International Journal of Bio-resource and Stress Management https://pphouse.org/ijbsm.php

Crossref

IJBSM August 2022, 13(8):861-867 Print ISSN 0976-3988 Online ISSN 0976-4038 **Article** AR3075

Research Article *Natural Resource Management*

DOI: HTTPS://DOI.ORG/10.23910/1.2022.3075

Advance Heat Tolerant Potato Hybrids Performance for Yield and Quality Parameters under Hot Prone Area

Murlidhar Sadawarti[1], V. K. Gupta[2], R. K. Samadhiya[1], S. P. Singh[1], R. K. Singh[3], Subhash Katare[1], Satyajit Roy[4], S. K. Chakrabarti[5] and Dharminder Verma[3]

[1]Dept. of Agriculture, ICAR-Central Potato Research Station, Gwalior, Madhya Pradesh (474 006), India
[2]Dept. of Agriculture, ICAR-Central Potato Research Institute Campus, Meerut, Uttar Pradesh (250 110), India
[3]Dept. of Agriculture, ICAR-Central Potato Research Institute, Shimla, Himachal Pradesh (171 001), India
[4]Dept. of Agriculture, ICAR-Directorate of Medicinal & Aromatic Plants Research, Anand, Gujrat (387 310), India
[5]Dept. of Agriculture, Uttar Banga Krishi Viswavidyalaya, Cooch Behar, West Bengal (736 165), India

Open Access

Corresponding murlidharsada@gmail.com

0000-0003-2469-2075

ABSTRACT

Field trial was conducted under AICRP (Potato) at ICAR-CPRI, Regional station, Gwalior, Madhya Pradesh, India during 2017–18, 2018–19 and 2019–20 with advanced potato hybrids viz. HT/7-1105, HT/7-620 and HT/7-1329 along with controls Kufri Lima, Kufri Surya, Kufri Khyati and Kufri Lauvkar in RBD with 3 replications during second week of October every year. Emergence among hybrids and varieties was >85.0%. Plant vigor was higher in Kufri Lima (4.4) followed by HT/7-1329 and Kufri Surya (4.0). At 60 days, all the hybrids except HT/7-620 recorded significantly higher tuber dry matter over Kufri Khyati (15.0%). At 75 and 90 days, 2 hybrids and controls except Kufri Khyati recorded significantly higher dry matter over hybrid HT/7-620 (17.4% for 75 days and 18.1% for 90 days). Total tuber yield of Kufri Lima (23.5 t ha^{-1}) followed by hybrid HT/7-1329 (23.4 t ha^{-1}) at 60 days at same level of GDD (Growing degree days) of 1134, Kufri Lima (32.4 t ha^{-1}) followed by Kufri Khyati (30.2 t ha^{-1}) and hybrid HT/7-1329 (29.4 t ha^{-1}) at 75 days at same level of GDD (Growing degree days) of 1291 and Kufri Lima (36.6 t ha^{-1}) followed by hybrid HT/7-1329 (35.6 t ha^{-1}) at 90 days at same level of GDD (Growing degree days) of 1426 recorded significantly higher or at par total tuber yield respectively than other controls/hybrids. Hybrid HT/7-1329 and Kufri Lima at 60, 75 and 90 days recorded highest economic return over other hybrids and varieties. Hence, Hybrid HT/7-1329 and variety Kufri Lima found to be most suitable for cultivation under early planting of hot prone areas of West-Central India for getting highest remunerative prices.

KEYWORDS: Economics, hot prone area, GDD, Heat tolerant hybrids, potato, tuber yield

***Citation* (VANCOUVER):** Sadawarti et al., Advance Heat Tolerant Potato Hybrids Performance for Yield and Quality Parameters under Hot Prone Area. *International Journal of Bio-resource and Stress Management*, 2022; 13(8), 861-867. HTTPS://DOI.ORG/10.23910/1.2022.3075.

Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

Conflict of interests: The authors have declared that no conflict of interest exists.

RECEIVED on 04th May 2022 RECEIVED in revised form on 03rd August 2022 ACCEPTED in final form on 16th August 2022 PUBLISHED on 27th August 2022

1. INTRODUCTION

Potato is one of the most important food crops worldwide with current global production of 370.4 million mt, having excellent performance in temperate regions, (Ávila-Valdés et al., 2020). India ranks 2nd in area and production of potato in the world after China which contribute 13% of world potato production in 2019 (Anonymous, 2021). In India potato production is mainly confined to Uttar Pradesh, West Bengal, Bihar, Gujarat, Madhya Pradesh, Punjab, Assam and Haryana and grown in an area of 2.05 mha with the production of 48.66 mt and the productivity is 23.67t ha-1 (Anonymous, 2020). Potato is vulnerable to increased temperatures (Hastilestari et al., 2018, Trapero-Mozos et al., 2018) which is uncontrollable factor affecting growth and yield. As a result of heat/ high temperature, there is estimation of losses of 18–32% worldwide (Hijmans, 2003), 13.72% in India and by 16.6% in Madhya Pradesh by 2050, respectively (Singh et al., 2008). The optimal yield for most commercial potato varieties is produced in average day time temperatures of 14–22°C. Optimum night temperature during pre-stolon initiation stage has been found to be 15–20°C, while it is 15°C after tuber initiation. Potato is badly affected by high temperature/ heat stress during tuber initiation (Basu and Minhas, 1991) and tuber bulking stages (Minhas and Kumar, 2005), reduces production and dry matter of tubers, increases respiration and the partitioning of photo-assimilates (Benites and Pinto, 2011, Levy and Veilleux, 2007, Tang et al., 2018).

Expansion of potato production into the developing nations mostly occurs in tropical and subtropical areas, where the average temperatures are more elevated than the ideal temperature which is a major limiting factor (Benites and Pinto, 2011) and brings heat stress sensations into the minds of potato producers. Furthermore, to this expansion, global warming consequences leading to changes in temperature regions (Aliche et al., 2019) and add dangers for sustainable potato production in most regions (van Oort, 2014) due to increased risk from heat stress due to climate change (Zhang et al., 2021). In India important heat prone potato producing states, viz., Gujarat, Madhya Pradesh and Karnataka have already started experiencing ill effects of higher temperature (Rana et al., 2011). Potato plants that are exposed to high temperature from the beginning of the growing period risk a higher reduction in tuber yield due to a delay in tuber initiation and shorter bulking duration, as well as a lower net assimilation rate (Aien et al., 2016, Navarro et al., 2011). Tuberization is reduced at night temperature of 20°C and there may not be any tuberisation 25°C and above, even though potato plants can tolerate day temperature of about 35°C (Minhas et al., 2001).

Temperature being the limiting factor, the planting time varies from region to region. High temperature during crop growth and tuberization restricts adoption of potatoes in early planting conditions of north-western plains and peninsular India (Luthra et al., 2006, Luthra et al., 2020). In West –Central India, early autumn crop is grown in the month of September/October and harvested pre-mature by November to December to get better market price have very low productivity due to high temperature prevailing during growth and development period of the crop. "*Kufri* Surya" and "Kufri Lima" heat tolerant varieties of potato developed by Central Potato Research Institute, Shimla, performs better than other varieties when temperatures are higher during planting and early growth period and gives economical yield even under high temperature above 20°C (Minhas et al., 2006, Minhas et al., 2011, Lutra et al., 2020). Climate change is likely to lead to an overall temperature increase of 1–1.4°C (Hijmans, 2003) and development of potato cultivars with increased heat tolerance appears to be important to cope with climate change. High tolerance deserves future attention given the likely negative impact of warmer (extreme) temperatures on potato production (Pradel, 2019). Hence, there is need for development of more heat tolerant varieties that can give economical yields in early plating time of west central India under higher temperatures, especially at higher night temperatures (Rana et al., 2011). Hence with this background few hybrids were evaluated under AICRP (Potato) trial at ICAR CPRI RS, Gwalior MP.

2. MATERIALS AND METHODS

Field trial was conducted at ICAR-Central Potato Research Institute, Regional station, Gwalior, Madhya Pradesh, India during second week of October every year of 2017–18, 2018–19 and 2019–20. Station is situated at 26°13–N latitude 78°14–E longitude and 206 . The soil was silty clay loam with pH 7.4 and EC 0.23 dS m^{-1}, low in organic (0.37%) and available nitrogen (165 kg ha^{-1}), medium in available phosphorous (20 kg ha^{-1}) and high in available potassium (395 kg ha^{-1}) and 1.28 g m^{-3}, 2.56 f m^{-3} and 44.47% in case of bulk density, particle density and water holding capacity. Annual average rainfall of the region is in the range of 600–800 mm. Trail was conducted with 3 advanced potato hybrid viz., HT/7-1105, HT/7-620 and HT/7-1329 along with four potato (control) varieties Kufri Lima, Kufri Surya, Kufri Khyati and Kufri Lauvkar. Trial was conducted during October to January in RBD with 3 replications and planting was done during second week of October (15–20 days earlier than main season planting) during all the three years with well sprouted tubers of 40–60 g. Plot size of experiment was 3.0×3.0 m^2. Row to row distance was 60 cm and plant to plant distance was 20 cm. Recommended dose of fertilizers ($N:P_2O_5:K_2O$) was applied

in the ratio of 180:80:120 kg ha^{-1} respectively. 50% of N and full dose of P and K were applied at the time of planting. Rest 50% of N was applied at the time of earthing up. Crop was dehaulmed at 60, 75 and 90 days after planting during the 3 years. Data on growth parameters viz., emergence %, plant vigour, number of stem plant^{-1}, compound leaves and height were recorded at 45–50 days of planting. Data on tuber number and weight/ ha were recorded at 60, 75 and 90 days after planting. Tubers were divided in 2 grades <20 g (Non marketable), and >20 g (marketable) at harvest. Dry matter content and haulm dry weight were determined by drying 100 g of fresh tuber tissue and 250 g fresh haulm in hot air oven at 60±2°C till constant weight and was calculated on fresh weight basis %.

Economics of various treatments was worked out on the basis of prevailing prices of inputs and output. A net return was calculated by subtracting the cost of total inputs from the cost of total produce. Cost of produce corresponds to value of the harvested crop which is approximately taken as ₹ 8000 t^{-1} for marketable tubers. Economics was worked out taking mean tuber yields and B: C ratio was worked out. Benefit cost ratio (B:C) indicates the returns one gets after investing one rupee. It was calculated by dividing the total returns with total costs of cultivation. Climatic data viz maximum/minimum temperature (°C) was recorded and mean temperature during planting, crop duration and GDD was calculated accordingly (Table 1). Growing degree days (GDD) were calculated throughout the season for each harvesting date. The formula is

GDD=(Min T+Max T)/2-Tb

Tb=Base temperature/or minimum threshold temperature. This is taken as 4.5 for potato (Narayan et al., 2014).

Data of the 3 years were pooled analyzed statistically with RBD and means were separated according to least significant difference (LSD) at 0.05 level of probability and data analysis was done using Opstat HAU computer package.

Table 1: Climatic parameters during crop growth

Crop duration	Mean temperature °C of crop duration				Mean Temperature °C							
					Maximum				Minimum			
Days	2017–18	2018–19	2019–20	Mean	2017–18	2018–19	2019–20	Mean	2017–18	2018–19	2019–20	Mean
60	22.7	22.6	21.8	22.4	32.1	32.2	29.8	31.4	13.7	13.1	13.9	13.6
75	21.6	21.1	20.4	21.0	30.2	30.5	28.1	29.6	12.9	11.7	12.7	12.4
90	20.4	20.0	18.9	19.8	29.1	29.1	26.5	28.2	11.7	11.7	11.4	11.6

3. RESULTS AND DISCUSSION

3.1. Growth attributing parameters

No significant difference was recorded for emergence percent among hybrids and varieties and however it was more than 86% in all the treatments. There were no significant differences in plant vigour (1–5 scale) but Kufri Lima (4.4), HT/7-1329 and Kufri Surya (4.0) had relatively more vigour than others. Plant height was significantly higher (Table 2) in all the hybrids and other controls over Kufri Lauvkar (39.6 cm) and highest was recorded in hybrid HT/7-620 (55.1 cm). Number of stems per plant was varied among the different genotypes and only hybrid HT/7-1105 (4.9) recorded significantly higher stem/plant over all other hybrids and controls. Hybrids HT/7-1105 (67.9), HT/7-620 (55.9) and control Kufri Surya (53.6) recorded significantly higher compound leaves plant^{-1} over Kufri Lauvkar (45.0) and others were at par in the present study (Table 3). Vanangamudi et al. (2007) reported similar variation in emergence, plant vigour, plant height, stem plant^{-1} and compound leaves plant^{-1}. Higher growth parameters in mentioned heat tolerant hybrids and varieties may be due to better maintenance of foliage in early planting conditions when average temperature was higher than optimum temperature (Table 1). This is in agreement with Singh and Lal (2015) where Kufri Surya recorded higher emergence %, significantly taller plants, a greater number of leaves plant^{-1} and consequently greater LAI as compared to local popular variety Lal Gulab under Sone riverbed of Patna district in Bihar. Variability was reported in Plant Height, Stems Number, DM Production, LAI and CGR when 21 varieties were evaluated under Cooch Behar conditions of West Bengal, India (Das et al., 2021).

Table 2: Growing degree days (GDD) during crop growth

Crop duration	Growing degree days			
Days	2017–18	2018–19	2019–20	Mean
60	1135	1134	1134	1134
75	1314	1280	1280	1291
90	1447	1415	1415	1426

3.2. Quality parameters

Dry matter accumulation and its partitioning in various

plant parts were influenced by the environmental conditions of the locality, along with the overall growth and development characteristics, which were very vital for contributing to potato tuber yield. The accumulated total dry matter through photosynthesis during a given period of growth was partitioned into given plant parts according to the needs of the developmental stages of the cultivars (Das et al., 2021). At 60 days, all the three hybrids and control Kufri Lima recorded significantly higher haulm dry weight over Kufri Khyati (9.2%), but at 75 days no significant difference was recorded among hybrids and controls and highest was recorded in Kufri Lima (13.0%). At 90 days hybrid HT/7-1105, HT/7-1329 and other controls except Kufri Surya recorded significantly higher haulm dry weight over hybrid HT/7-620 (11.3%) (Table 3). Variability in shoot dry weight and LAI was reported among genotypes at different days after planting under Cooch Behar, West Bengal conditions (Das et al., 2021).

With regard to tuber dry matter at 60 days, all the hybrids except HT/7-620 and controls recorded significantly higher dry matter over Kufri Khyati (15%). At 75 and 90 days, two hybrids and controls except Kufri Khyati recorded (Table 3) significantly higher dry matter over hybrid HT/7-620 (17.4% for 75 days and 18.1% for 90 days). Rehaman et al. (2014) reported variable dry matter contents in potato tubers harvested in their studies on heat tolerant varieties at different crop durations. Burton (1966a) reported that genetic differences among varieties in their ability to produce high solids, when grown on the same test plot.

Table 3: Growth and quality parameters of hybrids/ varieties at different growth stages

Hybrids/ varieties	Growth parameters					Haulm dry matter (%)			Tuber dry matter (%)		
	Emergence (%)	Vigor (1–5 scale)	Plant height (cm)	No. of Stem plant^{-1}	No. of Compound leaves plant^{-1}	60 days	75 days	90 days	60 days	75 days	90 days
HT/7-1105	87.7	3.4	44.0	4.9	67.9	11.0	12.1	12.5	16.7	19.0	20.0
HT/7-620	86.8	3.4	55.1	3.8	55.9	10.3	11.9	11.3	15.3	17.4	18.1
HT/7-1329	86.7	4.0	48.5	3.7	48.8	11.3	12.3	14.6	16.2	21.0	21.3
K. Lima	87.0	4.4	45.9	3.8	49.6	10.8	13.0	12.8	17.4	19.9	21.6
K Surya	90.2	4.0	42.4	3.9	53.6	9.6	11.6	11.9	17.3	19.3	20.2
K Khyati	85.6	3.3	43.4	3.4	47.7	9.2	11.6	12.2	15.0	17.9	18.4
K Lauvkar	88.2	3.4	39.6	3.4	45.0	10.0	12.3	13.0	16.1	19.8	20.3
SEm±	1.3	0.3	0.7	0.3	1.6	0.3	0.4	0.2	0.3	0.3	0.2
CD (p=0.05)	NS	NS	2.3	0.9	5.1	1.1	NS	0.7	0.9	0.9	0.7

3.3. Marketable tuber yield

At 60 days, control Kufri Lima (20 t ha^{-1}) followed by Hybrid HT/7-1329 (19 t ha^{-1}), Kufri Kufri Khyati (18 t ha^{-1}) and Surya (17 t ha^{-1}) recorded significantly higher marketable tuber yield over hybrid HT/7-620 (14.9 t ha^{-1}). At 75 and 90 days, control Kufri Lima (30 t ha^{-1} and 34 t ha^{-1}) followed by HT/7-1329 (26 t ha^{-1} and 33 t ha^{-1}), Kufri Khyati (25 t ha^{-1} and 31 t ha^{-1}), hybrid HT/7-620 (24 t ha^{-1} and 29 t ha^{-1}) and hybrids HT/7-1105 (24 t ha^{-1} and 28 t ha^{-1}) recorded significantly higher marketable tuber yield over Kufri Lauvkar (20.6 t ha^{-1} and 25.3 t ha^{-1}) and Kufri Surya (21.0 t ha^{-1} and 25.5 t ha^{-1}) respectively (Table 4). Singh and Lal (2015) reported that heat tolerant variety Kufri Surya had significantly more marketable and total aggregate tubers over Local variety Lal Gulab under Sone riverbed conditions of Patna district in Bihar. At 75 days, a heat tolerant hybrid CP-4054 (Kufri Lima) produced higher (21.3% and 30.9%) total and marketable tuber yields respectively than Kufri Surya at Karnal conditions when planted 15–20 days early than main season (Yadav et al., 2020). This confirms the result of the present study at 75 and 90 DAP.

3.4. Total tuber yield

At 60 days, Hybrid HT/7-1329 (23.4 t ha^{-1}) which is at par with control Kufri Lima (23.5 t ha^{-1}), and Kufri Khyati (22 t ha^{-1}) recorded significantly higher total tuber yield over other hybrids and controls. At 75 days Kufri Lima (32 t ha^{-1}) followed by Kufri Khyati (30 t ha^{-1}), HT/7-1329 (29 t ha^{-1}), HT/7-620 (28 t ha^{-1}) and HT/7-1105 (28 t ha^{-1}) recorded significantly (Table 4) higher total tuber yield over Kufri Lauvkar (24.5 t ha^{-1}) and Kufri Surya (24 t ha^{-1}). Vanangamudi et al. (2007) in their experiments also found superior yield in heat tolerant genotypes. Similarly, at 90 days, control Kufri Lima (37 t ha^{-1}) followed HT/7-1329 (36 t ha^{-1}), Kufri Khyati (33 t ha^{-1}), HT/7-620 (33 t ha^{-1}) and hybrids HT/7-1105 (31 t ha^{-1}) recorded significantly

Table 4: Yield (t ha^{-1}) of hybrids/ varieties at different growth stages

Hybrids/ varieties	Non marketable (<20 g)			Marketable (>20 g)			Total		
	60 days	75 days	90 days	60 days	75 days	90 days	60 days	75 days	90 days
HT/7-1105	4.7	4.3	3.0	15.9	23.6	28.2	20.6	27.9	31.2
HT/7-620	4.4	3.8	3.5	14.9	24.3	29.1	19.3	28.1	32.6
HT/7-1329	4.6	3.4	2.8	18.8	26.0	32.8	23.4	29.4	35.6
K. Lima	3.6	2.7	2.3	19.9	29.7	34.3	23.5	32.4	36.6
K Surya	3.3	2.7	2.4	17.2	21.0	25.3	20.5	23.7	27.8
K Khyati	3.5	5.2	2.8	18.4	25.0	30.6	21.9	30.2	33.4
K Lauvkar	4.1	3.9	2.6	15.2	20.6	25.5	19.3	24.5	28.1
SEm±	0.2	0.1	0.1	0.4	0.5	0.4	0.4	0.5	0.3
CD (p=0.05)	0.5	0.4	0.3	1.3	1.6	1.1	1.4	1.6	1.1

higher or at par total tuber yield over Kufri Lauvkar (28 t ha^{-1}) and Kufri Surya (28 t ha^{-1}) table 4. Rehman et. al (2014) in his experiment involving some CIP genotypes, exotic and local varieties reported superior performance of CIP genotypes than the popular variety Diamant. Joseph et al. (2006) found better performance of heat tolerant hybrid HT/92-621 (K. Surya) due to high tuber number (6.5) and tuber weight (37.8 g) over other heat tolerant hybrid under Kerala conditions. Significantly highest average tuber weight (55 g) ant tuber yield (281 g plant^{-1}) was recorded in HT/07-1329 when 18 heat tolerant genotype and 8 control varieties were studies under condition West Godavari district, Andhra Pradesh. Potato can give good yield even at day temperatures of 30–35°C provided nights are below 18°C. But if night temperature goes beyond 22°C there is very little tuberisation even when the day temperature is 25–27°C. So, heat tolerance in potatoes is concerned more with the minimum night temperature than the maximum day temperature (Burton, 1996b).

The heat tolerant hybrids, Hybrid HT/7-1329 produced higher total tuber yield (23 t ha^{-1}) at 60 DAP, at 90 days (36 t ha^{-1}) which was at par with best control Kufri Lima (37 t ha^{-1}) at same level of growing degree days (1134 and 1426) respectively. However, at 75 days and at 1291growing degree days (GDD) the best control Kufri Lima produced significantly superior yield (32 t ha^{-1}) than other genotypes (Table 1, 2 and 4. This indicates that hybrid HT/7-1329 required higher GDD of 1426 for higher yield potential along with control Kufri Lima. Worthington and Hutchinson (2005) reported that variety Atlantic recorded total and marketable yields 7% and 18% higher compared to 'Harley Blackwell' at same level of GDD. This confirms increasing GDD from 60 days to 75 and 90 days increased the marketable and total yield.

3.5. Economics

At 60 days, among hybrids and varieties hybrid HT/7-1329 (₹ 187200 gross return, ₹ 91002 net return and 2.0 B:C ratio) and Kufri Lima (₹ 188000 gross return, ₹ 91802 net return and 2.0 B:C ratio) recorded highest gross, net return and B:C ratio over other hybrids and varieties. At 75 days,

Table 5: Economics evaluation of hybrids/ varieties at the three growth stages

Hybrids/ varieties	60-day crop					75-day crop				
	Yield (t ha^{-1})	Cost of cultivation (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio	Yield (t ha^{-1})	Cost of inputs (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C Ratio
HT/7-1105	20.6	96198	164720	68522	1.7	27.9	104158	223120	118962	2.1
HT/7-620	19.3	96198	154480	58282	1.6	28.1	104158	224720	120562	2.2
HT/7-1329	23.4	96198	187200	91002	2.0	29.4	104158	235144	130986	2.3
K. Lima	23.5	96198	188000	91802	2.0	32.4	104158	259464	155306	2.5
K Surya	20.5	96198	163976	67778	1.7	23.7	104158	189656	85498	1.8
K Khyati	21.9	96198	175176	78978	1.8	30.2	104158	241760	137602	2.3
K Lauvkar	19.3	96198	154344	58146	1.6	24.5	104158	196104	91946	1.9

Table 5: Continue...

Hybrids/ varieties	90-day crop				
	Yield (t ha^{-1})	Cost of inputs (₹ ha^{-1})	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C Ratio
HT/7-1105	31.2	108938	249256	140318	2.3
HT/7-620	32.6	108938	260720	151782	2.4
HT/7-1329	35.6	108938	284480	175542	2.6
K. Lima	36.6	108938	293096	184158	2.7
K Surya	27.8	108938	221976	113038	2.0
K Khyati	33.4	108938	267304	158366	2.5
K Lauvkar	28.1	108938	224936	115998	2.1

Sale price of potato= ₹ 8000 t^{-1}; Average 1 USD=INR 64.2, 70.77, 71.2 in December, 2017, 2018, 2019 respectively; Average 1 USD=INR 64.2, 70.6, 71.29 in January, 2018, 2019, 2020 respectively

among hybrids and varieties Kufri Lima (₹ 259464 gross return, ₹ 155306 net return and 2.5 B:C ratio) followed by Kufri Khyati (₹ 241760 gross return, ₹ 137602 net return and 2.3 B: C ratio) and hybrid HT/7-1329 (₹ 235144 gross return, ₹ 130986 net return and 2.3 B: C ratio) recorded highest gross, net return and B:C ratio over other hybrids and varieties. At 90 days, Kufri Lima (₹ 293096 gross return, ₹ 184158 net return and 2.7 B:C ratio) and hybrid HT/7-1329 (₹ 284480 gross return, ₹ 175542 net return and 2.6 B:C ratio) recorded highest gross, net return and B:C ratio over other hybrids and varieties (Table 5). Average gross return (₹ 173379) as well as net return (₹ 100714) was maximum in Kufri Surya under improved management practices under Sone riverbed of Patna district in Bihar (Singh and Lal, 2015).

4. CONCLUSION

Among three hybrids tested, hybrid HT/7-1329 along with control Kufri Lima performed better for growth, quality, marketable and total tuber yield and recorded highest gross, net return and B:C ratio over other hybrids and varieties at 60, 75 and 90 days.

5. REFERENCES

Aien, A., Chaturvedi, A.K., Bahuguna, R.N., Pal, M., 2016. Phenological sensitivity to high temperature stress determines dry matter partitioning and yield in potato. Indian Journal of Plant Physiology 22(1), 63–69.

Anonymous, 2021. FAO Statistical Yearbook – World Food and Agriculture, 368. Accessed on 22nd January, 2022. Available at https://www.fao.org/3/cb4477en/cb4477en.pdf

Anonymous, 2020. Agricultural Statistics at a Glance. Ministry of Agriculture & Farmers Welfare Department of Agriculture, Cooperation & Farmers Welfare Directorate of Economics and Statistics Government of India, 0–388. Accessed on 2ndDecember, 2021. Available at https://eands.dacnet. nic.in/PDF/Agricultural%20Statistics%20at%20a%20Glance%20-%202020%20(English%20version).pdf

Avila-Valdes, A., Quinet, M., Lutts, S., Martínez, J.P., Lizana, X.C., 2020. Tuber yield and quality responses of

potato to moderate temperature increase during tuber bulking under two water availability scenarios. Field Crops Research 251, 107786.

Basu, P.S., Minhas, J.S., 1991. Heat tolerance and assimilate transport in different potato genotypes. Journal of Experimental Botany 42(7), 86–66.

Aliche, E.B., Oortwihn, M., Theeuwen, T.P.J.M., Bachem, C.W.B., van Eck, H.J., Visser, R.G.F., van der Linden, C.G., 2019. Genetic mapping of tuber size distribution and marketable tuber yield under drought stress in potatoes. Euphytica 215, 186. DOI 10.1007/s10681-019-2508-00123456789.

Benites, F.R.G., Pinto, C.A.B.P., 2011. Genetic gains for heat tolerance in potato in three cycles of recurrent selection. Crop Breeding and Applied Biotechnology 11(11), 133–140.

Burton, W.G., 1966a. The Potato. A Survey of Its History and Factors Influencing its Yield, Nutritive Value, Quality and Storage (2nd Edn.). Veenmand and Sonen, N.V., Wageningen, 521.

Burton, W.G., 1996b. Yield and content of dry matter: 1-the underlying physiological processes. In: Burton, W.G. (Ed.). The Potato. Longman Scientific & Technical, Essex, England, 84–155.

Das, S., Mitra, B., Luthra, S.K., Saha, A., Hassan, M.M., Hossain, A., 2021. Study on morphological, physiological characteristics and yields of twenty-one potato (*solanum tuberosum* L.) cultivars grown in

eastern Sub-Himalayan plains of India. Agronomy 11(2), 335.

Hastilestari, B.R., Lorenz, J., Reid, S., Hofmann, J., Pscheidt, D., Sonnewald, U., Sonnewald, S., 2018. Deciphering source and sink responses of potato plants (*Solanum tuberosum* L.) to elevated temperatures. Plant, Cell and Environment 41(11), 2600–2616.

Hijmans, R.J., 2003. The effect of climate change on global potato production. American Journal of Potato Research 80, 271–279.

Joseph, T.A., Krishna Parasad, K.S., Kumar, D., Rajkumar, J., Aipe, K.C., Pradeep Kumar, T., Minhas, J.S., 2006. Evaluation of heat tolerant potato hybrids under tropical conditions in Kerala. Potato Journal 33(3–4), 151–153.

Levy, D., Veilleux, R.E., 2007. Adaptation of potato to high temperatures and salinity- A review. American Journal of Potato Research 84, 487–506.

Luthra, S.K., Pandey, S.K., Singh, B.P, Kang, G.S., Singh, S.V., Pande, P.C., 2006. Potato Breeding in India. CPRI, Shimla Technical Bulletin No. 74, 90.

Luthra, S. K., Pandey, S.K., Singh, S.V., Kumar, V., Gopal, J., Singh, B.P., Naik, P.S., Gupta, V.K., Rawal, S., Malik, K., Bandana, Bhardwaj, V., Chakrabarti, S.K., Bonierbale, M., Kadian, M.S., Sharma, N., Arya, S., 2020. Kufri lima: A new heat tolerant potato variety. Potato Journal 47(2), 107–115.

Minhas, J.S., Kumar, D., Joseph, T.A., Krishna Prasad, K.S., Singh, B., 2001. Selection of heat tolerant potato genotypes and their performance under heat stress. Journal Indian Potato Association 28(1), 132–134.

Minhas, J.S., Kumar, D., Joseph, T.A., Raj, B.T., Khurana, S.M.P., Pandey, S.K., Singh, S.V., Singh, B.P., Naik, P.S., 2006. Kufri surya: A new heat-tolerant potato variety suitable for early planting in north-western plains, peninsular India and processing into French fries and chips. Potato Journal 33(1–2), 35–43.

Minhas, J.S., Rawat, S., Govindakrishnan, P.M., Kumar, D., 2011. Possibilities of enhancing potato production in non-traditional areas. Potato Journal 38(1), 14–17.

Minhas, J.S., Kumar, D., 2005. Tuberization in heat tolerant hybrid HT/92-621 under controlled temperature conditions. Potato Journal 32(3–4), 195–196.

Navarro, C., Abelenda, J.A., Cruz-Oró, E., Cuéllar, C.A., Tamaki, S., Silva, J., Shimamoto, K., Prat, S., 2011. Control of flowering and storage organ formation in potato by flowering locus T. Nature 478(7367), 119–122. DOI 10.1038/nature10431. PMID:21947007.

Narayan, S., Kanth, R.H., Narayan, R., Khan, F.A., Saxena, A., Hussain, T., 2014. Effect of planting dates and integrated nutrient management on productivity and profitability of potato (*Solanum tuberosum*) in Kashmir valley. Indian Journal of Agronomy 59(1), 145–150.

Rana, R.K., Sharma, N., Kadian, M.S., Girish, B.H., Arya, S., Campilan, D., Pandey, S.K., Carli, C., Patel, N.H., Singh, B.P., 2011 Perception of Gujarat farmers on heat tolerant potato varieties. Potato Journal 38(2), 121–129.

Reddy, T.Y., Reddi, G.H., 2002. Principles of Agronomy (2nd Edn.). Kalayani Publisher, New Delhi, India, 522.

Singh, J.P., Lal, S.S., Govindakrishnan, P.M., Dua, V.K., Pandey, S.K., 2008. Climate change and potato production in India. In: Proceedings of Global Potato Conference, New Delhi, 09–12 December.

Singh, S.K., Lal, S.S., 2015. Suitability of potato variety Kufri Surya for early planting under warmer condition in the Sone riverbed of Patna district in Bihar. Potato Journal 42(2), 111–115.

Tang, R., Niu, S., Zhang, G., Chen, G., Haroon, M., Yang, Q., Rajora, O.P., Li, X.Q., 2018 Physiological and growth responses of potato cultivars to heat stress. Botany 96(12), 897–912

Trapero-Mozos, A., Morris, W.L., Ducreux, L.J.M., McLean, K., Stephens, J., Torrance, L., 2018. Engineering heat tolerance in potato by temperature-dependent expression of a specific allele of HEAT-SHOCK COGNATE 70. Plant Biotechnology Journal 16(1), 197–207.

Van Oort, P.A.J., Saito, K., Zwart, S.J., Shrestha, S.A., 2014. A simple model for simulating heat-induced sterility in rice as a function of flowering time and transpirational cooling. Field Crop Research 156, 303–312.

Vanangamudi, K., Umarani, R., Ravichandran, G., Joseph, T.A., Manorama, K., 2007. Problems and perspectives in extending potato cultivation to nontraditional areas. Potato Journal 34(1–2), 34–38.

Pradel, W., Gatto, M., Hareau, G., Pandey, S.K., Bhardway, V., 2019. Adoption of potato varieties and their role for climate change adaptation in India. Climate Risk Management 23, 114–123.

Worthington, C.M., Hutchinsonchad, M., 2005. Accumulated growing degree days as a model to determine key developmental stages and evaluate yield and quality of potato in Northeast Florida. Proceedings of the Florida State Horticultural Society 118, 98–101.

Zhang, G., Tang, R., Niu, S., Si, H., Yang, Q., Rajora, O.P., Li, X.Q., 2021. Heat-stress-induced sprouting and differential gene expression in growing potato tubers: Comparative transcriptomics with that induced by postharvest sprouting. Horticulture Research 8, 226. DOI https://doi.org/10.1038/s41438-021-00680.