THEORETICAL AND PRACTICAL ASPECTS OF THE INTRODUCTION OF SAFFLOWER (*Carthamus tinctorius* L.) IN THE REPUBLIC OF MOLDOVA

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Abstract. *Carthamus tinctorius* L. (safflower) is an oilseeds plant and high potential crop because of multipurpose utilization. However, this plant has not been cultivated in the Republic of Moldova until now. The purpose was the evaluation of the biological and production potential of safflower in the eco-geographical area of the Republic of Moldova, during the vegetation season of 2015. This season was characterized as hotter and dryer compared to the entire period of meteorological observations because of high temperatures (2.2…3.3ºC higher than the normal) and 100…200 mm lower rainfall amounts. There were determined various morphological properties of spineless safflower varieties such as its dynamics of growth, plant height, branches per plant; time to abundant flowering, duration of flowering, heads per plant, seeds of different category per plant, weight of seeds collected from one plant, 100-seed weight. The vegetation period of safflower plants grown without irrigation from germination to complete maturity was 135 days. The number of inflorescences per plant varied in limits 5…39 (the mean was equal to 13.16). Approximately 83% of the experimental plants had approximately 3.73 undeveloped inflorescences. Safflower plant produced on average 314.38 white, shiny and smooth seeds, which were split into two categories: the first - seeds having length and diameter more than 0.7 cm and 0.4 cm respectively; and the second category - other seeds. 100-seed weight of the first and the second category seeds was 3.28±0.48, respectively 2.59±0.45g. The seed extracts contained 68.86±2.49 mg of polyphenols per g dry residue of extract and possessed antioxidant activity. The obtained results will serve as practical basis for introducing a new valuable species of plants in the agriculture of the Republic of Moldova.

Keywords: safflower, field, growth phases, seeds.

Rezumat. Aspecte teoretice şi practice de introducere a şofrănelului (*Carthamus tinctorius* L.) în Republica Moldova. *Carthamus tinctorius* L. (şofrănel) este o specie de plante oleaginoase şi de cultură de perspectivă ţinând cont de utilizarea multifuncţională. Cu toate acestea, până în prezent, această plantă nu se cultivă în Republica Moldova. Scopul a fost evaluarea potenţialului biologic şi de producţie a şofrănelului în zona eco-geografică a Republicii Moldova, în sezonul de vegetaţie al anului 2015. Acest sezon a fost caracterizat ca cel mai cald şi secetos pe parcursul întregii perioade de observaţii meteorologice, din cauza temperaturilor ridicate (cu 2,2...3,3ºC mai ridicate faţa de normal) şi a cantităţii de precipitaţii mai reduse cu 100...200 mm. Au fost determinate caracterele morfologice ale soiului fără spini de şofrănel, cum ar fi dinamica de creştere, înălţimea plantelor, lăstarii laterali pe plantă, timpul până la faza de înflorirea abundentă, durata de înflorire, inflorescenţe pe o plantă, seminţe din diferite categorii pe o plantă, masa seminţelor colectate de la o plantă, masa a 100 de seminţe. Perioada de vegetaţie a plantelor de şofrănel cultivate fără irigare de la germinare până la maturitate completă a fost de 135 zile. Numărul de inflorescenţe pe plantă a variat în limite de 5...39 (media a fost egală cu 13,16). Aproximativ 83% dintre plantele experimentale au avut aproximativ 3,73 inflorescenţe nedezvoltate. Planta de şofrănel a produs în medie 314,38 de seminţe albe, lucioase şi netede, care au fost separate în două categorii: prima - seminţe având o lungime şi un diametru mai mare de 0.7cm şi respectiv 0,4 cm, şi a doua categorie - alte seminţe. Masa a 100 de seminţe din prima şi a doua categorie a fost 3,28±0,48 şi respectiv 2,59±0,45g. Extractele de seminţe au conţinut 68,86±2,49mg de polifenoli per un g de reziduu uscat al extractului şi posedau activitatea antioxidantă. Rezultatele obţinute vor servi drept bază practică pentru introducerea unei noi specii valoroase de plante în agricultura Republicii Moldova.

Cuvinte cheie: şofrănel, câmp, faze de creştere, seminţe.

INTRODUCTION

Carthamus tinctorius L. (safflower), an annual plant of the family Asteraceae or Compositae, is an oilseeds plant traditionally cultivated in Central Asia, India and North Africa. In southern European countries, safflower was introduced in the 16th century from Egypt and it gradually spread to Eastern and Western Europe countries (Germany, Hungary, Romania, and Russian Federation). Many researchers reported that safflower was a very perspective crop because of multipurpose utilization. Red and yellow pigments from safflower petals are used as natural food colorants, oil from seeds is edible (MATTHAUS et al., 2015) and serves as raw material for biodiesel (PĂTRĂŞCOIU et al., 2013), biologically active compounds are extracted for pharmaceutical medicines and diet supplements (YU et al., 2013; ZHOU et al., 2014). Using the secondary metabolites from flowers and seeds of safflower some new pharmaceutical preparations was obtained (KHARISOVA, 2014). The phenolic compounds are contained in all the anatomical organs of the plant, but the greatest number was detected in flowers (JIANG et al., 2008). Due to the high concentration of phenolic compounds, safflower possesses a wide spectrum of biological activity, including antioxidant, analgesic, anti-inflammatory and antidiabetic activities (RAMMAL et al., 2009; YU et al., 2013). Safflower could become an alternative of other oilseeds such as sunflower, crop which suffers greatly in droughty seasons. The oil content of the safflower seeds is similar to that of olive and includes linoleic acid (63…72%), oleic acid (16…25%) and linolenic acid (1…6%) (ZUBKOV et al., 2014; GAUTAM et al., 2014). The economic significance of safflower seeds depends on the eco-geographical area of plant cultivation and various qualitative and quantitative characters. SHINWARI et al. (2014) reported that seed diameter, heads per plant and seeds per head have highly significant positive contribution to the seed yield of the plant. As *C. tinctorius* L. have not been cultivated in the Republic of Moldova, the main purpose of this research was to determine the biological characters and productivity of safflower by field introduction and growth in natural meteorological condition of the Republic of Moldova.

MATERIAL AND METHODS

Plant materials. Field experiments were carried out at the research field station of the Institute of Genetics and Plant Protection in Chisinau area of the Republic of Moldova (lat. 47°01', long. 28°75', alt. 85 m above sea level), in the season of 2015. Safflower seeds have been sowed in the last decade of March, the experiment consisting of 100 seeds in 5 repetitions; plants were grown in poor, dry soil, without irrigation.

The morphological characteristics of safflower plants have been studied according to AHMADZADEH (2013), namely plant height (m), number of inflorescences per plant, number of seeds per plant, 100-seed weight (g), seed yield (number or g).

The total polyphenolic content in seeds has been determined by Folin-Ciocalteu procedure (SINGLETON et al., 1999) and calculated in gallic acid equivalent, in mg per g of fresh seed weight (FW).

The antioxidant activity of the seed extract was detected *in vitro* by potentiometric procedure (SANO et al., 2003), using 2.2'-azobis(2-amidinopropane) dihydrochloride as generator of reactive peroxyl ROO·radicals. The activity indexes of the extracts were expressed in gallic acid equivalent (GAE), μMGAE per g of dry residue.

RESULTS AND DISCUSSIONS

Safflower seeds do not need stratification and germinated in field conditions during 10-15 days. After the germination of the seeds, the initial growth of the plants was slow during approximately 30-35 days, (Fig. 1 a). In this period, 18 to 25 leaves were produced at base stem. The introduced safflower was the spineless type of varieties. After that, the elongation of the stem and the appearance of branches started. The number of lateral branches ranged from 2 to 10 (Table 1). In mid-June, the stage of budding began and the height of the base stem of safflower plants in this period ranged between 33 and 78cm (Fig. 1 c). Each branch produced flowering heads commonly called capitula that have the composite type of inflorescence (Fig. 1 b).

The duration of the flowering phase was 30-5 days. The number of inflorescences per plant varied in limits 5…39; the mean value of character from the 100 plants was 13.16 (Table 1). Approximately 83% of the experimental plants had at mean 3.73 undeveloped inflorescences. The flowers were orange-red and enclosed by bracts in circular order (Fig. 1 b). In the Republic of Moldova, the vegetation season of 2015 was marked by high temperatures that were above normal by 2.2…3.3ºC and there were 100…200 mm less rainfall. Because of that, in the first decade of August, the safflower plants had dry yellow leaves (Fig. 1 d), but their deep root system allowed them to attain maturity and form achenes (Fig. 1 e) with seeds. In our experiments the safflower plant produced on average 314.38 white, shiny and smooth seeds (Fig. 1 f) having thick pericarp.

Table 1. Morphological characteristics of safflower plants.

Morphological characteristics per one plant	Plant height, m	Number of lateral branches	Number of inflorescence	Undeveloped inflorescence	Seed yield by category			
					category I		category II	
					number	g	number	g
Variation of characteristic	0.33-0.78	2-10	5-39	0-15	37-518	1.12-16.08	24-591	0.55-13.44
Mean per one plant	0.59	6.08	13.16	3.73	166.41	5.45	147.97	3.75

More than 60% of the experimental plants formed over 100 seeds per plant. The weight of 100-seeds was 2.94±0.07g on average. Our obtained data are in excellent agreement with the results presented by other scientists (KIZIL et al., 2008; AHMADZADEH, 2013; SHINWARI et al., 2014; KHAKI-MOGHADAM et al., 2015). Thus, the vegetation period of the introduced safflower was 135 days from germination to complete maturity in the season of 2015. Safflower plants grown without irrigation in drought climate conditions of this year have demonstrated high adaptive properties with good morphological characteristics and seed productivity. It is known that safflower seed size, length (shape), and density can potentially be used in selection techniques to improve seedling vigour while maintaining or improving the oil content.

Considering this fact, the collected plant seeds from each experimental were separated by category; category I – big, full seeds having length and diameter more than 0.7cm and 0.4 cm, respectively; and category II - other seeds. 100-seed weight of the first and the second category seeds was 3.28±0.48, respectively 2.59±0.45g. The distribution of the plant by number of collected seeds from one plant indicates that plants formed both categories of seeds. Most plants (66%) formed from 101 to 300 seeds of first category, and 42% - 101…300 seeds of the second category. We mention that 88…97% of the safflower plants formed up to 300 seeds of the first and the second category. The first category of safflower seeds was used for obtaining water-ethyl alcohol extracts and studying their polyphenolic content and antioxidant activity. Safflower seeds were grinded. The obtained powder was mixed with 70% water-alcohol solution in ratio of 1/10 without preliminary degreasing. The total polyphenolic content was determined as 68.86±2.49 mg/g dry residue of extract or 4.52±0.17 mg/g of fresh weight of seed. Total phenolic content of *C. tinctorius* seed extracts obtained by using soxhlet extraction method was equal to 126.0±2.4 mg/g dry weight (YU et al., 2013).

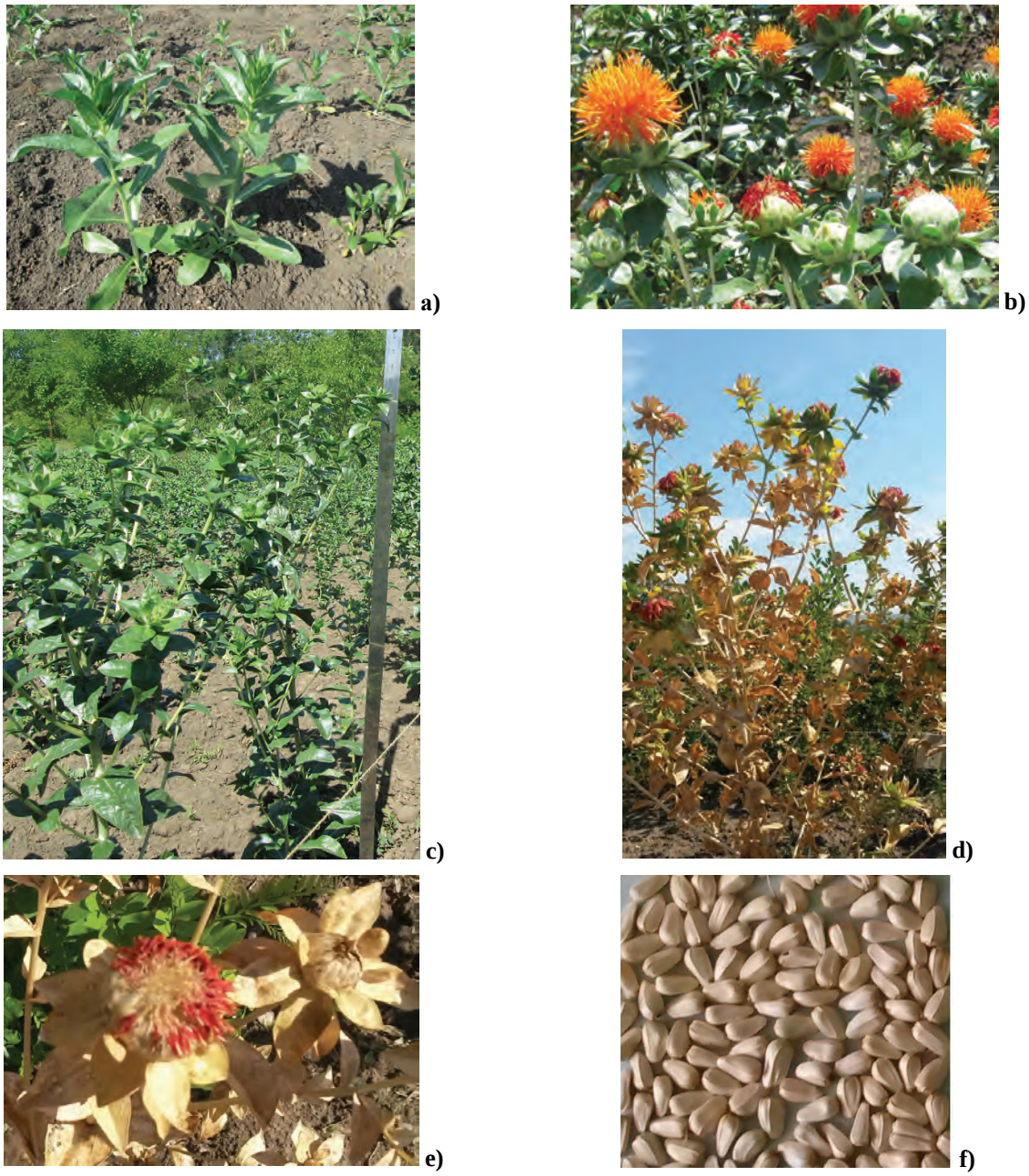

Figure 1. *Carthamus tinctorius* (original photos): a) plant in initial period of vegetation; b) flower; c) whole plant in budding period; d) whole plant in period of maturity; e) safflower achene; f) safflower seeds.

This determined index of leave extracts is 77.38±6.62 mg/g (KUSOGLU & KAHRAMAN, 2015), while the index of flower extracts equals 139.98±18.02 mg/g (KRUAWAN et al., 2006). Our results show that extracts from safflower seeds contained less polyphenolic compounds in comparison with the data reported by other researchers. Seed extracts possessed antioxidant activity equal to 137.70±20.12 µMGAE/g of dry residue; for comparison, the antioxidant activity of Milk thistle and fenugreek seed extract is 180.95±14.72 µMGAE/g and 23.80±0.21 µM GAE/g of dry residue (IVANOVA et al., 2015). In conclusion, this study has demonstrated the exceptional capacities of safflower plants for adaptation to drought conditions. These properties are reinforced by the biological characteristics and seed productivity. The obtained results will serve as practical basis for introducing a new valuable species of plants in the agriculture of the Republic of Moldova.

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REFERENCES

AHMADZADEH A. 2013. Genetic diversity and classification of spring safflower *(Carthamus tinctorius)* cultivars using morphological characters. *Advances in Bioresearch.* Edit. Society of Education. India. **14**(4): 125-131.

GAUTAM S., BHAGYAWANT S. S., SRIVASTAVA N. 2014. Detailed study on therapeutic properties, uses and pharmacological applications of safflower (*Carthamus tinctorius* L.). *International Journal of Ayurveda and Pharma Research*. Edit. Mahadev Publications. **2**(3): 5-16. http://www.ijapr.in/index.php/ijapr/article/view /237/223 (Accessed: February 12, 2016).

IVANOVA R., FLOREA V., MASCENKO N. 2015. Fenugreek (*Trigonella foenum-graecum* L.) as a potential new crop for the Republic of Moldova. *The scientific proceedings of the international network AgroBioNet "Agrobiodiversity for improving nutrition, health and life quality"*. Part I. Edit. University Publishing Center, Nitra, Slovak Republic: 289-293.

JIANG J. S., XIA P. F., FENG Z. M., ZHANG P. C. 2008. Chemical constituents from flowers of *Carthamus tinctorius*. *Chinese Materia*. *Medica.* Edit Zhongguo yao xue hui. Beijing. **33**(24): 2911-2913.

KHAKI-MOGHADAM A. & ROKHZADI A. 2015. Growth and yield parameters of safflower (*Carthamus tinctorius* L.) as influenced by foliar application under well-watered methanol and water deficit conditions. *Environmental and Experimental Biology*. Edit. University of Latvia. Riga. **13**: 93-97.

KHARISOVA A. V. 2014. *Pharmacognostical investigation of safflower* (*Carthamus tinctorius* L.). Ph. D. Thesis (pharmaceutical sciences), University of Samara. Russia. 360 pp.

KIZIL S., CAKMAK O., KIRICI S., INAN M. 2008. A comprehensive study on safflower (*Carthamus tinctorius* L.) in semi-arid conditions. *Biotechnology and Biotechnological Equipment.* Edit. Taylor & Francis Online. **22**(4): 947-953;; http://dx.doi.org/10.1080/13102818.2008.10817585 (Accessed: April 15, 2014).

KRUAWAN K. & KANGSADALAMPAI K. 2006. Antioxidant activity, phenolic compound contents and antimutagenic activity of some water extract of herbs. *Thai Journal of Pharmaceutical Sciences*. Edit Chulalongkorn University. Bangkok. **30**: 28-35.

KUSOGLU E. & KAHRAMAN S. 2015. Total phenolic content and radical scavenging activity of *Carthamus tinctorius* L. 2015. *International Journal of Electronics, Mechanical and Mechatronics Engineering.* Edit. Istanbul Aydın University. Istanbul. **5**(2): 943-947.

MATTHAUS B., ÖZCAN M. M., AL JUHAIMI F. Y. 2015. Fatty acid composition and tocopherol profiles of safflower (*Carthamus tinctorius* L.) seed oils. *Natural Products and Resources.* Edit. Taylor & Francis Online. **29**(2): 193-196. http://dx.doi.org/10.1080/14786419.2014.971316 (Accessed: October 20, 2014).

PĂTRĂȘCOIU M., RATHBAUER J., NEGREA M., ZELLER R. 2013. Perspectives of safflower oil as biodiesel source for South Eastern Europe (comparative study: Safflower, soybean and rapeseed). *Fuel*. Edit. Elsevier. **111**: 114–119. http://dx.doi.org/10.1016/j.fuel.2013.04.012. (Accesed: 2013).

RAMMAL H., YOUNOS C., BOUAYED J., CHAKOU A., NECERBEY N., SOULIMANI R. 2009. Apercu ethnobotanique et phytopharmacologique sur *Carthamus tinctorius* L. *Phytotherapie*. Edit. SPRINGER. **7**: 28–3. doi:10.1007/s10298-008-0361-8 (Accessed March 8, 2009).

SANO M., YOSHIDA R., DEGAWA M., MIYASE T, YOSHINO K. 2003. Determination of peroxyl radical scavenging activity of flavonoids and plant extracts using an automatic potentiometric titrator. *Journal of Agricultural Food Chemistry*. Edit. American Chemical Society Publications, Washington. **51**(10): 2912-2916.

SHINWARI Z. K., REHMAN H., RABBANI M. A. 2014. Morphological traits based genetic diversity in safflower (*Carthamus tinctorius* L.). *Pakistan Journal of Botany.* Edit. Pakistan Botanical Society, Karachi. **46**(4): 1389-1395.

SINGLETON V. L., ORTHOFER R., LAMUELA-RAVENTOS R. M. 1999. Analysis of total phenolics and other oxidation substrates and antioxidants by means of Folin-Ciocalteu reagent. In: *Methods in Enzymology. Oxidants and Antioxidants. Part A.* Edit. Lester Packer. New York, USA. **299**: 152-178.

YU S. Y., LEE Y. J., KIM J. D., KANG S. N., LEE S. K., JANG J. Y., LEE H. K., LIM J. H., LEE O. H. 2013. Phenolic composition, antioxidant activity and anti-adipogenic effect of hot water extract from safflower (*Carthamus tinctorius* L.) seed. *Nutrients.* Edit. MDPI, Basel. **5**(12): 4894-4907.

ZHOU X., TANG L., XU Y., ZHOU G., WANG Z. 2014. Towards a better understanding of medicinal uses of *Carthamus tinctorius* L. in traditional Chinese medicine: a phytochemical and pharmacological review. *Ethnopharmacology*. Edit. Elsevier Sequoia. Amsterdam. **151**(1): 27-43.

ZUBKOV V. V., MILYOKHIN A. V., KURKIN V. A., KHARISOVA A. V., PLATONOV I. A., PAVLOVA L. V. 2014. Prospects of safflower seeds oil in food and pharmaceutical industry. *Bulletin of the Samara Scientific Center*. Edit. Russian Academy of Sciences, Samara, Russia. **16**(5(3)): 1135-1139.

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