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Hail net cover, cultivar and pod size influence the chemical composition of dwarf French bean

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ABSTRACT

Dwarf French bean is cultivated in the open field, where unpredictable extreme weather events decreased crop yield quality. Hail net protection is therefore desirable. The pods are a rich source of sugars, organic acids and phenolic compounds and, as such, are an important nutritional vegetable. Due to consumer demand for half-sized pods in some traditional cuisines, the chemical profile of both pod sizes are desired. The aim of the study was to determine the effect of hail net covering on microclimatic conditions, specifically on light interception and temperature modification and, consequently, on the chemical profile of bean pods harvested in two sizes. The experiment was treated as a split–split plot designed three factorial experiment in four randomized replications. The main factor 'covering', had two levels, (hail net covered and uncovered plots); the sub-factor 'cultivar' had four levels, ('Berggold', 'Re dei burri' 'Paulista', 'Top crop') and the sub–sub-factor 'pod size', had two levels (half-size and full-size pods). Individual sugars and organic acids were analyzed, using high-performance liquid chromatography (HPLC). Total phenolic content was determined by spectrometry. Lighting was measured as the amount of photosynthetic active radiation (PAR). PAR under the hail net was reduced by 30–75% and mean daily temperature by 2.4 °C in comparison with the control. Significant genotypic effect was confirmed for vitamin C, while sugars, organic acids and total phenolics are affected mostly by interaction of two or three factors. Higher vitamin C content was found in cultivars classified as anthracnose resistant ('Berggold' and 'Paulista') compared to not resistant cultivars ('Re dei burri' and 'Top crop'). Covering decreased fructose, glucose and vitamin C contents. Total phenolics were decreased under hail net only in pods of green pod cultivar. Hail net also influenced the composition of individual sugars in yellow pod cultivars ('Berggold' and 'Re dei burri'), with which sweeter pods were harvested, with a higher fructose/glucose ratio. Pod size also significantly affected all chemical compounds analyzed bean pods. Younger half-sized pods had higher fructose and glucose content, as well as malic and citric acids and also total phenolic content, compared to full-sized pods. On the other side, younger pods contain significant lower amount of vitamin C and sucrose compared to older pods. Significant genotypic variation connected with hail net covering observed within yellow pod cultivars, provides opportunities for the plant breeders to develop special genotypes for maximizing the nutraceutical value of bean pods under hail net production.

1. Introduction

Dwarf French bean (*Phaseolus vulgaris* L.) is an important heat and drought tolerant plant species, cultivated and distributed worldwide (Lim, 2012). Total world production exceeds 17 million tons, with China, Indonesia, India and Turkey among the largest producers and consumers of this crop (FAOSTAT, 2012). Bean pods are rich in proteins, carbohydrates, dietary fiber, minerals, vitamins and antioxidant phytochemicals (Lim, 2012) and can be prepared steamed, boiled, stir-fried or baked in casseroles. It is rare among vegetables in retaining its antioxidant activity after most cooking treatments (Jimenez-Monreal et al., 2009). Snap beans are usually harvested before the pods are fully mature while the seeds are small. This usually occurs 12–14 days after the first blossoms

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open, and depends on weather conditions (Lim, 2012). There are many different cultivars of snap beans on the fresh vegetable market, which can be harvested in different pod sizes (Fox et al., 2005; Sanchez-Mata et al., 2000; Villanueva et al., 2004) in relation to consumer requirements and the characteristics of different cuisines (Koutsika-Sotiriou and Traka-Mavrona, 2008).

Intake of vegetables, among other factors, depends on the taste of the vegetable (Glanz et al., 1998), which is strongly related to the chemical composition (Auerswald et al., 1999). Among primary metabolites, sugars and organic acids contribute significantly to the flavor and consumer acceptance of dwarf French beans (VandenLangenberg et al., 2012). Vitamin C in fruits and vegetables is the most important vitamin for human nutrition, which reportedly reduce the risk of arteriosclerosis, cardiovascular diseases and some forms of cancer (Harris, 1996). Its synthesis is influenced by many pre- and post-harvest factors, as well as by pod size or maturity at harvest (Harris, 1996; Kader, 1996). Among secondary metabolites distributed in higher plants, polyphenolics play important roles in defense against various biotic and abiotic stress conditions (Russell et al., 2009). Much research work has already looked at the influence of genotype, growth technology and external factors on the content of phenolic compounds. These studies have mainly been done on tomato and bell pepper (Dumas et al., 2003; George et al., 2004; Ghasemnezhad et al., 2011; Marin et al., 2004) and very little information about phenolics in bean pods can be found in the literature. In our previous study the effect of different production systems on the chemical profile of dwarf French bean pods (cv. 'Top crop') was examined and sixteen individual phenolic compounds from four groups were detected. We showed that different production systems did not affect the general chemical composition of bean pods, they caused only changes in the content levels of some phenolic compounds (Jakopic et al., 2013).

Cultivation of dwarf French beans is conducted mainly on open fields, where it is important to consider extreme events connected to heavy rainfall, hail and gusts. These events can cause considerable damage to agriculture (Kunz et al., 2009). In order to decrease hail damage, a hail net has been widely used, mainly in orchards (Dussi et al., 2005; Stampar et al., 2002), although it could be also applicable in field vegetable production. In fruits orchards most hail nets used are black (Dussi et al., 2005). More recently, colored and neutral nets have also become available specifically for outdoors as physical protection (wind, birds, insects, excessive radiation) as well as for greenhouses to affect humidity, shade and temperature (Shahak, 2008; Stamps, 2009). The effect of hail nets on the interception of light and on the color and chemical composition of fruits have been well documented. Black nets reportedly reduce incident solar light by up to 45% in different fruit orchards all over the world (Andrews and Johnson, 1996; Dussi et al., 2005; Gindaba and Wand, 2007; Jakopic et al., 2009; Stampar et al., 2002). In some cases such reduction has a negative impact on the development and final fruit color, which is an important quality parameter for apple fruit commercial value (Iglesias and Alegre, 2006; Shahak, 2008; Stamps, 2009). In other studies, net photosynthesis of trees on sunny days and final quality of fruit yield are not reduced under black hail net protection especially in the Central European conditions (Andrews and Johnson, 1996; Dussi et al., 2005; Gindaba and Wand, 2007; Jakopic et al., 2009; Stampar et al., 2002).

There is little information available in the literature about hail net protection in vegetable production. Studies have mostly focused on the improvement of productivity, quality and harvest time of horticultural crops by using colored shade netting (Rajapakse and Kelly, 1995; Shahak, 2008). In leafy vegetable production, the use of red and pearl nets significantly increased the production of plants compared to protection with other color nets (blue, aluminum or black). The use of photo-selective and light dispersive netting in semi-arid and other areas is therefore suggested (Shahak, 2008). In Israel, bell pepper production is conducted under shade-net protection in order to avoid sunburn and produce high-quality fruit and to save on irrigation. Photo-selective nets (red, yellow and pearl) significantly increase (30–40%) the number of bell pepper fruits per plants compared to the control (black net), while fruit size is comparable with the black shade net control (Shahak, 2008). However, little or no information can be found concerning quality attributes such as the chemical profile of vegetable crops harvested under black hail net protection.

The aim of our study was to evaluate the effects of hail net use, cultivar and pod maturity stage on the chemical composition of dwarf French bean pods, more precisely on sugars, organic acids, vitamin C and total phenolics content. The study deals with a technological approach little used for vegetable production (hail netting protection), which, in the context of climate change and extreme weather events, is already common practice in fruit and vine production. Colored netting is designed mostly for manipulating growth and development of plants (Li et al., 2003; Rajapakse and Kelly, 1995) and for providing shade and physical protection to the plants (Shahak, 2008), while black netting is designed mainly for hail net protection (Shahak, 2008; Stamps, 2009; Stampar et al., 2002), and as such was used in our study. An open field experiment with dwarf French bean was therefore conducted, with and without black hail net covering, in order to evaluate the effects of netting on light interception and temperature conditions in the cultivation area and on changes in chemical composition in dwarf French bean pods. To our knowledge, this is the first report of chemical profile changes in a vegetable crop influenced by hail net covering and it provides a valuable insight into the chemical composition of different green and yellow potted cultivars of dwarf French bean.

2. Materials and methods

2.1. Site description

The experiment was conducted in an experimental field (at the Biotechnical Faculty of the University of Ljubljana, Slovenia (46°03′N and 14°31′E, 298 m a. s l.)) from April to July 2011. The soil of the experimental site is classified as gleyic fluvisol and endogenic fluvisol containing 28 g kg^{-1} soil organic matter in the 0–0.3 m soil layer. At the beginning of the season, the average initial soil nitrate content was 5.2 mg kg^{-1} for the same depth, soil assimilable P and K were 22 mg kg^{-1} and 28 mg kg^{-1}, respectively, thus suggesting application rates of macronutrient according to the Regulations on Integrated Production of Vegetables. Granulated mineral fertilizers were incorporated on the plots at a rate of 105 kg N ha^{-1}, 40 kg P ha^{-1} and 150 kg K ha^{-1} and 147 kg Ca ha^{-1}, as calcium nitrate, super phosphate and potassium sulfate, respectively. Normal cultural practices were followed for irrigation and no pesticides were used since no diseases or pests appeared during the experiment.

2.2. Experiment

Four commercial cultivars of dwarf French bean with round pods were included in the experiment: 'Paulista' (Royal Sluis, NL) and 'Top crop' (Franchi Sementi, IT) as green pod cultivars and 'Berggold' (Semenarna Ljubljana, SI) and 'Re dei burri' (Franchi Sementi, IT) as yellow pod cultivars. All cultivars are very productive and produce meaty, yellow or green, stringless pods of 12 to 14 cm. Cultivars differ according to the resistance to *Colletotrichum lindemuthianum* (Sacc. & Magnus) Lams. Scrib. ('Paulista' and 'Berggold', are classify as resistant cultivars to anthracnose, while 'Top Crop' and 'Re de burri,' are cultivars not resistant to anthracnose). To ensure full plant density on the experimental plots and to shorten the