Potato J (2020) 47 (1): 54-58

SCREENING FOR HOLLOW HEART IN POTATO (*SOLANUM TUBEROSUM* L.) GENOTYPES

SK Luthra*, VK Gupta[1] and Mehi Lal[1]

ABSTRACT: Hollow heart, a physiological disorder, impacts tuber quality and make marketable tubers unattractive and can have adverse effect on marketability of the produce. The investigation on one hundred eight(108) potato genotypes for presence of hollow heart symptoms revealed that 77 genotypes (71%) were free from hollow heart symptoms, while remaining 31 genotypes (29%) showed presence of 10-100% hollow heart symptoms. Most of the indigenous varieties and advanced clones were free from hollow heart symptoms. Screening of 5-10 medium sized tubers (80-100 gram) per genotype depending upon availability of tubers in initial or advanced clonal stages would be realistic approach for screening of hollow heart in potatoes. Parental line selected for hybridization in potato breeding must be free of hollow heart to achieve the desirable gain in the segregating population.

KEYWORDS: Hollow heart, quality, marketability, parental lines, advanced clones, potatoes

Potato (*Solanum tuberosum* L.) is the third most important food crop after rice and wheat. The change in global climate scenario associated with abiotic stresses is causing hollow heart, black heart, frost injury etc. Brown center and hollow heart are internal noninfectious physiological disorders characterized by a cavity in the pith region of the tuber. Development of the disorder is often associated with rapid tuber growth that may be preceded by a period of moisture or nutritional stress. Brown center (also known as incipient hollow heart, brown heart, or sugar center) is characterized by a region of cell death in the pith of the tuber that results in brown tissue. The brown center is initiated when tubers are small and tuber weight is about 60g. The hollow-heart may occur in the center or near the stem or bud end of the tubers, depending on when disorder is initiated (Stevenson *et al*., 2001).

The hollow heart is characterized by a star- or lens-shaped hollow in the center of the tuber (Hiller *et al*., 1985). The probability of brown center incidence that results in hollow heart is based on the rate of tuber growth following a period of stress (Hiller *et al*., 1985). The larger the tuber and the faster it grows, the greater the susceptibility of the tuber to incidence of hollow heart. The soil temperature below 13°C for 5 to 7 days during tuber initiation and early enlargement is known to be favourable for development of hollow heart. Generally it occurs under the condition of rapid tuber growth followed by period of slow growth (Wale *et al*., 2008). Over fertilization, excessive rainfall or irrigation, and too wide spacing of plants can contribute to hollow heart (Rich, 1983). Over doses of nitrogen application and deficiency of potassium also implicates this disorder.

The hollow heart and brown center negatively impact tuber quality and make cut fresh-market tubers unattractive and can have adverse effect on repeat sales. The crops for ware or processing are rejected sometimes due to presence of hollow heart. However, it does not affect the tuber's taste or nutrition, but may reduce the shelf life of the tubers during storage. Since large tubers are more prone to develop the disorder, and wide interplant spacing produces larger tubers, this situation

[1]ICAR-Central Potato Research Institute, Regional Station, Modipuram-250110, Meerut, Uttar Pradesh, India.
*Corresponding author:skluthra@hotmail.com

can result in higher incidence of hollow heart (Christ, 1998). Thus tuber appearance and internal defects of tubers play important role in marketability of the produce. This defect reduces tuber quality, resulting in economic loss to growers and processors. Incidence of hollow heart can be managed by varietal selection, planting distance, rate and timing of fertilizer application, and control of soil moisture. Selecting potato varieties that are known to be less susceptible and delaying planting until soil temperature reaches adequate levels can lessen the occurrence of brown center and hollow heart (Christ, 1998).

In breeding programme, clones having external defects like knobbiness, cracks, tuber shape irregularities etc are rejected from seedling stage onward, however, internal defects are given attention in advanced clonal stages, where enough tubers of manageable entries are available. The genesis of the present investigation started during harvest of advanced clonal stage in February 2017, where one of the advanced clone having passed six clonal stages showed majority of the tubers with hollow heart symptoms. Keeping above in mind, it was decided to examine all the advanced clones/varieties having enough tubers for presence of hollow heart in tubers.

A total of 108 genotypes along with eleven cultivars (Kufri Arun, Kufri Badshah, Kufri Bahar, Kufri Garima, Kufri Lalima, Kufri Lalit, Kufri Mohan, Kufri Pukhraj, Kufri Sindhuri, Kufri Surya and Atlantic) were screened for hollow heart during 2016-17 at ICAR-Central Potato Research Institute, Regional Station, Modipuram Meerut (29.1°N, 77.92°E, 300 masl). These genotypes were planted in the third week of October, 2016 at 60×20 cm spacing. The crop was raised following the standard agronomic practices (180N, 80P, 100K kg/ ha) of the regions with proper application of plant protection measures. Climatic parameters *viz*., minimum and maximum temperature, sunshine hours and rainfall were recorded from the meteorological laboratory during crop growth period. The day and night temperatures were estimated using Went' equation (1957):

Day temp. = t^0_{max}-1/4 (t^0_{max} - t^0_{min}) ; Night temp. = t^0_{min} + 1/4 (t^0_{max} - t^0_{min})

Maximum and minimum temperatures during the potato growing season ranged between 13.5-35°C and 2.5-17°C, respectively. The day (20.5°C) and night (13.75°C) temperature calculated as per formula of Went, 1944 reflected reduction of 2.75 to 4.5°C in maximum and augment of 2.75 to 4.5°C in minimum temperature. Total mean rainfall of 31 mm was recorded on two occasions during the crop period. During crop season at Modipuram, 1155 accumulated degree day were recorded. The haulms were cut after 90 days of planting and the crop was harvested two weeks after dehaulming.

Though the oversized tubers are more affected compared to medium and large-sized tubers (Abbas and Ranjan, 2015), but medium sized tubers constitute the major part of produce, traded and utilized for consumption. Therefore, medium sized (80-100 gram) 10 tubers were drawn randomly from each genotype at harvest for recording affected tubers with hollow heart. The tubers were half cut longitudinally from end to end with help of sharp knife. The hollow heart incidences were calculated as under-

Hollow heart (%) = (Number of hollow heart affected tubers/Total number of tubers) × 100

The result on screening of potato genotypes for hollow heart reflected presence of hollow heart characterized by a star shaped cavities or hollow in the centre of the tubers corresponding mostly to longitudinal direction of the cut tubers. The genotypes were grouped in to seven categories (no hollow heart to severity of hollow heart-10, 20, 40, 60, 80 and 100%) based on absence and presence/severity of the hollow heart in longitudinally cut tubers. As many as seventy

seven (77) of the 108 genotypes (71%) screened were found free from hollow heart symptoms, while remaining 31genotypes (29%) showed presence of 10-100% hollow heart symptoms **(Table 1)**. The genotypes devoid of hollow heart symptoms included 24 exotic germplasm lines from International Potato Center, Lima, Peru (CP4388, CP4389, CP4393, CP4395, CP4396, CP4398, CP4401, CP4423, CP4490, CP4491, CP4494, CP4495, CP4496, CP4498, CP4500, CP4503, CP4505, CP4510, CP4512, CP4513, CP4516, CP4517, CP4520, CP4521), ten indigenous varieties (Kufri Arun, Kufri Badshah, Kufri Bahar, Kufri Garima, Kufri Lalima, Kufri Lalit, Kufri Mohan, Kufri Pukhraj, Kufri Sindhuri, Kufri Surya and 44 advanced clones (MCIP/10-15, MCIP/11-163, MCIP/12-286, MCIP/13-21, MCIP/13-46, MCIP/13-96, MCIP/12-185, MCIP/12-453, MCIP/13-64, MP/10-123, MP/11-472, MP/12-175, MP/12-209, MP/12-415, MP/12-452, MP/12-457, MP/12-57, MP/9-21, MP/9-36, MS/11-664, MS/12-1283, MS/12-2116, MS/12-2241, MS/12-655, MS/12-935, MS/13-110, MS/13-132, MS/13-148, MS/13-149, MS/13-168, MS/13-287, MS/13-391, MS/13-401, MS/13-404, MS/13-496, MS/13-518, MS/13-527, MS/13-529, MS/13-540, MS/13-542, MS/13-576, MS/13-582, MP/13-100) from table and processing breeding programme. This indicates the due attention has been paid to develop and release indigenous potato varieties devoid of internal defects specifically hollow heart. It is interesting that most of the cultivated varieties fall under the nil category of hollow heart, except Atlantic. Brar and Rana (2016) evaluated storability and sprouting behaviour of three grades (small, medium and large) tubers of four cultivars. *i.e*. Kufri Bahar, Kufri Pukhraj, Kufri Pushkar and Kufri Badshah under storage condition and reported no symptom of black heart or hollow heart on these varieties. Although this study was under storage and present study was under field condition.

Thirty one (31) genotypes with symptoms of hollow heart are cause of concern as degree of hollow heart symptoms is known to be dependent on genotype, abiotic stresses (water stress or high temperature), crop management

Table 1. Screening for hollow heart in potato genotypes at Modipuram

Hollow heart affected tubers (%)	No of genotypes	Genotypes (%)	Name of genotypes
0 (Nil)	77	71.30	CP4388, CP4389, CP4393, CP4395, CP4396, CP4398, CP4401, CP4423, CP4490, CP4491, CP4494, CP4495, CP4496, CP4498, CP4500, CP4503, CP4505, CP4510, CP4512, CP4513, CP4516, CP4517, CP4520, CP4521, Kufri Arun, Kufri Badshah, Kufri Bahar, Kufri Garima, Kufri Lalima, Kufri Lalit, Kufri Mohan, Kufri Pukhraj, Kufri Sindhuri, Kufri Surya, MCIP/10-15, MCIP/11-163, MCIP/12-286, MCIP/13-21, MCIP/13-46, MCIP/13-96, MCIP/12-185, MCIP/12-453, MCIP/13-64, MP/10-123, MP/11-472, MP/12-175, MP/12-209, MP/12-415, MP/12-452, MP/12-457, MP/12-57, MP/9-21, MP/9-36, MS/11-664, MS/12-1283, MS/12-2116, MS/12-2241, MS/12-655, MS/12-935, MS/13-110, MS/13-132, MS/13-148, MS/13-149, MS/13-168, MS/13-287, MS/13-391, MS/13-401, MS/13-404, MS/13-496, MS/13-518, MS/13-527, MS/13-529, MS/13-540, MS/13-542, MS/13-576, MS/13-582, MP/13-100
10	4	3.70	CP4404, CP4406, CP4493, CP4514
20	6	5.56	CP4386, CP4397, CP4499, CP4504, CP4509, Atlantic
40	8	7.41	CP4492, CP4497, CP4502, CP4507, CP4508, CP4519, MS/12-682, MCIP/12-47
60	6	5.56	CP4501, CP4506, CP4511, MCIP/13-90, MCIP/13-108, MCIP/13-112
80	4	3.70	CP4515, MS/11-938, MS/11-1123, MS/12-636
100	3	2.78	CP4403, CP4518, MCIP/11-118

(spacing, fertilizers and irrigations) and environmental factors specifically temperature. Four exotic genotypes (4%) namely CP4404, CP4406, CP4493, CP4514 showed hollow heart symptoms in 10% of tubers. Six exotic genotypes (6%) namely CP4386, CP4397, CP4499, CP4504, CP4509 and Atlantic reflected hollow heart symptoms in 20% of tubers. Rex and Mazza (1989) also found Atlantic as highly susceptible variety to hollow heart in the Prairie Provinces. The author also noted moderate degree of hollow heart in medium to large sized tubers in exotic processing variety Atlantic in West Bengal (winter season crop) and Maharashtra (*kharif* season crop). Eight genotypes (7%) namely CP4492, CP4497, CP4502, CP4507, CP4508, CP4519, MS/12-682, MCIP/12-47 reflected hollow heart symptoms in 40% of tubers. Six genotypes (6%) namely CP4501, CP4506, CP4511, MCIP/13-90, MCIP/13-108 and MCIP/13-112 showed 60% infected tubers with hollow heart symptoms. The presence of 80% infected tubers with hollow heart was recorded in four genotypes (4%) namely CP4515, MS/11-938, MS/11-1123, MS/12-636; whereas three genotypes (3%) namely CP4403, CP4518, MCIP/11-118 (**Fig. 1**) recorded all the tubers (100%) infected severely with hollow heart.

The presence of hollow heart (20-100%) in 27 genotypes including the known susceptible exotic variety Atlantic pose a serious concern for plant breeders, while making selection for attaining high productivity. In initial clonal generations of potato breeding programme, availability of limited number of tubers per clones pose a restriction for sparing tubers for screening of hollow heart, which require examination of longitudinally cut tubers. Potato breeders, often use small size/number of tubers in initial clonal stages which do not predict the actual symptoms of hollow heart. Gopal and Khurana (2006) advised that selection for highly heritable traits like tuber skin and flesh colour, tuber shape, cracking and eye depth can be initiated at the seedling stage to reduce the plant population in subsequent generations for more effective selection. Tuber yield is not representative in initial clonal generations due to insufficient and non-uniform experimental material/plots size, and thus it is not considered in early clonal generations (Luthra *et al.*, 2020). Abbas and Ranjan (2015) reported that oversized tubers are more affected compared to medium and large-sized tubers. McCann and Stark (1989) reported Russet Burbank susceptibility to both brown center and hollow heart was highest soon after tuber initiation when the tubers are small. Management can affect the incidence of hollow heart by such methods as choice of cultivar, plant spacing, rate and

Fig. 1. Potato genotypes with severe (100%) hollow heart symptom

timing of fertilizer application, and control of soil moisture (Rex and Mazza, 1989). Planting with larger seed pieces that are less aged can also reduce brown center and hollow heart risk because of increased stem number per seed piece (Hiller and Thornton 2008; Rex and Mazza 1989). Bussan (2007) stressed that hollow heart resistance will become more important and hollow heart susceptibility greater than present in currently adapted varieties will prevent the adaptation of most new variety releases. Frequent occurrence of defects such as hollow heart, growth cracks, and brown spot, devastates potato production, therefore lines having such severe defects are eliminated at early breeding stages (Kazuyuki *et al*., 2015).

In Indian conditions, where marketable sized tuber constitute nearly 85-90% of productivity, thus screening of 5-10 medium sized tubers (80-100g) depending upon availability of tubers in advanced clonal stages would be realistic approach for screening of hollow heart in potatoes. Superior parents being utilized in breeding programme should be devoid of hollow heart to achieve the desirable breeding gain in the population.

CONCLUSION

In conclusion, seventy seven (72%) of the 108 genotypes screened were found free from hollow heart symptoms, while remaining 31 genotypes (28%) showed presence of 10-100% hollow heart symptoms. Most of the indigenous varieties and advanced clones were found free hollow heart symptoms. Therefore screening of parental lines and segregating population is desirable to identify and develop clones/ varieties devoid of hollow heart to achieve the desirable breeding gain in potatoes.

LITERATURE CITED

Abbas H and Ranjan RS (2015) Effect of soil moisture deficit on marketable yield and quality of potatoes. *Can Biosyst Eng* **57**: 1.25-1.37

Brar A and Rana MK (2016) Effect of different potato varieties and tuber sizes on physiological changes under ambient storage performance. *J Appl Nat Sci* **8** (2): 736-742

Christ BJ (1998) Identifying potato diseases in Pennsylvania. Penn State College of Agricultural Sciences. http://pubs.cas.psu.edu/FreePubs/pdfs/agrs75.pdf (April 2018)

Busan AJ (2007) Brown centre and hollow heart (The canon of potato science). *Potato Res* **50**: 395-398

Gopal J and Khurana SMP (2006) Handbook of potato production, improvement, and postharvest management. CRC Press: 606p

Hiller LK and Thornton RE (2008) Managing physiological disorders. In, Potato health management: Plant health management series. Johnson DA (ed), St. Paul, MN: The American Phytopathological Society: 235-245

Hiller LK, Koller DC and Thornton RE (1985) Physiological disorders of potatoes. *In, Potato Physiology*. Li PH (ed), Academic Press, New York: 389-455

Kazuyuki M, Kenji A, Seiji T, Takashi N and Motoyuki M (2015) Challenges of breeding potato cultivars to grow in various environments and to meet different demands. *Breed Sci* **65**: 3-16

Luthra SK, Gupta VK, Tiwari JK, Kumar V, Bhardwaj V, Sood S, Dalamu, Kaur RP, Kumar R, Vanishree G, Kumar D, Mhatre P and SK Chakrabarti SK (2020) Potato breeding in India. CPRI Technical Bulletin No 74 (revised), ICAR-CPRI, Shimla, Himachal Pradesh, India, 214p

McCann IR and Stark JC (1989) Irrigation and nitrogen management effects on potato brown center and hollow heart. *Hort Science* **24**(6): 950-952

Rex BL and Mazza G (1989) Cause, control and detection of hollow heart in potatoes: A review. *Am Potato J* **66**(3): 165-183

Rich AE (1983) Potato diseases. Academic press Inc, New York: 163p

Stevenson WR, Loria R, Franc GD and Weingartner DP (2001) Compendium of potato diseases. Second ed. APS press: 88p

Wale S, Platt HW and Cattlin N (2008) Diseases, pests and disorders of potatoes- A colour hand book. Manson Publishing Limited, London: 165p