'= container weight with residue, and k = empty container weight, 100 for percentage, and m = sample weight.

Statistical analyses. The data were object of ANOVA and differences among cultivars were tested using LSD test (Papakroni, 2001).

Biochemical analyses were carried out at the Microbiology Lab of the Agriculture Faculty at the University "Fan S. Noli" Korçë and at the Lab of "Olim" Company.

RESULTS AND DISCUSSION

Morphological (vegetative)characters and total yield of safflower cultivars. The obtained data showed that there were significant differences between cultivars for the main vegetative characters. The mean plant height (cm) varied from 115.1 cm for "Ruggero" up to 163.1 cm for "Esepheau"; the mean number of branches per plant varied from 8.7 branches per plant for "Guaimaro" up to 10.7 branches per plant for "Bellisario"; the number mean of heads per plant varied from 15.1 heads per plant for "Guaimaro" up to 27.5 heads per plant for "Esepheau"; the mean 1000 – seeds weight (g) varied from 31.53 g for "Esepheau" up to 50.35 g for "Guaimaro", while the mean total seed yield (kv ha^{-1}) varied from 13.8 kv ha^{-1} for "Ruggero" up to 20.9 kv ha^{-1} for "Esepheau" (Table 2).

Table 2. Morphological (vegetative) characters and total yield (kv ha^{-1}), according to safflower cultivars (different letters indicate significant difference at $P<0.05$).

Safflower cultivar	Plant height (cm)	Number of branches per plant	Number of heads per plant	1000 – seeds weight (g)	Seed yield (kv ha^{-1})
Bacum	118.8 c	10.5 a	23.5 b	41.75	17.9 b
Ruggero	115.1 c	10.4 a	21 b	44.33 b	13.8 c
Espheau	163.1 a	10.5 a	27.5 a	31.53 c	20.9 a
Bellisario	128.02 b	10.7 a	24.2 b	46.09 b	18.8 b
Guaimaro	117.8 c	8.7 b	15.1 c	50.35 a	15.1 c

There was found a strong right correlation between the plant height and the seed yield (r = 0.83), between the number of branches per plant and the number of heads per plant (r = 0.88), and between the number of heads per plant and seed yield (r = 0.8), while there was found a medium correlation between the plant height and the number of branches per plant (*r* = 0.7) (Table 3 and Figure 1). The data were similar to some previous reports (Çamaş *et al*., 2007; Arslan, 2007; Arslan & Küçük, 2005; Bassil & Kaffka, 2002; Baydar & Turgut, 1999).

Table 3. Correlation between morphological characters of safflower cultivars under Lushnja, Albania, climate conditions

	PH (cm)	*NBP*	*NHP*	*SY (kv/ha)*
Plant height (cm)	1			
Number of branches per plant	0.314346	1		
Number of heads per plant	0.710699	0.87954376	1	
Seed yield (kv/ha)	0.828184	0.48983295	0.80714	1

Previous reports have found that the highest seed yield of safflower cultivars ranged from 1168 to 3325 kg ha^{-1} (Ada, 2012; Azari & Khajehpour, 2005; Çamaş *et al*., 2007), thus, the lowest and the highest yields observed in the current study, were somewhat similar to those founds.

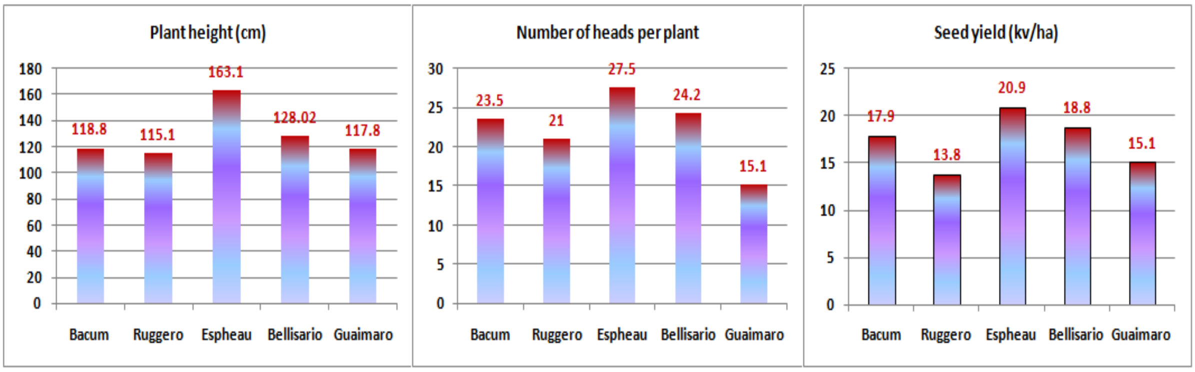

Figure 1. The plant height (cm), the number of heads per plant, and the seed yield (kv ha^{-1}) of five safflower cultivars grown under Lushnja, Albania, climate conditions.

Protein content (PC) (%). The observed data showed that for protein content (%) there were created two groups with significant differences. The highest mean protein content was observed for ”Ruggero” by 17.19% (group a), while for group b, the mean protein content varied from 15.41% for “Guaimaro” to 15.75% for “Bellisario” (Table 4 and Figure 2).

Fatty acid content (FAC) (%).The obtained data showed that there were significant differences between cultivars for the fatty acid content. The highest fatty acid content was observed for “Guaimaro” by 32.77%, followed by ”Bellisario” by 31.92%, while the lowest fatty acid content was observed for “Bacum” by 28.11% (Table 4 and Figure 2). Fatty acid content was higher than it was reported in some previous reports (Arslan, 2007; Coşge *et al*., 2007; Vosoughkia *et al*., 2011; Gecgel *et al*., 2012) where was found that fatty acid content of different safflower varieties was affected by sowing time and variety. Fatty acid content in those reports for different varieties ranged from 24.53% to 28.47% in winter sowing and from 21.23% to 25.76% in spring sowing. Environmental factors such as soil and climatic ones have played an important role in change of fatty acid composition and temperature is the most important factor affecting fatty acid composition (Baydar & Turgut, 1999). The obtained data showed that safflower cultivars express very good productivity characters (protein content and fatty acid content) under Lushnja, Albania, climate conditions.

Moisture content (MC) (%). The obtained data showed that there were not significant differences between cultivars for the moisture content and the seed moisture content was lower than the lowest accepted level (8%). Moisture content varied from 6.31% for "Ruggero" up to 7.1% for "Guaimaro" (Table 4 and Figure 2), which means that all these safflower cultivars have appropriate climate conditions in Lushnja and surrounded areas.

Fibre content (FC) (%). There were observed significant differences between cultivars for fibre content. Fibre content varied from 25.01% for "Guaimaro" up to 29.24% for "Espheau" (Table 4 and Figure 2).

Table 4. Protein content, fatty acid content, fibre content, and moisture content of different safflower cultivars under Lushnja climate conditions (different letters indicate significant difference at $P<0.05$).

Safflower cultivars	Biochemical characteristics			
	PC (%)	FAC (%)	MVC (%)	FC (%)
Bacum	15.65 b	28.11 c	6.51	27.05 b
Ruggero	**17.19 a**	30.64 b	6.31	25.4 c
Espheau	15.47 b	29.61 b	6.86	**29.24 a**
Bellisario	15.75 b	31.92 a	6.96	27.84 b
Guaimaro	15.41 b	**32.77 a**	**7.1**	25.01 c

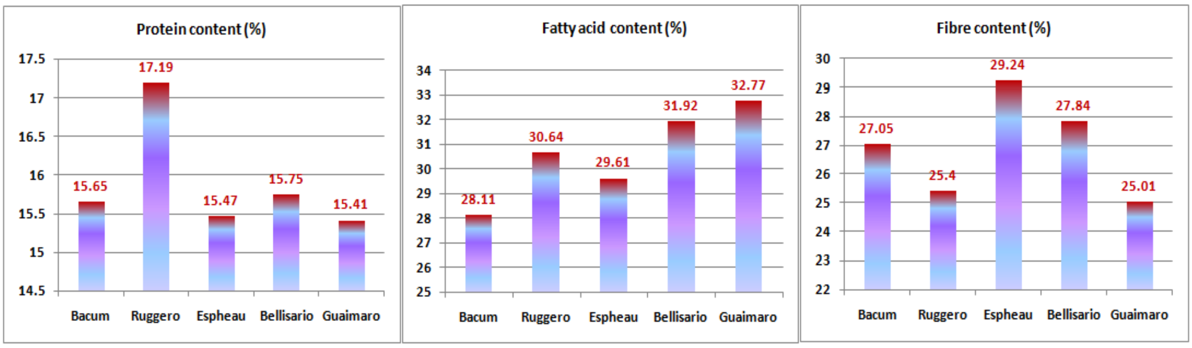

Figure 2. Protein content (%), fatty acid content (%), and fibre content (%) of five safflower cultivars grown under Lushnja, Albania, climate conditions.

CONCLUSIONS

The observed data indicated that the morphological characters, such as plant height, number of branches per plant, number of heads per plant, 1000-seeds weight, and biochemical seed characters, such as protein content, fatty acid content and fiber have been affected significantly by the cultivars. Five safflower cultivars showed generally a very good adaptation to the central Albania climate conditions. High values of oil content and seed yield must encourage the introduction and cultivation of this plant in Albania. Among the investigated cultivars, "Bellisario" seems to be the most appropriate cultivar with high seed yield (18.78 kv ha^{-1}), high protein content (15.75%), high fatty acid content (31.92%), relatively high moisture content (6.96%), and high fibre content (27.84%), followed by "Ruggero" with high protein content

(17.99%), high fatty acid content (30.64%), low moisture content (6.31%), and low fibre content (25.41%). Cultivar "Espheau" showed the lowest protein content (15.47%), relatively low fatty acid content (29.61%), relatively high moisture content (6.86%), and high fibre content (27.84%), but the highest seed yield (20.87 kv ha^{-1}). Cv. "Bellisario", "Ruggero" and "Espheau" can be recommended for cultivation in different locations across central and western part of Albania, since they showed significantly high yield performance and oil content.

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