PN Jagadev
Department of Plant Breeding and Genetics, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

Indices based on culm-leaf growth, spike-grain development and relative yield for identification of heat tolerant genotypes in triticale and wheat

PN Jagadev

DOI: https://doi.org/10.22271/chemi.2020.v8.i6ab.11057

Abstract

A study was conducted in a set of 18 triticale and 3 wheat cultivars to identify heat tolerant genotypes under late sowing condition. A numerical taxonomic approach based on culm and leaf growth, spike and grain development and relative yield indices was used and the dendrogram revealed 6 distinct clusters. Two clusters comprising of two triticale (Bulk MI_2 and TL 1210) and three wheat genotypes (OW 13, Sagarika and Utkalika) were identified as heat tolerant for use in breeding.

Keywords: Internode growth, grain development, relative yield, heat tolerance, wheat, triticale

Introduction

Triticale (x *Triticosecale* Wittmack) is a crop of very limited distribution. Work on various aspects of adaptation and particularly on response to temperature stress in this crop is therefore, much less than the related cereals. Since wheat (*Triticum aestivum* L. em. Thell.) is one of the parents of triticale and closely related to it, information on adaptation to high temperature in wheat is also relevant. Graphic analysis of internode growth pattern by the ideograph technique (Anderson and Schregardus, 1944) [1] is useful in studying the genetic variation of growth in cereals.. Hence, the present investigation was undertaken to employ the numerical taxonomic approach by the use of indices based on culm (internode) and leaf (leaf sheath) growth, spike and grain development and relative yield for distinguishing the clusters with different growth patterns to select the wheat and triticale genotypes for adaptation to heat stress.

Materials and Methods

A set of 17 tall triticale (x *Triticosecale* Wittmack) breeding lines, one released semi-dwarf triticale variety (TL 1210) were taken in the present investigation and three wheat varieties (Sagarika, Utkalika and OW-13) were also included for comparison with the triticale lines. A field trial was undertaken in two dates of sowing; the first (S_1) being the normal sowing (November 15) and the second (S_2) was the late sowing (December 17). The latter date was chosen to subject the plants to heat stress. The magnitude of stress was suggested by the average daily temperatures in two different phases in the two sowings. (S_1 pre-flowering phase: $22.35 \pm 2.17^{\circ}C$; S_1 post-flowering phase: $23.91 \pm 1.97^{\circ}C$; S_2 pre-flowering phase: $22.83 \pm 2.28^{\circ}C$; and S_2 post-flowering phase: $26.45 \pm 2.36^{\circ}C$).Varieties/lines were operational taxonomic units (OTUs) of the numerical taxonomic study indicated in Table 1.

The trial was laid in RBD with three replications. Each line/variety was grown in three rows/replication, each 3 m long and spaced 25 cm apart. Fertilizers were applied @ 100 kg N, 60 P_2O_5 and 40 kg K_2O per hectare. Data were recorded at maturity on different aspects of vegetative growth (length of successive internodes, $I_1 - I_6$, starting with the peduncle as I_1 and leaf sheaths, $L_1 - L_4$). Besides plot yield of grains, data on sampled plants were also recorded for number of spikelets/spike, number of grains/spike, number of grains/spikelet and 100-grain weight. Ten competitive plants were sampled per variety/replication at random at harvest. Numerical taxonomic methods were applied for identifying clusters basing on data of internode growth in S_1 and S_2 following Sneath and Sokal (1973) [6].

Corresponding Author:
PN Jagadev
Department of Plant Breeding and Genetics, Odisha University of Agriculture and Technology, Bhubaneswar, Odisha, India

The clusters were characterized in terms of response to stress for identifying stress-response types by simple numerical indexing method. A culm growth index (CGI) was calculated for each sowing by summing up individual scores (0, 1 or 2) for each internode. For assignment of scores, the mean of each variety was examined for its position in the lower middle or upper point of the range of values of all varieties. The deviation index, CGI (S_2) - CGI (S_1) was used as the culm growth index of heat tolerance. The leaf growth index (LGI) of heat tolerance was similarly calculated and the sum of these two quantities was called culm and leaf growth (CLG) index of tolerance. Genotypes with positive values were considered tolerant and those with negative and zero values were considered sensitive and moderately tolerant, respectively (Jagadev *et al*., 1988) [2].

Table 1: Details of triticale and wheat genotypes used in the study

Sl. No. in field trial	OTU No.	Name of the culture/ variety	Information about the genotypes
1	1	Bulk LI$_2$	Selection under low fertility and two irrigations.
2	2	Bulk LI$_1$	Selection under low fertility and one irrigation.
3	3	Bulk LI$_0$	Selection under low fertility and no irrigation.
4	4	Bulk MI$_2$	Selection under medium fertility and two irrigations.
5	5	Bulk HI$_2$	Selection under high fertility and two irrigations.
6	6	Bulk HI$_N$	Selection under high fertility and normal irrigation.
7	7	Adv. I	Selection under high fertility and normal irrigation.
8	8	Adv. III	Selection under high fertility and normal irrigation.
9	9	Adv. IV	Selection under high fertility and normal irrigation.
10	10	HF	Selection under high spike fertility.
11	-	HF 1	Died and discarded.
12	11	OW 13	Wheat variety (OUAT, Bhubaneswar).
13	12	Sagarika	Wheat variety (OUAT, Bhubaneswar).
14	13	GF 1	Selected for high grain filling.
15	14	GF 1-1a	Selected for grain filling, non-hairy, early, spreading.
16	15	Bulk 1a	Selected from LI$_2$ bulk, hairy, early, medium height.
17	16	Bulk 3	Selected from HI$_2$ bulk, early, medium height.
18	17	GF 1-1b	Selected for grain filling, non-hairy, early, medium height.
19	18	Bulk 1b	Selected from LI$_2$ bulk, non-hairy, early, tall.
20	19	GF 1-1c	Selected for grain filling, non-hairy, early, medium height.
21	20	TL 1210	Triticale variety (PAU, Ludhiana).
22	21	Utkalika	Wheat variety (OUAT, Bhubaneswar).
-	22	-	Average of all the above genotypes.

Since the two indices (CGI and LGI) were based on only growth characters, a comparison with an index involving aspects of reproductive development was considered important. Four characters (*viz*. Number of spikelets/spike, grains per spike and spikelet, 100-grain weight) were used for this index of heat tolerance, known as spike-grain development (SGD) index. For each trait, the degree of reduction in S_2 (as % of S_1 value) was scored 0, 1, 2 etc. at 10 % intervals (e.g., S_2/S_1 between 91-100 % = 0, between 81-90 % = 1 and so on). The scores of all the traits were added to obtain SGD index for each line/variety. The lower the index, the greater the degree of heat tolerance. Index values of 0-5 (lower 1/3rd range) was considered as tolerant, 6-10 (middle range) as moderately tolerant and above 10 as sensitive.

Since high temperature in the late sowing invariably caused reduction in yield, the relative S_2 yield (as % of S_1 yield) was taken as a simple and direct measure of response. High and low relative yield (RY) with reference to the grand mean of all the cultivars, would indicate tolerance and sensitivity. Genotypes with above-average yield considered as tolerant, equal/nearing the average yield as moderately tolerant and below-average yield as sensitive.

Results and Discussion
A numerical taxonomic approach with clustering analysis helped to identify distinct groups or clusters of lines/varieties with similar response to environment or adaptation pattern. Hence, this analysis was undertaken to identify clusters with different growth response to the stress of late sowing and to examine the scope of use of such classification for an evaluation of adaptation to such stress.

The similarity indices estimated on the basis of 22 OTUs ranged from 0.33 (between Utkalika and GF-1-1a) to 0.93 (between Bulk HI$_N$ and Bulk LI$_0$ and between GF 1-1c and GF 1). The triticales particularly Bulk LI$_1$, Bulk LI$_2$, Adv. IV, Bulk 1a, Bulk 1b and GF 1-1c were highly similar (average similarly of > 90 %) (Table 2). Cluster analysis based on Gower's coefficients using UPGMA (unweighted pair group method for arithmetic average analysis) classified all the 22 OTUs into 6 clusters, two of which included three wheat varieties (Fig. 1). Cluster 1 contained 9 triticales and the hypothetical average OTU (22), hence called as "*average cluster*". The composition of clusters of all the genotypes identified from the dendrogram at 85-phenon level, was given in Table 3. The clusters showed distinct culm growth patterns considering both the sowings (Fig. 2). Clusters 3 and 5 clearly showed a different type of growth response in S_2 as compared to other 4 clusters. In this the trend of S_1-S_2 growth difference in respect of 3 basal internodes were strikingly less than the same in other clusters. Since this kind of culm growth response accompanied by relatively greater reduction in total height, clusters 3 and 5 were identified as *sensitive* to high temperature stress. But in clusters 4 and 6, the trend of S_1-S_2 growth difference in the case of basal internodes being greater than the other clusters, correspondingly difference in total culm length were relatively less, which clearly identified as stress *tolerant*. The remaining two clusters i.e. 1 and 2 showed an intermediate type of growth response to stress, since cluster 1 represented the average and cluster 2 was closely related to that (Fig. 2).

Table 2: Similarity matrix of Gower's coefficients for 22 OTUs based on culm (internode) growth in triticale and wheat genotypes

| OTU No.	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
1	1.00																					
2	0.87	1.00																				
3	0.90	0.92	1.00																			
4	0.80	0.76	0.81	1.00																		
5	0.88	0.86	0.89	0.77	1.00																	
6	0.91	0.90	0.93	0.76	0.90	1.00																
7	0.79	0.76	0.73	0.66	0.78	0.75	1.00															
8	0.87	0.87	0.83	0.79	0.82	0.84	0.85	1.00														
9	0.86	0.91	0.87	0.77	0.87	0.86	0.78	0.88	1.00													
10	0.84	0.89	0.87	0.71	0.82	0.88	0.79	0.87	0.85	1.00												
11	0.79	0.76	0.83	0.72	0.77	0.82	0.62	0.72	0.72	0.74	1.00											
12	0.58	0.46	0.53	0.50	0.53	0.55	0.45	0.48	0.47	0.43	0.68	1.00										
13	0.91	0.88	0.89	0.75	0.88	0.91	0.78	0.86	0.89	0.85	0.79	0.57	1.00									
14	0.70	0.71	0.67	0.66	0.66	0.67	0.85	0.79	0.75	0.73	0.53	0.38	0.72	1.00								
15	0.79	0.79	0.79	0.70	0.80	0.78	0.76	0.80	0.80	0.75	0.70	0.49	0.84	0.72	1.00							
16	0.86	0.83	0.83	0.80	0.80	0.81	0.79	0.89	0.84	0.79	0.76	0.57	0.82	0.75	0.73	1.00						
17	0.82	0.81	0.77	0.76	0.78	0.79	0.84	0.89	0.85	0.79	0.64	0.46	0.82	0.88	0.79	0.85	1.00					
18	0.85	0.83	0.86	0.76	0.88	0.85	0.77	0.82	0.84	0.80	0.77	0.53	0.86	0.69	0.90	0.77	0.80	1.00				
19	0.89	0.88	0.92	0.79	0.89	0.89	0.74	0.86	0.85	0.85	0.82	0.56	0.93	0.69	0.83	0.82	0.79	0.88	1.00			
20	0.62	0.52	0.58	0.54	0.55	0.58	0.50	0.56	0.51	0.52	0.63	0.77	0.59	0.47	0.48	0.64	0.52	0.54	0.59	1.00		
21	0.53	0.42	0.49	0.45	0.48	0.50	0.36	0.44	0.42	0.38	0.62	0.78	0.52	0.33	0.44	0.52	0.42	0.48	0.52	0.81	1.00	
22	0.95	0.88	0.90	0.79	0.89	0.90	0.80	0.88	0.87	0.84	0.79	0.58	0.91	0.73	0.80	0.89	0.84	0.85	0.90	0.63	0.53	1.00
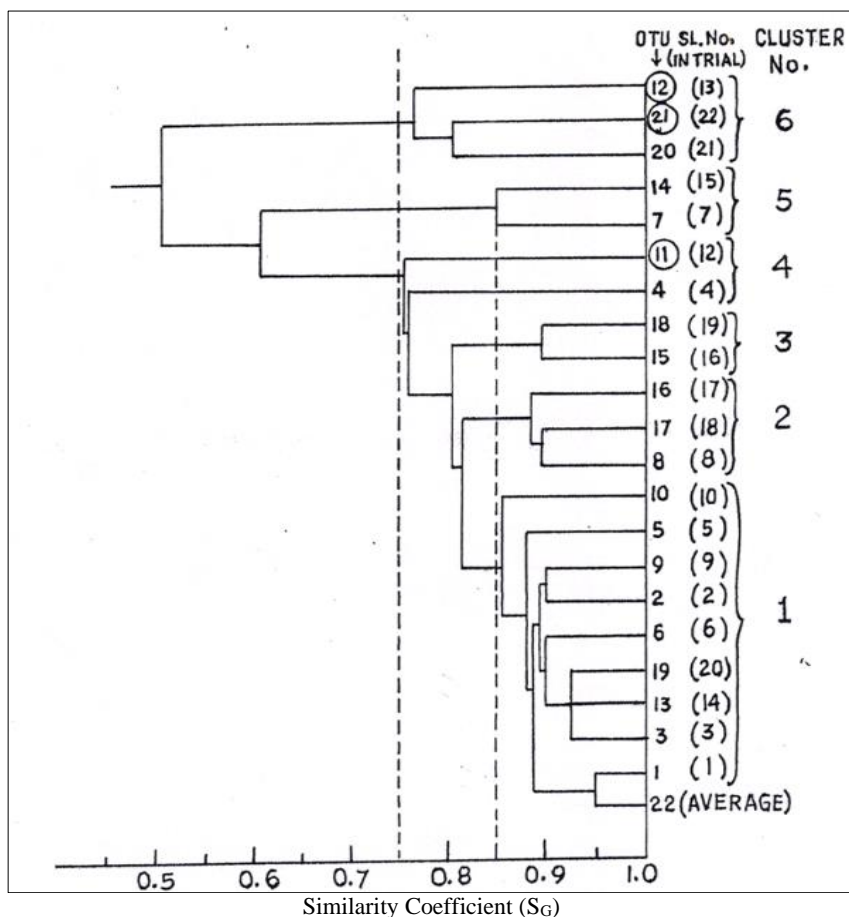
Fig 1: Dendrogram based on similarity coefficients of internode growth in S_1 and S_2.

Table 3: Composition of clusters identified from dendrogram at 85-phenon level of triticale and wheat genotypes

| Cluster No.	No. of genotypes	Composition of clusters (Sl. Nos. in field trial were given in parentheses)
1	9	Hypothetical average (OTU 22) and 9 triticale genotypes: Bulk LI$_2$ (1), Bulk LI$_1$ (2), Bulk LI$_0$ (3), Bulk HI$_2$ (5), Bulk HI$_N$ (6), Adv. IV (9), HF (10), GF 1 (14) and GF 1-1c (20).
2	3	3 triticale genotypes: Adv. III (8), Bulk 3 (17) and GF 1-1b (18)
3	2	2 tricale genotypes: Bulk 1a (16) and Bulk 1 b (19)
4	2	One triticale genotype : Bulk MI$_2$ (4) and one wheat genotype : OW 13 (12)
5	2	2 triticale genotypes : Adv. 1 (7) and GF 1-1a (15)
6	3	One triticale genotype : TL 1210 (21) and 2 wheat genotypes : Sagarika (13) and Utkalika (22)
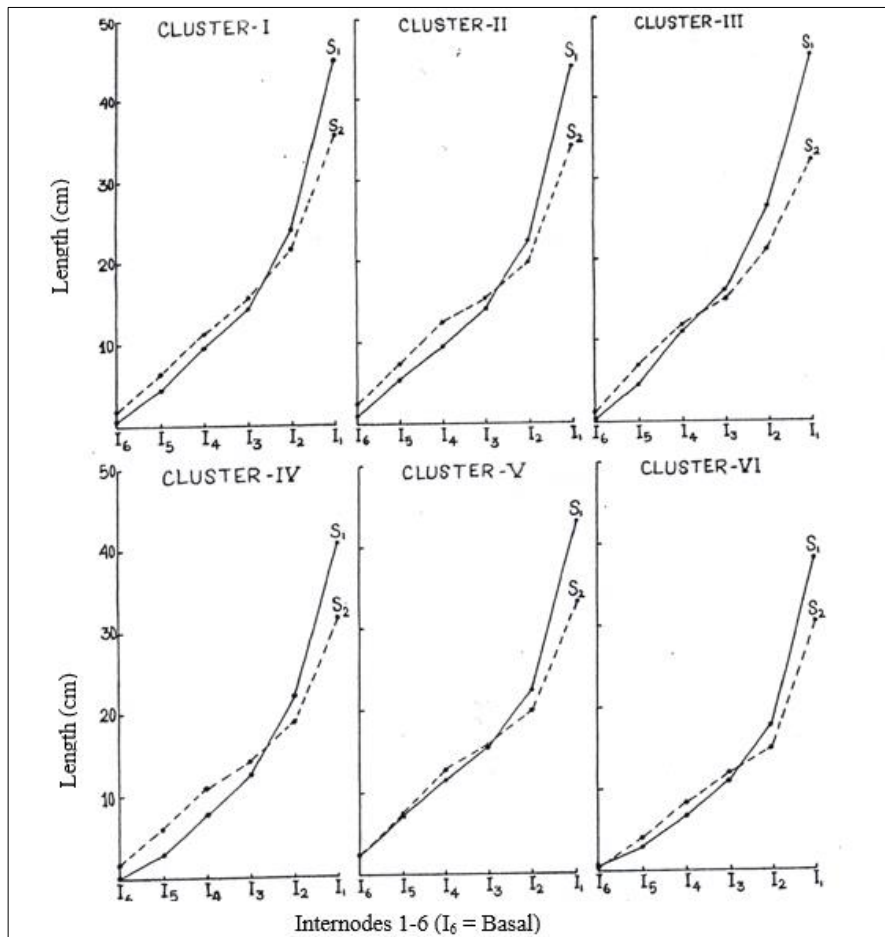
Fig 2: Ideographs of internode growth in different clusters of S_1 and S_2

For a meaningful characterization of the clusters, three different indices (*viz*., CLG, SGD and RY) of heat tolerance were devised. The index values and characterization of the clusters based on CLG (culm and leaf growth) of heat tolerance/sensitivity were presented in Table 4. The distribution of heat response types, i.e., tolerant (T), moderately tolerant/sensitive (M) and sensitive (S) was presented in a scatter diagram of the two sets of values of growth based sensitivity/tolerance index (Fig. 3). On the basis of the distribution of these broad types of stress (heat) response, the clusters could be characterized as sensitive (Clusters 3 and 5), tolerant (Clusters 4 and 6), moderately tolerant (Cluster 2) and mixed, i.e. T and S (Cluster 1).

Table 4: Culm and leaf growth (CLG) index of heat tolerance and characterization of clusters in triticale and wheat genotypes

Cluster No.	Sl. No. in field trial	Culm growth index	Leaf growth index	CLG index	Stress response of genotype*	Characterization of cluster
1	1	-1	-1	-2	S	T-S
	2	+2	-1	+1	T	
	3	+1	+1	+2	T	
	5	0	0	0	M	
	6	0	-3	-3	S	
	9	+2	0	+2	T	
	10	0	-3	-3	S	
	14	-1	-1	-2	S	
	20	-2	0	-2	S	
2	8	0	0	0	M	M
	17	+2	+4	+6	T	
	18	-1	+1	0	M	
3	16	-3	0	-3	S	S
	19	-2	-2	-4	S	
4	4	+1	+1	+2	T	T
	12	+4	0	+4	T	
5	7	-2	0	-2	S	S
	15	0	0	0	M	
6	13	+2	0	+2	T	T
	21	+1	+1	+2	T	
	22	0	0	0	M	

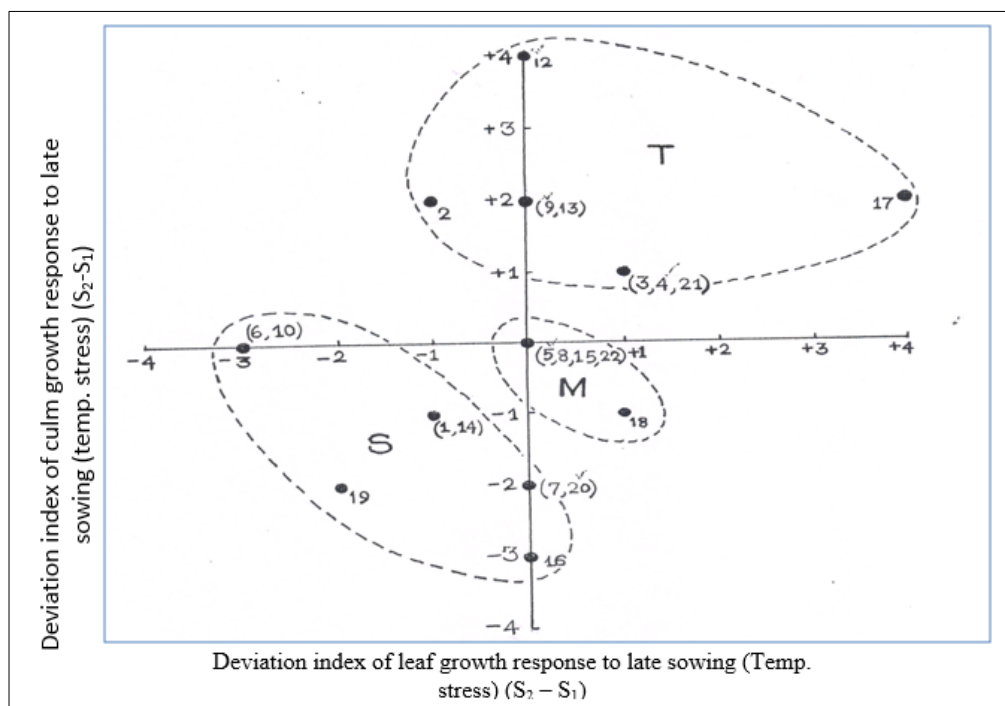*S=Sensitive, M=Moderately tolerant, T=Tolerant

Fig 3: Scatter plot of deviation indices for culm and leaf growth response to stress

The index values and characterization of clusters based on SGD (spike and grain development) of heat tolerance were presented in Table 5 and the following points were worth nothing.

1. The two clusters (Cl. 3 and 5) identified as sensitive (S) on the basis of growth (CLG) index showed sensitive or moderate type of response to stress as judged by the SGD index

2. Out of the two clusters (Cl. 4 and 6), similarly identified by the growth index as tolerant (T), one (Cl. 6) also appeared to be tolerant by the SGD criterion and the other (Cl. 4) showed moderate type of response.

3. Considering these two pairs of extreme clusters with similar growth response to stress, the SGD index also helped to identify those as the extremes, when the average SGD index of paired clusters considered.

4. The remaining closely related cluster pair (Cl. 1 and 2) would show all the types of stress-response as also noted earlier for growth. However, the average response in each case and for the pair was of the moderate (M) type.

5. The three cluster pairs were characterized as T or M or S by both measures of heat sensitivity/tolerance. The average SGD index values of those three cluster pairs were 3.7 for T, 6.3 for M and 10.3 for S response classes.

6. Thus growth based characterization of clusters was at least broadly comparable to the response categories based on later development (SGD).

Table 5: Spike and grain development (SGD) index of heat sensitivity and characterization of clusters grouped according to growth based response

Cluster No. (type of growth based response)	Sl. No. in field trial	SGD index value	Type of stress response	Average SGD index of cluster	Characterization of cluster	Average SGD index of paired clusters	Characterization of paired clusters
1 (T-S)	1	8	M	5.6	M	6.3	M
	2	3	T				
	3	1	T				
	5	5	T				
	6	7	M				
	9	3	T				
	10	6	M				
	14	5	T				
	20	12	S				
2 (M)	8	11	S	8.3	M		
	17	7	M				
	18	7	M				
3 (S)	16	15	S	12.0	S	10.3	S
	19	9	M				
5 (S)	7	9	M	8.5	M		
	15	8	M				
4 (T)	4	5	T	6.0	M	3.7	T
	12	7	M				
6 (T)	13	3	T	1.3	T		
	21	1	T				
	22	0	T				

*S = Sensitive, T = Tolerant, M = Moderately tolerant

The index values and characterization of clusters based on relative S_2 yield (RY) as a measure of heat tolerance were presented in Table 6 and the following inferences were established.

1. The sensitive cluster pair (Cl. 3 and 5) were evidently heat sensitive (S) by this RY criterion also.
2. In the case of 'tolerant' cluster pair (Cl. 4 and 6), one (Cl. 4) was evidently tolerant by the RY measure, but considering the RY index values for the paired clusters, the cluster pair was characterized as 'tolerant' (T).
3. In the remaining cluster pair (Cl. 1 and 2), the average cluster (Cl.1) was tolerant according to RY criterion, but considering the RY index values for paired clusters, the cluster pair was characterized as moderately tolerant (M).

Table 6: Relative S_2 yield (RY) index of heat sensitivity and characterization of clusters grouped according to growth based response

Cluster No.	Sl. No. in field trial	Yield (kg/ha)		Relative S_2 yield index (as % of S_1 yield)	Type of stress response	Average RY index of cluster	Characterization of cluster	Average RY index of paired cluster	Characterization of paired clusters
		S_1	S_2						
1	1	918.51	533.33	58.1	T	58.5	T	56.1	M
	2	888.88	414.81	46.7	S				
	3	770.36	562.96	73.4	T				
	5	1274.06	740.74	58.1	T				
	6	1037.03	444.44	42.9	S				
	9	1037.03	681.47	65.7	T				
	10	881.48	592.59	67.2	T				
	14	1066.66	385.18	36.1	S				
	20	814.81	637.03	78.2	T				
2	8	962.96	562.96	58.5	T	53.7	S		
	17	1081.48	533.33	49.3	S				
	18	918.51	488.88	53.2	S				
3	16	674.07	237.03	35.2	S	54.2	S	51.2	S
	19	1051.85	770.36	73.2	T				
5	7	1259.25	503.70	40.0	S	48.1	S		
	15	1318.51	740.73	56.2	M				
4	4	1185.18	740.74	62.5	T	65.0	T	57.4	T
	12	1185.18	799.99	67.5	T				
6	13	1259.25	562.96	44.7	S	49.7	S		
	21	1007.40	607.40	60.3	T				
	22	1274.07	562.96	44.2	S				
Grand Mean (of all clusters)				55.8					

*S=Sensitive, T= Tolerant, M= moderately tolerant

Hence, the numerical taxonomic analysis based on culm-leaf growth (Jagadev and Sinha, 2006, Sinha and Jagadev, 2003) [3, 5], spike-grain development and relative S_2 yield indices was found to be useful in selection of breeding lines of triticale and wheat for adaptation to high temperature stress in conformity with the findings of Mohapatra *et al.* (1995) [4] and the two clusters (Cl. 4 and 6), which included two triticale genotypes (Bulk MI_2 and T 1210) and three wheat varieties (Sagarika, Utkalika and OW 13) were identified as heat tolerant.

References
1. Anderson E, Schregardus D. A method for recording and analyzing variations of internode patterns. Ann. Mo. Bot. Gdn 1944;31:241-247.
2. Jagadev PN, Sinha SK, Mohapatra BK. Index based on internode growth as an aid to selection for high temperature tolerance in wheat and triticale. Plant Sci. Res 1988;10:69-74.
3. Jagadev PN, Sinha SK. Adaptation to temperature stress in triticale and wheat: a numerical taxonomic approach. Proc. 10th Orissa Bigyan Cong. (Nov.4-5) 2006, 94-97.
4. Mohapatra KC, Mishra CHP, Acharya B. Clustering of rice mutants by different methods of analysis. Indian J Genet 1995;55:138-147.
5. Sinha SK, Jagadev PN. A taxometric and semigraphic study of variation in internode growth pattern of triticale and wheat. Proc. 7th Orissa Bigyan Cong. (Nov. 9) 2003, 93-97.
6. Sneath PHA, Sokal RR. Numerical Taxonomy. W.H. Freeman and Co, San Francisco 1973, 228-235.sss