

# Evaluation of Antioxidant Traits in Fruits of Some Hot Pepper (*Capsicum* sp.) Genotypes under Greenhouse and Field Conditions

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**Abstract** Antioxidants are beneficial for the management of some chronic diseases such as cancer, neurodegenerative, cardiovascular and diabetic diseases. Through scavenging activities on free radicals, antioxidants reduce oxidative stress in human. Plant sources of antioxidants are better in potency and health risks than the synthetics, especially in fruits and vegetables. Research has established that consumption of vegetables reduces the risk of many chronic diseases due to the presence of antioxidants. Therefore, this experiment was conducted using seventeen (17) hot pepper (*Capsicum spp.*) genotypes to find out their antioxidant compositions. All samples for the genotypes were extracted using methanol and ethanol solvents. Total phenolic content was determined by using Folin-Ciocalteu method on absorbance at 765 nm. Lycopene and  $\beta$ -carotene were determined through the modified method of Sharoba on absorbance at 453nm, 505nm, and 663. For total flavonoid content, the modified aluminum chloride colorimetric method was used on absorbance at 510nm. Antioxidant activity was determined using 2, 2-diphenyl-1-picrylhydrazyl (DPPH) free radical scavenger method. The phenolic acids content recorded under field conditions were relatively higher in all genotypes than under greenhouse conditions. For carotenoids, whereas high lycopene content was recorded under greenhouse conditions  $\beta$  carotene yield was rather higher under field conditions. Total flavonoid content among the genotypes varied across the two experimental environments. DPPH free radical scavenging activity was generally high and showed a correlation with phenolic acids content across the environments. To conclude, the antioxidants studied among the genotypes were high in concentration and varied across environments.

**Keywords** Genotypes, Antioxidants, Environments, Concentrations, Pepper, Evaluation

## 1. Introduction

Hot pepper (*Capsicum spp.*) is one of the most divergent crops cultivated globally. It is ranked the third most important vegetable besides peas and tomatoes (Ochoa-Alej and Ramirez-Malagon, 2001; Ali, 2006). It is extensively used as food in the world over (Terry and Boyhan, 2006) perhaps due to the presence of many health promoting substances. In recent times, the potency of pepper as a source of natural antioxidants has been recognised and now being exploited through research. Antioxidants are phytochemicals that delay, inhibit or take away oxidative damages to cells in the body. Thus, they prevent or reduce oxidative events within the body (Halliwell, 2007) through scavenging of free

radicals from the cells (Dolas and Gotmar, 2015). Antioxidants in general contribute to solving many health related issues in humans. They prevent cardiovascular, carcinogenic and neurological diseases (Williamson *et al.*, 2000; Morton *et al.*, 2000) such as rheumatoid arthritis, cancers, eye, heart, alzheimer and parkinson's diseases (<http://www.betterhealth.vic.gov.au/bhcv2/bhcarticles.nsf/pages/Antioxidants>).

Comparatively, natural antioxidants are better than the synthetics, in that they have multiple health benefits with no adverse effects, readily acceptable by the body, and have antioxidant effects on human tissues (Reena *et al.*, 2016). Thus, consumers' quest for natural antioxidants and restriction on the usage of synthetic antioxidants as well as people's awareness of its health-related issues (Vazquez *et al.*, 2012) has pushed for greater investigations into these. Moreover, natural antioxidants are safer and have even greater antioxidant activity compared to the synthetics (Beutner *et al.*, 2001).

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Natural antioxidants are obtained from secondary metabolites available in fruits and vegetables. These include compounds such as carotenoids, alkaloids and phenolics (Hollman, 2001). Among these, polyphenols and carotenoids are the two main compounds which account for the highest antioxidant properties in plants (Zhang *et al.*, 2013). Flavonoids dominate phenolics in plant foods (Bors *et al.*, 1996) and are estimated to be two-thirds of all dietary phenols (Scalbert, and Williamson, 2000). Natural carotenoids are beneficial in the prevention of numerous types of cancers and other diseases. Among carotenoids, lycopene is by far the most potent antioxidant known because it possesses the highest singlet oxygen quenching rate (Rao and Rao, 2007). Also, it is able to fight cancers such as prostate, urinary bladder and colon cancers. Beta-carotene is also known to reduce the dangers of stroke, heart diseases, aging, vascular and other metabolic diseases (Shankaranarayanan *et al.*, 2018).

Like other vegetables, hot pepper (*Capsicum spp.*) genotypes contain most of the secondary metabolites which are very essential for human health. Phenolics have been reported to be higher in hot pepper (*Capsicum spp.*) than all other vegetables sources (Kumar *et al.*, 2009). A considerable intake of hot pepper (*Capsicum spp.*) could boost the antioxidants content and activities in man which in effect reduces the threat of carcinogenesis (Nishino *et al.*, 2009). As a result of the rise in preference for natural antioxidants by consumers, this research was set out to establish the following in some seventeen (17) hot pepper (*Capsicum spp.*) genotypes:

- To determine the concentrations of antioxidants traits (phenolics and carotenoids) in the pepper genotypes.
- To compare the performance of the antioxidant (phenolics and carotenoids) traits under two different environments (greenhouse and field conditions).
- To assess the impact of locations (greenhouse and field conditions) on the antioxidants traits (phenolics and carotenoids) in the pepper genotypes.

## 2. Materials and Method

### 2.1. Experimental Site

This experiment was conducted under greenhouse and field conditions. Crop cultivation and growth were done at the Forest and Horticultural Crops Research Centre (FOHCREC) of the University of Ghana, Kade in the Eastern Region of Ghana. Laboratory analyses of antioxidant contents of the pepper genotypes were done at the Department of Botany, College of Basic and Applied Sciences of University of Ghana Campus, Accra.

### 2.2. Pepper Genotypes used for the Experiment

We studied a total of Seventeen (17) genotypes obtained from Plant Genetic Resources Research Institute (PGRRI), Bunso and the Forest and Horticultural Crops Research

Centre (FOHCREC), Kade both in the Eastern Region of Ghana (Table 1).

**Table 1.** Sources of genotypes used for the study

Genotype	Source	Genotype	Source
Galaxy	FOHCREC-Kade	Local Hot Chili	FOHCREC-Kade
GR 202	FOHCREC-Kade	Pari Mild	FOHCREC-Kade
Vulcano	FOHCREC-Kade	9B	PGRRI-Bunso
Z-607	FOHCREC-Kade	7E	PGRRI-Bunso
Delhi Hot	FOHCREC-Kade	7A	PGRRI-Bunso
ICPN16#7	FOHCREC-Kade	9A	PGRRI-Bunso
Salmon Pepper	FOHCREC-Kade	9F	PGRRI-Bunso
Legon 18	FOHCREC-Kade	9H	PGRRI-Bunso
Mayford	FOHCREC-Kade		

FOHCREC= Forest and Horticultural Crops Research Centre, PGRRI= Plant Genetic Resources Research Institute

### 2.3. Experimental Design

The experiments were laid out in randomized complete block design with three (3) replications for each genotype. Genotypes were assigned to plots randomly using the drawing lots method.

### 2.4. Planting Distances under Greenhouse and Field Conditions

Under field conditions, plants were sown on ridges with the dimension of each as 82.6 m x 0.53 m and 0.7 m separating each of them. Seedlings were planted with the distance of 0.8 m x 0.59 m. For the greenhouse conditions, beds were 6m in length and 0.95m in width. A distance of 0.54m separated the beds. The planting distances were 0.6 m x 0.5 m.

### 2.5. Nursery and Cultural Practices

Seeds were sown in compartmentalized seed boxes filled with rice biochar (carbonated rice husk) as the medium. Two seeds were sown per cell. Effective watering was undertaken after germination until transplanting. To check damping-off disease at the nursery, the seedlings were sprayed with appropriate fungicide at two (2) weeks intervals until transplanting. Transplanting was done four (4) weeks after sowing of seeds.

### 2.6. Laboratory Analysis of Fruit Quality Traits

Laboratory analyses were performed for the following antioxidant traits of all the pepper genotypes: phenolic acids (gallic, vanillic, and rosmarinic acids), total flavonoids, lycopene and  $\beta$ -carotene contents as well as antioxidant activities ( $IC_{50}$  value). Dried and ground fruit samples of all the pepper genotypes were used for these analyses.

#### 2.6.1. Drying of the Fruits of Pepper Genotypes

Pepper fruits used for the chemical analyses were in the

fully ripe state. Non-specified sample of ripe fruits was oven-dried at 60°C for forty-eight (48) hours as described by Ikpeme *et al.* (2014).

#### 2.6.2. Preparation of Pepper Samples

Powdered pepper samples were prepared using the approach adopted by Tsai *et al.* (2009) with a slight modification. The fruits were pulverized into fine powder. Ten (10) grams of the pulverized sample of each genotype was extracted with 100 ml of methanol at 25°C at 20xg for 24 hours and later filtered through Whatman No. 1 filter paper. The residue was extracted with two additional 100 ml portions of methanol as described above and combined ethanolic extracts were concentrated under reduced pressure below 40°C to obtain the crude extract. The crude extracts were re-dissolved in methanol at concentration of 20 mg/ml and stored at 4°C for further analyses.

#### 2.6.3. Determination of Total Phenolic Content

Total phenolic content was determined by using Folin-Ciocalteu reagent based on modified version of the method by Harborne (1989). A volume of 1.0ml from each pepper genotype's sample was added to 1.0ml aqueous sodium carbonate solution. A 1.0ml volume of Folin-Ciocalteu reagent was added to the mixture and topped up to 10 ml. The mixture was agitated and allowed to stand for 90 minutes. The absorbance was measured at 765 nm by using UV/visible spectrophotometer (SpectraMax Plus 384, United states). The concentration of the total phenolic compounds was calculated based on standard curve of gallic acid (0.2 – 1.0 mg/ml) with the linear equation,  $y = 0.624x - 0.939$ , where  $R^2 = 0.995$ . The results were expressed as mg of gallic acid equivalent (GAE/mg) per 100 ml of the extract. For the determination of the concentrations of individual phenolic compounds, the following formulae were used: (a) gallic acid (mg/100ml):  $y = 0.0871x - 0.102$  (b) vanillic acid (mg/100ml):  $y = 0.053x + 0.012$  (c) rosmarinic acid (mg/100ml):  $y = 0.069x + 0.022$ .

#### 2.6.4. Determination of Lycopene and $\beta$ -Carotene Contents

The modified method of Sharoba (2009) was followed for this determination. To determine the concentrations of lycopene and  $\beta$ -carotene, the absorbance of the extracts were measured at the wavelengths 453nm, 505nm, and 663 by using spectrophotometer (SpectraMax Plus 384, United states). The following formulae according to Nagata and Yamashita (1992) were used to calculate for the concentration of lycopene and  $\beta$ -carotene respectively; a) Lycopene (mg/100ml) =  $-0.0458A_{663} + 0.372A_{505} - 0.0806A_{453}$  b)  $\beta$ -carotene (mg/100ml) =  $0.216A_{663} - 0.304A_{505} + 0.452A_{453}$ .

#### 2.6.5. Determination of Total Flavonoid Content of Pepper Genotypes

The modified aluminium chloride colorimetric method by Barros *et al.* (2007) was used to determine the flavonoid

content. Methanolic extract of pepper fruits (0.5 ml) was mixed with distilled water at 500  $\mu$ l and sodium nitrite,  $\text{NaNO}_2$  (5%, 30  $\mu$ l). The mixture was allowed to stand for 5 minutes. Aluminium chloride solution,  $\text{AlCl}_3 \cdot \text{H}_2\text{O}$  (10%, 60  $\mu$ l) was added to the mixture. The mixture was allowed to stand for 6 minutes after this. Sodium hydroxide,  $\text{NaOH}$  (1M, 200  $\mu$ l) and distilled water of 110  $\mu$ l were added to the mixture and made to thoroughly mixed. Absorbance was taken at 510 nm (SpectraMax Plus 384, United States). Concentration of total flavonoid content was computed based on standard curve of rutin (0.2 – 1.0 mg/ml) with the linear equation  $y = 0.0101x + 0.2238$  with  $R^2 = 0.9563$ . The results were expressed as mg of rutin equivalent (RE/mg) 100 ml of the extract.

#### 2.6.6. Determination of Antioxidant Activity of Pepper Genotypes Chemicals and Reagents

The chemical DPPH was secured from Sigma Aldrich Co. (St. Louis, USA). Other chemicals used were of analytical grade.

#### 2.6.7. 2, 2-Diphenyl-1-picrylhydrazyl (DPPH) Free Radical Scavenging Activity of Methanolic Extract

Diluted working solutions of the test extracts were prepared in methanol. The standard used was ascorbic acid. A volume of 100 $\mu$ l of test samples (0.6-20mg/ml) measured accurately in methanol was added to 5  $\mu$ l DPPH solution. A percentage of 0.002 DPPH was made in methanol. A microliter of the DPPH solution was mixed with 1 ml of sample solution and a standard solution to be tested separately. The solution mixture was kept in the dark for 30 minutes. Afterwards, an optical density was measured at 517 nm by a spectrophotometer against 1 ml methanol as the blank in 1 ml of DPPH solution (0.002%). The optical density was recorded and percentage inhibition was calculated using the formula by (El-Agbar *et al.*, 2008). The percentage inhibition of DPPH activity

$$= \left( \frac{A - B}{A} \right) \times 100$$

Where;

A- Optical density of the blank

B- Optical density of the sample

#### 2.7. Statistics and Estimation of $\text{IC}_{50}$

The development (decolorization) was plotted against sample extract concentration. A linear regression curve was established for the calculation of  $\text{IC}_{50}$  ( $\mu\text{g/ml}$ ).  $\text{IC}_{50}$  indicates the value of the sample needed to reduce the absorbance of the DPPH radical by 50%. All phytochemical analysis was carried out in triplicate and the averages were estimated.

#### 2.8. Analysis of Data

All data from the experiments were analyzed by using the GenStat Computer Statistical Software (2009) and XLSTAT statistical software (2015).

### 3. Results and Discussion

Analysis of variance (ANOVA) performed for all the antioxidant parameters revealed significant difference ( $P < 0.001$  and  $P \leq 0.05$ ) across genotypes, environments, and genotype x environment. However,  $IC_{50}$  under both experimental conditions and lycopene under greenhouse conditions were not significant (Tables 2, 3 and 4).

Three (3) phenolic acid compounds; gallic acid, vanillic acid and rosmarinic acid determined among the genotypes under field conditions were almost higher than that recorded under greenhouse conditions (Table 5). This might be due to suitable climatic conditions which favoured these traits under field conditions. Tolic *et al.* (2017) reported that variations in climatic conditions during growing seasons have influence on phenolics concentrations in fruits.

Among the phenolic compounds, vanillic acid concentration recorded the highest value irrespective of the growing condition. This ranged from 8.3–28.8 mg/100ml (Table 5) which was consistent with earlier report by Podesta (2009). This could be that the effect of genotype x

environment interaction on this trait was negligible among genotypes studied. Hence, its production could be stable under both conditions.

Genotype 9F exhibited superior performance for gallic, vanillic, and rosmarinic acids under field conditions with the concentrations 18.5mg/100ml, 28.8mg/100ml and 22.0mg/100ml respectively. Similarly, the performance of Pari Mild for gallic (18.8mg/100ml), vanillic (28.8mg/100ml), and rosmarinic (21.9mg/100ml) acids was relatively better and consistent under greenhouse conditions (Table 5). The consistency of these two genotypes to yield high concentrations of the phenolic acids under the environmental conditions indicate the ability of the respective environments to positively influence the genetic factors controlling this trait phenotypically in the two genotypes. This affirms the fact that gene expression phenotypically is environmentally induced and regulated (Kang, 1998). Genotype 9F and Pari Mild could be recommended for commercial production of the phenolic acids.

**Table 2.** Mean Squares from the Analysis of Variance of Antioxidant Properties for 17 Pepper Genotypes under Field Conditions

S. of Variation	Df	Mean		Squares				
		$IC_{50}$	VA	LC	GA	BC	RA	FC
Rep.	2	0.0068	21.33	0.0029	8.74	0.035	11.41	0.0066
Genotype	16	0.2979	85.87*	0.0031*	30.73*	0.027*	51.48*	0.1192*
Residual	32	0.0000	1.39	0.00012	1.26	0.004	1.56	0.0082
Total	50	0.3047	108.59	0.00612	40.73	0.066	64.45	0.134

\*Significant ( $P < 0.001$ ), • Significant ( $P \leq 0.05$ ),  $IC_{50}$  value, VA= vanillic acid content, LC = Lycopene content, GA = gallic acid content, BC = beta carotene content, RA = Rosmarinic acid, FC = total flavonoid content Df = degree of freedom, S. of Variation = Source of variation, Rep. = Replication.

**Table 3.** Mean Squares from the Analysis of Variance of Antioxidant Properties for 17 Pepper Genotypes under Greenhouse Conditions

S. of Variation	Df	Mean		Squares				
		$IC_{50}$	VA	LC	GA	BC	RA	FC
Rep.	2	0.0068	0.98	0.014	0.38	0.023	0.6	0.0098
Genotype	16	0.2964	78.3*	0.019	27.7*	0.104•	45.7*	0.0446*
Residual	32	0.0000	2.11	0.016	1.18	0.048	1.058	0.0035
Total	50	0.3032	81.39	0.049	29.26	0.175	47.36	0.0579

\*Significant ( $P < 0.001$ ), • significant ( $P \leq 0.05$ ),  $IC_{50}$  value, VA= vanillic acid content, LC = Lycopene content, GA = gallic acid content, BC = beta carotene content, RA = Rosmarinic acid, FC = total flavonoid content, Df = degree of freedom, S. of Variation = Source of variation, Rep. = Replication

**Table 4.** Mean Squares from the Analysis of Variance of Antioxidant Properties for 17 Pepper Genotypes (Combined)

S. of Variation	Df	Mean		Squares				
		$IC_{50}$	VA	LC	GA	BC	RA	FC
Rep.	2	0.014	9.95	0.0021	5.57	0.041	7.91	0.01274
Genotype	16	0.32	46.06*	0.0104	16.41*	0.088*	27.20*	0.09880*
Env.	1	0.801	381.73*	0.2024*	140.92*	0.17•	243.92*	0.00009
E x G	16	0.27	118.20*	0.0114	42.05*	0.044	69.99*	0.06505*
Residual	68	0.00	2.31	0.0079	1.42	0.026	1.58	0.00579
Total	103	1.405	558.25	0.2342	206.37	0.369	350.6	0.18328

\*Significant ( $P < 0.001$ ), • significant ( $P \leq 0.05$ ),  $IC_{50}$  value, VA= vanillic acid content, LC = Lycopene content, GA = gallic acid content, BC = beta carotene content, RA = Rosmarinic acid, FC = total flavonoid content, Df = degree of freedom, S. of Variation = Source of variation, Rep. = Replication.

**Table 5.** Mean Values for Gallic, Vanillic, and Rosmarinic Acids of 17 Pepper Genotypes Grown under Greenhouse and Field Conditions

Genotype	Garlic acid (mg/100 ml)			Vallinic acid (mg/100 ml)			Rosmarinic acid (mg/100 ml)		
	Environment			Environment			Environment		
	Field	Green H	Mean	Field	Green H	Mean	Field	Green H	Mean
7A	11.1	10.1	10.6	16.1	14.5	15.3	12.2	11.0	11.6
7E	13.2	11.5	12.3	20.1	16.7	18.4	15.3	12.7	14.0
9A	16.5	10.4	13.4	24.9	14.9	19.9	19.0	11.3	15.2
9B	15.1	12.7	13.9	22.7	18.8	20.7	17.2	14.3	15.8
9F	18.5	11.7	15.1	28.8	17.1	22.9	22.0	13.0	17.5
9H	12.3	13.1	12.7	18.2	20.0	19.1	13.5	14.7	14.1
Del H	15.7	8.1	11.9	23.6	11.1	17.4	18.0	8.4	13.2
Gal	9.5	7.8	8.6	13.4	10.7	12.1	10.1	8.1	9.1
GR	12.7	8.1	10.4	18.6	11.2	14.9	14.8	8.5	11.6
ICP	15.7	7.8	11.7	23.6	10.7	17.2	18.0	8.1	13.1
L18	13.4	12.1	12.7	20.5	17.3	18.9	15.1	13.4	14.2
LHC	15.8	11.8	13.8	23.7	17.5	20.6	19.4	13.2	16.3
MF	18.3	11.8	15.1	27.9	17.5	22.7	21.3	13.3	17.3
PM	6.7	18.8	12.8	8.3	28.8	18.5	6.5	21.9	14.2
Sal	15.3	8.1	11.7	23.2	11.1	17.2	18.0	8.4	13.2
Vul	9.4	16.3	12.9	13.9	25.4	19.6	10.5	19.4	14.9
Z-607	14.0	12.9	13.4	20.9	19.5	20.2	15.9	14.8	15.4
Grand M	13.7	11.4	12.5	20.5	16.6	18.6	15.7	12.6	14.2
LSD <sub>(0.05)</sub>	1.870	1.81	1.37	1.96	2.42	1.75	2.07	1.71	1.45

**Table 6.** Mean Values for Lycopene and  $\beta$  Carotene Content of 17 Pepper Genotypes Grown under Greenhouse and Field Conditions

Genotype	Lycopene(mg/100 ml)			$\beta$ carotene (mg/100 ml)		
	Environment			Environment		
	Field	Green H	Mean	Field	Green H	Mean
7A	0.09	0.19	0.14	0.37	0.23	0.30
7E	0.06	0.18	0.12	0.27	0.08	0.18
9A	0.05	0.09	0.07	0.23	0.16	0.20
9B	0.05	0.14	0.10	0.24	0.06	0.15
9F	0.05	0.40	0.23	0.21	0.4	0.31
9H	0.07	0.12	0.10	0.24	0.05	0.15
Del H	0.07	0.14	0.11	0.30	0.7	0.50
Gal	0.09	0.11	0.10	0.33	0.06	0.20
GR	0.08	0.22	0.15	0.35	0.26	0.31
ICP	0.05	0.19	0.12	0.26	0.07	0.17
L18	0.04	0.12	0.08	0.14	0.07	0.11
LHC	0.03	0.09	0.06	0.14	0.05	0.10
MF	0.15	0.16	0.16	0.26	0.07	0.17
PM	0.13	0.05	0.09	0.32	0.4	0.36
Sal	0.06	0.12	0.09	0.24	0.03	0.14
Vul	0.11	0.25	0.18	0.55	0.35	0.45
Z-607	0.07	0.18	0.13	0.33	0.34	0.34
Grand M	0.07	0.16	0.12	0.28	0.20	0.24
LSD <sub>(0.05)</sub>	0.018	0.209	0.103	0.106	0.366	0.187

With the carotenoid compounds measured among the genotypes, lycopene performed better under greenhouse conditions while  $\beta$  carotene produced better results under

field conditions (Table 6). For lycopene, the concentrations ranged from 0.03 - 0.4 mg/100 ml (Table 6). This result was inconsistent with previous findings (Fadupin *et al.*, 2012).

The  $\beta$ -carotene concentrations ranged from 0.03 - 0.55mg/100ml (Table 6) and higher than the concentrations reported by Chavez-Mendoza *et al.* (2013). Generally, the concentration of the compounds measured among the different genotypes varied across the two environments. This observation might be as a result of environmental differences, inherent genetic factors as well as genotype x environment interaction. Comparatively, commercial production could be more suitable under field conditions for  $\beta$  carotene while lycopene would be for greenhouse conditions.

Genotypes 9F and Vulcano recorded the highest lycopene and  $\beta$ -carotene contents respectively (Table 6). These genotypes could be considered for commercial production for the traits and crop improvement aimed at enhancing antioxidant composition traits in pepper.

The current experimental results revealed that total flavonoid content differed among the genotypes and across the growing environments. This suggests that genetic, environmental and the interaction of the two factors influenced the production of flavonoid. Thus, it indicates, rather than multiple environments, genotype selection for higher levels of flavonoids production and advancing pepper crop improvement would best be made by considering a specific environment. In general, flavonoid concentration among the genotypes considered in the

present experiment ranged between 0.22mg/100ml and 0.79mg/100ml in both environments (Table 7). This finding was not in agreement with earlier report (Rohanizah and Ishak, 2012). Four (4) genotypes Vulcano, Pari Mild, ICPN16#7 and Mayford performed best among the rest under both environments (Table 7) and could be considered for production under their respective environments.

Each of the genotypes used for the experiment yielded almost similar concentrations for antioxidant activities under both the field and greenhouse conditions (Table 7) depicting insignificant effect of environments on their production. Their mean concentrations ranged from 0.64 - 1.96mg/ml under both environments (Table 7). These results differed from the previous report by Yida *et al.* (2020). The difference in results between the present and earlier finding could be attributed to the different genotypes used as well as differences in the growing environments. The genotypes 7A showed the highest value for antioxidant activity irrespective of the growing condition and could be attributed to an inherent genetic make-up of the genotype for this trait. The mean values recorded for antioxidant activity among the genotypes were standard. This was reflected in their good yields of phenolics acids (Table 5) and confirmed that a positive relationship exists between antioxidant activity and total phenolic content in vegetables and fruits (Yida *et al.*, 2020).

**Table 7.** Mean values for total flavonoids and antioxidant activity of 17 pepper genotypes grown under greenhouse and field conditions

Genotype	Total flavonoid (RE/mg/100 ml)			IC <sub>50</sub> Values (mg/ml)		
	Environment			Environment		
	Field	Greenhouse	Mean	Field	Greenhouse	Mean
7A	0.24	0.42	0.33	0.92	0.64	0.78
7E	0.24	0.33	0.29	1.02	0.90	0.96
9A	0.58	0.49	0.54	1.22	1.60	1.41
9B	0.26	0.26	0.26	1.78	1.24	1.51
9F	0.53	0.51	0.52	1.3	1.04	1.17
9H	0.23	0.31	0.27	1.11	1.30	1.21
Del H	0.22	0.33	0.28	1.03	1.03	1.03
Gal	0.26	0.22	0.24	1.96	0.77	1.37
GR	0.22	0.5	0.36	0.95	1.32	1.14
ICP	0.25	0.65	0.45	1.11	0.99	1.05
L18	0.25	0.23	0.24	1.28	1.65	1.47
LHC	0.45	0.41	0.43	1.25	1.19	1.22
MF	0.68	0.33	0.51	1.43	0.83	1.13
PM	0.79	0.33	0.56	1.09	1.19	1.14
Sal	0.61	0.43	0.52	1.76	1.61	1.69
Vul	0.63	0.59	0.61	1.63	0.90	1.27
Z-607	0.23	0.36	0.30	1.09	0.71	0.90
Grand M	0.392	0.394	0.393	1.29	1.11	1.20
LSD <sub>(0.05)</sub>	0.150	0.099	0.088	*	*	6

\* -not comparable

## 4. Conclusions

Among the phenolic acids studied, vanillic acid yielded the highest concentration under both the greenhouse and field conditions. The antioxidant activities reflecting the scavenging potency of the genotypes were generally high and correlated with their phenolic acids contents across the two environments. Also, carotenoids (lycopene and  $\beta$  carotene) and total flavonoid contents varied across the two environmental conditions which proved that environmental influence played a role in the production. Generally, the antioxidants studied among the genotypes were high in concentration and varied across environments. Some genotypes performed better in yield for some of the antioxidants studied and could be considered for production.

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