**Effect of High Temperature on Seed Germination and Seedling growth of Wheat (*Triticum aestivum* L.)**

**ABSTRACT**

 The laboratory analysis was carried out to assess seed quality parameters at Department of Seed Science and Technology, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.) India. The study revealed that, among the sowing dates significant differences were observed. The study was conducted to examine the effect of high temperature on seed quality attributes were better in respect of 24th November sowing followed by 15th October and 20th December sowing. The variety HI-1544 produced higher seed yield than others, while GW-273 recorded less but stable performance during early as well as late sown conditions. Seed quality parameters viz., thousand seed weight (g), seed density (g cc-1), germination (%), vigour index, seedling dry weight (g), seed reserve utilization efficiency (g g-1) were better in the sowing of 24th November. However, electrical conductivity was lower in 24th November sowing. The variety GW-322 followed by HI-1544 had better quality than the rest varieties.

**Keywords:** High temperature, germination, seedling growth, sowing time, wheat

**INTRODUCTION**

 Seeds are the foundation of agriculture and key component of various cropping system to ensure optimum plant population. Technology has modernized much of farming's day-to-day operations, but without a high-quality seed, yields and crop quality would be decrease greatly. Quality seed increased crop yield by 20 to 25 % with the optimum agronomic practices. The ability of the seed to germinate, emerge into a uniform and vigorous field stand is a direct function of its quality (Grass *et al.,* 1994 and Hasan *et al.,* 2013). There is sufficient evidence that the parental growth environment influenced the quality of the seed produced. Variation in Seed quality, attributed to differences in environmental conditions prevailing during the formation, development, and maturation of the seed while still on the mother plant (Datta *et al.,* 1972; Peacock and Hawkins 1970).

Common wheat (*Triticum aestivum* L.) belongs to family Poaceae. It is the most important staple food crop in the world and second important crop in India after rice. However, almost 60% of country’s net cultivated area is rain fed and exposed to several abiotic and biotic stresses including heat stress. In India, delay in wheat sowing due to rice-wheat cropping system is one of the major factors responsible for reduced seed quality due to the sub-optimal temperature during germination, plant establishment and reproductive growth (Sattar *et al.,* 2010). High temperature following anthesis adversely affects grain development in wheat (Hasan and Ahmed 2005; Tashiro and Wardlaw 1990). High temperature accelerates the initial grain growth rate but shortens the grain growth period (Hasan and Ahmed 2005). There is general observation that the viability and the performance of the seed during its early stages of germination may be related to the ambient conditions under which that seed had formed, developed, and matured.

Seed development at high temperature can affect membrane integrity and can cause an increase in membrane leakage of both electrolytes and macromolecules during germination, which subsequently impairs germination and seedling vigor (Hassan *et al.,* 2013)). Grass and Burris (1995a) reported impaired germination and decline in seed vigor in wheat reflected in reduced shoot and root dry weight and higher seed conductivity due to high temperature during seed development and maturation.

**MATERIALS AND METHODS**

The experiment was conducted to evaluate the effect of different sowing dates on seed quality parameters of four wheat (Triticum aestivum L.) varieties under laboratory conditions.

##  **Experimental Design**

Design: Completely Randomized Design (CRD)
Replications: Three (3)
Location: Department of Seed Science and Technology, Institute of Agricultural Sciences, Bundelkhand University, Jhansi (U.P.)
Sowing Dates:
 D₁: 15th October 2024
 D₂: 24th November 2024
 D₃: 20th December 2024
Varieties:
 V₁: RAJ-4079
 V₂: GW-322
 V₃: GW-273
 V₄: HI-1544
Each treatment combination (3 sowing dates × 4 varieties = 12 treatments) was replicated three times.

##  **Evaluation Parameters**

### **Thousand Seed Weight (g)**

Measured by weighing 1000 randomly selected seeds using a digital seed counter and precision balance.

### **Germination Percentage (%)**

Calculated after a standard germination test (as per ISTA 2015) at 25 ± 2°C in a germinator:
Germination % = (Number of seeds germinated / Total seeds tested) × 100

 **Seedling Dry Weight (mg)**

Ten normal seedlings from each replication were dried at 70°C for 48 hours and weighed.
Mean Dry Weight = Total dry weight of 10 seedlings / 10

### **Vigour Index**

Calculated by the formula of Abdul-Baki and Anderson (1973):
Vigour Index = Germination % × Mean Seedling Length (cm)

###  **Seed Density (g/cm³)**

Determined using a water displacement method:
Seed Density = Weight of seeds (g) / Volume of water displaced (cm³)

###  **Electrical Conductivity (μS/cm/g)**

Measured using 50 seeds soaked in 75 ml of deionized water for 24 hours at 25°C. The leachate was analyzed using a conductivity meter:
EC = Conductivity reading (μS/cm) / Weight of seeds (g)

 **Statistical Analysis**

Data were subjected to analysis of variance (ANOVA) using CRD appropriate for factorial arrangements (3 sowing dates × 4 varieties). The following statistical tools were employed:
- ANOVA Table Construction: To assess the significance of treatment effects.
- F-test: To determine the significance of main effects and interactions.
- Critical Difference (CD) at 5% level (P<0.05): For mean separation where significant differences were found.
- Coefficient of Variation (CV%): To assess the reliability of the experiment.
 CV% = (Standard Deviation / Mean) × 100

**RESULTS AND DISCUSSION**

**Thousand seed weight**

The variety GW-322 showed highest 1000 seed weight (44.94 g) followed by HI-1544 (42.62 g). However, the lowest seed weight (35.89 g) was obtained in GW-273.The maximum 1000 seed weight was (43.40 g) was obtained in sowing date 24th November. At late sown conditions, the 1000 seed weight was significantly decreased as compared to normal sown conditions. The obtained data agrees with observations of Randhawa et al. (1976), Choudhury and Wardlaw (1978), Smika and Shawcraft (1980), Verma and Singh (1988) and Stuppler et al. (1990).

**Seed density**

The seed density differed significantly due to the varieties. The variety GW-322 recorded highest seed density (1.51 g cc-1) followed by HI-1544 (1.44 g cc-1)

The sowing dates had significant effect on seed density. Seed density was highest (1.70 g cc-1) for sowing date 24th November as compared to other sowing dates. While, sowing done on 20th December gave lowest seed density (1.15 g cc-1). Lu et al. (1993) found reduced grain density due to high temperature during seed development in maize. According to Hasan et al. (2013), due to high temperature after anthesis, the density of seed was reduced significantly in all wheat varieties.

**Germination percentage**

The data on germination percentage revealed that varieties, sowing dates and their interaction significantly affected the germination percentage. The variety GW-322 had recorded highest (94.78 %) germination percentage than rest of the varieties. However, the variety GW-273 recorded lowest (91.00 %) germination percentage. Germination percentage was significantly highest (94.17 %) at 24th November sowing date as compared to D1 (92.75 %) and D3 (92.08 %). Lower germination percentage on 20th December 2024 might be due to exposure of seeds to high temperature during the month of March. According to Hasan et al. (2013), seeds obtained from post-anthesis heat stress condition showed significantly lower germination percentage than normal condition.

**Vigour index-I and II**

Seedling vigour index-I is the effect of germination percentage and average length of root and shoot. The variety and sowing dates had significant effect on vigour index I. The variety HI-1544 recorded the highest vigour index I (2441.12) followed by GW-322 (2405.16). The variety GW-273 recorded lowest vigour index (2057.73). Vigour index I was significantly highest (2577.23) for sowing date 24th November 2024 as compared to D1 (2377.33) and D3 (1919.92) Seedling vigour index-II is effect of germination percentage and dry weight of seedling. The variety and sowing dates had significant effect on vigour index II. The variety GW-322 showed highest vigour index II (36.88) followed by HI-1544 (33.74). The lowest vigour index II was recorded by GW-273 (29.90). Vigour index II was significantly highest (36.85) due to snowing on 24th November 2024 as compared to D1 (33.68) and D3 (28.32). Ahmad et al. (1994) reported that smaller endosperm and lower grain weight Patil et al. (2000) reported that higher grain crude protein and lower grain size are the main causes of delayed sowing which resulting in low vigorous seed.

**Seedling dry weight (g)**

The variety and sowing dates had significant effect on seedling dry weight. The variety GW-322 showed highest seedling dry weight (0.39 g). The lowest seedling dry weight was recorded by RAJ-4079 (0.35 g). Seedling dry weight was significantly highest (0.43 g) in 24th November 2024 sowing date. The lowest seedling dry weight (0.30 g) recorded on 20th December 2024 sowing date. Decreased seedling dry weight with increase in parent plant temperature was reported by Grass and Burris (1995a) and Sechnyak et al. (1995). According to Hasan et al. (2013), seedling dry weight decreased when their parent experienced heat stress after anthesis.

**Electrical conductivity (µS cm-1**)

The varieties, sowing dates and their interaction had significant effect on electrical conductivity. The variety GW-322 (V2) recorded the lowest electrical conductivity (1.87 µS cm-1). However, the higher electrical conductivity was noticed in RAJ-4079 (1.99 µS cm-1). Electrical conductivity was lowest (1.68 µS cm-1) in 24th November 2024 sowing date. The highest electrical conductivity (2.26 µS cm-1) was recorded due to sowing on 20th December 2024. This might be due to more leak of solute or release of electrolytes resulted maximum EC value and low vigour under delayed sowing. Gul et al. (2012) reported that late sowing increases the EC of wheat seed but early sowing reduces the electrical conductivity. According to Hasan et al. (2013), seeds produced at high temperature stress released more electrolytes than those produced at normal conditions.

**Table 1. Effect of varieties, sowing dates and their interactions on thousand seed weight (g)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VarietiesSowing dates | V1 RAJ-4079 | V2 GW-322 | V3 GW-273 | V4 HI-1544 | Mean |
| D1 15 Oct | 41.06 | 43.61 | 33.69 | 42.40 | 40.19 |
| D2 24 Nov | 43.73 | 47.22 | 37.19 | 45.47 | 43.40 |
| D3 20 Dec | 38.01 | 44.00 | 36.80 | 40.00 | 39.70 |
| Mean | 40.93 | 44.94 | 35.89 | 42.62 | 41.10 |
|  | Variety | Sowing dates | Interaction |
| S.E. ± | 0.88 | 0.76 | 1.53 |
| C.D. at 5% | 2.54 | 2.20 | 4.39 |

**Table 2. Effect of varieties, sowing dates and their interactions on seed density (g cc-1)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VarietiesSowing dates | V1 RAJ-4079 | V2 GW-322 | V3 GW-273 | V4 HI-1544 | Mean |
| D1 15 Oct | 1.37 | 1.48 | 1.33 | 1.42 | 1.40 |
| D2 24 Nov | 1.66 | 1.80 | 1.60 | 1.73 | 1.70 |
| D3 20 Dec | 1.05 | 1.26 | 1.13 | 1.17 | 1.15 |
| Mean | 1.36 | 1.51 | 1.35 | 1.44 | 1.42 |
|  | Variety | Sowing dates | Interaction |
| S.E. ± | 0.011 | 0.010 | 0.021 |
| C.D. at 5% | 0.034 | 0.030 | 0.059 |

**Table 3. Effect of varieties, sowing dates and their interaction on germination (%)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VarietiesSowing dates | V1 RAJ-4079 | V2 GW-322 | V3 GW-273 | V4 HI-1544 | Mean |
| D1 15 Oct | 92.67 | 94.33 | 90.00 | 94.00 | 92.75 |
|  | (74.29) | (76.22) | (71.57) | (75.82) | (74.38) |
| D2 24 Nov | 93.33 | 96.33 | 92.00 | 95.00 | 94.17 |
|  | (75.03) | (78.96) | (73.57) | (77.08) | (76.03) |
| D3 20 Dec | 91.67 | 93.67 | 91.00 | 92.00 | 92.08 |
|  | (73.22) | (75.43) | (72.54) | (73.57) | (73.65) |
| Mean | 92.56 | 94.78 | 91.00 | 93.67 | 93.00 |
|  | (74.17) | (76.79) | (72.54) | (75.43) | (74.66) |
|  | Variety | Sowing dates | Interaction |
| S.E. ± | 0.51 | 0.44 | 0.89 |
| C.D. at 5% | 1.47 | 1.28 | 2.56 |

**Table 4. Effect of varieties, sowing dates and their interaction on vigour index-I**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VarietiesSowing dates | V1 RAJ-4079 | V2 GW-322 | V3 GW-273 | V4 HI-1544 | Mean |
| D1 15 Oct | 2363.33 | 2481.53 | 2080.50 | 2580.53 | 2377.23 |
| D2 24 Nov | 2524.32 | 2732.83 | 2260.50 | 2712.77 | 2577.23 |
| D3 20 Dec | 1819.30 | 2001.10 | 1829.20 | 2030.07 | 1919.92 |
| Mean | 2235.65 | 2405.16 | 2057.73 | 2441.12 | 2284.92 |
|  | Variety | Sowing dates | Interaction |
| S.E. ± | 49.67 | 43.02 | 86.03 |
| C.D. at 5% | 143.08 | 123.91 | 246.90 |

**Table 5. Effect of varieties, sowing dates and their interactions on vigour index-II**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VarietiesSowing dates | V1 RAJ-4079 | V2 GW-322 | V3 GW-273 | V4 HI-1544 | Mean |
| D1 15 Oct | 32.03 | 37.30 | 30.80 | 34.59 | 33.68 |
| D2 24 Nov | 35.46 | 40.43 | 33.03 | 38.47 | 36.85 |
| D3 20 Dec | 26.33 | 32.90 | 25.87 | 28.17 | 28.32 |
| Mean | 31.28 | 36.88 | 29.90 | 33.74 | 32.95 |
|  | Variety | Sowing dates | Interaction |
| S.E. ± | 0.56 | 0.48 | 0.97 |
| C.D. at 5% | 1.60 | 1.39 | 2.77 |

**Table 6. Effect of varieties, sowing dates and their interactions on seedling dry weight (g)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VarietiesSowing dates | V1 RAJ-4079 | V2 GW-322 | V3 GW-273 | V4 HI-1544 | Mean |
| D1 15 Oct | 0.36 | 0.38 | 0.37 | 0.37 | 0.37 |
| D2 24 Nov | 0.43 | 0.45 | 0.40 | 0.45 | 0.43 |
| D3 20 Dec | 0.27 | 0.33 | 0.30 | 0.28 | 0.30 |
| Mean | 0.35 | 0.39 | 0.36 | 0.37 | 0.37 |
|  | Variety | Sowing dates | Interaction |
| S.E. ± | 0.006 | 0.005 | 0.01 |
| C.D. at 5% | 0.02 | 0.02 | 0.03 |

**Table 7. Effect of varieties, sowing dates and their interaction on electrical conductivity (µS cm-1)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| VarietiesSowing dates | V1 RAJ-4079 | V2 GW-322 | V3 GW-273 | V4 HI-1544 | Mean |
| D1 15 Oct | 1.94 | 1.85 | 1.63 | 1.88 | 1.82 |
| D2 24 Nov | 1.71 | 1.60 | 1.77 | 1.63 | 1.68 |
| D3 20 Dec | 2.32 | 2.16 | 2.36 | 2.19 | 2.26 |
| Mean | 1.99 | 1.87 | 1.92 | 1.90 | 1.92 |
|  | Variety | Sowing dates | Interaction |
| S.E. ± | 0.02 | 0.02 | 0.03 |
| C.D. at 5% | 0.05 | 0.04 | 0.08 |

**CONCLUSIONS**

 The seed quality parameters viz. thousand seed weight, germination (%), seed density, seedling dry weight, vigor index and electrical conductivity better in 24th November 2024 sowing. Seed quality parameters were found to be adversely affected by delayed sowing due to increased atmospheric temperatures interacted with low relative humidity.

**DISCLAIMER (ARTIFICIAL INTELLIGENCE)**

Author (s) hereby declare that No generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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