



## Performance of potato (*Solanum tuberosum*) clones under water stress

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### ABSTRACT

An experiment was conducted at the Central Potato Research Institute Campus, Modipuram, during autumn crop seasons of 2008–09 and 2009–10, to assess the influence of different irrigation regimes on advanced clones of potato (*Solanum tuberosum* L.) developed at the International Potato Center, Lima. Three irrigation regimes adopted were: non-stress (five irrigations), moderate water deficit (three irrigations up to 55 days after planting) and severe water deficit (two irrigations up to 25 days after planting). seven clones and two varieties were screened. High canopy temperature was witnessed under reduced irrigation and a difference of 2.1°C was recorded between normal irrigated and severe water deficit treatments 80 days after planting. Plant height decreased significantly with reduced irrigation, especially under severe water deficit from 48.3 cm to 35.4 cm. Marketable tubers/plant reduced significantly from 7.2 (normal irrigation regime) to 3.9 (severe water deficit). Tuber yield was also reduced significantly from 560 g/plant (normal irrigation regime) to 271 g/plant (severe water deficit). Yield reduction under severe water deficit was minimum in CIP clone 397069.11 (39.6%), followed by clone 395195.7 (47.3%). The high yield maintenance ability of clones 395195.7 and 397069.11 under severe water stress was also supported by the higher drought tolerance index (0.983 and 0.566 respectively) and the lower drought susceptibility index (0.914 and 0.729 respectively). Across the clones, tuber dry matter content was higher under severely reduced irrigation (21.9%) compared to normal irrigation (18.9%). Among clones, maximum tuber dry matter content was recorded in clone 395195.7 (22.4%) compared to varieties Kufri Bahar (21.0%) and Kufri Pukhraj (18.2%).

**Key words:** Drought susceptibility index, Drought tolerance index, Potato, Tuber yield, Water deficit

Drought is commonly defined as a period without significant rainfall. Generally, drought stress occurs when the available water in the soil is reduced and atmospheric conditions cause continuous loss of water by transpiration or evaporation. Drought-stress tolerance is common in almost all plant species, but its extent varies from species to species. Water deficit is a global issue that needs to be taken into consideration to ensure survival of agricultural crops and sustainable food production (Jaleel *et al.* 2009).

Potato (*Solanum tuberosum* L.) is a drought-sensitive crop and the detrimental effects of drought on potato tuber yield and other related traits are well documented (ICPRE and UI-CALS 2002, Taligan and Tad-Awan 2004, Lahlou and Ledent

2005, Hassanpanah and Benam 2007, Schafleitner *et al.* 2007, Hassanpanah 2010). Water deficit, besides, is responsible for tuber yield reduction, decreased number of leaves, plant water potentials, leaf area, plant height, ground coverage and tuber number (Hassanpanah 2010). Lahlou *et al.* (2003), Schafleitner *et al.* (2007), Jose and Tad-Awan (2008) and Hassanpanah (2010) reported genotype-dependent differences of yield maintenance under water stress. The present study was aimed to identify high-yielding, drought-tolerant potato clones under variable water deficit conditions.

### MATERIALS AND METHODS

A field experiment was conducted during the winter (*rabi*) seasons of 2008–09 and 2009–10 at the Central Potato Research Institute Campus, Modipuram, Meerut (29° 4' N, 77° 46' E, 237 m asl) in a strip-plot design with three replications. Treatments consisted of a vertical factor-irrigation regimes, viz I<sub>1</sub>, normal irrigation; I<sub>2</sub>, moderate water deficit; I<sub>3</sub>, severe water deficit; and a horizontal factor- seven CIP clones (V<sub>1</sub>, 394034.7; V<sub>2</sub>, 395109.29; V<sub>3</sub>, 395112.6; V<sub>4</sub>, 395195.7; V<sub>5</sub>, 396037.15; V<sub>6</sub>, 397069.11; V<sub>7</sub>, 397073.7) and

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Table 1 Monthly meteorological parameters during crop seasons

Month	2008–09					2009–10				
	Monthly mean air temperature (°C)			Monthly BSS (hr)	Monthly rainfall (mm)	Monthly mean air temperature (°C)			Monthly BSS (hr)	Monthly rainfall (mm)
	Max.	Min.	Mean			Max.	Min.	Mean		
October	32.44	19.60	26.02	178.1	0.00	33.12	18.14	25.63	221.5	0.00
November	27.78	12.59	20.18	147.6	6.40	27.02	12.54	19.78	126.2	0.00
December	23.65	9.46	16.55	132.5	0.00	24.02	6.74	15.38	116.5	3.20
January	21.20	8.50	14.85	120.9	5.30	17.16	6.50	11.83	71.55	11.10

BSS, Bright sunshine hours

two Indian varieties ( $V_8$ , Kufri Bahar;  $V_9$ , Kufri Pukhraj). In the non-stressed treatment, five irrigations were given as and when required. In the moderate water-deficit treatment three irrigations were applied up to 55 days, whereas in the severe water deficit treatment only two irrigations were given up to 25 days after planting. Approximately, 50 mm water was applied at each irrigation by means of ridge and furrow method. The experiment was planted on 20 and 28 October in 2008 and 2009 respectively. Well-sprouted seed tubers of 50–60 g seed weight and 40–45 mm size were planted at a spacing of 60 cm  $\times$  20 cm in plots of 2.4 m  $\times$  1.4 m. The plots were fertilized with 180, 80 and 100 kg/ha of N,  $P_2O_5$  and  $K_2O$ , respectively. Half dose of nitrogen and full dose of P and K were applied in the field at the time of planting and remaining nitrogen was applied at earthing-up (25 days after planting). There were minor rainfalls (Table 1) during both the crop seasons, i.e. 2008–09 (11.7 mm) and 2009–10 (14.3 mm). Fungicides and insecticides were sprayed as and when required. Crop was dehaulmed manually 90 days after planting and harvested 15 days later, once tuber skin was sufficiently hardened.

#### Analyzed variables

Plant height was recorded on five random plants in each plot 75 days after planting. Canopy temperature was recorded with Infra Red Thermometer (Model 8872) at different crop stages. Total and marketable (> 20 g) tuber yield and number were recorded at harvest from the produce of the plot. Three tubers were taken from each plot and chopped into small pieces to estimate tuber dry matter content. A representative sample of 50 g was drawn and kept in oven at 80°C until constant weight was achieved. Drought susceptibility index (DSI) and drought tolerance index (DTI) were calculated as per Hassanpanah (2010). Data were analyzed statistically with the help of statistical software IRRISTAT (1999).

## RESULTS AND DISCUSSION

#### Plant height

Across clones and varieties, plant height decreased significantly with an increase in the water deficit during both

the years. The mean plant height decreased from 48.3 cm (normal irrigation) to 40.9 cm (moderate water deficit) and 35.4 cm (severe water deficit). It was the highest in clone 395195.7 (47.7 cm), followed by clone 397069.11 (46.2 cm) and clone 395109.29 (46.2 cm). The reduction in plant height can be associated with a decline in cell enlargement (hypertrophy) due to water stress. Water stress is known to suppress cell expansion and cell growth due to low turgour pressure. Our results confirm the findings of Kumar *et al.* (2007), Shao *et al.* (2008) and Jaleel *et al.* (2009).

#### Canopy temperature

Across genotypes, canopy temperature remained higher after 45 days in the severe water deficit treatment compared to normal irrigation. Irrigation at regular intervals in normal irrigation treatment kept the canopy cooler because of higher transpiration compared to moisture-stressed treatments. At 80 days after planting the canopy temperature was 2.1°C higher in the severe water deficit treatment than in the normal watered treatment (Fig 1).

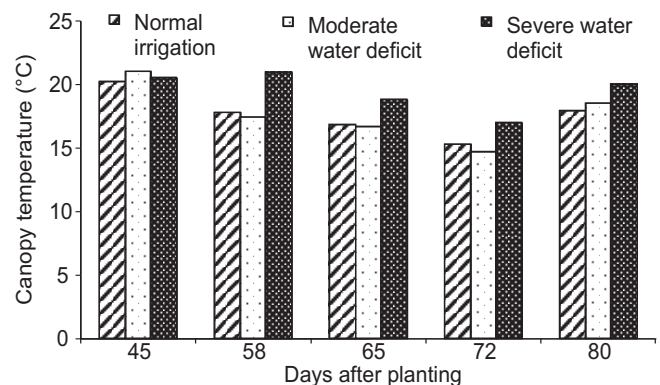


Fig 1 Canopy temperature (°C) at different crop stages under different irrigation regimes (mean of CIP clones and varieties over years)

#### Marketable tuber number

Marketable tuber number (> 20 g) decreased linearly as the water deficit increased, but the significant differences were between normal irrigation and severe water deficit, when

compared based on pooled data (Table 2). Non-significant differences between normal irrigated treatment and mild water deficit treatment can be ascribed to the fact that little water stress was experienced by the mild-stress treatment plots as irrigations were given up to 55 days. In severe water deficit treatment soil moisture was available up to the initial vegetative stage and stolon formation, but afterwards water stress became a limiting factor for proper tuberization and attaining size of marketable grade. Present findings agree with those of Deblonde and Ledent (2001), Hassan *et al.* (2002), Kumar *et al.* (2007), Schafleitner *et al.* (2007) and Hassanpanah (2010). The highest marketable tuber number under severe water stress were recorded in clone 396037.15 (4.62) and lowest in clone 395112.6 (2.84). Marketable tuber number in clones 395195.7 and 397069.11 was also at par with clone 396037.15.

*Marketable and total tuber yield*

Producing maximum marketable tuber yield is the farmers' ultimate aim to get maximum benefit. Over clones and varieties, the marketable and total tuber yield decreased significantly with an increase in water stress during both the years (Table 3). Reduced tuber yield under severe drought can be attributed to reduced crop growth (stem number, compound leaf number, plant height, percent ground cover, etc.) and tuber number. Reduced crop growth under water stress might have led to decrease in photosynthetic area. Perusal of the pooled data indicated that clone 395195.7 (335 and 386 g/plant) produced the highest marketable and total tuber yield, followed by clone 397069.11 (279 and 342 g/plant) under severe water deficit conditions. Control cultivar Kufri Pukhraj (227 and 285 g/plant) produced statistically similar marketable and total tuber yield as compared to clone 397069.11. Yield reduction under severe water deficit was minimum in clone 397069.11 (39.6%), followed by clone 395195.7 (47.3%) and was the highest in clone 395112.6 (62.4%). Lower yield reduction indirectly reflected the drought tolerance in clones 397069.11 and 395195.7, which was also evidenced by their high drought tolerance index. Tuber yield reduction due to water stress has been reported in potato by many researchers (Fabeiro *et al.* 2001, Hassan *et al.* 2002, Kashyap and Panda 2002, Tourneux *et al.* 2003, Schafleitner *et al.* 2007).

*Tuber dry matter content*

Across clones and varieties, the tuber dry matter content increased as the water stress increased (Table 2). The lowest dry matter content (18.9%) was recorded in the normal irrigated treatment and the highest (21.9%) in the severe water deficit treatment. Kumar *et al.* (2007) and Jose and Tad-Awan (2008) also reported difference in tuber dry matter content in water deficit treatments over control. There was large variation in clones with respect to tuber dry matter content. However, across irrigation regimes highest tuber dry matter

Table 2 Effect of moderate and severe water deficit on marketable tuber no./plant and tuber dry matter content of potato clones and varieties

Clone/variety	Tuber dry matter content (%)																									
	Marketable tuber no. (> 20g)					2008-09					2009-10															
	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean										
V <sub>1</sub> , 394034.7	7.90	6.02	3.22	5.72	6.98	5.71	4.93	5.87	7.44	5.87	4.08	5.79	18.5	22.3	21.1	20.7	19.8	19.7	20.9	20.2	19.2	21.0	21.0	20.4		
V <sub>2</sub> , 395109.29	8.06	5.15	3.16	5.46	6.32	4.95	4.11	5.13	7.19	5.05	3.64	5.29	18.5	21.1	22.5	20.7	20.6	20.1	23.5	21.4	19.6	20.6	23.0	21.1	21.1	
V <sub>3</sub> , 395112.6	9.78	6.73	2.24	6.25	5.39	3.94	3.44	4.26	7.59	5.34	2.84	5.25	20.1	21.2	21.3	20.9	18.8	20.0	22.2	20.4	19.5	20.6	21.8	20.6	20.6	
V <sub>4</sub> , 395195.7	9.28	4.22	5.50	6.33	4.98	3.93	3.38	4.09	7.13	4.08	4.44	5.22	18.1	23.6	24.6	22.1	21.5	23.2	23.3	22.7	19.8	23.4	24.0	22.4	22.4	
V <sub>5</sub> , 396037.15	8.22	5.76	5.78	6.59	6.45	5.97	3.46	5.29	7.34	5.87	4.62	5.94	18.7	21.3	23.4	21.1	20.4	20.7	23.0	21.4	19.6	21.0	23.2	21.3	21.3	
V <sub>6</sub> , 397069.11	8.22	5.40	5.25	6.29	5.30	4.33	3.37	5.33	6.76	4.87	4.31	5.31	18.2	19.2	21.8	19.7	19.8	19.3	20.9	20.0	19.0	19.3	21.4	19.9	19.9	
V <sub>7</sub> , 397073.7	10.48	7.47	4.35	7.43	5.17	4.45	3.36	4.33	7.83	5.96	3.86	5.88	18.5	19.4	22.3	20.1	17.0	18.4	19.7	18.4	17.8	18.9	21.0	19.2	19.2	
V <sub>8</sub> , Kufri Bahar	7.24	5.15	3.46	5.28	5.77	4.74	3.90	4.81	6.51	4.95	3.68	5.04	19.0	20.7	22.8	20.8	19.7	21.1	22.9	21.2	19.4	20.9	22.9	21.0	21.0	
V <sub>9</sub> , Kufri Pukhraj	7.26	5.40	3.29	5.32	6.88	5.07	4.60	5.52	7.07	5.24	3.95	5.42	16.3	19.7	19.5	18.5	16.3	18.3	19.1	17.9	16.3	19.0	19.3	18.2	18.2	
Mean	8.49	5.70	4.03		5.91	4.79	3.84		7.20	5.25	3.94	5.46	18.4	21.0	22.1		19.3	20.9	21.7		18.9	20.5	21.9		21.9	
LSD (P=0.05)																										
Irrigation (I)	1.44				0.679				0.88				1.24					1.01				1.12				
Clone/variety(V)	1.80				1.21				1.43				1.30					1.18				1.08				
Interaction IxV	3.12				NS				NS				2.00					NS			NS					

I<sub>1</sub>, Normal irrigation; I<sub>2</sub>, moderate water deficit; I<sub>3</sub>, severe water deficit; NS, non-significant

Table 3 Effect of moderate and severe water deficit on marketable and total tuber yield/plant of potato clones and varieties

Clone/variety	Marketable tuber yield/plant (g)												Total tuber yield/plant (g)												
	2008-09				2009-10				Pooled				2008-09				2009-10				Pooled				
	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	I <sub>1</sub>	I <sub>2</sub>	I <sub>3</sub>	Mean	
V <sub>1</sub> , 394034.7	416	341	137	298	299	245	185	243	358	293	161	270	543	434	209	395	367	303	228	299	455	368	218	347	
V <sub>2</sub> , 395109.29	469	403	193	355	332	224	164	240	401	314	179	298	577	504	254	445	411	276	223	303	494	390	238	374	
V <sub>3</sub> , 395112.6	623	521	181	442	351	227	202	260	487	374	192	351	789	601	221	537	391	276	223	300	590	438	222	417	
V <sub>4</sub> , 395195.7	940	449	429	606	404	283	241	309	672	366	335	458	1027	499	502	676	436	311	269	339	732	405	386	507	
V <sub>5</sub> , 396037.15	521	385	219	375	323	256	135	238	422	321	177	307	639	532	298	490	392	313	199	302	516	423	248	396	
V <sub>6</sub> , 397069.11	597	385	368	450	334	261	190	262	465	323	279	356	752	448	452	550	381	306	231	306	566	377	342	428	
V <sub>7</sub> , 397073.7	715	535	262	504	386	236	163	262	551	385	213	383	809	621	336	589	428	283	208	306	618	452	272	447	
V <sub>8</sub> , Kufri Bahar	558	430	199	395	359	275	162	265	459	352	181	331	631	505	258	464	402	316	200	306	517	411	229	385	
V <sub>9</sub> , Kufri Pukhraj	571	447	194	404	412	294	260	322	492	371	227	363	643	521	266	476	456	335	303	365	550	428	285	421	
Mean	601	433	242		356	256	189		478	344	216	-	712	518	311		407	302	233		560	410	271		
LSD (P=0.05)																									
Irrigation (I)		57.9				24.5				38.8				90.0				25.2				42.1			
Clone/variety(V)	121.2					50.6				74.2				141.6				60.0				76.0			
Interaction IxV	NS					NS				NS				NS				NS				NS			

I<sub>1</sub>, Normal irrigation; I<sub>2</sub>, moderate water deficit; I<sub>3</sub>, severe water deficit, NS, non-significant

Table 4 Drought susceptibility index and drought tolerance index of potato clones/varieties under moderate and severe water deficit (based on pooled total tuber yield/plant)

Clone/variety	Drought susceptibility index		Drought tolerance index	
	Moderate water deficit	Severe water deficit	Moderate water deficit	Severe water deficit
V <sub>1</sub> , 394034.7	0.647	1.003	0.458	0.252
V <sub>2</sub> , 395109.29	0.774	1.009	0.550	0.313
V <sub>3</sub> , 395112.6	0.827	1.104	0.795	0.408
V <sub>4</sub> , 395195.7	1.624	0.914	1.074	0.983
V <sub>5</sub> , 396037.15	0.853	1.058	0.591	0.326
V <sub>6</sub> , 397069.11	1.089	0.729	0.656	0.566
V <sub>7</sub> , 397073.7	1.074	1.118	0.926	0.512
V <sub>8</sub> , Kufri Bahar	0.831	1.104	0.705	0.363
V <sub>9</sub> , Kufri Pukhraj	0.877	0.982	0.797	0.488
Mean	0.955	1.002	0.728	0.468

content was recorded in clone 395195.7 (22.4%), followed by clone 396037.15 (21.3%).

#### Drought susceptibility index and drought tolerance index

Stress indices were used to screen and identify the drought tolerant genotypes. Deshmukh *et al.* (2004) reported that drought-resistant genotypes should have high drought tolerance index (DTI) and minimum drought susceptibility index (DSI). In the present study minimum DSI was recorded in clone 397069.11 (0.729), followed by clone 395195.7 (0.914) under severe water deficit treatment. The DTI values were maximum in clone 395195.7 (0.983), followed by clone 397069.11 (0.566) under severe water deficit treatment (Table 4). Differences in potato genotypes for DSI and DTI indices due to water stress were earlier reported by several workers in different crops (Schafleitner *et al.* 2007, Parameshwarappa and Salimath 2008, Hassanpanah 2010).

Minimum yield reduction under severe water deficit was recorded in clone 397069.11 (39.6%), followed by clone 395195.7 (47.3%) and was the highest in clone 395112.6 (62.4%). CIP clone 395195.7 had the highest dry matter (22.4%) content. All clones gave higher dry matter than high-yielding variety Kufri Pukhraj. Overall, CIP clones 395195.7 and 397069.11 were identified as promising genotypes for drought tolerance based on their high drought tolerance index, low drought susceptibility index and high yield maintenance under severe water deficit conditions.

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