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RESEARCH ARTICLE

Effect of leaf temperature and air temperature on graded yield of potato

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SUMMARY: The field trial was conducted during both the seasons (2009-2010 and 2010-2011) on PGI Farm without changing randomization. The experiment was laid out in *Rabi* season .Results revealed that increase in temperature resulted in a decrease in rate of photosynthesis. Higher leaf temperature reduced efficiency. Leaf temperature exhibited difference between drought and irrigated treatments. Leaf temperature should be optimum for easy stomatal conductance, which were maintained during 56 to 84 DAP. Analysis of the relationship between stomatal conductance and leaf temperature 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. Tuber yield was significantly correlated with planting date and was probably a response to changing temperatures during the growing season. Planting date had a significant effect on yield. The planting on 44th MW (D_2) produced more tuber yield which may be due to (D_2) planting experienced a mean temperature and RH and escaped the disease. It was observed from the data that during both the years of experimentation, planting on 44th MW, the irrigation scheduled at 1.2 IW/CPE (I_3D_2) was comparable with 1.0 IW/CPE (I_2D_2) and exhibited and produced significantly higher mean values of the gradewise yield of tubers, total fresh tuber yield and haulm yield (q ha^{-1}) than rest of the treatments. In potato, increased tuber production was more phenomenal with adequate irrigation, since the percentage of bigger tubers was more in irrigated plants than in un-irrigated plants. The maximum tuber yield was recorded in 44th MW, which was decreased as delayed in planting, this might due to the favourable climatic conditions during the crop growth period of early planting during 56 to 84 days, the minimum temperature was 8.7-9.7^{0}C. The beneficial effect of early planting might be associated with the prevalence of low temperature during the tuber development stge.

Key Words :
Leaf temperature, Air temperature, Graded yield, Potato

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The area under potato in Maharashtra is 18.8 thousand ha (2 % of India) with a production of 197.90 thousand MT and extremely low productivity of 10.52 t ha^{-1} (Anonymous, 2011). The part of North Satara and Pune districts are major potato growing areas of 80 per cent of area is under this crop in the state (Ahire, 1999). Due to increasing industrialization and job market created demand for processed and ready to eat convenience food, particularly in urban areas. The climatic parameters such as the rise in temperature have an adverse effect on potato production and productivity. The impact of climate change needs to be evaluated on potato production due to disease and insect pests. Therefore, the possible effect of different parameters of microclimate on potato crop growth and production during growing condition is to be critically investigated 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. Being a temperate crop, growth of potato and yield are adversely affected due to higher temperature, especially mean temperature of above 17°C. Hence, proper planting time must be framed to produce maximum yield by efficient utilization of natural resources. Exposure of crop to excellent growth period is only possible by proper planting dates and escaping the crop from many weather hazards. With this back ground in view, the present investigation was undertaken to know the radiation interception and light use efficiency as influenced by sowing windows in potato.

EXPERIMENTAL METHODOLOGY

The experiment was laid out in Split Plot Design in *Rabi* season with recommended 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)	
I_1D_1 - (0.8 IW/CPE) X (42 MW)	I_2D_1 - (1.0 IW/CPE) X (42 MW)
I_1D_2 - (0.8 IW/CPE) X (44 MW)	I_2D_2 - (1.0 IW/CPE) X (44 MW)
I_1D_3 - (0.8 IW/CPE) X (46 MW)	I_2D_3 - (1.0 IW/CPE) X (46 MW)
I_3D_1 - (1.2 IW/CPE) X (42 MW)	
I_3D_2 - (1.2 IW/CPE) X (44 MW)	
I_3D_3 - (1.2 IW/CPE) X (46 MW)	
B. Sub-plot treatments (two) Mulching (M)	
M_1- With mulch	M_2 - Without mulch

IRGA instrument (LI-6400XT) was used for estimation different microclimatic parameters of the crop within the height of 2 mt.

EXPERIMENTAL FINDINGS AND DISCUSSION

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

Effect of different treatments on leaf temperature :

The data pertaining to leaf temperature of potato as influenced by various treatments at different growth stages are housed in Table 1 and 2 (2009 and 2010). In general, during both the seasons, there was a rapid increase in mean leaf temperature from early growth stage to 56 days and thereafter it gradually decreased towards maturity of the crop. Lowest mean values of leaf temperature were recorded at harvest as 29.74 and 28.57^{0}C in 2009 and 2010, respectively.

Effect of irrigation levels and planting dates (IxD) :

At 28 DAP during first year, I_3D_2 significantly recorded minimum leaf temperature (21.65^{0}C) which was at par with I_2D_2 followed by I_1D_2, which was at par with I_3D_1. During second year, the mean leaf temperature was minimum with I_3D_2 (20.79^0 C) which was at par with I_2D_2, I_1D_2. The treatment I_1D_2 was again at par with I_3D_1 and I_2D_1. At 56 DAP during first year, minimum leaf temperature was obtained by I_3D_2 (12.16^0 C) followed by I_2D_2, which was at par with I_1D_2 and I_3D_1. During second year, minimum significantly mean leaf temperature was obtained with I_3D_2 (11.06^{0}C) which was at par with I_2D_2, I_1D_2. The treatment I_1D_2 was again at par with rests of the treatments except I_2D_3 and I_1D_3.

At 84 DAP during first year, I_3D_2 recorded significantly minimum leaf temperature (18.58^{0}C), followed by I_2D_2, which was at par with I_1D_2. The treatment I_1D_2 was again at par with rest of the treatments except I_2D_3 and I_1D_3. During second year, significantly minimum mean leaf temperature was registered under I_3D_2 (17.82^{0}C) followed by I_2D_2, which was at par with I_1D_2, I_3D_1 and I_2D_1. At harvest during both years, significantly minimum mean leaf temperature was registered under I_3D_2 (21.07 and 20.23^{0}C) followed by I_2D_2, which was at par with remaining treatments.

Effect of mulching :

The data presented in Tables 1 and 2 imply that the mean leaf temperature was significantly influenced due to mulching. The minimum mean leaf temperature 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 during the both years. The interaction combination of irrigation levels and planting dates with mulching (IxDxM) were found significant during both the years except 28 DAP (both years) and 56 DAP (second year Table 1 and 2).At 56 DAP, during first year the treatment combination $I_3D_2M_1$ recording lowest mean leaf temperature (9.11^{0}C) which was at par with $I_2D_2M_1$, $I_1D_2M_1$ and $I_3D_1M_1$.

At 84 DAP, during both years, the treatment combination $I_3D_2M_1$ was significantly superior, recording highest mean leaf temperature (13.11 and 12.53^{0}C) followed by $I_3D_2M_2$, which was at par with $I_2D_2M_1$ and $I_1D_2M_1$. At harvest during both years, the treatment combination $I_3D_2M_1$ was significantly superior, recording lower mean leaf temperature (13.57 and 12.97^{0}C) followed by $I_2D_2M_1$, which was at par with rest of the treatments except $I_3D_3M_2$, $I_2D_3M_1$, $I_2D_3M_2$, $I_1D_3M_1$ and $I_1D_3M_2$. Significantly maximum mean leaf temperature was obtained in $I_1D_3M_2$ at all the growth stages.

Effect of different treatments on air temperature :

The data pertaining to air temperature of potato as influenced by various treatments at different growth stages are presented in Table 3 and 4 (2009 and 2010). In general, during both the seasons, there was variation in mean air temperature from early growth stage up to harvest. Minimum air temperature was recorded at 56 DAP as 23.34 and 20.50^{0}C.

Effect of irrigation levels and planting dates (IxD) :

During the first year at 28 DAP the mean air temperature was minimum with I_3D_2 (25.92^{0}C) which was at par with I_2D_2,

Table 1 : Leaf temperature as influenced by various treatments (2009-2010)

Treatments	Leaf temperature (°C) 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 M.W)	27.62	27.81	27.72	23.14	24.21	23.68	27.83	30.34	29.09	30.38	31.22	30.80
I_1D_2 (0.8 IW/CPE x 44 M.W)	22.77	24.59	23.68	13.67	16.87	15.27	27.23	27.83	27.53	28.65	30.07	29.36
I_1D_3 (0.8 IW/CPE x 46 M.W)	29.26	30.79	30.02	26.21	38.09	32.15	30.89	31.91	31.40	34.09	32.89	33.49
I_2D_1 (1.0 IW/CPE x 42 M.W)	26.02	27.10	26.56	16.89	23.18	20.04	27.67	30.27	28.97	30.21	31.16	30.68
I_2D_2 (1.0 IW/CPE x 44 M.W)	19.84	24.58	22.21	10.37	16.27	13.32	24.37	27.75	26.06	28.04	30.06	29.05
I_2D_3 (1.0 IW/CPE x 46 M.W)	28.82	30.73	29.78	25.89	28.30	27.10	29.51	30.87	30.19	31.78	32.83	32.31
I_3D_1 (1.2 IW/CPE x 42 M.W)	23.86	24.92	24.39	13.83	17.91	15.87	27.49	29.21	28.35	29.16	30.52	29.84
I_3D_2 (1.2 IW/CPE x 44 M.W)	19.15	24.16	21.65	9.11	15.21	12.16	13.11	24.04	18.58	13.57	28.57	21.07
I_3D_3 (1.2 IW/CPE x 46 M.W)	28.29	29.46	28.88	24.88	25.69	25.28	28.40	30.34	29.37	30.43	31.76	31.10
Mean	25.07	27.13	26.10	18.22	22.86	20.54	26.28	29.17	27.73	28.48	31.01	29.74
	S.E±		CD at 5%	S.E±		CD at 5%	S.E±		CD at 5%	S.E±		CD at 5%
Main plot (I X D)	0.34		1.03	1.57		4.72	0.71		2.12	0.86		2.57
Sub plot (M)	0.20		0.59	0.54		1.62	0.37		1.11	0.36		1.07
Interactions												
I X M	0.34		NS	0.94		NS	0.65		NS	0.62		NS
D X M	0.34		NS	0.94		NS	0.65		NS	0.62		NS
(I X D) X M	0.60		NS	1.63		4.85	1.12		3.34	1.08		3.20

N.S. Non- significant

Table 2 : Leaf temperature as influenced by various treatments (2010-2011)

Treatments	Leaf temperature (°C)											
	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 M.W)	26.06	26.57	26.32	12.77	15.71	14.24	26.77	29.14	27.96	29.24	30.06	29.65
I_1D_2 (0.8 IW/CPE x 44 M.W)	21.88	23.64	22.76	9.42	14.11	11.77	26.19	26.77	26.48	27.57	28.93	28.25
I_1D_3 (0.8 IW/CPE x 46 M.W)	29.64	31.07	30.36	24.45	42.69	33.57	29.73	30.72	30.23	31.66	32.83	32.25
I_2D_1 (1.0 IW/CPE x 42 M.W)	24.17	25.02	24.60	12.61	15.20	13.91	26.61	28.11	27.36	29.07	29.99	29.53
I_2D_2 (1.0 IW/CPE x 44 M.W)	19.04	23.63	21.33	13.32	14.10	13.71	23.42	26.69	25.06	26.97	28.40	27.69
I_2D_3 (1.0 IW/CPE x 46 M.W)	28.15	29.58	28.87	15.73	26.77	21.25	28.40	29.71	29.06	30.60	31.61	31.11
I_3D_1 (1.2 IW/CPE x 42 M.W)	22.93	23.95	23.44	12.19	15.14	13.66	26.45	27.59	27.02	28.06	28.94	28.50
I_3D_2 (1.2 IW/CPE x 44 M.W)	18.37	23.22	20.79	8.53	13.59	11.06	12.53	23.10	17.82	12.97	27.49	20.23
I_3D_3 (1.2 IW/CPE x 46 M.W)	27.73	28.35	28.04	14.40	16.72	15.56	27.32	29.20	28.26	29.29	30.58	29.93
Mean	24.22	26.11	25.17	13.71	19.34	16.53	25.27	27.89	26.58	27.27	29.87	28.57

	S.Em	CD at 5%	S.Em	CD at 5%	S.Em	CD at 5%	S.Em	CD at 5%
Main plot (I X D)	0.83	2.50	1.91	5.72	0.79	2.38	0.91	2.73
Sub plot (M)	0.42	1.26	0.99	2.94	0.35	1.04	0.35	1.04
Interactions								
I X M	0.73	NS	1.71	NS	0.61	NS	0.61	NS
D X M	0.73	NS	1.71	NS	0.61	NS	0.61	NS
(I X D) X M	1.27	NS	2.96	NS	1.05	3.13	1.05	3.12

N S: Non significant

Table 3: Air temperature as influenced by various treatments (2009-2010)

Treatments	Air temperature (°C)											
	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)	28.37	28.91	28.64	29.75	30.75	30.25	31.96	34.02	32.99	33.51	37.29	35.42
I_1D_2 (0.8 IW/CPE x 44 MW)	25.67	27.75	26.71	26.75	28.59	27.67	28.69	30.94	29.81	30.82	33.59	32.20
I_1D_3 (0.8 IW/CPE x 46 MW)	33.38	34.51	33.94	34.5	36.21	35.35	36.82	37.12	36.97	37.48	38.31	37.89
I_2D_1 (1.0 IW/CPE x 42 MW)	25.66	28.71	27.18	29.11	29.45	29.28	31.25	32.71	31.97	32.34	35.95	34.14
I_2D_2 (1.0 IW/CPE x 44 MW)	25.54	26.25	25.89	24.42	29.84	27.13	27.47	30.41	28.93	28.64	33.19	30.91
I_2D_3 (1.0 IW/CPE x 46 MW)	32.96	33.66	33.31	33.66	35.96	34.81	36.22	37.96	37.09	37.53	39.96	38.74
I_3D_1 (1.2 IW/CPE x 42 MW)	25.67	28.66	27.13	27.84	28.69	28.26	30.14	31.09	30.59	30.38	34.05	32.21
I_3D_2 (1.2 IW/CPE x 44 MW)	24.82	27.03	25.92	23.34	27.47	25.40	26.86	28.53	27.69	25.41	31.03	28.22
I_3D_3 (1.2 IW/CPE x 46 MW)	30.48	34.89	32.68	30.17	32.66	31.38	32.25	35.99	34.12	35.06	38.78	36.92
Mean	28.05	30.04	29.05	28.83	31.07	29.95	31.29	33.19	32.24	32.35	35.79	34.07

	28 DAP S.E.m	28 DAP CD at 5%	56 DAP S.E.m	56 DAP CD at 5%	84 DAP S.E.m	84 DAP CD at 5%	At harvest S.E.m	At harvest CD at 5%
Main plot (I X D)	0.27	0.81	0.92	2.76	0.85	2.669	1.3	3.9
Sub plot (M)	0.13	0.37	0.51	1.51	0.67	2.15	0.79	2.37
Interactions								
I X M	0.22	NS	0.88	NS	0.88	NS	0.88	NS
D X M	0.22	NS	0.88	NS	0.88	NS	0.88	NS
(I X D) X M	0.38	1.12	0.52	1.56	1.67	5.01	1.52	4.52

NS: Non significant

Table 4 : Air temperature as influenced by various treatments (2010-2011)

Treatments	Air temperature (ºC) 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 M.W)	35.96	37.64	36.80	34.15	35.65	34.92	30.66	31.9	31.28	36.14	36.88	36.51
I_1D_2 (0.8 IW/CPE x 44 M.W)	30.95	31.54	31.24	30.08	33.75	31.91	28.73	34.31	31.52	32.87	37.02	34.94
I_1D_3 (0.8 IW/CPE x 46 M.W)	27.86	30.27	29.06	30.74	34.43	32.58	35.17	35.17	35.17	36.02	33.63	34.82
I_2D_1 (1.0 IW/CPE x 42 M.W)	36.41	36.64	36.52	29.28	32.65	30.96	30.86	31.27	31.06	31.12	37.25	34.18
I_2D_2 (1.0 IW/CPE x 44 M.W)	25.82	30.95	28.38	25.66	29.65	27.65	25.68	29.06	27.37	25.85	31.82	28.83
I_2D_3 (1.0 IW/CPE x 46 M.W)	27.25	30.11	28.68	26.39	31.77	29.08	26.12	32.82	29.41	29.51	34.99	32.25
I_3D_1 (1.2 IW/CPE x 42 M.W)	33.25	36.72	34.98	28.58	31.15	29.86	27.97	32.76	30.36	31.98	33.81	32.89
I_3D_2 (1.2 IW/CPE x 44 M.W)	27.12	29.17	28.11	20.50	26.94	23.72	21.55	28.35	24.95	24.15	29.35	26.75
I_3D_3 (1.2 IW/CPE x 46 M.W)	31.15	28.64	29.82	31.10	28.98	30.04	28.47	30.86	29.66	32.14	34.97	33.55
Mean	30.62	32.40	31.51	28.50	31.66	30.08	28.34	31.83	30.09	31.09	34.41	32.75

	28 DAP S.E±	28 DAP C.D. at 5%	56 DAP S.E±	56 DAP C.D. at 5%	84 DAP S.E±	84 DAP C.D. at 5%	At harvest S.E±	At harvest C.D. at 5%
Main plot (I X D)	0.46	1.39	0.89	2.67	0.97	2.91	1.16	3.47
Sub plot (M)	0.19	0.57	0.53	1.57	0.61	1.81	0.72	2.13
Interactions								
I X M	0.33	NS	0.92	NS	1.06	NS	1.24	NS
D X M	0.33	NS	0.92	NS	1.06	NS	1.24	NS
(I X D) X M	0.57	1.71	1.59	4.71	1.83	5.44	2.15	6.39

NS: Non significant

followed by I_1D_2, which was at par with I_3D_1. During second year I_3D_2 significantly recorded minimum air temperature (28.11 °C) which was at par with I_2D_2 and I_1D_2.The treatment I_3D_1 and I_2D_1were at par with each other. At 56 DAP during first year the minimum and significantly higher mean air temperature was obtained with I_3D_2 (23.34^{0}C) which was at par with I_2D_2.The treatment I_1D_2 was at par with I_3D_1 and I_2D_1. During second year minimum air temperature was obtained by I_3D_2 (20.50^{0}C) followed by I_2D_2 and I_1D_2. The treatment I_2D_2 was again at par with I_3D_1 and I_2D_1.

At 84 DAP during first year, significantly minimum mean air temperature was registered under I_3D_2 (26.86^{0}C) followed by I_2D_2, and I_1D_2, which was at par with I_3D_1 and I_2D_1. During second year same trend was obtained.At harvest, significantly minimum mean air temperature was registered under I_3D_2 (25.41^0 C) followed by I_2D_2, which was at par with I_1D_2. The treatment I_1D_2 was again at par with I_3D_1 and I_2D_1. During second year, minimum air temperature was obtained by I_3D_2 (24.15^0 C) followed by I_2D_2, which was at par with I_1D_2. The treatment I_1D_2 was again at par with I_3D_1, I_2D_1 and I_1D_1. Significantly maximum mean air temperature was obtained in I_1D_3 at all the growth stages.

Effect of mulching :

The data presented in Table 3 and 4 imply that the mean air temperature was significantly influenced due to mulching. Significantly minimum mean air temperature was recorded in mulching compared to without mulching at all the days of observations during both the years of experimentation.

Interactions effect :

Treatment 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) were found significant during both the years except at 28 during both years and for 56 DAP during second year only. At 28 DAP during second year, the treatment combination $I_3D_2M_1$ recording minimum mean air temperature (24.82^{0}C) was at par with $I_2D_2M_1$, $I_1D_2M_1$ and $I_3D_2M_1$, while rest of the treatments were at par with each others. At 56 DAP, during first year, the treatments combination $I_3D_2M_1$ was significantly superior, recording minimum mean air temperature (23.34^{0}C) followed by $I_2D_2M_1$, while rests of the treatments were at par with each other. Same trend was observed during second year.

At 84 DAP during first year, the treatments combination $I_3D_2M_1$ recorded minimum mean air temperature (26.86^0 C) followed by $I_2D_2M_1$, which was at par with $I_3D_2M_2$, while rests of the treatments were at par with each others. Same trend was observed during second year.At harvest, during first year, the treatments combination $I_3D_2M_1$ was significantly superior, recording minimum mean air temperature (25.41^{0}C) followed by $I_2D_2M_1$, which was at par with $I_3D_2M_2$, while rest of the treatments were at par with each other. During second year, significantly minimum mean air temperature was obtained by $I_3D_2M_1$ (24.15^0 C) followed by $I_2D_2M_1$, which was at par with $I_1D_2M_1$, $I_3D_2M_2$ and $I_3D_1M_1$, while rest of the treatments were at par with each other. Significantly maximum mean air temperature was observed in $I_1D_3M_2$ at all the growth stages.

Gradewise yield of tubers :

The data regarding gradewise yield of tubers (q ha^{-1}) as affected by various treatments during 2009-2010, 2010-2011 and total are presented in Table 5 and 6. The mean yield of small grades (< 25 g), medium (25-75 g) and big (>75 g) was, 15.31, 98.40 and 104.96 q ha^{-1} during first year and it was 11.95, 35.84 and 191.14 a ha^{-1} during first year second year.

Effect of irrigation levels and planting dates (I x D) :

The irrigation levels and planting dates significantly affected the gradewise yield of potato tubers during both the years.

Small grade (< 25 g) :

During first year, the treatment I_3D_2 significantly obtained highest yield of small grade tubers (19.28 q ha^{-1}) followed by I_3D_1 (18.09 q ha^{-1}), which was at par with I_2D_2 followed by I_3D_3 and I_2D_1.The treatment I_2D_1, I_1D_2 and I_2D_3 were at par with each other. The lowest yield was obtained in I_1D_1 (11.09 q ha^{-1}). During second year, the treatment I_3D_2 significantly obtained highest yield of small grade tubers (16.99 q ha^{-1}) followed by I_2D_2 (14.78 q ha^{-1}), I_3D_3, $I_3D_1$and I_1D_2. The treatments I_1D_2 and I_2D_1 were at par with each other. The lowest yield was obtained in I_1D_1 (8.53 q ha^{-1}).

Medium grade (25-75 g) :

During first year, the treatment I_3D_2 significantly obtained highest yield of medium grade tubers (123.94 q ha^{-1}) followed by I_3D_1, which was at par with I_2D_2 (115.06 q ha^{-1}) followed by I_3D_3 and I_2D_1. The treatment I_2D_1 was at par with I_1D_2 and I_2D_3. The lowest yield was obtained in I_1D_1 (71.27 q ha^{-1}). During second year, the treatment I_3D_2 significantly obtained highest yield of medium grade tubers (50.97 q ha^{-1}) which was followed by I_2D_2 (44.34 q ha^{-1}), I_3D_3, I_3D_1 and I_1D_2. The treatment I_1D_2 was at par with I_2D_1 followed by I_2D_3. The lowest yield was obtained in I_1D_1 (25.60 q ha^{-1}).

Large grade (>75 g) :

During first year, the treatment I_3D_2 significantly obtained highest yield of large grade tubers (132.20 q ha^{-1}) followed by I_3D_1 (124.05 q ha^{-1}), which was at par with I_2D_2 followed by I_3D_3 I_2D_1. The lowest yield was obtained in I_1D_1 (76.03 q ha^{-1}). During second year, the treatment I_3D_2 significantly obtained

Table 5 : Gradewise yield of tubers as influenced by different treatments (2009-2010)

Treatments	Tuber yield (q ha^{-1}) 2009-10											
	Small (upto 25 g)			Medium (25-75 g)			Large (>75 g)			Total		
	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)	12.24	9.94	11.09	78.66	63.89	71.27	83.90	68.15	76.03	174.80	141.97	158.39
I_1D_2 (0.8 IW/CPE x 44 MW)	14.98	14.10	14.54	96.30	90.67	93.49	102.72	96.72	99.72	214.01	201.49	207.75
I_1D_3 (0.8 IW/CPE x 46 MW)	12.05	10.34	11.19	77.49	66.44	71.97	82.66	70.87	76.76	172.20	147.64	159.92
I_2D_1 (1.0 IW/CPE x 42 MW)	15.92	13.76	14.84	102.33	88.43	95.38	109.15	94.32	101.74	227.40	196.50	211.95
I_2D_2 (1.0 IW/CPE x 44 MW)	19.20	16.59	17.90	123.43	106.68	115.06	131.66	113.79	122.73	274.29	237.07	255.68
I_2D_3 (1.0 IW/CPE x 46 MW)	15.27	13.34	14.31	98.15	85.78	91.97	104.69	91.50	98.10	218.11	190.63	204.37
I_3D_1 (1.2 IW/CPE x 42 MW)	19.20	16.98	18.09	123.44	109.16	116.30	131.67	116.43	124.05	274.32	242.57	258.44
I_3D_2 (1.2 IW/CPE x 44 MW)	20.77	17.78	19.28	133.54	114.33	123.94	142.44	121.95	132.20	296.76	254.06	275.41
I_3D_3 (1.2 IW/CPE x 46 MW)	17.58	15.47	16.52	113.04	99.42	106.23	120.57	106.05	113.31	251.19	220.94	236.07
Mean	16.36	14.26	15.31	105.15	91.64	98.40	112.16	97.75	104.96	233.67	203.65	218.66
	S.E.±	C.D. at 5%		S.E.±	C.D. at 5%		S.E.±	C.D. at 5%		S.E.±	C.D. at 5%	
Main plot (I X D)	0.19	0.57		1.21	3.64		1.29	3.88		2.70	8.09	
Sub plot (M)	0.08	0.24		0.51	1.52		0.55	1.62		1.14	3.38	
Interactions												
I X M	0.14	NS		0.89	NS		0.95	NS		1.97	NS	
D X M	0.14	NS		0.89	NS		0.95	NS		1.97	NS	
(I X D) X M	0.24	0.71		1.54	4.56		1.64	4.87		3.41	10.14	

N.S : Non significant

Table 6 : Gradewise yield of tubers as influenced by different treatments (2010-2011)

Treatments	Tuber yield (q ha^{-1})											
	Small (upto 25 g)			Medium (25-75 g)			Large (>75 g)			Total		
	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)	8.98	8.08	8.53	26.94	24.25	25.60	143.68	129.34	136.51	179.60	161.67	170.64
I_1D_2 (0.8 IW/CPE x 44 MW)	12.25	10.82	11.54	36.75	32.47	34.61	196.01	173.16	184.58	245.01	216.44	230.73
I_1D_3 (0.8 IW/CPE x 46 MW)	9.30	8.07	8.69	27.90	24.22	26.06	148.80	129.16	138.98	186.00	161.44	173.72
I_2D_1 (1.0 IW/CPE x 42 MW)	12.10	10.52	11.31	36.31	31.57	33.94	193.66	168.36	181.01	242.08	210.44	226.26
I_2D_2 (1.0 IW/CPE x 44 MW)	15.71	13.85	14.78	47.13	41.55	44.34	251.35	221.60	236.48	314.19	277.00	295.60
I_2D_3 (1.0 IW/CPE x 46 MW)	11.60	8.81	10.20	34.80	26.42	30.61	185.60	140.89	163.25	232.01	176.11	204.06
I_3D_1 (1.2 IW/CPE x 42 MW)	13.21	11.71	12.46	39.64	35.13	37.38	211.39	187.33	199.36	264.23	234.17	249.20
I_3D_2 (1.2 IW/CPE x 44 MW)	18.06	15.92	16.99	54.18	47.75	50.97	288.96	254.67	271.81	361.20	318.33	339.77
I_3D_3 (1.2 IW/CPE x 46 MW)	13.77	12.27	13.02	41.30	36.82	39.06	220.29	196.35	208.32	275.37	245.44	260.40
Mean	12.78	11.12	11.95	38.33	33.35	35.84	204.42	177.87	191.14	255.52	222.34	238.93

	Small S.E.m	Small CD at 5%	Medium S.E.m	Medium CD at 5%	Large S.E.m	Large CD at 5%	Total S.E.m	Total CD at 5%
Main plot(I X D)	0.13	0.38	0.38	1.13	2.01	6.03	2.51	7.54
Sub plot (M)	0.06	0.17	0.17	0.52	0.93	2.76	1.16	3.45
Interactions								
I X M	0.10	0.30	0.30	0.90	1.61	4.77	2.01	5.97
D X M	0.10	0.30	0.30	0.90	1.61	4.77	2.01	5.97
(I X D) X M	0.17	0.52	0.52	1.55	2.78	8.27	3.48	10.34

Table 7 : Interaction effect of irrigation levels and planting dates with mulching on gradewise yield of potato during 2010-2011)

Irrigation levels	M_1 (With mulch)	M_2 (Without mulch)	Mean	Planting dates	M_1 (With mulch)	M_2 (Without mulch)	Mean
			Small (upto 25 g) (q ha^{-1})				
I_1 (0.8 IW/CPE)	10.18	8.99	9.58	D_1 (42 M.W)	11.43	10.10	10.77
I_2 (1.0 IW/CPE)	13.14	11.06	12.10	D_2 (44 M.W)	15.34	13.53	14.43
I_3 (1.2 IW/CPE)	15.01	13.30	14.16	D_3 (46 M.W)	11.56	9.72	10.64
Mean	12.78	11.12	11.95	Mean	12.78	11.12	11.95
S.E.±	0.10			S.E.±	0.10		
C.D. at 5%	0.30			C.D. at 5%	0.30		
			Medium (25-75 g) (q ha^{-1})				
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)	30.53	26.98	28.75	D_1 (42 M.W)	34.30	30.31	32.30
I_2 (1.0 IW/CPE)	39.41	33.18	36.30	D_2 (44 M.W)	46.02	40.59	43.30
I_3 (1.2 IW/CPE)	45.04	39.90	42.47	D_3 (46 M.W)	34.67	29.15	31.91
Mean	38.33	33.35	35.84	Mean	38.33	33.35	35.84
S.E.±	0.30			S.E.±	0.30		
C.D. at 5%	0.90			C.D. at 5%	0.90		
			Large (>75 g) (q ha^{-1})				
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)	162.83	143.88	153.36	D_1 (42 M.W)	182.91	161.68	172.29
I_2 (1.0 IW/CPE)	210.21	176.95	193.58	D_2 (44 M.W)	245.44	216.47	230.96
I_3 (1.2 IW/CPE)	240.21	212.78	226.50	D_3 (46 M.W)	184.90	155.47	170.18
Mean	204.42	177.87	191.14	Mean	204.42	177.87	191.14
S.E.±	1.61			S.E.±	1.61		
C.D. at 5%	4.77			C.D. at 5%	4.77		

highest yield of medium grade of tubers (271.81 q ha^{-1}) followed by I_2D_2 (236.48 q ha^{-1}), I_3D_3, I_3D_1 and I_1D_2. The treatment I_1D_2 was at par with I_2D_1. The lowest yield was obtained in I_1D_1 (136.51 q ha^{-1}).

Effect of mulching :

In mulching, gradewise yield of tuber was significantly superior over without mulching during both years.

Interactions :

The data presented in Table 7 indicate that, during first year, interaction effect of irrigation levels with mulching and planting dates with mulching were non-significant, while during second year they were found significant.

Interaction effect of (IxM) :

During second year, the interaction combination of different treatments, I_3M_1 recorded significantly highest yield of small grade tubers (15.01 q ha^{-1}) (Table 6) medium grade tubers (45.04 q ha^{-1}) and large tuber yield (240.21q ha^{-1}) (Table 6) which were followed by I_3M_2, significantly superior over rest of the treatments. The treatment combination I_3M_2 and I_2M_1 were at par with each others. The treatments I_2M_2, I_1M_2 and I_1M_2 were recording the yield in descending order.

Interaction effect of (DxM) :

During second year, the interaction combination of different treatments, D_2M_1 was recorded significantly highest small grade tubers (15.34 q ha^{-1}), medium grade tubers (46.02 q ha^{-1}) and large tuber yield (245.44 q ha^{-1}) (Table 7), which were followed by D_2M_2 and D_3M_1. The treatments D_1M_1, D_1M_2 and D_3M_2 were yielding in descending order.

Interaction effect of (IxDxM) :

Perusal of the data Table 7 show that, during first year regarding small, medium and large grade tuber yield, the treatment combination $I_3D_2M_1$ was significantly superior contributing highest gradewise yield of tubers (20.77, 133.54 and 142.44 q ha^{-1}) followed by $I_3D_1M_1$ (19.20, 123.44 and 131.67q ha^{-1}), $I_2D_2M_1$ and $I_3D_2M_2$, while rest of the treatments were at par with each others. Significantly lowest tuber yield was obtained by $I_1D_1M_2$ in all cases. During second year Table 7 also showed that, regarding small, medium and large grade tuber yield, the treatments combination $I_3D_2M_1$ was significantly superior contributing highest gradewise yield of tubers (18.06, 54.18 and 288.96 q ha^{-1}) followed by $I_3D_2M_2$, $I_2D_2M_1$ and $I_2D_2M_2$, while rest of the treatments were at par with each others. Significantly lowest tuber yield was obtained by $I_1D_3M_2$ in all cases. The results were quoted by Jaiswal (1995), Chen GoLing (1977), Momirovic *et al.* (1997) and Subhash Chandra *et al.* (2002).

Leaf temperature :

Increase in temperature results in a decrease in rate of photosynthesis. Higher leaf temperature reduced efficiency. Leaf temperature exhibited difference between drought and irrigated treatments. Leaf temperature should be optimum for easy stomatal conductance, which were maintained during 56 to 84 DAP (Table 1 and 2). Analysis of the relationship between stomatal conductance and leaf temperature 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. Similar results were quoted by Wheeler *et al.* (1989), Ranalli *et al.* (1997), Dubey *et al.*(1998), Ramnik and Dubey (2000), Pleijel *et al.* (2002) and Bosnjak *et al*. (2004).

Air temperature :

Tuber yield was significantly (Table 3 and 4) correlated with planting date and was probably a response to changing temperatures during the growing season. Planting date had a significant effect on yield. Similar results were produced by Khan *et al.* (2002) and Patel *et.al*. (2000) The planting on 44th MW (D_2) produced more tuber yield which may be due to (D_2) planting experienced a mean temperature and RH and escaped the disease.

Graded yield :

It was observed from the data presented in Table 5 and 6 that during both the years of experimentation, planting on 44th MW, the irrigation scheduled at 1.2 IW/CPE (I_3D_2) was comparable with 1.0 IW/CPE (I_2D_2) and exhibited and which produced significantly higher mean values of the grade wise yield of tubers, total fresh tuber yield and haulm yield (q ha^{-1}) than rest of the treatments. The tuber production which was reduced by the effect of water stress on stem growth and reduction in number of branches, as well to a limited extent it effect on the tubers themselves. In potato, increased tuber production was more phenomenal with adequate irrigation, since the percentage of bigger tubers was more in irrigated plants than in un-irrigated plants. The maximum tuber yield was recorded in 44th MW, which was decreased as delayed in planting, this might due to the favourable climatic conditions during the crop growth period of early planting during 56 to 84 days the minimum temperature was 8.7-9.7^{0}C. The beneficial effect of early planting might be associated with the prevalence of low temperature during the tuber development stage. The results corroborate the findings of Ghosh and Sasgupta (1973), Birhman and Verma (1980), and Sharma and Verma (1987). Yadav *et al.* (2003) and Shiri-e-Janagard *et al.* (2009).

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