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Evaluation of heat tolerant potato (*Solanum tuberosum* L.) genotypes for growth, yield and quality parameters

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Abstract
A field experiment was conducted to identify heat tolerant potato genotypes suitable for cultivation in high temperature regions of South India. Eight potato genotypes (HT/14-95, HT/14-109, HT/12-834, HT/16-113, HT/12-116, HT/10-1554, HT/12-830 and HT/15-240) along with Kufri Surya as check were evaluated during *rabi* season of 2020-21 at College of Horticulture, Dr. YSR Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh. Experiment was laid out in RBD design with four replications. Genotypes HT/12-834, HT/15-240, and HT/14-109 performed better over other genotypes for growth attributes. Maximum number of tubers per plant was recorded in HT/12-834 while highest diameter of tubers and maximum average tuber weight were recorded in HT/10-1554. Membrane stability index was observed highest in Kufri Surya while highest chlorophyll content and chlorophyll stability index were recorded in genotype HT/12-830. Genotypes HT/12- 830, HT/12-834, and HT/15-240 were found significantly superior over the check variety Kufri Surya for total and marketable yield of tubers per hectare, while the genotypes HT/14-109 and HT/12-116 were found on par with it. Highest dry matter content was recorded in genotype HT/15-240 while Vitamin C content was found maximum in genotype HT/12-830. Lowest amount of reducing, non-reducing and total sugar content were observed in HT/14-109. In sensory evaluation, genotype HT/15-240 ranked first followed by HT/12-830 and HT/12-116 for consumer acceptance of boiled tubers while Kufri Surya ranked first for chips quality followed by genotypes HT/10-1554 and HT/14-109.

Keywords: Potato**,** heat tolerant genotypes, membrane stability index, chlorophyll stability index

Introduction
Potato (*Solanum tuberosum* L.) is a thermo sensitive crop and hence its cultivation is restricted to relatively cooler areas and seasons around the world. In India, about 80% of total potato production is in the north-western Indo-Gangetic plains during winter. About 10% is produced in Himalayas and Nilgiri hills during summer and production in the warmer plateau region during the rainy season as well as winter accounts for only 7%. Even though it is consumed on par with other vegetables, potato is not widely grown in the southern states of India, except in Nilgiri hills of Tamil Nadu, few districts of Karnataka (subtropical region) and a very limited area in Andhra Pradesh (some parts of Chittoor district and hills of Visakhapatnam district) and hills of Kerala (Rao, 2018) [9].

Genotype, temperature, and day length are the three important factors that determine flowering and tuberization in potato. For tuber development, night temperature is more crucial than day temperature. Tuberization is reduced at night temperature of 20 ℃ and there may not be any tuberization at night temperature of 25 ℃ and above. 10-17 ℃ is regarded as the optimum temperature for tuber formation. Potato can be successfully cultivated in high altitude areas during the winter season. However, its cultivation is almost negligible in plain lands of southern subtropical states, where the average day and night temperature is about 30 ℃ and 20-25 ℃ respectively. For successful cultivation of potato in non-traditional warmer areas, new varieties have to be developed that could tuberize well under high temperatures. Therefore, in view of the above facts, the present investigation was carried out to evaluate potato genotypes for their growth, yield, tuber quality and heat tolerance ability.

Materials and Methods
A field experiment was conducted at College of Horticulture, Dr. YSR Horticultural University, Venkataramannagudem, West Godavari district, Andhra Pradesh during *rabi* season of 2020-21 to evaluate growth, yield, quality and heat tolerance of different potato

genotypes. The experimental site is located in Krishna-Godavari agro-climatic zone of Andhra Pradesh at 17.4 °N latitude and 78.48 °E longitude with an altitude of 18 m above mean sea level. Annual rainfall of this region is about 880-1100 mm. The maximum temperature of this zone ranges from 29 to 42 ℃ and the minimum temperature ranges from 16 to 24 ℃. Experiment was conducted on red sandy loam soil having a pH of 6.8. Eight potato genotypes *viz.*, HT/14-95, HT/14-109, HT/12-834, HT/16-113, HT/12-116, HT/10-1554, HT/12-830, and HT/15-240 were procured from CPRI, Modipuram and evaluated along with heat tolerant variety Kufri Surya as check. A randomized block design was adopted with nine treatments and four replications. The maximum and minimum temperature on daily basis during the crop season has been averaged and presented in Figure-1. Ten plants were selected randomly from each treatment. Observations from these ten plants were recorded and the average was calculated.

Observations were recorded on growth parameters such as plant emergence at 30 DAP, plant height and plant spread at 60 DAP, number of shoots, number of nodes and total number of leaves per plant, leaf area, leaf area index, and average growth rate (AGR). Chlorophyll content of leaves was measured using SPAD meter. The modified method outlined by Nagarajan and Bansal (1986) [7] was used to study the Membrane stability index (MSI), where the electrical conductivity of the bathing medium before and after heat treatment due to leakage of total inorganic ions (mainly K+) were measured using an electrical conductivity meter. Chlorophyll stability index was estimated as per procedure given by Murthy and Majumdar (1962) [6].

Yield parameters *viz.* number of tubers per plant, diameter of tubers, average tuber weight, marketable and total yield per plant, and marketable and total yield per hectare were recorded and expressed in corresponding units. Tubers having more than 20 g weight were selected for determining the marketable yield. Dry matter (%), vitamin C (mg/100g), reducing sugar, non-reducing sugar and total sugar (%) of healthy, fully cured and uniform sized tubers were estimated. For sensory evaluation of boiled tubers and chips organoleptic test was conducted as per procedure given by Gupta *et al.* (2015) [3]. Statistical analysis of recorded data was carried out using OPSTAT software developed by CCS HAU, Hisar.

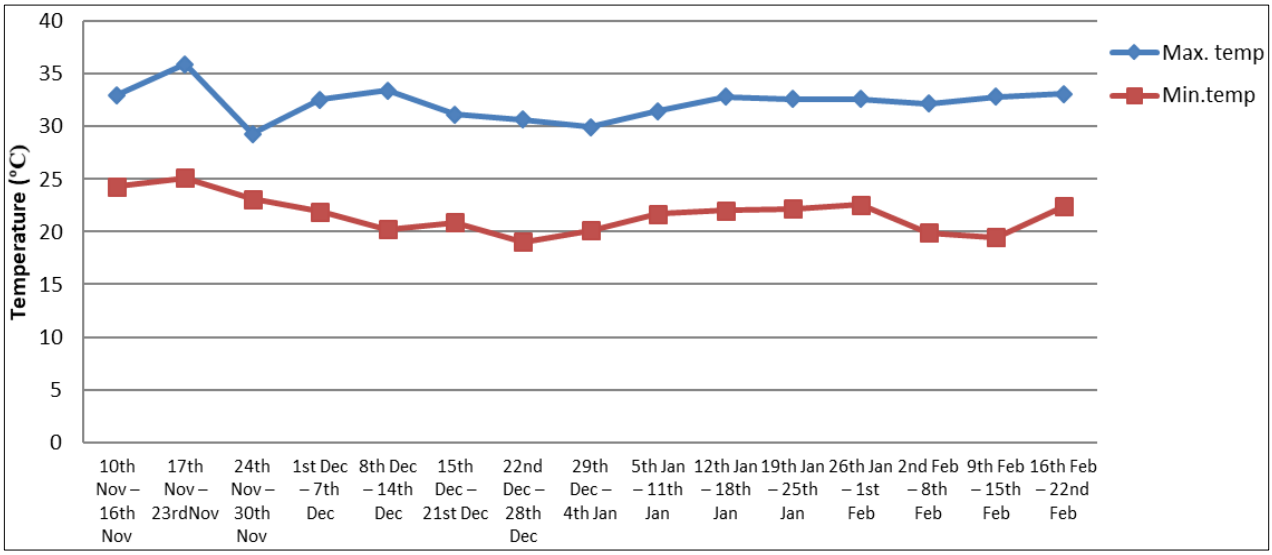

Fig 1: Average weekly temperature (minimum and maximum) recorded during the crop season (2020-21)

Results and Discussion

Growth attributes

Data presented in table revealed that, all genotypes had recorded statistically similar values for plant emergence, except HT/10-1554 and HT/14-95 (Table-1). HT/15-240 had significantly the highest plant height at 60 DAP which was on par with HT/12-834 while the lowest plant height was observed in HT/16-113. Maximum plant spread was recorded in genotype HT/12-834 which was found on par with genotype HT/12-116. Plant spread was recorded the lowest in genotype HT/16-113.

Table 1: Growth parameters of potato genotypes

Treatments	Plant emergence (%) at 30 DAP	Plant height (cm) at 60 DAP	Plant spread (cm) at 60 DAP	No. of shoots per plant	No. of nodes per plant	Total number of leaves per plant	Total leaf area (cm^2) at 60 DAP	Leaf area index (LAI)	Average growth rate (AGR)
HT/14-95	66.25	41.25	39.90	3.10	9.05	42.33	251.09	0.14	0.51
HT/14-109	77.88	44.74	45.33	4.38	10.00	55.88	385.84	0.22	0.77
HT/12-834	83.75	50.13	49.79	3.93	10.40	53.48	372.04	0.21	0.58
HT/16-113	74.58	34.16	39.85	3.28	8.35	46.90	305.18	0.17	0.31
HT/12-116	77.08	40.08	45.83	3.05	7.50	38.75	248.13	0.14	0.43
HT/10-1554	69.17	37.90	42.48	2.53	8.63	36.40	218.07	0.12	0.58
HT/12-830	82.92	44.03	43.91	3.45	8.95	50.68	343.99	0.19	0.45
HT/15-240	77.36	51.35	45.31	3.18	10.05	45.40	305.10	0.17	0.68
Kufri Surya	81.67	45.08	44.39	2.60	8.40	34.78	213.25	0.12	0.67
S.Em±	3.70	1.33	1.43	0.30	0.38	3.24	2.67	0.01	0.01
CD (P = 0.05)	10.50	3.77	4.06	0.86	1.07	9.20	7.59	0.03	0.02

In case of number of shoots/plant HT/14-109 registered highest value, which was statistically at par with HT/12-834 and the lowest was observed in genotype HT/10-1554. More number of shoots might be due to the presence of more number of eyes per seed tuber that sprouted to form the shoots. Number of nodes per plant was recorded the highest in genotype HT/12-834 which was found on par with HT/15-240 and HT/14-109. Minimum number of nodes per plant was recorded in genotype HT/12-116. Maximum number of leaves/plant was noted in HT/14-109 which was statistically at par with HT/12-834, HT/12-830, and HT/16-113. Minimum number of leaves was recorded in Kufri Surya. Maximum leaf area and average growth rate was recorded in HT/14-109 and it was significantly better than rest of the treatments. Minimum leaf area was observed in Kufri Surya and average growth rate was recorded the least in genotype HT/16-113. Highest leaf area index was recorded in genotype HT/14-109 which was found on par with genotype HT/12-834 while the lowest value was recorded in genotype HT/10-1554 and check variety Kufri Surya. Genotypes HT/15-240, HT/12-834, HT/12-116 and HT/14-109 were found better performing with respect to growth parameters over the rest of the genotypes studied. Genetic makeup and their response to prevailing environmental conditions might have resulted in better performance of above genotypes.

Physiological parameters

Chlorophyll content of leaves, membrane stability index and chlorophyll stability index are important physiological parameters that can be efficiently used to screen potato cultivars for heat tolerance (Paul *et al.*, 2016) [8]. Chlorophyll content in leaves was recorded the highest, in genotype HT/12-830 which was found on par with genotype HT/12-834 and the lowest was recorded in genotype HT/14-95. The highest membrane stability index was recorded in Kufri Surya followed by genotype HT/12-834 and it was found the lowest in genotype HT/16-113. Genotype HT/12-830 had highest chlorophyll stability index and it was recorded the lowest in Kufri Surya. Membrane stability index was found the least for the low yielding genotype HT/16-113. Chlorophyll content and chlorophyll stability index was recorded maximum for the high yielding genotype HT/12-830.

Table 2: Physiological parameters of potato genotypes

Treatments	Chlorophyll content	Membrane stability index (MSI)	Chlorophyll stability Index (CSI)
HT/14-95	39.03	23.25	87.31
HT/14-109	42.17	22.31	86.51
HT/12-834	46.69	38.61	90.40
HT/16-113	43.31	15.74	86.60
HT/12-116	41.22	24.59	93.14
HT/10-1554	44.38	20.92	89.16
HT/12-830	51.59	34.21	103.17
HT/15-240	45.57	37.30	86.92
Kufri Surya	43.39	46.01	78.66
S.Em±	1.79	0.46	0.61
CD (P = 0.05)	5.08	1.32	1.72

Yield parameters

Genotypes were found to have significant differences among them for all yield parameters. The highest number of tubers per plant was found in genotype HT/12-834. It might be due to the better growth parameters of this genotype, which recorded higher values for plant height, plant spread, number of leaves and leaf area index. Minimum number of tubers per plant was noticed in genotype HT/10-1554. Diameter of tubers was recorded maximum in genotype HT/10-1554 which was found on par with Kufri Surya, HT/14-109, and HT/15-240 while diameter of tubers was found minimum in genotype HT/16-113. Average tuber weight was found highest in genotype HT/10-1554 which was on par with HT/15-240, Kufri Surya, and HT/12-830. The lowest average weight of tubers was observed in HT/16-113. The varieties which produce more number of large and medium tubers are considered to be the best regarding consumer preference. The highest average tuber weight recorded in above mentioned genotypes might be due to the genetic character of the genotype and its interaction with environment which resulted in accumulation of more dry matter in tubers. Genotypes with maximum diameter were found to have more tuber weight. Also, average tuber weight was negatively correlated with number of tubers. The highest marketable yield and total yield per plant was recorded in genotype HT/12-830 which was found on par with HT/15-240 and HT/12-834 and it was recorded lowest in genotype HT/16-113. The genotypes HT/12- 830, HT/15-240, HT/12-834, and HT/14-109 were found significantly superior over the check variety Kufri Surya for marketable yield per plant, while the genotypes HT/12-116 and HT/10-1554 were found on par with it. For total yield per plant, the genotypes HT/12-830, HT/15-240, HT/12-834, HT/14-109 and HT/12-116 were found significantly superior over Kufri Surya, while the genotype HT/10-1554 was found statistically on par with it. Marketable and total tuber yield per plot as well as per hectare was recorded the highest in genotype HT/12-830 which was at par with HT/12-834 while the lowest yield was observed in genotype HT/16-113.Genotypes HT/12- 830, HT/12-834, and HT/15-240 were found to be significantly superior over the check variety Kufri Surya, while the genotypes HT/14-109 and HT/12-116 were found on par with it for both marketable and total tuber yield per plot and per hectare. Genotypes which had good growth attributes were found to be having better yield compared to other genotypes. It might be contributed to their genetic makeup and the interaction with the environment. The highest total tuber yield recorded in genotype HT/12-830, HT/12-834 and HT/15-240 could be attributed to their superior growth and yield parameters like plant height, plant spread, number of leaves, leaf area, leaf area index, number of tubers per plant and higher assimilate partitioning efficiency of towards tuber during bulking phase. Similar findings were also reported by Sadawarti *et al.* (2018) [10] and Sandhya *et al.* (2020) [11].

Table 3: Yield parameters of potato genotypes

Treatments	Number of tubers per plant	Diameter of tubers (cm)	Average tuber weight (g)	Marketable yield per plant (g)	Total yield per plant (g)	Marketable yield per hectare (t)	Total yield per hectare (t)
HT/14-95	4.27	4.79	42.14	165.39	179.65	11.88	12.81
HT/14-109	6.87	5.54	46.34	311.69	319.76	26.36	27.07
HT/12-834	9.10	5.25	37.59	326.61	341.88	31.11	32.55
HT/16-113	4.07	4.39	28.43	106.22	113.56	9.09	9.71
HT/12-116	6.75	5.20	47.93	290.03	300.14	24.33	25.15
HT/10-1554	2.90	5.59	69.55	188.03	198.88	14.24	15.03
HT/12-830	6.82	4.73	58.52	377.99	396.28	33.93	35.55
HT/15-240	5.33	5.47	67.75	351.27	358.30	29.49	30.09
Kufri Surya	3.64	5.55	67.15	237.79	242.31	22.28	22.69
S.Em±	0.32	0.09	4.40	19.29	19.64	1.78	1.80
CD (P = 0.05)	0.92	0.25	12.48	54.77	55.77	5.05	5.10

Plate 1: Tubers of different potato genotypes evaluated

Biochemical parameters

Data revealed that the highest dry matter content was recorded in genotype HT/15-240 and it was observed the lowest in HT/12-116 (Table 4). The location, cultivar, date of harvest and tuber curing influences the physical and biochemical changes in the structural components of potato tissue (Marwaha *et al.*, 2005) [5]. Tuber dry matter content is strongly a genetic based character and differs significantly among cultivars (Aggarwal *et al.*, 2017) [1]. Variation in dry matter content might be attributed to the inherent genetic makeup of the variety. High rate of cell division and elongation might have resulted in more dry matter accumulation in tubers of genotype HT/15-240.

The highest amount Vitamin C was recorded in genotype HT/12-830 whereas HT/12-116 recorded the minimum vitamin C content. The Vitamin C content of potato tubers is significantly influenced by a number of factors, but the most important is the variety (Hrabovska *et al.*, 2021) [4]. Among the genotypes evaluated, reducing, non-reducing and total sugar content were observed the lowest in genotype HT/14-109. During high temperature frying of potatoes, the non enzymatic Maillard reaction causes amino acids to react with carbonyl groups of reducing sugars resulting in darkening of potato chips which is not preferred by the consumers. Hence for processing purpose, optimum reducing sugar content of tubers should be < 0.1% and it should not exceed 0.33% (Davies, 1992) to get good quality products. The genotypes HT/14-109, HT/12-830, Kufri Surya, HT/14-95 and HT/16-113 had reducing sugar content less than 0.33% and they can be considered as best genotypes for processing purpose.

Table 4: Biochemical parameters of potato genotypes

Treatments	Dry matter content (%)	Vitamin C (mg/100 g)	Reducing sugar (%)	Non-reducing sugar (%)	Total sugar (%)
HT/14-95	18.11	14.37	0.22	0.19	0.41
HT/14-109	12.39	16.33	0.12	0.10	0.22
HT/12-834	18.52	19.46	0.58	0.28	0.86
HT/16-113	17.34	15.98	0.31	0.18	0.49
HT/12-116	11.13	13.87	0.45	0.24	0.69
HT/10-1554	17.31	17.80	0.33	0.15	0.48
HT/12-830	18.89	19.85	0.17	0.12	0.29
HT/15-240	20.34	18.73	0.37	0.25	0.62
Kufri Surya	15.95	17.64	0.19	0.16	0.35
S.Em±	0.12	0.09	0.02	0.02	0.02
CD (P = 0.05)	0.34	0.27	0.05	0.05	0.06

Appearance, aroma, taste, texture and bitterness of boiled tubers of nine genotypes were evaluated by giving score and results are presented in figure 2. Appearance of the genotypes HT/12-830, HT/14-95, HT/16-113, HT/12-116, HT/15-240, HT/14-109, HT/12-834, and HT/10-1554 were rated as very good. Appearance of Kufri Surya was rated as good while none of them was rated as fair or poor. Aroma was found moderate in all genotypes. Regarding taste, genotypes HT/15-240 and HT/12-116 were rated as very good. Genotypes HT/16-113, HT/12-830, HT/14-95, HT/14-109, Kufri Surya, and HT/10-1554 were rated as good while HT/12-834 was rated as fair. None of them was rated as poor. As far as the texture is concerned none of the genotypes were rated as floury. Texture of the genotypes HT/14-95, HT/12-116, HT/12-834, HT/16-113, HT/10-1554, Kufri Surya, HT/15-240, and HT/12-830 were rated as waxy, while texture of HT/14-109 was regarded as mealy. None of them was rated as soggy (watery). Bitterness is another important parameter that greatly influences consumer acceptance of a potato variety. Genotypes HT/15-240 and HT/12-830 were found free from bitterness, while genotypes Kufri Surya, HT/12-834, HT/14-109, HT/16-113, HT/10-1554, HT/12-116, and HT/14-95 were rated as slightly bitter. None of the entries were found highly bitter. HT/15-240 ranked first followed by HT/12-830 and HT/12-116 for ranking on consumer acceptance of boiled tubers.

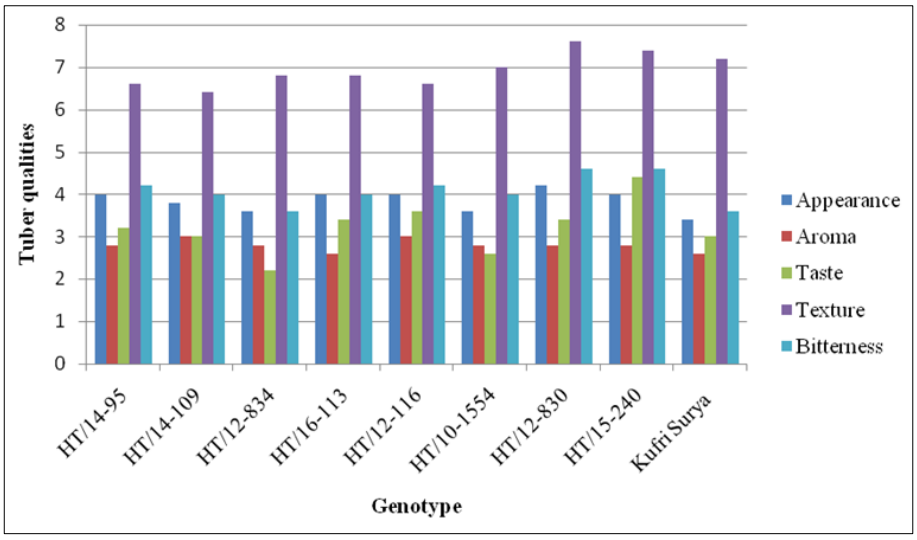

Fig 2: Quality of boiled tubers of different potato genotypes evaluated

Chips prepared from tubers of potato genotypes were evaluated for their colour, taste, crispiness and bitterness. Results are given in figure 3. Colour of chips is an important character that determines the processing quality of potato tubers and its consumer acceptance. Fried potato chips prepared from tubers of Kufri Surya, HT/12-830 and HT/14-109 were of desirable light yellow colour while it was yellow coloured in HT/10-1554. Chips prepared from genotypes HT/12-116, HT/16-113, HT/14-95, and HT/15-240 were brown in colour while it was of undesirable dark brown colour in genotype HT/12-834. The lowest rating for color in these genotypes might be due to the presence of high reducing sugars. The color of chips is mainly determined by the reducing sugar content of the potato tubers. Maillard reaction causes darkening of potato chips and potato tubers with high reducing sugar content will give dark coloured chips with bitter taste. As far as taste is concerned, it was rated as very good in chips prepared from genotypes HT/12-116 and HT/14-109. Taste was found good in genotypes HT/10-1554, HT/12-830, Kufri Surya, HT/15-240 and HT/14-95 while it was rated as fair in HT/12-834 and HT/16-113. Crispiness is an important quality parameter of potato chips. Excellent crispiness was noted in chips prepared from tubers of HT/12-834 and HT/15-240. It was rated as very good in genotypes HT/12-830, Kufri Surya, HT/10-1554, HT/16-113, HT/12-116 and rated as good in HT/14-95 and HT/14-109. Bitterness is the other parameter that determines consumer acceptance. Chips prepared from tubers of HT/14-95, HT/10-1554, HT/14-109 and Kufri Surya was found free from bitterness. Slight bitterness was found in HT/12-116, HT/15-240 and HT/12-830 while it was rated moderate in HT/16-113 and HT/12-834. Kufri Surya ranked first for chips quality followed by HT/10-1554 and HT/14-109.

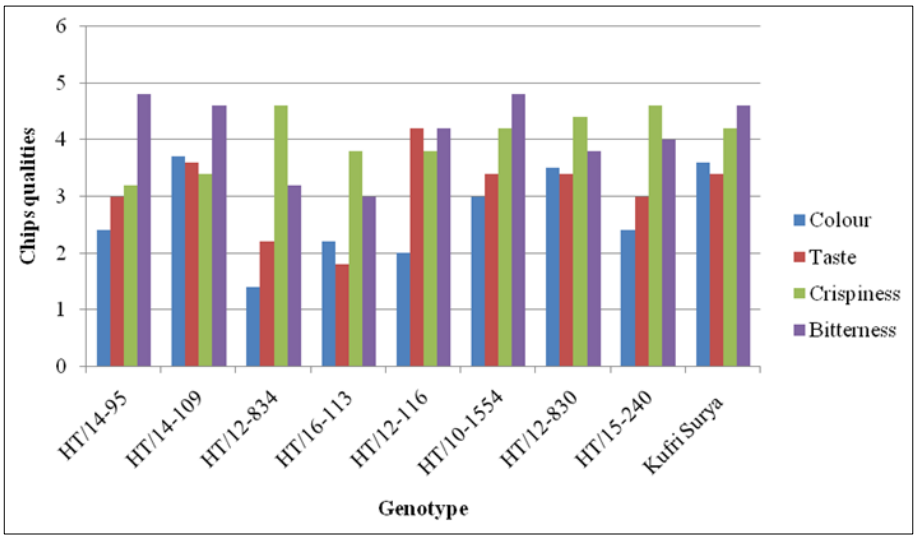

Fig 3: Quality of chips prepared from different potato genotypes evaluated

Plate 2: Chips prepared from tubers of different potato genotypes evaluated

Conclusion

Development of heat tolerant potato varieties suitable for cultivation under high temperature regions is one of the important objectives in potato breeding. Kufri Surya is the only commercially cultivated heat tolerant variety and the present study involved the evaluation of eight potato genotypes for their yield and heat tolerance in comparison with Kufri Surya. On the basis of results evolved from this investigation, it was concluded that genotypes HT/12- 830, HT/12-834, HT/15-240, HT/14-109 and HT/12-116 were high yielding at high temperature conditions of coastal Andhra Pradesh and hence these genotypes can be subjected for further evaluation and breeding purpose in development of heat tolerant potato varieties. Highest dry matter content was recorded in genotype HT/15-240 while Vitamin C content was found maximum in HT/12-830. The genotypes HT/14-109, HT/12-830, Kufri Surya, HT/14-95 and HT/16-113 having reducing sugar content less than 0.33% can be considered as best genotypes for processing purpose. In organoleptic studies, genotype HT/15-240 ranked first followed by HT/12-830 and HT/12-116 for ranking on consumer acceptance of boiled tubers, while Kufri Surya ranked first for chips quality followed by HT/10-1554 and HT/14-109.

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