



Screening and Evaluation of Potato (*Solanum tuberosum*) Genotypes to Identify the Sources of Resistance to Potato Apical Leaf-Curl Disease

Deva Shri Maan^{1*}, A. K. Bhatia¹ and Mandeep Rathee²

¹Ph. D. Student* and Professor¹, Department of Vegetable Science and

²Ph. D. Student, Department of Entomology, CCS Haryana Agricultural University, Hisar-125004, Haryana, India

*Corresponding Author E-mail: devashrimaan4@gmail.com

Received: 6.03.2017 | Revised: 18.03.2017 | Accepted: 20.03.2017

ABSTRACT

Studies on screening and evaluation of potato (*Solanum tuberosum* L.) genotypes for field resistance against apical leaf-curl diseases were conducted at Research Area, Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during winter (Rabi) season of 2012-13. Twenty genotypes of potato were planted on 16 October 2012 in randomized block design with three replicates to screen against apical leaf-curl disease. Infector rows were planted all-round the trial and after every tenth row. Out of 20 genotypes, Kufri Bahar, Kufri Chipsona-2, Kufri Frysona, HIS-98-19, HIS-98-34, HIS-98-55, HIS-98-58, CP 2370, CP 2378, CP 2379 and CP 2390 were found completely free from potato apical leaf-curl disease and considered as highly resistant. Out of these 20 genotypes, eight genotypes/varieties were planted on 16 October 2012 in a randomized block design with three replicates. Infector rows were planted around the plots. Analysis of variance revealed that sufficient variation existed among the eight genotypes for all the characters under study except plant vigour at 60 DAP, leaf area index and foliage senescence. Kufri Badshah showed better performance for most of the growth characters viz. plant height, plant vigour, number of leaves per hill, weight of stem per hill, weight of leaves per hill, weight of foliage per hill and leaf area index. Kufri Pushkar produced significantly maximum total (426.24 q/ha) and marketable yield (397.63 q/ha) closely followed by Kufri Badshah, which were statistically at par. Whitefly [*Bemisia tabaci* (Gennadius)] population was observed maximum in highly susceptible genotype CP 1588, Kufri Khyati and Kufri Pukhraj. The lower number of whitefly was found in Kufri Bahar and Kufri Pushkar that had lower disease incidence.

Key words: *Bemisia tabaci*, Percent apical leaf-curl disease, Kufri Bahar, Kufri Chipsona-2

INTRODUCTION

Potato (*Solanum tuberosum* L.) is one of the most important vegetable crops and ranks third among food crops after rice and wheat in the world as well as India from human

consumption point of view. India is the 3rd largest producer of potato in world after China and Russia and during 2010-11, this crop occupied 18.30 lakh hectares with a production of 36.57 million tonnes¹.

Cite this article: Maan, D.S., Bhatia, A.K. and Rathee, M., Screening and Evaluation of Potato (*Solanum tuberosum*) Genotypes to Identify the Sources of Resistance to Potato Apical Leaf-Curl Disease, *Int. J. Pure App. Biosci.* 5(3): 53-61 (2017). doi: <http://dx.doi.org/10.18782/2320-7051.2658>

Potato is also an important vegetable crop of Haryana. It occupies a premier position in both area and production in the state, which ranks first in production and second in area among vegetable crops. In 2010-11, the area and production of potato were 26780 hectares and 598164 tones, respectively². The productivity of potato crop in the state is lower (22.33 t/ha) than the potential yield. Potato crop is attacked by many diseases, which are widely spread and other, which affect the crop growth and production, are localized. Garg *et al.*⁵ reported a new disease on potato, which produced para crinkle symptoms and the potato plants infected with PALCV showed chlorotic blotching, crinkling, mosaic, apical leaf-curling and stunting. In Haryana state, the sporadic incidence of potato apical leaf-curl disease was observed first time in early October planted crop at Hisar during December 1996 and subsequently it spread to other parts of the state. Severe yield losses due to this disease have been reported in potato⁷. Annual loss due to potato viruses with an average of 30-40% incidence cause about 25-30% yield reduction⁶. Lakra⁷ reported that with 100 per cent disease incidence of PALCV, more than 50 per cent losses in yield has been reported in early sown crop of potato cultivar Kufri Ashoka. The most deleterious effect was observed on reduction in leaf area, chlorophyll content, plant height, number of stems per plant, number of tubers per plant and weight of tubers per plant⁸.

The indiscriminate use of insecticide results in not only environmental pollutions but is also responsible for so many health hazards. Further, the insects have developed resistance to certain insecticides. Therefore, to raise a disease free crop of potato, the only alternative lies in breeding disease resistant varieties. The genetic resistance is more safe, stable and economical in comparison to pesticide use. The pre-requisite for the development of disease resistant varieties is the availability of efficient and reliable screening techniques and the identification of

resistant sources. Some of the biochemical and morphological attributes, which act as a defense mechanism in the host plant against insects and diseases, are also of considerable importance. The biochemical reaction leading to susceptibility or resistance can be helpful in the screening germplasm at early stage against potato apical leaf curl disease in potato. Therefore, in view of the importance of crop and disease, the present investigation was planned.

MATERIAL AND METHODS

Screening of potato genotypes to identify the sources of resistance to potato apical leaf-curl disease

Studies on screening of potato genotypes for field resistance against apical leaf-curl diseases were conducted at Research Area, Department of Vegetable Science, CCS Haryana Agricultural University, Hisar during winter (*Rabi*) season of 2012-13. Disease free healthy potato tubers (seeds) of twenty genotypes *viz.*, Kufri Badshah, Kufri Pushkar, Kufri Bahar, Kufri Pukhraj, Kufri Khyati, Kufri Frysona, Kufri Surya, AICRP-EM-1, AICRP-EM-3, Kufri Chipsona-2, HIS/98-19, HIS/98-34, HIS/98-55, CP 1588, CP 2370, CP 2378, CP 2379 and CP 2390 along with infector rows of Kufri Khyati were planted all-around the trial for conducting the trial. The genetic material consisting of 20 potato genotypes were planted on 16 October 2012 in a single row of 3 m length accommodating fifteen plants at Research Farm of the Department of Vegetable Science, CCS Haryana Agricultural University, Hisar. The experiment was laid out in a Randomized Block Design with three replications. The observation on percent plant emergence was recorded at 30 days after planting. The number of infected plants was recorded at 20 days after planting and thereafter at ten days interval until 80 days after planting to identify the source of resistance to potato apical leaf-curl disease. The percent potato apical leaf-curl disease incidence was worked out as follows:

$$\text{Percent apical leaf – curl disease} = \frac{\text{Total number of plants effected with apical leaf curl disease of all the replications}}{\text{Total number of plants of all the replications}} \times 100$$

Evaluation of potato genotypes to identify the sources of resistance to potato apical leaf-curl disease

Eight genotypes/varieties selected out of twenty genotypes were evaluated. During the course of experiments, ten potato plants were selected at random in each replication and

$$\text{Plant emergence (\%)} = \frac{\text{Number of tubers emergent per plot}}{\text{Total number of tubers planted in each plot}} \times 100$$

Plant height (cm): Ten plants from each plot were selected at random and plant height was measured in centimeter. Height of the tallest shoot was measured from base of the plant to apex of last leaf unfolded at 45, 60, 75 and 90 days after planting and average was worked out.

Number of stems per hill: The same ten plants were used plant (hill) was used to record number of stems per hill, of which plant height was recorded their stems were counted, and then, average was worked out.

Number of leaves per hill: The same ten plants of which number of stems counted were used for counting number of leaves and average was worked out per stem.

Weight of leaves per hill (g): The leaves weight per hill was recorded at final harvest. It was recorded by weighing all the leaves of the same ten plants (hill) and it was calculated in gram.

Weight of stem per hill (g): Weight of stem per hill was recorded at final harvest for the same ten plants selected for number of stem parameter, their stems without leaf were weighed in gram, and then average was worked out.

Leaf area index (LAI): Leaf area index was calculated by using disc method on 100th day of planting before dehaulming. Two discs each from 50 fresh compound leaves were cut with the help of a puncture having radius (r) 1.5 cm. Hundred discs of leaves were taken with the help of a cork borer and leaf area was calculated on fresh weight basis of leaves.

treatment and observations were recorded for the following parameters:

Growth parameters:

Percent plant emergence: The count of plant emergence in the field of each treatment/genotypes was recorded at 30 days after planting and was converted into percent.

Leaf area index was worked out by using the following formula:

$$\text{LAI} = \frac{\pi r^2 \times Y \times 1000}{X \times Z \times 100 \times 100}$$

Where,

$\pi = 22/7$, $r =$ radius of a disc (circle) = 15/10, $X =$ weight of 100 discs, $Z =$ area of plot (3x2.4 m) and $Y =$ foliage weight per plot (kg).

Weight of foliage (g): Weight of foliage was recorded of the same ten plants at final harvest. It was calculated by weighing all the ten plants of each plot in gram and then worked out weight of foliage per hill.

Number of stomata per leaf: One full compound leaf each from each plot was taken randomly and fevicol was spread over all the leaf. Then after drying of fevicol, removed it with the help of cello tape from the leaf and kept it under the microscope to count the number of stomata.

Plant vigour at 60 DAP: Plant vigour was noted after 60 days of planting by visual observation according to 1-4 scale as suggested by Wooster and Farooq (1995). Where, 1= poor (small plant, weak stem, stunted growth), 2= moderate, 3= good and 4= excellent (tall plant, more number of leaves, strong stem)

Foliage senescence at harvest: Foliage senescence was noted at the time of harvesting by visual observation based on scale, *i.e.*, 1: least senescence; 10: maximum senescence.

Tuber yield parameters:

Total tuber yield (q/ha): Total yield of each treatment/genotypes (sum of weight of A, B, C and D grade tubers) was obtained in kilogram per plot. The values were later converted to quintal per hectare.

Marketable tuber yield (q/ha): Marketable yield was obtained by deducing the D grade

tuber yield from the total tuber yield in kilogram per plot. The values were later converted to quintal per hectare.

Harvest index: The harvest index was calculated by dividing the economic yield (total tuber yield per plot) with total biological yield and expressed as percent (Donald and Hamblin, 1976).

$$\text{Harvest index (\%)} = \frac{\text{Economic yield per plot}}{\text{Biological yield (Economic yield + foliage weight) per plot}} \times 100$$

Whitefly population at 10 days interval after emergence:

Whitefly population was counted on three plants from each plot. Counting of whitefly was done in early morning hours, as they are comparatively less active before sunrise. Number of whitefly was counted on three compound leaves at different positions, i.e.,

bottom, middle and top of the plant and then worked out whitefly per leaf.

Percent potato apical leaf-curl disease incidence at 20, 40, 60 and 80 DAP:

Number of plants showing apical leaf curl symptoms were counted in each plot/genotype and percent disease incidence was calculated as below:

$$\text{Apical leaf curl disease (\%)} = \frac{\text{No. of plants effected with apical leaf curl disease per plot}}{\text{Total number of plants per plot}} \times 100$$

The experiment was conducted in randomized block design. The data related to different characters were analyzed statistically by applying the Analysis of Variance Technique as suggested by Panse and Sukhatme (1957). To judge the significant difference between means of two treatments, the critical difference (C.D.) was worked out at 5% level of significance.

RESULTS AND DISCUSSION**Screening of potato genotypes to identify the sources of resistance to potato apical leaf-curl disease**

The apical leaf curl disease appeared after 30 DAP in Kufri Khyati (33.33%), K. Pukhraj (28.20%), CP 1588 (37.14%), AICRP-EM-3 (20.51%) (Table 1). At 40 days after planting, maximum disease was recorded in CP-1588 (60.00%) followed by Kufri Khyati (53.33%), Kufri Pukhraj (51.28) and AICRP-EM-3 (30.76%). The variety Kufri Sadabahar, Kufri Surya and AICRP-EM-1 showed 15.78, 7.50 and 7.50% disease incidence, respectively.

Rest 13 genotypes were free from potato apical leaf-curl disease. At 50 days of planting, the disease incidence increased in the susceptible genotypes and maximum incidence was observed in CP 1588 (68.57%) followed by Kufri Khyati (66.66%), Kufri Pukhraj (64.10) and AICRP-EM-3 (46.15%). There was also increased in the disease incidence in Kufri Sadabahar, AICRP-EM-1, and Kufri Surya, which was 18.42, 12.50 and 12.50%, respectively. Kufri Badshah showed the disease incidence at 50 days after planting which was 6.97%. Rest twelve genotypes/varieties were free from the disease. At 60 days after planting, the disease incidence increased and maximum incidence was recorded in Kufri Khyati (79.48%) followed by CP 1588 (77.14%), Kufri Pukhraj (76.92%) and AICRP-EM-3 (69.23%). The genotypes AICRP-EM-1, Kufri Surya, Kufri Badshah and Kufri Sadabahar exhibited less than 20 per cent disease incidence and the same twelve genotypes were free from the disease.

Table 1: Percent potato apical leaf curl disease (PALCD) incidence at 10 days interval of 20 days after planting

Varieties	PALCD 20 DAP	PALCD 30 DAP	PALCD 40 DAP	PALCD 50 DAP	PALCD 60 DAP	PALCD 70 DAP	PALCD 80 DAP
Kufri Bahar	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kufri Sadabahar	0.00	0.00	15.78	18.42	21.05	26.31	31.57
Kufri Badshah	0.00	0.00	0.00	6.97	13.95	18.60	20.93
Kufri Khyati	0.00	33.33	53.84	66.66	79.48	92.30	100
Kufri Pushkar	0.00	0.00	0.00	0.00	0.00	7.31	9.75
Kufri Pukhraj	0.00	28.20	51.28	64.10	76.92	87.17	100
Kufri Surya	0.00	0.00	7.50	12.50	17.50	20.00	22.50
Kufri Chipsona-2	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Kufri Frysona	0.00	0.00	0.00	0.00	0.00	0.00	0.00
AICRP-EM-1	0.00	0.00	7.50	12.50	20.00	22.50	25.00
AICRP-EM-3	0.00	20.51	30.76	46.15	69.23	82.05	97.43
HIS 98-19	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIS 98-34	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIS/98-55	0.00	0.00	0.00	0.00	0.00	0.00	0.00
HIS/98-58	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP 1588	0.00	37.14	60.00	68.57	77.14	91.42	100
CP 2370	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP 2379	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP 2378	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CP 2390	0.00	0.00	0.00	0.00	0.00	0.00	0.00

At 70 days of planting, Kufri Khyati (92.30%), CP 1588 (91.42%), Kufri Pukhraj (87.17%) and AICRP-EM-3 (82.05%) had the highest potato apical leaf-curl disease incidence. Kufri Sadabahar, AICRP-EM-1 and Kufri Badshah showed 26.31, 22.50 and 18.60% disease incidence, respectively. Kufri Surya had 20.00% disease incidence and Kufri Pushkar showed the symptoms at 70 days after planting having 7.31% disease incidence and rest were free from the disease. At 80 days of harvest, Kufri Khyati, Kufri Pukhraj and AICRP-EM-3 and CP 1588 showed 97 to 100% potato apical leaf curl disease incidence, while AICRP-EM-1, Kufri Sadabahar, Kufri Surya showed 25.00, 31.57 and 22.50% disease incidence, respectively. Kufri Badshah and Kufri Pushkar had 20.93% and 9.75% disease incidence, respectively. The rest of the genotypes namely, Kufri Bahar, Kufri Chipsona- 2, Kufri Frysona, HIS-98-19, HIS- 98-34, HIS -98-55, HIS -98-58, CP 2370, CP 2378, CP 2379 and CP 2390 were free from potato apical leaf-curl disease incidence. In a study conducted on screening of 180 accessions of potato against potato apical leaf-curl disease, one accession CP-1716 was resistant, while three accessions namely, CP 1813, CP 1818 and CP 1859 exhibited disease incidence <20%, and hence, moderately resistant³. Lakra¹⁰ also reported that the incidence of potato apical leaf-curl disease increased very slowly in Kufri Bahar, gradually in Kufri Jawahar, Kufri

Chandramukhi and Kufri Pushkar and rapidly in Kufri Khyati, Kufri Anand, Kufri Pukhraj, Kufri Sutlej, Kufri Ashoka and Kufri Badshah. **Evaluation of potato genotypes to identify the sources of resistance to potato apical leaf-curl disease**

The mean of sum of squares due to genotypes were highly significant (except leaf area index, plant vigour at 60 DAP and foliage senescence at harvest) for all the characters under study (Table 2) indicating sufficient genetic variation among the eight genotypes assessed, which suggested that the breeder can proceed for selection in the present material.

Growth parameters:

Percent plant emergence varied significantly among the selected genotypes at was recorded 30 DAP and ranged from 76.66 (CP 1588) to 96.11 (Kufri Pukhraj). Overall mean was 90.25%. Kufri Khyati and Kufri Sadabahar showed 88.88 and 83.33% plant emergence and rest showed more than 90% emergence (Table 3). At 45 DAP, the maximum plant height was recorded in Kufri Badshah (57.77 cm) followed by Kufri Sadabahar (40.19 cm). At 60 DAP, Kufri Badshah was significantly tallest (72.70 cm) among the genotypes followed by Kufri Sadabahar (48.70 cm), CP 1588 (46.77 cm), Kufri Pushkar (46.67 cm) and Kufri Khyati (46.00 cm). Significantly minimum plant height was recorded in Kufri Pukhraj 37.68 cm. Number of stems per hill was recorded significantly maximum in Kufri

Surya (4.90) followed by Kufri Pushkar (3.70), Kufri Badshah (3.63) and Kufri Pukhraj (3.60). Kufri Khyati exhibited minimum number of stems per hill (1.90). Number of leaves per hill ranged from 38.36 (Kufri Pukhraj) to 69.66 (Kufri Badshah). Overall mean was 52.92. Significantly maximum weight of leaves per hill was exhibited by 184.33 g (Kufri Badshah) followed by Kufri Pushkar (172.33 g) and Kufri Surya (156.00 g). The minimum weight of leaves per hill was recorded in 72.00 g (Kufri Pukhraj), Overall mean was 138.62 g. Weight of stem per hill (g) varied from 96.33 (Kufri Pukhraj) to 169.00 g (Kufri Badshah) with overall mean was 117.33 g. Phenotypic and genotypic coefficients of variance observed 15.73 and 24.47%, respectively.

Leaf area index ranged from 0.96 (CP 1588) to 1.85 (Kufri Badshah). Kufri Badshah exhibited significantly highest leaf area index (1.85) closely followed by Kufri Surya (1.83) which were statistically at par. CP 1588 showed significantly minimum leaf area index (0.96) closely followed by Kufri

Pukhraj (1.03) and Kufri Khyati (1.09). Among the genotypes Kufri Badshah produced significantly maximum weight (353.33 g) of foliage followed by Kufri Pushkar (289.00 g), Kufri Bahar (266.33 g) and Kufri Sadabahar (252.66 g). Kufri Pukhraj showed significantly lowest weight of foliage (168.33 g). Number of stomata per leaf varied from 2.33 to 7.33. The significantly highest number of stomata per leaf was observed in CP 1588 (7.33). Kufri Pukhraj had 4.33 number of stomata per leaf closely followed by Kufri Badshah (3.66), Kufri Khyati (3.33) and Kufri Sadabahar (3.33). Significantly minimum number of stomata per leaf was recorded in Kufri Pushkar (2.33) closely followed by Kufri Bahar (2.66). Plant vigor at 60 DAP ranged from 1.33 (CP 1588) to 3.66 (Kufri Badshah and Kufri Pushkar). Overall mean was 2.70. The maximum plant vigour was recorded in Kufri Badshah (3.66), Kufri Pushkar (3.66), Kufri Sadabahar (3.33) and Kufri Surya (3.00). CP 1588 and Kufri Pukhraj were poor in plant vigour, which showed 1.33 and 1.66, respectively.

Table 2: Analysis of variance (mean sum of squares) for different characters in potato

Source of variation	Replications	Varieties	Error
	d.f.		
	2	7	14
Per cent plant emergence 30 DAP	4.04	144.90**	8.58
Plant height (cm) 45 DAP	26.87	251.96**	0.95
Plant height(cm) 60 DAP	26.67	326.58**	0.96
Plant height(cm) 75 DAP	41.08	357.84**	0.45
Plant height 90 DAP	41.00	423.36**	0.95
Plant vigour 60 DAP	1.54	2.51	0.16
Number of stems per hill	5.16	24861**	0.16
Number of leaves per hill (g)	15374.62	34895.78**	6737.76
Weight of stem per hill (g)	619204.16	150666.66**	48361.31
Weight of leaves per hill (g)	460512.5	906064.28**	121669.64
Weight of foliage per hill (g)	1002837.5	421337.50**	115451.78
Leaf area index	0.03	0.36	0.01
Number of stomata	1.50	7.40**	0.40
Foliage senescence at harvest (%)	.003	1.48	0.01
Total yield (q/ha)	6528.12	23411.00**	927.18
Marketable yield (q/ha)	7385.48	20318.28**	1025.38
Harvest index (%)	43.26**	120.05**	8.53
Whitefly population 10 DAE	60.66*	5046.73**	37.81
Whitefly population 20 DAE	182.54	2430.23**	47.01
Whitefly population 30 DAE	0.79	12.80**	0.83
Per cent PALCD 40 DAP	28.12	1770.70**	8.41
Per cent PALCD 60 DAP	24.00	3627.50**	56.42
Per cent PALCD 80 DAP	11.29	4806.89**	19.14

**Significant at 1%

*Significant at 5%

DAP= Days after planting

DAE= Days after emergence

Table 3: Mean values of different characters in potato

Varieties	% Plant emergence at 30 DAP	Plant height at 45 DAP (cm)	Plant height at 60 DAP (cm)	Plant height at 75 DAP (cm)	Plant Height at 90 DAP (cm)	Plant vigour at 60 DAP	No. of stem per hill	No. of leaves per hill	Weight of stem per hill (g)
Kufri Bahar	95.98	35.13	45.60	53.57	58.47	3.00	2.66	50.06	118.00
Kufri Pushkar	93.33	37.64	46.67	54.03	58.83	3.66	3.70	51.01	116.66
Kufri Surya	93.32	30.50	42.31	47.34	54.52	3.00	4.90	53.16	99.33
Kufri Pukhraj	96.11	26.84	37.68	43.87	48.73	1.66	3.60	38.66	96.33
Kufri Khyati	88.88	36.27	46.00	53.31	53.39	2.00	1.90	42.96	111.00
Kufri Sadabahar	83.33	40.19	48.70	56.70	62.20	3.33	2.60	50.80	111.00
Kufri Badshah	94.44	57.77	72.70	80.42	87.94	3.66	3.63	69.60	169.00
CP 1588	76.66	37.23	46.77	55.30	60.22	1.33	3.10	67.30	117.33
CD (5%)	5.18	1.73	1.74	1.18	1.72	0.70	0.48	14.53	38.88
SE (m)	2.39	0.80	0.80	0.54	0.79	0.32	0.22	6.70	17.95

Table 3. (Contd...)

Varieties	Weight of foliage per hill (g)	Weight of Leaves per hill (g)	Leaf Area Index	Number of stomata per leaf	Foliage senescence (%)	Total yield (q/ha)	Marketable yield (q/ha)	Harvest Index (%)
Kufri Bahar	266.33	148.33	1.46	2.66	3.23	325.04	316.89	66.50
Kufri Pushkar	289.00	172.33	1.30	2.33	2.16	426.24	397.63	68.91
Kufri Surya	233.66	156.00	1.83	3.00	2.22	326.34	317.88	65.58
Kufri Pukhraj	168.33	72.00	1.03	4.33	2.52	320.69	273.74	68.09
Kufri Khyati	207.66	96.66	1.09	3.33	2.54	229.48	217.77	65.49
Kufri Sadabahar	252.66	141.66	1.55	3.33	2.24	343.14	336.89	64.80
Kufri Badshah	353.33	184.33	1.85	3.66	4.18	406.94	373.97	61.90
CP 1588	255.00	137.66	0.96	7.33	2.25	155.46	148.22	49.05
CD (5%)	61.67	60.07	0.23	1.12	0.19	53.84	56.62	5.17
SE (m)	28.48	19.61	0.07	0.51	0.08	24.86	26.14	2.38

Significant at 5%

Foliage senescence at harvest ranged from 2.16 (Kufri Pushkar) to 4.18 (Kufri Badshah). Significantly maximum foliage senescence was recorded in Kufri Badshah (4.18) closely followed by Kufri Bahar (3.23) which were statically at par. For rest of the genotypes, foliage senescence varied from 2.62 to 2.54 which were statistically at par. Overall mean was 2.67. Lakra¹⁰ reported that the incidence of potato apical leaf-curl disease increased very slowly in Kufri Bahar, gradually in Kufri Jawahar, Kufri Chandramukhi and Kufri Pushkar and rapidly in Kufri Khyati, Kufri Anand, Kufri Pukhraj, Kufri Sutlej, Kufri Ashoka and Kufri Badshah. The most deleterious effect was observed on reduction in leaf area, chlorophyll content, plant height, number of stems per plant, number of tubers per plant and weight of tubers per plant⁸.

Tuber yield parameters:

The genotypes showed significant difference for all the parameters studied. Total tuber yield

ranged from 155.46 to 426.24 q/ha. Overall mean was 316.66 (Table 3). Kufri Pushkar produced maximum total tuber yield 426.24 q/ha closely followed by Kufri Badshah (406.94 q/ha) which were statistically at par. The marketable yield was found significantly maximum (393.66 q/ha) in Kufri Pushkar closely followed by Kufri Badshah which was statically at par. Overall mean was 297.84 q/ha. CP 1588 recorded significantly minimum marketable yield (148.22 q/ha) followed by Kufri Khyati (217.77 q/ha) and Kufri Pukhraj (273.74 q/ha). Maximum harvest index (68.91%) was observed in Kufri Pushkar which was closely followed by Kufri Pukhraj (68.09%), Kufri Bahar (66.50%), Kufri Surya (65.98%), Kufri Khyati (65.49%) and Kufri Sadabahar (64.80%). Overall mean was 63.79%. CP 1588 showed significantly minimum harvest index (49.05%). Lakra (2009) reported that Kufri Bahar being a resistant cultivar had lowest degeneration

(yield reduction 4.5%). However, Kufri Chandramukhi, Kufri Jawahar, Kufri Badshah, Kufri Suttlej and Kufri Pushkar exhibited moderate reduction (17-19%) and rest of the cultivars namely Kufri Anand, Kufri Khyati, Kufri Ashoka and Kufri Pukhraj showed maximum reduction (45-61%) in yield after 5 years of exposure to the disease.

Whitefly population at 10 days interval after emergence:

There was significant difference among the genotypes with regard to whitefly population which ranged from 10.00 (Kufri Surya) to 116.66 (CP 1588) at 10 days after emergence. Overall mean was 49.41. CP 1588 showed highest number of whitefly population 116.66 closely followed by Kufri Khyati (96.66) which were statically at par (Table 4). Significantly, lower numbers of whiteflies were counted Kufri Surya followed by Kufri Badshah (19.33), Kufri Bahar (26.00) and Kufri Pushkar (35.00). Whitefly population decreased at 30 days after emergence and ranged from 2.33 (Kufri Surya) to 79.33 (CP 1588). Overall mean was 29.25. Kufri Badshah (7.33) Kufri Sadabahar (7.33), Kufri Bahar (15.00) and Kufri Pushkar (16.00) had lower whitefly population. Lakra⁹ also observed that crops sown after mid November had lower PALCV disease incidence and whitefly infestation. The crops sown in October had higher disease incidence and

whitefly infestation. A positive and significant correlation has been observed between the tomato leaf-curl virus disease incidence and whitefly numbers⁴.

Percent potato apical leaf-curl disease incidence at 20, 40, 60 and 80 DAP:

There was no disease at 20 DAP. Significant differences were recorded among the genotypes for per cent potato apical leaf-curl disease incidence which ranged from 0.00 (Kufri Bahar) to 35.66% (CP 1588) at 40 DAP (Table 4). Overall mean was 16.25%. Kufri Khyati and Kufri Pukhraj showed 27.33 and 26.66% per cent potato apical leaf-curl disease incidence respectively while rest of the varieties showed less than 5%. At 60 days after planting there was significant difference among the genotypes which ranged from 0.00 (Kufri Bahar) to 69.33% (CP 1588). Overall mean was 36.25%. Kufri Pukhraj and Kufri Khyati 63.66 and 66.66% disease incidence respectively, while Kufri Surya and Kufri Sadabahar had 15.89 and 12.33% disease incidence. Lower disease incidence was noted in Kufri Pushkar (6.66%) and Kufri Sadabahar (12.33%). Lower disease incidence in Kufri Badshah (6.66%) and Kufri Pushkar (6.66%). At 80 days after planting per cent potato apical leaf curl disease incidence ranged from 0.00 (Kufri Bahar) to 100% (CP 1588). Overall mean was 50.29%.

Table 4: Mean values of whitefly population and per cent apical leaf curl disease incidence in potato

Varieties	Whitefly population			Potato apical leaf curl disease incidence at 40 DAE (%)	Potato apical leaf curl disease incidence at 60 DAE (%)	Potato apical leaf curl disease incidence at 80 DAE (%)
	at 10 DAE	at 20 DAE	at 30 DAE			
Kufri Bahar	26.00	15.00	3.66	0.00	0.00	0.00
Kufri Pushkar	35.00	16.00	4.00	3.66	6.66	9.33
Kufri Surya	10.00	2.33	1.33	5.00	15.89	19.67
Kufri Pukhraj	75.66	46.66	9.33	26.66	63.66	95.00
Kufri Khyati	96.66	58.66	9.66	27.33	66.66	100.00
Kufri Sadabahar	16.00	9.00	3.00	6.33	12.33	33.66
Kufri Badshah	19.33	7.33	3.33	3.33	6.66	12.66
CP 1588	116.66	79.33	14.00	35.66	69.33	100
CD (5%)	10.87	12.07	1.62	5.12	13.28	7.73
SE (m)	5.02	5.57	0.74	2.36	6.13	2.18

Significantly maximum disease incidence was recorded in CP 1588 (100%) closely followed by Kufri Khyati (100%) and Kufri Pukhraj (95%) which were statistically at par and they were considered highly susceptible genotype. Kufri Bahar was completely free from disease (0.00%) while Kufri Pushkar showed (9.33%) less than 10% and considered as resistant variety. Kufri Badshah (12.66%) was considered as moderately resistant Kufri Sadabahar showed (33.00%) more than 20% disease incidence and considered as susceptible variety. Lakra⁷ reported that with 100 per cent disease incidence of PALCV, more than 50 per cent losses in yield has been reported in early sown crop of potato cultivar Kufri Ashoka. Lakra⁹ observed that crops sown after mid November had lower PALCV disease incidence while, crops sown in October had higher disease incidence.

It is concluded that among the twenty genotypes screened under field conditions in the present study against PALCD, the genotype Kufri Bahar, Kufri Chipsona-2, Kufri Frysona, HIS-98-19, HIS-98-34, HIS-98-55, HIS-98-58, CP 2370, CP 2378, CP 2379 and CP 2390 were highly disease resistant. Out of the 20 genotypes, eight varieties were studied in detail and Kufri Pushkar and Kufri Badshah were superior for plant growth and yield. Low population of whitefly and less number of stomata were the main characters, which contributed towards potato apical leaf-curl disease resistance. The genotypes were identified resistant to apical leaf curl disease incidence can be exploited for developing high yielding and disease resistant varieties in potato.

Acknowledgements

The authors express their deep sense of gratitude to Dr. R. K. Pannu, Dean, COA, CCSHAU, Hisar for providing necessary facilities for carrying out the research work and feel grateful to the faculty members of the Department of Vegetable Science and Statistics for their needful help.

REFERENCES

1. Anonymous: Area and production of vegetable Crops in Haryana during 2010-11. Directorate of Horticulture, Punchkula, Govt. of Haryana (2011a).
2. Anonymous: Directorate of Economics and statistics, during 2010-11. Ministry of Agriculture, Potato in India, Govt. of India FAOSTAT at 3. FAO. Org (2011b).
3. Baswana, K. S., Bhatia, A. K. and Gupta, A.: *Biennial Progress Report of AICRP (potato)* Hisar for the year 2007-09. Department of Vegetable Science, CCS HAU, Hisar, 28 p. (2009).
4. Borah, R. K. and Bardoloi, D. K.: Influence on planting time on the incidence of leaf-curl virus disease and whitefly population on tomato. *Indian J Virol.*, **14(1)**: 71-73 (1998).
5. Garg, I. D., Kumar, S., Khurana, S. M. P. and Lakra, B. S.: Association of geminivirus with potato apical leaf curl in India and its immuno-electron microscopic detection. *J. Indian Potato Assoc.*, **28(2-4)**: 227-232 (2001).
6. Khurana, S. M. P.: Potato viruses and viral diseases. *Technical Bull. No. 35(Revised)*, CPRI, Shimla, 94 p. (1999).
7. Lakra, B. S.: Leaf-curl: A threat to potato crop in Haryana. *J Myco Pl Pathol.*, **32**: 367 (2002).
8. Lakra, B. S.: Potato apical leaf-curl begomovirus- symptom, appraisal of a scale and losses in potato crop. *J. Indian Potato Assoc.*, **30(1-2)**: 119-120 (2003a).
9. Lakra, B. S.: Effect of date of planting on whitefly population, leaf-curl incidence and yield of potato cultivars. *J. Indian Potato Assoc.*, **30(1-2)**: 115-116 (2003b).
10. Lakra, B. S.: Degeneration of potato cultivars due to potato apical leaf-curl virus disease. *J Myco Pl Pathol.*, **39(3)**: 548 (2009).
11. Panse, V. G. and Sukhatme, P. V.: *Statistical Methods for Agricultural Workers*. ICAR Publication, New Delhi, India (1995).
12. Wooster, P. and Farooq, K. .: National programme of germplasm screening general instruction for trial and guide to data collection. Pak-Swiss Potato Development Project, PARC, Islamabad, Pakistan, 24 p. (1995).