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

PN Jagadev

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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 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 (S1) being the normal sowing (November 15) and the second (S2) 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. (S1 pre-flowering phase: 22.35 ± 2.17°C; S1 post-flowering phase: 23.91 ± 1.97°C; S2 pre-flowering phase: 22.83 ± 2.28°C; and S2 post-flowering phase: 26.45 ± 2.36°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 P2O5 and 40 kg K2O per hectare. Data were recorded at maturity on different aspects of vegetative growth (length of successive internodes, I1 – I6, starting with the peduncle as I1 and leaf sheaths, L1 – L4). 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 S1 and S2 following Sneath and Sokal (1973) [6].
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 internode 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 (S₂) - CGI (S₁) 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].

**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 HL5 and Bulk LI0; and between GF 1-1c and GF 1). The triticales particularly Bulk LI1, Bulk LI6, 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 S₂ as compared to other 4 clusters. In this the trend of S₂/S₁ 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 S₁-S₂ 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 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 LI2                    | Selection under low fertility and two irrigations. |
| 2                      | 2       | Bulk LI1                    | Selection under low fertility and one irrigation. |
| 3                      | 3       | Bulk LI6                    | Selection under low fertility and no irrigation. |
| 4                      | 4       | Bulk MI2                    | Selection under medium fertility and two irrigations. |
| 5                      | 5       | Bulk HI2                    | Selection under high fertility and two irrigations. |
| 6                      | 6       | Bulk HI5                    | 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      | Sagartika                   | 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 LI1: bulk, hairy, early, medium height. |
| 17                     | 16      | Bulk 3                      | Selected from HI3: bulk, early, medium height. |
| 18                     | 17      | GF 1-1b                     | Selected for grain filling, non-hairy, early, medium height. |
| 19                     | 18      | Bulk 1b                     | Selected from LI1: 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 S₂ (as % of S₁ value) was scored 0, 1, 2 etc. at 10 % intervals (e.g., S₂/S₁ 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 S₂ yield (as % of S₁ 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.
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   |
|---------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|------|
|         | 1.00 |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |      |
| 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 | 0.89 | 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 | 0.74 | 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 S1 and S2.

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 L1c (1), Bulk L1 (2), Bulk L1o (3), Bulk H1e (5), Bulk H1n (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 triticale genotypes: Bulk 1a (16) and Bulk 1 b (19) |
| 4           | 2               | One triticale genotype : Bulk MI: (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) |
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                           |                             |
|             | 1                      | +2                | +4                | +6        | T                           | M                           |
|             | 2                      | -2                | -2                | -4        | S                           |                             |
|             | 3                      | -3                | 0                 | -3        | S                           |                             |
|             | 5                      | +1                | +1                | +2        | T                           |                             |
|             | 7                      | +4                | 0                 | +4        | T                           |                             |
|             | 15                     | 0                 | 0                 | 0         | S                           |                             |
|             | 13                     | +2                | 0                 | +2        | T                           | M                           |
|             | 21                     | -1                | 0                 | 0         | T                           |                             |
|             | 22                     | 0                 | 0                 | 0         | M                           |                             |

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

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                      |                            |                           | 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                                |
|                                           | 19                     | 9              | M                      |                            |                           |                                    |                                  |
| 5 (S)                                     | 7                      | 9              | M                      |                            |                           | 8.5                                | M                                |
|                                           | 15                     | 8              | M                      |                            |                           |                                    |                                  |
| 4 (T)                                     | 4                      | 5              | T                      |                            |                           | 6.0                                | M                                |
|                                           | 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 |
|-------------|------------------------|---------------|-----------------------------------------------|------------------------|-----------------------------|-------------------------------|-----------------------------------|-------------------------------------|
| 1           | 1                      | 918.51        | 533.33                                        | 58.1                   | T                           | T                             | 58.5                              | T                                   |
|             | 2                      | 888.88        | 414.81                                        | 46.7                   | T                           | S                             | 56.1                              | M                                   |
|             | 3                      | 770.36        | 562.96                                        | 73.4                   | T                           | S                             | 53.7                              | S                                   |
|             | 4                      | 1274.06       | 740.74                                        | 58.1                   | T                           | T                             | 54.2                              | S                                   |
|             | 5                      | 1037.03       | 681.47                                        | 65.7                   | T                           | M                             | 48.1                              | S                                   |
|             | 6                      | 881.48        | 592.59                                        | 67.2                   | T                           | S                             | 51.2                              | S                                   |
|             | 7                      | 1081.48       | 533.33                                        | 49.3                   | T                           | S                             | 57.4                              | T                                   |
|             | 8                      | 918.51        | 488.88                                        | 53.2                   | T                           | S                             | 49.7                              | S                                   |
|             | 9                      | 1018.48       | 533.33                                        | 49.3                   | T                           | S                             | 57.4                              | T                                   |
|             | 10                     | 1066.66       | 385.18                                        | 36.1                   | T                           | S                             | 54.2                              | S                                   |
|             | 11                     | 814.81        | 637.03                                        | 78.2                   | T                           | S                             | 53.7                              | S                                   |
|             | 12                     | 962.96        | 562.96                                        | 58.5                   | T                           | T                             | 58.1                              | M                                   |
|             | 13                     | 1259.25       | 503.70                                        | 40.0                   | T                           | T                             | 53.7                              | S                                   |
|             | 14                     | 1318.51       | 740.73                                        | 56.2                   | T                           | M                             | 54.2                              | S                                   |
|             | 15                     | 1185.18       | 740.74                                        | 62.5                   | T                           | T                             | 48.1                              | S                                   |
|             | 16                     | 977.12        | 237.03                                        | 35.2                   | S                           | T                             | 51.2                              | S                                   |
|             | 17                     | 1051.85       | 770.36                                        | 73.2                   | T                           | T                             | 57.4                              | T                                   |
|             | 18                     | 1259.25       | 562.96                                        | 44.7                   | S                           | T                             | 48.1                              | S                                   |
|             | 19                     | 1318.51       | 740.73                                        | 56.2                   | T                           | T                             | 49.7                              | S                                   |
|             | 20                     | 1007.40       | 607.40                                        | 60.3                   | T                           | T                             | 57.4                              | T                                   |
|             | 21                     | 1274.07       | 562.96                                        | 44.2                   | S                           | T                             | 49.7                              | S                                   |
|             | 22                     | 1274.07       | 562.96                                        | 44.2                   | S                           | T                             | 49.7                              | 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) 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) and the two clusters (Cl. 4 and 6), which included two triticale genotypes (Bulk MI2 and T 1210) and three wheat varieties (Sagarika, Utkalika and OW 13) were identified as heat tolerant.

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