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Research article

Performance Evaluation of Hot Pepper Cultivars for Green Fruit Production under Open Field Conditions in Kathmandu Valley, Nepal

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ABSTRACT

An evaluation trial was conducted at Khumaltar during the second week of April in 2021 and 2022 to assess the performance of nine hot pepper (*Capsicum spp.*) cultivars received from the National Gene Bank, with 'Pusa Jwala' as the local check. The trial followed a randomized complete block design with three replications and a spacing of 60 × 60 cm. The crop was fertilized with 150:120:100 kg/ha of nitrogen, phosphorus, and potassium, respectively, along with 20 tons/ha of farmyard manure. The objective was to identify high-yielding cultivars with tolerance to insect pests and diseases, as well as traits preferred by consumers and farmers under open field conditions in the central mid-hills of Nepal. Observations were recorded on vegetative growth, pest and disease incidence, yield components, morphological traits, and end-user preferences. Among the tested cultivars, CO5066-2 showed superior performance in terms of uniform and vigorous growth, early fruiting (54 days), minimal insect damage (1.6 on a 1–5 scale), low leaf spot incidence (1.75), highest yield (13.68 t/ha; 525 g/plant), and strong acceptance by consumers (4.9) and farmers (4.0). CO5061 also performed well, with vigorous growth (4.0), moderate time to flowering (49.3 days) and fruit set (55.5 days), low insect damage (1.85), moderate leaf spot resistance (2.15), higher fruit set per node (1.05), and yield of 11.39 t/ha (410 g/plant). It also received favorable ratings from consumers (3.5) and farmers (3.7). Both CO5066-2 and CO5061 outperformed the check variety 'Pusa Jwala' in terms of yield, pest and disease resistance, and user preference. These cultivars are recommended for further on-farm validation in the central mid-hills of Bagmati Province.

Introduction

Hot pepper (*Capsicum annuum* L.) is one of the most important vegetable and spice crops cultivated across many parts of Nepal. Globally, hot pepper ranks as the second most important vegetable crop after tomato and is utilized in fresh, dried, and processed forms as a vegetable, spice, and condiment. In Nepal, hot pepper is cultivated on 10,276 ha, with dry chili production of 68,025 tons and an average productivity of 6.62 t/ha. In Bagmati Province, the cultivation area is 1,794 ha, with a production of 10,856 tons and a productivity of 6.05 t/ha (MoALD 2021). However, Nepal's average green chili yield remains significantly lower than the global average of 17.8 t/ha (Poudyal et al. 2023).

Hot pepper is an integral component of Nepalese cuisine, consumed both in green and dried forms. However, 80% of dried and 24% of green chilies consumed in Nepal are imported from India (Poudyal et al. 2023), highlighting the urgent need to enhance domestic production. Yield is influenced by both the genetic makeup of the plant and environmental conditions. Therefore, selecting high-yielding varieties with moderate to high tolerance to prevailing biotic and abiotic stresses is crucial. Improved genotypes can result in better growth, yield, and fruit quality (Seleshi 2011).

Capsicum spp. thrives in warm and humid climates, with optimal fruiting at daytime temperatures between 21 °C and 27 °C and nighttime temperatures between 15 °C and 20 °C. Growth and yield are negatively affected when temperatures fall below 15 °C or exceed 32 °C (Poudyal et al. 2019, Erickson and Markhart 2002). Peppers also exhibit significant diversity in fruit shape, size, color, pungency, and texture, making them valuable for both fresh consumption and processing (FMRL 2016). They are widely used not only as food but also in traditional medicine, valued for their nutritional properties and therapeutic effects such as relief from muscle pain, inflammation, and itching (Poulos 1993, FMRL 2016).

The crop displays extensive genetic variability among wild and cultivated accessions, differing in growth habit (determinate, sympodial, fasciculate), fruit quality traits (shape, weight, length, color, taste), and marketable output (Lester 1998). Despite its economic significance, hot pepper production in Nepal faces several challenges, including limited research, lack of improved varieties, poor agronomic practices (e.g., plant population, fertilizer application), and vulnerability to biotic and abiotic stresses (Alemu and Ermias 2000).

Each variety significantly influences yield and quality traits such as plant height, number of branches, fruits per plant, days to maturity, fruit length, single fruit weight, and dry fruit yield per plant (Lemma et al. 2008). In the central mid-hills of Nepal, both improved and local varieties are limited, and there is a lack of research-based varietal information suited to local agro-ecological conditions. Moreover, no systematic evaluation has been conducted on hot pepper cultivars derived from farmers' seed sources.

This study was conducted to evaluate selected hot pepper genotypes under open-field conditions in the central mid-hills, aiming to identify varieties with superior growth, fruit yield, quality, and resistance to pests and diseases. Such selection, combined with improved cultivation practices, could significantly enhance productivity and marketable yield. The primary objective was to identify the most suitable hot pepper genotypes for cultivation during the spring–summer season in the central hill region of Nepal.

Materials and Methods

The field experiment was conducted at the National Horticulture Research Center (NHRC), Khumaltar, using a randomized complete block design (RCBD) with three replications. A total of ten hot pepper varieties were tested, including seven advanced lines CO5061, CO5061-2, CO5062, CO5063, CO5065, CO5066-1, and CO5066-2, along with 'Suryamukhi', 'Dhede Local', and the widely cultivated check variety 'Pusa Jwala'.

Description of the study area

The experiment was conducted at the NHRC farm, Khumaltar, located at 27°40' N latitude and 85°20' E longitude, at an elevation of 1,275 meters above sea level. The site receives an average annual rainfall of 1,220 mm. The soil type is sandy clay loam with a pH of 5.9. The average minimum and maximum temperatures during the growing season were 12 °C and 30 °C, respectively (Khumaltar weather data, Agronomy Division).

Experimental materials, treatments and design

Among the tested varieties, seven (CO5061 to CO5066-2 and *Dhede Local*) were developed from farmer-collected local lines conserved at the National Gene Bank, while *Suryamukhi* and *Pusa Jwala* were adopted varieties commonly grown in Nepal. All seeds were multiplied under a caging system in a plastic tunnel before field transplanting.

The recommended fertilizer dose of 150:120:100 kg/ha N:P_2O_5:K_2O and 15 tons/ha farmyard manure (FYM) was applied. Urea (46% N) was used as the nitrogen source, applied in two splits: half at transplanting and half 30 days after transplanting. Di-ammonium phosphate (DAP) served as the source of phosphorus and supplemental nitrogen, while muriate of potash (MOP) provided potassium.

Seedlings were raised on beds in February under plastic-covered shade at night to protect against the cold. Daily irrigation was provided using a fine-mesh watering can. Transplanting was done in the second week of March with a spacing of 60 × 60 cm (row × plant). Each plot measured 2.4 m × 3.0 m (7.2 m^2) and contained four rows with five plants per row. Standard cultural practices recommended by NHRC were followed throughout the growing season.

The trial continued until September. Data were collected from 10 central plants per plot, excluding border rows, and average values were used for statistical analysis. Data collection protocols followed the guidelines outlined in the 'Field Guide for Vegetable Germplasm Testing, Evaluation, and Variety Registration/Release' (Gotame et al. 2019).

Table 1. Hot pepper cultivars evaluated in 2020 and 2021

S.N.	Cultivars	Source	Purity maintained year
1	CO5061	Gene Bank	2014
2	CO5061-2	Gene Bank	2018
3	CO5062	Gene Bank	2014
4	CO5063	Gene Bank	2014
5	CO5065	Gene Bank	2014
6	CO5066-1	Gene Bank	2018
7	CO5066-2	Gene Bank	2019
8	Dhede Local	Gene Bank	2014
9	Suryamukhi	NHRC	2013
10	Pusa Jwala	Nepal	2010

Data collection

In each treatment, ten plants from the central two rows of each plot were selected for measurement of qualitative and quantitative traits as described below:

Phenological and growth data: Days to 50% flowering: Number of days from transplanting until 50% of plants bear flowers. Days to first fruit set: Number of days from transplanting until the plant sets its first fruit. Days to first harvest: Number of days from transplanting to the first harvest date. Plant height (cm): Measured from the soil surface to the tip of the plant at maturity.

Yield and yield components: Number of fruits per plant: The Total number of fruits per plant was counted and averaged over sample plants. Fruit yield per plant (g): Total fruit weight per plant, averaged over sample plants. Total fruit yield per hectare (t/ha): Yield from all plants in each plot converted to a per-hectare basis.

Fruit quality: Fruit length (cm): Average length of ten ripe fruits from the second harvest, measured from tip to base using a vernier caliper. Fruit width (cm): Average width of ten ripe fruits from the second harvest, measured at the widest point using a vernier caliper. Fruit wall thickness (mm): Average pericarp thickness of ten ripe fruits from the second harvest, measured at the midpoint using a vernier caliper.

Disease incidence: Disease incidence (%): Starting 30 days after transplanting, plants were monitored regularly. The percentage of infected plants was calculated as per Agrios (2005). Alternaria leaf spot severity was recorded on a 1–9 scale, while virus infection was recorded as the percentage of infected plants.

To manage disease pressure, cultural control measures such as the removal of weeds that harbor disease vectors were practiced. Additionally, preventive fungicide applications were made using Mancozeb or copper oxychloride, applied in three rounds: at the vegetative stage, at fruit setting, and at the green pod stage, following label recommendations (EARO 2004). However, these treatments were not very effective, likely due to high humidity and continuous rainfall during the study period.

Acceptance test: Consumer and farmer acceptance was recorded on a 1 to 5 scale, where 1 = poor and 5 = excellent.

Data analysis: Analysis of variance (ANOVA) was performed for all parameters using the MSTAT-C statistical software. Mean separation was conducted using Duncan's Multiple Range Test at the 5% probability level.

Results

Growth parameter

Plant uniformity and vigor: The combined mean of plant uniformity and vigor was not statistically significant. The combined mean of plant uniformity ranged from 3.4 (CO5061-2) to 4.4 (CO5063) on a scale. Plants showed greater uniformity in 2022 compared to 2021 (Table 1). Similarly, the combined mean of plant vigor ranged from 3.5 (Suryamukhi) to 4.4 (CO5063, CO5066-1, CO5066-2). However, plant vigor was significant in 2021, where the least vigorous plants were CO5062 and Suryamukhi, and the most vigorous plants (score 5.0) were Dhede Local, as shown in Table 2.

Plant height: Combined plant height ranged from 51.1 cm (Pusa Jwala) to 92 cm (CO5066-1), followed by 81.6 cm (CO5061), with significant varietal variation. Varietal differences were highly significant in both years. In the first year, CO5061 had the tallest plants (93.7 cm), while Pusa Jwala had the shortest. In the second year, the shortest plant height (56.5 cm) was recorded in Pusa Jwala, and the tallest (93 cm) in CO5066-1 (Table 2).

Table 2. Combined mean of plant uniformity, plant vigor, and plant height of hot pepper cultivars for 2 years (2021 and 2022) test at Khumaltar

Cultivars	Plant uniformity[x]			Plant vigor[y]			Plant height, cm		
	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
CO5061	4.0	4.0	4.0	4.0[b]	4.0	4.0	93.7	69.6	81.6[ab]
CO5061-2	3.5	3.3	3.45	3.7[abc]	3.7	3.85	79.8	53.8	66.8[bc]
CO5062	3.0	4.3	3.65	3.0[c]	5.0	4.0	81.2	59.5	70.3[bc]
CO5063	4.5	4.3	4.4	4.5[ab]	4.3	4.4	93.3	64.7	79.0[ab]
CO5065	4.0	4.3	4.15	4.0[b]	4.0	4.0	78.0	75.9	76.9[abc]
CO5066-1	4.5	4.3	4.4	4.5[ab]	4.3	4.4	91.0	93.0	92.0[ab]
CO5066-2	4.0	4.7	4.35	4.5[ab]	4.3	4.4	82.7	56.9	69.8[bc]
Dhede Local	4.5	4.0	4.25	5.0[a]	3.3	4.15	85.7	50.9	68.3[bc]
Suryamukhi	3.5	4.0	3.75	3.0[c]	4.0	3.5	64.5	58.5	61.5[bc]
Pusa Jwala	4.5	4.0	4.25	4.0[b]	4.0	4.0	57.8	56.5	51.1[c]
GM	4.0	4.12	4.06	4.02	4.09	4.07	80.8	63.9	72.35
CV%	15.66	11.10	10.05	9.51	13.3	16.47	10.75	15.7	13.16
F-test (05)	ns	ns	ns	**	ns	ns	**	**	*
LSD (0.05)	-	-	-	0.849	-	-	7.01	11.23	21.54

*[x]1: poor, 2: fair, 3: good, 4: very good, 5: excellent [y]1: poor, 2: fair, 3: good, 4: very good, 5: vigorous, ns: non-significant, *significant at P=0.05 and ** significant at P=0.1, In column figures with the same letter(s) do not differ significantly by DMRT at 0.05 level*

Crop phenology and growth traits

Days to flowering and fruit set: The combined mean of two years' data showed a significant difference in days to 50% flowering. The earliest flowering occurred in Dhede Local at 39.4 days after transplanting, while CO5062 required the longest time, followed by CO5061 with 49.3 days. This variation is likely due to inherent genetic differences among the varieties. Analysis of variance indicated that days to 50% flowering were significantly affected by variety in both years (Table 3).

Table 3. Combined mean of days to 50% flowering and fruit set of hot pepper cultivars for the two years (2021 and 2022) test at Khumaltar

Cultivars	Days to flowering			Days to fruit set		
	2021	2022	Mean	2021	2022	Mean
CO5061	57	41.7	49.3[ab]	61.0	50.0	55.5[ab]
CO5061-2	58	39.7	48.8[ab]	62.0	47.7	54.9[ab]
CO5062	60.5	39.7	50.1[a]	63.0	49.3	55.65[ab]
CO5063	47	39.3	43.1[ab]	61.5	47.3	54.4[ab]
CO5065	53.5	38.0	45.7[ab]	58.0	47.0	52.5[ab]
CO5066-1	50	46.7	48.3[ab]	57.5	55.7	56.6[ab]
CO5066-2	52	44	48a[b]	57.0	51.7	54.35[ab]
Dhede Local	43.5	35.3	39.4[b]	49	43.6	46.3[b]
Suryamukhi	60	38.0	49a[b]	73.0	45.7	59.3[a]
Pusa Jwala	56	42.0	49a[b]	61	49.0	55.0[ab]
GM	53.75	40.4	47.09	60.3	48.7	54.45
CV%	6.31	7.56	9.39	9.69	14.42	9.13
F-test	**	**	*	**	ns	*
LSD (0.05)		11.32	10.0	12.55		11.24

*ns: non-significant, *significant at P=0.05 and **significant at P=0.1. In column figures with the same letter(s) do not differ significantly by DMRT at 0.05 level*

Days to first fruit set were also significantly influenced by variety. Dhede Local reached first fruit set earliest at 46.3 days, whereas Suryamukhi required the longest duration of 59.3 days (Table 3). Most tested varieties performed similarly to the locally released variety, Pusa Jwala. The delayed flowering and fruit set observed in the first year may be attributed to climatic conditions.

Fruit set percentage: The highest fruit set percentage was observed in CO5066-1 (95.4), followed by Pusa Jwala (90.6), and the lowest was in Dhede Local (74.5) (Figure 1).

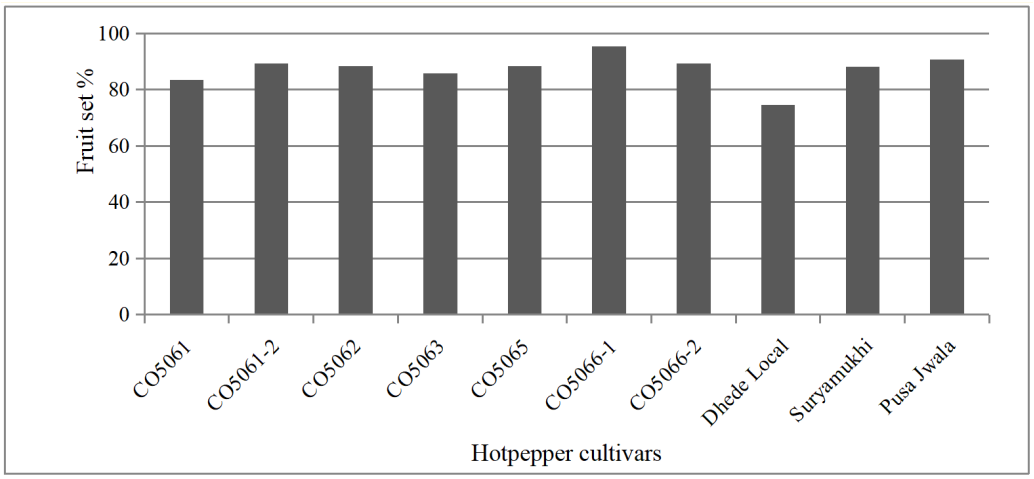

Figure 1. Combined mean of fruit set percentage of ten hot pepper cultivars

Number of flowers and fruits per node: Combined mean of flowers and fruits per node was not significant; however, it was significant in the first year. The combined mean of flowers per node ranged from 1.05 (Co5066-1) to 1.55 (Dhede Local and Suryamukhi). Similarly, the combined mean of fruits per node ranged from 1.0 (Co5062, Co5065, Co5066-1) to 1.35 (Suryamukhi) (Table 4).

Table 4. Combined mean of flowers and fruits number per node of hot peppers for the 2 years (2021 and 2022) test at Khumaltar

Cultivars	**No of flowers/node**			**No of fruits/node**		
Year	2021	2022	Mean	2021	2022	Mean
CO5061	1.5	1.1	1.3^{ab}	1.0	1.1	1.05^{b}
CO5061-2	1.4	1.1	1.25^{ab}	1.1	1.1	1.1^{b}
CO5062	1.3	1.0	1.15^{b}	1.0	1.0	1.0^{b}
CO5063	1.4	1.2	1.3^{ab}	1.0	1.2	1.1^{b}
CO5065	1.3	1.0	1.15^{ab}	1.0	1.0	1.0^{b}
CO5066-1	1.1	1.0	1.05^{b}	1.0	1.0	1.0^{b}
CO5066-2	1.4	1.0	1.2^{b}	1.1	1.0	1.05^{b}
Dhede Local	1.4	1.7	1.55^{ab}	1.1	1.2	1.15^{ab}
Suryamukhi	1.7	1.4	1.55^{ab}	1.3	1.4	1.35^{a}
Pusa Jwala	1.6	1.0	1.4^{ab}	1.3	1.0	1.15^{ab}
GM	1.41	1.15	1.29	1.09	1.1	1.095
CV%	14.29	23.7	23.024	11.56	29.02	8.85
F-test	*	ns	ns	*	ns	ns
LSD (0.05)	0.429			0.279		

*ns: non-significant, *significant at P=0.05 and **significant at P=0.1. In column figures with the same letter(s) do not differ significantly by DMRT at the 0.05 level*

Insect and disease incidence

Insect damage caused by aphids and leaf-eating caterpillars was observed in both years; however, varietal differences were not statistically significant (Table 5). Despite this, CO5066-2 and Suryamukhi exhibited slightly lower insect damage compared to Pusa Jwala.

The major disease observed during the cropping season was leaf spot. Although the combined mean varietal differences for leaf spot incidence were not statistically significant, CO5066-2 showed the lowest level of infection (1.75 on a 1–5 scale), whereas the highest levels were recorded in Suryamukhi (2.5) and Dhede Local (2.35) (Table 5). Virus infection was observed across all cultivars, ranging from 28 percent in CO5061-2, CO5062, and Suryamukhi, to 62 percent in Dhede Local. All purified collection (CO) lines had lower virus infection levels compared to the registered cultivar Pusa Jwala and Dhede Local (Table 5).

Table 5. Combined mean values of insect damage, leaf spot disease, and virus infection of hot peppers for the 2 years (2021 and 2022) test at Khumaltar

Cultivars	**Insect (1-5)[y]**			**Virus infected plant (%)**	**Disease, leaf spot (1-5)[y]**		
Year	2021	2022	Mean	2019	2021	2022	Mean
CO5061	2.0	1.7	1.85	45	2.0	2.3	2.15
CO5061-2	2.0	1.3	1.65	28	2.0	2.0	2.0
CO5062	2.0	2.3	2.15	28	2.0	2.3	2.15
CO5063	2.0	2.0	2.0	38	2.0	2.0	2.0
CO5065	1.5	2.3	1.9	33	2.0	1.7	1.85
CO5066-1	2.0	1.7	1.85	38	2.0	2.3	2.15
CO5066-2	1.5	1.7	1.6	38	1.5	2.0	1.75
Dhede Local	1.5	2.0	1.75	62	2.0	2.7	2.35
Suryamukhi	1.5	1.7	1.6	28	3.0	2.0	2.5
Pusa Jwala	2.0	1.3	1.65	55	2.0	2.0	2.0
GM	1.8	1.81	1.8	39.3	2.05	2.13	2.09
CV%	26.85	25.4	19.51	33.97	10.64	21.55	16.09
F-test	ns	ns	ns	ns	ns	ns	ns

[y]1: none, 5: susceptible, *ns: non-significant*

Yield and yield components

Number of fruits per plant: The number of fruits per plant was significantly influenced by variety at the 1% probability level ($P < 0.01$) (Table 6). The combined mean showed that CO5066-1 produced the highest number of fruits per plant (298), which was nearly double that of the check variety Pusa Jwala (151). The lowest number of fruits per plant was observed in Dhede Local (60). This variation is likely due to the genetic characteristics of the varieties.

Fruit yield per plant: Fruit yield per plant was significant in both years. The combined mean yield was highest in CO5066-1 (534 g), followed by CO5066-2 (525 g) and CO5061 (410 g). The lowest fruit yield per plant was recorded in Dhede Local (144 g) (Table 6).

Total fruit yield per hectare: Total fruit yield per hectare was significantly influenced by variety in the first year. The combined mean showed that the highest total fruit yield was recorded in CO5066-2 (13.678 t/ha), followed by CO5061 (11.39 t/ha) and CO5066-1 (11.327 t/ha). The lowest yield (3.489 t/ha) was obtained from Dhede Local (Table 6). The low yield in Dhede Local may be partly attributed to a higher rate of disease infestation. These results indicate that significant variation in total fruit yield among hot pepper varieties may be linked to their genetic potential and their response to environmental conditions.

Table 6. Mean values of the number of fruits and the weight of fruit per plant of hot peppers for the two years test at Khumaltar (2021 and 2022)

Cultivars	**Fruits/plant (no)**			**Fruits/plant (g)**			**Yield (t/ha)**		
Year	2021	2022	Mean	2021	2022	Mean	2021	2022	Mean
CO5061	131	353	242^{ab}	263	557	410^{ab}	7.29^{bcde}	15.487	11.39^{ab}
CO5061-2	76	149	112^{cd}	237	346	291^{ab}	6.57^{cde}	9.005	7.78^{abcd}
CO5062	55	160	107^{cd}	137	309	223^{ab}	3.8^{de}	5.369	4.58^{bcd}
CO5063	195	203	199^{abc}	391	346	368^{ab}	10.86^{bc}	7.070	8.96^{abcd}
CO5065	54	99	76^{cd}	116	222	169^{b}	3.23^{de}	4.155	3.69^{cd}
CO5066-1	183	413	298^{a}	288	780	534^{a}	8.0^{bc}	14.654	11.33^{abc}
CO5066-2	161	212	186^{abcd}	510	540	525^{a}	14.16^{ab}	13.199	13.68^{a}
Dhede Local	56	65	60^{d}	139	150	144^{b}	3.85^{cde}	3.131	3.49^{d}
Suryamukhi	141	270	205^{abc}	136	660	398^{ab}	3.77^{de}	15.828	9.79^{abcd}
Pusa Jwala	73	229	151^{bc}	160	438	299^{ab}	4.44^{cde}	9.173	6.81^{abcd}
GM	112.5	215.3	163.9	237.7	434.8	336.2	6.597	9.707	8.152
CV%	26.76	33.43	34.81	39.547	43.07	31.33	39.47	39.2	31.65
F-test	*	**	*	**	*	*	**	ns	*
LSD (0.05)	80.57	99.07	129.08	261.9	595.3	391.2	7.277		7.68

*ns: non-significant, *significant at P=0.05 and **significant at P=0.1. In column figures with the same letter(s) do not differ significantly by DMRT at the 0.05 level*

Fruit size and quality of physiologically matured fruit

Average fruit weight: The highest average fruit weight was recorded in CO5061-2 (4.8 g), followed by CO5066-2 (4.3 g) and CO5062 (3.6 g). In contrast, the lowest average fruit weight was observed in CO5061 and CO5063 (1.02 g) (Figure 2).

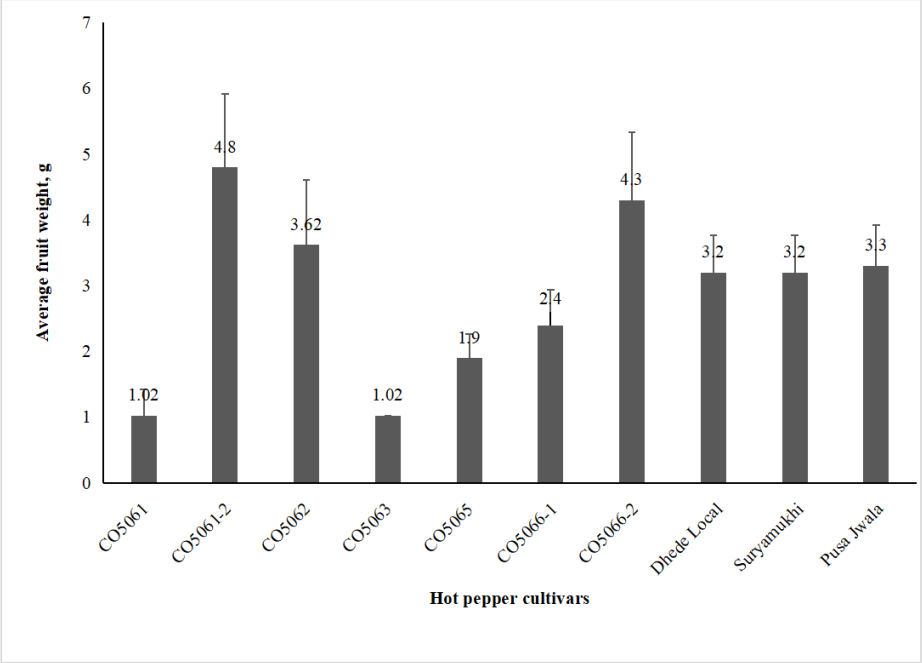

Figure 2. Average fruit weight (g) of hot pepper cultivars with error bars representing standard deviation

Fruit length and width

The longest fruit length (6.8 cm) was recorded in the variety Pusa Jwala, followed by CO5065 and Dhede Local (6.7 cm each), while the shortest fruit length was observed in CO5062 (2.9 cm) (Fig. 3). The highest fruit width (14.5 mm) was measured in CO5062, followed by Suryamukhi (13.0 mm) and CO5061-2 (11.2 mm), whereas the narrowest fruit width (5.5 mm) was found in CO5065 (Fig. 3). The observed variation in fruit size may be attributed to inherent genetic differences among the varieties and/or the environmental conditions of the growing area. Fruit length was significantly affected by variety at the 0.1% level ($P < 0.001$).

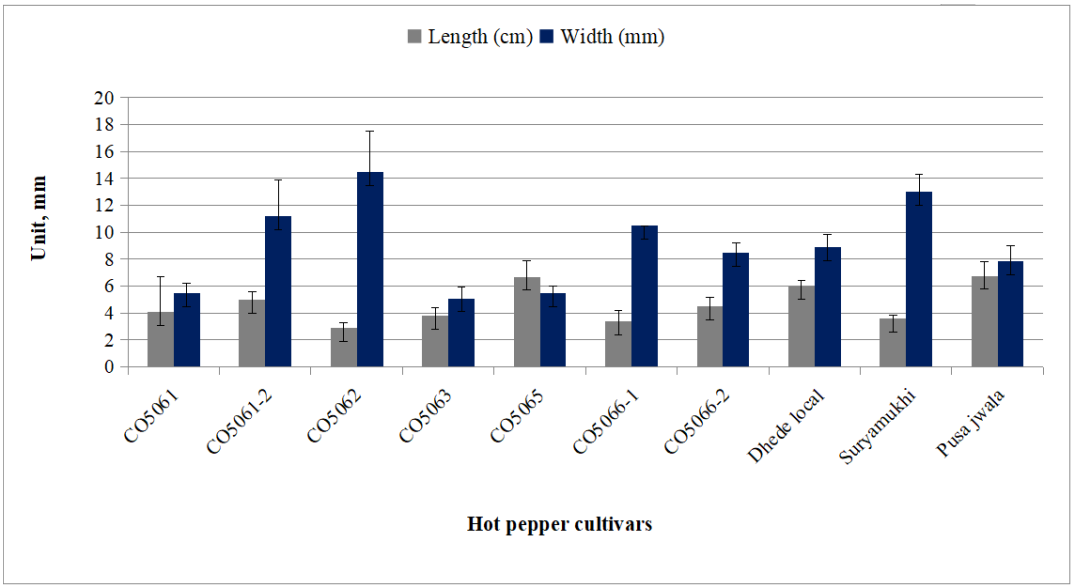

Figure 3. Average fruit length and width of hot pepper cultivars with error bars representing standard deviation

Fruit pericarp thickness: The thickest fruit pericarp (1.69 mm) was attained by CO5061-2, whereas the thinnest (0.12 mm) ones were attained by CO5065 (Figure 4). In this result, the variation might be due to genetic characters on fruit pericarp thickness. These pericarp differences might be because the varieties have assimilate partitioning capacity, which might result in thickest or thinnest fruit pericarp, and are due to agro-ecological variations.

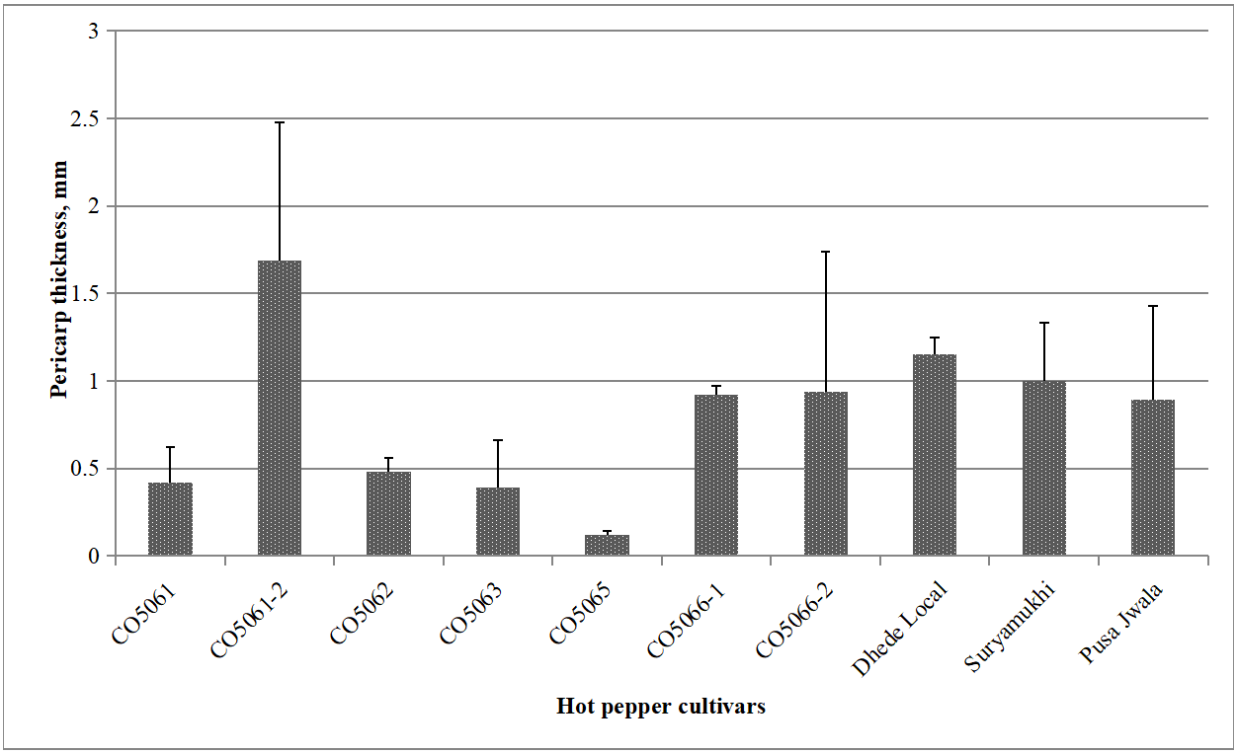

Figure 4. Average pericarp thickness of hot pepper cultivars with error bars representing standard deviation

Seed number: The number of seeds contained in a fruit was varied from 29 (CO5063) to 108 (CO5066-2). A smaller number of seeds is preferred by the consumers.

Fruit morphological characters of hot pepper genotypes: Among the tested cultivars, five exhibited elongated fruit shapes, while the remaining five had triangular shapes. Similarly, five cultivars showed a distinct neck at the base of the fruit. CO5062 and Pusa Jwala displayed an acute shape at the pedicel attachment; CO5061, CO5061-2, and CO5066-1 had a truncate attachment, while the rest showed an obtuse form. Immature fruit color ranged from light green in CO5062, CO5063, and Pusa Jwala to bright green in Suryamukhi. All cultivars had two-lobed fruits, except CO5061 and Pusa Jwala, which had three lobes (Table 7). The shape and size of the fruits of the studied hot pepper genotypes are shown in Figure 5.

Table 7. Fruit characteristics of hot pepper genotypes

Cultivars	Fruit shape	Shape at the pedicle attachment	Neck at the base of the fruit	Immature fruit color	Number of locules
CO5061	Triangular	Truncate	Absent	Green	3
CO5061-2	Triangular	Truncate	Absent	Green	2
CO5062	Elongated	Acute	Absent	Light green	2
CO5063	Elongated	Obtuse	Present	Light green	2
CO5065	Elongated	Obtuse	Present	Green	2
CO5066-1	Triangular	Truncate	Absent	Green	2
CO5066-2	Triangular	Obtuse	Present	Green	2
Dhede Local	Elongated	Obtuse	Absent	Green	2
Suryamukhi	Triangular	Obtuse	Present	Bright green	2
Pusa Jwala	Elongated	Acute	Present	Light green	3

Figure 5. Outlook of fruit shape and size of ten hot pepper cultivars

Consumers' and farmers' response to tested hot pepper cultivars: Based on fruit size, shape, color, freshness, and taste, the most preferred cultivar among consumers was CO5066-2 (rating: 4.9), followed by CO5065 (4.5), while the least preferred was Dhede Local (3.0) (Table 8). Similarly, from the farmers' perspective, considering plant appearance, market value, yield, and resistance to insect pests and diseases, CO5061-2 was the most preferred (4.3), followed by CO5062 (4.2) and Pusa Jwala (4.1). Overall, CO5066-2, CO5061-2, and CO5062 were the most favored cultivars by both consumers and farmers.

Table 8. Average scores for consumer and farmers' acceptance test of hot pepper cultivars

Cultivars	**Consumer acceptance test (1-5)[y]**						**Farmers' acceptance test (1-5)[y]**					
	Size	**Shape**	**Color**	**Freshness**	**Taste**	**Mean**	**Plant appearance**	**Market value**	**Yield**	**Insects**	**Diseases**	**Mean**
CO5061	3.3	3.0	3.7	3.3	4.0	3.5	3.0	4.0	3.3	3.7	4.3	3.7
CO5061-2	4.3	3.7	3.7	4.7	4.7	4.2	4.3	4.7	4.7	3.7	4.0	4.3
CO5062	3.7	4.0	4.0	4.3	4.7	4.1	4.0	4.3	4.3	4.0	4.3	4.2
CO5063	4.3	4.0	4.3	4.3	4.7	4.3	3.7	4.0	4.3	3.0	3.0	3.6
CO5065	4.7	4.0	4.3	4.7	4.7	4.5	4.7	4.0	4.0	3.0	3.0	3.7
CO5066-1	3.3	3.0	4.0	3.3	3.3	3.4	3.0	3.7	3.3	4.3	4.3	3.7
CO5066-2	4.7	4.7	4.0	4.3	4.7	4.9	4.0	4.7	4.3	3.3	4.0	4.0
Dhede Local	3.0	3.0	3.0	3.0	3.0	3.0	3.0	3.0	2.0	4.0	4.0	3.2
Suryamukhi	4.0	4.0	4.1	4.0	4.1	4.0	3.7	4.3	4.3	3.0	3.0	3.7
Pusa Jwala	3.7	3.7	4.7	4.0	4.3	4.1	4.3	4.0	4.0	4.0	4.0	4.1
GM	3.9	3.71	3.98	3.99	4.22	4.01	3.77	4.07	3.85	3.6	3.79	3.82
CV%	33.16	29.27	22.48	37.21	24.59		37.72	23.16	27.08	28.31	26.11	
F-test (05)	ns	ns	ns	ns	ns		ns	ns	ns	ns	ns	

[y]1: poor, 5: excellent, n*s: non-significant*

Discussion

The increase in plant height observed in the first year may primarily be attributed to better soil nutrient availability and the genetic variability among varieties in nutrient uptake efficiency (Vos and Frinking 1997, El-Tohamy et al. 2006). The variation in days to 50 % flowering aligns with the findings of Amare et al. (2013), who reported that the variety Melka Zala took the longest time to reach 50 % flowering (99 days from seeding). Seleshi (2011) and Melaku et al. (2015) also indicated that flowering time is largely influenced by genetic factors. Similarly, the observed differences in days to fruit set may be due to the inherited traits of the hot pepper varieties. This result is consistent with Tibebu and Bizuayehu (2014), who reported non-significant differences in days to fruit set among varieties Marako Fana and Melka Shote.

The higher fruit set percentage observed in some cultivars may be attributed to more favorable pollination conditions, short-styled flowers tend to facilitate easier pollination, while long-styled flowers promote self-pollination as stigmas pass through the anther sacs in erect flowers. Studies by Gupta (2003) on hot pepper genotypes revealed considerable variation in flowering ability, fruit set, yield, and other qualitative traits under different agro-climatic conditions. This finding is consistent with Seleshi (2011), who reported significant differences in the number of fruits per plant among nine hot pepper cultivars.

The results on the number of fruits per plant align with the findings of Gogoi and Gautam (2002), who reported that fresh fruit yield per plant ranged from a high of 679.23 g in Balijuri to a low of 52.01 g in Latabih-II. Similar trends were observed in total fruit yield per hectare, as reported by Abrham et al. (2017a), who found that among 19 varieties tested in the Wolaita area, introduced varieties performed better and out-yielded the locally released ones. Specifically, the introduced variety 0514 produced a higher yield than Melaka Shote. Dhakal et al. (2006) also noted that four genotypes, Mr. Lee No. 3 selex, Susan's Joy, CCA-119A, and CCA-3288, produced 234.5%, 122.98%, 49.06%, and 25.48% higher marketable yield, respectively, compared to Pusa Jwala. Although commercial cultivars NS-1701 and Suryamukhi yielded less than Pusa Jwala in general, in the first year of this study, Suryamukhi outperformed Pusa Jwala. This variation in yield may be attributed to environmental effects (Tesfaw et al. 2013). Moreover, yield variation among varieties can be explained by differences in genetic makeup and adaptability to environmental conditions (Fekadu and Dandena 2006, Tesfaw et al. 2013). Yadeta et al. (2011) also reported a positive correlation between the number of fruits per plant and total fruit yield.

Year-to-year variation in fruit yield might result from temperature fluctuations in the growing environment, as well as from traits such as canopy diameter that affect branching. Variability in fruit development across cultivars could be due to heat stress and the genetic capacity of each variety to tolerate such stress, especially during the reproductive stage, which is more sensitive to high day and night temperatures than vegetative growth. These findings are in line with Sato et al. (2006), who reported that moderately elevated temperatures reduced fruit set in tomato plants due to decreased pollen release and viability. Similarly, MARC (2005) found that variation in marketable yield among varieties was largely due to genetic differences and/or agro-ecological adaptation.

A positive relationship was observed between fruit weight and fruit size (length and width). A similar finding was reported by Russo (2003), who noted that fruit weight increased linearly with both fruit length and width. This result is supported by MARC (2005), which indicated that variation in fruit length, from 15 cm to 7 cm in a similar varietal trial, was likely due to inherited traits or environmental influences. Variation in fruit diameter may also result from genetic differences among varieties or the environmental conditions of the growing areas. Kawarkhe et al. (1989) found the maximum fruit length in Pusa Jwala (9.6 cm), whereas Dhakal et al. (2006) reported a shorter length (5.5 cm) for the same variety, which is less than the findings of the present study. Similarly, Amare et al. (2013) observed that fruit diameter could also be influenced by the growing environment. MARC (2005) reported that the variety Mareko Fana had a fruit diameter of 2 cm, again highlighting the influence of genetic and environmental factors. Differences in pod width among varieties may be due to variations in dry matter partitioning ability and soil fertility at the growing sites.

This study is also supported by findings from Abrham et al. (2017a), who reported that pod thickness ranged from 0.99 mm to 5.63 mm among 19 genotypes tested at Areka, attributed to genotypic variation. Larger and wider hot pepper fruits are generally considered superior in quality and are in higher demand for both fresh and dry use in the Nepali market. Therefore, traits such as fruit length and pericarp thickness are likely to enhance consumer preference over thinner and shorter fruits. Fruits with thicker pericarp are more resistant to transportation damage and retain higher dry matter content (Rego et al. 2011). Larger fruits are more appealing to consumers and often fetch premium prices. Although fruit shape is primarily determined by variety, it is also influenced by environmental conditions, particularly temperature, as shown in studies conducted in Japan (Pagamas and Nawata 2007, 2008).

Conclusion

The study demonstrated significant genetic variability among ten hot pepper cultivars evaluated under open-field conditions in the central mid-hills of Nepal. Among the cultivars, CO5066-2 and CO5061 exhibited superior agronomic performance, including vigorous growth, earlier flowering, higher fruit yield, disease and pest resistance, and strong acceptance by both farmers and consumers. These lines significantly outperformed the standard check variety, 'Pusa Jwala', in terms of yield (13.68 t/ha and 11.39 t/ha vs. 6.81 t/ha) and quality traits. The findings suggest that these cultivars hold great promise for commercial cultivation and should be prioritized for on-farm validation and potential variety release in the Bagmati Province. Their adoption could help reduce dependency on imports, improve local production, and enhance market competitiveness of Nepalese hot peppers.

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Data availability statement

The dataset includes raw measurements of phenological traits, plant growth traits, yield attributes, and farmer preference scores. Researchers are welcome to contact the corresponding author for any additional information or clarification.

Declaration on the use of generative AI tools

Generative AI tools (such as ChatGPT by OpenAI) were used solely to improve the grammar and formatting of the manuscript. The content was critically reviewed and edited by the authors to ensure academic accuracy and integrity.

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