

Genetic Variability, Heritability and Path Analysis Identify Direct Selection Criteria for Seed Number Per Fruit and Attributing Traits in Chilli (*Capsicum annuum* L.)

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Abstract

The global demand for sweet peppers is increasing in countries such as Cameroon, highlighting the need for a robust breeding program. This study aimed to identify indirect selection criteria for seed number per fruit and associated traits among 12 accessions of sweet bell pepper using 17 quantitative traits. Fifteen plants per accession were randomly selected to measure agromorphological traits in a randomized complete block design with three replicates at Obala. Statistical analyses, including analysis of variance, hierarchical clustering, and path coefficient analysis, were performed using R software. Significant variation was observed across most traits, with the date of first fruiting ranging from 32.67 to 40 days after planting and 50% maturity occurring between 48 and 53.33 days after transplanting. Broad-sense heritability (H^2) values ranged from 4% (date of first fruiting) to 94% (date of first harvest). Path analysis revealed that fruit weight (0.57), total fruit weight (0.56), length of the fruit peduncle (0.35), Date of First Fruiting (0.30), Width of Mature Leaves (0.16), and date of 50% maturity (0.12) had positive direct effects on the number of seeds per fruit. Among these, fruit weight, total fruit weight, and peduncle length exhibited the largest direct effects. Cluster analysis grouped the accessions into four distinct clusters, indicating significant genetic diversity. These findings underscore the potential to improve the seed

number per fruit in sweet pepper through targeted breeding. Further studies involving biochemical and molecular markers are recommended for deeper characterization.

Keywords

Capsicum annuum, Genetic Variability, Path Analysis, Character Association, Number of Seed Per Fruit

1. Introduction

Capsicum annuum ($2n = 2x = 24$) is widely cultivated for its fruits, which are valued for their rich antioxidant content, diverse flavors, and high nutritional value [1]. These fruits are an excellent source of bioactive compounds that promote human health by reducing the risks of cancer, heart disease, and diabetes. They are also rich in vitamin C and zinc, which are crucial for maintaining a healthy and strong immune system [2]. Furthermore, the crop offers smallholder farmers an attractive income due to its favorable market prices throughout the year, especially during off-season production, thereby contributing to improved living standards. Despite its importance, the cultivation of *C. annuum* faces several challenges, including low production levels, a lack of high-yielding varieties tolerant to diverse climatic conditions, limited seed availability, and insufficient knowledge of appropriate cultivation techniques [3] [4]. These constraints have led local markets to depend on external production areas for supply, highlighting the urgent need to provide farmers with germplasm that meets their needs. Effective selection for desirable traits relies on the presence of genetic variability and heritability, which ensure the transfer of favourable characteristics across generations [5]. Plant genetic diversity offers breeders the opportunity to develop improved varieties with desirable traits. These include farmer-preferred traits such as high yield potential and large seeds, as well as breeder-preferred traits like pest and disease resistance [3]. Understanding genetic diversity and its distribution among varieties is essential for the effective conservation and utilization of genetic resources [6] [7]. Additionally, combining association studies and path coefficient analysis with heritability and genetic gain estimates can effectively guide trait selection and crop improvement [8]. While studies on genetic variability and trait associations have been conducted in other crops, such as *Solanum tuberosum* [9], research on the genetic variability and interrelationships among sweet pepper varieties is limited, particularly under the specific pedoclimatic conditions of Cameroon's bimodal rainforest zone. This gap is especially pronounced in seed production. Identifying traits that directly influence seed number per fruit is crucial for enhancing seed production efficiency. The present study aimed to identify indirect selection criteria for seed number per fruit and associated traits among 12 accessions of sweet bell pepper using 17 quantitative traits.

2. Material and Methods

2.1. Study Site

The study was conducted in Obala, located between 3°57'0" and 4°14'0" north latitude and between 11°21'0" and 11°38'0" east longitude. The region belongs to a transitional equatorial climate, characterized by an average rainfall of 1,476 mm/year and an average annual temperature of 25.5°C.

2.2. Plant Material

The plant material consisted of 12 accessions of *C. annuum*, sown during the growing season 2023-2024. The characteristics of these accessions are detailed in **Table 1**.

Table 1. Description of the seeds of the twelve sweet pepper accessions.

Origins	Codes	Description of seeds	
		Weight (g)	Germination rate (%)
Obala	O1	50	85
Obala	O2	50	85
Obala	O3	5	80
Obala	O4	5	90
Obala	O5	5	80
Yaounde	Y1	5	85
Yaounde	Y2	50	85
Yaounde	Y3	100	88
Ebebda	E1	10	85
Ebebda	E2	100	85
Ayos	A1	5	90
Bafia	B1	10	85

2.3. Field Experimentation and Data Accession

The study was conducted with plant spacing of 0.5 × 0.5 m with a forage area of 0.25 m² [10]. Each accession was treated as an individual experimental unit. Chicken manure was applied to the pots according to [11]. Two weeks after establishment, each plant was received 25 g/plant of NPK (20-10-10) compound fertilizer. From flowering stage onwards, foliar fertilizer (Di Grow Rouge) was applied every 10 days throughout the propagation cycle of the plants. Fungicide (PERSISTENT and PENCOZEB 80WP) and insecticide (CARDINAL 35EC) were applied every 15 days to control pest and diseases. The plants were watered every 2 days with watering cans to maintain adequate moisture in the grapes. Weed control was done chemically one week before transplanting and manually at 20-day intervals. Fifteen plants were randomly selected from each accession for data accession. Observations were grouped as follows:

- Growth parameters at the 50% flower: Mature Leaf Length of leaves (MLL,

cm), of Mature Leaf Width (MLW, cm), Plant Height (PH, cm), and Diameter at Collar (DC, cm).

- Flowering parameters at the 50% flowering: Date of First Flowering (D1F, days), date of 50% flowering (D50F, days), Date of First Fruiting (D1Fr, days) were.
- Yield parameters at the harvest, fruit traits were measured from a representative sample of 15 fruits per accession. Date of 50% Maturity (D50M, days), Number of seed per Fruit (NSF, No), Total Number of Fruits (TNF, No), and the Fruit Yield (FY). These included Fruit Diameter (FD, mm), Fruit Length (FL, mm), Width of Fruit (WF, mm), Length of the Fruit Peduncle (LFP, mm). The average of each measurement was calculated for each variety [4]. A digital scale with an accuracy of 0.001 g was used to evaluate the Fruit Weight (FW, g) and Total Fruit Weight (TFW, g).

2.4. Data Analysis

Statistical analyses were performed using R software. Analysis of variance (ANOVA) and the least significant difference (LSD) test at a significance level of 5% ($p < 0.05$) were used to compare genotypes when differences were significant. A hierarchical ascending classification grouped the accessions into clusters, with the optimal number of clusters determined using the K-means method. Genetic parameters were performed using variability package of R software. The genetic advance, expressed as a percentage of the mean, was categorized as low ($<10\%$), moderate (10 - 20%), or high ($>20\%$). Heritability was categorized as low $< 30\%$, moderate 30 - 60%; high $> 60\%$ as in [12] [13]. Distribution of 12 *Capsicum annum* L. genotypes in different clusters grown in Obala was constructed to visualize genetic similarity among sweet pepper accessions.

Path coefficient analysis was performed using simple correlations to assess the direct and indirect effects of Number of Seeds per Fruit and attributing traits at both genotypic and phenotypic levels. This method evaluated the direct association of one variable (cause) through another on the final outcome (effect), with path coefficients calculated at the genotypic level for all yield-attributing traits [14].

3. Results

3.1. Phenotypic Variability

The analysis revealed significant phenotypic variations across the sweet pepper accessions for most of the assessed traits (Table 2).

Growth Parameters: Plant height (PH) ranged from 27.5 ± 4.36 cm (O1) to 42.5 ± 4.9 cm (Y2). Diameter at Collar (DC) varied from 4.83 ± 1.36 cm (A1) to 10.6 ± 1.8 cm (O5). Mature leaf length (MLL) was between 11.3 cm (Y3) and 17.6 ± 1.84 cm (Y2), while mature leaf width (MLW) ranged from 5.9 ± 1.28 cm (O3) to 8.6 ± 0.26 cm (O5).

Flowering Parameters: The date of first flowering (D1F) ranged from 28.33 ± 4.72 days (O5) to 36 days (Y3), while the date of 50% flowering (D50F) ranged from 42 days (Y1) to 47 days (O2). The date of first fruiting (D1Fr) ranged from 33.67 ± 4.72 days (A1) to 41 ± 1.73 days (O4).

Yield Parameters: Total number of fruits (TNF) ranged from 1.67 ± 0.58 fruits (O1) to 4.5 ± 0.71 fruits (Y2). Total fruit weight (TFW) ranged from 71.67 ± 30.14 g (O1) to 240 ± 25.98 g (O5). Fruit yield (FY) ranged from 0.07 ± 0.01 (O1) to 0.24 ± 0.03 (O5). The date of 50% maturity (D50M) ranged from 48 ± 3 days (O5) to 53.33 ± 0.58 days (O1). Fruit length (FL) ranged from 4.43 ± 0.4 cm (B1) to 6.65 ± 1.20 cm (Y1), while fruit width (WF) ranged from 3.75 ± 1.06 cm (Y2) to 5.5 cm (Y3). Fruit diameter (FD) varied from 40.23 ± 5.12 mm (B1) to 63 mm (E1). Fruit peduncle length (LFP) was highest in Y1 (5.05 ± 1.49 cm) and lowest in B1 (3.1 ± 0.17 cm). Average fruit weight (FW) ranged from 23 \pm 16.64 g (A1) to 80 g (Y3). The number of seeds per fruit varied from 205 ± 7.07 (O2) to 325 (Y3).

3.2. Principal Component and Cluster Analysis

To assess the divergence among accessions, principal component analysis (PCA) and hierarchical ascending classification (HAC) were performed (**Figure 1**). The first two PCA axes explained 66.4% of the total variation, with 44.3% attributed to Dimension 1 and 22.1% to Dimension 2.

- Dimension 1: Accessions such as O5, Y3, and Y1 (right side of the graph) were characterized by strong positive coordinates, reflecting high values for Fruit Weight (FW), Fruit Diameter, and WF. Conversely, accessions like B1, O4, and Y2 (left side of the graph) displayed strong negative coordinates, indicating high D1F values and low values for the Number of Seeds per Fruit, Length of Fruit Peduncle (LFP), Fruit Diameter, FL, and WF. O5 was distinct for its high Total Number of Fruits (TNF) and Total Fruit Weight (TFW) but low D1F and D1Fr values.
- Dimension 2: O1 (top of the graph) exhibited traits close to the population mean. O5 (bottom of the graph) had high TNF and TFW values but low D1F and D1Fr values. These patterns highlight the diversity among accessions and the grouping of traits associated with yield components (**Figure 1**).

The hierarchical ascending classification (HAC) analysis grouped the studied accessions into three distinct clusters based on trait similarities (**Table 3**). Cluster 1: Comprising B1, O2, O4, and Y2, this cluster is characterized by: High values for Total Number of Fruits (TNF) and Total Fruit Weight (TFW). Low values for Date of 50% Flowering (D50F). Cluster 2: Containing Y1, Y3, O1, E1, A1, E2, and O3, accessions in this cluster exhibited: High values for Fruit Length (FL) and Number of Seeds per Fruit. Low values for Mature Leaf Width (MLW) and Mature Leaf Length (MLL). Cluster 3: Represented solely by O5, this cluster is defined by: High values for Date of First Flowering (D1F). Low values for Number of Seeds per Fruit, Length of the Fruit Peduncle (LFP), Fruit Weight (FW), Fruit Width

Table 2. Analysis of variances (mean sum of squares) and descriptive analysis for 17 characters in *C. annuum*.

Genotypes	PH	DC	MLL	MLW	DIF	D50F	DIFr	D50M	FL	WF	FD	TNF	TFW	LFP	FY	NSF	FW
A1	34 ± 8.89 ^{ab}	4.83 ± 1.36 ^c	14 ± 2.15 ^{abc}	7.33 ± 1.81 ^{ab}	29.33 ± 4.16 ^b	42 ± 1.73 ^{abc}	33.67 ± 4.72 ^c	49.67 ± 1.53 ^b	6 ± 0.5 ^{ab}	3.97 ± 0.55 ^a	42.9 ± 6.55 ^a	4 ± 1 ^{ab}	121.67 ± 27.53 ^{ab}	3.73 ± 0.5 ^{abc}	0.12 ± 0.03 ^{ab}	244.67 ± 13.65 ^{a-d}	23 ± 16.64 ^e
	35.6 ± 2.65 ^{ab}	9.3 ± 2.36 ^{ab}	16.03 ± 1.14 ^{ab}	7.4 ± 0.7 ^{ab}	35 ± 1 ^{ab}	43 ± 1.73 ^{abc}	40 ^{abc}	53.67 ± 0.58 ^a	4.43 ± 0.4 ^c	3.93 ± 0.51 ^a	40.23 ± 5.12 ^a	3 ± 1 ^{bc}	75 ± 22.91 ^b	3.1 ± 0.17 ^c	0.1 ± 0.03 ^b	209.33 ± 7.57 ^{cd}	30 ± 5 ^{de}
E1	34 ^{ab}	5.8 ^{bc}	15 ^{abc}	7.6 ^{ab}	35 ^{ab}	43 ^{abc}	39 ^{abc}	50 ^b	4.7 ± 0.6 ^{bc}	6 ^a	63 ^a	3 ^{abc}	100 ^{ab}	5 ^a	0.1 ^{ab}	225 ^{bcd}	60 ^{ab}
E2	29.75 ± 5.3 ^b	8.65 ± 1.77 ^{abc}	14.5 ± 1.83 ^{abc}	7.05 ± 0.07 ^{ab}	31 ± 7.07 ^{ab}	45.5 ± 3.54 ^{ab}	37.5 ± 10.6 ^{abc}	51 ± 2.83 ^{ab}	6.25 ± 1.77 ^{ab}	4.95 ± 0.63 ^a	49.95 ± 7.42 ^a	3.5 ± 2.12 ^{abc}	135 ± 106.07 ^{ab}	4 ^{abc}	0.135 ± 0.11 ^{ab}	271 ± 18.38 ^{ab}	50 ± 28.28 ^{abcde}
	27.5 ± 4.36 ^b	8.67 ± 1.88 ^{abc}	15.8 ± 3.48 ^{ab}	7.9 ± 1.15 ^{ab}	35 ± 1 ^{ab}	45 ± 2.64 ^{abc}	39.67 ± 2.08 ^{abc}	53.33 ± 0.58 ^a	6.17 ± 0.76 ^a	4.6 ± 0.1 ^a	49.133 ± 3.44 ^a	1.67 ± 0.58 ^c	71.67 ± 30.14 ^b	4.367 ± 0.4 ^{ab}	0.07 ± 0.03 ^b	263.67 ± 24.01 ^{ab}	43.33 ± 5.77 ^{abc}
O2	28.75 ± 0.35 ^b	9.05 ± 0.91 ^{ab}	15.4 ± 1.83 ^{ab}	7.6 ± 1.55 ^{ab}	36 ± 0 ^a	47 ± 0 ^a	41.5 ± 0.71 ^a	52 ± 1.41 ^{ab}	5 ± 0 ^{bc}	4.1 ± 0.14 ^a	41.55 ± 2.33 ^a	2.5 ± 0.71 ^{bc}	75 ± 14.14 ^b	4.05 ± 0.35 ^{abc}	0.07 ± 0.01 ^b	205 ± 7.07 ^d	32.5 ± 3.54 ^{bcdde}
	31.5 ± 9.73 ^{ab}	8.63 ± 0.72 ^{ab}	11.43 ± 0.56 ^c	5.9 ± 1.28 ^b	33.67 ± 3.51 ^{ab}	43 ± 4 ^{abc}	38.33 ± 4.62 ^{abc}	51 ± 3 ^{ab}	4.83 ± 0.29 ^{bc}	4.33 ± 0.29 ^a	44.23 ± 3.16 ^a	2.67 ± 2.08 ^{bc}	98.33 ± 67.88 ^b	4.5 ± 1.31 ^{ab}	0.09 ± 0.067 ^b	265.67 ± 27.79 ^{ab}	40 ± 5 ^{abcd}
O4	29.13 ± 7.064 ^b	8.37 ± 1.76 ^{abc}	13.96 ± 1.81 ^{abc}	7.4 ± 0.75 ^{ab}	35.33 ± 1.15 ^{ab}	45 ± 2.64 ^{abc}	41 ± 1.73 ^{ab}	52 ± 1 ^{ab}	5.3 ± 0.26 ^{ab}	4.1 ± 0.5 ^a	42.47 ± 4.61 ^a	2.67 ± 0.58 ^{bc}	80 ± 18.03 ^b	3.567 ± 0.4 ^{abc}	0.08 ± 0.02 ^b	237 ± 39.96 ^{bcd}	31.67 ± 5.77 ^{cde}
	39.67 ± 0.57 ^a	10.6 ± 1.8 ^a	17.17 ± 2.10 ^a	8.6 ± 0.26 ^a	28.33 ± 4.72 ^b	39.33 ± 2.08 ^c	32.67 ± 5.13 ^c	48 ± 3 ^b	5.13 ± 1.09 ^{bc}	4.7 ± 0.85 ^a	46.96 ± 8.13 ^a	6 ^a	240 ± 25.98 ^a	4.77 ± 0.68 ^a	0.24 ± 0.03 ^a	306.33 ± 12.66 ^a	50 ± 8.66 ^{ab}
Y1	29.25 ± 2.47 ^b	7.55 ± 1.90 ^{abc}	12.45 ± 0.7 ^{bc}	6.55 ± 0.21 ^b	31.5 ± 6.36 ^{ab}	42 ± 0 ^{bc}	34.5 ± 4.94 ^{bc}	52 ± 1.414 ^{ab}	6.65 ± 1.20 ^a	5.25 ± 1.77 ^a	54.3 ± 19.94 ^a	3 ± 1.41 ^{bc}	202.5 ± 187.38 ^{ab}	5.05 ± 1.49 ^a	0.2 ± 0.19 ^{ab}	283 ± 108.89 ^{abc}	72.5 ± 53.03 ^{abc}
	42.5 ± 4.9 ^a	9.4 ± 0.14 ^{ab}	17.6 ± 1.84 ^a	8.65 ± 0.91 ^a	34.5 ± 2.12 ^{ab}	44 ± 2.83 ^{abc}	38 ± 2.83 ^{abc}	51.5 ± 2.12 ^{ab}	4.5 ± 0 ^c	3.75 ± 1.06 ^a	38.65 ± 11.25 ^a	4.5 ± 0.71 ^{ab}	135 ± 21.21 ^{ab}	3.4 ± 0.14 ^{bc}	0.135 ± 0.02 ^{ab}	210 ± 14.14 ^{cd}	27.5 ± 3.54 ^e
Y3	31 ^{ab}	7 ^{bc}	11.3 ^c	6.8 ^{ab}	36 ^{ab}	46	40 ^{bc}	52 ^{ab}	6 ^{ab}	5.5 ^a	59.9 ^a	2 ^{bc}	155 ^{ab}	4 ^{abc}	0.155 ^{ab}	325 ^a	80 ^a

PH: Plant Height; DC: Diameter at Collar; MLL: mature leaf length; MLW: width of mature leaves; DIF: date of first flowering; D50F: Date of 50% Flowering; D50M: Maturity; FL: Fruit Length; WF: Width of fruit; FD: Fruit Diameter; TNF: Total Number of Fruits; TFW: Total Weight Fruit; LFP: Length of the Fruit Peduncle; FY: Fruit Yield; NSF: Number of seeds per fruit; FW: fruit weight per plant; DIFr: date of first fruiting.

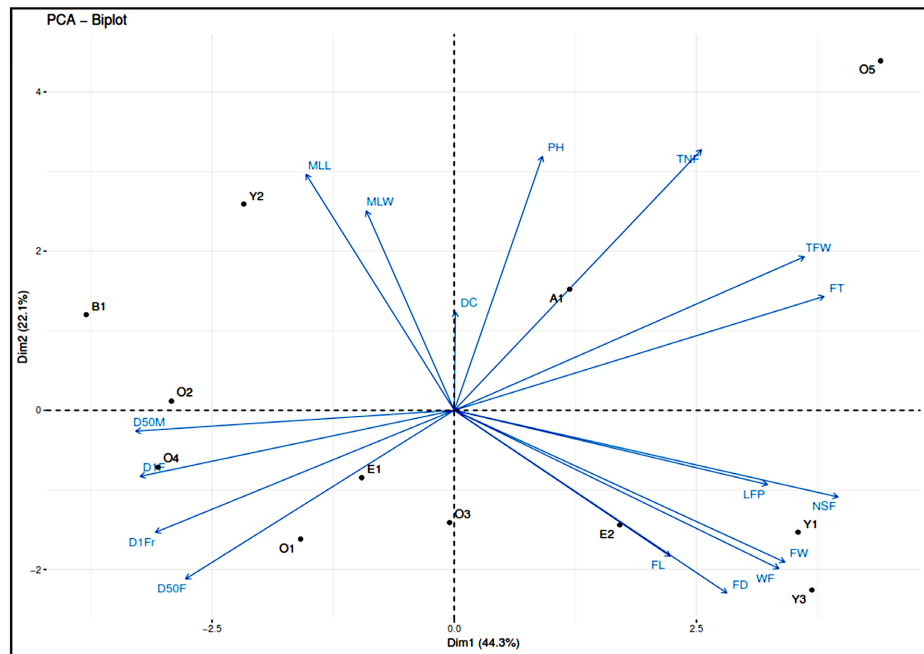


Figure 1. Distribution of the assessed accessions of the main traits contributing to the dimensions 1 and 2.

(WF), and Fruit Length (FL) (**Table 3**). The cluster analysis provides a clear picture of phenotypic variability, highlighting distinct patterns of divergence among accessions. These differences could reflect genetic variation or environmental factors influencing the assessed traits.

3.3. Estimates of Genetic Parameters for Various Morphological Characters

The estimates for phenotypic and genotypic variances, genotypic coefficient of variation (GCV), phenotypic coefficient of variation (PCV), heritability in the broad sense (H^2), and genetic advance (GA) are presented in **Table 4**. The phenotypic variance ranged from 0.252 for MC to 5919.39 for Total Weight Fruit, while the genotypic variance ranged from 0.001 for FY to 1040.21 for Total Weight Fruit. For all traits, the phenotypic coefficient of variation (PCV) was higher than the genotypic coefficient of variation (GCV), indicating that environmental factors played a significant role in influencing these traits. The highest PCV was observed for Average Fruit Weight (70.55%), followed by Total Weight Fruit (48.98%). In contrast, the lowest PCV was recorded for Date of First Harvest (2.41%). Similarly, the highest GCV was observed for Total Weight Fruit (48.98%), while the lowest GCV was recorded for Date of 50% Maturity (2.19%).

Heritability in the broad sense (H^2) ranged from 4% for Date of First Fruiting to 94% for Date of First Harvest. High heritability values ($H^2 > 60\%$) were recorded for traits such as Date of First Harvest (94%) and Number of Seeds per Fruit (66%). On the other hand, traits such as Date of First Flowering (11%), Date of First Fruiting (4%), Date of 50% Maturity (22%), Average Fruit Length (14%), and

Fruit Shape (13%) showed low heritability values ($H^2 < 30\%$). The remaining traits exhibited moderate heritability values ($30\% < H^2 < 60\%$), including traits like Total Weight Fruit. The genetic advance (GA), expressed as a percentage of the mean, ranged from 0.89% for Date of First Fruiting to 76.32% for Total Weight Fruit. Traits with high genetic advance, such as Total Weight Fruit, indicate substantial potential for genetic improvement through selection (**Table 4**).

Table 3. Distribution of 12 *Capsicum annum* L. genotypes in different clusters grown in Obala.

Groups	Number of individuals	Individuals of the group	Characteristics
G1	4	B1, O2, O4 and Y2	High values for the variables TNF, TFW Low value for DATE OF 50% FLOWERING (D50F)
G2	7	Y1, Y3, O1, E1, A1, E2 and O3	High values for the variables FL et NSF Low values for MLW and MLL variable
G3	1	O5	High values for the variables D1F Low values for NSF, LFP, FW, WF and FL.

TNF: Total Number of Fruits, TFW: Total Weight Fruit, D50F: date of 50% flowering, FL: Fruit Length, NSF: Number of seeds per fruit. MLW: width of mature leaves, MLL: Length of mature leaves, D1F: date of first flowering, LFP Length of the Fruit Peduncle, WF: Width of fruit, FW: fruit weight per plant.

Table 4. Estimates of Range, Mean, Genotypic, Environmental and Phenotypic variances and Coefficient of variations, Heritability in broad sense, Genetic advance for 19 characters of 12 Pepper genotypes.

Genetic parameters	PH	DC	MLL	MLW	D1Fr	D50F	D1F	D50M	FL	WF	FD	FW	TNF	TFW	LFP	FY	NSF
Range	20.5 - 46	3.6 - 12.6	10.8 - 19.3	4.8 - 9.4	27 - 45	37 - 48	23 - 37	45 - 54	4 - 7.5	3 - 6.5	30.7 - 68.4	4 - 110	1 - 6	35 - 335	3 - 6.1	0.03 - 0.34	200 - 360
Mean	32.77	8.33	14.7	7.42	37.78	43.5	33.11	51.36	5.39	4.45	46.06	41.39	3.28	121.79	4.07	0.12	252.43
EV	36.26	3.11	4.42	1.28	20.63	6.99	14.15	4.23	0.51	0.56	66.83	297.59	1.52	4379.19	0.43	0.01	1245.65
GV	4.56	1.03	1.57	0.09	0.45	1.16	1.26	0.88	0.27	0.07	7.76	74.95	0.72	1040.21	0.18	0.001	529.89
PV	40.83	4.14	5.98	1.371	21.08	8.15	15.42	5.11	0.77	0.64	74.59	372.54	2.24	5419.39	0.6173	0.01	1775.55
ECV	18.37	21.17	14.31	15.23	12.02	6.08	11.36	4.01	13.18	16.83	17.75	41.676	37.55	54.34	16.19	54.34	13.98
GCV	6.512	12.18	8.5	4.13	1.77	2.48	3.39	1.82	9.56	6.18	6.05	20.91	25.76	26.48	10.46	25.96	9.12
PCV	19.5	24.43	16.64	15.79	12.15	6.56	11.86	4.4	16.29	17.93	18.75	46.63	45.54	60.45	19.28	60.34	16.69
H ²	0.11	0.25	0.26	0.07	0.02	0.14	0.08	0.17	0.34	0.12	0.1	0.2	0.32	0.19	0.29	0.18	0.3
GA	1.47	1.043	1.31	0.165	0.2	0.84	0.66	0.8	0.63	0.19	1.85	7.99	0.98	29.11	0.48	0.03	25.9

Maxi, Maximum; Mini, Minimum; GV, Genotypic Variance; PV, Phenotypic Variance; EV: Environmental Variance; ECV: Environmental Coefficient of Variance; PCV: Phenotypic Coefficient of Variance; GCV: Genotypic Coefficient of Variance; H², Heritability (Broad Sense); GA, Genetic Advance; PH: Plant Height; DC: Diameter at Collar; MLL: mature leaf length; MLW: width of mature leaves; D1F: date of first flowering; D50F: Date of 50% Flowering; D50M: Date of 50% Maturity; FL: Fruit Length; WF: Width of fruit; FD: Fruit Diameter; TNF: Total Number of Fruits; TFW: Total Weight Fruit; LFP: Length of the Fruit Peduncle; FY: Fruit Yield; NSF: Number of seeds per fruit; FW: fruit weight per plant; D1Fr: date of first fruiting.

3.4. Path analysis Identify Direct and Indirect Selection Criteria for Seed Number Per Fruit

3.4.1. Genotypic Path Analysis

The correlation coefficients of Number of Seeds per Fruit with associated traits were divided into direct and indirect effects (**Table 5**). The path analysis revealed that Number of Seeds per Fruit was primarily influenced by Fruit Weight (FW), Total Weight Fruit, and Length of the Fruit Peduncle (LFP), which exhibited the largest direct effects on the trait. Positive direct effects were observed for Date of 50% Maturity (D50M) (0.12), Mean Leaf Width (MLW) (0.16), Date of First Ripe Fruit (D1Fr) (0.30), Length of the Fruit Peduncle (LFP) (0.35), Total Weight Fruit (TFW) (0.56), and Fruit Weight (FW) (0.57). Among these, Fruit Weight (FW) had the highest positive direct effect (0.57), while Date of 50% Maturity (D50M) had the lowest positive direct effect (0.12).

In contrast, several traits exhibited negative direct effects on Number of Seeds per Fruit. These included vegetative traits such as Plant Height (−0.01), Diameter at Collar (DC) (−0.04), and Mean Leaf Length (MLL) (−0.24), as well as yield traits such as Date of First Flowering (D1F) (−0.84), Total Number of Fruits (TNF) (−0.50), Date of 50% Flowering (D50F) (−0.20), Fruit Width (WF) (−0.19), and Fruit Thickness (FT) (−0.12). Among these, Total Number of Fruits (TNF) exhibited the lowest negative direct effect (−0.50).

Table 5. Estimates of genotypic direct effects (diagonal) and indirect effects (off-diagonal) of traits via other independent traits on Number of Seeds per Fruit of 12 pepper genotypes at Obala.

Pheno.path	PH	DC	MLL	MLW	D1F	D1Fr	D50F	D50M	FL	WF	FD	FW	TNF	TFW	LFP	FT
PH	−0.01	−0.001	−0.05	−0.013	0.31	−0.11	0.11	0.001	0.002	0.14	0.07	−0.24	−0.4	0.28	−0.11	−0.04
DC	0.00	−0.04	−0.10	0.13	−0.59	0.20	0.05	0.06	0.00	−0.06	0.05	0.06	−0.07	0.15	0.16	−0.02
MLL	0.00	−0.01	−0.24	0.17	−0.60	0.03	0.02	0.08	0.00	0.14	0.19	−0.40	−0.09	−0.04	−0.17	0.03
MLW	0.00	−0.03	−0.25	0.16	−0.50	0.19	−0.08	0.11	0.00	0.07	0.14	−0.23	−0.90	0.07	−0.07	0.00
D1F	0.00	−0.03	−0.08	0.09	−0.84	0.33	−0.16	0.12	0.00	0.07	0.10	−0.16	0.32	−0.30	−0.11	0.06
D1Fr	0.00	−0.02	−0.03	0.10	−0.90	0.30	−0.19	0.08	0.00	0.10	0.08	0.02	0.37	−0.40	−0.26	0.10
D50F	0.01	0.01	0.03	0.06	−0.66	0.28	−0.20	−0.03	0.00	0.08	0.01	−0.12	0.54	−0.57	−0.33	0.15
D50M	0.00	−0.02	−0.17	0.16	−0.85	0.19	0.06	0.12	0.00	0.16	0.13	−0.39	0.34	−0.48	−0.33	0.12
FL	0.00	0.01	0.06	−0.05	0.47	−0.26	0.06	−0.10	0.00	−0.12	−0.19	0.28	0.20	−0.01	0.16	0.00
WF	0.01	−0.01	0.17	−0.06	0.31	−0.14	0.08	−0.10	0.00	−0.19	−0.28	0.77	0.01	0.31	0.36	−0.09
FD	0.00	0.01	0.16	−0.08	0.29	−0.08	0.01	−0.05	0.00	−0.19	−0.28	0.50	0.10	0.12	0.23	−0.04
FW	0.00	0.00	0.20	−0.10	0.23	0.01	0.04	−0.08	0.00	−0.26	−0.23	0.57	0.00	0.28	0.44	−0.08
TNF	−0.01	−0.01	−0.04	0.03	0.55	−0.23	0.22	−0.08	0.00	0.00	0.06	0.00	−0.50	0.54	0.02	−0.11
TFW	0.00	−0.01	0.02	0.02	0.46	−0.22	0.20	−0.10	0.00	−0.11	−0.06	0.30	−0.48	0.56	0.31	−0.13
LFP	0.00	−0.02	0.12	−0.03	0.27	−0.22	0.19	−0.11	0.00	−0.19	−0.12	0.70	−0.03	0.49	0.35	−0.10
FT	0.00	−0.01	0.05	0.00	0.46	−0.23	0.23	−0.12	0.00	−0.13	−0.10	0.35	−0.43	0.57	0.29	−0.12

PH: Plant Height; DC: Diameter at Collar; MLL: Mature Leaf Length; MLW: Width of Mature Leaves; D1F: date of first flowering; D50F: Date of 50% Flowering; D50M: Date of 50% Maturity; FL: Fruit Length; WF: Width of fruit; FD: Fruit Diameter; TNF: Total Number of Fruits; TFW: Total Weight Fruit; LFP: Length of the Fruit Peduncle; FY: Fruit Yield; NSF: Number of Seeds per Fruit; FW: Fruit Weight per Plant; D1Fr: Date of First Fruiting. Red coloured diagonal values indicate positive or negative direct effect.

Plant Height demonstrated a high positive indirect effect on Date of First Flowering (D1F) (0.31), Total Weight Fruit (TFW) (0.28), Fruit Width (WF) (0.14), and Date of 50% Flowering (D50F) (0.11). However, it also showed significant negative indirect effects on Total Number of Fruits (TNF) (−0.40), Fruit Weight (FW) (−0.24), Length of the Fruit Peduncle (LFP) (−0.11), and Date of First Ripe Fruit (D1Fr) (−0.11). Fruit Weight (FW) exhibited a significant positive indirect effect through Length of the Fruit Peduncle (LFP) (0.44), Date of First Flowering (D1F) (0.23), Total Weight Fruit (TFW) (0.28), and Mean Leaf Length (MLL) (0.20). Conversely, it displayed notable negative indirect effects through Fruit Width (WF) (−0.26), Fruit Diameter (−0.23), and Mean Leaf Width (MLW) (−0.10).

Date of 50% Flowering (D50F) showed a negative indirect effect on Date of First Flowering (D1F) (−0.66), Total Weight Fruit (TFW) (−0.57), Length of the Fruit Peduncle (LFP) (−0.33), and Fruit Weight (FW) (−0.12). On the other hand, it exhibited high positive indirect effects on Total Number of Fruits (TNF) (0.54), Date of First Ripe Fruit (D1Fr) (0.28), and Fruit Thickness (FT) (0.15). Date of 50% Maturity (D50M) had a strong positive indirect effect on Total Number of Fruits (TNF) (0.34), Date of First Ripe Fruit (D1Fr) (0.19), Fruit Weight (FW) (0.16), Mean Leaf Width (MLW) (0.16), Fruit Diameter (0.13), and Fruit Thickness (FT) (0.12). In contrast, it showed significant negative indirect effects on Date of First Flowering (D1F) (−0.85), Total Weight Fruit (TFW) (−0.48), Fruit Weight (FW) (−0.39), Length of the Fruit Peduncle (LFP) (−0.33), and Mean Leaf Length (MLL) (−0.17). Total Weight Fruit (TFW) had a strong positive indirect effect through Date of First Flowering (D1F) (0.46), Fruit Weight (FW) (0.30), Length of the Fruit Peduncle (LFP) (0.31), and Date of 50% Flowering (D50F) (0.20). However, its negative indirect effects were notable through Total Number of Fruits (TNF) (−0.48), Date of First Ripe Fruit (D1Fr) (−0.22), Fruit Thickness (FT) (−0.13), Fruit Width (WF) (−0.11), and Date of 50% Maturity (D50M) (−0.10). Length of the Fruit Peduncle (LFP) exhibited a negative indirect effect on Date of First Ripe Fruit (D1Fr) (−0.22), Fruit Width (WF) (−0.19), Fruit Diameter (−0.12), Date of 50% Maturity (D50M) (−0.11), and Fruit Thickness (FT) (−0.10). In contrast, it showed high positive indirect effects on Fruit Weight (FW) (0.70), Total Weight Fruit (TFW) (0.49), Date of First Flowering (D1F) (0.27), Date of 50% Flowering (D50F) (0.19), and Mean Leaf Length (MLL) (0.12). Fruit Diameter showed a negative indirect effect on Fruit Width (WF) (−0.19) and positive indirect effects on Fruit Weight (FW) (0.50), Date of First Flowering (D1F) (0.29), Length of the Fruit Peduncle (LFP) (0.23), Mean Leaf Length (MLL) (0.16), Total Weight Fruit (TFW) (0.12), and Total Number of Fruits (TNF) (0.10).

3.4.2. Phenotypic Path Analysis

At the phenotypic level, among 16 characters, 7 traits showed a direct and positive effect on Number of Seeds per Fruit (**Table 6**). The Total Weight Fruit (TFW) exhibited the highest direct positive effect (0.65), followed by Fruit Thickness (FT) (0.46). In contrast, several traits showed a negative direct effect on Number of Seeds per Fruit, including Total Number of Fruits (TNF) (−0.61), Plant Height

(-0.12), Diameter at Collar (DC) (-0.15), Mean Leaf Length (MLL) (-0.23), Date of First Flowering (DF1) (-0.15), Date of 50% Flowering (D50F) (-0.16), Fruit Width (WF) (-0.16), Fruit Length (FL) (-0.02), and Fruit Diameter (-0.03).

At the phenotypic level, Date of First Flowering (D1F) (0.36), Date of First Ripe Fruit (D1Fr) (0.37), Date of 50% Flowering (D50F) (0.34), and Date of 50% Maturity (D50M) (0.32) showed the highest positive indirect effects on Total Number of Fruits (TNF). Conversely, six traits Plant Height (-0.39), Mean Leaf Width (MLW) (-0.22), Fruit Width (WF) (-0.09), Fruit Weight (FW) (-0.16), Length of the Fruit Peduncle (LFP) (-0.18), and Fruit Thickness (FT) (-0.48) exhibited the lowest negative indirect effects on Total Number of Fruits (TNF) (Table 6).

Plant Height demonstrated high positive indirect effects on Total Weight Fruit (TFW) (0.33) and Fruit Thickness (FT) (0.18). However, it also exhibited a strong negative indirect effect on Total Number of Fruits (TNF) (-0.39). Fruit Weight (FW) displayed significant positive indirect effects through Total Weight Fruit (TFW) (0.40) and Fruit Thickness (FT) (0.27). However, its negative indirect effects were most pronounced through Total Number of Fruits (TNF) (-0.16) and Fruit Width (WF) (-0.12).

Table 6. Estimates of phenotypic direct effects (diagonal) and indirect effects (off-diagonal) of traits via other independent traits on Number of Seeds per Fruit of 12 pepper genotypes at Obala.

geno.path	PH	DC	MLL	MLW	D1F	D1Fr	D50F	D50M	FL	WF	FD	FW	TNF	TFW	LFP	FT
PH	-0.12	-0.01	-0.06	0.01	0.07	-0.04	0.08	-0.02	0.00	0.01	0.00	-0.01	-0.39	0.33	0.01	0.18
DC	-0.01	-0.15	-0.10	0.01	-0.02	0.00	0.01	0.00	0.00	-0.02	0.00	0.07	-0.12	0.23	0.03	0.13
MLL	-0.03	-0.07	-0.23	0.02	0.00	-0.01	0.01	0.01	0.00	0.05	0.01	-0.07	-0.17	0.08	-0.03	0.03
MLW	-0.03	-0.07	-0.17	0.03	-0.01	-0.01	0.01	-0.01	0.01	0.01	0.00	-0.03	-0.22	0.16	0.00	0.09
D1F	0.05	-0.03	0.00	0.00	-0.15	0.06	-0.08	0.03	0.01	0.05	0.01	-0.12	0.36	-0.41	-0.03	-0.29
D1Fr	0.06	-0.01	0.03	0.00	-0.12	0.08	-0.11	0.03	0.01	0.03	0.01	-0.10	0.37	-0.37	-0.02	-0.26
D50F	0.06	0.01	0.01	0.00	-0.07	0.06	-0.16	0.03	0.00	0.04	0.00	-0.07	0.34	-0.34	-0.02	-0.22
D50M	0.04	-0.01	-0.05	0.00	-0.09	0.05	-0.09	0.05	0.00	0.04	0.01	-0.12	0.32	-0.36	-0.04	-0.22
FL	0.01	0.02	0.03	-0.01	0.07	-0.03	0.02	0.00	-0.02	-0.10	-0.02	0.13	-0.03	0.15	0.06	0.16
WF	0.01	-0.02	0.07	0.00	0.04	-0.02	0.04	-0.01	-0.01	-0.16	-0.02	0.21	-0.09	0.32	0.10	0.27
FD	0.00	-0.01	0.07	0.00	0.06	-0.02	0.02	-0.01	-0.01	-0.14	-0.03	0.21	-0.05	0.28	0.08	0.24
FW	0.00	-0.04	0.06	0.00	0.07	-0.03	0.04	-0.02	-0.01	-0.12	-0.02	0.27	-0.16	0.40	0.08	0.27
TNF	-0.08	-0.03	-0.06	0.01	0.09	-0.05	0.09	-0.03	0.00	-0.02	0.00	0.07	-0.61	0.52	0.05	0.35
TFW	-0.06	-0.05	-0.03	0.01	0.09	-0.04	0.09	-0.03	-0.01	-0.08	-0.01	0.17	-0.49	0.65	0.08	0.41
LFP	0.00	-0.03	0.04	0.00	0.03	-0.01	0.03	-0.01	-0.01	-0.11	-0.01	0.14	-0.18	0.34	0.15	0.26
FT	-0.05	-0.04	-0.01	0.01	0.10	-0.05	0.08	-0.02	-0.01	-0.10	-0.01	0.16	-0.48	0.59	0.09	0.46

PH: plant height, DC: Diameter at Collar, MLL: Length of Mature Leaves, MLW: Width of Mature Leaves, D1F: Date of First Flowering, D1Fr: Date of First Fruiting; D50F: Date of 50% Flowering, D50M: Date of 50% Maturity, FL: Fruit Length, WF: Width of fruit, FD: Fruit Diameter, FW: Fruit Weight per Plant; TNF: Total Number of Fruits, TFW: Total Weight Fruit, LFP Length of the Fruit Peduncle, FY: Fruit Yield. Red coloured diagonal values indicate positive or negative direct effect.

Date of 50% Flowering (D50F) showed a notable negative indirect effect on Total Weight Fruit (TFW) (-0.34) and Fruit Thickness (FT) (-0.22), while exhibiting a strong positive indirect effect on Total Number of Fruits (TNF) (0.34). Date of 50% Maturity (D50M) had high positive indirect effects on Total Number of Fruits (TNF) (0.32), whereas its negative indirect effects were evident on Total Weight Fruit (TFW) (-0.36), Fruit Thickness (FT) (-0.22), and Fruit Weight (FW) (-0.12). Total Weight Fruit (TFW) showed significant positive indirect effects through Fruit Thickness (FT) (0.41) and Fruit Weight (FW) (0.17), while its negative indirect effect was strongest via Total Number of Fruits (TNF) (-0.49). Length of the Fruit Peduncle (LFP) exhibited a negative indirect effect on Total Number of Fruits (TNF) (-0.18) and Fruit Width (WF) (-0.11). However, it showed strong positive indirect effects on Total Weight Fruit (TFW) (0.34), Fruit Thickness (FT) (0.26), and Fruit Width (WF) (0.14). Fruit Diameter demonstrated a negative indirect effect on Fruit Width (WF) (-0.14) and Total Number of Fruits (TNF), while exhibiting high positive indirect effects on Total Weight Fruit (TFW) (0.28), Fruit Thickness (FT) (0.24), and Fruit Weight (FW) (0.21).

4. Discussion

4.1. Phenotypic Variability

All phenotypic traits examined in this study showed significant differences among sweet pepper accessions, indicating a wide range of variability. This finding aligns with previous studies by [15] and [16]. For plant height, values ranged from 20.5 to 46 cm, highlighting significant qualitative differences among the accessions. However, this result contrasts with [17], who reported plant heights ranging from 85.15 cm to 214.90 cm, with a general mean of 194.84 cm. Regarding mature leaf length, measurements varied from 11.99 cm for the Y3 accession to 14.95 cm for the Y2 accession. These results are slightly higher than those reported by [18], who found leaf lengths ranging between 9.85 and 13 cm. This study also revealed variation in flowering times among accessions. The average duration of the first flowering date ranged from 28 days after transplanting for the O5 accession to 35 days for the B1, O1, and O4 accessions. The time to reach 50% flowering ranged from 35 to 37 days after transplanting across all accessions. These results are consistent with [18], who reported a time interval of 69 to 80 days after sowing to achieve 50% flowering. [19] also observed significant differences in flowering times across sweet pepper varieties and emphasized the importance of earliness in selecting chili varieties. Significant differences were observed among collected landraces for most assessed traits, highlighting the presence of genetic diversity. Similar findings were reported by [20]. Average fruit length ranged from 5 cm in the O2 accession to 6.14 cm in the E2 accession, a result comparable to the findings of [4], who recorded fruit lengths between 5.88 and 9.95 cm for five chili varieties. Fruit weight ranged from 34.4 g in the B1 accession to 71.56 g in the A1 accession. This result surpasses the findings of [18], who observed fruit weights ranging from 6.60 to 42.83 g. [21] demonstrated that high temperatures negatively impact fruit size

and weight. The study also found variation in average fruit widths, which ranged from 4.28 cm in the O4 accession to 5.37 cm in the Y1 accession. These values are significantly higher than those reported by [21], who documented widths between 1.45 cm and 1.92 cm. Regarding yield components, the significant differences among sweet pepper accessions can be attributed to variations in vegetative development. Accessions O5 (0.188 kg), Y3 (0.1835 kg), and Y1 (0.154 kg), which achieved the highest yields, were also among those with superior vegetative development. These findings are in agreement with studies by [22] and [23], which showed positive correlations between vegetative growth and yield components, such as fruit number and weight, in chili peppers. Similarly, significant variations in morphological traits, yield, and yield attributes among accessions were noted by [20]. The number of days taken to achieve 50% flowering ranged from 45.50 to 61.13 days, with a mean of 56.20 days, as reported by [17].

4.2. Principal Components and Cluster Analysis

The first two principal components (PCs) explained 68.4% of the total variation, highlighting key discriminant traits related to yield and fruit characteristics. Among these, fruit width, fruit weight, and plant height were the most notable contributors to the first principal component.

Hierarchical Cluster Analysis (HCA) revealed that the 12 bell pepper accessions studied were grouped into three significantly distinct clusters. This differs from previous findings by [11] and [18], who identified four groups. [24] emphasized that hierarchical cluster analysis enables more effective exploration of complex datasets. The identified clusters provide valuable insights for plant breeders. This classification aids in selecting compatible parental lines for controlled intra-specific crosses, with the goal of producing vigorous hybrids with high marketable fruit yield potential [11]. In contrast, [20] classified genotypes into six distinct groups based on cluster analysis. Additionally, multivariate and Bayesian clustering indicated that landraces were not primarily grouped by their geographical origin but rather aligned with the traits of their fruits.

4.3. Genetic Parameters

For all traits analyzed, the phenotypic coefficient of variation (PCV) was consistently higher than the genotypic coefficient of variation (GCV), indicating that environmental factors significantly influenced these traits. This observation aligns with the findings of [25], who reported that the interaction between genotypes and their environments resulted in lower GCV values compared to PCV. Similarly, [26] highlighted variable morphological responses among cultivars under aluminum stress conditions.

High PCV and GCV values were recorded for traits like the number of seeds per fruit (68.02 and 52.16, respectively), as well as for dry fruit yield per plant, fruit volume, and plant growth parameters such as the number of primary and secondary branches, plant height, and fruit surface area [27]. Traits in this study demon-

strated varying degrees of variability: low (<10%), moderate (10 - 20%), and high (>20%) for PCV and GCV. Grain yield, for instance, had high PCV and GCV values (26.91 and 25.9, respectively), while plant height after flowering exhibited low PCV and GCV values (7.96 and 5.16). Heritability estimates ranged from low (<30%) to moderate (30 - 60%) and high (>60%), as defined by [12]. [15] also found high PCV and GCV values for traits like fruit yield per plant and ascorbic acid content, suggesting wide genetic variability and better responsiveness to selection. Conversely, [28] observed minimal differences between PCV and GCV values for certain traits, indicating lower environmental influence. The highest heritability (0.99) was recorded for 1000-grain weight, followed by grain yield (0.93). Conversely, traits like the number of grains per row (0.14) and ear height (0.27) exhibited lower heritability values. Most traits studied fell within the moderate heritability range, suggesting that their genetic components can be effectively passed from one generation to the next, as reported by [29]. [30] came to the conclusion that heritability values for 12 traits ranging between 22.68% and 69.97%. High heritability coupled with high genetic advance was noted for traits such as average fruit weight, fruit yield per plant, fruit diameter, days to first harvest, and ascorbic acid content. These findings indicate the predominance of additive gene action in the inheritance of these traits, enhancing the efficiency of selection programs [15] [31]. [27] reported high heritability and genetic advance for fruit yield per plant, average fruit weight, seed weight per fruit, and pericarp weight per fruit, emphasizing their potential for improving hot pepper cultivars.

4.4. Path Analysis Identify Direct and Indirect Selection Criteria for Seed Number Per Fruit

Our study highlights that certain morphological traits are significantly linked to plant productivity and Number of Seeds per Fruit. This information can guide breeding programs aimed at improving yield and Number of Seeds per Fruit [24]. Correlation analysis revealed significant relationships between various quantitative morphological traits and fruit yield. A strong positive association was observed between specific traits and Number of Seeds per Fruit, identifying these as potential indicators for selecting high-yielding accessions [11]. While correlation measures the association between Number of seeds per fruit, and other traits, path coefficient analysis dissects these correlations into direct effects (path coefficients) and indirect effects (mediated by other variables). Path analysis results indicated that Fruit Weight (0.57), Total Weight Fruit (0.56), Length of Fruit Peduncle (0.35), D1Fr (0.30), MLW (0.16), and Date of 50% Maturity (0.12) exhibited positive direct effects on the Number of Seeds per Fruit. Among these, Fruit Weight, Total Weight Fruit, and Length of Fruit Peduncle had the largest direct effects, making them critical traits for selection in breeding programs aimed at enhancing the Number of Seeds per Fruit. [32] identified key component traits with significant direct effects on fresh fruit yield through path analysis. In contrast, [27] emphasized the Number of Seeds per Fruit as the primary determinant of yield per

plant, advocating for focused selection on this trait to enhance yield potential. Similarly, [33] reported that traits with positive direct phenotypic and genetic effects on fruit yield contribute significantly to yield improvement. At both genotypic and phenotypic levels in this study, the Total Weight Fruit (0.65) had the highest direct positive effect on the Number of Seeds per Fruit. Genotypic path analysis explores relationships between genetic components (e.g. genes, alleles, and their interactions), whereas phenotypic path analysis examines observable traits while accounting for genetic, environmental, and other factors. [34] observed that traits such as total red ripe fruits per plant, percent marketable red ripe fruits per plant, average red ripe fruit weight, and average dry fruit weight had the highest positive and direct effects on red ripe fruit yield per plant at both phenotypic and genotypic levels. These traits were deemed critical for selection programs aimed at yield improvement. Similarly, [35] identified Fruit Weight, Number of Fruits per Plant, Fruit Breadth, Thousand Seed Weight, Fruit Length, and Number of Seeds per Fruit as the key contributors to yield in bell peppers. In contrast, certain traits exhibited negative direct effects on the Number of Seeds per Fruit. These included vegetative traits such as Plant Height (−0.01), DC (−0.04), MLL (−0.24), and yield traits like D1F (−0.84), Total Number of Fruits (TNF) (−0.50), Date of 50% Flowering (D50F) (−0.20), WF (−0.19), and FT (−0.12). [28] reported a negative correlation between fruit length and marketable fruit yield per plant, driven by the negative indirect effects of marketable fruits per plant (−0.1934), fruit width (−0.0069), and pericarp thickness (−0.0057) at the genotypic level. [14] noted that chlorophyll content at the mature green stage had the most substantial negative direct effect on fruit yield per plant, followed by ascorbic acid and beta carotene content at the colored stage.

5. Conclusion

The present study aimed to identify direct selection criteria for the number of seeds per fruit (NSF) and related traits across 12 accessions of sweet bell pepper, using 17 quantitative traits. The evaluated germplasm displayed substantial genetic variability, providing a robust foundation for the improvement of NSF, growth, and related traits in *Capsicum annuum*. Significant genetic variability was observed, with heritability ranging from 4% (date of first fruiting) to 94% (date of first harvest), and genetic advance highlighting strong improvement potential for traits like total fruit weight. Principal component analysis explained 68.4% of the total variation, while cluster analysis grouped the accessions into three distinct clusters. Path analysis revealed that fruit weight, total fruit weight, and length of the fruit peduncle had the strongest positive effects on NSF, making them key traits for selection. These findings provide valuable insights for breeding programs and highlight the potential of these accessions for improving agronomic traits in *Capsicum annuum*. Future research should incorporate molecular and biochemical approaches to deepen genetic understanding and optimize selection strategies.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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