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Effect of Sowing Windows on Growth Functions like RGR in Relation to Dry Matter Accumulation in Potato

V. A. Apotikar, A. V. Solanke*, K.J. Kubde* and S. R. Dalal**

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 RGR and NAR was found near the crop with mulching and five irrigations. A positive linear correlation existed between the RGR and NAR and the dry matter accumulation in the potato. Proportion of dry matter partitioned to tubers increased with plant weight. The data emphasizes the importance of the use of detailed studies on the relationship between RGR and NAR and dry matter production in the analysis of relative efficiencies of the different treatments. 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 relationship between dry matter production and RGR and NAR 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 not only in accumulation of dry matter but also conversion of this into RGR and NAR due to its complimentary effect in better use of natural resources like light, soil moisture. RGR and NAR 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 RGR and NAR.*

Key words: *sowing window, dry matter, RGR and NAR*

INTRODUCTION

Potato is one of the most important crops of the world, ranking next to rice and wheat. It assumes greater significance for its ability to provide food security to millions of people across the globe, as it provides more dry matter content, proteins and calories from per unit area of land and time. It is a wholesome food which is rich in carbohydrates, phosphorus, calcium, vitamin C and vitamin A, minerals and is high yielding short duration crop with high protein calorie ratio. Potato is one of the unique crop grown in our country having high productivity and supplementing food needs. (Gupta, 2006). 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 RGR and NAR 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

* Dr. PDKV, Akola, Mahatma Phule Krushi Vidyapeeth Rahuri District: Ahmednagar (M.S.), *E-mail: varsha.malve@gmail.com*

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

Relative Growth Rate (g g^{-1} day^{-1})

The relative rate at which a plant incorporates new material into substance is measured by Relative Growth Rate (RGR) of dry matter accumulation. According to Blackman (1919) the increase in dry matter of plant is a process of continuous compound interest wherein the increment in any interval adds to the 'capital' for subsequent growth. He called RGR as the efficiency index. The RGR is expressed in g g^{-1} day^{-1} and worked out as per the formula given by Fisher (1921).

$$RGR(g\,g^{-1}\,day^{-1}) = \frac{Loge\,W_2 - Log\,W_1}{t_2 - t_1}$$

where,

W_2 and W_1 are the total dry matter weight (g) at time t_2 and t_1, respectively.

Log_e = Natural logarithm to the base 'e' = 2.3026

Net Assimilation Rate (g cm^{-2} day^{-1})

Gregory (1917) suggested the concept of 'Net Assimilation Rate (NAR) or 'Average Assimilation Rate' (E) which defined as the net increase in plant weight (photosynthesis-respiration) per unit of assimilatory surface per unit time. Moreover, the NAR represents the photosynthetic efficiency of leaves and exhibits the increase in total dry weight of the plant per unit leaf area per unit time. The NAR is expressed in g dm^2 day^{-1} and is calculated by the formula given by Williams (1946).

$$NAR(g\,dm^2\,day^{-1}) = \frac{W_2 - W_1}{t_2 - t_1} \times \frac{Loge\,L_2 - Loge\,L_1}{L_2 - L_1}$$

Where,

W_2 and W_1 are the total dry matter weight (g) at time t_2 and t_1, respectively.

L_2 and L_1 are the total leaf area (dm^2) at time t_2 and t_1,respectively.

Log_e = Natural logarithm to the base 'e' = 2.3026.

RESULTS AND DISCUSSION

The important findings of the experiment studies under different irrigation levels, planting dates and mulching are presented in this chapter under appropriate heads.

Effect of different treatments on relative growth rate

Data with respect to relative growth rate (RGR) of potato as influenced by various treatments at different growth stages are housed in Table 1.

In general, during both seasons, mean RGR was consistently increased as the crop headed towards maturity. The highest mean values of RGR was recorded at 56 DAP as 0.101 g g^{-1} day^{-1}.

Effect of irrigation levels and planting dates (IxD)

During the first year between 0-28 DAP, the mean relative growth rate was maximum with I_3D_2 (0.06 g g^{-1} day^{-1}) followed by I_2D_2 (0.04 g g^{-1} day^{-1}) and significantly superior to rest of the treatments. The treatment I_2D_2 was again at par with I_1D_2, while remaining treatments were at par with each others. During second year, I_3D_2 recorded maximum mean relative growth rate (0.07 g g^{-1} day^{-1}) followed by I_2D_2, which was at par with I_1D_2, I_3D_1 and I_2D_1.

Between 28-56 DAP during both years, the maximum and significantly higher mean relative growth rate was obtained with I_3D_2 (0.07 and 0.08 g g^{-1} day^{-1}) followed by I_2D_2, which was at par with I_1D_2.

Between 56-84 DAP significantly maximum mean relative growth rate was registered under I_3D_2

(0.05 g g^{-1} day^{-1}) followed by I_2D_2 and I_1D_2, which was at par with remaining treatments except I_2D_3 and I_1D_3 during first year. The treatment I_3D_2 (0.033 g g^{-1} day^{-1}) followed by I_2D_2, which was at par with remaining treatments except I_2D_3 and I_1D_3 during second year.

Effect of mulching

The data presented in Table 1 implies that the mean relative growth rate was significantly influenced due to mulching. The maximum and significantly higher mean relative growth rate 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, on pooled basis, the treatment combination $I_3D_2M_1$ was significantly superior, recording the highest mean relative growth rate (0.094 g g^{-1} day^{-1}) followed by $I_2D_2M_1$, which was at par with $I_3D_2M_2$, $I_1D_2M_1$, while rest of the treatments were on par with each other.

Between 28-56 DAP and 56-84 DAP, $I_3D_2M_1$ recorded the highest mean relative growth rate (0.101 g g^{-1} day^{-1} 0.073 g g^{-1} day^{-1}) followed by $I_2D_2M_1$, which was at par with $I_1D_2M_1$, $I_3D_1M_1$.

Effect of different treatments on net assimilation rate

Data with respect to net assimilation rate (NAR) of potato as influenced by various treatments at different growth stages are housed in Table 2.

In general, during both seasons, mean NAR was consistently increased as the crop headed towards maturity. The highest mean values of net assimilation rate (NAR) were recorded at 56 DAP as 60.06 mg cm^{-2} day^{-1} .

Effect of irrigation levels and planting dates (IxD)

On pooled analysis basis, between 0-28 DAP, the mean net assimilation rate was maximum with I_3D_2 (18.76 mg cm^{-2} day^{-1}) followed by I_2D_2 (14.31 mg cm^{-2} day^{-1}) and significantly superior to rest of the treatments. The treatment I_1D_2 was at par with I_3D_1 and I_2D_1, while remaining treatments were at par with each others.

Between 28-56 DAP, the maximum and significantly higher mean net assimilation rate was obtained with I_3D_2 (50.24 mg cm^{-2} day^{-1}) followed by I_2D_2, which was at par with I_1D_2, while remaining treatments were at par with each others.

Between 56-84 DAP, significantly maximum mean net assimilation rate was registered under I_3D_2 (12.64 mg cm^{-2} day^{-1}) followed by I_2D_2. The treatment I_1D_2 was at par with remaining treatments I_3D_1 and I_2D_1.

Between 84-harvest, significantly maximum mean net assimilation rate was obtained under I_3D_2 (2.10 mg cm^{-2} day^{-1}) followed by I_2D_2. The treatment I_2D_2 was at par with remaining treatments I_1D_2 and I_3D_1.

Effect of mulching

The data presented in Table 2 implies that the mean net assimilation rate was significantly influenced due to mulching. The maximum significantly higher mean net assimilation rate 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 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 both the year, the treatments combination $I_3D_2M_1$ was significantly superior, recorded the highest mean net assimilation rate (21.42 mg cm^{-2} day^{-1}) followed by $I_2D_2M_1$, while rest of the treatments were on par with each others.

Between 28-56 DAP, the treatments combination $I_3D_2M_1$ was significantly superior, recording the highest mean net assimilation rate (60.06 mg cm^{-2} day^{-1}) followed by $I_2D_2M_1$, $I_1D_2M_1$, $I_3D_2M_2$, which was at par with $I_3D_1M_1$, $I_2D_1M_1$.

Between 56-84 DAP, the treatments combination $I_3D_2M_1$ was significantly superior, recording the highest mean net assimilation rate (16.26 mg cm^{-2} day^{-1}) followed by $I_2D_2M_1$ and $I_3D_2M_2$, while rest of the treatments were on par with each others.

Between 84-harvest, during both years, the treatments combination $I_3D_2M_1$ was significantly superior, recording the highest mean net assimilation rate (2.97 mg cm^{-2} day^{-1}) followed by $I_2D_2M_1$ (2.23 mg cm^{-2} day^{-1}), which was at par with $I_1D_2M_1$ and $I_3D_2M_1$, while rest of the treatments were at par with each others.

It might be due to sufficiently available soil moisture from initial growth stage up to maturity phase with high frequency irrigation level and planting on 44th MW. This might be due to 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. The rate of increase in mean NAR plant-1 was numerically higher at 56 DAP with all the irrigation levels. Earlier, Thorne (1961) also demonstrated the antogenetic drift i.e. decrease in NAR values with plant age, as well NAR usually decreases during growth and development phase of a plant stand.

Dry matter accumulation

Water deficit affects crop growth depending on the stage of growth and the degree or intensity of water stress (Table 3). Dry matter production is known to be affected significantly by soil moisture stress. Likewise, the beneficial effects of increased irrigation frequency 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. It is observed from the data presented in Table 1 to 2 that during both the years of experimentation, of crop growth in respect of total dry matter accumulation plant-1, while at all the days of observation regarding fresh tuber weight plant-1, planting on 44th MW, the irrigation scheduled at 1.2 IW/CPE (I3D2) was comparable with 1.0 IW/CPE (I2D2) and produced significantly higher mean values of these attributes than rest of the treatments.

Whereas, during the same period, irrigation scheduled at 0.8 IW/CPE and planting on 46th MW (I1D3) treatment recorded significantly the lowest mean total dry matter accumulation and fresh tuber weight plant-1 compared to other treatments. Thus, the taller but sturdy plants with higher spread and dry matter accumulation at higher soil moisture regimes produced more number of total dry matter accumulation plant-1 with higher fresh tuber weight resulting into higher yield. Similar trend was observed at 28, 56, 84 DAP and at harvest. Lowest total dry matter was recorded in 46 MW at all the days after planting. These results are corroborated with the findings of Shiri-e-Janagard et al. (2009) reported that moisture-stress will reduce the leaf area which results in reducing the photosynthesizing surface which will ultimately reduce the dry matter accumulation in potato crop under stressed treatments. The early planting recorded maximum dry matter than late once. The similar results were recorded by Gronowicz et al. (1992). This might be due to the favourable climatic condition available during crop growth period.

CONCLUSION

Irrigation scheduled at 1.2 IW/CPE (5 irrigations at 18 to 20 days interval) and planting on 44th MW (29thOct to 04thNov) (I3D2) recorded highest mean values of all these growth functions viz., mean RGR, NAR, LAI and LAD plant-1, whereas Irrigation scheduled at 0.8 IW/CPE (3 irrigations at 25 to 27 days interval) and planting on at 46th MW (12thNov to 18thNov) (I1D3) treatment exhibited numerically lowest mean values of various stages of crop growth. Growth analysis study in respect of mean RGR, NAR, LAI and LAD revealed that during both the seasons at all the growth stages of potato, numerically higher mean values each growth function were recorded in mulching, whereas

Table 1
Mean relative growth rate (gm gm-1 day-1) as influenced by various treatments.

Treatments	*Pooled*								
	0-28 DAP			*28-56 DAP*			*56-84 DAP*		
	M_1	M_2	*mean*	M_1	M_2	*mean*	M_1	M_2	*mean*
I_1D_1	0.032	0.024	0.019	0.044	0.035	0.026	0.012	0.007	0.006
I_1D_2	0.042	0.028	0.023	0.047	0.041	0.029	0.014	0.007	0.007
I_1D_3	0.014	0.011	0.009	0.033	0.022	0.018	0.012	0.002	0.005
I_2D_1	0.034	0.026	0.020	0.044	0.036	0.027	0.012	0.007	0.006
I_2D_2	0.046	0.034	0.027	0.054	0.043	0.032	0.023	0.007	0.010
I_2D_3	0.028	0.015	0.014	0.045	0.031	0.025	0.012	0.006	0.006
I_3D_1	0.041	0.027	0.022	0.046	0.037	0.028	0.013	0.007	0.006
I_3D_2	0.094	0.041	0.045	0.101	0.049	0.050	0.073	0.007	0.027
I_3D_3	0.030	0.020	0.017	0.042	0.034	0.026	0.012	0.007	0.006
mean	0.040	0.013	**0.026**	0.051	0.018	0.034	0.020	0.003	0.012

	S.Em±	*CD at 5%*	*S.Em±*	*CD at 5%*	*S.Em±*	*CD at 5%*
Main plot (I X D)	0.002	0.007	0.002	0.006	0.001	0.002
Sub plot (M)	0.001	0.002	0.001	0.003	0.000	0.001
Interactions						
I X M	0.001	NS	0.002	NS	0.000	NS
D X M	0.001	NS	0.002	NS	0.000	NS
(I X D) X M	0.002	0.006	0.003	0.008	0.001	0.002

Note- I_1-(0.8 IW/CPE), I_2-(1.0 IW/CPE), I_3-(1.2 IW/CPE), D_1-(42 MW), D_2-(44 MW), D_3-(46 MW), M_1- (with mulch), M_2- (without mulch)

Table 2
Mean net assimilation rate (gm cm-2 day-1) as influenced by various treatments.

Treatments	*Pooled*											
	28 DAP			*56 DAP*			*84 DAP*			*AT harvest*		
	M_1	M_2	*mean*	M_1	M_2	*mean*	M_1	M_2	*mean*	M_1	M_2	*mean*
I_1D_1	9.05	8.40	8.73	22.05	18.69	20.37	5.29	4.68	4.99	1.23	0.99	1.11
I_1D_2	11.43	10.41	10.92	40.65	22.39	31.52	6.46	5.87	6.17	2.20	1.10	1.65
I_1D_3	5.66	5.18	5.42	15.17	10.34	12.76	3.41	2.57	2.99	0.97	0.56	0.76
I_2D_1	9.30	8.74	9.02	30.34	18.85	24.60	5.58	5.00	5.29	1.35	1.01	1.18
I_2D_2	17.34	12.35	14.85	43.89	27.66	35.77	12.09	6.86	9.48	2.23	1.18	1.70
I_2D_3	7.08	6.61	6.84	18.31	11.78	15.05	3.98	3.31	3.65	1.13	0.82	0.97
I_3D_1	10.35	9.64	9.99	33.42	19.91	26.67	5.77	5.43	5.60	2.00	1.04	1.52
I_3D_2	21.42	12.18	16.80	60.06	40.41	50.24	16.26	9.03	12.64	2.97	1.23	2.10
I_3D_3	8.59	7.69	8.14	19.92	12.81	16.36	5.01	3.46	4.24	1.16	0.97	1.06
mean	11.13	9.02	10.08	31.54	20.32	25.93	7.10	5.13	6.12	1.69	0.99	1.34

	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)	0.77	2.31	2.57	7.72	0.33	0.98	0.08	0.25
Sub plot (M)	0.42	1.26	0.91	2.70	0.16	0.48	0.04	0.11
Interactions								
I X M	0.74	NS	1.57	NS	0.28	NS	0.07	NS
D X M	0.74	NS	1.57	NS	0.28	NS	0.07	NS
(I X D) X M	1.27	3.79	2.72	8.09	0.48	1.43	0.11	0.34

Note- I_1-(0.8 IW/CPE), I_2-(1.0 IW/CPE), I_3-(1.2 IW/CPE), D_1-(42 MW), D_2-(44 MW), D_3-(46 MW), M_1- (with mulch), M_2- (without mulch)

Table 3
Mean dry matter accumulation (g) plant-1 as influenced periodically by various treatments

Treatments	*Pooled*											
	28 DAP			*56 DAP*			*84 DAP*			*AT harvest*		
	M_1	M_2	*mean*	M_1	M_2	*mean*	M_1	M_2	*mean*	M_1	M_2	*mean*
I_1D_1	40.43	39.14	26.52	72.92	68.78	47.23	39.92	39.02	26.31	2.68	1.88	1.52
I_1D_2	43.79	40.66	28.15	78.91	73.11	50.67	43.78	40.91	28.23	3.76	2.83	2.20
I_1D_3	34.00	32.51	22.17	68.78	60.85	43.21	34.42	32.51	22.31	2.03	0.85	0.96
I_2D_1	41.07	39.55	26.87	74.97	71.40	48.79	40.57	39.67	26.75	2.94	2.18	1.71
I_2D_2	45.34	41.96	29.10	82.11	73.75	51.95	45.21	42.06	29.09	3.93	3.35	2.43
I_2D_3	36.26	34.87	23.71	72.04	65.18	45.74	37.01	34.74	23.92	2.14	1.10	1.08
I_3D_1	41.89	40.03	27.31	76.11	72.48	49.53	42.30	40.53	27.61	3.09	2.58	1.89
I_3D_2	64.19	52.22	38.80	115.20	97.06	70.75	64.19	52.74	38.98	4.02	3.79	2.60
I_3D_3	39.00	38.26	25.75	72.67	66.71	46.46	38.12	37.76	25.29	2.51	1.42	1.31
mean	42.88	19.96	31.42	79.30	36.07	57.69	42.83	20.00	31.42	3.01	1.11	2.06

	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)	1.75	5.26	3.47	10.42	1.64	4.93	0.10	0.31
Sub plot (M)	0.79	2.35	1.64	4.88	0.83	2.47	0.07	0.21
Interactions								
I X M	1.37	NS	2.85	NS	1.44	NS	0.12	NS
D X M	1.37	NS	2.85	NS	1.44	NS	0.12	NS
(I X D) X M	2.37	7.05	4.93	14.64	2.49	7.40	0.22	0.64

Note- I_1-(0.8 IW/CPE), I_2-(1.0 IW/CPE), I_3-(1.2 IW/CPE), D_1-(42 MW), D_2-(44 MW), D_3-(46 MW), M_1- (with mulch), M_2- (without mulch)

numerically lower mean values of were recorded in without mulching.

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