Evaluation of yield and other agronomic traits in pepper (*Capsicum chinense* Jacq.) under greenhouse conditions in the humid tropics

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Yield measured as total number of fruits and total fruit weight per plant and 12 other agronomic traits were evaluated for ten pureline accessions of pepper (*Capsicum chinense* Jacq.) in two trials (wet and dry season) under greenhouse conditions, each arranged in a randomized complete block design with three replications. The main objectives were to determine the strength of associations among the traits and their stability over trials. Significant differences ($P \leq 0.05$ to 0.001) were observed among accessions in both trials for days to 50% fruiting, number of fruits per plant in the first five pickings, fruit weight per plant in the first five pickings, total number of fruits per plant, plant height, fruit length, fruit width, average fruit weight, fruit wall thickness, while significant differences for days to 50% flowering, number of fruits per plant in the second five pickings, fruit weight per plant in the second five pickings, total fruit weight per plant and plant canopy width were only observed in Trial 2, the dry season trial. Total number of fruits per plant and total fruit weight per plant were auto-correlated and were both generally positively associated with number of fruits and fruit weight per plant in the first and second five pickings and negatively associated with days to 50% flowering and fruiting. Comparison of linear regression lines showed that pepper accession performances over trials could be described by a single line or parallel lines for days to 50% fruiting, number of fruits and fruit weight per plant in the first five pickings, total number of fruits per plant, plant height, fruit length, fruit width, average fruit weight and fruit wall thickness, suggesting no accession x trial interactions of the crossover type (the relative rank of the accessions did not change). Two accessions (UAE-257 and FGY-335) showed consistent yields over trials. The implications of the results are discussed.

Keywords: Comparison of regression lines, early flowering and fruiting, open-sided greenhouse cultivation, stability of traits

Pepper (*Capsicum chinense* Jacq.) is a short-lived herbaceous perennial (Basu and De 2003), that is a member of the plant family, Solanaceae (Bosland et al. 1996; Eshbaugh 1993). It is indigenous to the Caribbean, Central and South America (Shoemaker and Teskey 1955; Heiser 1976; Bosland and Votava 2000; Elibox et al. 2015) and is consumed mostly as a fresh vegetable or a spice to enhance the taste of foods, but sometimes it is processed into sauces (Sinha and Petersen 2011), pharmaceuticals (Stewart et al. 2005), cosmetics, and sprays used in the defence industry (Bosland and Votava 2000). Traditionally, in the Caribbean, pepper is cultivated as an annual in open-fields (Sinha and Petersen 2011; Elibox et al. 2015, 2017; Ali et al. 2019) where environmental conditions particularly rainfall intensity in the wet season have adverse effects on yield measured as total number of fruits per plant and total fruit weight per plant (Ali et al. 2019). However, in recent times, there has been a thrust in the Caribbean, particularly in Trinidad and Tobago and Jamaica, towards cultivation of pepper in greenhouses as a means of improving yield (Lawrence, 2013; DeGannes et al. 2014). Greenhouse production of the closely allied species, *C. annuum*, has been successfully performed in Jamaica (Lawrence 2013) and according to Cantliffe et al. (2008), it may increase profits four-fold when compared to open-field production.

Recently, the performances of 68 pureline accessions of *C. chinense* for yield were conducted under open-field conditions by Ali

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et al. (2019). In that study it was found that the two measures of yield (total number of fruits per plant and total fruit weight per plant) were weakly associated and that total number of fruits per plant was associated with number of fruits per plant in the first and second five pickings (harvests), fruit width and average fruit weight whereas total fruit weight per plant was associated with fruit weight per plant in the first and second five pickings and shorter times to 50% flowering and fruiting. Furthermore, the relative rank of the accessions did not change over seasons for days to 50% flowering and fruiting, fruit weight per plant in the second five pickings, total fruit weight per plant and fruit width. Such studies have not been performed for pepper under greenhouse conditions and such information is vital as greenhouse structures are costly to set up, maintain and if intensive greenhouse production of pepper does not result in a significant yield advantage over open-field conditions, farm losses will be severe. Therefore, the aim of this study was to evaluate yield (measured as total number of fruits and total fruit weight per plant) and 12 other agronomic traits for ten *C. chinense* pureline accessions already evaluated under open-field conditions (Ali et al. 2019) in a standard greenhouse production system in the humid tropics.

Material and methods

Ten pureline pepper accessions viz. CAB-110, UAE-257, GAC-291, UAP-328, GAJ-7, FGY-335, K-40, TT-41, K-57 and LAM-301 (Table 1) were selected based on representation from the three phylogenetic groups of Moses and Umaharan (2012) and prior yield performances under open-field conditions (Ali et al. 2019). The study was conducted under a standard open-sided, gutter-connected galvanized steel greenhouse (38.1 m long x 32.9 m wide x 4.9 m high) (Westbrook Greenhouse Systems Ltd., Ontario, Canada) that was covered with clear plastic (Dura-Film, AT Plastics Inc, Edmonton, Alberta, Canada) at Nature's Green Farms, Thick Village, Siparia, Trinidad and Tobago. The topography of the area is flat and the soil type is the fertile San Francique clay (Ali et al. 1973). The temperature in the greenhouse ranged from 17.0 – 39.5ºC and 23.0 – 35.5ºC during the dry (January to June) and wet (July to December) seasons respectively, whereas the relative humidity in both seasons had a similar range, 30.5 – 100.0%. The annual rainfall in the area is 1300 mm.

Experimentation was carried out in two trials, of which one was planted in September during the wet season of 2015 (Trial 1) and the other in January during the dry season of 2016 (Trial 2). Both trials were arranged in a randomized complete block design with three replications with 16 plants (4 x 4 layout) per replicate planted in beds and a spacing of 0.6 m between plants. Seedling establishment, harvesting procedures, and cultural practices were according to Elibox et al. (2015) and Ali et al. (2019), respectively.

Data collection from four guarded plants per replicate for 13 traits (Table 1) was as described by Ali et al. (2019). Additionally, fruit wall thickness per replicate was taken as the mean value for ten representative fruits from the second picking. Each fruit was cut with a sharp scalpel at its widest point and the wall thickness was measured using a digital caliper (Stanley, Connecticut, USA). In both trials, a total of ten pickings (harvests) per trial were obtained.

Statistical analyses were performed using NCSS (2007) with the exception of the comparison of linear regression lines which was performed using COLR (CARDI 1974). Analysis of variance was conducted to determine the significance of accession differences for all 14 traits evaluated in each trial. Where differences were significant for a trait ($P \leq 0.05$), within accession coefficient of variation (CV_{within}), between accession coefficient of variation (standard deviation between the mean of the accessions divided by the general mean) and an index of discrimination ($ID = CV_{between} / CV_{within}$) were

calculated. Pearson's product moment correlation was used to assess the strength of associations between traits found to be significant in each trial. Spearman's rank correlation was performed to determine whether the relative rank of the accessions changed over trials for each trait for which there were significant differences among the accessions in both trials. Also, for these traits, the accession mean values over trials were regressed against the mean values in Trial 1 and Trial 2 and these linear regression lines were compared to determine if accession performances were similar over trials.

Table 1: Mean performance for yield (measured as total number of fruits per plant and total fruit weight per plant) and 12 other agronomic traits in ten pureline accessions of *Capsicum chinense* Jacq. under greenhouse conditions (Trial 1 wet season)

Accession	Origin	DTFL	DTFR	NFP 1st 5p	FWP 1st 5p	NFP 2nd 5p	FWP 2nd 5p	TNFP	TFWP	PH	PCW	FL	FW	Fr wt	FWT
CAB-110	Belize	57.0	90.7	48.3	0.60	56.7	0.63	104.7	1.20	66.3	102.9	46.0	34.5	11.5	2.1
UAE-257	Ecuador	59.3	95.0	94.0	1.27	72.0	0.63	166.0	1.90	42.5	95.8	53.7	36.3	14.1	2.1
GAC-291	Cuba	54.0	78.7	73.0	0.97	55.7	0.70	128.3	1.67	62.8	100.8	40.5	39.3	17.0	2.7
UAP-328	Peru	58.7	87.3	36.7	0.83	28.7	0.57	65.7	1.40	66.7	92.9	46.3	45.9	26.9	3.4
GAJ-7	Jamaica	67.0	99.7	45.7	0.67	31.7	0.33	77.7	1.00	61.3	91.7	38.6	49.8	18.1	2.5
FGY-335	French Guiana	76.7	107.3	45.7	0.83	65.7	0.87	111.3	1.67	79.2	87.5	38.0	43.5	17.4	2.4
K-40	Trinidad	58.0	90.3	54.0	0.80	68.0	0.77	121.7	1.60	64.6	104.6	43.0	43.4	16.9	2.2
TT-41	Trinidad	56.7	84.7	50.0	0.67	55.0	0.63	105.0	1.23	70.2	103.3	38.5	46.7	18.0	2.3
K-57	Trinidad	59.3	91.0	36.7	0.23	40.0	0.27	76.7	0.50	72.9	100.4	33.9	35.1	8.1	1.6
LAM-301	Brazil	54.0	87.7	29.0	0.47	50.0	0.67	78.7	1.13	53.3	99.6	46.3	39.6	17.0	2.4
Sig. (P ≤)	-	NS	0.05	0.01	0.05	NS	NS	0.05	NS	0.01	NS	0.01	0.001	0.001	0.001
Mean	-	60.1	91.2	51.3	0.73	52.3	0.61	103.6	1.33	64.0	98.0	42.5	41.4	16.5	2.4
SEM	-	5.90	5.07	9.44	0.162	12.66	0.164	18.46	0.272	5.50	10.40	2.52	0.80	1.21	0.11
LSD	-	-	12.33	22.96	0.39	-	-	44.90	-	13.38	-	6.12	1.93	2.94	0.28
CV_{within}	-	0.17	0.10	0.32	0.38	0.42	0.47	0.31	0.35	0.15	0.18	0.10	0.03	0.13	0.08
$CV_{between}$	-	0.11	0.09	0.37	0.39	0.28	0.30	0.29	0.31	0.16	0.06	0.14	0.13	0.30	0.19
ID	-	0.7	0.9	1.2	1.0	0.7	0.6	1.0	0.9	1.1	0.3	1.3	3.8	2.3	2.3

DTFL: days to 50% flowering; DTFR: days to 50% fruiting; NFP 1st 5p: number of fruits per plant first five pickings; FWP 1st 5p: fruit weight (kg) per plant first five pickings; NFP 2nd 5p: number of fruits per plant second five pickings; FWP 2nd 5p: fruit weight (kg) per plant second five pickings; TNFP: total number of fruits per plant; TFWP: total fruit weight (kg) per plant; PH: plant height (cm); PCW: plant canopy width (cm); FL: fruit length (mm); FW: fruit width (mm); Fr wt: average fruit weight (g); FWT: fruit wall thickness (mm); ID: index of discrimination; NS: not significant; CV: coefficient of variation.

Results

Trial 1

Differences among the pepper accessions with respect to all traits evaluated in Trial 1 were significant ($P \leq 0.05 - 0.001$) except for days to 50% flowering, number of fruits and fruit weight per plant in the second 5 pickings, total fruit weight per plant and plant canopy width (Table 1). FGY-335 took the longest time (107.3 days) for 50% of the plants to produce one mature fruit per replicate (days to 50% fruiting), while GAC-291 showed earliest fruiting time of 78.7 days after transplanting. UAE-257 had the highest number of fruits per plant in the first five pickings (94.0), highest fruit weight per plant in the first five pickings (1.27 kg) and largest total number of fruits per plant (166.0). LAM-301 had the smallest number of fruits per plant in the first five pickings (29.0), K-57 had the lowest fruit

weight per plant in the first five pickings (0.23 kg) and UAP-328 had the smallest total number of fruits per plant (65.7).

For the fruit traits, UAE-257 had the longest fruit (53.7 mm), GAJ-7 the widest fruit (49.8 mm), while UAP-328 had the heaviest fruits (26.9 g) and the thickest fruit walls (3.4 mm). In contrast, K-57 had the shortest fruits (33.9 mm), the second smallest fruit width (35.1 mm), the lightest fruits (8.1 g), and the thinnest fruit walls (1.6 mm). CAB-110 had the narrowest fruit width (34.5 mm). Of the traits evaluated in Trial 1, fruit width had the largest index of discrimination (ID = 3.8) followed by average fruit weight and fruit wall thickness (ID = 2.3).

In Trial 1, total number of fruits per plant showed strong correlations with number of fruits per plant in the first five pickings ($r = 0.92$, $P \leq 0.001$) and fruit weight per plant in the first five pickings ($r = 0.77$, $P \leq 0.01$) (Table 2). Number of fruits per plant in the first five pickings also showed a strong positive correlation with fruit weight per plant in the first five pickings ($r = 0.83$). Average fruit weight showed strong positive correlations with fruit width ($r = 0.73$, $P \leq 0.05$) and fruit wall thickness ($r = 0.94$, $P \leq 0.001$).

Table 2: Pearson's correlations among the nine traits for which there were significant differences among the ten pureline accessions of *Capsicum chinense* Jacq. grown under greenhouse conditions in the humid tropics in Trial 1 wet season

	NFP 1st 5p	FWP 1st 5p	TNFP	PH	FL	FW	Fr wt	FWT
DTFR	-0.07	0.06	0.02	0.19	-0.10	0.18	-0.10	-0.20
	NFP 1st 5p	0.83	0.92	-0.54	0.47	-0.26	-0.16	-0.12
		FWP 1st 5p	0.77	-0.47	0.61	0.09	0.36	0.37
			TNFP	-0.44	0.46	-0.34	-0.26	-0.27
				PH	-0.79	0.24	0.01	0.00
					FL	-0.28	0.21	0.23
						FW	0.73	0.56
							Fr wt	0.94

Pearson's correlations are significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ for 8 d.f. when $r = 0.63$, 0.77 and 0.87, respectively.

DTFR: days to 50% fruiting; NFP 1st 5p: number of fruits per plant first five pickings; FWP 1st 5p: fruit weight per plant first five pickings; TNFP: total number of fruits per plant; PH: plant height; FL: fruit length; FW: fruit width; Fr wt: average fruit weight;, FWT: fruit wall thickness.

Trial 2

Differences among the pepper accessions with respect to all traits evaluated in Trial 2 were significant ($P \leq 0.05 – 0.001$) (Table 3). UAE-257 showed earliest time to flowering (55.7 days). CAB-110 showed early flowering (60.0 days), earliest time to fruiting (83.0 days), produced the highest number of fruits (115.3, 90.0) and fruit weight (1.37, 0.73 kg) per plant in the first and second five pickings, respectively, and had the largest total number of fruits (205.3) and total fruit weight per plant (2.11 kg). In comparison, UAP-328 showed the longest times to 50% flowering (69.3 days) and fruiting (103.7 days), and produced the lowest number of fruits per plant in the first and second five pickings (24.7, 18.3), and the lowest total number of fruits per plant (42.0). K-57 also showed late flowering (66.7 days) and fruiting (101.0 days), produced the lowest (0.27 kg and 0.23 kg) fruit weight per plant in the first and second five pickings, and had the lowest total fruit weight per plant (0.49 kg).

For fruit traits, UAE-257 had the longest fruits (56.6 mm), GAC-291 the widest fruit (51.4 mm) and UAP-328 had the heaviest fruits (24.7 g) with the largest fruit wall thickness (2.52 mm). In comparison, K-57 had smallest fruit length (33.9 mm), fruit width (35.6 mm), average fruit weight (7.8 g) and fruit wall thickness (1.38 mm) (Table 3). In Trial 2, number of fruits per plant in the first five pickings had the largest index of discrimination (ID = 2.5) followed by total number of fruits per plant, fruit wall thickness, total fruit weight per plant, average fruit weight and fruit weight per plant in the first five pickings (IDs 2.3 - 1.8).

Total number of fruits per plant showed a strong positive correlation ($r = 0.92$, $P \leq 0.001$) with total fruit weight per plant and they both showed strong positive correlations ($r = 0.88$ - 0.99, $P \leq 0.001$) with number of fruits and fruit weight per plant in the first and second five pickings and moderate to strong negative correlations ($r = -0.71$ – -0.92, $P \leq 0.05$ - 0.001) with days to 50% flowering and fruiting (Table 4). Number of fruits and fruit weight per plant in the first and second five pickings showed strong correlations ($r = 0.82$ - 0.94, $P \leq 0.01$ - 0.001) among themselves and moderate to strong negative correlations ($r = -0.66$ – -0.93, $P \leq 0.05$ - 0.001) with days to 50% flowering and fruiting. Days to 50% fruiting also showed strong positive correlation with days to 50% flowering ($r = 0.85$, $P \leq 0.01$). Average fruit weight showed moderate to strong positive correlations ($P \leq 0.05$ - 0.01) with fruit width ($r = 0.68$) and fruit wall thickness ($r = 0.77$).

Table 3: Mean performance for yield (measured as total number of fruits per plant and total fruit weight per plant) and 12 other agronomic traits in ten pureline accessions of *Capsicum chinense* Jacq. under greenhouse conditions (Trial 2 dry season)

Accession	DTFL	DTFR	NFP 1st 5p	FWP 1st 5p	NFP 2nd 5p	FWP 2nd 5p	TNFP	TFWP	PH	PCW	FL	FW	Fr wt	FWT
CAB-110	60.0	83.0	115.3	1.37	90.0	0.73	205.3	2.11	137.0	156.0	54.9	43.7	17.0	2.05
UAE-257	55.7	86.7	79.3	1.17	66.7	0.70	146.3	1.86	149.0	189.7	56.6	44.8	20.5	1.74
GAC-291	63.7	90.0	75.7	1.20	62.3	0.63	137.7	1.84	131.7	161.3	51.7	51.4	22.8	2.18
UAP-328	69.3	103.7	24.7	0.40	18.3	0.23	42.0	0.62	161.0	164.3	45.1	46.7	24.7	2.52
GAJ-7	65.7	96.7	58.7	0.70	49.0	0.40	107.7	1.11	119.0	135.7	40.2	46.7	16.3	2.13
FGY-335	67.0	96.0	86.3	1.07	57.0	0.47	143.3	1.55	132.3	147.7	42.5	44.5	19.4	2.03
K-40	65.0	95.3	67.3	0.67	34.7	0.27	101.7	0.96	117.7	142.3	49.2	45.8	15.5	1.97
TT-41	63.3	91.7	69.0	0.87	57.0	0.50	126.0	1.38	133.3	172.3	47.3	47.7	16.0	1.77
K-57	66.7	101.0	38.0	0.27	41.3	0.23	79.0	0.49	152.3	146.7	33.9	35.6	7.8	1.38
LAM-301	61.7	94.7	82.3	0.97	61.7	0.47	143.7	1.41	138.3	192.7	47.0	42.3	15.1	2.34
Sig. ($P \leq$)	0.05	0.01	0.001	0.001	0.001	0.001	0.001	0.001	0.01	0.05	0.001	0.01	0.001	0.001
Mean	63.8	93.9	69.7	0.87	53.8	0.46	123.3	1.33	137.2	160.9	46.8	44.9	17.5	2.01
SEM	2.16	3.23	5.89	0.112	7.94	0.076	10.98	0.165	6.66	11.63	2.48	1.95	1.51	0.095
LSD	5.26	7.84	14.32	0.272	19.31	0.185	26.7	0.401	16.19	28.29	6.04	4.74	3.68	0.231
CV_{within}	0.06	0.06	0.15	0.22	0.26	0.28	0.15	0.21	0.08	0.13	0.09	0.08	0.15	0.08
$CV_{between}$	0.06	0.07	0.36	0.41	0.36	0.4	0.36	0.4	0.1	0.12	0.15	0.09	0.27	0.16
ID	1.1	1.1	2.5	1.8	1.4	1.4	2.3	1.9	1.2	1.0	1.6	1.2	1.8	2.0

DTFL: days to 50% flowering; DTFR: days to 50% fruiting; NFP 1st 5p: number of fruits per plant first five pickings; FWP 1st 5p: fruit weight (kg) per plant first five pickings; NFP 2nd 5p: number of fruits per plant second five pickings; FWP 2nd 5p: fruit weight (kg) per plant second five pickings; TNFP: total number of fruits per plant; TFWP: total fruit weight (kg) per plant; PH: plant height (cm); PCW: plant canopy width (cm); FL: fruit length (mm); FW: fruit width (mm); Fr wt: average fruit weight (g); FWT: fruit wall thickness (mm); ID: index of discrimination; CV: coefficient of variation.

Table 4: Pearson's correlations among the 14 traits evaluated for the ten pureline accessions of *Capsicum chinense* Jacq. grown under greenhouse conditions in the humid tropics in Trial 2 dry season

	DTFR	NFP 1st 5p	FWP 1st 5p	NFP 2nd 5p	FWP 2nd 5p	TNFP	TFWP	PH	PCW	FL	FW	Fr wt	FWT
DTFL	0.85	-0.66	-0.70	-0.75	-0.81	-0.71	-0.74	0.01	-0.62	-0.75	-0.03	-0.03	0.23
	DTFR	-0.87	-0.90	-0.90	-0.93	-0.90	-0.92	0.26	-0.32	-0.81	-0.27	-0.14	0.14
		NFP 1st 5p	0.92	0.91	0.82	0.98	0.90	-0.41	0.19	0.62	0.14	0.04	0.01
			FWP 1st 5p	0.88	0.94	0.92	0.99	-0.28	0.35	0.77	0.41	0.37	0.15
				NFP 2nd 5p	0.91	0.97	0.90	-0.20	0.29	0.55	0.03	-0.05	-0.15
					FWP 2nd 5p	0.88	0.97	-0.11	0.43	0.76	0.33	0.31	-0.01
						TNFP	0.92	-0.24	0.36	0.78	0.40	0.35	0.10
							TFWP	-0.04	0.43	0.83	0.51	0.60	0.32
								PH	0.45	-0.07	-0.38	0.15	-0.04
									PCW	0.51	0.05	0.25	0.14
										FL	0.52	0.54	0.24
											FW	0.77	0.54
												Fr_wt	0.68

Pearson's correlations are significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ for 8 d.f. when $r = 0.63$, 0.77 and 0.87, respectively.

DTFL: days to 50% flowering; DTFR: days to 50% fruiting; NFP 1st 5p: number of fruits per plant first five pickings; FWP 1st 5p: fruit weight per plant first five pickings; NFP 2nd 5p: number of fruits per plant second five pickings; FWP 2nd 5p: fruit weight per plant second five pickings; TNFP: total number of fruits per plant; TFWP: total fruit weight per plant; PH: plant height; PCW: plant canopy width; FL: fruit length; FW: fruit width; Fr wt: average fruit weight; FWT: fruit wall thickness.

Stability of traits evaluated over trials

Spearman's rank correlations were large ($r = 0.84$) and significant ($P \leq 0.01$) only for fruit wall thickness (Table 5). However, comparison of linear regression lines (COLR, CARDI 1974) showed that pepper accession performances over trials could be described by a single line or parallel lines for days to 50% fruiting, number of fruits and fruit weight per plant in the first five pickings, total number of fruits per plant, plant height, fruit length, fruit width, average fruit weight and fruit wall thickness, suggesting no accession x trial interactions of the crossover type (the relative rank of the accessions did not change).

Table 5: Spearman's rank correlations and comparison of linear regression lines (COLR) for the nine traits (which showed significant within trial accession differences) evaluated for the ten pureline accessions of pepper (*Capsicum chinense* Jacq.) over Trial 1 and Trial 2

Parameter	Spearman's correlation	COLR
DTFR	0.19	Single
NFP 1st 5p	0.22	Parallel
FWP 1st 5p	0.34	Single
TNFP	0.53	Single
PH	0.12	Parallel
FL	0.63	Parallel
FW	0.58	Parallel
Fr wt	0.40	Single
FWT	0.84	Single

Spearman's correlations significant at $P \leq 0.05$, $P \leq 0.01$, $P \leq 0.001$ when r = 0.65, 0.79, 0.90, respectively, for N = 10.
Spearman's correlations are comparing for each trait the ranks of the accessions over Trial 1 and Trial 2.
Single: the mean performance of an accession for a trait was the same over Trial 1 and Trial 2; Parallel: the mean performance of an accession was not the same over Trial 1 and Trial 2, but the relative rank of the accessions did not change over trials; both Single and Parallel lines indicate the accession x trial interactions were not of the crossover type.
DTFR: days to 50% fruiting; NFP 1st 5p: number of fruits per plant first five pickings; FWP 1st 5p: fruit weight per plant first five pickings; TNFP: total number of fruits per plant; PH: plant height; FL: fruit length; FW: fruit width; Fr wt: average fruit weight; FWT: fruit wall thickness.

Discussion

This study was the first greenhouse evaluation of yield expressed as total number of fruits per plant and total fruit weight per plant and other associated traits in *C. chinense* in the humid tropics. Both measurements of yield viz. total number of fruits and total fruit weight per plant were strongly associated for the ten pureline accessions when grown under greenhouse conditions. This result is in variance to that of Ali et al. (2019) for a larger set of 68 pureline *C. chinense* accessions (which included the ten accessions evaluated in this study) which found weak but significant associations between the two measures of yield in the dry and wet seasons. The strong associations in this study maybe due to the choice of accessions evaluated as these two yield measurements also had strong associations (r = 0.77 and 0.81, $P \leq 0.01$) among the ten accessions used in this study in both the dry and wet seasons under open-field conditions (Ali et al. 2019).

The choice of accessions may also explain the strong associations between the two yield measurements with number of fruits and fruit weight per plant in the first and second five pickings in this study. In the study of Ali et al. (2019), total number of fruits per plant was only strongly associated with number of fruits per plant in the first and second five pickings while total fruit weight per plant was positively associated only with fruit weight per plant in the first and second five pickings. In both this study and that of Ali et al. (2019), plant height and plant canopy width were not associated with yield or fruit characteristics.

The much smaller CV_{within} for most traits in Trial 2 suggests greater environmental

influence on traits in the dry versus the wet season. However, the results showed that environmental factors under greenhouse conditions did not have large effects on yield and several of its associated traits within trials and over trials. This was evident from the comparison of regression lines which showed that accession performances in Trial 1 and Trial 2 for days to 50% fruiting, number of fruits and fruit weight per plant in the first five pickings, total number of fruits per plant, plant height, fruit length, fruit width, average fruit weight and fruit wall thickness can be described by either single or parallel lines, suggesting no accession x trial interactions of the crossover type. Among those nine traits, only two traits viz. days to 50% fruiting and fruit width were found to be stable under open-field conditions (Ali et al. 2019). This may reflect the more uniform conditions under the greenhouse relative the open-field in the dry and wet seasons.

No accession in this study realized at least 200 total fruits per plant in either trial except for accession CAB-110 which had 205.3 fruits in Trial 2. However, under open-field conditions (Ali et al. 2019), CAB-110, UAE-257 and GAC-291 consistently produced at least 200 fruits per plant during both the wet and dry seasons. Furthermore, accession UAE-257 that consistently produced over 2.00 kg of fruits per plant during both the wet and dry seasons under open-field conditions (Ali et al. 2019) was only able to consistently produce approximately 1.90 kg per plant in this study. As well, mean total fruit weight per plant in both trials of this study were similar but small (1.33 kg) compared to 1.80 kg for the same set of ten accessions under open-field conditions. The aforementioned together with the earlier times to 50% flowering and fruiting (12 - 20 days shorter) under open-field conditions (Ali et al. 2019) suggest that it is more beneficial to grow pepper under open-field conditions as the production cost is cheaper (Seepersad et al. 2013). Lozano-Fernández et al. (2018) also reported greater yields of bell pepper (*C. annuum*) under open-field relative to greenhouse conditions.

Interestingly, one pepper accession, FGY-335 (originating in French Guiana) had greater yields under greenhouse conditions as compared to the open-field in both the dry and wet seasons. The other 58 pepper accessions that were evaluated under open-field conditions should also be evaluated under greenhouse conditions to determine if there are other accessions that result in superior yields under greenhouse production relative to the open-field. These can form the basis of a breeding programme to produce new pepper varieties that are suited to greenhouse production. Two other accessions, GAJ-7 (Greater Antilles) and K-57 (Upper Amazon) had greater yields in the wet season under greenhouse production than the open-field. In this context, greenhouse cultivation can be looked at as an alternative production system for wet season cultivation to increase yields.

In this study, average fruit weight was strongly and positively associated with fruit width and fruit wall thickness over trials. These results are in agreement with those obtained for *C. chinense* (Lannes et al. 2007) and *C. annuum* (Ben-Chaim and Paran, 2000; Maalekuu et al. 2005). However, the results of this study differ from that of Elibox et al. (2017) who reported that fruit weight in *C. chinense* was not associated with endocarp, mesocarp, exocarp or total pericarp thickness. However, unlike this study, the study of Elibox et al. (2017) was performed under open-field conditions.

Conclusion

This greenhouse study performed over two seasons revealed significant differences among the ten pureline *C. chinense* accessions except for days to 50% flowering, number of fruits and fruit weight per plant in the second five pickings, total fruit weight per plant and plant canopy width in Trial 1 (wet season). Total number of fruits per plant and total fruit weight per plant were auto-correlated and were both generally positively associated with number of

fruits and fruit weight per plant in the first and second five pickings and moderately negatively associated with days to 50% flowering and fruiting. No accession produced more than 200 total fruits per plant and fruit weight per plant over 2 kg except CAB-110 in Trial 2 (dry season). Generally, yields under greenhouse production were found to be inferior to open-field production. However, one accession, FGY-335 from the Lower Amazon, had greater yields under greenhouse conditions as compared to yields in the open-field in both the dry and wet seasons.

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