

Indices and their applicability under high temperature in potato (*Solanum tuberosum* L.) cultivars

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ABSTRACT

The increasing temperature is going to be more vulnerable for cool season crops like potato which requires an optimum productivity temperature of 18 to 20 °C. Thus, breeding for heat tolerance has become very important. Therefore, some previously used indices for abiotic stress tolerance have been used in our study for screening of high temperature stress tolerance in potato. Three high yielding (Kufri jyoti, Kufri megha and Kufri pokraj) and two local (Rangpuria and Badami) commonly grown potato cultivars were selected for our experiment. Potato cultivars were sown under normal condition and two high temperature conditions (polyhouse and early season) and indices such as HSI (heat susceptibility index), HTI (heat tolerance index), GM (geometric mean) and HII (heat intensity index) were used to evaluate the performance of the cultivars under all the three temperature conditions. The positive and significant correlation between HTI (heat tolerance index), and GM (geometric mean) as well as with tuber yield under all the conditions revealed that these indices were efficient in selecting the high temperature tolerant potato cultivars. We recorded the equal applicability of these two indices for both high yielding and local group of potato cultivars. Our study revealed that cultivar Kufri megha and Rangpuria showed higher heat tolerance between high yielding and local cultivars respectively.

1. INTRODUCTION

In the global climate change scenario, temperature is predicted to rise by 1.5–5.8 °C by 2100 which is going to cause severe heat stress leading to threats in agricultural production [1]. Tropical countries that already suffer from crop failures due to heat stress are predicted to be especially susceptible to climate change [2]. To combat irregular changes in the temperature, breeders are facing the challenge of developing high-yielding heat-tolerant cultivars to ensure adequate food availability for the growing global population. Similar to other abiotic stresses, heat stress negatively affects the vegetative and reproductive phases of plant and even may perturb the cellular homeostasis [3]. Deleterious effect of heat stress on the physiology and biochemistry of potato crop has also been reported [4]. Potato (*Solanum tuberosum* L.) is the third most consumed staple food, after rice and maize [5], and is recognized as a good source of carbohydrates. It needs a temperature optimum of 15°C-25°C for maximum productivity [6]. It has been estimated that potato production in India may decline by 3.16 and 13.72% by the year 2020 and 2050 respectively. Adoption of mitigation measures like growing the heat tolerant cultivar can arrest the proposed decline [7]. Though studies have begun to explicate the genetics and physiology of the reaction to high temperature stress in crops, but yield-based indices are required for the assessment of high temperature tolerance for applied plant breeding programs. The geometric mean (GM) and the stress tolerance index (STI) [8] have been used for evaluating genotypic performance across years or environments. STI was developed to spot genotypes that perform better under both stress and non-stress conditions. The stress susceptibility index (SSI) [9] has been found to be correlated with

yield and canopy temperature in wheat [10]. These indices have been used in the evaluation of drought resistance in common bean [11]. Thus, in our study we have aimed to find out the applicability of these indices in screening heat tolerant potato cultivars.

2. MATERIALS AND METHODS

Experimental design and growth condition

The seeds of three high yielding cultivars (HYC) of potato Kufri megha, Kufri jyoti and Kufri pokraj were collected from Central Potato Research Station (CPRS), Shillong, India. Two locally available varieties known as 'Rangpuria' and 'Badami' were collected from Gingia, district of Sonitpur, Assam, India. Field experiment was conducted in the experimental field of Tezpur University campus in a factorial randomized block design with three replications. Potato tubers were grown under three conditions, n= grown in normal growing season (October 2013- February 2014), p=grown in a polyhouse chamber (October 2013- February 2014) and e= early sowing of potato seeds (August 2013–November 2013). The polyhouse was wooden structure of size 3×2×2 m built and covered with PVC (polyvinyl chloride) film (of about 0.15 mm thickness and 85 % of transmittance) with proper aeration to avoid upsurge of CO₂. The dimensions of the plots were (2.6 × 2) m with four rows (65 and 25 cm from row to row and plant to plant). Meteorological data for 'n' and 'e' were obtained from meteorological tower of Krishi Vigyan Kendra, Napaam, Tezpur (situated near the experimental field). Three irrigations have been provided during the crop growing season. For 'p' thermohygrometers were placed inside the polyhouse for continuous monitoring of air temperature and relative humidity. Soil thermometers were placed in all the treatments to record the soil temperature. Soil water monitoring was done with the help of tensiometers and maintained above - 30 kPa (at 20 cm below the soil surface) to ensure that the plant did not suffer water stress. The duration of the HYCs and local varieties were 90 and 100 days respectively. Under treatment 'n', the HYCs showed symptoms of maturity (yellowing of leaves) at 90 days after sowing (DAS) and were harvested at 100 DAS whereas the local varieties were matured at 95 DAS and were harvested at 100 DAS. Under treatment 'p' both HYCs and local varieties were matured and harvested at 75 and 80 DAS respectively whereas under 'e' both the varieties matured at 60 DAS and were harvested at 70 DAS.

The air temperature (average, minimum and maximum) and relative humidity of the entire crop growing season for each field trial was recorded, the mean of which has been presented in table 1.

Table 1: Temperature and humidity during the field experiments

	Temperature(°C)			Relative humidity (%)		
	Average	Maximum	Minimum	Average	Maximum	Minimum
On Season	22.23	27.8	16.8	65.94	69.3	62
Polyhouse	25.03	29.43	19.43	75.43	80.1	72.45
Early season	32.73	35.24	29.2	70.86	75.4	68.2

Studied parameters

The relative growth rate (RGR)

The relative growth rate (RGR) was measured using the formulae given by [12]:

$$RGR = (\ln W_2) - (\ln W_1) / (t_2 - t_1)$$

Where, W₁=Weight of above ground plant biomass at time t₁; W₂=Weight of above ground plant biomass at time t₂; t₁ and t₂ are the initial and final DAS at which measurements were taken.

The tuber bulking rate (TBR)

The tuber bulking rate (TBR) was determined by using the formula as given by [4]:

$$TBR = (\text{Weight of tubers at } t_2 - \text{Weight of tubers at } t_1) / (t_2 - t_1)$$

Where; t_1 and t_2 are the initial and final DAS at which measurements were taken.

On dying of the vines the potato tubers were dug from $1m^2$ area, cleaned and weight was taken with the help of a balance. Crop yield expressed in qha^{-1} was further used to calculate various indices.

Studied Indices

The following heat indices were studied for each cultivar grown in both 'e' and 'p' using the equations for SSI [Fisher and Maurer, 1978]

Heat susceptibility index, $HSI = [(1) (Y_s/Y_n)] / [(1) (X_s/X_n)]$,

Heat tolerance index, $HTI = (Y_n \times Y_s) / X_s^2$,

Heat intensity index $HII = 1 - (X_s/X_n)$

Geometric mean, $GM = (Y_s \times Y_n)^{1/2}$ (Fernandez, 1993)

The high temperature yield data (polyhouse: Y_p and early season: Y_e) and normal temperature yield data (on season: Y_n) in this study were used in place of the cultivar mean values for yield under stress (Y_s) and potential yield under non-stress (Y_n) variables, respectively, in the equations for the above indices. X_s and X_n are the mean yield of all cultivars per trial under stress and non-stress conditions.

3. RESULTS AND DISCUSSION

The recorded temperature within the polyhouse was higher by 2-3 °C compared to the normal condition whereas in the early season 8-10 °C increased temperature was noted. Relative humidity was highest inside the polyhouse compared to the normal season, followed by early season sowing (Table 1).

Irrespective of cultivars, RGR was highest inside the polyhouse followed by early season and normal condition. Among the high yielding cultivars highest RGR was recorded by cultivar Kufri jyoti followed by Kufri pokraj and Kufri megha. However Badami recorded better RGR compared to Rangpuria (Fig 1a). The recorded TBR value was highest in the normal season followed by polyhouse and then early season. Here the trend of cultivars was reverse as that of RGR (Fig 1b).

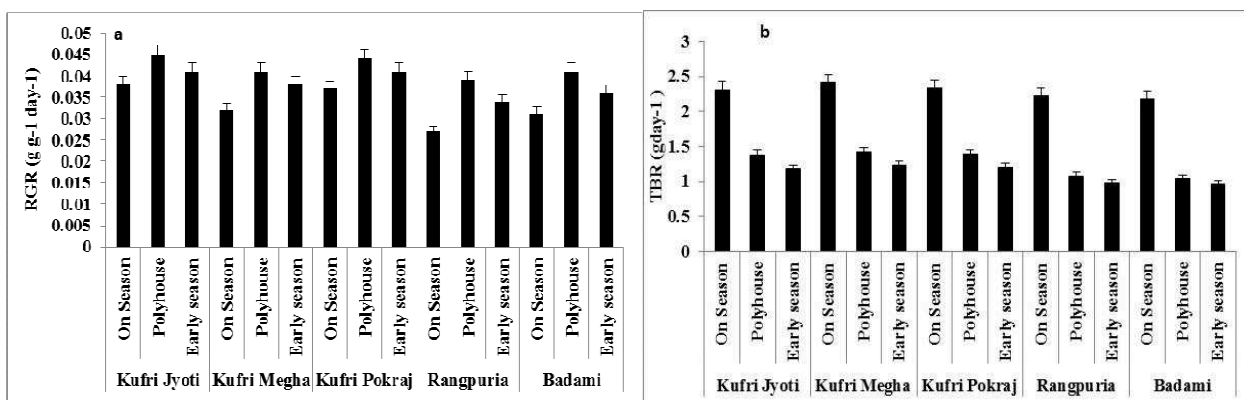


Fig1: Effect of two high temperature environments on (a) relative growth rate (RGR) and (b) tuber bulking rate (TBR)

Cultivars Kufri megha and Rangpuria exhibited relatively high HTI and GM and relatively low HSI values (Table 2). These cultivars showed fairly high temperature tolerance both in early season and polyhouse conditions. Based on GM and HSI, Kufri pokraj was also a good performer, however it showed limited yield potential under early sowing condition. Lower yield potential of the cultivars Kufri jyoti (high yielding cultivar) and Badami (local cultivar) under high temperature environment might be due to their genotypic variability which is also evident from their lower HTI and GM with high HSI value (Table 2). These cultivars exhibited higher relative growth rate and lower tuber bulking rate (Fig 1 a,b) compared to the others. This is due to the impact of high temperature on these cultivars which triggers higher growth of the haulm [13]. The recorded more RGR from both the high temperature treatment also support this statement. High temperature also disturb the assimilate translocation process leading to reduced sink strength of the tubers and finally

lower yield potential of the cultivars. Irrespective of cultivars the recorded reduced TBR in both the high temperature environment compared to normal condition also support this.

Table 2: Analysis of the geometric mean (GM), heat susceptibility index (HSI) and heat tolerance index (HTI) on tuber yield for two trials under high temperature stress conditions

Cultivars	Inside Polyhouse				Early Sown condition			
	GM	HSI	HTI	*Rank	GM	HSI	HTI	*Rank
Kufri jyoti	52.47	1.05	0.86	3	48.65	1.35	0.73	3
Kufri megha	68.87	0.81	1.48	1	66.08	1.03	1.36	1
Kufri pokraj	60.53	0.94	1.14	2	53.71	1.32	0.90	2
Rangpuria	11.09	1.03	0.03	4	10.87	1.22	0.03	4
Badami	9.55	1.09	0.02	5	9.30	1.30	0.02	5
HII	0.49				0.55			

*Genotypes are ranked on the basis of HTI

Both the high temperature conditions varied in terms of their HII (Table 2). Polyhouse trial was found to be less severe (HII=0.49) compared to the field trial (early sowing; HII=0.55) and resulted in higher reduction of crop yield from early sowing. The recorded moderate HII value for both the trials could be more efficiently used to differentiate the better one as too high or low HII value are less informative [14] and hence could not be used as a proficient index.

Table 3: Correlation analysis between yield and stress indices

	Inside Polyhouse	Early sown condition
GM×Ye	0.985**	0.991**
GM×Yp	0.999**	0.976**
HSI×Ye	-0.524	-0.465
HSI×Yp	-0.615	-0.044
HTI×Ye	0.994**	0.999**
HTI×Yp	0.999**	0.985**
GM×HSI	-0.762	-0.348
GM×HTI	0.986**	0.986**
HSI×HTI	-0.836	-0.487

** = Significant at p 0.01 $GM = (Y_s \times Y_n)/2$; $HSI = [1 - (Y_s/Y_n)] / [1 - (X_s/X_p)]$; $HTI = (Y_n \times Y_s)/X_p^2$, where Y_s and Y_n indicate yield under stress and non-stress conditions (respectively), Y_e & Y_p are the yields under early season and polyhouse respectively. Heat intensity index (HII) = $1 - (X_s/X_n)$. X_s and X_n are the mean yield of all cultivars per trial under stress and non-stress conditions respectively.

Though field trial is the most appropriate measure to study the heat tolerance of any crop but we have taken two high temperature environments (in the field and polyhouse) in the present experiment. The recorded moderately steady results between both the high temperature environments of all the studied cultivars based on HTI (Table 2) indicate the higher degree of similarity among them.

The calculated higher correlation value ($r=0.986^{**}$) of HTI and GM (Table 3) rank them as the most useful indices for determination of heat tolerance in potato. We obtained higher correlation between HTI and GM with yield in both the high temperature environment compared to HSI (Table3). It makes these indices (GM & HTI) more efficient for use in breeding of heat tolerant cultivars which has also been reported in the previous works of [15]) in mung bean under drought stress. Negative correlation was obtained between HTI and HSI both in polyhouse ($r= -0.836$) as

well as in the early season ($r=0.487$). HSI also showed negative correlation with GM as well as yield in both the conditions (Table 3). Thus, HSI proves its inapplicability for evaluation of heat tolerance among cultivars.

4. CONCLUSION

One of the approaches of improving yield performance in crops under stress is breeding of stress tolerant cultivars [16] which necessitate the screening of the cultivars for stress tolerance. In this regard the use of indices is a proficient tool for screening tolerant cultivars. In our experiment GM and HTI has been identified as important heat tolerance indices for potato. Based on these indices, under high temperature environment (polyhouse & early sowing), Kufri megha and Rangpuria is considered as the heat tolerant potato cultivars among the high yielding and local cultivars respectively.

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