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RESEARCH ARTICLE

Exploiting important horticultural and quality traits of some traditional pepper genotypes

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ABSTRACT

Worldwide pepper (*Capsicum annum* L.) is considered one of the most important vegetable crops grown and consumed. It is widely recognized that peppers pods synthesize and store a wide array of bioactive phytochemicals beneficial for human health such as vitamins A, C and E, as well as phenolic, flavonoids, carotenoids and capsaicinoids with well-known antioxidant properties. It has been reported that the levels of these compounds vary depending on various factors such as genotypic differences, pre- and post-harvest agricultural practices. Besides, although, processing industries widely use in their product mostly hybrid cultivars, recently, the interest of consumers has been shifted towards local/traditional cultivars of peppers for their low input/water demand, particularly under the ongoing climatic change context, associated to their high nutritional value. Therefore, in this study, four local pepper genotypes consisting of (Baklouti, Beldi, Kairouan and Nabeul) were compared for their main horticultural traits and vitamin C content. The result revealed significant differences affecting most of the tested attributes. The highest plant height was recorded for the cultivars Nabeul and Kairouan (119.67 cm) and the lowest for the variety Baklouti (66 cm). Added to this, the highest plant cover area was recorded for the cultivars Nabeul (39 cm^2) and the lowest for the variety Baklouti (19 cm^2). Kairouan showed the highest yield (1841, 66 g/plant) while Baklouti showed the lowest (1644, 08 g/plant). Average fruit weight varied from 37.75 g in cultivar Kairouan to 34.33 g in Beldi variety. The highest SPAD index was recorded for the cultivar Beldi (62.97) and the lowest for the variety Kairouan (47.8). Besides, the highest chlorophyll fluorescence was recorded for the cultivar Beldi (0.77) while Baklouti showed the lowest (0.72). It is also worthy to underline that in this experiment, no blossom end rot symptoms were noticed in all genotypes. Vitamin C content, Brix and pH varied also significantly in the different pepper genotypes. Cultivar Beldi exhibited the highest vitamin C content (39,73 mg/g fw) and the lowest was recorded for Kairouan (18,13 mg/fw). Titratable acidity varied from 0.51% in cultivar Nabeul to 0.34% in Beldi.

Keywords: Pepper, traditional cultivars, processing, horticultural performances, functional quality.

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INTRODUCTION

Peppers (*Capsicum annum* L.) are among the most important crops plants included in the Solanaceae family. They are one of the most widely consumed vegetables throughout the world owing to their attractive colours and strong flavour. Aside from their sensory properties, peppers are also considered good source of nutrients and bioactive compounds such as vitamins, carotenoids, anthocyanins, phenolic acids and flavonoids beneficial for human health (Hamed el al., 2019). Pepper is consumed in various forms fresh, dehydrated spices and various processed products (Maria et al., 2010). Because of their antioxidant properties, ascorbic acid, carotenoids and vitamin E contents, peppers are currently attracting much attention due

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to possible links to prevention of certain types of cancer, cardiovascular diseases, atherosclerosis and delay of the ageing process. The texture, in particular the crispness of the pepper is an important quality attribute to consumers (Howard et al., 2000; Sidonia et al., 2007). Therefore, in this study, four local pepper genotypes were assessed for their horticultural performances and ascorbic acid content for their possible integration in processed product industry.

MATERIALS AND METHODS

Plant culture

The field-experiments were conducted in 2022 at the Research and Experimental Station of Teboulba, Monastir, Tunisia. Four pepper cvs (Baklouti, Nabeul, Kairouan and Beldi) were used in these experiments. Sowing was carried out on April 14th 2022 in plug-seedling trays. Peppers were transplanted on Mai 12th 2022 in open-field with a spacing of approximately 0.4 m within the row and 0.7 m between rows, matching a density of about 4 plants/m² and grown to maturity. Irrigation was applied using a drip method with 4 L h^{-1} drippers placed at 0.4 m intervals along the irrigation line.

Drip irrigation ran for 1–3 h, at 1–2-day intervals, depending on potential evapotranspiration of the research station, climate data and crop coefficient. The production methods were in accordance with the procedures utilized by the research and experimental station of Teboulba, Monastir, Tunisia and recommended by developed farming systems. They included fertilization with synthetic chemical fertilizers (145 kg N ha^{-1}, 140 kg P2O5 ha^{-1}, 210 kg K2O ha^{-1}). Chemical fertilizer solution was added to water irrigation by pump injection twice a week. The production methods also included a hand weeding control and plant-pathogen control with synthetic chemical pesticides. Pesticides were applied once a cycle. Plant height and cover area were measured at the end of the experiment. Plant height was taken from the root collar to the highest point of the plant. Plant yield was expressed in grams fresh weight per plant. Average fruit weight was expressed in gram fresh weight and the percentage of blossom-end rots was expressed as the ratio between the number of rotted fruits and the total number of fruits.

Determination of chlorophyll index and chlorophyll fluorescence parameters

The SPAD-502 meter (Konica, Minolta, Japan) was utilized to estimate the leaf chlorophyll index. Generally, a relative SPAD index (ranging from 0–99) is obtained in the fully expanded young leaves (Ghosh, 1993). Chlorophyll fluorescence indices were recorded on three fully expanded young leaves in the middle portion of shoots using a pulse amplitude modulation fluorometer ((FluorPen FP 100). The data were recorded whenever the plants were adapted in the dark for 20 min, and later, the data were analyzed by PamWin-3 software as described in detail by Maxwell and Johnson, (2000). The parameters included: the minimum value for chlorophyll fluorescence (F0), the maximal possible fluorescence value (Fm), the difference between F0 and Fm (Fv), the maximal quantum yield of PS II (Fv/Fm), and the non-photochemical quantum efficiency of PSII Y (NO).

Fruit sampling

Pepper pods were hand harvested randomly from the rows at the red-ripe stage (Fig.1) and delivered quickly to the laboratory to determine the yield, average fruit weight and the percent of blossom end rot. After that, pepper pods were cut into small pieces and homogenized in a laboratory blender. The obtained juice was used to determine pH, Brix, titratable acidity and total vitamin C contents.

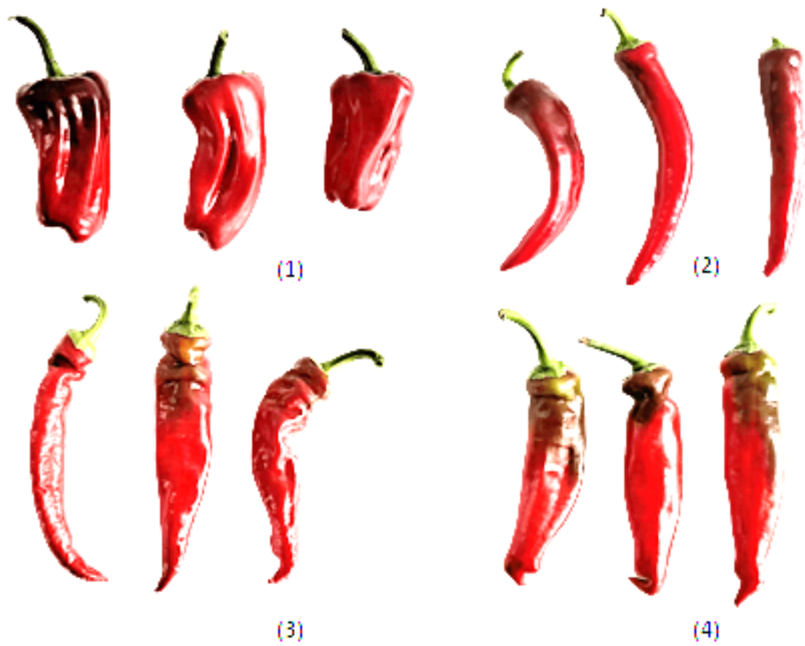

Fig. 1: Traditional pepper cultivars (1): Baklouti; (2): Beldi; (3): Kairouan and (4): Nabeul harvested at the red ripe stage of maturity

Determination of pH, Total Soluble Solids, Titratable Acidity and Ascorbic Acid Contents

pH values were determined using a digital pH-meter (pH Meter PCE-228) with the application of the electrode directly into the homogenate. Total soluble solids content (TSS) was determined using a hand-held digital refractometer (ATAGO™ Digital Hand-Held Pocket Honey Refractometer, PAL-22S) placing a small sample of blended pulp on the reading prism. Results were expressed as °Brix. Titratable acidity was determined by titration with 0.1 N NaOH until reaching pH 8.1 and results were expressed in grams of citric acid per 100 g of sample. Finally, ascorbic acid content was determined by the titratability of 5 g of the blended pulp homogenized with 20 mL distilled water. Ascorbic acid content was measured by extracting the fruit homogenate (5 mL) with acetic acid solution 2% (5 mL) and then titrated against 2, 6-dichlorophenol-indophenol (Miller, 1998).

Statistical analysis

The experiment was arranged in a completely randomized design with 3 replications. Statistical analyses were carried out by analysis of variance (ANOVA) and least significant differences (LSD) at P = 0.05 are presented.

RESULTS AND DISCUSION

Plant height, yield, average fruit weight and plant cover area

The obtained values of plant height, yield, average fruit weight and plant cover of four pepper genotypes are displayed in figure 2. The result showed a significant difference between the pepper genotypes. The plant height varied from 66 cm in Baklouti to 119.67 cm in Nabeul and Kairouan. Mercado et al. (1997) reported that plant height increases at increasing temperatures reaching 20 and 40 cm respectively at temperatures of 25/14°C and 29/20°C. Generally, the assessed plant material showed different vegetative behaviour with respect to temperature. This result was statistically confirmed by the analysis of variance which revealed a highly significant effect depending on the genotype. Nabeul and Kairouan genotypes are likely more adapted to high temperature unlike Baklouti. The differences among pepper genotypes are probably due to their genetic background. Plant height indicates plant vigour ordinarily and it depends upon growth habit of the plant. Soil nutrients are also very important for the height of plants (Houssein et al., 2012).

Yield varied significantly among the studied pepper genotypes ($P < 0.05$). The highest yield 1841, 66 g/plant was obtained by Kairouan and the lowest 1644, 08 g/plant was obtained by Baklouti. Pepper varieties show significant variations in yield/plant and these variations were presumably correlated to genetic variations (Jan et al., 2020). Our results were similar with the finding of Sujiprihati et al. (2007) who found variability in yield/plant among different pepper varieties grown in Cikabayan, Darmaga Indonesia. Genefianti et al. (2008) reported that total yield of the crop was directly proportional to number of fruits per plant. Fitriani et al. (2013) concluded that total yield of different chilli varieties was controlled by environmental conditions greater than genetic attributes. Yield is a complex phenomenon and partitioning of dry matter between vegetative and reproductive parts is an important process that causes variations in yield (Edna et Singandhupe, 2004). Imtiyaz et al. (2000) also have reported quadratic relationship between water applied and marketable yield of cabbage, carrot, onion, green pepper, rape, okra and broccoli under sprinkler irrigation. Bell pepper is highly sensitive to temperature variation and high temperature promotes flower drops and reduce fruit yield (Sagar et al., 2015).

Fig.2 shows that fruit weight was significantly affected by genotypic differences. The highest fruit weight was reported in Kairouan (37.75 g) and the lowest in Beldi (34.33 g). The obtained results are in line with those of Al-Said & Kamal (2008) which reported average fruit weight ranging from 46.9 g to 48 g in different pepper genotypes in Egypt. The study indicated that large bell pepper fruit yields can be attained with management practices, such as row covers or high plant population densities that result in vigorous growth and a large number of nodes per land area. Other management practices, such as pruning or breeding selection programmes, that encourage branching at lower population densities might also improve fruit yields (Peter et al., 1995). The variety Nabeul covers the highest area (39 cm^2) unlike to the variety Baklouti (19 cm^2) (Fig.2).

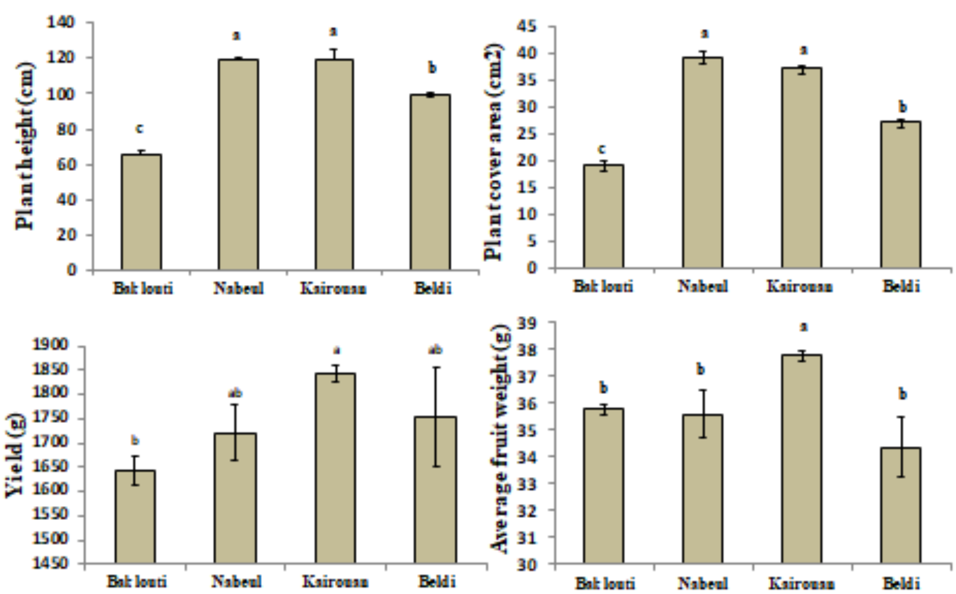

Fig. 2: Plant height, yield, average fruit weight and plant cover area of four pepper genotypes.

Spad index and chlorophyll fluorescence

Chlorophyll fluorescence has been routinely used for non-invasive monitoring of plant photosynthetic activity to identify improved plant performance. It is one of the most popular techniques in plant physiology providing detailed information on the state of photosystem II (PSII) at a relatively low cost (Murchie et al., 2013). Spad index and chlorophyll fluorescence values of the studied pepper genotypes are reported in table 1. Spad index and fluorescence values varied significantly among the studied pepper genotypes (P≤0.05). The highest SPAD index (62.97) was recorded in cultivar Beldi, while the lowest (47.8) recorded was in cultivar Kairouan. Similarly, the highest chlorophyll fluorescence value was recorded for the cultivar Beldi with 0.77 while cultivar Baklouti showed the lowest value 0.72 suggesting different photosynthetic activity in pepper genotypes. The obtained data for the studied pepper genotypes falls within values reported by different studies. Flávio et al. (2018) reported recently values ranging from 56.73 to 58.55 for different pepper genotypes grown under field conditions in Brazil and plants presenting SPAD index of 58.5 at the flowering stage showed the highest fruit yield suggesting that the quantification of the SPAD index at the reproductive stages can be used in the prognosis of pepper production. The discrepancy in the obtained data might be related to genotypic differences and environmental conditions and/or their interactions.

Table 1: Spad index and chlorophyll fluorescence of different pepper genotypes.

Cultivars	Baklouti	Nabeul	Kairouan	Beldi
Spad index	60.2±3.33 a	51.8±71.4 b	47.8±1.33 b	62.97±2.42 a
Fv/Fm	0.72±0.003 c	0.76±0.005 ab	0.75±0.005 b	0.77±0.007 a

Blossom-end rot susceptibility

Blossom-end rot values (figure 3) varied significantly among the studied pepper genotypes (P≤0.05). No blossom end rot symptoms were noticed for Kairouan with respect to the other varieties. The variety Baklouti show the highest percent of Blossom end rot (7%). Blossom-end rot is due to reduced the import of Ca into the fruits, which increases transpiration and subsequently the fraction of Ca transported to the leaves (Aikman et al., 1990). Other factors such as light, temperature, air humidity (R'him et al., 2005), soil humidity (R'him et al., 2005), the size and growth rate of the fruit (R'him et al., 1999; Marcelis et al., 1999) are also considered as possible causes of blossom-end rot. Indeed, we also note that there is a varietal effect concerning susceptibility to blossom end rot, the variety Baklouti is the most susceptible. This result coincides with the work of Roca and Martinez (1997) who reported that the varietal factor remains the most important element that risks causing blossom end rot in the pepper pods. It has been recently suggested that an induction of reactive oxygen species and impaired sugar metabolism may be associated with blossom-end rot damage (Aloui et al., 2015).

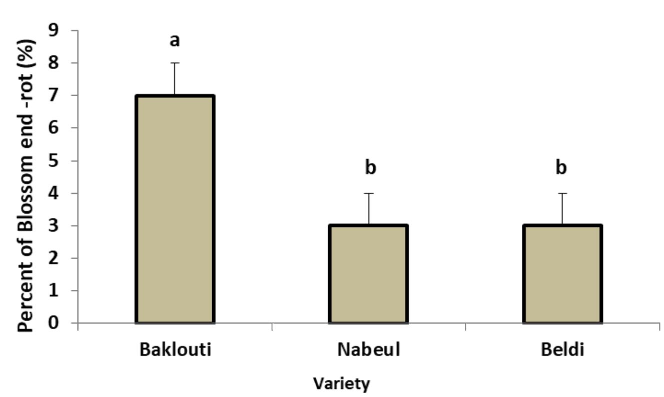

Fig 3: Occurrence of blossom end-rot in the studied pepper genotypes

pH, total soluble solids, titratable acidity and ascorbic acid contents

It is evident from Table 2 that the pH value of showed significant variation among pepper varieties. The highest pH value was found in variety Kairouan and lowest was noted in variety Baklouti.

The mean data showed significant variation among different pepper genotypes. Baklouti and Nabeul showed the highest °Brix (13) while Kairouan show the lowest with 10.6 (Table 2). The total soluble solids (TSS) increased as ripening of the fruit increased due to the greater degradation or biosynthesis of the polysaccharides and the accumulation of sugars. The metabolic processes related to the advance of ripening, probably due to dissociation of some molecules and structural enzymes in soluble compounds, directly influence the levels of total soluble solids, where fruits in advanced stages of ripening present the highest levels of soluble solids (Lyon et al., 1992).

Table 2: pH, Total Soluble Solids, Titratable Acidity and Ascorbic Acid Contents of peppers harvested at the red stage

Traits	Baklouti	Nabeul	Kairouan	Beldi
Brix (°Brix)	13±0.07 a	13±0.07 a	10.6±0.07 c	12.5±0.07 b
pH	4.3±0.16 b	4.5±0 a	4.7±0 a	4.6±0.04 a
Titratable Acidity	0.47±0.05 a	0.51±0.01 a	0.35±0.03 b	0.49±0.06 a
Vitamin C (mg/100g fw)	35.66±2.89 a	34.8±2.67 a	18.13±1.69 b	39.73±4.36 a

Total soluble solids (TSS), titratable acidity (TA) and pH values were also analysed (Table 2). The TSS mainly comprises total sugars and organic acids, among other constituents (Tadesse et al. 2002). These components are often evaluated in fruit and vegetables analyses as they are critical to the overall sensory quality evaluation and can be used along with colour change to determine the maturity of peppers (Tadesse et al. 2002). There was a significant difference among pepper cultivars for titratable acidity. TA values varied from 0.35 g citric acid / 100 g in variety Kairouan to 0.51 g citric acid / 100 g in variety Nabeul (Table.2). TA of different pepper cultivars increased with ripening, while the fruit ripens the metabolic reactions increase, increasing the concentration of organic acids involved in the Krebs cycle. Apart from this, these acids make up the energetic reserves and the metabolic reactions that involve the synthesis of pigments, enzymes and other materials and the degradation of pectins and celluloses, which are essential for the ripening process. The organic acids are active substances during ripening in these alterations. Change in TA and pH are founded on changes in citric, malic and ascorbic acid. Concentrations of these acids are known to diminish during ripening (Taher et al., 2018).

Ascorbic acid plays a key role in defence against oxidative stress, and is particularly abundant in photosynthetic tissues (Foyer et al, 1983; Smirnoff and Wheeler, 2000) such as leaves and young green fruit. Most (> 90%) of the ascorbic acid is localised in the cytoplasm, but a large proportion is exported to the apoplast. In this study, the total vitamin C varied from 18.13 mg/100 g fw in Kairouan to 39.73 mg/100 g fw in variety Beldi (Table 2). It has been reported that ripening stage can induce ascorbic acid content up 30% in red peppers compared to greens (Howard et al., 2000).

The quality of peppers is determined by their composition. Among the most important factors that affect composition are environmental cultivation conditions, variety, ripeness, maturity, and pre-harvest and post-harvest handling (Rajput and Parulekar 2004).

Ripening of peppers involves a series of complex reactions, which are of special importance to the quality of the pepper. The degree of ripening required for different markets is the single most important commercial factor in relation to quality. Harvesting at the correct stage of maturity is essential to achieve optimum quality and, also, for maintenance of the quality after harvesting (Ranajit et al., 2013).

Additionally, Aloui et al. (2015) noticed a strong correlation between ascorbic acid content of bell pepper and the protection against blossom-end rot. However, in our study cultivar Kairouan with the lowest ascorbic acid content exhibited no BER symptoms which stress the need for further studies at this regard in future growing seasons.

CONCLUSION

In this study, the pepper pods of different traditional pepper cultivars showed satisfying horticultural traits (attractive visual appearance associated with suitable fruit weight). Additionally, the study confirmed the importance of pepper genotypes as a source of vitamin C. The content of vitamin C in pepper was influenced by genotypic differences and varied significantly between the studied genotypes. Except for Kairouan, all cultivars showed interesting content of vitamin C. Further detailed assessment of the whole phytochemical fingerprint and the radical scavenging activity of those genotypes should be performed for better characterization of additional traditional pepper genotypes. These studies are required particularly under the ingoing climatic changes worldwide.

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