

# KUFRI DAKSH: A NEW WATER-USE EFFICIENT TABLE POTATO VARIETY WITH CROSS TOLERANCE TO HIGH TEMPERATURE STRESS

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**ABSTRACT:** Kufri (K) Daksh is a main season, medium maturing, high yielding, water-use-efficient table potato variety that can be grown in regions with limited water availability. It is a clonal selection from the cross between CP1748, having high water use efficiency and LT-1 tolerating high temperature stress. Its plants are tall and vigorous with field resistance to late blight. Its tubers are white-cream (light yellow), ovoid with shallow to medium eyes and cream flesh with good keeping quality. It is fertilizer responsive and can yield 30-35 t/ha under low water ( $\leq 20\%$ ) availability in middle Gangetic plains. K Daksh has better trade-off for high CO<sub>2</sub> gain and low water loss through optimization in plant canopy leaf area and plant height components. K Daksh can be an excellent choice to tolerate high temperature and water stress regimes in changing climatic scenarios.

**KEYWORDS:** Potato, variety, water use efficiency, tolerance, drought, high temperature stress

## INTRODUCTION

Potato (*Solanum tuberosum* L.) is the world's fourth most important food crop and yields more food calories per unit water than cereals. Compared to other leading food crops, potato grows more rapidly, require less land, and can withstand harsher climates. These qualities enable this crop to potentially attain the position of third most staple food globally (Wang *et al.* 2023).

Notwithstanding the plant's extensive distribution and capacity to thrive in diverse environmental and climatic circumstances, environmental issues impact potato growth (Handayani *et al.* 2019). Nevertheless, due to its sparse root system and inadequate capacity to recover from water stress, potato is susceptible to drought conditions, which in turn restricts their yield. That is why traditional potato varieties are susceptible to water stress and likely have a limited

genetic base for drought tolerance (Sprenger *et al.* 2015). Consequently, it is predicted that worldwide drought will reduce the potential potato yield by 18–32% between 2040 and 2069 (Obidiegwu *et al.* 2015).

It is generally known that several field crops, including potato, respond differently to water stress in terms of growth characteristics and production. Agronomic traits (plant height, leaf number and total above-ground biomass) and physiological traits (chlorophyll content, rate of photosynthesis, stomatal conductance, transpiration, relative water content (RWC)) are useful indicators of drought tolerance (Mthembu *et al.* 2022). To achieve successful breeding, precise knowledge of effective drought tolerance traits, their heritability, the interaction between genotype and environment, and appropriate selection strategies for the desired traits are necessary (Muthoni *et al.* 2016).

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From an agronomic perspective, the concept of drought tolerance is associated with the ability of crops to produce higher yields in conditions of limited water availability (Minhas *et al.* 2003).

The expansion of potato cultivation in water-scarce environments poses significant research challenges (Qin *et al.* 2019), and elite cultivars with improved drought resistance and wide adaptation are needed in India and other countries that are facing water scarcity problems. So far, ICAR-CPRI has released three water-use efficient varieties, i.e. Kufri Thar-1 (Kumar *et al.* 2021), Kufri Thar-2 (Luthra *et al.* 2020) and Kufri Thar-3 (Kumar *et al.* 2020) for different agroclimatic zones. Apart from water stress, high-temperature stress during crop growth and tuberization restricts the adoption of this crop in early planting conditions of northwestern plains and peninsular India (Luthra *et al.* 2013; 2018). Therefore, a water-use efficient variety having tolerance to high temperature stress shall be adopted more in different agro-ecologies of the country and shall prove more remunerative to the potato growers. Keeping changing climate scenario and increasing food and nutrition demand in view, water stress tolerant variety K Daksh (WS/07-113) has been developed and released to extend potato cultivation in non-traditional and drought prone areas for sustainable productivity and to ensure farmers' income.

## BACKGROUND

Female (♀) parent (CP1748) was selected, having high water use efficiency ( $\Delta^{13}\text{C}$ ), high transpiration rate and better water mining capacity ( $\Delta^{18}\text{O}$ ) using isotope ratio mass spectrophotometer (IRMS) at UAS Bangalore. Male (♂) parent (LT-1) potato accession is known worldwide for heat tolerance.. These parents were selected to combine these characteristics to impart water and high

temperature stress tolerance in the offspring. These parents were used in hybridization at Kufri (32°N, 77°E, 2501 AMSL) in Shimla hills in 2007. Seedlings were raised at the ICAR-Central Potato Research Institute, Regional Station, Modipuram (29°N, 76°E, 222AMSL). The initial selection of genotypes was based on tuber characteristics *viz.*, shape, eye depth, skin colour etc. In subsequent generations, selections were made based on tuber yield under water deficit conditions attained through delayed irrigations. Several promising clones were identified and finally, advanced clone WS/07-113 was evaluated under normal and reduced water regime at Modipuram during 2015-18. The clone was introduced in 2018 in the All-India Co-ordinated Research Project on Potato (AICRP-Potato) for systematic multi-location evaluation in different potato growing agro-climatic regions of the country. After these three-year multilocation trials during 2019-22, this advanced clone was recommended for release as a new variety in 40<sup>th</sup> AICRP (Potato) Group Meeting during 07-09 October 2022 at SKUAST Srinagar. It was recommended as medium maturing (90 days), water & heat stress tolerant, high-yielding clone (32 t/ha) having substantial yield advantage over the check varieties and moderately resistant to late blight. The advanced clone WS/07-113 was recommended for the central and eastern plains of India. Subsequently, advanced clone WS/07-113, christened as 'Kufri Daksh' was released by the "Central Sub-committee on Crop Standards, Notification and Release of Varieties for Horticultural Crops", Ministry of Agriculture and Co-operation, Government of India, New Delhi in June 2023. The variety Kufri Daksh is recommended as a water use efficient variety suitable for planting in central plains (Gujrat, Madhya Pradesh and Chhattisgarh) and eastern plains (Orissa and Uttar Pradesh).

## Varietal Description

**Plant:** Medium, plant canopy semi-compact, stem medium hollow, predominantly green, wings highly developed and wavy.

**Foliage:** Green, leaves open, leaflet width medium, leaflets ovate, leaflet waviness of margins medium, rachis green, midrib colouration absent (Fig.1).

**Flower:** Flowering medium, inflorescence medium, floral stalk green, floral stalk-pedicle articulation clearly visible and located above the middle, calyx green, corolla white, corolla medium in size, anther yellow, anther cone normally developed, stylar length longer than stamen column and stigma bilobed (Fig.1).

**Tubers:** Whitish cream (light yellow), ovoid tubers with shallow to medium eyes and cream flesh (Fig.1).

**Sprout:** Sprout red purple, shape cylindrical, pubescence at sprout base is strong (Fig.1).

## Evaluation in Station Trials at Modipuram (at 90 days)

In field trials at Modipuram, WS/07-113 consistently out yielded the control (K Bahar), both in well-watered control and water deficit stress at 90 days in three successive replicated yield trials during 2015-16 to 2017-18 except 2016-17 (well-watered control) (Table 1). Under mild stress conditions, clone WS/07-

113 (32.4 t/ha) recorded distinctly higher (>14.5%) mean tuber yield over K Bahar (28.3 t/ha). Similarly, clone WS/07-113 (36.7 t/ha) under well-watered conditions had a higher mean tuber yield than Kufri Bahar (35.2 t/ha).

## Water use efficiency (WUE) in clone WS/07-113 at Modipuram

Adaptation to water deficit stress may involve several morphological and physiological characteristics of the plant like WUE, leaf water loss, chlorophyll fluorescence and proline accumulation in the leaves of potatoes. WUE is a crucial trait for developing varieties with resilience to drought. In agronomic trials, WUE was calculated with the following formula-

$$\text{WUE} = \text{Tuber yield (q ha}^{-1}\text{)} / \text{water applied through irrigation (mm)}$$

Mean water use efficiency (WUE) was highest in WS/07-113 (1.501 q/ha-mm) and far superior to Kufri Bahar (1.432 q/ha-mm) during 2016-17 of evaluation under semi-dry moisture (0.60-0.65 bars) regime (Table 2).

## Drought tolerance in clone WS/07-113 at Modipuram

To assess the resilience to water stress conditions, the drought susceptibility index (DSI) and drought tolerance index (DTI) were calculated as suggested by Hassanpanah (2010). Analysis revealed that clone WS/07-

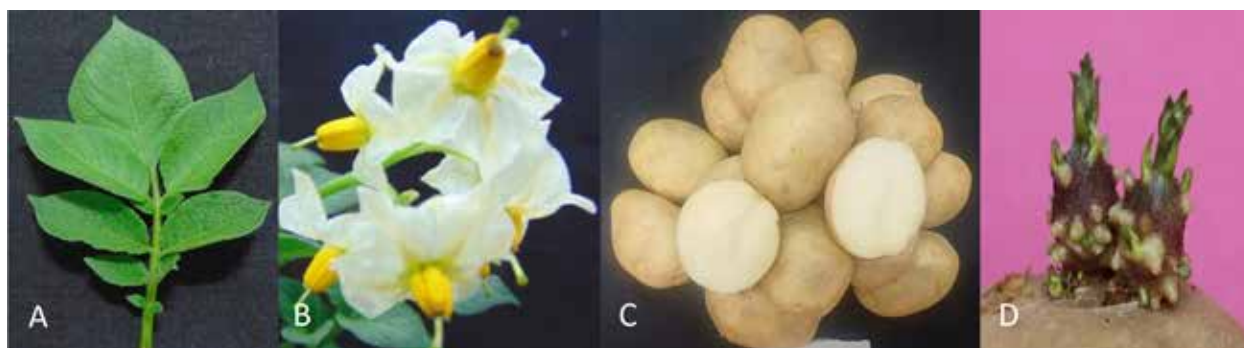


Fig. 1. WS/07-113 (K Daksh): (A) Leaflet (B) Inflorescence (C) Tubers and (D) Sprout

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**Table 1. Mean performance of clone WS/07-113 during 2015-18 under well-watered (control) and reduced moisture level at Modipuram.**

Genotype	2015-16		2016-17		2017-18		Mean	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
	Total tuber yield (t/ha)							
WS/07-113	29.5	24.0	42.3	38.8	38.2	34.3	36.7	32.4
Kufri Bahar	27.6	22.8	42.8	30.2	35.2	31.9	35.2	28.3
CD (0.05)	1.26		2.29		3.54			
	Marketable tuber yield (t/ha)							
WS/07-113	26.9	22.0	38.1	34.8	32.4	29.8	32.5	28.8
Kufri Bahar	26.2	21.4	39.9	26.0	30.0	27.4	32.0	25.0
CD (0.05)	1.11		2.56		3.67			
*No. of Rep	3		3		3			
*No. of Geno	6		7		4			

\*Indicate composition of evaluation trial in the respective year

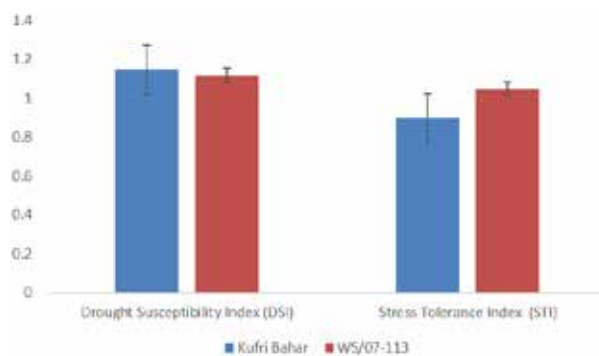
**Table 2. Mean performance of advanced drought tolerant clone WS/07-113 during 2016-17 under different irrigation levels at Modipuram.**

Genotype (G)	TY (t/ha) and Irrigation* (I)			Mean	WUE (q/ha-mm)			Mean
	Wet	Moist	Semi-dry		Wet	Moist	Semi-dry	
WS/07-113	37.2	31.7	29.5	32.8	1.255	1.284	1.501	1.35
Kufri Bahar	33.1	30.2	28.2	30.5	1.115	1.224	1.432	1.26
LSD (0.05)	I: 2.4	G: 3.9	I x G: NS		I: 0.101	G: 0.164	I x G: NS	
	Marketable tuber yield (t/ha)				Total tuber number ('000'/ha)			
WS/07-113	35.0	29.5	27.9	30.8	671	557	505	578
Kufri Bahar	31.2	28.4	26.4	28.7	537	425	544	502
LSD (0.05)	I: 2.5	G: 3.1	I x G: NS		I: NS	G: NS	I x G: NS	

\*Wet (0.20-0.25 bars), Moist (0.40-0.45 bars) and Semi-dry (0.60-0.65 bars)

Total water (including rains) appl. was 297, 247 & 197 mm in wet, moist & semi-dry regime, resp.

113 had the lowest DSI (1.11) and lowest yield reduction under stress, compared to K Bahar, having comparatively higher DSI (1.15) and yield reduction. Besides, clone WS/07-113 recorded the highest DTI (1.05) as compared to K Bahar (0.89) under water stress (Fig.2). All these parameters resulted in an improved trade-off for carbon assimilation and yield formation in the clone WS/07-113. Evaluation of drought associated traits showed a higher Pn rate (25.6  $\mu$  mol CO<sub>2</sub> m<sup>-2</sup>s<sup>-1</sup>) as compared to K Bahar (12.5  $\mu$  mol CO<sub>2</sub> m<sup>-2</sup>s<sup>-1</sup>), resulting into higher WUE (5.83 Pn/ mol H<sub>2</sub>O) against K Bahar (5.11 Pn/ mol H<sub>2</sub>O) (Table 3).



**Fig.2. Drought Susceptibility Index (DSI) and Stress Tolerance Index (STI) in WS/07-113.**

[DSI= (1-Y<sub>st</sub>/Y<sub>pt</sub>) /DI and DI=1-Y<sub>s</sub>/Y<sub>p</sub>, STI= k[(Y<sub>pt</sub>\*Y<sub>st</sub>)/(Y<sub>p</sub>)<sup>2</sup>], where: k=(Y<sub>st</sub>)<sup>2</sup>/(Y<sub>s</sub>)<sup>2</sup>, Y<sub>st</sub> -yield stress, Y<sub>pt</sub> -yield cont, Y<sub>s</sub> -mean yield of all cvs in stress and Y<sub>p</sub> - mean yield of all cvs in cont.]

**Table 3. Physiological traits associated with drought stress in clone WS/07-113**

Genotype	Pn rate ( $\mu\text{mol CO}_2\text{m}^{-2}\text{s}^{-1}$ )		Stomatal conductance ( $\text{mmol CO}_2\text{m}^{-2}\text{s}^{-1}$ )		Transpiration ( $\text{mmol H}_2\text{Om}^{-2}\text{s}^{-1}$ )		WUE (Pn/mol $\text{H}_2\text{O}$ )	
	Control	Stress	Control	Stress	Control	Stress	Control	Stress
WS/07-113	26.7	25.6	0.588	0.446	4.14	4.39	6.47	5.83
K Bahar	23.2	12.5	0.444	0.118	4.40	2.45	5.28	5.11
	CD (0.05)				CD (0.05)			
T	1.45		0.043		0.339		-	
G	2.29		0.068		0.537		-	
V × T	3.23		0.097		0.759		-	

### Fertilizer requirement trials

Advanced potato clone WS/07-113 responded to optimum doses of 180 kg/ha N and 80 kg/ha  $\text{P}_2\text{O}_5$  and 100 kg/ha  $\text{K}_2\text{O}$  to attain optimum marketable (23.3 t/ha) and total tuber yield (24.5 t/ha) under water deficit stress, i.e., 33% less irrigation water (Table 4).

### Evaluation under AICRP-Potato Trials

Replicated yield trials with local controls (Table 5a) were conducted during 2019-20 to 2021-22 at 5 locations (Bhubaneswar, Faizabad, Deesa, Gwalior and Hisar) in the first year, and at 6 locations (Bhubaneswar, Faizabad, Deesa, Gwalior, Raipur and Hisar) in subsequent two years under AICRP (Potato). Since advanced clone was evaluated for specific traits i.e. less water regime. Therefore, watering/irrigations were executed either following IW: CPE or mm CPE values uniformly at all locations (Table 5b). In all the locations, uniformly

two irrigations were saved compared to six irrigations in well-watered control.

### Performance in Eastern plains

**Middle Gangetic plains (Faizabad):** Under targeted environment having water deficit stress treatment ( $I_2$ ) at 90 days, WS/07-113 (30.6 t/ha) recorded 4.8% and 29.7% higher total tuber yield than K Thar-2 (29.2 t/ha) and K Sindhuri (23.6 t/ha), respectively (Table 6).

**East coast plains and hills (Bhubaneswar):** Under the targeted environment having water deficit stress treatment ( $I_2$ ) at 90 days, WS/07-113 (19.6 t/ha) yielded 8.9% and 21.7% higher total tuber yield than K Thar-1 (18.0 t/ha) and K Jyoti (16.1 t/ha), respectively (Table 6).

### Performance in Central Plains

**Deesa:** Clone WS/07-113 (34.5 t/ha) yielded 19.8% and 3.6% higher total tuber yield than

**Table 4. Influence of N-P-K nutrition on marketable and total tuber yield in clone WS/07-113 (Pooled mean of 2015-16 and 2016-17).**

Nutrition* (kg/ha)	Marketable tuber yield (t/ha)				Total tuber yield (t/ha)			
	WS/07-113		Kufri Bahar		WS/07-113		Kufri Bahar	
	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
75%N-P-K	25.4	22.0	20.6	16.0	26.6	23.7	22.7	17.7
100%N-P-K	24.8	23.3	21.9	16.8	25.9	24.5	23.8	18.9
125%N-P-K	25.1	24.6	23.5	17.7	27.8	26.3	25.8	19.1
CD 0.05	Nutrition: NS				Nutrition: NS			

\*Recommended dose: 180-80-100 N-P-K kg/ha

**Table 5a. Details of control used at AICRP locations during 2019-20, 2020-21 and 2021-22.**

Variety	BHN	DES	FZB	GWL	HIS	RPR*	KOTA	MDP
V <sub>1</sub>	WS/07-113	WS/07-113	WS/07-113	WS/07-113	WS/07-113	WS/07-113	WS/07-113	WS/07-113
V <sub>2</sub>	K Thar-1	K Thar-2	K Thar-2	K Thar-1	K Thar-3	K Thar-2	K Thar-2	K Thar-3
V <sub>3</sub>	K Jyoti	K Pukhraj	K Sindhuri	K Jyoti	K Bahar	K Sindhuri	K Sindhuri	K Pukhraj

\*Raipur included in 2020-21

**Table 5b. Details of irrigation/watering treatments executed in multi-location trials during 2019-20, 2020-21 and 2021-22 under AICRP.**

Treatment	Gwalior, Hisar, Modipuram, Kota		Bhuvneshwar, Deesa, Faizabad, Raipur	
	IW: CPE	Irrigations	CPE (mm)	Irrigations
I <sub>1</sub>	2.5	6	20	6
I <sub>2</sub>	1.5	4	30	4

**Table 6. Performance of clone WS/07-113 under AICRP in Eastern plains at 90 days.**

Location	Irrigation	WS/07-113	Kufri Thar-2	Kufri Sindhuri
Faizabad	I <sub>1</sub>	32.9	31.4	27.4
Bhubaneswar*	I <sub>1</sub>	21.2	19.2	16.9
Overall mean		27.1	25.3	22.1
% Yield increase ±		-	7.1	22.6
Faizabad	I <sub>2</sub>	30.6	29.2	23.6
Bhubaneswar*	I <sub>2</sub>	19.6	18.0	16.1
Overall mean		25.1	23.6	19.8
% Yield increase ±		-	6.4	26.8

\*Bhubaneswar: K Thar-1 and K Jyoti

**Table 7. Performance of clone WS/07-113 under AICRP in Central Plains at 90 days.**

Location	Irrigation	WS/07-113	Kufri Thar-2	Kufri Pukhraj
Deesa	I <sub>1</sub>	45.7	42.6	44.8
Gwalior*	I <sub>1</sub>	31.8	31.7	29.2
Raipur**	I <sub>1</sub>	18.5	20.4	20.4
Overall mean		32.0	31.6	31.5
% Yield increase ±		-	1.3	1.6
Deesa	I <sub>2</sub>	34.5	28.8	33.3
Gwalior*	I <sub>2</sub>	28.9	29.6	25.0
Raipur**	I <sub>2</sub>	16.7	13.5	16.8
Overall mean		26.7	24.0	25.0
% Yield increase ±		-	11.2	6.8

\*Gwalior: K Thar-1, and K Jyoti; \*\*Raipur: K Thar-2, K Sindhuri

K Thar-2 (28.8 t/ha) and K Pukhraj (33.3 t/ha), respectively at 90 days (Table 7).

**Gwalior:** Clone WS/07-113 (28.9 t/ha) yielded 15.6% higher total tuber yield than Kufri Jyoti (25.0 t/ha) and at par with Kufri Thar-1 (29.6 t/ha) at 90 days (Table 7).

**Raipur:** WS/07-113 (16.7 t/ha) yielded 23.7% higher total tuber yield than Kufri Thar-2/ Kufri Pukhraj (13.5 t/ha) and at par with Kufri Sindhuri (16.8 t/ha) at 90 days (Table 7).

### Performance in north Indian plains in replicated yield trials (2019-20 to 2021-22)

**Hisar:** At 90 days, clone WS/07-113 yielded (30.6 t/ha) at par with K Bahar (29.8 t/ha) (Table 8).

### Yield performance of clone WS/07-113 over all locations in AICRP trials

The results on a pooled mean basis reflected that clone WS/07-113 with a total tuber yield

**Table 8. Performance of clone WS/07-113 under AICRP at Hisar (Northern Plains) at 90 days.**

Year	Irrigation	WS/07-113	Kufri Thar-3	Kufri Bahar	CD (0.05)
2019-20	I <sub>1</sub>	26.3	29.3	30.0	5.39
2020-21	I <sub>1</sub>	39.8	40.8	35.0	3.88
2021-22	I <sub>1</sub>	32.1	35.3	40.1	0.97
Overall mean		32.7	35.1	35.0	-
% Yield increase ±		-	-6.8	-6.6	-
2019-20	I <sub>2</sub>	29.9	31.9	21.4	5.39
2020-21	I <sub>2</sub>	37.3	39.5	32.0	3.88
2021-22	I <sub>2</sub>	24.5	31.7	36.1	0.97
Overall mean		30.6	34.4	29.8	-
% Yield increase ±		-	-11.0	2.7	-

of 27.6 t/ha showed a yield increase by 7% and 15% over K Thar-1, 2 or 3 and local checks, respectively, at 90 days (Table 9).

**Tuber dry matter content (%):** Clone WS/07-113 (18.8%) possessed at par tuber dry matter content with K Thar 1/2/3 and local check (18.3) at 90 days crop duration under AICRP evaluation (Table 10).

### Disease resistance

Advanced clone WS/07-113 possessed field resistance to late blight (Table 11), and therefore, it is likely to replace the late blight

**Table 9. Total tuber yield (t/ha) of clone WS/07-113 under AICRP at 90 days.**

Year	Irrigation	WS/07-113	Kufri Thar-1/2/3	Local check	Mean
2019-20	I <sub>1</sub>	26.7	28.2	26.3	27.1
2020-21	I <sub>1</sub>	31.0	30.2	28.5	29.9
2021-22	I <sub>1</sub>	35.7	32.8	30.2	32.9
	Mean	31.1	30.4	28.3	29.9
% Yield increase ±		-	2.3	9.9	-
2019-20	I <sub>2</sub>	23.2	22.9	21.8	22.6
2020-21	I <sub>2</sub>	28.4	25.9	22.5	25.6
2021-22	I <sub>2</sub>	31.1	29.0	27.4	29.2
	Mean	27.6	25.9	23.9	25.8
% Yield increase ±		-	6.6	15.5	-

2019-20: Bhubneshwar, Faizabad, Deesa, Gwalior and Hisar  
2020-21: Bhubneshwar, Faizabad, Deesa, Gwalior, Raipur and Hisar

2021-22: Bhubneshwar, Faizabad, Deesa, Gwalior, Raipur and Hisar

**Table 10. Tuber dry matter content in WS/07-113 at 90 days.**

Year	Irrigation	WS/07-113	K Thar-1/2/3	Local check	Mean
2019-20	I <sub>1</sub>	18.9	19.3	18.0	18.7
2020-21	I <sub>1</sub>	19.0	19.9	18.5	19.2
2021-22	I <sub>1</sub>	18.7	20.1	16.5	18.4
	Mean	18.9	19.8	17.7	18.8
2019-20	I <sub>2</sub>	19.0	18.4	18.4	18.5
2020-21	I <sub>2</sub>	19.2	19.6	18.5	19.1
2021-22	I <sub>2</sub>	18.3	19.9	18.1	18.8
	Mean	18.8	19.3	18.3	18.8

susceptible varieties like K Bahar. It showed a lesion area of 5.23 cm<sup>2</sup> as compared to K Bahar, which exhibited 8.34 cm<sup>2</sup>. For AUDPC also proposed that it showed less AUDPC in comparison to the variety K Bahar.

### Keeping Quality

Advanced clone WS/07-113 possessed medium (6-8 weeks) dormancy. Physiological weight loss, rottage, total weight loss and firm tuber appearance were comparable to K Bahar after 90 days of storage at room temperature. After 90 days, sprouting was 46%, rottage was 0%, sprout weight was 4.9 g/5kg fresh weight, and weight loss was 12.8% in clone WS/07-113, whereas, K Bahar recorded higher sprouting (74%), and comparable rottage (0.7%), sprout weight (4.2 g/5kg fresh weight) and weight loss 12.9% (Table 12).

### Evaluation of clone WS/07-113 for heat tolerance

This advanced clone was also evaluated for heat tolerance at Modipuram (75 days)

**Table 11. Reaction to late blight in foliage and tuber at Modipuram.**

Hybrid/ variety	Lesion area (cm <sup>2</sup> )	Remarks/ result
<i>Tuber slice test</i>		
WS/07-113	5.23	Moderately resistant
Kufri Bahar	8.34	Susceptible

Hybrid/variety	AUDPC	rAUDPC	Remarks/ result
Field Evaluation			
WS/07-113	728.8	0.347	Moderately resistant
Kufri Bahar	1350.7	0.643	Susceptible

**Table 12. Keeping quality traits after 90 days of storage at room temperature.**

Variety	Sprouting (%)	Rottage (%)	Sprout weight (g/5kg Fr. Wt.)	Weight loss (%)
WS/07-113	46	0.0	4.9	12.8
K Bahar	74	0.7	4.2	12.9
K Pukhraj	100	1.3	16.6	16.3
Mean	80	0.6	8.3	13.6

and Raipur (90 days). At Modipuram, clone WS/07-113 performed well and yielded (24.8 t/ha) more over K Surya (23.0 t/ha) and was comparable to K Kiran (24.7 t/ha). At Raipur, advanced clone WS/07-113 (42.56 t/ha) yielded more over K Kiran (39.31 t/ha) and K Surya (37.54 t/ha), as depicted in Tables 13 & 14.

### Package of practices for cultivation of potato variety Kufri Daksh (WS/07-113)

#### *Selection of field and land preparation:*

Sandy loam soil with 6.5-7.5 pH is most suitable for potato cultivation. Summer cultivation of the field is necessary to control diseases and pests. Green manuring is recommended to improve soil organic carbon and control of soil and tuber-borne diseases. Field should be levelled and well drained. The field is prepared by 1-2 ploughing with mould board plough or disc harrow followed

by 2 cross harrowing and 2-3 tilling with tiller. Afterwards, cross planking is done for better soil moisture conservation.

**Seed treatment:** After harvesting, wash the seed tubers in clean water and treat them (dip or spray) with 3% boric acid for 15-20 minutes. Dry tubers in shaded places and keep them in cold storage. The boric acid solution, once prepared, can be used 20 times in dipping. This is effective in management of black scurf and common scab.

**Sowing/planting time:** In Rabi season, the optimum planting time is are Last week of October to the first fortnight of November (for Gujrat and Orissa) and the last week of October to the first week of November (for Madhya Pradesh, Chhattisgarh and Uttar Pradesh).

**Seed and planting:** Take out seed tubers from cold store at least 10 days before planting. Do not bring out seed bags in direct sunlight, as tubers may rot due to sudden exposure to high temperatures. Spread the tubers in thin layer under shade, preferably in diffused light for sprouting and allow sprouts to become 0.5-1.0 cm long, thick and green. Carry sprouted tubers to the fields in seed trays or baskets for planting to avoid sprout damage. Remove white, pale, thin sprouted, diseased and rotten tubers. Seed size tubers should have a diameter of 30 to 55 mm (40-60 g), and seed rate may vary from 35-40 q/ha. Whole tuber is recommended for disease free quality seed production. For optimum plant population, crop geometry of 60 cm as inter-row and 20 cm intra-row spacing is desirable. Planting depth of 10-12 cm is better for achieving uniform emergence.

**Nutrient management:** Apply 10-15 t/ha well rotten FYM before planting. This, along with green manuring, reduces half the dose of phosphorus and potassium. For seed crop, generally 90 kg nitrogen, 80 kg phosphorous and 100 kg potash per hectare at the time

Table 13. Evaluation under high-temperature stress at Modipuram (75 days).

Hybrid/variety	Emergence (%)	Marketable tuber yield (t/ha)	Total tuber yield (t/ha)	TDMC (%)	Foliage senescence (%)
WS/07-113	83.3	22.6	24.8	18.9	50
K Bahar	90.0	16.0	16.8	17.9	75
K Kiran	72.2	22.9	24.7	17.2	50
K Surya	80.0	22.4	23.0	18.7	50
CD (0.05)	7.70	3.23	3.25	-	-
CV (%)	21.3	8.96	8.53	-	-

Table 14. Evaluation for heat tolerance at Raipur (90 days).

Hybrid/variety	Emergence (%)	Foliage senescence (%)	Tuber yield (t/ha)		TDMC (%)
			Total	Marketable	
WS/07-113	98.6	35.0	42.6	40.5	18.54
K Kiran	97.2	22.3	39.3	37.3	19.28
K Surya	98.6	21.7	37.5	36.4	19.09
S.Ed	1.61	3.29	1.75	1.91	0.24
CD (0.05)	NS	7.04	3.75	4.09	0.52
CV (%)	2.04	17.18	5.18	6.02	1.57

of planting and 90 kg nitrogen per hectare at the time of earthing-up is recommended. For ware crops, at Modipuram, optimum nitrogen, phosphorous and potassium levels are 180, 80 and 100 kg/ha, under mild water stress conditions (33% less irrigation water). Nutrient management in other agro-ecologies may differ and regional recommendations may be adopted to obtain optimum productivity for variety.

**Weed control measures:** Herbicides can be used to control weeds if their intensity is high. Pre-plant incorporation of fluchloralin (0.70-1.0 kg/ha) or pre-emergence application of metribuzin (0.50-0.75 kg/ha) or post-emergence application of paraquat (0.40- 0.50 kg/ha) at about 5% emergence of potato crop controls annual grasses and broad leaf weeds effectively. Inter-culture and earthing operations are recommended to provide aeration in root zone, improving nitrogen use and controlling second flush of weeds. This is done after 22-25 days of planting when the crop is 8-12 cm tall. The remaining nitrogen dose is also applied at this stage.

**Irrigation:** If sufficient soil moisture is unavailable, then pre-planting irrigation is done to ensure uniform emergence. First irrigation should be applied 12-14 day after planting. Second irrigation is applied after earthing at 25-27 days. Subsequently, 1-3 irrigations at 12-15 days interval are sufficient as the variety has tolerance for water deficit stress. However, it also yields very well under normal irrigation. Light irrigation should be applied, and the ridges should not submerge under water in any case.

### Disease and Pest Management

**Late Blight:** Prophylactic spray (just at the time of canopy closure) with mancozeb or propineb or chlorothalonil @ 0.2% (2 g/l of water) followed by need based application of cymoxanil + mancozeb or dimethomorph +

mancozeb or fenamidone + mancozeb @ 0.3% (3 g/l of water) for effective management of late blight.

**White flies and aphid:** For seed crops, Seed treatment with imidacloprid (200 SL) @ 0.04% (4 ml/10 l) for 10 minutes before planting. Place yellow sticky traps (size 15 × 30 cm<sup>2</sup>) just above the canopy height @60 traps per hectare at equidistance from each other for mass trapping of white flies/aphids. First spray with imidacloprid (200 SL) @ 0.03% (3 ml/10 l of water) at 85% crop emergence. Second spray with thiamethoxam (25 WG) @ 0.05% (5 gm/10 l of water) after 10-15 days of first spray.

### Other Insect and Pests:

In early planted crop, against leaf hoppers and mites, foliar spray of imidacloprid (200 SL) @ 0.03% (3 ml/10 l of water) or dicofol 18.5 EC @ 2 l/ha at 30-35 days after planting should be given. In main crop, for the management of cutworms, white grubs, beetles and leaf eating caterpillars spray chlorpyrifos 20EC @ 2.5 l/ha.

**Harvesting:** Stop irrigation 10-15 days before haulm cutting. Harvest crop after 15-20 days of haulm cutting and at proper soil moisture. After harvest, dry the produce in shade and keep tubers in heaps for 10-15 days for skin curing. Remove all damaged and rotten tubers. To get good returns, grade the produce, pack in gunny bags and label them. Store them immediately in cold storage, if meant for selling later in the season.

**Expected yield of variety:** Expected yield of the variety under deficit water (20% less) conditions is around 28 t/ha and under normal irrigation conditions is around 31 t/ha.

### CONCLUSIONS

Advanced potato clone WS/07-113 released as variety Kufri Daksh for central and eastern

plains of India is a main season, medium maturing, high yielding, water-use-efficient table potato variety that can be grown in regions with limited water availability and high-temperature stress. Its plants are tall and vigorous, with field resistance to late blight. Its tubers are white-cream (light yellow), ovoid with shallow to medium eyes and cream flesh with good keeping quality. It is fertilizer responsive and capable of yielding 30-35 t/ha under low water ( $\leq 20\%$ ) availability in middle Gangetic plains. Kufri Daksh could be an excellent choice to tolerate high temperature and water stress regimes in changing climatic scenarios.

### CONFLICT OF INTEREST

The authors declare that they have no conflict of interest

### ETHICAL STATEMENT

This article does not contain any studies with human participants or animals performed by any of the authors

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