*Indian J. Plant Physiol.*, Vol. 8, No. 3 (N.S.) pp. 277-286 (July-Sept., 2003)

# GROWTH, YIELD AND PHENOLOGICAL RESPONSE OF WHEAT CULTIVARS TO DELAYED SOWING

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Received on 9 Oct. 2002, Revised on 10 July, 2003

## SUMMARY

**A pot experiment conducted with 12 diverse wheat cultivars involving traditional tall and modern semi-dwarf to examine the impact of delayed sowing on growth, yield and some morpho-physiological and phenological characters revealed that delayed sowing in general caused marked reduction in growth and morpho-physiological characters such as plant height, leaf area per shoot and pot, number of shoots per pot, spike length, total dry weight per pot and dry weight per shoot of all the wheat cultivars at anthesis. Delayed sowing hastened the emergence of seedling, maximum tillering stage, emergence of flag leaf and spike, resulting in shortening the total growth duration of wheat plants. Delayed sowing caused significant reduction in biological and economic yields, through reduction in the number of spikes per pot, number of grains per spike, 1000 grain weight and grain and total dry weight per shoot without affecting some characters like grain spike ratio, spike weight ratio, harvest index and grain growth rate. Among the cultivars, traditional tall C 306 and K 68 manifested higher biological as well as economic yields than semi-tall and semi-dwarf cultivars under normal (D1) and 30 days late sown condition (D2), while failed to show superiority under 60 days delay of sowing (D3). The detrimental effect of delayed sowing on grain yield was maximum through reduction in the number of grains per spike followed by 1000 grain weight and number of spikes per pot.**

*Key words*: **Harvest index, leaf weight ratio, peduncle, post-anthesis, spike.**

## INTRODUCTION

In India, wheat is generally grown during winter-spring season (mid November to mid April) after the harvesting of *Kharif* crops, thus any delay in monsoon and subsequently delay in the harvesting of wet season crops like scented rice, groundnut, toria, pigeon pea, cotton, sugarcane etc. forces wheat to be sown late upto middle of January (Aslam *et al.* 1989). As a result the reproductive (spike initiation to anthesis) and ripening (anthesis to maturity) growth phases of late sown wheat crop is generally exposed to high temperature stress during the month of March and April, which in turn reduces the growth, yield and quality of grains mainly by shortening the reproductive and ripening growth phases (Shpiler and Blum 1986, Zhong-hu and Rajaram 1994, Abrol and Ingram 1996, Nagarajan 2002), and reducing the number of shoots per plant or per unit land area, number of grains per ear and 1000 grain weight (Bishnoi and Gill1972, Rawson and Bagga 1979, Nazir et al. 1980, Rawson 1986, Shpiler and Blum 1986, Saini *et al.* 1988, Wardlaw *et al.* 1989, Choudhary *et al.* 1992, Stone and Nicolas 1994, Zhong-hu and Rajaram 1994, Reynolds *et al.* 1994, Nagarajan 2002) without showing adverse effect on grain growth rate and harvest index (Sofield *et al.* 1974, Nagarajan 2002). Beside, the crop receive less

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photosynthetically active radiation (PAR) than its early sown counterparts, resulting in significant reduction of biomass and grain yield (Penelia *et al.* 1993). The grain filling is relatively more affected than the period from sowing to anthesis and occasionally the crop is prematurely ripened (Asana 1976, Al-Khatib and Paulsen 1984). The adverse physiological and biochemical changes and their detrimental effects on growth and productivity of wheat crop under high temperature have been reported by several workers (Berry and Bjorkman 1980, Jenner 1991a, b, Reynold *et al.* 1994). Significant reduction in leaf area, chlorophyll content and productivity of wheat cultivars have been reported by Ashraf and Bhatti (1998).

The present study was aimed to study the changes in morphological, phenological, growth and yield responses of diverse wheat cultivars to moderate (30 days) and extreme (60 days) levels of delayed sowing to identify some morpho-physiological and yield contributing characters having greater stability under high temperature stress for the development of promising wheat cultivars for late sown condition by their integration through hybridization.

## MATERIALS AND METHODS

A pot culture experiment was conducted with 12 diverse wheat cultivars with three dates of sowing, D1 ($25^{th}$ November-normal date of sowing), D2 ($25^{th}$ December- 30 days delay from D1) and D3 ($25^{th}$ January- 60 days delay from D1). Seeds of all 12 wheat cultivars namely C 306, K 68 (traditional tall), Sonalika, HD 2285, Moti (improved semi-dwarf, short duration), HD 2329, Kundan (improved semi-dwarf, medium duration) and Kalyansona, HD 2643, HD 2687, PBW 343 (improved semi-dwarf, long duration) and a *triticale* cv. DT 46 were sown in earthen pots (30 × 35 cm) each filled with 10 kg of air dried soil and fertilized with N, $P_2O_5$ and $K_20$ @ 1.0, 1.5 and 1.0 g/pot, respectively, on $25^{th}$ of November (D1), December (D2) and January (D3) 2001-02 in five replicates. Each pot had six plants from sowing until maturity. Further, nitrogen was applied @ 1.0 g/pot at crown root formation and spike initiation stages. Growth observations such as height and number of shoots per pot were recorded at 10 days interval to measure the rate of plant elongation and tiller production and their mortality, while other growth traits *i.e.*, leaf area/shoot and pot, leaf weight ratio, dry weigh per shoot and pot were recorded at anthesis. The number of leaves per main shoot and their emergence rate was measured by counting and marking of leaf number until the emergence of flag leaf on main shoot. The yield and yield attributes such as number of spikes per pot, number of grains per spike, 1000 grain weight, grain and total dry weight per shoot, harvest index, spike weight and grain spike ratio were recorded after harvesting the plants at maturity. The spike weight ratio was determined by dividing the spike weight with total shoot weight (spike weight/total shoot weight). The grain spike ratio was determined by dividing the grain weight with spike weight (grain weight/spike weight). Pre-anthesis dry matter production (%) was determined by dividing the total dry shoot weight at anthesis with total dry shoot weight at maturity and multiplied by 100.

## RESULTS AND DISCUSSION

The growth response of wheat cultivars to varying dates of sowing was distinct at various growth stages. Growth parameters of all the cultivars were reduced drastically at anthesis both by one and two month delayed sowing. The extent of reduction in growth and growth characters became more pronounced with delay in sowing (Tables 1, 2). Delayed sowing by one month (D2) and two months (D3) from normal date of sowing (D1) reduced the height of plant by 10 and 20%, number of shoots/pot by 0 and 18%, spike length by 14 and 21%, leaf area/shoot by 27 and 30%, leaf area/pot by 18 and 33%, total dry weight/pot by 9 and 36%, dry weight/shoot by 8 and 20%, respectively, while the same did not affect the total number of leaves/shoot, leaf weight ratio and specific leaf weight markedly (Table 1, 2). Delay in sowing enhanced the rate of leaf emergence, productive tiller percentage and hastened the maximum tillering stage in all the cultivars (Table 2). Wheat cultivars failed to show marked varietal differences in leaf emergence rate, whereas, there were marked variation among the cultivars in days to maximum tillering stage and productive tiller percentage (Table 2). The long and medium-short duration cultivars took 60 and 70 days respectively to reach maximum tillering stage under normal sowing date (D1), 50 and 60 days under 30 days delayed sowing (D2) and only 40 and 50 days under 60 days late sown condition (D3) (Table 2). Significant reduction in growth and growth characters of

**Table 1.** Effect of delayed sowing on growth and growth parameters of wheat cultivars at anthesis.

| Cultivar | Plant height (cm) | | | Spike length ($cm^2$) | | | Total number of leaves/M.S. | | | No. of shoots/ pot | | | Leaf weight ratio | | | Leaf area/shoot ($cm^2$) | | | Productive tiller percentage | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 |
| **Short duration** | | | | | | | | | | | | | | | | | | | | | |
| C 306 | 110 | 100 | 84 | 12.5 | 12.0 | 10.5 | 9 | 9 | 9 | 30 | 30 | 24 | 0.20 | 0.20 | 0.20 | 148 | 104 | 105 | 73 | 88 | 92 |
| DT 46 | 102 | 93 | 86 | 12.0 | 10.2 | 9.0 | 9 | 9 | 9 | 32 | 33 | 25 | 0.21 | 0.19 | 0.22 | 164 | 113 | 100 | 83 | 87 | 82 |
| Sonalika | 100 | 90 | 78 | 13.5 | 11.2 | 10.0 | 9 | 9 | 9 | 32 | 36 | 25 | 0.21 | 0.19 | 0.16 | 125 | 85 | 82 | 83 | 87 | 83 |
| HD 2285 | 90 | 82 | 72 | 12.5 | 10.5 | 9.5 | 8 | 8 | 8 | 33 | 34 | 23 | 0.23 | 0.23 | 0.22 | 153 | 90 | 106 | 85 | 83 | 92 |
| Moti | 68 | 60 | 53 | 11.0 | 10.0 | 9.0 | 8 | 8 | 8 | 35 | 33 | 30 | 0.24 | 0.21 | 0.22 | 95 | 90 | 65 | 67 | 67 | 100 |
| **Medium duration** | | | | | | | | | | | | | | | | | | | | | |
| K 68 | 116 | 105 | 85 | 12.5 | 10.0 | 10.0 | 9 | 9 | 9 | 32 | 31 | 30 | 0.22 | 0.19 | 0.26 | 138 | 106 | 103 | 71 | 86 | 93 |
| HD2329 | 80 | 73 | 68 | 12.8 | 10.8 | 9.3 | 9 | 9 | 9 | 32 | 32 | 23 | 0.23 | 0.17 | 0.20 | 140 | 88 | 85 | 73 | 76 | 90 |
| Kundan | 90 | 82 | 75 | 13.0 | 11.0 | 10.5 | 9 | 9 | 9 | 35 | 34 | 23 | 0.20 | 0.20 | 0.24 | 132 | 107 | 100 | 67 | 89 | 100 |
| **Long duration** | | | | | | | | | | | | | | | | | | | | | |
| K. Sona | 92 | 84 | 73 | 12.7 | 11.5 | 10.0 | 10 | 10 | 10 | 32 | 28 | 28 | 0.23 | 0.21 | 0.23 | 147 | 118 | 116 | 62 | 65 | 90 |
| HD 2643 | 88 | 80 | 70 | 11.7 | 9.6 | 9.5 | 10 | 10 | 10 | 34 | 35 | 26 | 0.21 | 0.21 | 0.22 | 140 | 106 | 113 | 57 | 75 | 83 |
| HD 2687 | 83 | 75 | 68 | 12.0 | 10.5 | 9.5 | 10 | 10 | 10 | 30 | 31 | 30 | 0.20 | 0.22 | 0.28 | 135 | 104 | 95 | 53 | 60 | 77 |
| PBW343 | 88 | 78 | 70 | 11.0 | 10.3 | 10.0 | 10 | 10 | 10 | 30 | 32 | 30 | 0.22 | 0.20 | 0.25 | 145 | 100 | 87 | 60 | 65 | 100 |
| Mean | 92 | 84 | 74 | 12.3 | 10.6 | 9.7 | 9 | 9 | 9 | 32 | 32 | 26 | 0.22 | 0.20 | 0.22 | 138 | 100 | 96 | 70 | 77 | 90 |
| **CD at 5%** | | | | | | | | | | | | | | | | | | | | | |
| V | 15 | | | NS | | | NS | | | 2.0 | | | NS | | | 27 | | | 6 | | |
| D | 6 | | | 1.2 | | | NS | | | 5.0 | | | NS | | | 25 | | | 8 | | |
| VD | 20 | | | 1.5 | | | NS | | | 6.0 | | | NS | | | 32 | | | 10 | | |

D1, D2, D3 are varying dates of sowing i.e., 25[th] Nov., 25[th] Dec., 25[th] Jan. respectively; M.S. (Main shoot)

**Table 2.** Effect of delayed sowing on growth characters of wheat cultivars at anthesis.

| Variety | Leaf area/pot ($dm^2$) | | | Leaf emergence rate (days $leaf^{-1}$) | | | Specific leaf wt. (mg $cm^{-2}$) | | | Total dry matter (g $pot^{-1}$) | | | Dry wt/shoot (g) | | | Days to maximum tillering (day) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | **D1** | **D2** | **D3** | **D1** | **D2** | **D3** | **D1** | **D2** | **D3** | **D1** | **D2** | **D3** | **D1** | **D2** | **D3** | **D1** | **D2** | **D3** |
| **Short duration** | | | | | | | | | | | | | | | | | | |
| C 306 | 34.0 | 27.2 | 18.1 | 6.4 | 5.3 | 4.4 | 5.3 | 6.2 | 6.0 | 78 | 75 | 45 | 2.47 | 2.44 | 1.82 | 70 | 60 | 50 |
| DT 46 | 33.9 | 30.5 | 24.0 | 6.4 | 5.3 | 4.4 | 5.2 | 5.6 | 5.1 | 71 | 80 | 65 | 2.80 | 2.60 | 2.64 | 70 | 50 | 40 |
| Sonalika | 31.0 | 25.6 | 16.8 | 5.8 | 5.2 | 4.4 | 5.5 | 5.4 | 5.2 | 73 | 71 | 48 | 2.15 | 1.80 | 1.90 | 60 | 50 | 40 |
| HD 2285 | 37.1 | 31.4 | 24.0 | 7.0 | 6.0 | 5.0 | 4.6 | 5.2 | 4.7 | 75 | 65 | 45 | 2.13 | 1.87 | 1.94 | 70 | 60 | 50 |
| Moti | 32.4 | 20.0 | 18.0 | 7.2 | 5.9 | 5.0 | 5.1 | 5.4 | 4.7 | 63 | 45 | 35 | 1.58 | 1.27 | 1.10 | 70 | 60 | 40 |
| **Medium duration** | | | | | | | | | | | | | | | | | | |
| K 68 | 33.4 | 26.8 | 28.0 | 6.4 | 5.6 | 4.7 | 5.4 | 5.6 | 5.2 | 73 | 65 | 50 | 2.20 | 2.00 | 1.63 | 70 | 60 | 50 |
| HD2329 | 31.5 | 24.0 | 18.7 | 6.4 | 5.6 | 4.4 | 5.3 | 5.8 | 4.9 | 70 | 70 | 45 | 2.06 | 2.25 | 1.67 | 70 | 60 | 40 |
| Kundan | 31.0 | 32.5 | 22.8 | 6.4 | 5.6 | 4.7 | 6.2 | 5.6 | 5.7 | 81 | 83 | 48 | 2.25 | 2.40 | 2.03 | 70 | 60 | 40 |
| **Long duration** | | | | | | | | | | | | | | | | | | |
| K. Sona | 40.2 | 31.3 | 29.6 | 6.6 | 5.8 | 5.0 | 4.8 | 5.0 | 4.9 | 75 | 68 | 56 | 2.08 | 2.43 | 2.00 | 70 | 60 | 50 |
| HD 2643 | 37.1 | 27.2 | 25.5 | 6.4 | 5.8 | 5.0 | 5.0 | 5.6 | 4.4 | 78 | 64 | 45 | 2.17 | 1.80 | 1.76 | 60 | 50 | 40 |
| HD 2687 | 32.8 | 28.6 | 31.3 | 6.6 | 5.8 | 5.0 | 5.2 | 5.3 | 5.3 | 75 | 61 | 50 | 2.70 | 1.93 | 1.70 | 60 | 50 | 40 |
| PBW 343 | 37.6 | 33.7 | 28.2 | 6.6 | 5.8 | 5.0 | 4.5 | 5.7 | 5.4 | 70 | 65 | 55 | 2.30 | 2.04 | 1.82 | 60 | 50 | 40 |
| **Mean** | 34.3 | 28.2 | 23.8 | 6.5 | 5.6 | 4.8 | 5.2 | 5.5 | 5.1 | 74 | 68 | 49 | 2.24 | 2.0 | 1.83 | 67 | 56 | 43 |
| CD at 5% | | | | | | | | | | | | | | | | | | |
| V | 2.6 | | | NS | | | 0.8 | | | 8.5 | | | 0.50 | | | 5 | | |
| D | 3.5 | | | 1.0 | | | NS | | | 6.5 | | | 0.35 | | | 8 | | |
| VD | 5.2 | | | 1.0 | | | 1.2 | | | 12.0 | | | 075 | | | 10 | | |

wheat by delayed sowing mainly resulted from marked reduction in their growth duration caused by relatively higher temperature prevailing during the critical growth phases of late sown crop plants (Table 4). Longer growth duration of wheat plants under normal sowing provided an opportunity to accumulate more biomass as compared to late sown plants and henceforth manifested higher grain and biological yield/pot (Table 4). Poor dry weight/shoot and biological yield/pot under late sown condition was probably due to reduced leaf area per shoot and per pot in all the wheat cultivars. Ashraf and Bhatti (1998) reported marked reduction in photosynthetic area of wheat plants under late sown condition.

All the cultivars, irrespective of their growth duration and stature, showed marked phenological response to varying dates of sowing. Regardless of varietal variation, the duration of development phases (sowing to seedling emergence, seedling emergence to flag leaf emergence, sowing to anthesis, anthesis to maturity and finally sowing to maturity) were markedly reduced by delayed sowing of wheat (Table 3). Normal date of sowing (D1) registered seedling emergence within 10 days, and 30 days delayed sowing (D2) exhibited the same in 12 days, while delay of sowing by 60 days (D3) manifested seedling emergence within 8 days. This may perhaps be due to prevailing slightly lower ambient temperature during 1st and 2nd dates of sowing (D1-25th November and D2-25th December) and higher ambient temperature during 3rd date of sowing (D3-25th January). Delay of sowing by one month (D2) reduced the mean duration from seedling emergence to

**Table 3.** Effect of delayed sowing on phenological characters of wheat cultivars.

| Variety | Sowing to seedling emergence (days) | | | Seedling emergence to flag leaf emergence (D) | | | Sowing to anthesis (days) | | | Anthesis to maturity (days) | | | Sowing to maturity (days) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 |
| **Short duration** | | | | | | | | | | | | | | | |
| C 306 | 10 | 12 | 8 | 58 | 48 | 40 | 85 | 75 | 60 | 45 | 35 | 30 | 130 | 110 | 90 |
| DT 46 | 10 | 12 | 8 | 58 | 48 | 40 | 85 | 75 | 60 | 45 | 35 | 30 | 130 | 110 | 90 |
| Sonalika | 10 | 12 | 8 | 52 | 47 | 40 | 80 | 75 | 60 | 50 | 35 | 30 | 130 | 110 | 90 |
| HD 2285 | 10 | 12 | 8 | 55 | 48 | 40 | 80 | 75 | 60 | 50 | 35 | 30 | 130 | 110 | 90 |
| Moti | 10 | 12 | 8 | 58 | 47 | 40 | 85 | 75 | 60 | 45 | 35 | 30 | 130 | 110 | 90 |
| **Medium duration** | | | | | | | | | | | | | | | |
| K 68 | 10 | 12 | 8 | 58 | 50 | 42 | 90 | 80 | 65 | 45 | 35 | 25 | 135 | 115 | 90 |
| HD2329 | 10 | 12 | 8 | 58 | 50 | 40 | 90 | 80 | 65 | 45 | 35 | 25 | 135 | 115 | 90 |
| Kundan | 10 | 12 | 8 | 58 | 50 | 42 | 90 | 75 | 60 | 45 | 40 | 30 | 135 | 115 | 90 |
| **Long duration** | | | | | | | | | | | | | | | |
| K. Sona | 10 | 12 | 8 | 66 | 58 | 45 | 100 | 85 | 70 | 40 | 35 | 25 | 140 | 120 | 95 |
| HD 2643 | 10 | 12 | 8 | 64 | 58 | 45 | 100 | 85 | 70 | 40 | 35 | 25 | 140 | 120 | 95 |
| HD 2687 | 10 | 12 | 8 | 66 | 58 | 45 | 100 | 85 | 70 | 40 | 35 | 25 | 140 | 120 | 95 |
| PBW 343 | 10 | 12 | 8 | 66 | 58 | 45 | 100 | 85 | 70 | 40 | 35 | 25 | 140 | 120 | 95 |
| **Mean** | 10 | 12 | 8 | 60 | 52 | 42 | 90 | 79 | 64 | 44 | 35 | 27 | 135 | 115 | 92 |
| CD at 5% | | | | | | | | | | | | | | | |
| V | NS | | | 5 | | | 6 | | | 4 | | | 8 | | |
| D | 2 | | | 8 | | | 10 | | | 6 | | | 12 | | |
| VD | 2 | | | 12 | | | 12 | | | 8 | | | 14 | | |

flag leaf emergence by 8 days (13%), sowing to anthesis by 11 days (12%), anthesis to maturity by 9 days (20%) and finally from sowing to maturity by 20 days (15%), while delay of sowing up to 60 days (D3) reduced the duration of same developmental phases by 18 (30%), 26(29%), 17(39%) and 43 days (32%), respectively. In other words, 30 and 60 days late sowing delayed the crop maturity only by 10 and 17 days, respectively when compared with normal date of sowing. The extent of reduction in developmental phases by 60 days delayed sowing (D3) was almost double to that of 30 days delayed sowing (D2). Both one and two month delayed sowing caused greater reduction in the duration from anthesis to maturity (20-39%) than those from sowing to anthesis (12-29%) and sowing to maturity (15-32%). Large extent of reduction in the durations of developmental phases of wheat crop under high temperature regime caused by late sowing has been reported by several workers (Asana 1976, Midmore *et al.* 1984, Rawson, 1986, Saini and Dadhwal 1986, Shpiler and Blum 1986, Wardlaw *et al.* 1989, Zhong-hu and Rajaram 1994, Nagarajan 2002). In general the diverse wheat cultivars showed greater extent of variation in reduction of their development phases under 30 days delay of sowing than under 60 days delay of sowing, which may perhaps be due to forced maturity and pre-mature senescence of wheat plants under extreme delayed sown condition, where plants are exposed to hyper thermal stress (Al-Khatib and Paulsen 1984, Nagarajan 2002). Among diverse wheat cultivars, HD 2329, which has been recommended for normal irrigated condition and Kundan recommended for rained condition, both required 90 days to anthesis under normal date of sowing (D1), however, Kundan flowered (anthesis) 5 days earlier to HD 2329 both under 30 and 60 days delayed sowing (D2 and D3) without showing any difference in sowing to maturity duration under same dates of sowing (Table 4). This indicated the possibility of escaping nature of Kundan under high temperature regime of late sown condition, which could be a desirable phenological character of wheat for late sown condition.

Regardless of stature and growth duration of cultivars, the biological yield was reduced by 28 and 50% with delay of 30 and 60 days from normal date of sowing respectively, which accounted for 29 and 52 percent reduction in economic yield and 29 and 45 percent reduction in straw yield under 30 and 60 days delayed sowing, respectively (Table 4). The extent of reduction in economic and straw yield were almost at par by delayed sowing. Reduction in grain yield to the extent 29 and 52 percent by 30 and 60 days delayed sowing respectively could be attributed to the reduction in shoots/pot by 9 and 21 percent, grains/spike by 12 and 29 percent and 1000 grain weight by 13 and 24 percent, respectively (Table 5). The grain and total dry weight/shoot reduced drastically, while pre-anthesis dry matter production improved significantly by delayed sowing (Table 5). The extent of reduction in growth and productivity of wheat by two month delayed sowing was almost double to that of one month delay in sowing (Table 4). All the characters measured in terms of proportion/ratio such as leaf weight ratio, spike weight ratio, grain spike ratio, harvest index and also the grain growth rate showed non-significant reduction (greater stability) under delayed sowing in almost all the cultivars (Table 5). Irrespective of varying dates of sowing, the traditional tall cultivars of wheat viz, C 306 and K 68 invariably manifested higher economic as well as biological yield as compared to semi-dwarf wheat cultivars under normal (D1) and 30 days delayed sowing (D2), but failed to maintain same status under 60 days late sowing (D3). Wheat cultivars showed marked variation in various growth and yield characters both under normal and late sown conditions, but the extent of varietal variation declined with the degree of late sowing. Zhong-hu and Rajaram (1994) and Nagarajan (2002) have also reported varietal variation in wheat characters under delayed sowing. Among the various cultivars, HD 2329 showed greater stability in the number of shoots/pot, HD 2643 exhibited greater stability in grains/spike, while Kundan manifested greater stability in 1000 grain weight under the late sowing (Table 4). Thus the cultivars with their greater stability in different yield components may perhaps be helpful in breeding wheat cultivars for late sown condition through their integration. The late sown wheat crop generally get exposed to high temperature regimes (35-40°C) during grain filling period and suffer from grain yield reduction of 270 kg/ha/degree rise in temperature (Rane *et al.* 2000). The detrimental effect of both 30 and 60 days late sowing was maximum in the number of grains/spike (14 and 29%) followed by 1000 grain weight (13 and 24%) and least in the number of shoots/pot (9 and 21%). However, late sowing did not affect the grain growth rate, which was about 0.5g/pot/



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**Table 4.** Effect of delayed sowing on growth, grain yield and yield attributes of wheat cultivars at maturity.

| Variety | No. of spikes/ pot | | | No. of grains/ spike | | | 1000 grain weight (g) | | | Grain yield (g $pot^{-1}$) | | | Biological yield (g $pot^{-1}$) | | | Harvest index (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 |
| **Short duration** | | | | | | | | | | | | | | | | | | |
| C 306 | 32 | 28 | 27 | 40 | 36 | 27 | 50 | 44 | 40 | 68 | 45 | 30 | 144 | 94 | 76 | 47 | 48 | 40 |
| DT 46 | 30 | 28 | 27 | 48 | 41 | 33 | 39 | 36 | 32 | 53 | 41 | 30 | 134 | 94 | 78 | 40 | 44 | 39 |
| Sonalika | 32 | 28 | 26 | 38 | 25 | 24 | 51 | 44 | 36 | 61 | 42 | 25 | 123 | 94 | 57 | 49 | 45 | 44 |
| HD 2285 | 36 | 30 | 28 | 43 | 36 | 31 | 47 | 39 | 36 | 63 | 43 | 33 | 126 | 88 | 67 | 50 | 49 | 49 |
| Moti | 34 | 31 | 30 | 36 | 32 | 23 | 44 | 35 | 30 | 55 | 38 | 24 | 103 | 75 | 55 | 54 | 50 | 43 |
| **Medium duration** | | | | | | | | | | | | | | | | | | |
| K 68 | 40 | 39 | 31 | 41 | 37 | 27 | 44 | 41 | 33 | 71 | 59 | 29 | 155 | 131 | 73 | 46 | 45 | 40 |
| HD2329 | 33 | 31 | 30 | 37 | 33 | 29 | 47 | 40 | 36 | 60 | 41 | 34 | 120 | 84 | 70 | 50 | 49 | 49 |
| Kundan | 31 | 27 | 23 | 31 | 30 | 24 | 57 | 52 | 49 | 54 | 44 | 29 | 120 | 90 | 65 | 45 | 49 | 44 |
| **Long duration** | | | | | | | | | | | | | | | | | | |
| K. Sona | 32 | 26 | 23 | 47 | 44 | 38 | 39 | 33 | 31 | 55 | 41 | 30 | 118 | 90 | 63 | 46 | 46 | 48 |
| HD 2643 | 33 | 32 | 24 | 34 | 33 | 31 | 50 | 41 | 36 | 58 | 46 | 29 | 128 | 94 | 63 | 45 | 49 | 46 |
| HD 2687 | 28 | 27 | 25 | 58 | 46 | 28 | 36 | 30 | 23 | 58 | 40 | 25 | 125 | 90 | 65 | 46 | 44 | 38 |
| PBW 343 | 35 | 28 | 24 | 36 | 30 | 29 | 44 | 40 | 35 | 56 | 35 | 28 | 125 | 75 | 60 | 45 | 47 | 46 |
| **Mean** | 33 | 30 | 26 | 41 | 35 | 29 | 46 | 40 | 35 | 60 | 43 | 29 | 128 | 92 | 66 | 47 | 47 | 44 |
| CD at 5% | | | | | | | | | | | | | | | | | | |
| V | 4 | | 8 | | | | 8 | | | 6 | | | 16 | | | 4 | | |
| D | 5 | | 6 | | | | 6 | | | 10 | | | 20 | | | NS | | |
| VD | 8 | | 10 | | | | 12 | | | 14 | | | 24 | | | 5 | | |

**Table 5.** Effect of delayed sowing on yield components of wheat cultivars at maturity.

| Variety | Grain growth rate (mg spike$^{-1}$ day$^{-1}$) | | | Dry weight/shoot (g) | | | Grain wt./shoot (g) | | | Spike wt. ratio | | | Grain spike ratio | | | Pr. ADMP (%) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 | D1 | D2 | D3 |
| **Short duration** | | | | | | | | | | | | | | | | | | |
| C 306 | 47 | 46 | 36 | 4.5 | 3.4 | 2.8 | 2.1 | 1.6 | 1.1 | 0.63 | 0.67 | 0.62 | 0.75 | 0.72 | 0.65 | 55 | 72 | 65 |
| DT 46 | 42 | 43 | 37 | 4.9 | 3.5 | 2.8 | 1.9 | 1.5 | 1.1 | 0.51 | 0.58 | 0.60 | 0.76 | 0.75 | 0.65 | 57 | 74 | 94 |
| Sonalika | 38 | 31 | 33 | 3.8 | 2.5 | 2.2 | 1.9 | 1.1 | 1.0 | 0.64 | 0.61 | 0.62 | 0.77 | 0.73 | 0.71 | 56 | 72 | 86 |
| HD 2285 | 40 | 40 | 37 | 4.0 | 3.0 | 2.4 | 2.0 | 1.4 | 1.1 | 0.67 | 0.68 | 0.63 | 0.75 | 0.71 | 0.76 | 53 | 62 | 80 |
| Moti | 35 | 34 | 27 | 3.0 | 2.4 | 1.7 | 1.6 | 1.2 | 0.8 | 0.69 | 0.66 | 0.68 | 0.77 | 0.76 | 0.73 | 53 | 53 | 65 |
| **Medium duration** | | | | | | | | | | | | | | | | | | |
| K 68 | 40 | 43 | 36 | 3.9 | 3.4 | 2.3 | 1.8 | 1.5 | 0.9 | 0.61 | 0.61 | 0.59 | 0.75 | 0.73 | 0.67 | 56 | 69 | 71 |
| HD2329 | 40 | 37 | 44 | 3.6 | 2.7 | 2.2 | 1.8 | 1.3 | 1.1 | 0.64 | 0.61 | 0.66 | 0.78 | 0.80 | 0.74 | 57 | 63 | 76 |
| Kundan | 40 | 40 | 40 | 3.9 | 3.4 | 2.8 | 1.8 | 1.6 | 1.2 | 0.63 | 0.65 | 0.66 | 0.72 | 0.74 | 0.68 | 58 | 70 | 72 |
| **Long duration** | | | | | | | | | | | | | | | | | | |
| K. Sona | 42 | 46 | 52 | 3.7 | 3.5 | 2.7 | 1.7 | 1.6 | 1.3 | 0.61 | 0.60 | 0.64 | 0.76 | 0.77 | 0.75 | 56 | 69 | 74 |
| HD 2643 | 42 | 40 | 48 | 3.9 | 2.9 | 2.6 | 1.7 | 1.4 | 1.2 | 0.60 | 0.64 | 0.63 | 0.77 | 0.77 | 0.73 | 56 | 62 | 68 |
| HD 2687 | 52 | 42 | 40 | 4.5 | 3.3 | 2.6 | 2.1 | 1.5 | 1.0 | 0.62 | 0.60 | 0.61 | 0.74 | 0.73 | 0.62 | 60 | 58 | 65 |
| PBW 343 | 40 | 34 | 44 | 3.6 | 2.6 | 2.4 | 1.6 | 1.2 | 1.1 | 0.60 | 0.63 | 0.62 | 0.75 | 0.74 | 0.73 | 64 | 78 | 76 |
| **Mean** | 42 | 40 | 40 | 3.9 | 3.0 | 2.5 | 1.8 | 1.4 | 1.1 | 0.62 | 0.63 | 0.63 | 0.76 | 0.75 | 0.70 | 57 | 67 | 74 |
| CD at 5% | | | | | | | | | | | | | | | | | | |
| V | 5 | | | 0.8 | | | 0.32 | | | NS | | | NS | | | 6 | | |
| D | NS | | | 1.0 | | | 0.32 | | | NS | | | NS | | | 8 | | |
| VD | 7 | | | 1.5 | | | 0.85 | | | NS | | | NS | | | 12 | | |

Pr. ADMP: Pre-anthesis dry matter production.

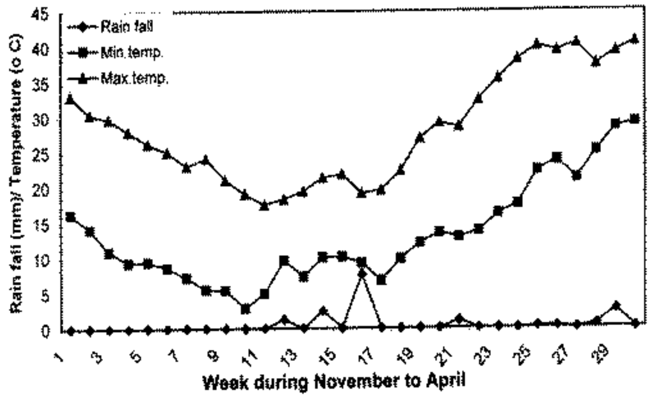


**Fig. 1. Weekly weather data during the crop growing months**

day with both 30 and 60 days of delayed sowing (Table 5) and harvest index of wheat cultivars. Maximum extent of reduction in grains/spike by delayed sowing may perhaps be due to greater reduction in the reproductive growth phase (spike initiation to anthesis) of wheat plants. Sphiler and Blum (1986) also reported greater sensitivity of reproductive growth phase to high temperature stress in wheat. Marked reduction in 1000 grain weight under late sowing was possibly due to reduction in grain filling duration, as the grain growth rate was least affected by delayed sowing (Table 5). However, lowest extent of reduction in the number of spikes/pot could perhaps be due to determination of spike bearing shoots at effective tillering stage during vegetative growth phase, which was perhaps not exposed to hyper thermal stress under late sowing. Thus significant reduction in grain yield of wheat cultivars by delayed sowing could mainly have resulted from marked reduction in sowing to anthesis and anthesis to maturity durations due to exposure of late sown plants to slightly higher temperature, which in turn reduced the build up of growth and yield components such as tillering, photosynthetic surface per shoot and pot, biological yield/pot, number of spikes/pot, number of grains/spike and 1000 grain weight markedly (Table 1-5) without marked reduction in harvest index and grain growth rate (Table 4, 5). These findings are in general agreement with the previous reports (Bishnoi and Gill 1972, Asana 1976, Fisher and Maurer 1976, Warrington *et al.* 1977, Bajwa *et al.* 1987, Wardlaw *et al.* 1989, Shpiler and Blum 1986, 1991, Chaudhary *et al.* 1992, Penelia *et al.* 1993, Reynold *et al.* 1994, Nagarajan 2002).

Thus, it may be concluded that apart from traditional tall wheat cultivars viz., C 306 and K 68, the modern semi dwarf cultivars namely HD 2329, HD 2643 and Kundan, which showed greater stability in the number of shoots/pot, number of grains/spike and 1000 grain weight, respectively under the late sown condition, could be used as parents in breeding wheat cultivars for terminal heat tolerance.

## REFERENCES


Abrol, Y.P. and Ingram, K.T. (1996). Effect of higher day and night temperature on growth and yield of some crops. In : F. Bazzaz and W. Sombrock (eds.), Global Climate Change and Agriculture Production, pp. 123-140. Food and Agriculture Organization and John Wiley & Sons, New York.

Al-Khatib, K. and Paulsen, G.M. (1984). Mode of high temperature injury to wheat during grain Development. *Physiol. Plant.* **61:** 363-368.

Asana, R.D. (1976). Physiological Approaches to Breeding for Drought Resistant Crops. Indian Council of Agricultural Research Publication, New Delhi.

Asharf, M.Y. and Bhatti, A.S. (1998). Effect of delayed sowing on some parameters of photosynthesis in wheat (*Triticum aestium* L.). *Wheat Inf. Serv.* **46:** 46-48.

Asalam, M., Majid, A., Hobbs, P.R., Hashmi N. I. And Byerlee, D. (1989). Wheat in the rice-wheat cropping system of the Punjab: A synthesis of On Farm Research Results 1984-1989. PARC/CIMMYT Paper No. 89-3, CIMMYT, Mexico.

Berry, J. and Bjorkman, O. (1980). Photosynthetic response and adaptation to temperature in higher plants. *Annu. Rev. Plant Physiol.* **31:** 491-532.

Bajwa, M.A., Khan, N.I., Khan, S.H. and Khan, F.A. (1987). Effect of date of planting on the grain yield of six wheat cultivars. *J. Agric. Res.* **25:** 35-43.

Bishnoi, K.C. and Gill, P.S. (1972). Performance of dwarf wheats under varying dates of sowing and seed rates. *Haryana Agric. Univ. J. Res.* **2:** 190-196.

Chaudhary, M.H., Sattar, A. and Ibrahim, M. (1992). Yield performance of seven wheat cultivars at different dates of sowing. *RACHIS* **11:** 60-64.

Fisher, R.A. and Maurer, R. (1976). Crop temperature modification and yield potential in dwarf spring wheat. *Crop Sci.* **16:** 855-859.

Jenner, C.F. (1991a). Effect of exposure of wheat ears to high temperature on dry matter accumulation and carbohydrate metabolism in the grain of two cultivars. I. Immediate response. *Aust. J. Plant physiol.* **18:** 165-177.

Jenner, C.F. (1991b). Effect of exposure of wheat ears to high temperature on dry matter accumulation and carbohydrate metabolism in the grain of two cultivars. II. Carryover effects. *Aust. J. Plant Physiol.* **18:** 179-180.

Nazir, M.S., Khan, A., Ali, G. and Akhtar, M. (1980). Relationship between growing period, and yield components of three short duration wheat genotypes. *J. Agric. Res.* **18:** 141-145.

Nagarajan, S. (2002). Physiological traits associated with yield performance of spring wheat (*Triticum aestivum*) under late sown condition. *Indian J. Agri. Sci.* **72:** 135-140.

Penelia, J.R. and Bagga, A.K. and Wasnik, K.G. (1993). Effect of late sown condition on productivity and nitrogen status in wheat. *Indian J. Plant Physiol.* **36:** 178-184.

Rane, J., Shoren, J. and Nagarajan, S. (2000). Heat stress environments and impact on wheat productivity in India: Guestimate to losses. *Indian Wheat News Letter* **6:** 5-6.

Rawson, H.M and Bagga, A.K. (1979). Influence of temperature between floral initiation and flag leaf emergence on grain number in wheat. *Aust. J. Plant Physiol.* **6:** 391-400.

Rawson, H.M. (1986). High temperature tolerant wheat : a description of variation and search for some limitations for productivity. *Field Crops Res.* **14:** 197-212.

Reynolds, M.P., Balota, M., Delgado, M.I.B., Amani, I. and Fisher, R.A. (1994). Physiological and morphological traits associated with spring wheat yield under hot, irrigated condition. *Aust. J. Physiol.* **21:** 717-730.

Saini, A.D., Dadhwal, V.K. and Nanda, R. (1988). Pattern of changes in yield of Kalyansona and Sonalika varieties of wheat in sowing dates experiments at different locations. *Ann. Agric. Res.* **9:** 88-97.

Sharma, K.C. and Singh, M. (1972). Yielding abilities of dwarf wheat at different dates of sowing and seed rates. *Indian J. Agric. Sci.* **42:** 1110-1115.

Sphiler, L. and Blum, A. (1986). Differential reaction of wheat cultivars to hot environments. *Euphytica* **35:** 483-492.

Sphiler, L. and Blum, A (1991). Heat tolerance for yield and its components in different wheat cultivars. *Euphytica* **51:** 257-263.

Sofield, I., Evans, L.T. and Wardlaw, I.F. (1974). The effect of temperature and light on grain filling in wheat. R. Soc. N.Z. Bull **12:** 909-915.

Stone, P.J. and Nicolas, M.E. (1994). Wheat cultivars vary widely in their responses of grain yield and quality to short periods of post-anthesis heat stress. *Aust. J. Plant Physiol.* **21:** 887-900.

Wardlaw, I.F., Dawson, I.A., Munibi, P. and Fewster, R. (1989). The tolerance of wheat to high temperature during reproductive growth. I. Survey procedures and general response patterns. *Aust. J. Agric. Res.* **40:** 1-15.

Warrington, I.J., Dunstone, R.I. and Green, L.M. (1977). Temperature effects at three development stages on the yield of the wheat ear. *Aust. J. Agric. Res.* **28:** 11-27.

Zhong-hu, H. and Rajaram, S. (1994). Differential response of bread wheat characters to high temperature. *Euphytica* **72:** 197-203.