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Evaluation of Hot Pepper (Capsicum annuumL.) Genotypes for Yield and Quality in Mid-hills of Bagmati Province, Nepal

Surendra Lal Shrestha[1@]

[1]National Horticulture Research Centre, Khumaltar, Lalitpur, Nepal @:shsurendra@hotmail.com
https://orcid.org/0000-0003-1109-6514

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ABSTRACT

The study was carried out to evaluate and select high yielding, insect pest and disease resistant hot pepper genotypes with preferred characters at open field conditions for central mid-hills of Nepal in 2018 and 2019. Seedlings of six hot pepper genotypes AVPP9905, AVPP9813, AVPP0506, Suryamukhi, Pusa Jwala and Kantipure were transplanted on April first week at Khumaltar, Lalitpur. Crop geometry was maintained with the 60 x 60 cm in randomized complete block design with three replications and fertilized with 150:120:100 NPK kg + 20 ton FYM per hectare. Observations were recorded on vegetative growth, insect pest and disease, yield attributing parameter and response of consumers and farmers. Among the tested genotypes, AVPP9905 showed superior performance that was vigoros, earliest days to flowering (41) and fruit set (47 days), least insect damage (2.0), least disease; alternaria leaf spot (1.8), higher number of fruits per node (1.25), superior yield (26.19 t/ha) and 960 g per plant. Consumers and farmers preference were 4.4 and 4.5.and the maximum fruit size was 18.7 g. The second superior cultivar was AVPP0506 which showed vigor (4.0), medium days to flowering (44.3) and fruit set (49 days), less insect damage (2.2), less disease; alternaria leaf spot (2.1), higher number of fruits per node (1.3), superior yield (14.28 t/ha) and 548 g per plant, consumers (3.8) and farmers preferred (4.8). Hence it could be generalized that introduced genotypes from the world Vegetable Centre, Taiwan were more promising than local check cultivars (Pusa Jwala and Kantipure) in terms of growth, fruit yield and insect pest and disease resistance, and farmers and consumers preference. These two genotypes are recommended for cultivation in central mid-hills of Bagmati Province in open field conditions.

Keywords : Disease resistant, High yielding genotypes, Open pollinated, Open field, Consumer preferences

सारांश

धेरै उत्पादन दिने र रोग कीरा सहने पिरो खुर्सानीका ३ जिनोटाइपहरु (AVPP9905, AVPP9813, AVPP0506) नेपालका प्रचलित जातहरु Suryamukhi, Pusa Jwala र Kantipure संग २०१७ र २०१८ को अप्रिलमा खुमलटारमा मुल्यांकन गरिएको थियो । स्थानिय चेक जातको लागि पुसा ज्वाला र कान्तिपुरे समावेस गरिएको थियो । बेर्नाहरुलाई लाइन देखि लाइन ६० से.मी. र बोट देखि बोट ६० से.मी. को दुरीमा ३ रेप्लिकेशनमा रोपिएका थियो । प्लटहरुमा १५०:१२०:१०० के.जी. ना.फो.पो. र गोठेमल २० टन प्रति हेक्टरका दरले दिइएको थियो । यस परिक्षणको मुख्य उद्देश्य बढी उत्पादन दिने, रोग कीरा सहन सक्ने र अन्य आवश्यक गुणहरु भएको जातहरु बागमती प्रदेशको मध्य पहाडी क्षेत्रको खुल्ला जमिनमा खेती गर्नको लागि छनौट तथा सिफारिस गर्नु हो । यसैको सिलसिलामा यसका वानस्पतिक बृद्धी, रोग कीराको आक्रमण, उत्पादनका अभिन्न पक्षहरु र कृषक तथा उपभोक्ताको मुल्याङ्कन आदि पक्षहरुमा डाटा संकलन गरिएको थियो । सबै गुणहरुको आधारमा ६ जिनोटाइपहरु मध्ये AVPP९९०५ ले सर्वोकृष्ट नतिजा दिएको पाइयो । छिटो बृद्धी हुने र फूल फुल्ने (४१ दिन) तथा फल लाग्ने (४७ दिने), सबैभन्दा कम रोग (स्कोर २) र कीरा (स्कोर २.०) लाग्ने, प्रति आँखामा धेरै फल (१ : २५) लाग्ने, उत्कृष्ट फल उत्पादन (२६.१९ ट./हे. र ९६० ग्राम/बोट), कृषकले बढी मन पराउने (४.४) र उपभोक्ताले रुचाएका वा मन पराउने (४.५), ठुलो साइज भएका फल (१८.७ ग्राम) दिएको पाइयो । यसपछिको अर्को उत्कृष्ट जिनोटाइप ब्खए०५०६ छिटो बृद्धी हुने (४.०) र

मध्यम फूल (४४.३ दिन) तथा फल लाग्ने (४९ दिन), कम रोग (२.१) र कीरा (२.२) लाग्ने, प्रति आँखामा फल (१.३) लाग्ने, उत्कृष्ट फल उत्पादन (१४.२८ ट./हे. र ५४८ ग्राम/बोट), कृषक (४.८) र उपभोक्ता (३.८) ले रुचाएको पाइयो । यसरी World Vegetable Center, Taiwan बाट ल्याई यस परिक्षणमा समावेस गरिएका जिनोटाइपहरुको बोटको राम्रो बृद्धी, कम रोग कीराको आक्रमण, बढी उत्पादन, कृषक तथा उपभोक्ताले रुचाएको आधारमा यहाँका पुसा ज्वाला र कान्तिपुरे जातभन्दा उत्कृष्ट देखिएका छन् । त्यसैले AVPP९९०५ र AVPP०५०६ जिनोटाइपहरु बागमती प्रदेशको मध्य पहाडी क्षेत्रको खुल्ला जमिनमा खेती गर्नको लागि छनौट तथा सिफारिस गरिएको छ ।

INTRODUCTION

Hot pepper (*Capsicum annuum* L.) is one of the most important spice crops cultivated in many parts of Nepal. Hot pepper is the world's most important spice crop that ranks second after tomato and uses as fresh, dried, vegetable, spices and condiments (Acquaah 2004). Area covered by hot pepper cultivation is 10276 ha, dry chili production is 68025 tons and productivity is 6.62 ton/ha. In Bagmati province, the cultivation area is 1794 ha, production is 10856 tons and productivity is 6.05 ton/ha (MoAD 2021). However, the green yield of hot pepper is very low compared to the world's average green production (17.8 t/ha) (FAO 2016). It is an integral component of every Nepalese kitchen. Both green and dried chilies are commonly used for various purposes but 80% and 24% of dry and green chilies respectively are being imported from India (Anonymous 2004). This indicates that there is high need for further improvement of pepper yield in Nepal. Yield is dependent on the genetic background of the plant and the environment, and therefore focus should be on varieties with high yielding, and moderate to high tolerance to biotic and abiotic environmental conditions. Variety is an important factor for successful crop production. An improved genotype can show better growth, higher yield, and quality of hot pepper (Seleshi 2011).

Hot pepper grows under warm and humid weather conditions and the best fruit is obtained at 21-27°C during the day time and 15-20°C at night with the lowest 15°C and the highest 32°C. Outside these limits, the yield tends to decrease on temperature, soil type, moisture availability and pH of 6.5 to 7.5 preferable (IAR 1996).

Hot pepper originated from tropical regions and requires high temperatures for vegetative growth and fruit development. Favorable temperatures for the growth of hot pepper are in the range of 25-28°C during the day and 18-22°C during the night. When the temperature falls below 15°C or exceeds 32°C, growth is usually retarded and the yield is decreased (Mercado et al 1997; Erickson and Markhart 2002).

According to FMRL (2016), the fruits of hot pepper vary in shape, color, pungency, texture and are an important vegetable fruit for the fresh market and processed products. It is widely used as food and medicine (FMRL 2016). It is a rich source of vitamins A and E. Both hot and sweet peppers contain more vitamin C to prevent flu colds than any other vegetable crop. Moreover, pepper is used as a spice in many dishes, as decoration in food, adds flavor and colour, provides relief for several ailments, reduces muscle pain, inflammation and itching, act as a heart stimulant which regulates blood flow and strengthens the arteries and perhaps with the potential to reduce heart attacks (http://database.prota.org, 2016). The nutritional value of hot pepper pays special attention because it is a rich source of vitamin A, C and E. Both hot and sweet peppers contain more vitamin C than any other vegetable crops (Poulos 1993).

It is rich in proteins, lipids, carbohydrates, fibers, mineral salts (Ca, P, Fe) and in vitamins A, D3, E, C, K, B2 and B12 (El-Ghoraba et al 2013). The fruits are an excellent source of health-related phytochemical compounds such as ascorbic acid (vitamin C), carotenoids (pro-vitamin A), tocopherols (vitamin E), flavonoids, and capsaicinoids that are very important in preventing chronic diseases such as cancer, asthma, coughs, sore throats, toothache, diabetes and cardiovascular diseases (El-Ghoraba et al 2013; Wahyuni et al 2013).

Pepper (*Capsicum annum*) present important genetic variability of wild and cultivated accessions that differ in their vegetative growth (determined, sympodial, fascicular etc.), their criteria of fruit quality (shape, weight, length, color, taste etc.) and their marketable output (Pikersgill 1997; Lester 1998).

Fruit yield as well as quality improvement efforts continue to be the major objective of pepper improvement programme. Productivity of pepper can be increased by cultivating new genotypes.

Despite the crop's importance in terms of yield and income generation, its production and productivity is by many factors such as limited research works, lack of improved varieties, poor agronomic practices (including population density, fertilizer rates), biotic and abiotic stresses (Alemu and Ermias 2000).

The present situation indicates that there are limited varieties including both improved and the locals for the cultivation in mid hill region of Nepal. As a result, varietal information for the improvement of the crop for high yield and quality in the existing agro-ecology is insufficient. There has also been no research on evaluation of hot pepper which enables the growers to select the best performing varieties in the study area. Evaluation of selected varieties was therefore one of the objectives to solve the existing problems of obtaining the desired varieties for hot pepper growers and processors. Better adaptable and well performing variety with improved cultural practices could be a possibility to increase quality and marketable production. Despite its economic, nutritional, and medicinal purposes, the research done so far on this crop is very limited. Therefore, the current research was conducted to identify best hot pepper variety for fruit yield and quality. Hence, the present study aimed to identify the most appropriate chilly genotypes suitable for central hills condition of Nepal for spring-summer season.

MATERIALS AND METHODS

Description of the Study Area

The study area was carried out at National Horticulture Research Centre (NHRC), Khumaltar located at 27°40' N latitude and 85°20' E longitude. Altitude of the location is 1275 masl and annual rainfall is 1220 mm respectively. The type of soil is sandy clay loam with pH 5.9. The minimum and maximum temperature is12°C and 30°C respectively.

Experimental Materials, Treatments, and Design

The experiment consisted of six hot pepper genotypes namely AVPP9905, AVPP9813, AVPP0506, Pusa Jwala, Kantipure and Suryamukhi. Among four genotypes, three of them (AVPP9905, AVPP9813, AVPP0501) were obtained from World Vegetable Center, Taiwan (WorldVeg) and the rest three were collected in the country. Recommended dose of fertilizer; 120:100:60 kg NPK and 15 ton farm yard manure per hectare was applied where Urea (46% N) was used as source of nitrogen (N) and applied by split doses (half at planting and the remaining half at 30 days after transplanting). DAP was used as a source of phosphorous and nitrogen. MOP was used as a source of potassium. The experiment was laid out in randomized complete block design (RCBD) with three replications. The transplanting was done at a spacing of 60 x 60 cm between rows and plants respectively. Each plot consisted of four rows and five plants per row in a plot size of 2.4 m x 3.0 m (7.2 m^2). All other cultural practices were done as per the recommendation of NHRC, Khumaltar.

The trial was conducted from March to September 2018 and 2019. Seeds were sown in February in seed bed and covered by raised shade with plastic sheet in the night to protect with cold night. Watering was done every day with a fine meshed watering can and hand weeded. There were 4 rows per plot and 5 plants per row with a total of 20 plants per plot. Data were collected from the middle 10 plants from central rows excluding border rows and the rest of parameters were recorded from the average of those ten sample plants per plot.

Table 1. Chili pepper germplasms evaluated in 2018 and 2019 at NHRC, Khumaltar

2018	2019	Source	Introduced year
AVPP9813	AVPP9813	World Veg Center	2011
AVPP9905	AVPP9905	World Veg Center	2011
AVPP0506	AVPP0506	World Veg Center	2011
Suryamukhi	Suryamukhi	NHRC, Khumaltar	2013
Pusa Jwala	Pusa Jwala	Nepal	
Kantipure	Kantipure	Kathmandu	

Data collection

Ten plants from each plot were randomly selected from the central two rows, and qualitative and quantitative traits were measured as indicated below.

Phenological and growth data

Days to 50% flowering: The days recorded when 50% of the plants bear flowers after transplanting.
Days to first fruit set: This was recorded when a plant starts to set the first fruit.
Days to the first harvest: The number of days from transplanting to the date of the first harvest was recorded.
Plant height (cm): The length of the plant was measured from the soil surface to the tip of plants in each plot at plant maturity.

Yield and yield components

Number of fruits per plant: The number of fruits per plant was obtained by counting all fruits produced and divided by the number of sample plants.
Marketable numbers of fruits per plant: The average number of fruits free from diseases, insect pest, and other defects were obtained by counting from sample plants.
Marketable fruit yield (t/ha): Was determined by sorting fruits according to color, shape, size, and free of any mechanical or disease injuries and acceptable by the market.
Total fruit yield (t/ha): The total sum of marketable and unmarketable fruit yield of plants measured, and the yields obtained from plots were converted to a hectare base.

Fruit quality

Fruit length (cm): Average fruit length measured from tip of the fruit to basal end of ten ripe sample fruits of the second harvest were measured using vernier caliper.
Fruit width (cm): Average fruit width of ten ripe fruits of the second harvest was measured at the widest point of the fruits using vernier caliper.
Fruit wall thicknesses (mm): An average of ten ripe fruits of the second harvest was cut at the middle of the fruit, and the fruit wall (pericarp) thickness was measured using vernier caliper.

Disease incidence

Disease incidence (%): Thirty days after transplanting, the plants were regularly monitored and recorded. The number of infected plants was recorded, and the percentage of infected plants with disease incidence was estimated as suggested by Agrios (2005).

Data Analysis

Analysis of variance for all parameters was carried out as per the procedures given in MSTATC. Duncan's Multiple Range Test for mean separations was used at 5% probability level as suggested by Gomez and Gomez (1984). All significant mean separation was compared using Least Significant Difference (LSD) test at 5% probability level.

RESULTS

Growth parameter

Plant uniformity and vigor

Two years combined mean of plant uniformity and vigor was not significantly different between genotypes. Combined mean of plant uniformity was ranged from 3.3 (Pusa Jwala) to 4.1 (Suryamukhi). In first year, it was significantly highest where the most uniform plants were recorded in Kantipure (4.7) followed by Suryamukhi (4.3) and the least uniformity was in AVPP0506 (3.0) (**Table** 2). Similarly, combined mean of plant vigor was ranged from 3.6 (Pusa Jwala) to 4.3 (Suryamukhi).

Plant height (cm)

Combined plant height was significantly differences and was ranged from 57 cm (AVPP9905) to 68 cm (Suryamukhi). In both the years, varietal difference was significant. In first year, Kantipure had the tallest plant height (61.4 cm) and AVPP9813 had the least plant height whereas in second year, the least plant height (57 cm) was obtained in AVPP9905 and the highest in Suryamukhi (89.6 cm) (**Table** 2).

Table 2. Plant uniformity, plant vigor and plant height of hot pepper genotypes at Khumaltar (2018 and 2019)

Genotypes	Plant uniformity[y]			Plant vigor[z]			Plant height(cm)		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
AVPP9905	4.0	3.7	3.8	3.7	4.3	4.0	57.5	57.0	57.0
AVPP9813	3.7	3.7	3.7	3.7	4.3	4.0	47.5	68.3	57.9
AVPP0506	3.0	4.0	3.5	3.7	4.3	4.0	58.5	61.0	59.7
Suryamukhi	4.3	4.0	4.1	4.0	4.7	4.3	48.0	89.6	68.8
Kantipure	4.7	3.0	3.8	4.7	3.7	4.2	61.4	65.6	63.5
P. Jwala	3.3	3.3	3.3	3.3	4.0	3.6	49.0	66.6	57.8
GM	3.8	3.6	3.72	3.85	4.21	4.03	53.6	68.0	60.8
F-test (P=05)	*	ns	ns	ns	ns	ns	*	*	*
LSD (P=0.05)	1.05	-	-	-	-	-	7.01	11.23	9.21
CV%	20.3	16.5	16.52	19.3	10.29	11.77	22.02	13.2	18.44

[y] 1:none, 9:dead [z] 1:poor, 5:excellent

Crop phenology and growth traits

Days to flowering and fruit set

The combined mean of earliest days to 50% flowering (39 days after transplanting) was found in Kantipure, whereas the Suryamukhi and Pusa Jwala required the longest days (49 days) to 50% flowering (**Table** 3).This variation might be due to inherited differences in variety. Analysis of variance revealed that the days to 50% flowering had significantly affected by variety (V) in second year (**Table** 3).

Days to first fruit set was significantly affected by variety. The result indicated that the earlier days to first fruit set (45 days) was found in cultivar Kantipure. Suryamukhi (61.8 days) and Pusa Jwala (58.5 days) required longer time to flower. In this study, the result showed that introduced genotype AVPP9905, AVPP9813 and AVPP0506 found 19.3%, 12.8% and 14.5% days earlier to first fruit set than local released variety Pusa Jwala.

Days to first harvest and fruit maturity

The shortest number of days to first harvest was recorded in Kantipure (72.3 days). The longest days to attain first harvest were recorded in Suryamukhi (83 days) (**Figure** 1). The variation in days to first

harvest could be due to the differences in the growing environmental and climatic conditions along with genetic make-up of the genotypes. Varietal differences on days to harvest was significant where Kantipure was ready to harvest earliest (72.3 days) followed by AVPP9905 and AVPP9813 (80.3 days), and the latest was in Suryamukhi (83 days) (**Figure** 1). As far as days to harvesting of ripened fruits is concerned, the longest days to harvest was found in AVPP0506 (106 days) followed by AVPP9905 (102 days) (**Figure** 2).

Table 3. Days to flowering, fruit set, harvest and maturity of hot pepper genotypes at Khumaltar (2018 and 2019)

Genotypes	Days to Flowering			Days to fruit set		
	2018	2019	Mean	2018	2019	Mean
AVPP9905	42	39.7	40.8	51.7	42.7	47.2
AVPP9813	45	43.7	44.3	55.7	46.3	51
AVPP0506	45	40.0	42.5	51.0	49	50
Suryamukhi	47	51.0	49	66.3	57.3	61.8
Kantipure	48	33.0	39	51.3	38.7	45
P. Jwala	44	54.3	49.1	48	69.0	58.5
GM	45.16	43.61	44.39	54	50.5	52.25
F-test (P=05)	ns	*	ns	*	ns	ns
LSD (P=0.05)		11.32		17.17		
CV%	9.09	19.32	13.6	16.91	12.42	16.91

ns; non significant; *significant at P= 0.05 and ** significant at P=0.0.1

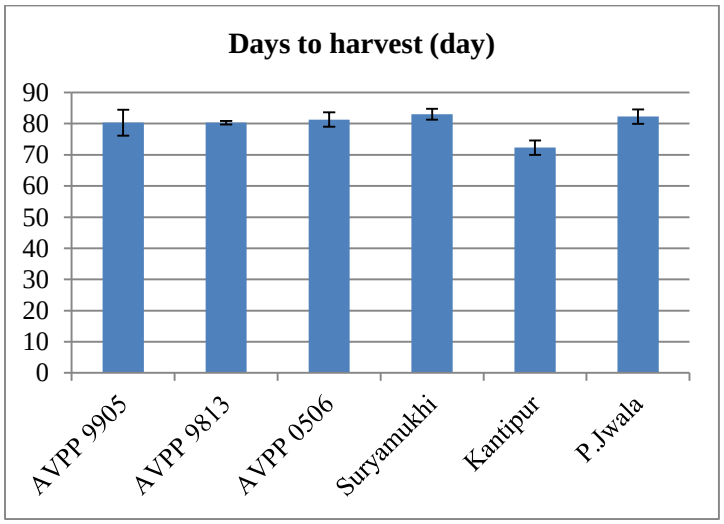

Figure 1. Days to harvest of six hot pepper genotypes

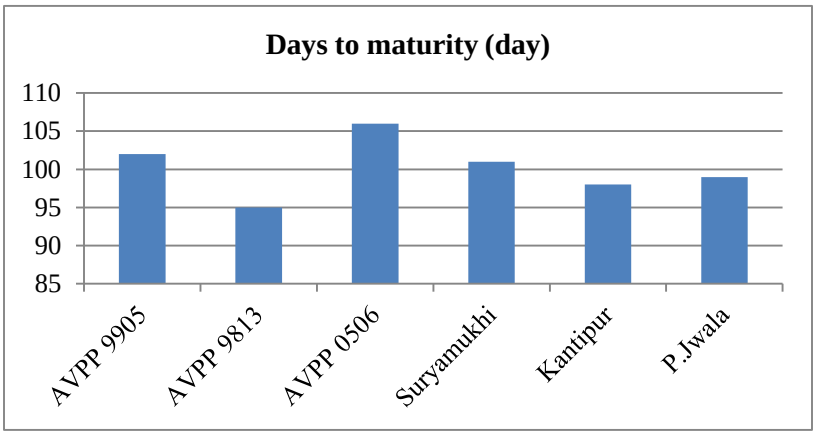

Figure 2. Days to maturity of six hot pepper genotypes

Fruit set percentage

Significantly higher fruit set percent was observed in Suryamukhi (93.7%) followed by Kantipure (82.3%) and the lowest were in AVPP9813 (76.6%) (**Figure** 2). AVPP0506 and Suryamukhi beared the flowers on the apical part of the shoots that might be associated with better fruit set probably due to apical dominance.

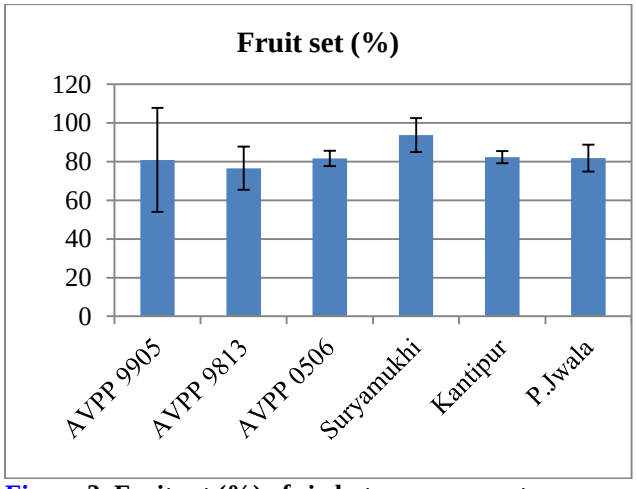

Figure 3. Fruit set (%) of six hot pepper genotypes

Table 4. Number of flowers and fruits per node (number) of hot peppers at Khumaltar (2018 and 2019)

Genotypes	#Flowers/node			#Fruits/node		
	2018	2019	Mean	2074	2075	Mean
AVPP 9905	2.1	1.2	1.65	1.3	1.2	1.25
AVPP 9813	1.6	1.3	1.45	1.1	1.1	1.1
AVPP 0506	1.9	1.3	1.60	1.5	1.1	1.3
Suryamukhi	1.6	1.1	1.35	1.4	1.1	1.25
Kantipure	1.3	1.5	1.4	1.1	1.2	1.15
P.Jwala	1.5	1.3	1.4	1.3	1.0	1.15
GM	1.66	1.28	1.47	1.28	1.12	1.2
F-test (P=0.05)	ns	ns	ns	ns	ns	Ns
CV%	34.23	16.8	18.04	16.56	26.74	11.59

ns; non significant; *significant at P= 0.05 and ** significant at P=0.0.1

Insect pest and disease incidence

Insect damage due to aphids and leaf eating caterpillar was noticed in both the years but the varietal difference was not significant (**Table** 5). However, AVPP9905 and AVPP9813 had less insect damage as compared to Pusa Jwala. The major disease appeared during the crop season was alternaria leaf spot. In first year it was significantly differences between genotypes where AVPP9905 and AVPP9813 was least infected (1.0). The highest infection was observed on Kantipure (4.0) and Suryamukhi (3.0). This result indicated the response of varieties to disease reaction and had a significant variation for yield, quality, and disease incidence that could be attributed to the genetic potential of specific genotype and the growing environmental conditions. Introduced genotypes; AVPP9905, AVPP9813 and AVPP0506 had less virus infection as compared to the registered cultivar (Pusa Jwala) and locally adopted check cultivars; Kantipure and Suryamukhi. Besides the cultural method of disease management (avoiding weeds that harbor diseases, killing of the cut worms etc.), fungicide known as Mancozeb/copper oxichloride was sprayed three times during the crop period as a preventive measures. The first spray was done at vegetative growth, second at fruit setting stage and third at green fruit stage, and was practiced according to the label (EARO 2004). The application of these fungicides did not control the diseases expected to manage. The reason could be due to continuous rainfall followed by high humidity during the experimental period.

Table 5. Insect damage, leaf spot disease and virus infection of hot peppers at Khumaltar (2018 and 2019)

Genotypes	Insect damage (1-5)[y]			Virus plant (%)	Leaf spot (1-5)[y]		
	2018	2019	Mean	2018	2018	2019	Mean
AVPP9905	2.3	1.7	2.0	6.8	1.0	2.6	1.8
AVPP9813	2.0	2.3	2.1	6.8	1.0	2.6	1.8
AVPP0506	2.7	1.7	2.2	6.8	2.3	2.0	2.15
Suryamukhi	3.0	2.0	2.5	33	3.0	2.6	2.8
Kantipure	2.0	3.0	2.5	45	4.0	3.0	3.5
P.Jwala	2.5	2.0	2.2	6.8	2.0	2.0	2
GM	2.41	2.12	2.25	17.53	2.21	2.46	2.34
F-test (P=0.05)	ns	ns	ns	*	**	ns	ns
LSD (P=0.05)				1.22	1.03	2.6	
CV%	6.82	2.11	5.12	46.73	26	24.2	25.1

[y] 1:none, 5:susceptible

ns; non significant; *significant at P= 0.05 and ** significant at P=0.0.1

Yield and yield components

Number of fruits per plant

The number of fruits per plant was significantly ($P < 0.01$) affected by genotype (**Table** 6). The number of fruits per plant was significantly highest in Suryamukhi (286) and AVPP0506 (253) as compared to Pusa Jwala (180). The least number of fruits per plant was found in Kantipure (70). This variation might be due to genetic characteristics of varieties. Suryamukhi and AVPP0506 have upward short fruits and more branches might be contributed to higher number of fruits.

Fruits yield per plant

Fruits yield per plant was significantly differences in both the years. The highest fruit yield (960 g/plant) was found in AVPP9905 followed by AVPP9813 (837 g/plant) and Suryamukhi (664 g/plant) respectively where the least yield (191 g/plant) was recorded in Kantipure (**Table** 6).

Total fruit yield per hectare

The results revealed that the total fruit yield per hectare was significantly affected by genotype in both the years. The highest total fruit yield (26.19 t/ha) was produced in AVPP9905 followed by AVPP9813 (18.70 t/ha) and AVPP0506 (14.28 t/ha) whereas the lowest (4.74 t/ha) was recorded on Kantipure (**Table** 6). Kantipure had very low yield which could be due to higher disease infestation (**Table 5**). This result revealed the significant variation of hot pepper varieties coupled with genetic traits that might have a better response to total fruit yield.

Table 6: Fruit/plant (no) and fruit/plant (g) of hot peppers at Khumaltar (2018 and 2019)

Genotypes	Fruits/plant (no)			Fruits/plant (g)			Yield (t/ha)		
	2018	2019	Mean	2018	2019	Mean	2018	2019	Mean
AVPP9905	58	106	82	829	1090	960	23.03	29.36	26.195
AVPP9813	159	187	173	849	825	837	15.37	22.04	18.70
AVPP0506	253	253	253	565	530	548	14.96	13.61	14.285
Suryamukhi	305	268	286	674	654	664	17.22	6.60	11.91
Kantipure	82	59	70	272	109	191	6.89	2.58	4.74
P.Jwala	166	194	180	606	437	522	13.31	12.15	12.73
GM	170.5	177.8	174.1	632.5	607.5	620.0	15.13	14.39	14.76
F-test (P=0.05)	*	*	**	*	*	*	*	*	*
LSD (P=0.05)	148.6	154.1	60.0	431.2	595.3	283.6	9.23	10.11	9.67
CV%	47.9	47.59	13.40	37.5	53.8	17.79	36.4	28.55	31.47

ns; non significant; *significant at P= 0.05 and ** significant at P=0.0.1

Fruit size and quality

Average fruit weight

The highest average fruit weight (18.7 g) was recorded in AVPP9905 followed by AVPP9813 (6.4 g) and Kantipure (5.6 g) respectively whereas the least weight was in AVPP0506 (3.6 g) (**Figure** 4).

Fruit length and width

The longest fruit length (11.8 cm) was found in AVPP9905 followed by Pusa Jwala (9.4 cm) and AVPP9813 (8 cm) respectively whereas the shortest was measured in Suryamukhi (4.3 cm) (**Figure** 5). The highest fruit width (19 mm) was attained by the AVPP9905 followed by AVPP9813 (13.5 mm) and Suryamukhi (12.7 mm) whereas the narrowest fruit width (10.1 mm) was attained by AVPP0506 (**Figure** 5).The variations in fruit size could be due to the difference in varieties inherited characteristics and or due to environmental conditions of the growing areas. Fruit length was significantly differences between ($P < 0.001$) varieties.

Fruit pericarp thickness

The thickest fruit pericarp (2.7 mm) was attained by AVPP9905 whereas the thinner (1.1 mm) ones were attained by variety Kantipure (**Figure** 6). In general, introduced varieties had better thickness than the local released varieties that could possibly contribute better fresh and dry fruit yield. In this result, the variation might be due to genetic characters effect on fruit pericarp thickness. These pericarp differences might be due to differences in assimilate partitioning capacity of the varieties that might be resulted in thickest or thinnest fruit pericarp and or due to agro-ecological variations.

Seed number

Number of seeds contain in a fruit was varied from 29 (AVPP9905) to 55 (Suryamukhi) (**Figure** 7). Less number of seeds is preferred by the consumers.

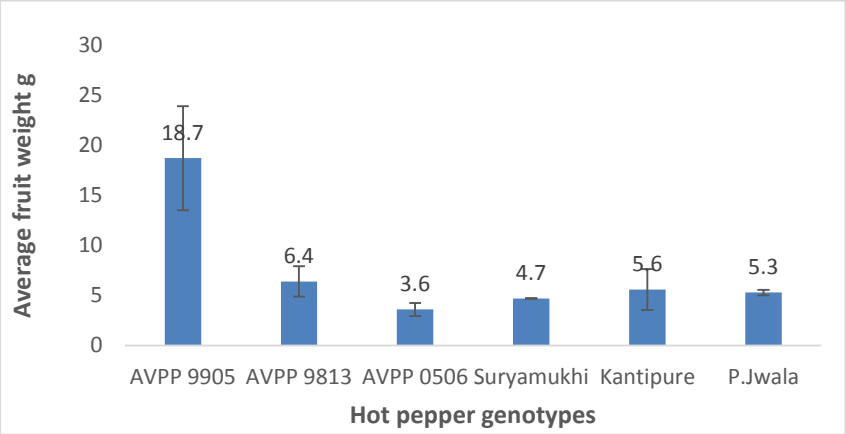

Figure 4. Fruit weight (g) of hot pepper genotypes

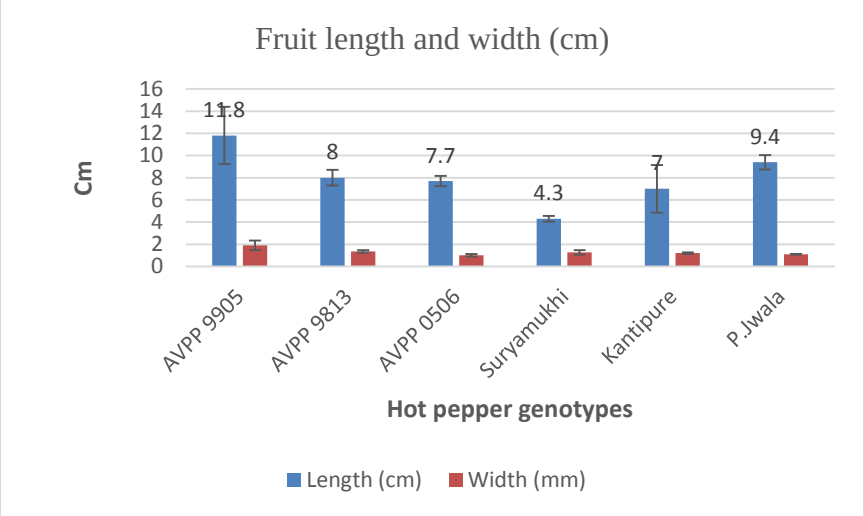

Figure 5. Fruit length (cm) of hot pepper genotypes

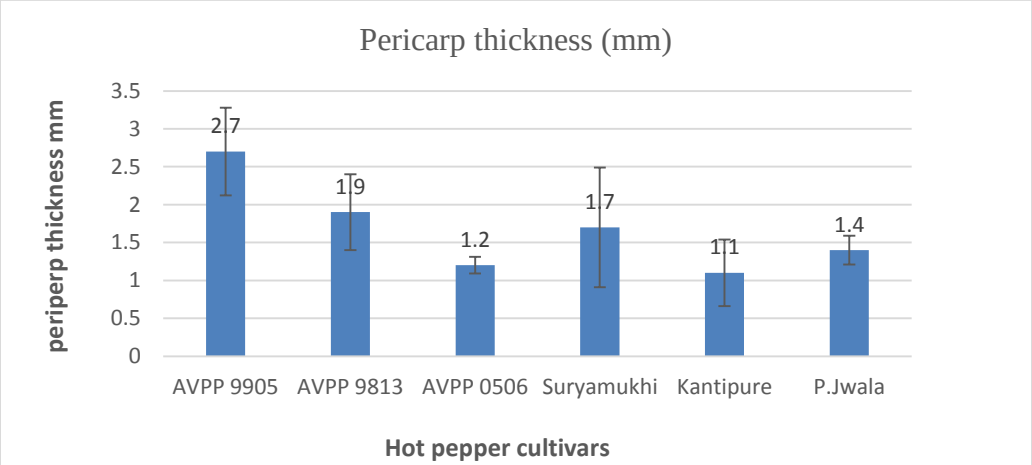

Figure 6. Pericarp thickness (mm) of hot pepper genotypes

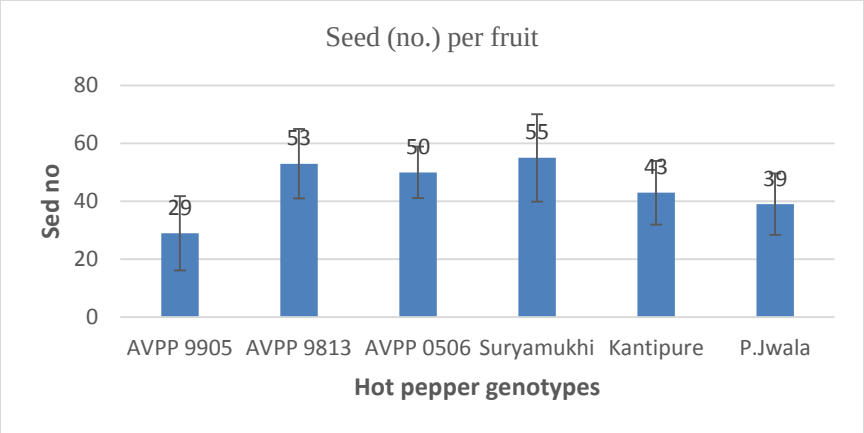

Figure 7. Number of seed contain in the fruit of hot pepper genotypes

Fruit morphological characters

All genotypes had elongated shaped fruits except Suryamukhi which had short and triangular shaped. All the genotypes had neck at base of fruit. Obtuse shape at pedicel attachment was found in AVPP9905 and AVPP9813, Acute was seen in AVPP0506 and Pusa Jwala and Suryamukhi but Kantipure had lordata shape. Immature fruit color ranged from cream color (AVPP9905) to green color (Kantipure). All the genotypes had 3 lobed fruits except AVPP9813 (2 lobes) (**Table** 7).

Table 7: Fruit characteristics of hot pepper genotypes at NHRC Khumaltar

Genotypes	Fruit shape	Shape at pedicel attachment	Neck at base of fruit	Immature fruit color	Number of locules
AVPP9905	Elongated	Obtuse	Present	Cream	3
AVPP9813	Elongated	Obtuse	Present	Green	2
AVPP0506	Elongated	Acute	Present	Light green	3
Suryamukhi	Triangular	Lordata	Present	Bright green	3
Kantipure	Elongated	Lordata	Present	Green	3
P. Jwala	Elongated	Acute	Present	Light green	3

Consumers and farmers response

On the basis of fruit size, shape, color and freshness, consumers most preferred cultivar was AVPP9905 (4.4) followed by AVPP9813 (4.3). However, based on size, shape and freshness, AVPP9905 had most preferred character (**Table** 8). Likewise, farmers' most preferred cultivar on the basis of plant appearance, market value, yield, insect and disease was AVPP0506 (4.8) followed by AVPP9905 and Pusa Jwala (4.5). In both the consumers and farmers perspectives, AVPP9905, AVPP0506 and AVPP9813 were most preferred genotypes.

Table 8. Consumer and farmers acceptance test of hot pepper genotypes at NHRC Khumaltar

Genotypes	Consumers acceptance test (1-5)[y]					Farmers acceptance test (1-5)[y]					
	Size	Shape	Color	Freshness	Mean	Plant appearance	Market value	Yield	Insect	Disease	Mean
AVPP9905	5	4.4	3.3	5	**4.42**	4.3	4.3	4.0	4.7	5	**4.5**
AVPP9813	4.2	3.3	4.7	5	**4.3**	3.7	4.3	3.7	5.0	5	**4.3**
AVPP0506	3.0	3.0	4.1	5	**3.8**	4.7	4.3	5.0	5.0	5	**4.8**
Suryamukhi	3.3	3.3	4.3	5	**3.97**	3.7	4.3	4.0	5.0	5	**4.4**
Kantipure	3.3	3.7	4.7	4	**3.92**	3.0	4.7	2.3	5.0	3.7	**3.7**
P. Jwala	3.0	3.0	4.0	4.7	**3.67**	4.0	4.7	4.0	5.0	4.7	**4.5**
GM	3.64	3.44	4.11	4.78		3.88	4.44	3.83	4.94	4.72	
F-test (P=0.05)	**	**	ns	ns		*	ns	1.286	ns	ns	
LSD(P=0.05)	0.517	0.634				0.857					
CV%	10.76	14.3	17.28	9.10		12.12	12.77	18.45	4.77	14.81	

[y]1:poor, 5: excellent
ns; non significant; *significant at P= 0.05 and ** significant at P=0.0.1

DISCUSSIONS

The increase in plant height in second year could be mainly due to better availability of soil nutrients in the growing areas, based on the varietal variability to absorb nutrients from the soil (Vos and Frinking 1997; El-Tohamy et al 2006).The result of variation in days to flowering agrees with that of Amare et al (2013) who reported that maximum number of days for fifty percent of the plants in a plot to flower was taken by variety MelkaZala (99 days) from seeding date. Seleshi (2011) and Melaku et al (2015) indicated that earliness or delayed in the days to 50% flowering could be affected by inherited characters. This result on days to fruit set might be due to the effect of inherited characters of the hot pepper. The result agrees with Tibebu and Bizuayehu (2014) who reported that locally released variety Marako Fana and Melka Shote was non-significant in days to fruit set but variety Marako Fana attained longest days to first fruit set (95.29 days after seeding).

The result on days to first harvest of this study also supports the result of Seleshi (2011) who had reported the earliest day to first harvest (83.92) was attained by introduced genotype AVPP0514, whereas the longest day to first harvest (90.67 days) was recorded by locally released variety Melka Shote (90.67). The variety of hot pepper response to days to the first harvest might be due to genetic traits and earliness or lateness of days to 50% flowering and days to first fruit set. Similarly, Seleshi (2011) reported that among eight elite hot pepper varieties MelkaShote compared to variety Gojeb Local attained highest days to the first harvest by 51.1% in Jimma.

The result of this study on fruit set percentage supports the findings of Dhakal et al (2006) who had also reported Suryamukhi had the highest fruit set (%) followed by CO-5678. Chaudhary (2004) also reported higher fruit set percentage in Suryamukhi than in Jwala. Higher fruit set percent in some genotypes might be due to more convenient pollination in the short styled flowers and promotion of self-pollination in the long styled flowers when passing the stigmas through the anther sacs in the erect flowers. Gupta (2003) studies on chili genotypes revealed that great variation exists in ability to flowering, fruit set, yield and other qualitative attributes under different agro-climates.

In agreement with the current findings, Yemane (2017) reported that among five released hot pepper varieties, Melka Awaze and Melka Shote varieties are the most outstanding ones due to their highest biomass and disease tolerance, which leads to high yield per hectare. Therefore, the use of the best

variety, coupled with recommended cultural practice were found to be the most important component of integrated pest and diseases management options for hot pepper production.

This finding is also in line with Seleshi (2011), who reported that nine cultivars of hot peppers had shown significant differences in total pod per plant performance. In line with this study, Danial and Abraham (2020) reported the significant difference among four cultivars of hot pepper in the number of fruits per plant that ranged from 46.2 to 113.2 in 2013 and 35.56 to 53.56 in 2014 at Derashea.

This result on fruits per plant is in line with the result of Gogoi and Gautam (2002) who had also reported fresh fruit yield per plant ranged from the highest of 679.23g in Balijuri to the lowest of 52.01 g in Latabih-II. Similar results on total fruit yield per hectare were reported by Abrham et al (2017a) who had obtained among 19 varieties tested in Wolaita area, introduced varieties performed well and out yielded the locally released varieties. According to the report, introduced genotype AVPP0514 resulted higher than AVPP Melaka Shote. Dhakal et al (2006) had also mentioned the scrutiny of data revealed that the 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 than that of Pusa Jwala. The commercial cultivars NS-1701 and Suryamukhi produced even lower yield than Jwala but in this first year Suryamukhi gave higher yield than Pusa Jwala. This variation in yield may be due to environmental effect (Tesfaw et al 2013). The yield variation among varieties could be due to genetic makeup of varieties and the ability to adapt environmental conditions (Fekadu and Dandena 2006; Tesfaw et al 2013).Fruits per plant was positively correlated with total fruit yield according to Yadeta et al (2011).

The year to year variation in fruit yield might be due to the influence of growing environment's temperature, associated traits like canopy diameter that could limit the number of branches. The variation in fruit development among varieties could be due to the temperature stress of the growing environment and capabilities of each varieties to withstand the stress specially on the reproductive development which is more sensitive to high temperature stress (day and night temp) than vegetative development. This result is line with work of Sato et al (2006), who reported that the reduction of fruit set under moderately elevated temperature stress was mostly due to a reduction in pollen release and viability in tomato plant. The result is in conformity with the work of MARC (2005) in which the marketable yield variation of varieties is due to their differences in genetic makeup and/or agro-ecological adaptations.

Hence there was positive relationship between fruit weight and fruit size (length and width). Similar result was reported by Russo (2003) who observed a positive relationship between fruit weight and pod size, where fruit weight increased linearly with pod length and pod width. The result agrees with MARC 2005 who reported that the long fruit length (15 cm) and short fruit length (7 cm) at similar varietal trial were most probably be attributed due to their inherited traits and or influenced by growing environment. The variation in fruit diameter could be due to differences in varieties inherited characteristics and or due to environmental conditions of the growing areas. In similar manner, Gebremeskel et al (2015) also reported that the mean value of fruit diameter can significantly affected by varieties that treated alike. In the same line, Kawarkhe et al (1989) found maximum fruit length in Jwala (9.6 cm) but Dhakal et al (2006) found the fruit length of Jwala (5.50 cm) that is shorter than this study. Similarly, Amare et al (2013) reported that fruit diameter could also be influenced by variety in the growing environment. In line with this study, Mebratu et al (2014) reported that increased yield attributed to the enhanced pod length, pod width and pod wall thickness. This result is in line with MARC (2005) which showed that variety Mareko Fana had a fruit diameter of 2 cm. The pod width difference among varieties could be due to different dry matter partitioning ability of plants and the soil fertility status of the growing locations.

The result of this study was also supported by the result of Abrham et al (2017a) who found that among 19 genotypes, pod thickness ranged 0.99- 5.63 mm at Areka due to variation in genotypes. Larger and wider hot pepper fruits are considered to be the best in quality and have better demand for fresh as well as

dry fruit use in Nepali market. Therefore, subjectively this quality attributes along with fruit length and pericarp thickness could be better preference to consumers over the thinner and shorter fruit. Fruits with thickest pericarp are the most withstand to transportation shocks and have the highest dry matter) (Rego et al 2011). Larger pepper fruits are the most attractive by consumer and so get premium prices. Also, higher is the size of fruits greater is the capability for storage of photosynthates and lower is the rate transpiration (Barera et al 2008). The fruit shape depends largely on the variety but it is also influenced by environmental conditions especially the temperature regime (Pagamas and Nawata, 2007, 2008).

CONCLUSION

Among the tested genotypes, AVPP9905 showed superior performance which was vigorous, earliest days to flowering (40.8) and fruit set (47), least insect damage score (2.0), least disease; alternaria leaf spot score (1.8), higher number of fruits per node (1.25) , superior yield (26.195 t/ha) and 960 g per plant, consumers (4.4) and farmers preferred (4.5), and big fruit size (18.7 g). The next superior cultivar is AVPP0506 which has vigorous (4.0), medium days to flowering (42.5) and fruit set (50 days), less insect damage (2.2), less disease; alternaria leaf spot (2.1), higher number of fruits per node (1.3), superior yield (14.28 t/ha) and 548 g per plant, consumers (3.8) and farmers preferred (4.8). Hence it could be generalized that introduced varieties were more promising than local check cultivars (Pusa Jwala and Kantipure) in terms of growth, fruit yield and insect pest and disease resistance, and farmers and consumers preference. These two genotypes are recommended for cultivation in central mid-hills of Bagmati Province in open field conditions. It could be generalized that hot pepper varieties responded differently for in terms of yield, quality, and disease incidence. Therefore, it can be concluded that variety introduction is very important in boosting production and productivity. The result also showed that there are potential introduced varieties which could be an option for farmers for choosing appropriate cultivars.

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