PLANT SCIENCE TODAY
Vol x(x): xx–xx
https://doi.org/10.14719/pst.8193

eISSN 2348-1900

RESEARCH ARTICLE

Genetic evaluation of cucumber (*Cucumis sativus* L.) genotypes for quality parameters under protected environment

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Received: 11 March 2025; Accepted: 14 September 2025; Available online: Version 1.0: 10 November 2025

Cite this article: Payal S, Arshia P, Shorya K, Neelam B, Himanshu T, Abhishek K, Parveen S. Genetic evaluation of cucumber (*Cucumis sativus* L.) genotypes for quality parameters under protected environment. Plant Science Today (Early Access). https:/doi.org/10.14719/pst.8193

Abstract

Six cucumber genotypes of cucumber (*Cucumis sativus* L.) cultivars used for the present study in mid-hills of Himachal Pradesh under protected conditions. The experiment was carried out at Vegetable Research Farm, Department of Vegetable Science and Floriculture, CSK Himachal Pradesh Krishi Vishvavidyalaya, Palampur in Randomized Block Design with four replications in spring-summer and rainy season during 2023. The outcomes of the present investigation revealed that the cultivar PN (Punjab Naveen) and PU (Pusa Uday) were the best performing cultivars among all the cultivars in relation of quality parameters of cucumber. The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. The results indicated that yield per plant had significant positive association with shelf life, phosphorus content, calcium content during summer season while calcium content, shelf life and phosphorus content expressed significant positive correlation during the rainy season. The path coefficient analysis on phenotypic and genotypic level revealed that among these characters, phosphorus content exhibited highest positive direct effect on yield per plant followed by diameter of seed during summer season and number of seeds per fruit followed by shelf life, calcium content, disease incidence and test weight showed positive direct effect on yield per plant during the rainy season, thus indicating that direct selection for yield improvement in cucumber can be performed.

Keywords: cucumber; gynoecious; monoecious; protected; quality

Introduction

Cucumber (*Cucumis sativus* L.) is an important commercial salad vegetable belonging to the family Cucurbitaceae. It is cultivated in different parts of the world (India, China, Camerron, Russian Federation and Turkey) and comprised of 117 genera and 825 species (1). It is the second largest cultivated cucurbit after watermelon for trade and export. It grows best at a temperature of 18-24 °C but does not withstand frost. In India, its production is 1608 thousand metric tonnes from an area of 116 thousand hectare with productivity of 13.86 metric tonnes per hectare (2). Protected cultivation has become popular for taking all the year-round production and fetching maximum prices for better livelihood of the farmers. This cultivation helps to remove glut from the market, hence provide better quality cucumbers to the consumers. Nowadays quality of vegetable produce has been achieving highest demand due to prevailing health concerns. With a water content exceeding 90 %, cucumbers are valued for their refreshing and hydrating properties, particularly in warm climates. They are recognized for their potential cooling effect when ingested and are utilized for relaxation and alleviation of physical stress (3). In traditional medicinal contexts, cucumbers are esteemed for their therapeutic benefits against conditions such as jaundice and constipation (4). Additionally, their antioxidant properties may help reduce oxidative stress and inflammation (5). Cucumbers contribute to weight loss and rehydration owing to their low-calorie content (16 calories per cup), high fiber content in the skin and have essential nutrients such as vitamin K and potassium (6). The advent of hybrid cucumber varieties in recent years has markedly influenced productivity trends, cultivation techniques and geographic expansion (7). Genetic advancements and the adoption of modern agricultural technologies, particularly in management practices, are pivotal for achieving optimal quality standards. These developments have spurred interest and engagement among both commercial and non-commercial growers in cucumber cultivation (8). The role of genetic variability in a crop is of paramount importance in selecting the best genotypes for making rapid improvement in quality characters as well as to select most potential parents for making the hybridization programme successful (9). Any crop improvement programme primarily depends on the amount of genetic variability available and the extent to which the economic traits are heritable. Therefore, this current study has been conducted to find out the variability among genotypes in order to get the most diverse parents for hybridization program under protected environment for quality improvement.

Materials and Methods

Study area and plant material

The experiment was carried out at Department of Vegetable Science and Floriculture, College of Agriculture, Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur Himachal Pradesh (32°6′ N; 76°3′ E and 1290.80 m above mean sea level) under naturally ventilated polyhouse during spring-summer and rainy season 2023. The nursery was raised in soil-less media containing mixture of perlite:cocopeat:vermiculite in the ratio of 1:3:1 and was transplanted after 25 days under naturally ventilated polyhouse. The cucumber varieties (Him Palam Kheera-1, Him Palam Kheera-2, Punjab Kheera-1, Gyno G-1, Pusa Uday and Punjab Naveen) seed was procured from CSK HPKV, Palampur, Punjab Agriculture University and IARI, New Delhi.

Experimental design

The experiment with six treatments was carried out in Randomised Block Design with spacing 70 × 30 cm in four replications. To ensure optimal growth and yield, consistent watering, soil mounding, nutrient application, stacking and pest control measures were adopted as per package of practices (10).

Nutrient application

The recommended package of practices was followed to raise healthy crop of cucumber. Before planting in pits, chemical fertilisers (50 kg of nitrogen, phosphorus and potassium per acre) were applied along with 5 tonnes of vermicompost. Following three weeks of transplanting, fertigation was carried out three times a week using liquid fertilisers (19:19:19) at a rate of 5.0 g/L of water and was stopped 15 days before the last fruit harvesting.

Quality traits

The observations were recorded for different quality traits *viz*., protein content (g/100g), vitamin C (mg/100g), total soluble solids (° Brix), calcium content (mg/100g), phosphorus content (mg/100g), number of seeds per fruit, length of seed (mm), diameter of seed (mm), test weight (g), seed viability (%) and germination percentage (%). Five competitive plants were selected randomly from each of the plots and its replications for recording the data. The observation of the following quantitative traits has been taken according to the methodology described by Kaur and Sharma (11).

Statistical analysis

The quality analysis was carried out following standard procedures in the previous studies (12, 13). The obtained data were subjected to analysis of variance using established statistical methods (14). Genetic variability for different parameters was estimated using conventional approaches (15). Heritability along with expected genetic advance were calculated accordingly to the previous research (16). The genotypic and phenotypic correlations were calculated (17) and path coefficient analysis was performed using standard biometric techniques (18, 19).

Results and Discussion

Quality traits

Disease incidence (%)

In the present study, mean performance among cucumber genotypes revealed significant differences for all the characters (Table 1). Data pertaining to disease incidence (%) of Powdery Mildew (PM) revealed that during summer season cultivar PN (4.63 %) and HPK-2 (4.87 %) showed minimum disease incidence, while cultivar PU (8.62 %) showed minimum disease incidence during rainy season. Effective management practices, such as resistant cultivars and integrated pest management, are essential for mitigating these effects and optimizing production (20). Significant variation in this trait has also been reported in previous studies (21), where the range of disease incidence (%) varied from 5.72 to 29.73.

Shelf life (days)

During summer season, cultivar HPK-1 (6.42 days) exhibited maximum shelf life, while cultivar PN (4.28 days) and PU (4.42 days) showed minimum shelf life during rainy season The shelf life of cucumbers is affected by physiological factors and storage conditions, influencing overall marketable yield. Improved postharvest handling can extend shelf life, maximizing economic returns by minimizing losses (22). Similarly, in another experiment (23), the shelf life (days) ranging from 4.92 to 8.43. In another study (24) it is also reported the shelf life (days) in cucumber valued from 2.24 to 3.80.

TSS (°Brix)

During summer season, cultivar PN (3.28 °Brix) exhibited maximum TSS (Table 1). Similar results were found during rainy season where cultivar PU (3.28°Brix) exhibited maximum TSS followed by PN (3.16° Brix) and were statistically at par with each other. Higher TSS levels typically indicate enhanced fruit maturity and flavor, which can contribute to increased marketable yield (25). In a previous experiment, total soluble solids (°Brix) were found to vary from 2.73 to 5.01, which is in agreement with the findings of the present study (26).

Table 1. Mean performance of disease, shelf life and TSS in cucumber (*Cucumis sativus* L.) genotypes

Cultivar	Disease incidence (%) PM		Shelf life (Days)		TSS (°Brix)	
	Summer	Rainy	Summer	Rainy	Summer	Rainy
HPK-1	5.35^{c}	10.23^{bc}	6.42^{a}	6.12^{b}	2.66^{d}	2.59^{c}
PK-1	7.21^{a}	11.42^{a}	5.98^{b}	6.06^{b}	2.58^{d}	2.61^{c}
Gyno-G1	6.04^{b}	9.57^{c}	6.22^{ab}	6.68^{a}	2.97^{c}	2.98^{b}
PU	5.58^{c}	8.62^{d}	4.89^{c}	4.42^{c}	3.17^{ab}	3.28^{a}
PN	4.63^{d}	10.60^{b}	4.91^{c}	4.28^{c}	3.28^{a}	3.16^{ab}
HPK-2	4.87^{d}	12.08^{a}	6.12^{b}	5.93^{b}	3.03^{bc}	2.99^{b}
CD (P = 0.05)	0.37	0.74	0.26	0.25	0.16	0.18
CV	3.69	3.94	2.50	2.51	3.14	3.50

Mean followed by common letters are not significantly different at α = 0.05 ($p \le 0.05$) according to Fisher's LSD Post Hoc test.

Table 2. Mean performance of ascorbic acid, phosphorus and calcium content in cucumber (*Cucumis sativus* L.) genotypes

Cultivar	Ascorbic acid content (mg/100g)		Phosphorus content (mg/100g)		Calcium content (mg/100g)	
	Summer	Rainy	Summer	Rainy	Summer	Rainy
HPK-1	2.28^{e}	2.32^{e}	27.42^{a}	27.63^{a}	11.26^{a}	11.28^{a}
PK-1	2.67^{d}	2.55^{d}	26.93^{a}	26.58^{b}	10.82^{b}	10.65^{b}
Gyno-G1	2.94^{c}	2.84^{c}	24.82^{b}	24.31^{c}	10.89^{b}	10.92^{ab}
PU	3.43^{b}	3.62^{b}	19.74^{d}	20.04^{e}	8.40^{e}	8.520
PN	3.80^{a}	3.92^{a}	20.38^{cd}	20.19^{e}	9.62^{d}	8.520
HPK-2	2.87^{cd}	2.97^{c}	21.21^{c}	21.53^{d}	10.30^{d}	10.53^{b}
CD (P = 0.05)	0.21	0.17	1.07	0.64	0.19	0.58
CV	3.95	3.11	2.52	1.51	1.04	3.13

Mean followed by common letters are not significantly different at α = 0.05 ($p \leq 0.05$) according to Fisher's LSD Post Hoc test.

Ascorbic acid (mg/100g)

During both summer and rainy season, cultivar PN (3.80 mg/100g) showed maximum ascorbic acid content (Table 2). Elevated ascorbic acid levels are associated with improved fruit quality and overall biomass, positively impacting marketable yield (27). Previous studies (28) have documented similar results for ascorbic acid (mg/100g) and recorded the range of trait from 2.32 to 3.42 mg/100g while another investigation (29) recorded for ascorbic acid (mg/100g) ranged from 3.12 to 4.11 mg/100g.

Phosphorus content (mg/100g)

During summer season, cultivar HPK-1 (27.42 mg/100g) had the maximum value for phosphorus content followed by PK-1 (26.93 mg/100g) (Table 2) and HPK-1 (27.63 mg/100g) had the maximum phosphorus content during rainy season. Adequate availability of phosphorus is critical for optimal yield and fruit quality, as it supports metabolic processes and flowering (30). The phosphorus content (mg/100g) in the previous study showed the same results as of current experiment *viz*., 16.54 to 32.62 mg/100g (11).

Calcium content (mg/100g)

During both summer and rainy season, cultivar HPK-1 (11.26 mg/100g; 11.28 mg/100g) exhibited maximum content of calcium. Calcium is vital for cucumber development, as it strengthens cell walls and regulates physiological processes, promoting structural integrity and reducing susceptibility to diseases. Adequate calcium levels enhance fruit quality and shelf life by preventing disorders such as blossom end rot and ensuring proper growth (24). Similar result for this trait were also reported in earlier studies (31), where calcium content (mg/100g) ranging from 8.12 to 12.54 mg/100g.

Total sugars (%)

For total sugar content during both summer and rainy season, cultivar PN (3.26 %; 3.30 %) exhibited maximum total sugars. Total sugars in cucumbers are crucial for determining fruit quality, as they influence flavor, palatability and consumer preference. Elevated total sugar content also reflects the plant's photosynthetic efficiency and overall health, contributing to improved marketable yield (11). Previous studies have reported similar results for ascorbic acid content (mg/100 g), with values ranging from 2.65 % to 3.29% (32).

Reducing sugars (%)

During summer season, cultivar PN (0.83 %) exhibited maximum reducing sugars followed by PU (0.79 %) and HPK-2 (0.78 %) (Table 3). In rainy season, cultivar PU (0.88 %) had the maximum amount of reducing sugars followed by HPK-1 (0.79 %) and PN (0.76 %). Higher levels of reducing sugars indicate effective carbohydrate metabolism, which supports plant energy needs and promotes healthy fruit development (33). Similarly, in another experiment, reducing sugars were observed to range from 0.58 % to 0.87% (32).

Number of seeds per fruit

During both summer and rainy season, cultivar PN (192.13; 204.91) and PU (188.18; 194.68) showed maximum number of seeds per fruit. The number of seeds in cucumbers is critical for reproductive success, as it directly influences fruit set and overall yield potential. Additionally, seed quantity affects genetic diversity and can enhance consumer appeal, as larger, well-seeded fruits are often preferred in the market (34). In a similar experiment, the number of seeds per fruit was observed to range from 143.34 to 195.97 (26).

Test weight (g)

Cultivar PN (35.32 g) had the maximum test weight of seeds during summer season followed by PU (33.17 g) and Gyno-G1 (31.72 g) (Table 4). Similar trend for test weight was found during rainy season. Test weight of seeds in cucumbers is a key indicator of seed quality, as it reflects viability, vigor and potential germination rates. Higher test weights are associated with better seed performance and establishment, ultimately contributing to improved crop yield and consistency (35). Similar results for this trait were also reported in earlier studies, with test weight (g) ranging from 26.73 to 37.42 g (31).

Length of seed (mm)

In summer season, cultivar PN (1.28 mm) and PU (1.25 mm) had the maximum length of seed, whereas for rainy season, cultivar PN (1.31

Table 3. Mean performance of total sugar, reducing sugar and number of seeds in cucumber (*Cucumis sativus* L.) genotypes

Cultivar	Total sugar (%)		Reducing sugar (%)		Number of seeds per fruit	
	Summer	Rainy	Summer	Rainy	Summer	Rainy
HPK-1	2.92^{b}	2.84^{b}	0.75^{a}	0.79^{b}	145.66^{d}	148.31^{cd}
PK-1	2.51^{c}	2.53^{c}	0.58^{b}	0.61^{c}	158.31^{b}	153.29^{c}
Gyno-G1	3.06^{ab}	2.91^{b}	0.60^{b}	0.62^{c}	153.11^{c}	154.16^{c}
PU	3.11^{ab}	3.18^{a}	0.79^{a}	0.88^{a}	188.18^{a}	194.68^{b}
PN	3.26^{a}	3.30^{a}	0.83^{a}	0.76	192.13^{a}	204.91^{a}
HPK-2	2.94^{b}	2.94^{b}	0.78^{a}	0.75^{b}	146.62^{d}	142.68^{d}
CD (P = 0.05)	0.20	0.19	0.10	0.08	4.09	7.83
CV	3.81	3.62	8.07	6.26	1.37	2.59

Mean followed by common letters are not significantly different at α = 0.05 ($p \leq 0.05$) according to Fisher's LSD Post Hoc test.

Table 4. Mean performance of test weight, length and diameter of seed in cucumber (*Cucumis sativus* L.) genotypes

Cultivar	Test weight (g)		Length of seed (mm)		Diameter of seed (mm)		Yield per plant (g)	
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
HPK-1	28.36[c]	27.87[c]	0.98[bc]	0.91[e]	2.98[b]	3.02[b]	2594.19±47.93[a]	2216.73±29.53[b]
PK-1	27.21[c]	28.02[c]	0.93[cd]	0.95[d]	3.07[b]	3.06[b16.]	2494.34±21.36[b]	2083.26±46.62[c]
Gyno-G1	31.72[b]	32.23[b]	1.02[b]	1.09[c]	3.02[b]	3.08[b]	2025.37±25.31[c]	1964.37±11.03[d]
PU	33.17[b]	33.62[b]	1.25[a]	1.19[b]	3.57[a]	3.48[a]	1838.72±6.7[d]	1693.19±42.3[e]
PN	35.32[a]	36.18[a]	1.28[a]	1.31[a]	3.63[a]	3.52[a]	1660.61±12.1[e]	1682.41±32.4[e]
HPK-2	27.11[c]	26.43[c]	0.91[d]	0.94[de]	3.06[b]	3.04[b]	2438.6±26[b]	2331.93±24.55[a]
CD (P = 0.05)	1.65	2.04	0.05	0.04	0.13	0.13	91.84	105.20
CV	2.97	3.65	2.93	2.13	2.28	2.22	2.321	2.898

Mean followed by common letters are not significantly different at α = 0.05 ($p \leq 0.05$) according to Fisher's LSD Post Hoc test.

mm) had the maximum length of seed followed by PU (1.19 mm) and Gyno-G1 (1.09 mm). Seed length in cucumbers is an important trait influencing germination and seedling vigor, as longer seeds are often associated with higher nutrient reserves. This trait can enhance early growth rates and overall establishment, positively impacting crop yield and uniformity. Previous studies have also reported seed length (mm) in cucumber, ranging from 0.89 to 168 mm (24).

Seed diameter (mm)

In case of diameter of seed during both summer and rainy season, cultivar PN (3.63 mm, 3.52 mm) and PU (3.57 mm, 3.48 mm) had the maximum diameter of seed, respectively and were statistically at par with each other (Table 4). Larger seed diameters can enhance early growth and resilience, ultimately contributing to improved yield and crop uniformity (28). Seed diameter (mm) has also been reported in previous studies, with values ranging from 3.31 to 4.29 mm (32).

Yield per plant

The fruit yield per plant summer season ranged from 1660.61 to 2594.19 g (Table 4). Significantly maximum value for these traits was noticed in Him Palam Kheera-1. During rainy season the fruit yield per plant ranged from 1682.41 to 2331.93 g, where maximum yield was recorded for Him Palam Kheera-2. Maximisation of marketable yield is the ultimate objective of every research effort. This is also the key factor in acceptance or rejection of a cultivar by the farmer (25). Fruit yield per plant provides a measure of individual plant output, influenced by factors like pollination and plant vigour (28). Higher fruit yield per plant signifies efficient cultivation methods and healthy plants. A wide genetic variation in yield per plant has also been reported in previous studies, with values ranging from 1582.29 to 2010.63 g (21).

Parameters of variability

The estimates of variability *viz.*, coefficients of variability (phenotypic and genotypic), heritability (in broad sense) and genetic advance as percent of mean (genetic gain) were worked out for selection of various characters.

As can be perused from Table 5, the phenotypic coefficient of variability (PCV) in our present investigation for summer season was high for yield per plant (34.32 %), moderate for ascorbic acid content (18.37 %), disease incidence (16.82 %), reducing sugar (15.79 %) and length of seed (15.34 %) and low for phosphorus content (14.68 %), number of seeds per fruit (12.73 %), test weight (11.51 %), calcium content (10.36 %), TSS (9.76 %), diameter of seed (9.37 %) and total sugars (9.18 %). Similarly, the genotypic coefficients of variability (GCV) were high for yield per plant (33.32 %), moderate for disease incidence (16.41 %), ascorbic acid content (17.95 %), length of seed (15.05 %) and low for phosphorus content (14.46 %), reducing sugar (13.57 %), number of seeds per fruit (12.66 %), shelf life (11.67 %), test weight (11.11 %), calcium content (10.31 %), TSS (9.24 %) and diameter of seed (9.09 %).

The phenotypic coefficient of variability (PCV) for rainy season was high for yield per plant (36.42), moderate for ascorbic acid content (17.28 %), disease incidence (16.22 %), reducing sugar (15.49 %), Shelf life (15.43 %) length of seed (15.18 %) and low for phosphorus content (14.59 %), number of seeds per fruit (11.83 %), calcium content (10.29 %), test weight (10.21 %), TSS (9.92 %), total sugars (9.53 %) and diameter of seed (9.29 %). Similarly, the genotypic coefficient of variability (GCV) was high for yield per plant (32.92 %), moderate for ascorbic acid content (17.21 %), disease incidence (16.01 %), reducing sugar (15.43 %) and low for length of seed (14.85 %), shelf life (14.67 %), phosphorus content (14.02 %), number of seeds per fruit (11.16 %), TSS (9.04 %), diameter of seed

Table 5. Estimates of phenotypic and genotypic coefficients of variability, heritability, genetic advance and genetic gain characters in cucumber (*Cucumis sativus* L.)

Characters	Coefficient of variation (%)				Heritability (%)		Genetic gain	
	PCV		GCV					
	Summer	Rainy	Summer	Rainy	Summer	Rainy	Summer	Rainy
Disease incidence (%) PM	16.82	16.22	16.41	16.01	95.18	96.68	32.99	39.48
Shelf life (days)	10.36	15.43	10.31	14.67	98.97	97.79	21.14	21.62
TSS (°Brix)	9.76	9.92	9.24	9.04	89.62	83.62	18.02	13.72
Ascorbic acid content (mg/100g)	18.37	17.28	17.95	17.21	95.37	98.32	36.11	38.82
Phosphorus content (mg/100g)	14.68	14.59	14.46	14.02	97.04	97.34	29.34	31.51
Calcium content (mg/100g)	11.93	10.29	11.67	8.36	95.59	98.84	23.51	20.08
Total sugar (%)	12.73	9.53	12.73	9.26	98.83	88.73	25.93	15.02
Reducing sugar (%)	11.51	15.49	11.11	15.43	93.31	78.84	22.12	22.52
Number of seeds per fruit	9.18	11.83	8.35	11.16	82.73	98.23	15.65	29.28
Test weight (g)	15.79	10.21	13.57	8.76	73.84	94.31	24.02	20.14
Length of seed (mm)	15.34	15.18	15.05	14.85	96.34	97.84	30.45	25.62
Diameter of seed (mm)	9.37	9.29	9.09	9.01	94.05	94.15	18.17	17.83
Yield per plant (g)	34.32	33.32	36.42	32.92	97.62	97.26	68.99	66.93

(9.01 %), test weight (8.76 %) and calcium content (8.36 %). In an earlier study, moderate PCV and GCV for ascorbic acid (19.47 and 17.24) and low for reducing sugar (12.83 and 13.70), test weight (11.65 and 12.87) and TSS (10.16 and 9.28) (9).

High heritability (>80 %) was estimated for summer season (Table 5) *viz*., calcium content (98.97 %), number of seeds per fruit (98.83 %), yield per plant (97.62 %), phosphorus content (97.04 %), length of seed (96.34 %), shelf life (95.59 %), ascorbic acid content (95.37 %), disease incidence (95.18 %), diameter of seed (94.05 %), test weight (93.31 %), TSS (89.62 %) and total sugars (82.73 %). Moderate heritability (50-80 %) was recorded for reducing sugar (73.84 %). High heritability (>80 %) was estimated for rainy season *viz*., calcium content (98.84 %), ascorbic acid content (98.32 %), number of seeds per fruit (98.23 %), length of seed (97.84 %), shelf life (97.79 %), phosphorus content (97.34 %), yield per plant (97.26 %), disease incidence (96.68 %), test weight (94.31 %), diameter of seed (94.15 %), total sugars (88.73 %) and TSS (83.62 %). This indicated that a large portion of phenotypic variance is contributed through genotypic variance and therefore, a reliable selection can be made for these traits based on phenotypic expression. Moderate heritability (50-80 %) was recorded for reducing sugar (78.84 %), which indicates a considerable influence of environment on the expression of above-mentioned trait. Higher magnitude of heritability suggested major role of genotypes factor in the expressing of characters. Characters with low heritability are considered less dependable because their genotypic expression is strongly influenced by environmental factors (36). Thus, the degree of success in selection depends upon the magnitude of the heritability value, furthermore; the progress in selection is also directly proportional to the amount of genetic advance. Therefore, the effect of selection is realized more quickly in those characters which have high heritability as well as genetic advance.

An inquisition of data in Table 5 revealed that genetic gain for summer season (expressed as percent of population mean) ranged from 15.65 to 68.99 percent for different characters under study. It was found high for yield per plant (68.99 %), moderate for ascorbic acid (36.11 %), disease incidence (32.99 %), length of seed (30.45 %), phosphorus content (29.34 %), total sugars (25.93 %), reducing sugar (24.02 %), shelf life (23.51 %), test weight (22.12 %), calcium content (21.14 %) diameter of seed (18.17 %) and TSS (18.02 %), while it was low for number of seeds per fruit (15.08 %). Similarly, for rainy season, genetic gain ranged from 13.72 % to 66.93 % for different characters. It was found high for yield per plant (66.93 %), moderate for disease incidence (39.48 %), ascorbic acid (36.82 %), phosphorus content (31.51 %), number of seeds per fruit (29.28 %), length of seed (25.62 %), test weight (20.14 %), calcium content (20.08 %), reducing sugar (22.52 %), shelf life (21.62 %), diameter of seed (17.83 %) and total sugars (15.02 %), while it was low for TSS (13.72 %). The expression of the traits with high heritability and genetic advance is predominantly governed by additive gene effects and therefore, selection based on phenotypic performance will be useful to improve these characters in the future (37).

Correlation studies

All the possible phenotypic and genotypic correlation coefficient between yield and quality components during the summer and rainy season is given in Table 6 and 7. The present study disclosed that, genotypic correlation coefficient was higher than their phenotypic ones indicating strong association of two characters genetically. In our investigation, during both the summer and rainy season correlation coefficient among seven traits indicated that yield per plant had significant negative association at phenotypic and genotypic levels with test weight (-0.939, -0.981); (-0.901, -0.984), ascorbic acid content (-0.928, -0.949); (-0.781, -0.817), length of seed (-0.892, -0.929); (-0.918, -0.948), number seeds per fruit (-0.861, -0.877); (-0.915 -0.953), diameter of seed (-0.829, -0.868); (-0.871, -0.939), TSS (-0.815, -0.895); (-0.660, -0.712) and total sugars (-0.722, -0.814); (-0.630, -0.682). While significant positive correlation at phenotypic and genotypic levels of yield per plant was observed in shelf life (0.814, 0.853), phosphorus content (0.724, 0.733), calcium content (0.713, 0.725) during summer season while calcium content (0.752, 0.815), shelf life (0.748, 0.760) and phosphorus content (0.564, 0.596) expressed significant positive correlation during the rainy season. Diameter of seed was observed to have significant negative correlation with shelf life (-0.964, -1.007), calcium content (0.864, -0.891) and phosphorus content (-0.771, -0.788) during the summer season, while shelf life (-0.897, -0.974), calcium content (-0.834, -0.953), phosphorus content (-0.753, -0.789) and disease incidence (-0.486, -0.502) showed significant negative correlation during the rainy season with character diameter of seed. Whereas significant positive correlation was observed with number of seeds per fruit, length of seed, ascorbic acid content, test weight, TSS, total sugars and reducing sugars during both summer and rainy season. Length of seed exhibited highly significant positive correlation with number of seeds per fruit (0.943, 0.956); (0.932, 0.944), test weight (0.914, 0.965); (0.941, 0.996), ascorbic acid content (0.845, 0.884); (0.913, 0.927), TSS (0.745, 0.785); (0.775, 0.816), total sugars (0.709, 0.773); (0.758, 0.853) and reducing sugars (0.485, 0.624). Reducing sugars was found to have significant negative correlation with disease incidence (-0.757, -0.990), phosphorus content (-0.640, -0.757), calcium content (-0.512, -0.613) and shelf life (-0.490, -0.598) during the summer season while shelf life (-0.657, -0.697), calcium content (-0.569, -0.665) and phosphorus content (-0.472, -0.534) exhibited significant negative correlation during rainy season. Total sugars showed highly significant positive correlation with TSS, test weight, ascorbic acid content and number of seeds per fruit during both the seasons. Similarly test weight exhibited highly significant positive correlation with ascorbic acid content (0.839, 0.870); (0.796, 0.840), number of seeds per fruit (0.829, 0.864); (0.878, 0.924) and TSS (0.756, 0.813); (0.670, 0.747) during the summer and rainy season. Number of seeds per fruit expressed significant positive correlation with TSS and ascorbic acid content during both the summer and rainy season. While shelf life and phosphorus content were found to have significant negative correlation with TSS and ascorbic acid content during both the seasons. Ascorbic acid exhibited significant positive correlation with TSS during summer (0.857, 0.922) as well as rainy (0.865, 0.930) season. While TSS was found to have significant negative correlation with calcium content (-0.714, -0.761) and disease incidence (-0.651, -0.722) during the summer season and with calcium content (-0.762, -0.871) during the rainy season. Studies on such quality parameters are very limited; however, correlations between yield and various horticultural traits have been reported in previous investigations. (25, 26, 38-42).

Path coefficients analysis

Path coefficient analysis enables the subdivision of correlation coefficients into direct and indirect effects of various characters on yield and its attributing traits (9). The data on path coefficient analysis at phenotypic and genotypic level showing direct and

Table 6. Estimates of genotypic and phenotypic correlation coefficients between different characters in cucumber for summer season

Characters		Calcium content	TSS	Ascorbic acid	Phosphorus content	Shelf life	No. of seeds per fruit	Test weight	Total sugars	Reducing sugars	Length of seed	Diameter of seed	Yield per plant
Disease incidence (%)	P	0.309^{NS}	-0.651*	-0.402^{NS}	0.622*	0.295^{NS}	-0.252^{NS}	-0.395^{NS}	-0.781*	-0.757*	-0.415^{NS}	-0.401^{NS}	0.350^{NS}
	G	0.317^{NS}	-0.722*	-0.440^{NS}	0.627*	0.314^{NS}	-0.255^{NS}	-0.413^{NS}	-0.813*	-0.990*	-0.419^{NS}	-0.397^{NS}	0.374^{NS}
Calcium content	P		-0.714*	-0.776*	0.853*	0.895*	-0.837*	-0.615*	-0.479*	-0.512*	-0.779*	-0.864*	0.713*
	G		-0.761*	-0.796*	0.867*	0.916*	-0.841*	-0.642*	-0.555*	-0.613*	-0.797*	-0.891*	0.725*
TSS (°Brix)	P			0.857*	-0.859*	-0.736*	0.683*	0.756*	0.799*	0.589*	0.745*	0.720*	-0.815*
	G			0.922*	-0.973*	-0.749*	0.713*	0.813*	0.931*	0.727*	0.785*	0.802*	-0.895*
Ascorbic acid content (mg/100g)	P				-0.830*	-0.886*	0.889*	0.839*	0.609*	0.492*	0.845*	0.873*	-0.928*
	G				-0.863*	-0.922*	0.907*	0.870*	0.741*	0.522*	0.884*	0.935*	-0.949*
Phosphorus content (mg/100g)	P					0.752*	-0.680*	-0.588*	-0.661*	-0.640*	-0.662*	-0.771*	0.724*
	G					0.799*	-0.696*	-0.616*	-0.726*	-0.757*	-0.689*	-0.788*	0.733*
Shelf life	P						-0.970*	-0.778*	-0.502*	-0.490*	-0.896*	-0.964*	0.814*
	G						-0.992*	-0.798*	-0.574*	-0.598*	-0.932*	-1.007*	0.853*
No. of seeds per fruit	P							0.829*	0.511*	0.426^{NS}	0.943*	0.957*	-0.861*
	G							0.864*	0.576*	0.520*	0.956*	0.998*	-0.877*
Test weight	P								0.775*	0.400^{NS}	0.914*	0.815*	-0.939*
	G								0.846*	0.449^{NS}	0.965*	0.837*	-0.981*
Total sugars	P									0.547*	0.709*	0.599*	-0.722*
	G									0.794*	0.773*	0.634*	-0.814*
Reducing sugars	P										0.485*	0.549*	-0.373^{NS}
	G										0.624*	0.672*	-0.408^{NS}
Length of seed (mm)	P											0.916*	-0.892*
	G											0.965*	-0.929*
Diameter of seed (mm)	P												-0.829*
	G												-0.868*

Table 7. Estimates of genotypic and phenotypic correlation coefficients between different characters in cucumber for rainy season

Characters		Calcium content	TSS	Ascorbic acid	Phosphorus content	Shelf life	No. of seeds per fruit	Test weight	Total sugars	Reducing sugars	Length of seed	Diameter of seed	yield per plant
Disease incidence (%)	P	0.417^{NS}	-0.430^{NS}	-0.295^{NS}	0.192^{NS}	0.280^{NS}	-0.490*	-0.602**	-0.341^{NS}	-0.344^{NS}	-0.479*	-0.486*	0.616**
	G	0.511*	-0.461^{NS}	-0.306^{NS}	0.191^{NS}	0.317^{NS}	-0.505*	-0.621**	-0.476*	-0.481*	-0.494*	-0.502*	0.695**
Calcium content	P		-0.762**	-0.821**	0.804**	0.865**	-0.825**	-0.645**	-0.655**	-0.569*	-0.719**	-0.834**	0.752*
	G		-0.871**	-0.891**	0.836**	0.915**	-0.876**	-0.688**	-0.715**	-0.665**	-0.778**	-0.953**	0.815**
TSS (°Brix)	P			0.865**	-0.917**	-0.644**	0.686**	0.670**	0.801**	0.429^{NS}	0.775**	0.765**	-0.660**
	G			0.930**	-0.976**	-0.721**	0.748**	0.747**	0.899**	0.563*	0.816**	0.812**	-0.712**
Ascorbic acid content (mg/100g)	P				-0.917**	-0.859**	0.882**	0.796**	0.822**	0.449^{NS}	0.913**	0.914**	-0.781*
	G				-0.936**	-0.886**	0.911**	0.840**	0.908**	0.482*	0.927**	0.945**	-0.817**
Phosphorus content (mg/100g)	P					0.743**	-0.693**	-0.596**	-0.787**	-0.472*	-0.737**	-0.753**	0.564*
	G					0.757**	-0.703**	-0.615**	-0.863**	-0.534*	-0.746**	-0.789**	0.596**
Shelf life	P						-0.908**	-0.652**	-0.725**	-0.657**	-0.768**	-0.897**	0.748**
	G						-0.932**	-0.710**	-0.787**	-0.697**	-0.785**	-0.974**	0.760**
No. of seeds per fruit	P							0.878**	0.717**	0.452^{NS}	0.932**	0.968**	-0.915**
	G							0.924**	0.822**	0.518*	0.944**	1.003**	-0.953**
Test weight	P								0.680**	0.183^{NS}	0.941**	0.838**	-0.901**
	G								0.816**	0.303^{NS}	0.996**	0.898**	-0.984**
Total sugars	P									0.617**	0.758**	0.732**	-0.630**
	G									0.695**	0.853**	0.874**	-0.682**
Reducing sugars	P										0.288^{NS}	0.502*	-0.280^{NS}
	G										0.311^{NS}	0.604**	-0.321^{NS}
Length of seed (mm)	P											0.911**	-0.918**
	G											0.936**	-0.948**
Diameter of seed (mm)	P												-0.871**
	G												-0.939**

Table 8. Path coefficient analysis showing the direct and indirect effect of characters on net yield in cucumber at phenotypic and genotypic level summer season

Characters		Disease incidence (%)	Calcium content	TSS	Ascorbic acid	Phosphorus content	Shelf life	No. of seeds per fruit	Test weight	Total sugars	Reducing sugars	Length of seed	Diameter of seed	yield per plant
Disease incidence (%)	P	-0.317	-0.073	0.072	0.017	0.367	-0.138	0.169	0.219	0.067	0.006	0.040	-0.081	0.350^{NS}
	G	-0.307	-0.076	0.088	0.006	0.372	-0.159	0.175	0.248	0.055	0.006	0.049	-0.086	0.374^{NS}
Calcium content	P	-0.098	-0.238	0.079	0.034	0.503	-0.420	0.564	0.341	0.041	0.004	0.075	-0.175	0.713*
	G	-0.097	-0.241	0.092	0.011	0.515	-0.464	0.580	0.385	0.038	0.004	0.094	-0.194	0.725*
TSS (°Brix)	P	0.206	0.170	-0.111	-0.038	-0.506	0.346	-0.460	-0.419	-0.069	-0.005	-0.072	0.146	-0.815*
	G	0.222	0.183	-0.122	-0.013	-0.578	0.379	-0.492	-0.487	-0.063	-0.004	-0.092	0.175	-0.895*
Ascorbic acid content (mg/100g)	P	0.127	0.184	-0.095	-0.044	-0.489	0.416	-0.598	-0.465	-0.052	-0.004	-0.082	0.177	-0.928*
	G	0.135	0.192	-0.112	-0.014	-0.512	0.467	-0.625	-0.522	-0.050	-0.003	-0.104	0.204	-0.949*
Phosphorus content (mg/100g)	P	-0.197	-0.203	0.096	0.037	0.589	-0.353	0.458	0.326	0.057	0.005	0.064	-0.156	0.724*
	G	-0.192	-0.209	0.118	0.012	0.594	-0.404	0.480	0.369	0.049	0.005	0.081	-0.172	0.733*
Shelf life	P	-0.093	-0.213	0.082	0.039	0.443	-0.469	0.653	0.432	0.043	0.004	0.087	-0.195	0.814*
	G	-0.096	-0.220	0.091	0.013	0.475	-0.506	0.684	0.479	0.039	0.004	0.110	-0.219	0.853*
No. of seeds per fruit	P	0.080	0.199	-0.076	-0.039	-0.401	0.455	-0.673	-0.460	-0.044	-0.003	-0.091	0.194	-0.861*
	G	0.078	0.202	-0.087	-0.013	-0.413	0.502	-0.690	-0.518	-0.039	-0.003	-0.113	0.217	-0.877*
Test weight	P	0.125	0.146	-0.084	-0.037	-0.346	0.365	-0.558	-0.555	-0.067	-0.003	-0.088	0.165	-0.939*
	G	0.127	0.154	-0.099	-0.012	-0.366	0.404	-0.596	-0.600	-0.058	-0.003	-0.114	0.182	-0.981*
Total sugars	P	0.248	0.113	-0.089	-0.027	-0.390	0.236	-0.344	-0.430	-0.086	-0.005	-0.068	0.121	-0.722*
	G	0.249	0.134	-0.113	-0.011	-0.431	0.291	-0.397	-0.508	-0.068	-0.005	-0.091	0.138	-0.814*
Reducing sugars	P	0.240	0.121	-0.065	-0.021	-0.377	0.230	-0.287	-0.222	-0.047	-0.009	-0.047	0.111	-0.373^{NS}
	G	0.304	0.147	-0.088	-0.007	-0.450	0.303	-0.359	-0.269	-0.054	-0.006	-0.073	0.146	-0.408^{NS}
Length of seed (mm)	P	0.131	0.185	-0.083	-0.037	-0.390	0.421	-0.635	-0.507	-0.061	-0.004	-0.097	0.186	-0.892*
	G	0.128	0.192	-0.095	-0.013	-0.409	0.472	-0.659	-0.579	-0.052	-0.004	-0.118	0.210	-0.929*
Diameter of seed (mm)	P	0.127	0.205	-0.080	-0.038	-0.454	0.452	-0.645	-0.452	-0.052	-0.005	-0.089	0.203	-0.892*
	G	0.121	0.214	-0.097	-0.013	-0.468	0.510	-0.688	-0.502	-0.043	-0.004	-0.114	0.218	-0.868*

Residual factor (P) = -0.00976; Residual factor (G) = 0.01819. Diagonal bold values are direct effect.

Table 9. Path coefficient analysis showing the direct and indirect effect of characters on net yield in cucumber at phenotypic and genotypic level for rainy season

Characters		Disease incidence (%)	Calcium content	TSS	Ascorbic acid	Phosphorus content	Shelf life	No. of seeds per fruit	Test weight	Total sugars	Reducing sugars	Length of seed	Diameter of seed	yield per plant
Disease incidence (%)	P	**0.290**	0.208	0.027	0.041	-0.139	0.149	-0.277	-0.174	0.054	-0.111	0.537	0.009	0.616**
	G	0.331	0.285	0.020	0.052	-0.138	0.152	-0.323	-0.212	0.069	-0.154	0.606	0.005	0.695**
Calcium content	P	0.121	0.500	0.048	0.114	-0.581	0.460	-0.465	-0.186	0.104	-0.183	0.806	0.016	0.752**
	G	0.169	0.559	0.038	0.150	-0.602	0.440	-0.561	-0.235	0.104	-0.213	0.955	0.010	0.815**
TSS (°Brix)	P	-0.125	-0.381	-0.063	-0.120	0.663	-0.342	0.387	0.193	-0.128	0.139	-0.869	-0.015	-0.660**
	G	-0.153	-0.487	-0.044	-0.157	0.703	-0.346	0.479	0.255	-0.131	0.180	-1.002	-0.009	-0.712**
Ascorbic acid content (mg/100g)	P	-0.086	-0.410	-0.054	-0.139	0.663	-0.456	0.498	0.230	-0.131	0.145	-1.023	-0.018	-0.781**
	G	-0.101	-0.498	-0.041	-0.169	0.674	-0.426	0.584	0.286	-0.132	0.154	-1.138	-0.010	-0.817**
Phosphorus content (mg/100g)	P	0.056	0.402	0.058	0.127	-0.723	0.394	-0.391	-0.172	0.125	-0.152	0.826	0.015	0.564*
	G	0.063	0.467	0.043	0.158	-0.720	0.364	-0.450	-0.210	0.126	-0.171	0.916	0.009	0.596**
Shelf life	P	0.081	0.432	0.041	0.119	-0.537	0.531	-0.512	-0.188	0.116	-0.212	0.861	0.017	0.748**
	G	0.105	0.511	0.032	0.149	-0.545	0.480	-0.597	-0.242	0.115	-0.223	0.964	0.011	0.760**
No. of seeds per fruit	P	-0.142	-0.412	-0.043	-0.122	0.501	-0.482	0.564	0.253	-0.114	0.146	-1.044	-0.019	-0.915**
	G	-0.167	-0.489	-0.033	-0.154	0.506	-0.448	0.641	0.315	-0.120	0.166	-1.159	-0.011	-0.953**
Test weight	P	-0.175	-0.322	-0.042	-0.110	0.431	-0.346	0.495	0.289	-0.108	0.059	-1.054	-0.016	-0.901**
	G	-0.205	-0.384	-0.033	-0.142	0.443	-0.341	0.592	0.341	-0.119	0.097	-1.223	-0.010	-0.984**
Total sugars	P	-0.099	-0.327	-0.050	-0.114	0.569	-0.385	0.404	0.196	-0.159	0.199	-0.850	-0.014	-0.630**
	G	-0.157	-0.399	-0.040	-0.153	0.621	-0.378	0.526	0.278	-0.146	0.222	-1.047	-0.010	-0.682**
Reducing sugars	P	-0.100	-0.284	-0.027	-0.062	0.342	-0.349	0.255	0.053	-0.098	0.323	-0.323	-0.010	-0.280NS
	G	-0.159	-0.372	-0.025	-0.081	0.384	-0.335	0.332	0.103	-0.101	0.320	-0.381	-0.007	-0.321NS
Length of seed (mm)	P	-0.139	-0.359	-0.049	-0.126	0.533	-0.408	0.526	0.271	-0.121	0.093	-1.121	-0.018	-0.918**
	G	-0.163	-0.434	-0.036	-0.156	0.537	-0.377	0.605	0.340	-0.124	0.099	-1.228	-0.010	-0.948**
Diameter of seed (mm)	P	-0.141	-0.417	-0.048	-0.127	0.544	-0.476	0.546	0.242	-0.117	0.162	-1.021	-0.019	-0.871**
	G	-0.166	-0.533	-0.036	-0.159	0.568	-0.468	0.642	0.306	-0.128	0.193	-1.149	-0.011	-0.939**

Residual factor (P) = 0.02731; Residual factor (G) = -0.01555. Diagonal bold values are direct effect.

indirect effects of significant characters over yield per plant is tabulated in Table 8 and 9. The path coefficient analysis on phenotypic and genotypic level revealed that among these characters, phosphorus content (0.589, 0.594) exhibited highest positive direct effect on yield per plant followed by diameter of seed (0.203, 0.218) during summer season and number of seeds per fruit (0.564, 0.641) followed by shelf life (0.531, 0.480), calcium content (0.500, 0.559), disease incidence (0.290, 0.331) and test weight (0.289, 0.341) showed positive direct effect on yield per plant during the rainy season. Further, number of seed per fruit (-0.673, -0.690) followed by test weight (-0.555, -0.600), shelf life (-0.469, -0.506), calcium content (-0.238, -0.241), TSS (-0.111, -0.122), total sugars (-0.086, -0.068), length of seed (-0.097, -0.118) and ascorbic acid content (-0.0446, -0.0148) showed negative contribution to the yield per plant during the summer season at phenotypic and genotypic level. While during rainy season negative contribution to the yield per plant was expressed at phenotypic and genotypic level by length of seed (-1.121, -1.228) followed by phosphorous content (-0.723, -0.720), total sugars (-0.159, -0.146), ascorbic acid content (-0.139, -0.169), TSS (-0.063, -0.044) and diameter of seed (-0.019, -0.011). It is evident from the data that during summer season, at phenotypic and genotypic level shelf life had positive indirect effect on yield per plant through number of fruits per plant (0.653, 0.684) followed by phosphorous content (0.443, 0.475), test weight (0.432, 0.479), length of seed (0.087, 0.110), TSS (0.082, 0.091), total sugars (0.043, 0.039), ascorbic acid content (0.039, 0.013) and reducing sugar (0.004, 0.004). Test weight showed negative indirect effect on yield per plant both at phenotypic and genotypic level through number of seeds per plant (-0.558, -0.596) followed by phosphorous content (-0.346, -0.366), length of seed (-0.088, -0.114), TSS (-0.084, -0.099), total sugars (-0.067, -0.058), ascorbic acid (-0.037, -0.012) and reducing sugars (-0.003, -0.003). While during rainy season, both at phenotypic and genotypic level number of seeds per fruit had negative indirect effect on yield per plant through length of seed (-1.044, -1.159) followed by shelf life (-0.482, -0.448), calcium content (-0.412, -0.489), disease incidence (-0.142, -0.167), ascorbic acid (-0.122, -0.154), total sugars (-0.114, -0.120), TSS (-0.043, -0.033) and diameter of seed (-0.019, -0.011). However, shelf life showed positive indirect effect on yield per plant through length of seed (0.861, 0.964) followed by calcium content (0.432, 0.511), ascorbic acid (0.119, 0.149), total sugars (0.116, 0.115), disease incidence (0.081, 0.105), TSS (0.041, 0.032) and diameter of seed (0.017, 0.011). Positive direct effects of phosphorus content, shelf life and number of seeds per fruit on yield was also reported (38). Similarly, positive direct effects of calcium content and test weight on yield were observed, while ascorbic acid and total sugars exhibited negative direct effects (25).

Conclusion

The present study concluded that cultivar PN and PU were the best performing cultivars among all the cultivars in relation of quality parameters of cucumber during both the seasons. The correlation coefficients among the different characters were worked out at both phenotypic and genotypic levels. The results indicated that yield per plant had significant positive association with shelf life, phosphorus content, calcium content during summer season while calcium content, shelf life and phosphorus content expressed significant positive correlation during the rainy season. Thus, from the correlation studies it is concluded that selection should be made on the basis above results to bring desired improvement in the yield of cucumber. The path coefficient analysis on phenotypic and genotypic level revealed that among these characters, phosphorus content exhibited highest positive direct effect on yield per plant followed by diameter of seed during summer season and number of seeds per fruit followed by shelf life, calcium content, disease incidence and test weight showed positive direct effect on yield per plant during the rainy season, thus indicating that direct selection for yield improvement in cucumber can be performed.

Acknowledgements

The authors feel privileged to thank the Head, Department of Vegetable Science and Floriculture, CSK HPKV, Palampur, Himachal Pradesh, India, for providing financial support and technical guidance to undertake the experiment.

Authors' contributions

PS[1] and PS[2] performed the experiment. PS[1], PS[2] and NB designed the research. PS[1], AP and SK wrote the manuscript. PS[1], AP, SK, AK and NB revised and corrected the manuscript. All authors have contributed to different sections of writing, reviewing, correction and statistical analysis. All authors read and approved the final manuscript. [PS[1] - Payal Sharma and PS[2] - Parveen Sharma].

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

Ethical issues: None

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Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

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