RESEARCH PAPER

Stomatal conductance and stomatal resistance studies in relation to haulm yield in potato

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The experiment was laid out in *Rabi* season(2009-2010 and 2010-2011). IRGA instrument (LI-6400XT) was used for estimation different microclimatic parameters of the crop within the height of 2 mt. In general, during both seasons, there was a rapid increase in mean stomatal conductance from early growth stage to 56 days and thereafter it gradually decreased towards maturity of the crop.Highest mean values of stomatal conductance were recorded at 56 DAP interval as 0.38 and 0.52 mol. m^{-2} s^{-1} in 2009 and 2010, respectively. Further, there was also gradual increase in mean stomatal resistance from early growth stage towards maturity of the crop. Lowest mean values of stomatal resistance were recorded at 28 DAP interval as 4.21 and 3.28 mol. m^{-2} s^{-1} in 2009 and 2010, respectively. Increased stomatal conductance appeared to be the reason for the first peak whereas for the second peak non stomatal characters may be responsible. Stomatal resistance governs photosynthesis and transpiration .Decrease in soil moisture content increased stomatal resistance. High temperature was associated with decreased stomatal resistance. Stomatal resistance is affected by many factors including PAR, leaf age, air temperature and the CO_2 concentration.Analysis of the relationship between PAR, leaf age, air temperature and the CO_2 concentration at the various growth stages for the different treatments showed that 1.2 IW/CPE ratio and planting on 44th MW with mulching treatment proved to be superior to the other treatments. It is observed from the data that during both the years of experimentation, of haulm yield (q ha^{-1}), mulching produced significantly higher mean values of these haulm yield (q ha^{-1}) than without mulching. The haulm production which was reduced by the effect of water stress on stem growth and reduction in number of branches, as well as to a limited extent on the tubers themselves.

Key words **:** Stomatal conductance, Stomatal resistance, Haulm yield, Potato

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INTRODUCTION

The major potato growing countries in the world are China, Russian Federation, India, USA, Ukraine, Poland, Germany, Belarus, Netherlands, France, UK, Canada, Turkey and Romania. India ranks 4th in area and 3rd in production in the world. The total potato production in India is about 36.57 million tonnes from about 1.83 million ha with productivity of 19.98 t ha^{-1} during 2009-2010. Potato is grown over the states under very diverse conditions. The plant leaves must remain turgid for leaf expansion, to keep stomata open for higher photosynthetic rate. In plant, leaves functions as an optical organs and spectral radiation properties are attuned to environment in which they live. The efficiency of absorption of PAR partly determines the efficiency of photosynthesis of plant. The PAR is absorbed more efficiently and centering around 400-700 nm, determines the plant development. Among the main factors which affect the rapid establishment of the crop canopy are genotypes, planting date, planting density, temperature and the availability of water and nutrients in the soil. Potato is a weather sensitive crop influenced by environmental conditions. With this back ground in view, the present investigation was undertaken to know the relationship between stomatal conductance with haulm yield as affected by irrigation levels in potato.

RESEARCH METHODOLOGY

The experiment was laid out in Split Plot Design in *Rabi* season during 2009-2010 and 2010-2011 with recommended

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dose of fertilizer (120:60:120 NPK kg ha^{-1}). There were eighteen treatments comprised of nine main plot treatments and two sub-plot treatments:

Treatment details **:** A. Main plot treatments (Nine)	
Irrigation levels (I) X Planting dates (D)	
I1D1- (0.8 IW/CPE) X (42 MW)	I2D1- (1.0 IW/CPE) X (42 MW)
I1D2- (0.8 IW/CPE) X (44 MW)	I2D2- (1.0 IW/CPE) X (44 MW)
I1D3- (0.8 IW/CPE) X (46 MW)	I2D3- (1.0 IW/CPE) X (46 MW)
I3D1- (1.2 IW/CPE) X (42 MW)	
I3D2- (1.2 IW/CPE) X (44 MW)	
I3D3- (1.2 IW/CPE) X (46 MW)	
B. Sub-plot Treatments (Two) Mulching (M)	
M1- With mulch	M2- Without mulch

IRGA instrument (LI-6400XT) was used for estimation different microclimatic parameters of the crop within the height of 2 mt. The microclimate observations were recorded as:

Sr. No.	Particulars	Frequency	Period (DAP)	Sample size
1	Stomatal conductance	4	28, 56, 84, and at harvest	One plant from each net plot
2	Stomatal resistance	4	_"_	--do--

RESEARCH FINDINGS AND ANALYSIS

The experimental findings of the present study have been presented in the following sub heads:

Effect of different treatments on stomatal conductance :

The data pertaining to stomatal conductance of potato as influenced by various treatments at different growth stages are housed in Table 1 and 2 (2009-2010 and 2010-2011). In general, during both seasons, there was a rapid increase in mean stomatal conductance from early growth stage to 56 days and thereafter it gradually decreased towards maturity of the crop.Highest mean values of stomatal conductance were recorded at 56 DAP interval as 0.38 and 0.52 mol. m^{-2} s^{-1} in 2009 and 2010, respectively.

Effect of irrigation levels and planting dates (IxD) :

During the first year at 28 DAP the mean stomatal conductance was maximum with I_3D_2 (0.86 mol. m^{-2} s^{-1}) followed by I_2D_2 and I_1D_2, which was at par with I_3D_1, I_2D_1 and I_1D_1. At 56 DAP during first year, the significantly maximum mean stomatal conductance was obtained with I_3D_2 (0.73 mol. m^{-2} s^{-1}) followed by I_2D_2, which was at par with I_1D_2, I_3D_1 and I_2D_1. During second year maximum stomatal conductance was obtained by I_3D_2 (1.07 mol. m^{-2} s^{-1}) followed I_2D_2, which was at

Table 1 : Stomatal conductance as influenced by various treatments 2009-2010

Treatments	Stomatal conductance (mol. m^{-2} s^{-1}) 28 DAP M$_1$ (With mulch)	28 DAP M$_2$ (Without mulch)	28 DAP Mean	56 DAP M$_1$ (With mulch)	56 DAP M$_2$ (Without mulch)	56 DAP Mean	84 DAP M$_1$ (With mulch)	84 DAP M$_2$ (Without mulch)	84 DAP Mean	At harvest M$_1$ (With mulch)	At harvest M$_2$ (Without mulch)	At harvest Mean
I_1D_1 (0.8 IW/CPE x 42 MW)	0.25	0.22	0.24	0.30	0.30	0.30	0.21	0.21	0.21	0.25	0.17	0.21
I_1D_2 (0.8 IW/CPE x 44 MW)	0.30	0.25	0.27	0.47	0.40	0.43	0.38	0.35	0.36	0.35	0.25	0.30
I_1D_3 (0.8 IW/CPE x 46 MW)	0.17	0.10	0.14	0.18	0.18	0.18	0.13	0.13	0.13	0.11	0.10	0.10
I_2D_1 (1.0 IW/CPE x 42 MW)	0.25	0.23	0.24	0.42	0.32	0.37	0.32	0.25	0.28	0.28	0.18	0.23
I_2D_2 (1.0 IW/CPE x 44 MW)	0.39	0.33	0.36	0.50	0.42	0.46	0.45	0.37	0.41	0.47	0.29	0.38
I_2D_3 (1.0 IW/CPE x 46 MW)	0.22	0.14	0.18	0.26	0.25	0.26	0.20	0.18	0.19	0.14	0.12	0.13
I_3D_1 (1.2 IW/CPE x 42 MW)	0.26	0.24	0.25	0.43	0.35	0.39	0.38	0.27	0.33	0.33	0.20	0.26
I_3D_2 (1.2 IW/CPE x 44 MW)	1.07	0.65	0.86	0.81	0.65	0.73	0.71	0.55	0.63	0.61	0.59	0.60
I_3D_3 (1.2 IW/CPE x 46 MW)	0.25	0.15	0.20	0.30	0.29	0.29	0.21	0.20	0.20	0.17	0.14	0.16
Mean	0.35	0.26	0.30	0.41	0.35	0.38	0.33	0.28	0.31	0.30	0.23	0.26
	S.E.	C.D. (P=0.05)		S.E.	C.D. (P=0.05)		S.E.	C.D. (P=0.05)		S.E.	C.D. (P=0.05)	
Main plot (I X D)	0.01	0.04		0.05	0.16		0.05	0.16		0.05	0.14	
Sub plot (M)	0.01	0.02		0.01	0.03		0.01	0.03		0.01	0.03	
Interactions												
I X M	0.01	NS		0.02	0.06		0.02	0.06		0.02	NS	
D X M	0.01	NS		0.02	0.06		0.02	0.06		0.02	NS	
(I X D) X M	0.02	0.06		0.03	0.10		0.03	0.10		0.03	0.08	

NS=Non significant

Table 2 : Stomatal conductance as influenced by various treatments 2010-2011

Treatments	Stomatal conductance (mol. $m^{-2} s^{-1}$)											
	28 DAP			56 DAP			84 DAP			At harvest		
	M_1 (With mulch)	M_2 (Without mulch)	Mean	M_1 (With mulch)	M_2 (Without mulch)	Mean	M_1 (With mulch)	M_2 (Without mulch)	Mean	M_1 (With mulch)	M_2 (Without mulch)	Mean
I_1D_1 (0.8 IW/CPE x 42 MW)	0.28	0.25	0.27	0.42	0.42	0.42	0.32	0.21	0.26	0.25	0.17	0.21
I_1D_2 (0.8 IW/CPE x 44 MW)	0.33	0.28	0.30	0.59	0.52	0.55	0.45	0.35	0.40	0.35	0.25	0.30
I_1D_3 (0.8 IW/CPE x 46 MW)	0.20	0.13	0.17	0.30	0.30	0.30	0.13	0.13	0.13	0.11	0.10	0.10
I_2D_1 (1.0 IW/CPE x 42 MW)	0.28	0.26	0.27	0.54	0.44	0.49	0.38	0.25	0.31	0.28	0.18	0.23
I_2D_2 (1.0 IW/CPE x 44 MW)	0.42	0.36	0.39	0.62	0.52	0.57	0.53	0.37	0.45	0.47	0.29	0.38
I_2D_3 (1.0 IW/CPE x 46 MW)	0.25	0.17	0.21	0.38	0.38	0.38	0.21	0.20	0.20	0.14	0.12	0.13
I_3D_1 (1.2 IW/CPE x 42 MW)	0.29	0.27	0.28	0.55	0.44	0.50	0.38	0.27	0.33	0.33	0.20	0.26
I_3D_2 (1.2 IW/CPE x 44 MW)	1.10	0.68	0.89	1.37	0.77	1.07	1.21	0.55	0.88	0.67	0.59	0.63
I_3D_3 (1.2 IW/CPE x 46 MW)	0.28	0.23	0.25	0.42	0.39	0.40	0.21	0.20	0.21	0.17	0.14	0.16
Mean	0.38	0.29	0.34	0.58	0.46	0.52	0.42	0.28	0.35	0.31	0.23	0.27
	S.E.	C.D. (P=0.05)		S.E.	C.D. (P=0.05)		S.E.	C.D. (P=0.05)		S.E.	C.D. (P=0.05)	
Main plot (I X D)	0.01	0.04		0.05	0.15		0.05	0.16		0.05	0.14	
Sub plot (M)	0.01	0.02		0.01	0.04		0.01	0.03		0.01	0.03	
Interactions												
I X M	0.01	NS		0.02	0.07		0.02	0.06		0.02	NS	
D X M	0.01	NS		0.02	0.07		0.02	0.06		0.02	NS	
(I X D) X M	0.02	0.06		0.04	0.12		0.03	0.10		0.03	0.08	

NS=Non significant

par with I_1D_2, I_3D_1, I_2D_1 and I_1D_1.

At 84 DAP during first year, significantly maximum mean stomatal conductance was registered under I_3D_2 (0.63 mol. $m^{-2} s^{-1}$) followed by I_2D_2, which was at par with I_1D_2, I_3D_1 and I_2D_1.At harvest during first year, significantly maximum mean stomatal conductance was registered under I_3D_2 (0.60 mol. $m^{-2} s^{-1}$) followed by I_2D_2, which was at par with I_1D_2 and I_3D_1. Significantly lowest mean stomatal conductance was obtained in I_1D_3 at all the growth stages. During second year of experimentation similar trend as that of first year was observed at all the stages of observations *i.e.* 28, 84 DAP and at harvest except at 56 DAP.

Effect of mulching :

The data presented in Table 1 and 2 implies that the mean stomatal conductance was significantly influenced due to mulching. The significantly maximum higher mean stomatal conductance was recorded in mulching compared to without mulching at all the days of observations during both the years of experimentation.

Interactions effect :

Treatments combination of irrigation levels with mulching (IxM) and planting dates with mulching (DxM) were found non significant except 56 and 84 DAP during the both years. The interaction combination of irrigation levels and planting dates with mulching (IxDxM) were found significant during both the years.

Interactions:

Interaction effect of (I x M) :

At 56 DAP during first year, the interaction combination of different treatments, I_3M_1 was recorded significantly highest mean stomatal conductance (0.51 mol. $m^{-2} s^{-1}$) followed by I_3M_2, which was at par with I_2M_1 (Table 3). While rests of the treatments were at par with each other. Same trend was also observed in second year.At 84 DAP during first year, the interaction combination of different treatments, I_3M_1 was recorded significantly highest mean stomatal conductance (0.43 mol. $m^{-2} s^{-1}$) followed by I_3M_2, which was at par with I_2M_1 (Table 4). While I_2M_2, I_1M_1 and I_1M_2 were at par with each other. During second year, I_3M_1 was obtained highest mean stomatal conductance (0.60 mol. $m^{-2} s^{-1}$) followed I_2M_1, which was at par with I_3M_2.

Interaction effect of (D x M):

At 56 DAP during first year, the interaction combination of different treatments, D_2M_1 was recorded significantly highest stomatal conductance (0.59 mol. $m^{-2} s^{-1}$) followed by D_2M_2, D_1M_1 and D_1M_2 in descending order. During second year, D_2M_1 has registered maximum stomatal conductance (0.86 mol. $m^{-2} s^{-1}$) followed by D_2M_2 and D_1M_1, which was at par with D_1M_2(Table

3). At 84 DAP during first year, the interaction combination of different treatments, D_2M_1 was recorded significantly highest stomatal conductance (0.51 mol. m^{-2} s^{-1}) followed by D_2M_2, D_1M_1 and D_1M_2, while D_3M_1 was at par with D_3M_2. During second year, same trend was observed (Table 4).

Interaction effect of (IxDxM) :

At 28 DAP during first year, the treatment combination $I_3D_2M_1$ recorded highest mean stomatal conductance (1.07mol. m^{-2} s^{-1}) followed by $I_3D_2M_2$ and $I_2D_2M_1$, which was at par with $I_2D_2M_2$, while rests treatments were at par with each others. At 56 DAP during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording highest mean stomatal conductance (0.81mol. m^{-2} s^{-1}) followed by $I_3D_2M_2$ and $I_2D_2M_1$, which was at par with $I_1D_2M_1$, $I_3D_1M_1$, $I_2D_2M_2$, $I_2D_1M_1$, $I_1D_2M_2$.

At 84 DAP, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording highest mean stomatal conductance (0.71 mol. m^{-2} s^{-1}) followed by $I_3D_2M_2$ and $I_2D_2M_1$, which was at par with $I_1D_2M_1$, $I_3D_1M_1$, $I_2D_2M_2$ and $I_1D_2M_2$. During second year $I_3D_2M_1$ was registered highest stomatal conductance (1.21 mol. m^{-2} s^{-1}) followed by $I_3D_2M_2$ which was at par with $I_2D_2M_1$ and $I_1D_2M_1$. At harvest, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording highest mean stomatal conductance (0.61 mol. m^{-2} s^{-1}), which was at par with $I_3D_2M_2$ followed by $I_2D_2M_1$ and $I_1D_2M_1$, which was at par with $I_3D_1M_1$, $I_2D_2M_2$ and $I_2D_1M_1$. During second year $I_3D_2M_1$ was registered highest stomatal conductance (0.67 mol. m^{-2} s^{-1}) followed by $I_3D_2M_2$, $I_2D_2M_1$ and $I_1D_2M_1$, which was at par with $I_3D_1M_1$, $I_2D_2M_1$ and $I_2D_1M_1$.During second year of experimentation similar trend as that of first year was observed at all the stages of observations *i.e.* 28, 56 DAP except at 84 DAP and at harvest.

Effect of different treatments on stomatal resistance :

The data pertaining to stomatal resistance of potato as influenced by various treatments at different growth stages are housed in Table 5 and 6. In general, during both seasons, there was gradual increase in mean stomatal resistance from early growth stage towards maturity of the crop. Lowest mean values of stomatal resistance were recorded at 28 DAP interval as 4.21 and 3.28 mol. m^{-2} s^{-1} in 2009 and 2010, respectively.

Effect of irrigation levels and planting dates (IxD) :

During the first year at 28 DAP the mean stomatal resistance was minimum with I_3D_2 (1.24 mol. m^{-2} s^{-1}) followed by I_2D_2 and I_1D_2, which was at par with I_3D_1. During second year I_3D_2 significantly recorded minimum stomatal resistance (1.83 mol. m^{-2} s^{-1}) which was at par with I_2D_2 and I_1D_2, while remaining treatments were at par with each others. At 56 DAP during first year, significantly minimum mean stomatal resistance was registered under I_3D_2 (1.64 mol. m^{-2} s^{-1}) which was at par with I_2D_2, I_1D_2 and I_3D_1. During second year I_3D_2 recorded significantly minimum stomatal resistance (1.38 mol. m^{-2} s^{-1}), followed by I_2D_2, and I_1D_2, which was at par with I_3D_1.

At 84 DAP during first year, the minimum and significantly higher mean stomatal resistance was obtained with I_3D_2 (1.79 mol. m^{-2} s^{-1}) which was at par with I_2D_2. The treatment I_2D_2 was again at par with rest of the treatments except I_3D_3, I_2D_3 and I_1D_3. During second year minimum stomatal resistance was obtained by I_3D_2 (1.28 mol. m^{-2} s^{-1}) which was at par with I_2D_2, I_1D_2 and I_3D_1. At harvest during first year, significantly minimum mean stomatal resistance was

Table 3 : Interaction effect of irrigation levels and planting dates with mulching on stomatal conductance at 56 DAP

Irrigation levels	M_1 (With mulch)	M_2 (Without mulch)	Mean	Planting dates	M_1 (With mulch)	M_2 (Without mulch)	Mean
Stomatal conductance (mol. m^{-2} s^{-1}) 2009-2010							
I_1 (0.8 IW/CPE)	0.32	0.29	0.31	D_1 (42 MW)	0.38	0.32	0.35
I_2 (1.0 IW/CPE)	0.39	0.33	0.36	D_2 (44 MW)	0.59	0.49	0.54
I_3 (1.2 IW/CPE)	0.51	0.43	0.47	D_3 (46 MW)	0.25	0.24	0.24
Mean	0.41	0.35	0.38	Mean	0.41	0.35	0.38
S.E.±	0.02			S.E.±	0.02		
C.D. (P=0.05)	0.06			C.D. (P=0.05)	0.06		
Stomatal conductance (mol. m^{-2} s^{-1}) 2010-2011							
Irrigation levels	M_1 (With mulch)	M_2 (Without mulch)	Mean	Planting dates	M_1 (With mulch)	M_2 (Without mulch)	Mean
I_1 (0.8 IW/CPE)	0.44	0.41	0.43	D_1 (42 MW)	0.50	0.43	0.47
I_2 (1.0 IW/CPE)	0.51	0.45	0.48	D_2 (44 MW)	0.86	0.60	0.73
I_3 (1.2 IW/CPE)	0.78	0.53	0.66	D_3 (46 MW)	0.37	0.36	0.36
Mean	0.58	0.46	0.52	Mean	0.58	0.46	0.52
S.E.±	0.02			S.E.±	0.02		
C.D. (P=0.05)	0.07			C.D. (P=0.05)	0.07		

registered under I_3D_2 (2.48 mol. m^{-2} s^{-1}) which was at par with rest of the treatments except I_3D_3, I_2D_3 and I_1D_3. During second year, minimum stomatal resistance was obtained by I_3D_2 (1.32 mol. m^{-2} s^{-1}) which was at par with I_2D_2. The treatment I_2D_2 was again at par with I_1D_2 and I_3D_1. Significantly highest mean stomatal resistance was obtained in I_1D_3 at all the growth stages.

Effect of mulching :

The data presented in Table 5 and 6 implies that the mean stomatal resistance was significantly influenced due to mulching. The mean minimum stomatal resistance was recorded in mulching compared to without mulching at all the days of observations during both the year of experimentation.

Interactions effect :

Treatments combination of irrigation levels with mulching (IxM) and planting dates with mulching (DxM) were found non significant during the both years. The interaction combination of irrigation levels and planting dates with mulching (IxDxM) was found significant during both the years.

Interaction effect of (IxDxM):

At 28 DAP, during first year, the treatment combination $I_3D_2M_1$ recording lowest mean stomatal resistance (0.93 mol. m^{-2} s^{-1}) which was at par with $I_3D_2M_2$ followed by $I_2D_2M_1$, which was at par with $I_2D_2M_2$ and $I_1D_2M_1$. During second year, $I_3D_2M_1$ (1.67 mol. m^{-2} s^{-1}) was significantly superior over rest of the treatments combinations and at par with $I_2D_2M_1$, $I_3D_2M_2$, $I_1D_2M_1$, $I_2D_2M_2$ and $I_1D_2M_2$.At 56 DAP, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording lowest mean stomatal resistance (1.44 mol. m^{-2} s^{-1}) which was at par with $I_3D_2M_2$, $I_2D_2M_1$ and $I_1D_2M_1$. During second year, significantly lowest mean stomatal resistance (1.04 mol. m^{-2} s^{-1}) was obtained $I_3D_2M_1$ which was at par with $I_3D_2M_2$, followed by $I_2D_2M_1$, which was also at par with $I_2D_2M_2$ and $I_1D_2M_1$.

At 84 DAP, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording lowest mean stomatal resistance (1.02 mol. m^{-2} s^{-1}) followed by $I_2D_2M_1$, which was at par with $I_3D_2M_2$, $I_1D_2M_1$, $I_3D_1M_1$ and $I_1D_1M_1$. During second year, $I_3D_2M_1$ (1.09 mol. m^{-2} s^{-1}) was significantly superior over rest of the treatment combinations and was at par with $I_3D_2M_2$, $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_1M_1$ and $I_2D_1M_1$.At harvest, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording lowest mean stomatal resistance (1.27 mol.m^{-2} s^{-1}), which was at par with $I_2D_2M_1$. The treatment combination $I_2D_2M_1$ was again at par with $I_3D_2M_2$ and $I_2D_2M_2$. During second year significantly lowest mean stomatal resistance (0.97 mol. m^{-2} s^{-1}) was recorded by $I_3D_2M_1$, which was at par with $I_3D_2M_2$ and $I_2D_2M_1$. The treatment combinations $I_2D_2M_1$ was again at par with $I_1D_2M_1$ and $I_3D_1M_1$.

Effect of different treatments on haulm yield :

The haulm yield as affected by various treatments during 2009-2010, 2010-2011 and pooled are presented in Table 7. From the data Table 7 it would be seen that the mean haulm yield was 7.49 q ha^{-1}, 7.29 q ha^{-1} and 7.39 q ha^{-1} in 2009-2010, 2010-2011 and pooled, respectively.

Table 4 : Interaction effect of irrigation levels and planting dates with mulching on stomatal conductance at 84 DAP

Irrigation levels	M_1 (With mulch)	M_2 (Without mulch)	Mean	Planting dates	M_1 (With mulch)	M_2 (Without mulch)	Mean
Stomatal conductance (mol. m^{-2} s^{-1}) 2009-2010							
I_1 (0.8 IW/CPE)	0.24	0.23	0.24	D_1 (42 MW)	0.30	0.24	0.27
I_2 (1.0 IW/CPE)	0.32	0.27	0.29	D_2 (44 MW)	0.51	0.42	0.47
I_3 (1.2 IW/CPE)	0.43	0.34	0.39	D_3 (46 MW)	0.18	0.17	0.17
Mean	0.33	0.28	0.31	Mean	0.33	0.28	0.31
S.E.±	0.02			S.E.±	0.02		
C.D. (P=0.05)	0.06			C.D. (P=0.05)	0.06		
Stomatal conductance (mol. m^{-2} s^{-1}) 2010-2011							
Irrigation levels	M_1 (With mulch)	M_2 (Without mulch)	Mean	Planting dates	M_1 (With mulch)	M_2 (Without mulch)	Mean
I_1 (0.8 IW/CPE)	0.30	0.23	0.26	D_1 (42 MW)	0.36	0.24	0.30
I_2 (1.0 IW/CPE)	0.37	0.27	0.32	D_2 (44 MW)	0.73	0.42	0.58
I_3 (1.2 IW/CPE)	0.60	0.34	0.47	D_3 (46 MW)	0.18	0.18	0.18
Mean	0.42	0.28	0.35	Mean	0.42	0.28	0.35
S.E.±	0.02			S.E.±	0.02		
C.D. (P=0.05)	0.06			C.D. (P=0.05)	0.06		

Table 5 : Stomatal resistance as influenced by various treatments 2009-2010

Treatments	Stomatal resistance (mol. m^{-2} s^{-1}) 28 DAP V_1 (With mulch)	28 DAP V_2 (Without mulch)	28 DAP Mean	56 DAP V_1 (With mulch)	56 DAP V_2 (Without mulch)	56 DAP Mean	84 DAP V_1 (With mulch)	84 DAP V_2 (Without mulch)	84 DAP Mean	At harvest V_1 (With mulch)	At harvest V_2 (Without mulch)	At harvest Mean
I_1D_1 (0.8 IW/CPE x 42 MW)	3.98	4.35	4.17	3.36	4.80	4.08	3.48	4.35	3.92	6.50	7.20	6.85
I_1D_2 (0.8 IW/CPE x 44 MW)	3.30	3.72	3.51	2.25	3.69	2.97	2.82	3.82	3.32	4.33	4.50	4.42
I_1D_3 (0.8 IW/CPE x 46 MW)	7.05	9.94	8.49	6.80	8.79	7.79	5.74	6.59	6.16	10.46	19.09	14.78
I_2D_1 (1.0 IW/CPE x 42 MW)	3.85	4.26	4.05	2.79	4.52	3.65	3.43	4.12	3.77	5.45	5.58	5.52
I_2D_2 (1.0 IW/CPE x 44 MW)	2.57	3.02	2.80	2.21	2.86	2.54	2.25	3.49	2.87	2.00	4.06	3.03
I_2D_3 (1.0 IW/CPE x 46 MW)	4.03	7.11	5.57	5.23	5.31	5.27	5.04	5.21	5.13	9.06	11.68	10.37
I_3D_1 (1.2 IW/CPE x 42 MW)	3.58	4.06	3.82	2.64	3.75	3.19	3.13	4.05	3.59	4.48	4.89	4.69
I_3D_2 (1.2 IW/CPE x 44 MW)	0.93	1.54	1.24	1.44	1.84	1.64	1.02	2.55	1.79	1.27	3.68	2.48
I_3D_3 (1.2 IW/CPE x 46 MW)	4.03	4.48	4.26	4.72	5.09	4.90	4.51	4.54	4.53	7.34	7.56	7.45
Mean	3.70	4.72	4.21	3.49	4.52	4.00	3.49	4.30	3.90	5.66	7.58	6.62
	S.E.		C.D. (P=0.05)	S.E.		C.D. (P=0.05)	S.E.		C.D. (P=0.05)	S.E.		C.D. (P=0.05)
Main plot (I X D)	0.11		0.33	0.60		1.81	0.45		1.36	1.47		4.39
Sub plot (M)	0.08		0.25	0.13		0.39	0.14		0.40	0.24		0.72
Interactions												
I X M	0.15		NS	0.23		NS	0.24		NS	0.42		NS
D X M	0.15		NS	0.23		NS	0.24		NS	0.42		NS
(I X D) X M	0.25		0.75	0.40		1.18	0.41		1.21	0.72		2.15

NS=Non significant

Table 6 : Stomatal resistance as influenced by various treatments 2010-2011

Treatments	Stomatal resistance (mol. m^{-2} s^{-1}) 28 DAP V_1 (With mulch)	28 DAP V_2 (Without mulch)	28 DAP Mean	56 DAP V_1 (With mulch)	56 DAP V_2 (Without mulch)	56 DAP Mean	84 DAP V_1 (With mulch)	84 DAP V_2 (Without mulch)	84 DAP Mean	At harvest V_1 (With mulch)	At harvest V_2 (Without mulch)	At harvest Mean
I_1D_1 (0.8 IW/CPE x 42 MW)	3.23	3.50	3.37	4.42	4.84	4.63	2.18	3.47	2.83	4.98	6.85	5.91
I_1D_2 (0.8 IW/CPE x 44 MW)	2.01	2.33	2.17	3.66	3.85	3.76	1.98	2.64	2.31	3.33	4.63	3.98
I_1D_3 (0.8 IW/CPE x 46 MW)	4.00	8.00	6.00	7.91	11.04	9.48	4.88	9.03	6.96	8.29	10.08	9.18
I_2D_1 (1.0 IW/CPE x 42 MW)	3.20	3.33	3.27	4.27	4.73	4.50	2.09	3.47	2.78	4.70	6.73	5.72
I_2D_2 (1.0 IW/CPE x 44 MW)	2.00	2.32	2.16	2.86	3.36	3.11	1.78	2.14	1.96	2.37	4.46	3.41
I_2D_3 (1.0 IW/CPE x 46 MW)	3.50	4.33	3.92	4.52	7.90	6.21	3.58	4.70	4.14	7.52	9.44	8.48
I_3D_1 (1.2 IW/CPE x 42 MW)	3.00	3.20	3.10	3.98	4.52	4.25	2.06	2.71	2.39	4.24	5.20	4.72
I_3D_2 (1.2 IW/CPE x 44 MW)	1.67	2.00	1.83	1.04	1.72	1.38	1.09	1.46	1.28	0.97	1.67	1.32
I_3D_3 (1.2 IW/CPE x 46 MW)	3.33	4.00	3.67	4.48	4.98	4.73	3.18	4.36	3.77	6.63	7.18	6.90
Mean	2.88	3.67	3.28	4.13	5.21	4.67	2.54	3.77	3.16	4.78	6.25	5.51
	S.E.		C.D. (P=0.05)	S.E.		C.D. (P=0.05)	S.E.		C.D. (P=0.05)	S.E.		C.D. (P=0.05)
Main plot (I X D)	0.27		0.80	0.18		0.55	0.40		1.21	0.73		2.17
Sub plot (M)	0.09		0.25	0.10		0.31	0.12		0.34	0.21		0.63
Interactions												
I X M	0.15		NS	0.18		NS	0.20		NS	0.37		NS
D X M	0.15		NS	0.18		NS	0.20		NS	0.37		NS
(I X D) X M	0.26		0.76	0.31		0.93	0.35		1.03	0.64		1.89

NS=Non significant

Effect of irrigation levels and planting dates (IxD) :

During first year, the treatment I_3D_2 was significantly obtained highest haulm yield (12.33 q ha^{-1}) followed by I_2D_2 (10.17 q ha^{-1}). The treatment I_1D_2, I_3D_1 and I_2D_1 were at par with each other. The treatment I_3D_1, I_2D_1, I_1D_1 I_3D_3 and I_2D_3 were also at par with each other. The lowest yields were obtained in I_1D_3 (3.56 q ha^{-1}). During second year, the treatment I_3D_2 was significantly obtained highest haulm yield (12.13 q ha^{-1}) followed by I_2D_2 (8.46 q ha^{-1}).The treatment I_2D_2 was again at par with I_1D_2 and I_3D_1. The treatment I_3D_1 was again at par with I_2D_1, I_2D_1 and I_3D_3 and I_1D_1. The lowest yields were obtained in I_1D_3 (4.02 q ha^{-1}). In pooled analysis, the treatment

Table 7 : Total haulm yield as influenced by different treatments

Treatments	Haulm yield (q ha^{-1})								
	2009-2010			2010-2011			Pooled		
	M_1 (With mulch)	M_2 (Without mulch)	Mean	M_1 (With mulch)	M_2 (Without mulch)	Mean	M_1 (With mulch)	M_2 (Without mulch)	Mean
I_1D_1 (0.8 IW/CPE x 42 MW)	7.00	6.00	6.50	6.63	6.29	6.46	6.81	6.15	6.48
I_1D_2 (0.8 IW/CPE x 44 MW)	8.33	7.44	7.89	8.54	7.52	8.03	8.44	7.48	7.96
I_1D_3 (0.8 IW/CPE x 46 MW)	3.78	3.33	3.56	4.42	3.63	4.02	4.10	3.48	3.79
I_2D_1 (1.0 IW/CPE x 42 MW)	8.00	6.67	7.33	7.56	6.64	7.10	7.78	6.65	7.22
I_2D_2 (1.0 IW/CPE x 44 MW)	12.33	8.00	10.17	8.63	8.29	8.46	10.48	8.15	9.31
I_2D_3 (1.0 IW/CPE x 46 MW)	6.33	6.00	6.17	5.97	4.76	5.37	6.15	5.38	5.77
I_3D_1 (1.2 IW/CPE x 42 MW)	8.00	6.67	7.33	8.29	6.96	7.63	8.15	6.81	7.48
I_3D_2 (1.2 IW/CPE x 44 MW)	12.99	11.67	12.33	12.29	11.96	12.13	12.64	11.81	12.23
I_3D_3 (1.2 IW/CPE x 46 MW)	6.33	6.00	6.17	6.63	6.29	6.46	6.48	6.15	6.31
Mean	8.12	6.86	7.49	7.66	6.93	7.29	7.89	6.90	7.39
	S.E.±	C.D. (P=0.05)		S.E.±	C.D. (P=0.05)		S.E.±	C.D. (P=0.05)	
Main plot (I X D)	0.41	1.22		0.43	1.28		0.52	1.56	
Sub plot (M)	0.19	0.57		0.14	0.42		0.16	0.49	
Interactions									
I X M	0.33	NS		0.24	0.72		0.28	0.85	
D X M	0.33	NS		0.24	0.72		0.28	0.85	
(I X D) X M	0.57	1.70		0.42	1.25		0.49	1.47	

NS=Non-significant

Table 8 : Interaction effect of irrigation levels and planting dates with mulching on haulm yield

Irrigation levels	M_1 (With mulch)	M_2 (Without mulch)	Mean	Planting dates	M_1 (With mulch)	M_2 (Without mulch)	Mean
Total haulm yield (q ha^{-1}) (2010-11)							
I_1 (0.8 IW/CPE)	6.37	5.59	5.98	D_1 (42 MW)	7.67	6.44	7.05
I_2 (1.0 IW/CPE)	8.89	6.89	7.89	D_2 (44 MW)	11.22	9.04	10.13
I_3 (1.2 IW/CPE)	9.11	8.11	8.61	D_3 (46 MW)	5.48	5.11	5.30
Mean	8.12	6.86	7.49	Mean	8.12	6.86	7.49
S.E.±	0.24			S.E.±	0.24		
C.D. (P=0.05)	0.72			C.D. (P=0.05)	0.72		
Total haulm yield (q ha^{-1}) Pooled							
Irrigation levels	M_1 (With mulch)	M_2 (Without mulch)	Mean	Planting dates	M_1 (With mulch)	M_2 (Without mulch)	Mean
I_1 (0.8 IW/CPE)	6.45	5.70	6.08	D_1 (42 MW)	7.58	6.54	7.06
I_2 (1.0 IW/CPE)	7.94	6.93	7.43	D_2 (44 MW)	10.52	9.15	9.83
I_3 (1.2 IW/CPE)	9.09	8.26	8.67	D_3 (46 MW)	5.38	5.20	5.29
Mean	7.82	6.96	7.39	Mean	7.82	6.96	7.39
S.E.±	0.28			S.E.±	0.28		
C.D. (P=0.05)	0.85			C.D. (P=0.05)	0.85		

I_3D_2 obtained highest haulm yield (12.23 q ha^{-1}) followed by I_2D_2 (9.31 q ha^{-1}). The treatment I_2D_2 and I_1D_2 were at par with each other. The treatment I_1D_2 was again at par with I_3D_1, I_2D_1, and I_1D_1. The lowest yields were obtained in I_1D_3 (3.79 q ha^{-1}).

Effect of mulching :

In mulching, haulm yield (8.12 q ha^{-1}) was significantly superior over without mulching (6.86 q ha^{-1}). Similar trend was also obtained in second year and in pooled analysis.

Interactions:

Interaction effect of (IxM) :

The data presented in Table 8 indicate that, during first year, interaction effect of irrigation levels and mulching was not significant.

During second year, the interaction combination of different treatments, I_3M_1 was recorded significantly highest mean haulm yield (9.11 q ha^{-1}) and was at par with I_2M_1 (8.89 q ha^{-1}) (Table 7). In pooled analysis significantly highest mean haulm yield was obtained I_3M_1 (9.09 q ha^{-1}) and was at par with I_3M_2.

Interaction effect of (DxM):

The data presented in Table 8 indicate that, during first year, interaction effect of planting dates and mulching was non-significant.During second year, the interaction combination of different treatments, D_2M_1 was recorded significantly highest haulm yield during 2010-11 (11.22 q ha^{-1}) followed by D_2M_2 (Table 8). The treatment D_1M_2 was at par with D_3M_1, D_3M_2 and D_1M_1. The lowest tuber yield was observed in D_1M_1 (7.67q ha^{-1}).

Pooled result indicates that, the treatments combination D_2M_1 (10.52 q ha^{-1}) was significantly superior over rest of the treatments followed by D_2M_2, D_1M_1 and D_1M_2. The lowest tuber yield was obtained in D_3M_2 (5.20 q ha^{-1}).

Interaction effect of (IxDxM):

Perusal of the data from Table 7, during first year, the treatment combination $I_3D_2M_1$ was significantly superior contributing highest haulm yield (12.99 q ha^{-1}) and was at par with $I_2D_2M_1$ (12.33 q ha^{-1}) followed by $I_3D_2M_2$, while rest of the treatments were at par with each other. During second year, $I_3D_2M_1$ recorded highest haulm yield (12.29 q ha^{-1}) and was at par with $I_3D_2M_2$, while rest of the treatments ware at par with each other.

At lower levels of irrigation, the second peak of net photosynthesis was absent (Table 1 and 2). Increased stomatal conductance appeared to be the reason for the first peak whereas for the second peak non stomatal characters may be responsible. These results are in agreement with those obtained by Gordon *et al.* (1997and 2001), Amer and Hatfield (2004) , Miyashita *et al.* (2005)

Stomatal resistance governs photosynthesis and transpiration (Table 3 and 4). Decrease in soil moisture content increased stomatal resistance. High temperature was associated with decreased stomatal resistance. Stomatal resistance is affected by many factors including PAR, leaf age, air temperature and the CO_2 concentration.Analysis of the relationship between PAR, leaf age, air temperature and the CO_2 concentration at the various growth stages for the different treatments shows that 1.2 IW/CPE ratio and planting on 44^{th} MW with mulching treatment proved to be superior to the other treatments. These results are in agreement with those obtained by Indira and Kabeera Thumma (1990), Gordon *et al.* (1997and 2001) and Saha *et al.* (1997).

It is observed from the data presented in Table 6 that during both the years of experimentation, of haulm yield (q ha^{-1}), mulching produced significantly higher mean values of these haulm yield (q ha^{-1}) than without mulching. The haulm production which reduced by the effect of water stress on stem growth and reduction in number of branches, as well as to a limited extent it effect on the tubers themselves. Similar consistency in results was reported by Abhijit Sarma and Dutta (1999). Jaiswal (1995) and GoLing (1997) reported that the beneficial effect of mulching might be associated with the prevalence of low temperature during the tuber development stage. On the other hand, during second year and in pooled results, without mulching recorded significantly lowest tuber, haulm yield than mulching. A reduced water supply leads to stomatal closure, thus indirectly impairing photosynthesis. Without mulching produced maximum small grade tubers than without mulching. This might be due to less favourable temperature available during tuber development stage and source sink relationship affected due to soil moisture stress. These results are in conformity with those reported by Bhushan and Acharya (2000) in without mulching, whereas with mulching, the photosynthetic surface (leaf area) was the key contributor towards the yield diversity.

Conclusion:

The application of irrigation at 1.2 IW/CPE ratio and planting on 44th MW with mulching of sugarcane trash @ 5 t ha-1 recorded higher values of crucial microclimatic parameters beneficial for potato growth *viz.*, stomatal conductance (0.81, 1.37 mol. m^{-2} s^{-1}) and relative humidity (78, 88 %) at tuber formation stage (56 DAP) obtaining maximum tuber yield (328.98 q ha-1) and haulm yield (12.64 q ha-1) on pooled basis. Mulching of sugarcane trash @ 5 t ha^{-1} significantly reduced the consumptive use (8.57 %) and daily water use (8.38 %) and increased the water use efficiency (19.62 %) by obtaining the higher tuber yield (244.60 q ha^{-1}) over without mulching (231.00 q ha-1) on pooled basis. Irrigation applied at 1.2 IW/ CPE ratio and planting on 44th MW with mulching of sugarcane trash @ 5 t ha^{-1} significantly obtained the higher tuber yield of 328.98 q ha^{-1} with higher monetary returns on pooled basis

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