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Effect of different sowing windows on growth functions LAI and LAD in potato

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Abstract
The field trial was conducted during both the seasons (2009-10 and 2010-11) on PGI Farm without changing randomization. The experiment was laid out in *rabi* season. The various components of growth functions *viz.* absolute growth rate, crop growth rate, relative growth rate, net assimilation rate, leaf area index, leaf area duration were calculated at an interval of 28 days on the basis of dry matter accumulation. The highest LAI and LAD was found near the crop with mulching and five irrigations.
The approach has been recognized as a more rational means of growth than the traditional growth analysis techniques. In present studies, this point has been amply illustrated by the differences in the calculated production efficiencies of different treatments. Apart from measured growth indices such as LAI and final yields, a useful index of crop productivity can be obtained by computing the growth functions as shown by this study.
Analysis of the data shows that numerically higher mean values of each growth function at the various growth stages for the different treatments shows that 1.2 IW/CPE ratio and early planting with mulching treatment proved to be superior to the other treatments due to its complimentary effect in better use of natural resources like light, soil moisture.
LAI and LAD related with amount of dry matter produced by crop, as increasing the number of irrigation and early planting with mulching, as the amount of dry matter produced by crop and converted into LAI and LAD.

Keywords: Sowing window, LAI and LAD

Introduction
Potato requires cool temperature and sandy loam soil with plenty of humus and moisture (Alim, 1974) [1]. Potatoes are grown throughout the world and more than billions of people eat potato. About 328.87 million tonnes of potatoes are produced in the world over an area of about 19.13 million hectare. Potato possesses the characteristics of high yield, low cost nutrition and palatable food (Herklots, 1972) [5]. Potatoes are used for several industrial purposes such as for the production of starch, alcohol, dextrin and glucose.
The non adoption of improved agro-techniques in a climate change scenario as irrigation scheduling, variable planting dates and use of mulch are the limiting factors for low productivity and poor in creation of favorable microclimatic conditions. Globally this climate change should also be addressed in eco-friendly manner.
With this back ground in view, the present investigation was undertaken to know the growth attributes like LAI and LAD as influenced by sowing windows in potato.

Material and Methods
The field trial of Potato (Variety) Kufri Pukhraj was conducted during both the seasons (2009-10 and 2010-11) on PGI Farm without changing randomization. The experiment was laid out 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)	
M1 - With mulch	M2 - Without mulch

Results and Discussion

Effect of different treatments on leaf area index

The leaf area index (LAI) computed on the data of leaf area and ground area plant^{-1} in potato as influenced by various treatments at different growth stages are presented in Table 1 and 2 (2009 and 2010).

In general, during both seasons, mean LAI was progressively increased with the advancement in age of crop up to 56 DAP and thereafter it steadily decreased as the crop approached towards maturity. The highest mean values of LAI were noted at 56 days as 9.21 and 9.69 in 2009 and 2010, respectively.

Effect of irrigation levels and planting dates (IxD)

During the first year between 0-28 DAP, the mean leaf area index was maximum with I_3D_2 (10.15), which was at par with I_2D_2 (9.41) and significantly superior to rest of the treatments. The treatment I_2D_2 was at par with I_1D_2 and I_3D_1, while remaining treatments were at par with each others. During second year, I_3D_2 recorded maximum mean leaf area index (11.05), which was at par with I_2D_2, I_1D_2 and I_3D_1, while remaining treatments were at par with each other.

Between 28-56 DAP during both years, the maximum and significantly higher mean leaf area index was obtained with I_3D_2 (11.42 and 13.75) followed by I_2D_2, which was at par with I_1D_2, I_3D_1, I_2D_1, I_1D_1. During second year same trend was observed except I_1D_1, while remaining treatments were at par with each other.

Between 56-84 DAP during both years, significantly maximum mean leaf area index was registered under I_3D_2 (9.59 and 10.15) which was at par with I_2D_2, I_1D_2 and I_3D_1. During second year same trend was observed except I_3D_1, while remaining treatments were at par with each other.

Between 84-at harvest during first year, significantly maximum mean leaf area index was obtained under I_3D_2 (7.57) followed by I_2D_2 which was at par with I_1D_2. During second year I_3D_2 recorded maximum mean leaf area index (9.03) which was at par with I_2D_2, rest of treatments were at par with each other.

Effect of mulching

The data presented in Table 1 and 2 implies that the mean leaf area index was significantly influenced due to mulching. The maximum and significantly higher mean leaf area index 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 both the years. The interaction combination of irrigation levels and planting dates with mulching (IxDxM) were found significant during both the years.

Between 0-28 DAP, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording the highest mean leaf area index (10.60) which was at par with $I_2D_2M_1$, $I_3D_2M_2$, $I_1D_2M_1$ and $I_3D_1M_1$, while rest of the treatments were at par with each others. During second year, $I_3D_2M_1$ recorded significantly the highest mean leaf area index (11.80) which was at par with $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_1M_1$, $I_3D_2M_2$ and $I_2D_2M_2$.

Between 28-56 DAP, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording the highest mean leaf area index (12.19) which was at par with $I_2D_2M_1$, $I_3D_2M_2$, $I_1D_2M_1$, $I_3D_1M_1$ During second year, $I_3D_2M_1$ recorded the highest mean leaf area index (16.52) followed by $I_2D_2M_1$, which was at par with $I_1D_2M_1$, $I_3D_2M_2$, and $I_3D_1M_1$.

Between 56-84 DAP, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording the highest mean leaf area index (10.36) which was at par with $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_1M_1$, $I_3D_2M_2$ and $I_2D_2M_2$. During second year $I_3D_2M_1$ obtained the highest mean leaf area index (10.60), which was at par with $I_2D_2M_1$, $I_1D_2M_1$ and $I_3D_2M_2$, while rest of the treatments were on par with each other.

Between 84-harvest, during first year, the treatments combination $I_3D_2M_1$ was significantly superior, recording the highest mean leaf area index (8.29) which was at par with $I_2D_2M_1$. The treatment $I_2D_2M_1$ was again at par with $I_3D_2M_2$, $I_1D_2M_1$ and $I_3D_1M_1$. During second year $I_3D_2M_1$ (9.74) which was at par with $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_2M_2$, $I_3D_1M_1$, $I_2D_1M_1$ and $I_2D_2M_2$, while rest of the treatments were at par with each other.

Effect of different treatments on leaf area duration.

Data pertaining to leaf area duration (LAD) of potato as influenced by various treatments at different growth stages are housed in Table 3 and 4 (2009 and 2010). In general, during both seasons, there was a rapid increase in mean LAD from early growth stage to 56 days and thereafter it gradually decreased towards maturity of the crop. The highest mean values of LAD were recorded at 56 DAP interval as 73.63 and 76.01 days in 2009 and 2010, respectively.

Effect of irrigation levels and planting dates (IxD)

During the first year between 0-28 DAP, the mean leaf area duration was maximum with I_3D_2 (87.89 days), which was at par with I_2D_2 and I_1D_2 and significantly superior to rest of the treatments. The treatment I_1D_2 was at par with I_3D_1, I_2D_1 and I_1D_1, while remaining treatments were at par with each other. During second year, I_3D_2 recorded maximum mean leaf area duration (94.01 days), 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, while remaining treatments were at par with each other.

Between 28-56 DAP, during both years, the maximum and significantly higher mean leaf area duration was obtained with I_3D_2 (102.84 and 110.18 days) followed by I_2D_2, which was at par with I_1D_2, I_3D_1, I_2D_1, while remaining treatments were at par with each other.

Between 56-84 DAP, during both years, significantly maximum mean leaf area duration was registered under I_3D_2 (74.71 and 80.31 days) which was at par with I_2D_2. The treatment I_2D_2 was again at par with I_1D_2, I_3D_1 and I_2D_1, while remaining treatments were at par with each other.

Effect of mulching

The data presented in Table 3 and 4 implies that the mean leaf area duration was significantly influenced due to mulching. The maximum and significantly higher mean leaf area duration 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 both the years. The interaction combination of irrigation levels and planting dates with mulching (IxDxM) were found significant during both the years.

Between 0-28 DAP, during first year, the treatment combination $I_3D_2M_1$ was significantly superior, recording the highest mean leaf area duration (94.27 days) which was at par with $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_2M_2$, $I_2D_2M_2$, $I_3D_1M_1$, $I_2D_1M_1$, $I_1D_1M_1$, $I_1D_2M_2$ while rest of the treatments were on par with each other. During second year, $I_3D_2M_1$ recorded significantly the highest mean leaf area duration (97.77 days) which was at par with $I_3D_2M_2$, $I_2D_2M_1$, $I_1D_2M_1$, $I_2D_2M_2$, $I_3D_1M_1$, $I_2D_1M_1$ and $I_1D_1M_1$.

Between 28-56 DAP, during first year, the treatments combination $I_3D_2M_1$ was significantly superior, recording the highest mean leaf area duration (110.98 days) followed by $I_3D_2M_2$, which was at par with $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_1M_1$, $I_2D_1M_1$, $I_2D_2M_2$ and $I_1D_1M_1$. During second year, $I_3D_2M_1$ recorded the highest mean leaf area duration (122.16 days) followed by $I_3D_2M_2$, which was at par with $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_1M_1$, $I_2D_2M_2$, $I_2D_1M_1$, $I_1D_1M_1$ and $I_1D_2M_2$, while rests of the treatments were at par with each others.

Between 56-84 DAP, during both the years, the treatments combination $I_3D_2M_1$ was significantly superior, recording the highest mean leaf area duration (79.32 and 85.32 days) which was at par with $I_3D_2M_2$, which was at par with $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_1M_1$, $I_2D_1M_1$ and $I_2D_2M_2$, while rest of the treatments were on par with each other.

During both the years of investigation, growth analysis study in potato (Table 54 to 65) revealed that all the growth functions *viz.*, mean AGR in the form of dry matter, LAI, LAD CGR etc. plant^{-1} were conspicuously increased from initial stage up to 56 DAP of crop. Moreover, numerically mean maximum values of all the growth functions were observed during grand growth and tuber development phase of crop. Mulching recorded numerically highest mean values of all these growth functions, whereas without mulching exhibited numerically lowest mean values of these functions throughout the stages of crop growth during both seasons.

It might be due to sufficiently available soil moisture from initial growth stage up to maturity phase with sugarcane trash mulching. This might be due to soil moisture conservation with the favourable climatic condition available during crop growth period that improved the leaf area and total dry matter of potato crop, which led to record maximum values of these growth functions under higher moisture regimes.

Water deficit affects crop growth depending on the stage of growth and the degree or intensity of water stress. Dry matter productions, leaf area, leaf area duration (LAD) are known to be affected significantly by soil moisture stress Patel *et al*. (2000). Significant increase in leaf area, LAI, LAD and CGR with successive increase soil moisture content in mulching was recorded. Likewise, the beneficial effects of mulching on the improvement of all the growth functions in potato crop were also reported by many research workers at different locations along with favourable climatic condition available during crop growth period. Similar consistency in results was reported by Chen GoLing (1997) [3], Bharat and Acharya (2000) [2], and Gouranga and Ashwani (2007) [4].

The various growth components and their derivatives (AGR, CGR, RGR, NAR, LAI and LAD) are interdependent and having synergistic effect on overall crop growth performance; which indirectly leads to produce the optimum economic yields in potato crop at their physiological maturity phases considerably.

Such critical scrutiny of these growth functions in the life span of potato crop pertaining to application of mulching conserve the soil moisture regimes and favourable climatic condition available during crop growth period, have been studied earlier by many research workers at different locations and conditions.

Table 1: Mean leaf area index as influenced by various treatments 2009-10

Treatments	Mean leaf area index											
	0-28 DAP			28-56 DAP			56-84 DAP			84-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)	7.26	6.14	6.70	9.21	8.90	9.06	7.13	5.99	6.56	4.51	3.76	4.13
I_1D_2 (0.8 IW/CPE x 44 MW)	9.07	7.27	8.17	10.54	9.35	9.95	9.28	7.30	8.29	6.83	4.76	5.79
I_1D_3 (0.8 IW/CPE x 46 MW)	1.38	0.74	1.06	8.15	4.74	6.45	4.77	1.20	2.99	1.40	1.02	1.21
I_2D_1 (1.0 IW/CPE x 42 MW)	8.73	6.43	7.58	10.06	9.20	9.63	7.38	6.75	7.07	5.70	4.05	4.88
I_2D_2 (1.0 IW/CPE x 44 MW)	10.26	8.57	9.41	10.69	9.71	10.20	9.35	8.63	8.99	7.15	5.89	6.52
I_2D_3 (1.0 IW/CPE x 46 MW)	5.43	4.64	5.03	8.70	7.12	7.91	6.33	5.18	5.75	3.52	3.08	3.30
I_3D_1 (1.2 IW/CPE x 42 MW)	8.90	7.18	8.04	10.50	9.25	9.88	9.24	6.92	8.08	6.44	4.55	5.49
I_3D_2 (1.2 IW/CPE x 44 MW)	10.60	9.70	10.15	12.19	10.65	11.42	10.36	8.82	9.59	8.29	6.85	7.57
I_3D_3 (1.2 IW/CPE x 46 MW)	7.19	6.12	6.66	8.99	7.75	8.37	6.85	5.54	6.20	4.37	3.61	3.99
Mean	7.65	6.31	6.98	9.89	8.52	9.21	7.86	6.26	7.06	5.36	4.17	4.76
	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)	0.54	1.61		0.40	1.19		0.67	2.02		0.34	1.03	
Sub plot (M)	0.20	0.59		0.22	0.67		0.22	0.65		0.13	0.38	
Interactions												
I X M	0.35	NS		0.39	NS		0.38	NS		0.22	NS	
D X M	0.35	NS		0.39	NS		0.38	NS		0.22	NS	
(I X D) X M	0.60	1.78		0.67	2.00		0.66	1.95		0.38	1.14	

Table 2: Mean leaf area index as influenced by various treatments 2010-11

Treatments	Mean leaf area index											
	0-28 DAP			28-56 DAP			56-84 DAP			84-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)	8.63	6.67	7.65	10.06	7.96	9.01	7.26	6.14	6.70	6.33	5.08	5.71
I_1D_2 (0.8 IW/CPE x 44 MW)	10.92	8.95	9.93	11.00	9.70	10.35	9.90	7.51	8.70	8.49	6.61	7.55
I_1D_3 (0.8 IW/CPE x 46 MW)	5.92	2.83	4.38	8.15	5.24	6.70	1.38	1.07	1.23	3.49	2.65	3.07
I_2D_1 (1.0 IW/CPE x 42 MW)	9.09	7.29	8.19	10.49	9.25	9.87	8.73	6.43	7.58	7.45	5.62	6.53
I_2D_2 (1.0 IW/CPE x 44 MW)	10.94	10.18	10.56	11.05	9.71	10.38	10.26	8.57	9.41	8.70	7.44	8.07
I_2D_3 (1.0 IW/CPE x 46 MW)	7.99	6.27	7.13	9.20	7.62	8.41	5.43	3.94	4.68	5.68	4.19	4.93
I_3D_1 (1.2 IW/CPE x 42 MW)	10.90	8.77	9.84	10.88	9.35	10.11	9.07	7.27	8.17	8.12	6.20	7.16
I_3D_2 (1.2 IW/CPE x 44 MW)	11.81	10.29	11.05	16.52	10.99	13.75	10.60	9.70	10.15	9.74	8.32	9.03
I_3D_3 (1.2 IW/CPE x 46 MW)	8.10	6.42	7.26	9.55	7.75	8.65	7.19	6.12	6.66	6.26	4.29	5.27
Mean	9.37	7.52	8.44	10.77	8.62	9.69	7.76	6.31	7.03	7.14	5.60	6.37
	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)	0.75	2.26		0.45	1.36		0.50	1.49		0.34		1.02
Sub plot (M)	0.25	0.73		0.24	0.72		0.17	0.51		0.15		0.44
Interactions												
I X M	0.43	NS		0.42	NS		0.30	NS		0.26		NS
D X M	0.43	NS		0.42	NS		0.30	NS		0.26		NS
(I X D) X M	0.74	2.19		0.73	2.17		0.52	1.53		0.45		1.33

Table 3: Mean leaf area duration as influenced by various treatments 2009-10

Treatments	Mean leaf area duration (Days)								
	0-28 DAP			28-56 DAP			56-84 DAP		
	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)	78.90	58.30	68.60	81.52	65.76	73.64	52.42	45.39	48.91
I_1D_2 (0.8 IW/CPE x 44 MW)	82.97	78.26	80.61	85.49	79.68	82.58	65.83	50.37	58.10
I_1D_3 (0.8 IW/CPE x 46 MW)	48.30	41.79	45.05	43.73	35.74	39.74	33.14	10.32	21.73
I_2D_1 (1.0 IW/CPE x 42 MW)	79.35	69.40	74.37	83.26	68.66	75.96	64.41	46.07	55.24
I_2D_2 (1.0 IW/CPE x 44 MW)	88.81	80.73	84.77	89.75	82.11	85.93	69.32	60.97	65.14
I_2D_3 (1.0 IW/CPE x 46 MW)	59.78	56.86	58.32	64.20	51.67	57.94	46.08	39.64	42.86
I_3D_1 (1.2 IW/CPE x 42 MW)	79.50	69.42	74.46	83.69	69.52	76.60	65.15	47.27	56.21
I_3D_2 (1.2 IW/CPE x 44 MW)	94.27	81.52	87.89	110.98	94.71	102.84	79.33	70.10	74.71
I_3D_3 (1.2 IW/CPE x 46 MW)	64.74	58.25	61.49	75.75	59.21	67.48	49.34	42.81	46.08
Mean	75.18	66.06	70.62	79.82	67.45	73.63	58.34	45.88	52.11
	S.Em±		CD at 5%	S.Em±		CD at 5%	S.Em±		CD at 5%
Main plot (I X D)	4.04		12.13	3.66		10.99	4.18		12.55
Sub plot (M)	1.81		5.39	1.65		4.93	1.41		4.20
Interactions									
I X M	3.14		NS	2.87		NS	2.44		NS
D X M	3.14		NS	2.87		NS	2.44		NS
(I X D) X M	5.44		16.17	4.97		14.79	4.24		12.60

Table 4: Mean leaf area duration as influenced by various treatments 2010-11

Treatments	Mean leaf area duration (Days)								
	0-28 DAP			28-56 DAP			56-84 DAP		
	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)	80.85	60.20	70.52	84.52	61.01	72.76	57.32	46.11	51.72
I_1D_2 (0.8 IW/CPE x 44 MW)	85.57	80.26	82.91	87.89	81.68	84.78	69.91	54.37	62.14
I_1D_3 (0.8 IW/CPE x 46 MW)	50.80	44.79	47.80	46.73	38.24	42.49	38.14	14.82	26.48
I_2D_1 (1.0 IW/CPE x 42 MW)	81.90	70.40	76.15	84.66	70.52	77.59	68.43	50.57	59.50
I_2D_2 (1.0 IW/CPE x 44 MW)	90.21	84.22	87.21	92.75	84.81	88.78	74.82	66.37	70.59
I_2D_3 (1.0 IW/CPE x 46 MW)	62.78	55.01	58.89	66.20	53.57	59.89	50.08	41.53	45.80
I_3D_1 (1.2 IW/CPE x 42 MW)	81.90	71.92	76.91	86.29	71.16	78.72	69.05	50.77	59.91
I_3D_2 (1.2 IW/CPE x 44 MW)	97.77	90.26	94.01	122.17	98.21	110.19	85.33	75.30	80.31
I_3D_3 (1.2 IW/CPE x 46 MW)	66.74	60.05	63.39	77.25	60.56	68.90	52.84	44.04	48.44
Mean	77.61	68.57	73.09	83.16	68.86	76.01	62.88	49.32	56.10
	S.Em±		CD at 5%	S.Em±		CD at 5%	S.Em±		CD at 5%
Main plot (I X D)	3.67		11.00	3.92		11.77	3.94		11.82

Sub plot (M)	1.93	5.76	1.87	5.58	1.48	4.40
Interactions						
I X M	3.35	NS	3.25	NS	2.56	NS
D X M	3.35	NS	3.25	NS	2.56	NS
(I X D) X M	5.81	17.28	5.63	16.74	4.44	13.20

Conclusion

Growth attributes study in respect of mean LAI, LAD etc revealed that during both the seasons at all the growth stages of potato, numerically higher mean values of each growth function were recorded with application of irrigation at 1.2 IW/CPE ratio and early planting on D2 (44th MW), whereas numerically lower mean values of said parameters were recorded at application of irrigation at 0.8 IW/CPE ratio and late planting on D3 (46th MW).

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