INFLUENCE OF AGROECOLOGICAL FACTORS ON ARTICHOKE YIELD AND QUALITY: REVIEW

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Abstract
Environmental conditions and climate change on a global scale affect the overall agriculture and food supply. Globe artichoke (Cynara cardunculus var. scolymus (L.) Fiori) is widely distributed all over the world. Immature inflorescence, commonly called capitula or head, is used in human consumption. These vegetables are a good source of human health promoting components. Artichokes are widely used in human diet, characterized by low protein and fat, high content of minerals, vitamins, inulin, carbohydrates and polyphenolic compounds. Relationship between plant growth and development is tight and complicated. Many agroecological factors, such as temperature, irrigation and fertilization level, planting and harvesting date, influence processes of growing and development of globe artichoke. Biologically active compounds in plants are dependent on climate conditions, seasonal changes, cultivar properties and maturity. Pre-germination is required for better plant establishment in the field. Better plant growing and development can be ensured by regular irrigation which provides 85 – 100% from evaporation and applied fertilization before planting and during vegetation period according to soil properties. The biochemical quality of artichoke heads differs between cultivars, head fraction, and stage of head development. This indicates possibility to grow artichokes in Latvia.
Key words: *Cynara cardunculus*, germination, quality, irrigation.

Introduction

Cynara cardunculus comprises three taxa: two domesticated forms – globe artichoke (var. *scolymus* L.) and cultivated cardoon (var. *altilis*) - and the wild cardoon (var. sylvestris). Wild cardoon is the ancestor of both cultivated forms (Velez et al., 2012, Durazzo et al., 2013). The globe artichoke (Cynara cardunculus var. scolymus (L.) Fiori), (Fam. Asteraceae) is widely distributed all over the world and especially in the South Europe (Italy, Spain, France, Greece), Middle East (Turkey, Israel), North Africa (Egypt, Tunisia), South America (Argentina, Chile), United States and also in China (Pandinoet et al., 2013). Last year the production of artichokes increased. Artichokes mainly grow in Italy, which had the production of 547 799 tonnes in 2013. The top three leaders in Europe are Italy, Spain (199 900 tonnes) and Greece (28 600 tonnes). In Baltic countries artichokes are commercially grown in Lithuania with the production of 100 tonnes in 2013 (http://faostat3.fao.org/download/Q/QC/E). In Latvia artichokes do not grow in commercial areas, only in home gardens.

Globe artichoke is a perennial herbaceous plant. In Latvia artichoke is cultivated as annual or biennial plant. In the first year the plant develops a rosette of leaves – 1 m and more in height and around 1 m in diameter. The plant’s above ground parts in autumn die off, but underground part overwinters. In the second year develop a long stem (1 – 2 m high) and inflorescence. Each plant can develop several heads, aggregated in groups. Iin Latvia artichoke is cultivated mostly as an annual plant because winter periods are characterized with low soil and air temperature. Long periods without snow or thaws are typical in the wintering period. It negatively influences overwintering of perennial and annual plats (Bratch, 2014). Artichokes are usually propagated generatively by seeds and vegetatively by root or shoot cuttings. Generatively propagated artichoke gives yield in the second year. Yield can be developed in the first year if vernalized seeds are used. In the vegetative propagation method, artichoke roots are dug out in late autumn and stored in greenhouses or cellars over the winter period. In spring when the plant starts sprouting, it is divided into several plants up to the number of growing centres (Baumane, 1967; Fernandez and Curt, 2005).

Artichoke has a long history as a herbal medicine, it was used in folk medicine since Roman times (Christaki et al., 2012). Leaf extracts are used as a chloretic, hepatoprotective, anticarcinogenic, antioxidative, antibacterial, antifungal, antimicrobical, bile-expelling, cholesterol-reducing and urinative remedy in medicine. It also reduces occurrence of cardio-vascular disease and forms of cancer (Kolodziej and Winiarska, 2010; Colla et al., 2012; Pandino et al., 2011; Lombordo et al., 2015). Artichoke extracts also have stimulating properties on gastro-intestinal activity, blood-clotting time, capillary resistance and neutralizing effect on toxic substances in the human body (Kolodziej and Winiarska, 2010).

The edible part of the plant is immature inflorescence, commonly called capitula or head. It is consumed in the food throughout the world raw, boiled, steamed, or fried. Artichoke heads are characterized by low protein and fat, high content of minerals, vitamins, carbohydrates, inulin and polyphenolic compounds, which include mono- and di-caffeoylquinic acid and flavonoids (Kolodziej and Winiarska, 2010; Pandino et al., 2013). S. Lombordo et al. refer to particular flavonoids apigenin and luteolin and their glycosides as widely distributed biologically active substances in globe artichoke (Lombordo et al., 2010). All these compounds have strong antioxidant properties, although their content varies between different artichoke varieties. In France 17 globe artichoke varieties (spring genotype biomass – leaves and floral stem) were analysed for total polyphenol content. The amount of polyphenols ranged between 0.72 and 36.44 g kg^{-1} dry mass (Ciancolini et al., 2013).

Other parts of globe artichoke can also be used for food purposes. From seed can be obtained oil, from roots - inulin. Artichoke can also be used as green forage for ruminant feeding and as natural rennet for traditional cheese making. Artichoke can be used also as energy source for solid biofuel or bioethanol (Fernandez et al., 2006; Ciancolini et al., 2013; Costa et al., 2014).

The aim of this literature survey is to give a review on globe artichoke biology and influence of agroecolocigal factors on yield and quality.

Materials and Methods

Monographic method has been used for this review. Scientific literature from different scientific journals all around the world has been used in it. Literature includes information from investigations performed in Romania, Greece, Italy, France, Brazil, Egypt, Iran – the countries well known as artichoke producers in the world. Data obtained in The Netherlands and Poland are included as well, representing countries close to the Nordic boundary of artichoke growing in the Europe.

Results and Discusion

Germination conditions

The International Seed Testing Association defines germination as the emergence and development of the seedling to a stage where the aspect of its essential structures indicates whether it is able to develop further into a satisfactory plant under favourable conditions (Cone and seed…, 2005). Seed germination starts when seeds are provided with optimal amount of water and adequate temperature. Using pre-germination for more effective establishment of plants is quite popular for vegetable crops. Different substrates can be used for seed pre-germination: filter paper, sand, soil, compost, peat etc. Temperature and substrate are important factors influencing germination and germination capacity. Temperature determines germination capacity and rate, as well as breaking and induction of seed dormancy. The optimal germination temperature can vary between varieties of the same species. In Serbia the artichoke seed germination was tested on three different substrates: filter paper, sand and compost under three temperatures regimes: 16 h in the dark, at the temperature of 20 °C and 8 h under the light of 750 lux; constant temperature 20 °C; hardening for 10 days at 10 °C and continued the germination at 25 °C. Filtre paper was saturated with water and sand, and compost was provided with a sufficient amount of water to ensure optimal seed swelling. The highest seed germination was observed on filter paper (95.7%) and compost (96.2%), under constant temperature regime of 20 °C. First seedling counting was done after 7 days and final counting – after 21 days (Lekič et al., 2011). Another experiment has been carried out in Italy by S.A. Raccuia et al. (2004), where 8 wild cardoon (*Cynara cardunculus* L. var. *sylvestris* Lam.) population seeds were placed under salt stresses. Seeds were germinating in Petri dishes on Whatman paper in the NaCl and in the polyethylene glycol solution and placed in incubator in the dark at 20 °C. Results showed that in polyethylene glycol solution the germination was higher than in NaCl solution (Raccuia et al., 2004). This indicates a low abiotic stress resistance of artichoke germs. To prevent negative influence of different factors, the optimal pre-germination conditions for artichoke have to be ensured: suitable substrate, constant temperature regime (20 – 25 °C) and stable moisture.

Growing and development

Drought is one of the main abiotic stresses limiting plant growth and development in Southern countries. Limited water supply is a major factor influencing physiological and metabolic processes in plant. Water stress can significantly reduce plant height, shoot and root dry weight. In Iran significant differences between vegetative parameters were found when different irrigation intervals were applied on artichoke plants. After longer drought period reduced root and leaf vegetative parameters were observed. The total fresh weight with 3 day irrigation interval was 41.78 g, with 6 day irrigation interval - 33.48 g and with 12 day irrigation interval it was only 18.74 g (Tahna et al., 2014). S.V. Archontoulis with colleagues report that artichokes are tolerant to limited water conditions because they have a very deep root system, it can exceed even 5 metres (Archontoulis et al., 2010). However, in Egypt, S.A. Saleh (2012) with colleagues report that artichoke productivity is strongly influenced by the amount of irrigation water. Best plant growth, development and yield can be obtained if the optimal water supply is ensured – 75 to 100% from evaporation. In experiment with 3 different water irrigation levels (daily supplied 85, 100, and 115% from evaporation amount) the best result showed variant with 115% irrigation. Increased water amount positively influences plants vegetative parameters. The same tendency was observed also regarding the total yield of heads (3960 g per plant) and marketable yield (3374 g per plant). The lowest total yield (3701 g per plant) and marketable yield (3145 g per plant) was harvested from artichoke plants with 85% irrigation from evaporation (Saleh et al., 2012).

G. Colla et al. (2012) observed that higher salinity in the nutrient solution reduces plant growth parameters such as leaf dry biomass and leaf number. In Poland, researchers also observed that irrigation, fertigation, and harvest date significantly influence vegetative parameters of one year old artichoke plants. Best results showed the variant with fertigation, where fresh weight of single plant was 401 g, in irrigation variant – 362 g and in control variant – 267 g at the first harvest time (in August). At the second harvest time (in October) plants were better developed, with a higher number of leaves, longer and wider leaves. Average fresh weight of single plant in fertigation variant was for 50.5% higher than in the control variant; in irrigation variant it was 32.4% higher than in control (Kolodziej and Winiarska, 2010). S. Hejazi (2013) with colleagues report that intensive use of chemical fertilization can reduce crop yield, but organic manure can improve soil properties. They observed that the planting date and fertilization did not significantly influence artichoke vegetative parameters. However, there is limited research about fertilization influence on artichoke growth (Hejazi et al., 2013). In Romania, an investigation with 3 Cynara cardunculus L. var. altilis DC (cardoon) cultivars was established. If two years of investigation are compared, better results were obtained in the second year, when there were more rainfalls and they positively influenced cardoon growing and development (Bolohan et al., 2013, 2014). In Italy an investigation was carried out with the aim to determine the influence of sowing date and plant density on the artichoke yield. Results showed that the best sowing time in Italy was summer, when the yield was about two times higher than for the plants sown in autumn. Plant density 1.7 – 2.5 plant per m^2 decreased the number of heads per plant if compared with plant density 1.25 plants per m^2, however, yield per unit of area increased (Elia et al., 1991). In Iran, 3 different sowing dates (April 19, May 5 and 20) were compared. The highest leaf area was observed for plants sown on the first date. Also a higher globe artichoke forage yield was observed in variant with the first sowing date – 0.93 kg m^2, in the second and third sowing dates, accordingly, 0.63 and 0.69 kg m^2 where harvested (Hosseinzadeh et al., 2013). Environmental and climatic factors, including photoperiod, light intensity, temperature, soil moisture, and fertility influence the leaf number changes in the growing season. Summarizing the findings of others on the influence of agroecological factors on artichoke growth we can conclude that optimal moisture which provides 85 – 100% from evaporation and applied fertilization before planting and during vegetation period are required.

Yield quality

Abiotic stresses have a significant influence on the nutritional quality of artichoke heads. They cause changes in the content of biochemically active compounds in the plants and following the artichoke heads. The balance between stress factors and factors ensuring plant development and growth leads to a high quality artichoke yield. Long term water stress can significantly reduce photosynthetic activity, antioxidant activity and vitamin C amount in artichoke plants. Proline accumulation in plants is a response to osmotic pressure of the soil during drought stress. After a longer drought period the content of proline in artichoke heads was higher. Chlorophyll and carotenoid play an important role in photosynthesis processes - the longer drought period, the lower content of chlorophyll pigments. K and Na content in plants is the most important indicator of ions in plant tolerance opposed to salinity and drought stress (Tanha et al., 2014). G. Colla (2012) with colleagues observed that higher salinity in the nutrient solution improved biochemical composition of artichoke and cultivated cardoon leaf. They observed higher content of ascorbic acid, total polyphenols, chlorogenic acid, luteolin (Colla et al., 2012). Polyphenols have been implicated in various aspects of plant growth, reproduction, response to abiotic stresses and pathogen challenges. G. Pandino (2013) with colleagues observed influence of air temperature and solar radiation on accumulation of polyphenols in globe artichoke in different harvest times. Low air temperature and solar radiation in February positively influenced polyphenol accumulation (13.04 g kg^{-1} of DM). In Poland, researchers observed that irrigation and fertigation positively influence flavonoids content in the plants. Higher amount of flavonoids was observed in the fertigation variant (Kolodziej and Winiarska, 2010). A. Salata (2012) with colleagues in Poland investigated two artichoke varieties and reported that weather conditions influence the content of chemical compounds in artichoke heads. Higher dry weight, L-ascorbic acid, raw fibre, total protein and sugars content in artichoke heads were in the year when higher temperature (19 °C in August and 13 °C in September) and rainfall (45 and 102 mm in August and September) during heads harvesting time were registered. Differences were observed also between cultivars, head fraction, and the stage of head development.

There have also been reported differences in biochemical composition between plant parts (Pandino et al., 2013). From 3 years data obtained by A. Salata and colleagues mean content of L-ascorbic acid was higher in receptacle (14.54 – 15.82 g 100 g^{-1} fresh weight) than in head bracts (6.49 – 11.29 100 g^{-1} fresh weight). Total protein and total sugars also showed the same tendency – accumulation was more intense in receptacle than bracts. Crude fibre showed a contrary situation – in bracts it was two times more than in receptacle (Salata et al., 2012). In Italy it was observed that inner bracts and receptacles contain higher amount of polyphenols than floral stem and outer bracts, as well as, varied between genotypes (Lombordo et al., 2010). F. Fratianni (2007) with colleagues also studied polyphenolic content changes in different fractions of head. Inner bracts and receptacles contain a higher amount of polyphenols than intermediate bracts and outer bracts, although these observations significantly varied between genotypes (Fratianni et al., 2007).

In Portugal, it was found, that content of phenols depends on the plant part, physiological plant stage, and botanical variety. Cultivated artichokes are richer in phenols than wild artichokes. The highest phenol content is reported for artichoke leaves, but least – for stalks (Velez et al., 2012).

Conclusions

Artichoke growing is becoming more and more popular in the world, - expanding more and more towards North European countries, the growing area increases. Higher yield and quality of artichoke buds can be obtained by ensuring optimal growing conditions. Average air temperature (15 – 20 °C), irrigation (85 – 100% from evaporation) and fertilization level, optimal planting and harvesting time give notably better results. This indicates possibility to grow artichokes in Latvia. Investigations on proper agrotechnological solutions for artichoke growing in Latvian agroclimatic conditions have to be performed.

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