



(\*) Corresponding author:  
ushamina@jnu.ac.in

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#### ORCID:

SK: 0009-0006-3304-0609  
MU: 0000-0002-8371-3561  
VM: 0000-0001-7711-5242

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# Field-based assessment of sowing date-induced temperature stress on growth, sensitivity, and yield of four cucurbit species

K. Smiti <sup>1</sup>, U. Mina <sup>1(\*)</sup>, M. Verma <sup>2</sup>

<sup>1</sup> School of Environmental Sciences, Jawaharlal Nehru University, New Delhi 110067, India.

<sup>2</sup> National Bureau of Plant Genetic Resources, ICAR, New Delhi, India.

**Key words:** Bottle gourd, cucumber, Composite cucurbit growth index (CCGI), *Cucumis sativa*, growing degree days, *Lagenaria siceraria*, *Luffa acutangula*, *Luffa cylindrica*, oxidative stress, ridge gourd, sensitivity index (SI), sponge gourd.

**Abstract:** Climate-induced thermal stress is a major constraint limiting cucurbit productivity in subtropical agro-ecosystems. This study quantified the impact of sowing date-induced temperature variations (-0.49°C to +1.9°C) across three regimes - optimal (SD1), late (SD2), and very late (SD3) - on phenological, physiological, biochemical, and yield traits of four Cucurbitaceae species (ridge gourd, sponge gourd, bottle gourd, cucumber) over two seasons (summer-spring and kharif) in field experiments at IARI, New Delhi, India. Climatic suitability analysis indicated that summer-spring crops performed best within a temperature deviation of 0 to 0.95°C deviation, while kharif crops showed optimal performance near 0 to -0.2°C. The composite cucurbit growth index (CCGI) and sensitivity index (SI) revealed species-specific thermal responses, with sponge gourd showing maximum sensitivity during summer-spring and ridge gourd during kharif. Mid-season sowing (SD2) favored greater growth stability, as indicated by higher CCGI (0.466 in summer-spring and 0.388 in kharif). Overall, summer-spring provided more stable productivity (CCGI 0.4325; SI -0.0163) than kharif (CCGI 0.3458; SI -0.0899). These results highlight the utility of integrated indices for assessing crop resilience and identify mid-season sowing as an effective strategy to sustain cucurbit productivity under increasing climate variability.

Table S1 - Monthly meteorological parameters (Mean  $\pm$  SD) in the respective seasons

| Month                       | Tmax<br>(°C)   | Tmin<br>(°C)   | Avg. Temp<br>(°C) | Rainfall<br>(mm) | Humidity<br>(%) | BSS<br>(hrs)  | Evaporation<br>(mm) |
|-----------------------------|----------------|----------------|-------------------|------------------|-----------------|---------------|---------------------|
| <i>Summer spring season</i> |                |                |                   |                  |                 |               |                     |
| February                    | 25.2 $\pm$ 1.6 | 10.1 $\pm$ 2.3 | 17.7 $\pm$ 1.4    | 1.3 $\pm$ 4.2    | 88.8 $\pm$ 2.9  | 7.3 $\pm$ 2.4 | 3.3 $\pm$ 0.6       |
| March                       | 32.4 $\pm$ 4.5 | 15.3 $\pm$ 3.3 | 23.8 $\pm$ 3.7    | 0.0 $\pm$ 0.0    | 88.8 $\pm$ 1.7  | 7.4 $\pm$ 1.3 | 3.3 $\pm$ 1.0       |
| April                       | 40.2 $\pm$ 1.7 | 19.9 $\pm$ 2.4 | 30.0 $\pm$ 1.8    | 0.0 $\pm$ 0.0    | 87.6 $\pm$ 1.8  | 7.4 $\pm$ 2.2 | 3.3 $\pm$ 0.8       |
| May                         | 39.7 $\pm$ 3.8 | 24.8 $\pm$ 3.1 | 32.3 $\pm$ 3.0    | 2.4 $\pm$ 7.2    | 87.0 $\pm$ 2.3  | 7.3 $\pm$ 2.5 | 3.3 $\pm$ 1.3       |
| June                        | 40.4 $\pm$ 3.9 | 26.0 $\pm$ 2.6 | 33.2 $\pm$ 2.8    | 0.8 $\pm$ 3.6    | 86.7 $\pm$ 2.6  | 7.4 $\pm$ 2.5 | 3.2 $\pm$ 0.5       |
| <i>Kharif season</i>        |                |                |                   |                  |                 |               |                     |
| July                        | 33.3 $\pm$ 1.1 | 24.8 $\pm$ 1.0 | 29.0 $\pm$ 1.0    | 10.0 $\pm$ 13.7  | 87.4 $\pm$ 6.5  | 3.8 $\pm$ 2.8 | 3.5 $\pm$ 0.5       |
| August                      | 34.0 $\pm$ 1.5 | 25.5 $\pm$ 1.0 | 29.7 $\pm$ 1.1    | 5.4 $\pm$ 10.2   | 80.7 $\pm$ 6.3  | 5.5 $\pm$ 3.6 | 3.8 $\pm$ 0.7       |
| September                   | 34.0 $\pm$ 3.1 | 23.9 $\pm$ 1.5 | 29.0 $\pm$ 2.1    | 6.4 $\pm$ 6.4    | 84.4 $\pm$ 7.6  | 6.0 $\pm$ 3.8 | 4.0 $\pm$ 4.0       |
| October                     | 31.5 $\pm$ 3.0 | 20.0 $\pm$ 3.0 | 25.7 $\pm$ 2.4    | 4.4 $\pm$ 17.6   | 88.5 $\pm$ 7.2  | 6.1 $\pm$ 3.0 | 3.5 $\pm$ 1.0       |
| November                    | 29.3 $\pm$ 2.2 | 17.2 $\pm$ 1.8 | 23.3 $\pm$ 1.7    | 0.0 $\pm$ 0.0    | 90.1 $\pm$ 1.9  | 4.1 $\pm$ 2.9 | 1.8 $\pm$ 0.4       |

Table S2 - Phenological days (time required to reach the mentioned stages) during summer-spring season

| Summer-spring season |             |               |                                |                                |                          |                 |
|----------------------|-------------|---------------|--------------------------------|--------------------------------|--------------------------|-----------------|
| Crop                 | Sowing date | Emergence     | Cotyledons completely unfolded | First flower open on main stem | First fruit on main stem | Harvested       |
| Ridge Gourd          | SD1         | 13 $\pm$ 1    | 21 $\pm$ 1                     | 60.33 $\pm$ 0.58               | 87.67 $\pm$ 1.53         | 125 $\pm$ 0     |
|                      | SD2         | 8 $\pm$ 1     | 12.67 $\pm$ 1.53               | 52.67 $\pm$ 1.53               | 79.33 $\pm$ 4.04         | 121 $\pm$ 0     |
|                      | SD3         | 6 $\pm$ 1     | 10.67 $\pm$ 0.58               | 46.33 $\pm$ 2.52               | 72.33 $\pm$ 1.53         | 117 $\pm$ 0     |
| Bottle Gourd         | SD1         | 6.7 $\pm$ 0.6 | 13.3 $\pm$ 1.2                 | 70.7 $\pm$ 2.5                 | 82.7 $\pm$ 1.5           | 110.0 $\pm$ 0.0 |
|                      | SD2         | 5.3 $\pm$ 0.6 | 10.3 $\pm$ 1.5                 | 66.7 $\pm$ 4.7                 | 79.0 $\pm$ 4.0           | 107.0 $\pm$ 0.0 |
|                      | SD3         | 5.0 $\pm$ 1.0 | 7.7 $\pm$ 0.6                  | 60.3 $\pm$ 3.2                 | 69.7 $\pm$ 1.5           | 98.0 $\pm$ 0.0  |
| Sponge Gourd         | SD1         | 5.3 $\pm$ 0.6 | 14.3 $\pm$ 2.1                 | 113.3 $\pm$ 1.2                | 136.0 $\pm$ 1.7          | 144.0 $\pm$ 0.0 |
|                      | SD2         | 4.7 $\pm$ 0.6 | 10.3 $\pm$ 2.1                 | 112 $\pm$ 2.0                  | 132.7 $\pm$ 2.9          | 140.0 $\pm$ 0.0 |
|                      | SD3         | 3.7 $\pm$ 0.6 | 7.7 $\pm$ 1.2                  | 0.0 $\pm$ 0.0                  | 0.0 $\pm$ 0.0            | 130.0 $\pm$ 0.0 |
| Cucumber             | SD1         | 5.7 $\pm$ 0.6 | 13.0 $\pm$ 1.0                 | 47.3 $\pm$ 1.5                 | 84.7 $\pm$ 4.5           | 110.0 $\pm$ 0.0 |
|                      | SD2         | 5.3 $\pm$ 0.6 | 9.3 $\pm$ 1.5                  | 45.3 $\pm$ 2.5                 | 82.0 $\pm$ 2.0           | 105.0 $\pm$ 0.0 |
|                      | SD3         | 4.0 $\pm$ 0.0 | 6.7 $\pm$ 0.6                  | 42.0 $\pm$ 5.3                 | 79.0 $\pm$ 4.6           | 102.0 $\pm$ 0.0 |

Table S3 - Phenological days (time required to reach the mentioned stages) during Kharif season

| Kharif season |             |               |                                |                                |                          |                 |
|---------------|-------------|---------------|--------------------------------|--------------------------------|--------------------------|-----------------|
| Crop          | Sowing date | Emergence     | Cotyledons completely unfolded | First flower open on main stem | First fruit on main stem | Harvested       |
| Ridge Gourd   | SD1         | 15 $\pm$ 1    | 24.67 $\pm$ 1.53               | 58.67 $\pm$ 1.53               | 87.33 $\pm$ 1.53         | 125 $\pm$ 0     |
|               | SD2         | 11 $\pm$ 1    | 14 $\pm$ 1                     | 54 $\pm$ 1                     | 82 $\pm$ 1               | 115 $\pm$ 0     |
|               | SD3         | 9 $\pm$ 1     | 10.67 $\pm$ 0.58               | 48 $\pm$ 1                     | 75.33 $\pm$ 1.53         | 107 $\pm$ 0     |
| Bottle Gourd  | SD1         | 9.0 $\pm$ 1.0 | 16.0 $\pm$ 1.0                 | 68.0 $\pm$ 1.0                 | 86.0 $\pm$ 1.0           | 116.0 $\pm$ 0.0 |
|               | SD2         | 7.0 $\pm$ 1.0 | 15.0 $\pm$ 1.0                 | 67.0 $\pm$ 2.0                 | 81.0 $\pm$ 1.0           | 113.0 $\pm$ 0.0 |
|               | SD3         | 4.0 $\pm$ 1.0 | 11.0 $\pm$ 1.0                 | 67.0 $\pm$ 1.0                 | 77.0 $\pm$ 1.0           | 108.0 $\pm$ 0.0 |
| Sponge Gourd  | SD1         | 7.0 $\pm$ 1.0 | 16.0 $\pm$ 1.0                 | 69.0 $\pm$ 1.0                 | 83.0 $\pm$ 1.0           | 116.0 $\pm$ 0.0 |
|               | SD2         | 5.0 $\pm$ 1.0 | 15.0 $\pm$ 1.0                 | 67.0 $\pm$ 1.0                 | 81.0 $\pm$ 1.0           | 113.0 $\pm$ 0.0 |
|               | SD3         | 4.0 $\pm$ 1.0 | 11.0 $\pm$ 1.0                 | 65.0 $\pm$ 1.0                 | 81.0 $\pm$ 1.0           | 108.0 $\pm$ 0.0 |
| Cucumber      | SD1         | 9.0 $\pm$ 1.0 | 16.0 $\pm$ 1.0                 | 68.0 $\pm$ 1.0                 | 92.3 $\pm$ 1.5           | 116.0 $\pm$ 0.0 |
|               | SD2         | 7.0 $\pm$ 1.0 | 15.0 $\pm$ 1.0                 | 67.0 $\pm$ 1.0                 | 78.0 $\pm$ 1.0           | 113.0 $\pm$ 0.0 |
|               | SD3         | 4.0 $\pm$ 1.0 | 11.0 $\pm$ 1.0                 | 63.0 $\pm$ 2.6                 | 76.0 $\pm$ 1.0           | 108.0 $\pm$ 0.0 |

Table S4 - Growing degree day (GDD) values of cucurbits at each developmental stage during summer-spring season

| Crop         | Sowing date | Emergence      | Cotyledons completely unfolded | First flower open on main stem | First fruit on main stem | Harvested      |
|--------------|-------------|----------------|--------------------------------|--------------------------------|--------------------------|----------------|
| Ridge Gourd  | SD1         | 26.65 ± 1.53   | 56.33 ± 5.28                   | 522.42 ± 8.80                  | 965.80 ± 30.08           | 1595.40 ± 0.00 |
|              | SD2         | 51.32 ± 4.68   | 78.90 ± 9.20                   | 584.30 ± 21.47                 | 1035.62 ± 77.97          | 1764.50 ± 0.00 |
|              | SD3         | 129.37 ± 11.67 | 189.92 ± 10.35                 | 670.05 ± 41.06                 | 1120.88 ± 16.21          | 1773.20 ± 4.35 |
| Bottle Gourd | SD1         | 47±4.2         | 101.3±7.6                      | 1064.05±54.6                   | 1326.3±35.1              | 1945.1±0.0     |
|              | SD2         | 125.3±6.6      | 176.1±17.6                     | 1219.8±101.8                   | 1506.6±99.8              | 2152.7±0.0     |
|              | SD3         | 260.8±16.1     | 305.8±9.2                      | 1343.1±76.5                    | 1572.8±37.7              | 2222.4±0.0     |
| Sponge Gourd | SD1         | 38.2±3.4       | 109±14.9                       | 1996±51.2                      | 2538.2±33.7              | 2715.1±0.0     |
|              | SD2         | 118.6±5.0      | 176.5±22.8                     | 2284.3±20.7                    | 2704.9±61.3              | 2862.3±0.0     |
|              | SD3         | 239.8±8.3      | 306.7±19.8                     | 0.0±0.0                        | 0.0±0.0                  | 2905.4±0.0     |
| Cucumber     | SD1         | 9.0±0.2        | 27.8±1.2                       | 333.1±18.6                     | 814.8±73.5               | 1340.1±0.0     |
|              | SD2         | 38.2±3.5       | 38.2±3.5                       | 458.1±37.5                     | 1068.8±37.3              | 1460.1±0.0     |
|              | SD3         | 96.1±0.0       | 125.9±7.4                      | 589.2±79.8                     | 1299.6±80.9              | 1621.9±0.0     |

Table S5 - Growing degree day (GDD) values of cucurbits at each developmental stage during kharif season

| Crop         | Sowing date | Emergence      | Cotyledons completely unfolded | First flower open on main stem | First fruit on main stem | Harvested      |
|--------------|-------------|----------------|--------------------------------|--------------------------------|--------------------------|----------------|
| Ridge Gourd  | SD1         | 26.65 ± 1.53   | 56.33 ± 5.28                   | 522.42 ± 8.80                  | 965.80 ± 30.08           | 1595.40 ± 0.00 |
|              | SD2         | 51.32 ± 4.68   | 78.90 ± 9.20                   | 584.30 ± 21.47                 | 1035.62 ± 77.97          | 1764.50 ± 0.00 |
|              | SD3         | 129.37 ± 11.67 | 189.92 ± 10.35                 | 670.05 ± 41.06                 | 1120.88 ± 16.21          | 1773.20 ± 4.35 |
| Bottle Gourd | SD1         | 47±4.2         | 101.3±7.6                      | 1064.05±54.6                   | 1326.3±35.1              | 1945.1±0.0     |
|              | SD2         | 125.3±6.6      | 176.1±17.6                     | 1219.8±101.8                   | 1506.6±99.8              | 2152.7±0.0     |
|              | SD3         | 260.8±16.1     | 305.8±9.2                      | 1343.1±76.5                    | 1572.8±37.7              | 2222.4±0.0     |
| Sponge Gourd | SD1         | 38.2±3.4       | 109±14.9                       | 1996±51.2                      | 2538.2±33.7              | 2715.1±0.0     |
|              | SD2         | 118.6±5.0      | 176.5±22.8                     | 2284.3±20.7                    | 2704.9±61.3              | 2862.3±0.0     |
|              | SD3         | 239.8±8.3      | 306.7±19.8                     | 0.0±0.0                        | 0.0±0.0                  | 2905.4±0.0     |
| Cucumber     | SD1         | 9.0±0.2        | 27.8±1.2                       | 333.1±18.6                     | 814.8±73.5               | 1340.1±0.0     |
|              | SD2         | 38.2±3.5       | 38.2±3.5                       | 458.1±37.5                     | 1068.8±37.3              | 1460.1±0.0     |
|              | SD3         | 96.1±0.0       | 125.9±7.4                      | 589.2±79.8                     | 1299.6±80.9              | 1621.9±0.0     |

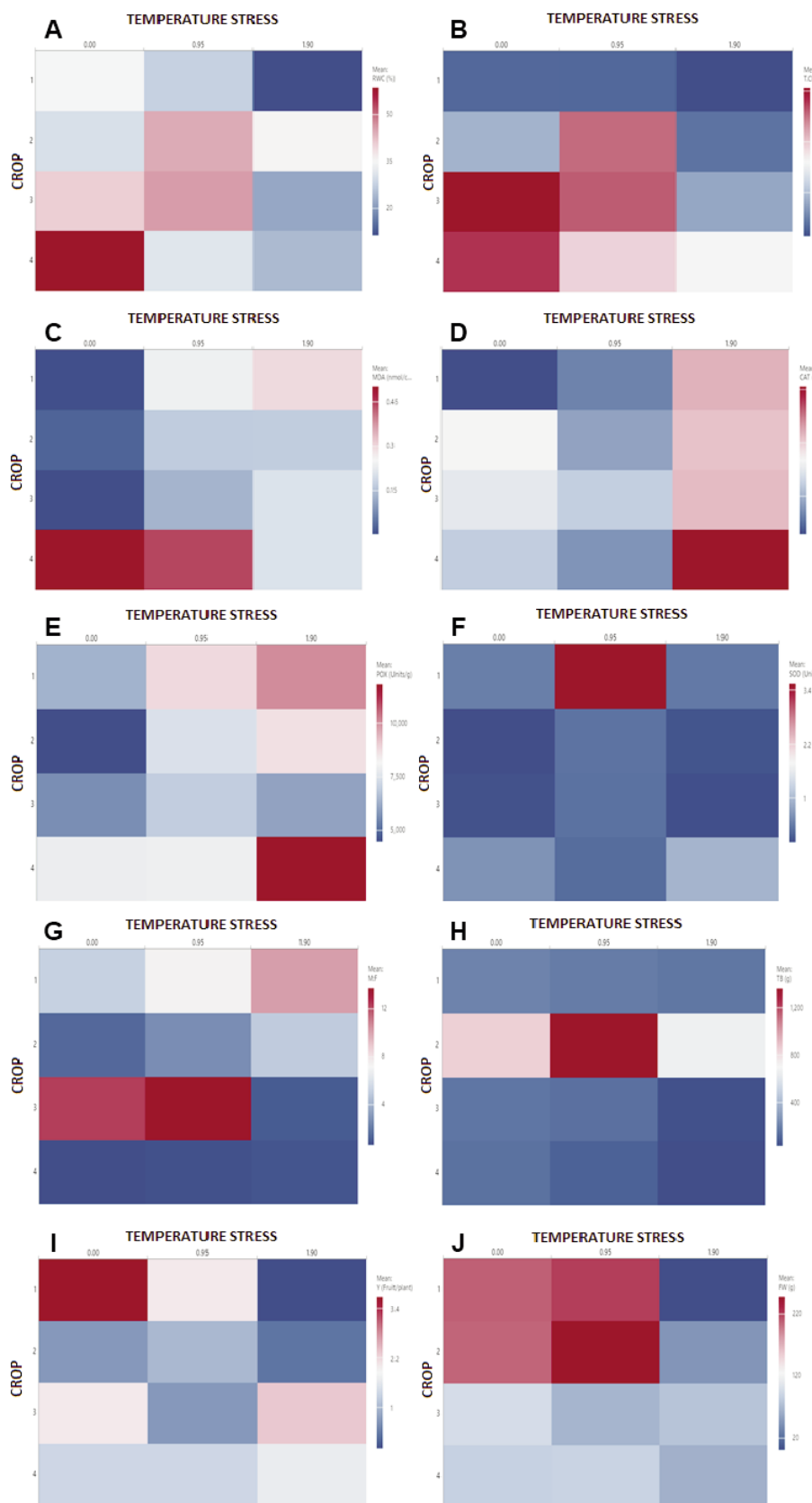


Fig. S1 - Heatmap of (a) Relative water content (RWC; %) (b) Total chlorophyll content (T.CHL; mg/g) (c) Catalase (CAT) activity (d) Lipid peroxidation (MDA; nmol/cm) (e) Peroxidase (POX) activity (mmol tetra-guaiacol/min/ g FW) (f) Superoxide Dismutase (SOD) activity (g) Male: Female flower ratio (M: F) (h) Total biomass (TB; g) (i) Yield (Y; Fruit/plant) (j) Fruit weight (FW; gm) in summer-spring

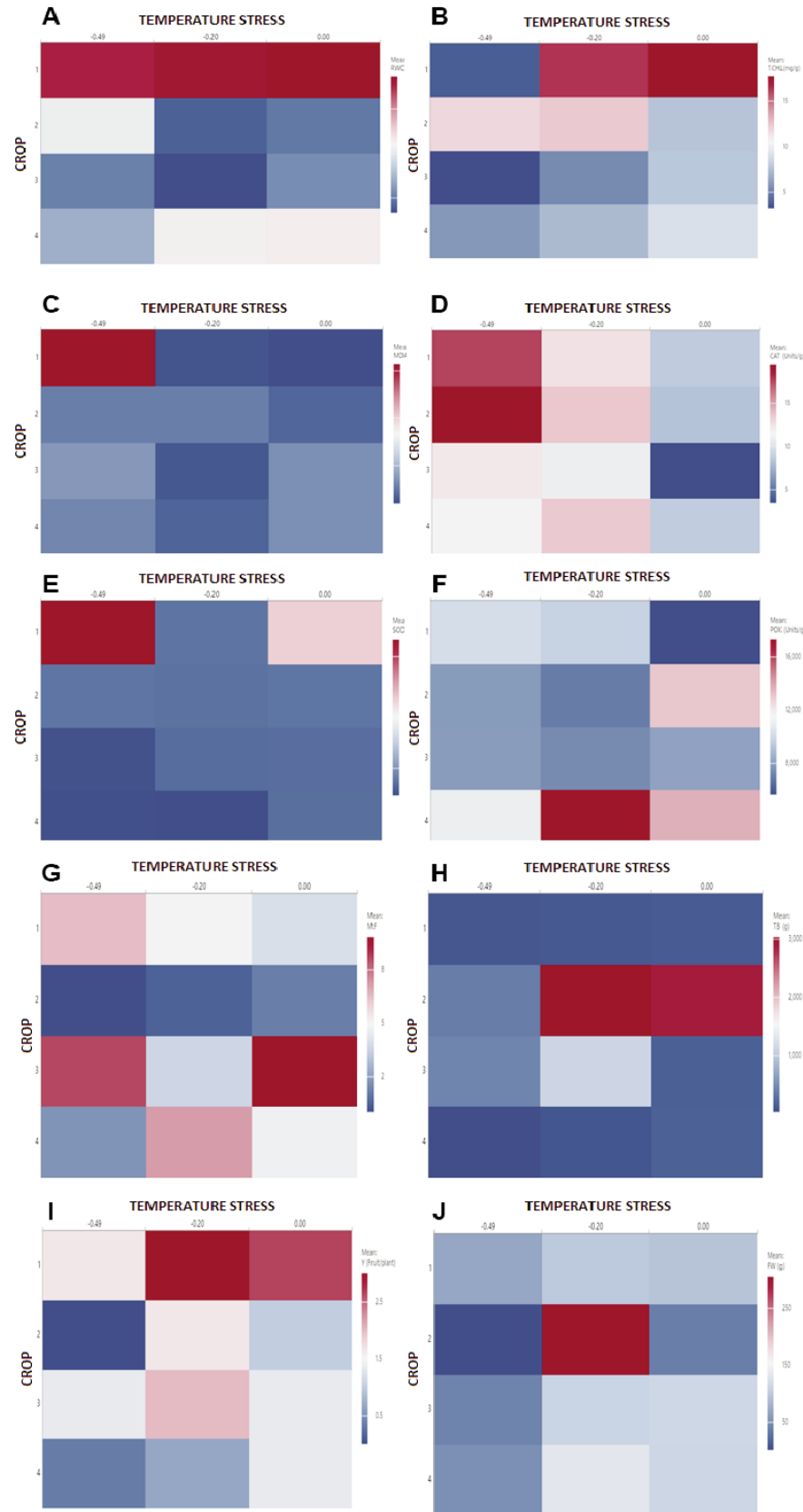


Fig. S2 - Heatmap of (a) Relative water content (RWC; %) (b) Total Chlorophyll Content (T.CHL; mg/g) (c) Catalase (CAT) activity (d) Lipid peroxidation (MDA; nmol/cm) (e) Peroxidase (POX) activity (mmol tetra-guaiacol /min/ g FW) (f) Superoxide Dismutase (SOD) activity (g) Male: Female flower ratio (M: F) (h) Total biomass (TB; g) (i) Yield (Y; Fruit/plant) (j) Fruit weight (FW; gm) in kharif

Table S6 - Physiological, reproductive and yield parameters of cucurbits across

| Season        | SD | Crop         | Relative water content (%) | MDA (nmol/cm) | Catalase (units/g) | Peroxidase (units/g) | Superoxidase dismutase (units/g) | Total Chlorophyll (mg/g) | Male to female flower ratio | Fruit/plant | Fruit weight (g) | Total biomass (g) |
|---------------|----|--------------|----------------------------|---------------|--------------------|----------------------|----------------------------------|--------------------------|-----------------------------|-------------|------------------|-------------------|
| Summer spring | 1  | Ridge Gourd  | 34.8 ± 2.5                 | 0.004 ± 0.001 | 2.31 ± 1.6         | 6309.8 ± 1744        | 0.41 ± 0.3                       | 3.04 ± 0.1               | 5 ± 0.78                    | 4 ± 0.57    | 208.3 ± 16       | 202 ± 9.9         |
| Summer spring | 2  | Ridge Gourd  | 27.4 ± 3.6                 | 0.238 ± 0.06  | 5.09 ± 1.1         | 8822.7 ± 3114        | 3.53 ± 0.1                       | 3.02 ± 0.1               | 7 ± 1                       | 2 ± 1       | 221.7 ± 89       | 177 ± 10          |
| Summer spring | 3  | Ridge Gourd  | 11.2 ± 6.2                 | 0.297 ± 0.1   | 17.47 ± 5.1        | 10081.8 ± 344        | 0.37 ± 0.3                       | 1.40 ± 0.08              | 10 ± 2.2                    | 0 ± 0       | 0 ± 0            | 159 ± 6           |
| Summer spring | 1  | Bottle Gourd | 30.03 ± 5.34               | 0.03 ± 0.01   | 13.53 ± 3.39       | 4442.36 ± 910.48     | 0.01 ± 0.00                      | 8.84 ± 0.86              | 1.37 ± 0.29                 | 0.67 ± 0.33 | 206.44 ± 146.69  | 856.59 ± 19.67    |
| Summer spring | 2  | Bottle Gourd | 44.47 ± 8.57               | 0.17 ± 0.02   | 6.93 ± 1.74        | 7426.07 ± 585.93     | 0.31 ± 0.02                      | 25.44 ± 2.09             | 2.60 ± 1.01                 | 1.00 ± 0.58 | 247.33 ± 123.78  | 1362.66 ± 302.29  |
| Summer spring | 3  | Bottle Gourd | 35.42 ± 8.47               | 0.17 ± 0.00   | 16.70 ± 4.30       | 8660.40 ± 346.57     | 0.05 ± 0.02                      | 3.95 ± 0.28              | 4.87 ± 2.13                 | 0.33 ± 0.33 | 42.73 ± 42.73    | 658.83 ± 17.21    |
| Summer spring | 1  | Sponge Gourd | 40.67 ± 3.17               | 0.00 ± 0.00   | 11.93 ± 1.85       | 5585.21 ± 237.17     | 0.03 ± 0.02                      | 30.57 ± 0.18             | 12.33 ± 3.84                | 2.00 ± 0.00 | 95.44 ± 1.28     | 156.16 ± 22.52    |
| Summer spring | 2  | Sponge Gourd | 45.97 ± 1.73               | 0.13 ± 0.03   | 9.75 ± 1.41        | 6890.98 ± 630.81     | 0.30 ± 0.01                      | 26.17 ± 2.49             | 13.67 ± 3.53                | 0.67 ± 0.33 | 64.45 ± 32.23    | 138.60 ± 23.57    |
| Summer spring | 3  | Sponge Gourd | 21.70 ± 2.06               | 0.21 ± 0.12   | 17.06 ± 4.01       | 5984.65 ± 656.76     | 0.02 ± 0.01                      | 7.80 ± 0.12              | 1.00 ± 1.00                 | 2.33 ± 0.88 | 75.67 ± 11.57    | 40.24 ± 6.59      |
| Summer spring | 1  | Cucumber     | 58.53 ± 4.29               | 0.50 ± 0.15   | 9.64 ± 1.99        | 7816.73 ± 671.19     | 0.59 ± 0.10                      | 28.00 ± 1.31             | 0.60 ± 0.60                 | 1.33 ± 0.33 | 85.00 ± 14.57    | 139.84 ± 12.58    |
| Summer spring | 2  | Cucumber     | 31.13 ± 2.30               | 0.44 ± 0.04   | 6.06 ± 2.26        | 7912.59 ± 320.50     | 0.24 ± 0.04                      | 19.14 ± 0.68             | 0.67 ± 0.67                 | 1.33 ± 0.67 | 86.65 ± 43.57    | 89.68 ± 3.47      |
| Summer spring | 3  | Cucumber     | 24.40 ± 2.69               | 0.21 ± 0.12   | 24.42 ± 6.31       | 11823.62 ± 594.58    | 0.92 ± 0.12                      | 15.84 ± 0.92             | 0.80 ± 0.80                 | 1.67 ± 0.33 | 61.33 ± 9.82     | 32.73 ± 5.52      |
| Kharif        | 1  | Ridge Gourd  | 88.18 ± 2.2                | 0.056 ± 0.005 | 8.67 ± 2.8         | 5591.8 ± 2356        | 1.73 ± 0.38                      | 17.7 ± 5.9               | 4 ± 0.6                     | 3 ± 0.5     | 93 ± 6           | 122 ± 10          |
| Kharif        | 2  | Ridge Gourd  | 86.96 ± 2.4                | 0.065 ± 0.01  | 12.56 ± 1.5        | 9634.1 ± 1755        | 0.26 ± 0.05                      | 16.4 ± 2.2               | 5 ± 0.2                     | 3 ± 1.0     | 96.8 ± 3.8       | 105 ± 6.2         |
| Kharif        | 3  | Ridge Gourd  | 83.97 ± 0.5                | 0.943 ± 0.03  | 17.69 ± 1.9        | 10148.5 ± 2693       | 2.84 ± 2.1                       | 3.7 ± 2.0                | 7 ± 1.5                     | 2 ± 0.5     | 66.7 ± 25.6      | 95 ± 2.5          |
| Kharif        | 1  | Bottle Gourd | 19.27 ± 6.44               | 0.10 ± 0.02   | 8.23 ± 1.13        | 13079.26 ± 356.18    | 0.26 ± 0.01                      | 7.62 ± 0.32              | 1.17 ± 0.67                 | 1.00 ± 0.00 | 35.43 ± 5.30     | 2897.56 ± 1227.52 |
| Kharif        | 2  | Bottle Gourd | 14.83 ± 3.07               | 0.16 ± 0.01   | 13.67 ± 1.28       | 6902.57 ± 309.35     | 0.24 ± 0.01                      | 12.37 ± 0.62             | 0.44 ± 0.42                 | 1.67 ± 0.00 | 304.29 ± 9.60    | 3023.33 ± 35.07   |
| Kharif        | 3  | Bottle Gourd | 47.17 ± 2.98               | 0.16 ± 0.00   | 19.46 ± 2.12       | 7787.91 ± 1172.70    | 0.27 ± 0.00                      | 11.85 ± 0.65             | 0.00 ± 0.00                 | 0.00 ± 0.00 | 0.00 ± 0.00      | 372.07 ± 65.77    |
| Kharif        | 1  | Sponge Gourd | 23.30 ± 8.34               | 0.20 ± 0.05   | 3.42 ± 0.86        | 7995.93 ± 218.43     | 0.20 ± 0.01                      | 7.73 ± 0.40              | 9.83 ± 2.13                 | 1.33 ± 0.33 | 111.32 ± 36.25   | 149.87 ± 68.79    |
| Kharif        | 2  | Sponge Gourd | 11.60 ± 3.07               | 0.07 ± 0.01   | 10.84 ± 1.28       | 7313.60 ± 309.35     | 0.20 ± 0.01                      | 5.29 ± 0.62              | 3.57 ± 0.42                 | 2.00 ± 0.00 | 107.67 ± 9.60    | 1112.00 ± 35.07   |
| Kharif        | 3  | Sponge Gourd | 20.80 ± 7.93               | 0.22 ± 0.04   | 12.25 ± 3.81       | 7813.28 ± 406.17     | 0.03 ± 0.01                      | 3.18 ± 0.69              | 8.67 ± 2.60                 | 1.33 ± 0.67 | 39.15 ± 19.64    | 427.68 ± 117.64   |
| Kharif        | 1  | Cucumber     | 52.80 ± 3.26               | 0.20 ± 0.05   | 8.72 ± 1.25        | 13652.57 ± 121.16    | 0.21 ± 0.00                      | 9.02 ± 0.22              | 4.64 ± 4.19                 | 1.33 ± 0.33 | 110.00 ± 15.95   | 152.88 ± 63.98    |
| Kharif        | 2  | Cucumber     | 51.83 ± 2.74               | 0.10 ± 0.03   | 13.57 ± 0.94       | 17302.01 ± 1272.17   | 0.01 ± 0.00                      | 7.22 ± 0.47              | 7.22 ± 6.41                 | 0.67 ± 0.33 | 130.65 ± 15.37   | 84.67 ± 5.96      |
| Kharif        | 3  | Cucumber     | 30.23 ± 3.20               | 0.18 ± 0.00   | 11.28 ± 3.27       | 10974.00 ± 803.68    | 0.02 ± 0.01                      | 5.77 ± 0.69              | 1.67 ± 1.67                 | 0.33 ± 0.33 | 48.17 ± 24.55    | 34.34 ± 5.41      |

Table S7 - Yield Indices of cucurbits across different sowing dates

| Season | SD | Crop | TOL = $Y_p - Y_s$ | (YSI) = $Y_s/Y_p$ | MP           |
|--------|----|------|-------------------|-------------------|--------------|
| 1      | 1  | 1    | 0                 | 0                 | 0            |
| 1      | 2  | 1    | 1.666666667       | 0.5454545455      | 2.833333333  |
| 1      | 3  | 1    | 3.666666667       | 0                 | 1            |
| 2      | 1  | 1    | 0                 | 0                 | 0            |
| 2      | 2  | 1    | -0.3333333333     | 1.125             | 2.833333333  |
| 2      | 3  | 1    | 1                 | 0.625             | 2.166666667  |
| 1      | 1  | 2    | 0                 | 0                 | 0            |
| 1      | 2  | 2    | -0.3333333333     | 1.5               | 0.7886751346 |
| 1      | 3  | 2    | 0.3333333333      | 0.5               | 0.5          |
| 2      | 1  | 2    | 0                 | 0                 | 0            |
| 2      | 2  | 2    | -0.6666666667     | 1.666666667       | 1.333333333  |
| 2      | 3  | 2    | 1                 | 0                 | 0.5          |
| 1      | 1  | 3    | 0                 | 0                 | 0            |
| 1      | 2  | 3    | 1.3333            | 0.33335           | 1.33335      |
| 1      | 3  | 3    | -0.3333333333     | 1.166666667       | 2.166666667  |
| 2      | 1  | 3    | 0                 | 0                 | 0            |
| 2      | 2  | 3    | -0.6666666667     | 1.5               | 1.666666667  |
| 2      | 3  | 3    | -3.333333333e-05  | 1.000025          | 1.33335      |
| 1      | 1  | 4    | 0                 | 0                 | 0            |
| 1      | 2  | 4    | -3.333333333e-05  | 1.000025          | 1.33335      |
| 1      | 3  | 4    | -0.3333333333     | 1.25              | 1.5          |
| 2      | 1  | 4    | 0                 | 0                 | 0            |
| 2      | 2  | 4    | 0.6666333333      | 0.500025          | 1.000016667  |
| 2      | 3  | 4    | 0.9999333333      | 0.25005           | 0.8333666667 |

Table S8 - Cumulative cucurbit growth Index mean values and sensitivity index values

| Season        | Crop    | Sowing date | Mean index value $\pm$ SD | Sensitivity index | Average SI (Late sowing) |
|---------------|---------|-------------|---------------------------|-------------------|--------------------------|
| Summer-spring | 1 (RG)  | 1           | 0.4576 $\pm$ 0.0131       | 0                 |                          |
| Summer-spring | 1 (RG)  | 2           | 0.5465 $\pm$ 0.0440       | 0.1943001083      | -0.02140895394           |
| Summer-spring | 1 (RG)  | 3           | 0.3491 $\pm$ 0.0215       | -0.2371180162     |                          |
| Summer-spring | 2 (BG)  | 1           | 0.4430 $\pm$ 0.0945       | 0                 |                          |
| Summer-spring | 2 (BG)  | 2           | 0.4714 $\pm$ 0.0930       | 0.06412520113     | -0.1064775902            |
| Summer-spring | 2 (BG)  | 3           | 0.3203 $\pm$ 0.0663       | -0.2770803815     |                          |
| Summer-spring | 3 (SG)  | 1           | 0.5149 $\pm$ 0.0134       | 0                 |                          |
| Summer-spring | 3 (SG)  | 2           | 0.4530 $\pm$ 0.0170       | -0.1200692052     | -0.1727891155            |
| Summer-spring | 3 (SG)  | 3           | 0.3988 $\pm$ 0.0437       | -0.2255090258     |                          |
| Summer-spring | 4 (CUC) | 1           | 0.3774 $\pm$ 0.0767       | 0                 |                          |
| Summer-spring | 4 (CUC) | 2           | 0.3959 $\pm$ 0.0154       | 0.04883999009     | 0.1354899498             |
| Summer-spring | 4 (CUC) | 3           | 0.4613 $\pm$ 0.0471       | 0.2221399095      |                          |
| Kharif        | 1 (RG)  | 1           | 0.4022 $\pm$ 0.0429       | 0                 |                          |
| Kharif        | 1 (RG)  | 2           | 0.3419 $\pm$ 0.0171       | -0.1497972652     | -0.3379965887            |
| Kharif        | 1 (RG)  | 3           | 0.1905 $\pm$ 0.0780       | -0.5261959122     |                          |
| Kharif        | 2 (BG)  | 1           | 0.3003 $\pm$ 0.1137       | 0                 |                          |
| Kharif        | 2 (BG)  | 2           | 0.4263 $\pm$ 0.0303       | 0.4196478811      | 0.02706475008            |
| Kharif        | 2 (BG)  | 3           | 0.1905 $\pm$ 0.0127       | -0.365518381      |                          |
| Kharif        | 3 (SG)  | 1           | 0.4147 $\pm$ 0.0644       | 0                 |                          |
| Kharif        | 3 (SG)  | 2           | 0.4125 $\pm$ 0.0082       | -0.005211396563   | -0.08576993242           |
| Kharif        | 3 (SG)  | 3           | 0.3457 $\pm$ 0.0397       | -0.1663284683     |                          |
| Kharif        | 4 (CUC) | 1           | 0.3559 $\pm$ 0.0068       | 0                 |                          |
| Kharif        | 4 (CUC) | 2           | 0.3727 $\pm$ 0.0255       | 0.04746390605     | 0.03716063261            |
| Kharif        | 4 (CUC) | 3           | 0.3654 $\pm$ 0.0194       | 0.02685735917     |                          |