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Stomatal Conductance of Potato Grown under Sub-tropical Conditions

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Abstract

Production of potato (*Solanum tuberosum* L.) under sub-tropical conditions may be feasible. However, suitable cultivars need to be evaluated to maximize yield. A characteristic that could be used to identify superior cultivars is high stomatal conductance. A field experiment was carried out at the institutional farm of Uttar Banga Krishi Viswavidyalaya, Pundibari, Cooch Behar, West Bengal, India, from November to February of 2006-2007 and 2007-2008 to determine how stomatal conductance, and other factors, affected yield of potato. The cultivars Kufri Pukhraj (V_1), TPS 92 PT 27 (V_2), Kufri Ashoka (V_3), HPS II/13 (V_4), Kufri Jyoti (non-certified, after 6th generation of V_8; locally available from the plain source of Dhupguri) (V_5), Kufri Chipsona 2 (V_6), Kufri Chandramukhi (V_7), Kufri Jyoti (certified seed, hill source cultivar of Solan) (V_8), Local Cultivar (V_9) and Kufri Jyoti (2nd generation saved seed of V_8) (V_{10}) were used. Yield of Kufri Jyoti (V_8) had among the highest stomatal conductance, internal humidity and internal CO_2 levels in leaves. Kufri Jyoti (V_8) had the highest tuber bulking and final tuber yield followed by Kufri Pukhraj and 92 PT 27. Stomatal conductance can be used as a criterion to identify potato cultivars suited for production under sub-tropical conditions.

1. Introduction

Photosynthesis is the most important process to be understood in order to maximize potato (*Solanum tuberosum* L.) productivity (Dean, 1994). It is not the absolute rate of photosynthesis that is important, but the relationship between photosynthesis and respiration, termed net photosynthetic rate. Selection of cultivars with high net photosynthetic rate, and high stomatal conductance, will result in higher yield if all other factors are equal (Dwelle, 1985). Gaur and Pandey (2000) reported that problems of potato production in sub-tropical regions are different from those experienced in temperate regions and linked to higher temperatures. Warmer conditions during periods of active growth and tuberization reduce tuber yields, in part, because stomatal conductance is impaired. The study was undertaken to evaluate potato cultivars based on stomatal conductance for their ability to be grown under sub-tropical conditions

2. Materials and Methods

Field experiments were carried out at the farm of Uttar Banga Krishi Viswavidyalaya University at Pundibari, Cooch Behar, West Bengal, India, from November to February in 2006-2007 and 2007-2008. The farm is situated at 26°19′86″N latitude and 89°23′53″E longitude at an elevation of 43 m above mean sea level. The climate is sub-tropical with rainfall between 2100 and 3300 mm, high humidity, and a cool winter from December to February where freezing weather is the exception. About 80% of rain fall is received from June to September. Temperatures range from 7.1-8°C to 24.8-32.2°C. The climatic condition makes the agro-ecological condition complex and dynamic.

Composite soil samples from experimental plots in both years were collected and analyzed before starting the experiment. The experimental soil was an inseptisol, and had a pH 5.5, organic carbon of 0.639%, cation exchange capacity of 14.54 me 100 g^{-1}, available nitrogen was 107.59 kg ha^{-1}, available phosphorus was 15.36 kg ha^{-1} and available potassium was 71.68 kg ha^{-1}.

The experiment was arranged in a Randomized Complete Block Design using cultivars: V_1=Kufri Pukhraj, V_2=92PT27,

V_3=Kufri Ashoka, V_4=HPS II/13, V_5=Kufri Jyoti (non-certified, after 6th generation of V_8; locally available from the plain source of Dhupguri), V_6=Kufri Chipsona 2, V_7=Kufri Chandramukhi, V_8=Kufri Jyoti (hill source seed of Solan), V_9=Local seed and V_{10}=Kufri Jyoti (2nd generation saved seed of V_8) and replicated three times. The stomatal conductance rate, internal CO_2 and inlet humidity of the leaves were measured at 4th leaf of each plant at 40, 60 and 80 days after planting (DAP) with a hand held Portable Photosynthesis System (Model CI-340, CID, Inc., Camas, WA). Tuber bulking rate was measured by determining dry weight increase of tubers at 60 and 80 DAP. Dry matter was determined by placing 50 g of potato tuber tissue into a forced air drying oven at 60°C until weight stabilized and the percentage of water loss was recorded. Data were accumulated at 60 and 80 DAP. Final yield was determined at 80 DAP. Data were subjected to ANOVA in Indostat Servive (Windostat, ver. 7.0, Ameerpet, Hyderabad, India). If interactions were significant they were used to explain results.

3. Results and Discussion

Year affected all measured variables except stomatal conductance; sampling date affected all variables measured on both dates, and cultivar affected all measured variables (Table 1). Most interactions affected all responses with the year by cultivar interaction affecting tuber dry matter and final yield. The year by sampling date by cultivar interaction affected stomatal conductance, internal CO_2, inlet relative humidity and tuber bulking rate.

3.1. Stomatal conductance rate

Conductance of the diffusion and the transport of CO_2 play a major role in the ratio CO_2:O_2, and therefore the net CO_2 uptake or net O_2 evolution and photorespiration ratio, wherein the mirror effect is used to simulate the variation of this ratio (Andre, 2011d). In the first year, at the first sampling date, cv. Kufri Jyoti (hill source cultivar of Solan) had the highest stomatal conductance. In the second sampling date of that year that cultivar was similar to that of cv. Kufri Jyoti (Farmer's saved seed from last year) which were both higher than the other entries. In the second year at the first sampling date cv. Kufri Jyoti (hill source cultivar of Solan) and the Local cultivar had similar stomatal conductance that were higher than the other entries. In the second sampling date of that year cv. Kufri Jyoti (hill source cultivar of Solan) and cv. Kufri Jyoti (Farmer's saved seed from last year) had similar stomatal conductance that were higher than the other entries. The results are in confirmation with Hirasawa and Hardy, (1999). One can thus view the role of *PR* as sinks that can (or cannot) absorb and dissipate the excess energy (electron transport rate) produced in chloroplasts. This ability is a function of the ratio of maximum rates of oxygenation and carboxylation of rubisco. This factor is termed oxygenation capacity (OC) (Andre, 1986, 2011b). The sink effect has been observed in many experiments (Andre, 2011b).

3.2. Internal CO_2

Among the cultivars there were differences found in both the years at the sampling dates (Table 2). The cv. Kufri Jyoti (hill source seed of Solan) had the highest internal CO_2 in both years at both sampling dates. Results corroborated the finding of Teng et al. (2004)

3.3. Inlet relative humidity

There were differences in inlet relative humidity in leaves between cultivars and years (Table 2). Values varied only 11% at the first sampling date in both years and 32% in the second sampling date in both years. The cv. Kufri Jyoti (hill source seed of Solan) had among the highest inlet relative humidity. Differences in the inlet relative humidity at the

Table 1: ANOVA results for effects of year, sampling date and cultivar on measured variables from potato.

Source	Stomatal conductance	Internal CO_2	Inlet relative humidity	Tuber bulking rate	Tuber dry matter	Final yield
Year (Y)	ns	*	**	**	**	**
Sampling date (S)	**	**	**	**	-- [a]	--
Cultivar (C)	**	**	**	**	**	**
Interactions						
Y×S	ns	**	*	**	--	--
Y×C	**	**	**	**	*	**
S×C	**	**	*	**	--	--
Y×S×C	**	**	**	**	--	--

ns, *, **non-significant or significant at $p \leq 0.05$ or $p \leq 0.01$, ANOVA. [a] "--" indicates this main or interaction effect is not applicable since the variable was only measured at the last sampling date.

Table 2: Interaction effect of year, sampling date and cultivar on stomatal conductance, internal CO_2, inlet relative humidity and tuber bulking rate in potato

Sampling Year	×date	×cv	Stomatal conductance rate (mmol m^{-2} s^{-1})	Internal CO_2 (µmol mol^{-1})	Inlet relative humidity (%)	Tuber bulking rate (g m^{-2} day^{-1})
1[a]	1	V_8	350.72	392.95	87.74	69.7
		V_4	301.82**	361.44*	84.55**	51.42**
		V_9	296.81**	327.57**	83.53**	52.27**
		V_1	287.25*	319.66**	86.70	59.85
		V_2	275.94**	364.91*	86.87	54.96**
		V_{10}	275.01**	371.03	78.33*	45.46*
		V_5	266.94*	370.77	82.59**	52.38**
		V_6	255.45*	384.76	80.86**	46.93*
		V_7	254.51*	372.05	82.56**	46.13*
		V_3	245.74*	349.25**	79.12**	50.13**
1	2	V_8	239.60	231.22	65.54	76.37
		V_5	238.28	174.15*	54.68**	55.61**
		V_2	215.94**	147.08*	63.32	62.60
		V_4	202.61**	193.20**	61.87	57.75**
		V_{10}	193.72**	160.22*	47.52*	54.16*
		V_9	177.67*	112.20*	57.99**	55.90**
		V_6	161.59*	113.23**	52.02**	51.68*
		V_7	143.79*	168.14*	47.21**	49.80*
		V_3	141.06**	178.08*	44.39*	53.67*
		V_1	138.49*	216.94	62.95	64.00
2	1	V_8	361.24	369.09	87.36	68.58
		V_9	321.88	325.16*	83.08**	53.02**
		V_2	285.12**	357.39	85.41	56.80**
		V_3	277.50**	348.68**	78.56*	50.73*
		V_1	270.86**	316.39*	85.67	61.09
		V_{10}	261.62*	356.49	77.97*	46.56*
		V_5	258.78*	349.48**	81.87**	54.35**
		V_4	248.78*	365.66	83.55**	54.11**
		V_7	246.70**	349.65**	83.06**	48.23*
		V_6	229.35**	367.91	80.09**	49.08*
2	2	V_8	239.21	234.11	66.21	80.2
		V_5	231.04	175.21**	54.32**	62.21*
		V_2	215.61**	150.52*	63.78	68.72**
		V_{10}	194.64**	167.99*	46.60*	69.44**
		V_4	187.97**	196.34**	62.12**	71.40**
		V_9	180.91**	115.87*	58.26**	77.68
		V_6	163.83*	122.32*	52.35**	51.64**
		V_3	146.65*	185.73**	43.65*	62.61*
		V_7	143.71*	175.87**	47.34*	66.66**
		V_1	138.45*	218.92	61.41	71.22**

ns, *, **non-significant or significant at $p \leq 0.05$ or $p \leq 0.01$, Least Squares Means analysis. [a]1=First year and first sampling date; 2: Second year and second sampling date; V_1: Kufri Pukhraj; V_2: 92 PT 27; V_3: Kufri Ashoka; V_4: HPS II/13; V_5: Kufri Jyoti (Non Certified, after 6th generation of V_8, Locally available from the plain source of Dhupguri); V_6: Kufri Chipsona-2; V_7: Kufri Chandramukhi; V_8: Kufri Jyoti (hill source cultivar of Solan); V_9: Local Cultivar; V_{10}: Kufri Jyoti (2nd generation saved seed of V_8).

second sampling date in both years may be due to lower rate of stomatal conductance of the leaves at maturity.

3.4. Tuber bulking rate

The highest tuber bulking rate was for cv. Kufri Jyoti (hill source seed of Solan) in both sampling dates and years (Table 2).

3.5. Dry matter content in tubers at harvest

Year and cultivar affected dry matter content (Table 3). *Kufri Chipsona* and *Kufri Chandramukhi 2* had the highest dry matter content. The lowest yield was for *Kufri Pukhraj* and the *Local cultivar* in both years and similar to previous results (Khurana et al., 1992; De'an and YinFa, 1995).

3.6. Final yield

Final yield was affected by the year by cultivar interaction (Table 4). Kufri Jyoti (hill source cultivar of Solan) and *Kufri Pukhraj* had the highest final yield. There were no differences between cvs. 92 PT-27, Kufri Jyoti, Local cultivar, HPS II/13, Kufri Ashoka, Kufri Chandramukhi, Kufri Jyoti farmer's saved seed, and Kufri Chipsona 2 which had the lowest yield. Genotype played a role in variation of final tuber yields. The increase in final yield of tubers corresponded to the higher dry matter accumulation in leaves and stems, and higher transpiration rate (Sinha et al., 1982).

Table 3: Interaction of year and cultivar on tuber dry matter in potato

Year×Cultivar		Tuber dry matter (%)
1[a]	V_6	22.18
	V_7	20.60
	V_2	18.36**
	V_4	18.19**
	V_8	17.63**
	V_3	17.46**
	V_{10}	17.32**
	V_5	17.22**
	V_9	17.12**
	V_1	16.39**
2	V_6	23.67
	V_7	20.77
	V_4	18.56**
	V_8	18.36**
	V_2	18.26**
	V_3	17.96**
	V_5	17.46**
	V_{10}	17.36**
	V_9	17.26**
	V_1	16.65**

*, **non-significant or significant at $p \leq 0.05$ or $p \leq 0.01$; Least Squares Means analysis; [a]1: First year; 2: Second year; V_1: Kufri Pukhraj; V_2: 92 PT 27; V_3: Kufri Ashoka; V_4: HPS II/13; V_5: Kufri Jyoti (Non-certified, after 6th generation of V_8, Locally available from the plain source of Dhupguri); V_6: Kufri Chipsona-2; V_7: Kufri Chandramukhi; V_8: Kufri Jyoti (hill source cultivar of Solan); V_9: Local cultivar; V_{10}: Kufri Jyoti (2nd generation saved seed of V_8)

Table 4: Interaction of year and cultivar on final yield of potato

Year×Cultivar		Final tuber yield (t ha^{-1})
1[a]	V_8	27.35
	V_1	23.53
	V_2	22.11**
	V_5	19.91**
	V_4	17.27**
	V_6	16.99**
	V_9	16.91**
	V_3	16.77**
	V_7	16.19**
	V_{10}	15.69**
2	V_8	30.68
	V_1	24.61
	V_2	24.11**
	V_9	23.58**
	V_4	21.93**
	V_7	21.53**
	V_3	21.44**
	V_5	20.9**
	V_{10}	20.36**
	V_6	18.99**

4. Conclusion

It appears that some potato genetic material is suitable for production under sub-tropical conditions. This appears to be due to improved stomatal conductance, increased internal CO_2 and higher inlet relative humidity. There was likely increased transportation of photosynthates from source to sink which could result in higher tuber bulking rate and yield.

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