Horticultural Performance and Functional Quality Traits of Four Hot Pepper Landraces from Tunisia

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Abstract

Worldwide pepper (*Capsicum annuum* L.) is considered one of the most important vegetable crops grown and consumed. We have comprehensively assessed the horticultural performance and the functional quality traits of four hot pepper genotypes adapted to various climatic conditions in Tunisia comprising of 'Semmane' 'Jerid', 'Mahdia' and 'Kairouan'. Most of the pepper genotypes showed satisfactory yields ranging from 1163.25 to 1841.67 g plant^{-1} in 'Jerid' and 'Kairouan' respectively underlying a good productivity particularly under the ongoing climatic changes and high temperature. Capsaicinoids, carotenoids and tocopherols contents varied significantly among the studied pepper genotypes ($P \leq 0.05$). Capsaicinoids content ranged from 1.81 µg g^{-1} FW in 'Kairouan' to 193.71 µg g^{-1} FW in 'Jerid'. 'Semmane' exhibited the highest value of carotenoids content (174.52 µg g^{-1} FW). Finally, the highest tocopherols content was recorded to 'Jerid' (31.24 µg g^{-1} FW). Although other traits were not considered in this study, the hot pepper genotype 'Semmane' exhibited the highest value of carotenoids content and might be suitable to grow for fresh and/or processing purposes or to be considered as starting point for future breeding programs targeting the development of new cultivars for the next decade.

Keywords: *Pepper, horticultural performances, physiological attributs and functional quality.*

Introduction

Peppers (*Capsicum annuum* 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 with a production attaining 36.77 million tons in the world and 425000 tons. In Tunisia owing to their attractive colours and strong flavour. Pepper fruits have been recognized as natural sources of various bioactive compounds (Duah et al., 2021). 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 (Diaz-Sanchez et al., 2021; Moon al., 2023). Therefore, this study targeted to assess the horticultural performance and the functional quality attributes of four hot pepper landraces grown under open field conditions.

Materials and Methods

The field-experiment was conducted during 2022 growing season at the Research and Experimental Station of Teboulba, Monastir, Tunisia (35.637178, 10.957276). Four pepper genotypes were used in this experiment consisting of Semmane, Jerid, Kairouan and Kairouan. Sowing was carried out in plug-seedling trays during May. Pepper seedlings were transplanted in open-field in a sandy soil at the beginning of June with a spacing of approximately 0.4 m within the row and 0.7 m between rows, matching a density of about 4 plants.m^{-2} and grown until maturity. Drip irrigation was applied during 1-3 h at different days intervals in agreement with the local evapotranspiration potential, climatic conditions, crop coefficient and growth stage. The growing calendar was also in accordance with the techniques used by the Research station and high-yielding neighbouring farmers. The method included the use of synthetic chemical fertilizers (145 kg N ha^{-1}, 140 kg P_2O_5 ha^{-1}, 210 kg K_2O ha^{-1}). Chemical fertilizer solution was added to water irrigation by pump injection twice a week. The production method also consists of hand weeding and plant-pathogen control with synthetic chemical pesticides. Pesticides were applied once a cycle. The experimental design was a randomized complete block design with three blocks (replicates). During 2022 growing season, the average temperature ranged between 24.88-33°C, relative humidity ranged between 55-88% and rainfall ranged between 0-5 mm. Photosynthesis and leaf transpiration were measured in single pepper leaves using a portable photosynthesis system model (CI-301 CO_2 Gaz analyser (CID Inc, Camas, WA, USA), and this measurement was conducted one hour after sunrise and stomatal conductance was measured using promoter (DELTA- T AP4). Photosynthesis, transpiration and stomatal conductance were expressed as µmol m^{-2} s^{-1}. Plant height was measured at the end of the experiment. It was taken from the root collar to the highest point of the plant. The yield was evaluated considering the weight of fruits per plant. Plant yield was expressed as grams of fresh weight $plant^{-1}$. Regarding average fruit weight, a random sample of pepper fruits was used and average fruit weight was deduced by dividing the weight of the sample by the number of the fruit within the sample. Average fruit weight was expressed in gram of fresh weight.

Fruit sampling

Peppers were collected from each plant at the commercial red mature ripening stage. Fresh pepper fruits were harvested from each bloc and delivered to the laboratory. The selected pepper fruits were washed with deionized water, cut into small pieces and homogenized in a laboratory blender (Waring Laboratory Science, Torrington, CT, US). The obtained homogenates were used to assess capsaicinoids, carotenoids and tocopherols.

Determination of capsaicinoid content

Using the techniques of Daood et al. (2014). In a crucible mortar, three grams of pepper homogenate were crushed with quartz sand. After carefully pouring 50 mL of analytical grade methanol, the liquid was placed into a 100 mL Erlenmeyer flask fitted with a stopper. After three minutes of ultrasonication, the mixture was filtered through filter paper. The filtrate was then filtered using a 0.22 µm PTFE (Chromfilter) syringe into vails after being diluted ten times (9:1) using 9 mL of chromatography grade methanol and 1 mL of filtrate from different pepper landraces. The filtrate was then filtered through a 25 µm syringe and placed into a 10 mL glass beaker. Using an Eppendorf pipette, 1 mL of methanol and 1 mL of the filtrate (from the syringe filter) were further diluted into vails. Total capsaicinoid content was expressed as mg kg^{-1} FW.

Determination of carotenoid content

Total carotenoids were determined according to the protocols of Daood et al. (2014). About 2.5 g of homogenized pepper samples from different landraces were crushed in a crucible mortar with quartz sand. A volume of 20 mL of methanol was added for 1-2 min, and the upper layer poured into an Erlenmeyer flask. 10 mL of methanol (analytical grade) was then added to 50 mL of dichloroethane in a 100 mL graduated cylinder and shaken gently. The mixture was poured into the remaining homogenized pepper sample in the crucible mortar and then transferred into the Erlenmeyer flask and shaken vigorously. A few drops of distilled water were added and shaken gently and the mixture was separated with a burette into a flat bottom flask using a filter paper containing sodium sulfate anhydrous in a separating funnel. 5 mL of dichloroethane was added to the filtrate through a filter paper for further extraction and evaporated using a rotary evaporation chamber during 10 min at 70 ◦C and 40 ◦C vacuum, respectively. The flask was offloaded from the chamber tube after all filtrate evaporated. 5 mL of pigment eluents and 5 mL of analytical grade methanol were respectively dropped into the flask and shaken evenly and an ultrasonic shaker was used where necessary to ensure that no residue was left in the flask. Then the solution was filtered through a 0.22 µm PTFE membrane syringe into the veils and injected into the HPLC column. An HPLC (Hitachi Chromaster, Tokyo, Japan) instrument consisting of a Model 5110 Pump, a Model 5210 Auto Sampler, a Model 5430 Diode Array detector, and a Model 5440 FL detector, was used for the determination of all compounds. All chemicals, including analytical and HPLC grade solvents, were obtained from VWR (Budapest, Hungary, and Darmstadt, Germany). Total carotenoids content was expressed as mg kg^{-1} FW.

Determination of Tocopherol Content

The procedure of Abushita et al. (1997) was adopted for the extraction of tocopherol using n-hexane. The analysis was conducted by the mean of an HPLC (Hitachi Chromaster, Tokyo, Japan). The system was composed of a model 5110 gradient pump, a model 5210 autosampler, and a 5440-fluorescence detector. The Nucleosil 5 mm (250 × 4.6 mm i.d.) column was also used for separation with a mobile phase (99.5:0.5 n-hexane: ethanol). The excitation and emission wavelengths were detected at 295 nm and 320 nm, respectively, as outlined in Duah et al. (2021). Total tocopherol content was expressed as mg kg^{-1} FW.

Statistical Analysis

The variability influencing horticultural performance and functional quality traits of hot pepper landraces were determined by variance (ANOVA) analysis. The means comparison was performed by the Duncan test ($p < 0.05$) if significant differences were spotted. The statistical evaluations were conducted using the IBM SPSS Statistics software for Windows, Version 21.0. (IBM Corp., Armonk, NY, USA).

Results and Discussion

Plant height, yield, average fruit weight

The obtained values of plant height, yield and average fruit weight plant of four pepper genotypes are displayed in Table 1. The result showed a significant difference between pepper genotypes. The plant height varied from 79 cm in 'Semmane' to 115.33 cm in 'Mahdia'. Generally, the assessed plant material showed different vegetative behavior with respect to temperature. This result was statistically confirmed by the analysis of variance which revealed a highly significant effect depending on the genotype. Mahdia is likely more adapted to high temperature unlike Semmane. The differences among pepper genotypes are probably due to their genetic make-up. Plant height is often used as an indicator of plant vigor, but it generally depends on the plant's growth habit. Soil nutrients are also very important for the height of plants (Mohammed Houssein et al., 2012). Yield varied significantly among the studied pepper genotypes ($P < 0.05$). The highest yield 1841.66 g plant^{-1} was obtained by 'Kairouan' and the lowest 1163.25 g plant^{-1} was obtained by 'Jerid'. Pepper genotypes show significant variations in yield plant^{-1} and these variations were presumably correlated to genetic variations (Jan et al., 2020). Genefianti et al. (2008) reported that total yield of the crop was directly proportional to number of fruits per plant. Fitriani et al. (2013) outlined that total yield of different chilli varieties was controlled by environmental conditions greater than genetic attributes. All genotypes showed satisfying yields underlying a good productivity under the ongoing climatic changes and high temperature particularly applying for open-field grown crops during this particular period of time. The average fruit weight ranged from 6.5 g in 'Jerid' to 37.75 g in 'Kairouan'. 'Semmane' and 'Mahdia' showed average fruit weight generally appreciated by fresh market consumers. Ilić et al. (2017) assessed old traditional Serbian pepper landraces (Nizača, Lokošnička and Turšijara), grown in South Serbia and reported variations in fruit weight ranging from 46 g in Nizaca to 60 g in Tursijara. The investigated pepper genotypes exhibited acceptable agronomic traits. Pepper genotypes showed significant variations in yield and these variations are generally controlled by the environmental conditions greater than genetic attributes (Miller and Rice-Evans, 1997; Fitriani et al., 2013).

Table 1. Agronomic attributes of pepper genotypes grown under open-field.

Genotypes	Plant height (cm)	Yield (g)	Average fruit weight (g)
Semmane	79±1.67b	1687.25±40b	34.33±1.11a
Jerid	85.67±4.44b	1163.25±47.17c	6.5±0.5b
Mahdia	115.33±1.78a	1634.92±22.55b	33.83±0.39a
Kairouan	87.33±1.78b	1841.67±17.94a	37.75±0.17a

Physiological traits

Photosynthesis, transpiration and stomatal conductance of four pepper genotypes are shown in Table 2. The results show significant differences between the varieties, indicating variability in their physiological response to growing conditions. Photosynthesis revealed that 'Kairouan' recorded the highest intensity with 14,88 µmol m^{-2} s^{-1}, followed by 'Mahdia'. These varieties, with their high photosynthetic activity, were found to be the most efficient in terms of light utilization and CO_2 conversion into energy, giving them an higher performances in terms of growth and yield under favorable conditions (R'him et al., 2005). The lowest photosynthesis activity was detected in 'Jerid' (12.29 µmol m^{-2} s^{-1}). 'Jerid' could have a reduced capacity for light capture, probably due to the reduced size of leaves and stomata (R'him, 2005). Regarding transpiration, 'Semmane' displayed the highest transpiration rate (3.96 µmol m^{-2} s^{-1}), these genotype with high rate, signaling a more intense environmental interaction and therefore an increased water loss by evaporation, which could make them more sensitive to water stress in dry periods. Conversely, 'Jerid' with lower transpiration rate, seem to better conserve water, indicating a better adaptation to arid environments, where reducing water loss is crucial. This is consistent with the origin of these varieties and their adaptability, as reported previously by R'him et al. (2008, 2010). In terms of stomatal conductance, 'Mahdia' recorded the highest value (402.67 µmol m^{-2} s^{-1}), followed by Kairouan and Semmane. On the other hand, 'Jerid' displayed the lowest stomatal conductance (285.33 µmol m^{-2} s^{-1}). This low conductance, coupled with limited transpiration, could be due to the small size of its stomata (R'him, 2005), which makes this variety less reactive to environmental variations compared to the other varieties studied.

Table 2. Photosynthesis, transpiration and stomatal conductance of four pepper genotypes grown in Tunisia.

Genotypes	Photosynthesis (µmol m^{-2} s^{-1})	Transpiration (µmol m^{-2} s^{-1})	Stomatal conductance (µmol m^{-2} s^{-1})
Semmane	13.79±0.36 b	3.96±0.09 a	367±28 b
Jerid	12.29±0.3 c	3.13±0.02 c	285.33±11.78 c

Mahdia	14.48±0.56 a	3.6±0.32 b	402.67±6.22 a
Kairouan	14.88±0.09 a	3.68±0.35 b	363.33±20.44 b

Functional quality traits

Capsaicinoids, carotenoids and tocopherols contents of the studied pepper genotypes are reported in table 3. Capsaicinoids content varied significantly among the studied pepper genotypes ($P \leq 0.05$). The highest value (193.71 µg g^{-1} FW) was recorded in 'Jerid', while the lowest (1.81 µg g^{-1} FW) was recorded in cultivar 'Kairouan'. Capsaicinoid content is strongly influenced by genetic traits (Jeeatid et al., 2018). Our results are in agreement with various authors (Alam et al., 2020; Castillo-Aguilar et al., 2021; Diaz-Sanchez et al., 2021; Moon al., 2023; Diaz-Sanchez et al., 2021). However, differences compared to previously published data, would be explained by the fact that capsaicinoid synthesis does not only depend on the variety but also on the growing conditions. Indeed, the variation in temperatures and relative humidity during fruit development (from fruit set to maturity) also contributes to the variation in capsaicinoid contents (Garcès-Claver et al., 2007; Rahmen and Inden, 2012). It has been reported that the amount of capsaicinoids is highly variable in pepper, depending strongly on the variety, but also on many parameters such as the stage of maturity, the growing season and irrigation (Reyes-Escogido et al., 2011). Total carotenoids showed large variability among the tested pepper landraces and ranged from 45.94 µg g^{-1} FW in 'Kairouan' to 174.52 µg g^{-1} FW in 'Semmane'. Our results were similar with the conclusions of several other studies (Maiani et al. (2009); Rodríguez et al. (2020); Da Silveira et al. (2016) Martínez-Ispizua et al. (2021) and Moon et al. (2023)), highlighting the importance of genetic characteristics in determining carotenoid content in pepper varieties. The observed variation among the different studied varieties is primarily attributed to the varietal effect. Also, the effect of the environment under which the fruit was formed (Wall et al., 2001) could have an impact mainly temperature (Russo and Howard, 2002), light (Doumandji et al 2012) and even cold (Markus et al, 1999). Da Silveira et al. (2016) reported large variability among pepper landraces regarding total carotenoids content confirmed the influence of genotypic make-up on this particular trait. Tocopherols content ranged from 19.38 µg g^{-1} FW in 'Kairouan' to 31.24 µg g^{-1} FW in 'Jerid'. Tocopherols content is probably affected by lipid content, which varies with variety and stage of maturity (Kanner et al., 1979; Jorge et al., 1998).

Table 3. Functional quality traits of four pepper genotypes grown in Tunisia.

Genotypes	Capsaicinoids (µg g^{-1} FW)	Carotenoids (µg g^{-1} FW)	Tocopherols (µg g^{-1} FW)
Semmane	36.65±0.32b	174.52±21.09a	23.32±1.92b
Jerid	193.71±1.32a	147.40±12.70a	31.24±5.21a
Mahdia	3.01±0.09c	64.33±10.16b	19.85±0.86b
Kairouan	1.81±0.19c	45.94±5.97b	19.38±0.3b

Conclusion

The study provides a clear insight not only into horticultural performances but also into the functional quality of different pepper genotypes. The study also showed that most of the genotypes are cumulating useful agronomic, physiological and functional quality traits suitable to be exploited for further breeding programs and selections process aiming to develop high-yielding genotypes with minimal requirement (inputs and water) particularly under the ongoing climatic changes worldwide.

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