CHAPTER-II
REVIEW OF LITERATURE

Among cereals, wheat has been focus of agronomical investigations all over the world resulting into voluminous research reports on various aspects of meteorological requirements, cultural practices, irrigation, fertilizer, and other monetary and non-monetary inputs. An attempt has been made in this chapter to critically examine available research results and review related to present investigation in a summarized and classified manner so as to use it as a background literature.

Effect of climate change on wheat:

Luo et al. (2003) performed simulation studies on effects of climate change on quality of wheat and found that climate change can degrade the quality of wheat at drier sites of South Australia.

Ortiz et al. (2008) discussed about adaptation of wheat to climate change in Indo-Gangetic Plains for 2050 and suggested that global warming is beneficial for wheat crop production in some regions, but may reduce productivity in critical temperature areas, so it is urgent to develop some heat-tolerant wheat germplasm to adapt wheat production to climate change.

Lobell et al. (2011) estimated that climate change from 1980 to 2008 has already reduced global production of wheat by 5.5 % relative to a counterfactual without climate change.

Asseng et al., (2011) and Lobell et al., (2012) argue that an increase in extreme temperature events with increasing mean temperatures is likely to further contribute to yield decline in wheat.


Asseng et al. (2014) reported that for each °C increase in global mean temperature, there would be a reduction in global wheat production of about 6%, with a 50 % probability of between 4.2 % and 8.2 % loss based on the multi-model ensemble.
According to Asseng et al. (2014) the number of days to anthesis and to maturity declined with increasing temperature, and accompanied yield losses in an experiment at CIMMYT.

Liu et al. (2016) through simulation studies found that 1°C warming would result in 3 % decrease in wheat yield in China. In India, the decrease in wheat yield is expected to be much severe with 8 % decline with every 1°C rising of temperature.

Therefore, identifying suitable sowing date and growing varieties tolerant to heat and drought stress have been identified as important climate change adaptation strategies (Bondeau et al., 2007 and Muller et al., 2010).

**Effect of date of sowing on wheat:**

Joshi and Singh (1983) found that normal sowing on 05\(^{th}\) November gave 10.2 % and 19.9 % increase in grain and 21.1 % and 3.2 % increase in straw production over early sowing (05\(^{th}\) October) and late sowing (05\(^{th}\) December) respectively and late sowing adversely affected test weight and influenced number of spikes per unit area.

Kaneria (1983) indicated that crop sown on 30\(^{th}\) November increased total and effective tillers, ear length, number of grains/spike and test weight.

Nayak et al. (1983) suggested third week of November as optimum sowing time for wheat. The grain yield declines with the delay in sowing beyond optimum time.

Singh and Dixit (1985) found highest ear bearing tillers and grains/spike by sowing on 10\(^{th}\) November. Delay in sowing beyond 25\(^{th}\) November decreased grain yield/spike, test weight, straw and grain yield.

Girothia et al. (1987) reported that crop gave significantly more number of ear bearing tillers, 1000 grain weight, grain and straw yield on 15\(^{th}\) to 20\(^{th}\) November sowing than late sowing on 06\(^{th}\) to 10\(^{th}\) December.

Patel et al. (1987) registered maximum grain yield (3663 kg/ha) on 15\(^{th}\) November and delay in sowing beyond 15\(^{th}\) November, resulted reduction in yield.

Bali et al. (1988) observed that sowing of crop on normal date (24\(^{th}\) November) increased yield attributes like spikelets/spike, grains/spike, grain weight/spike and 1000 grain weight which resulted in to maximum grain yield. There was reduction in grain yield due to delay in sowing up to 24\(^{th}\) December.
Verma and Singh (1988) reported that highest grain yield (4290 kg/ha) was recorded on 21\textsuperscript{st} November which was significantly higher than that with 11\textsuperscript{st} December sowing (3441 kg/ha).

Sharma and Choker (1989) reported that November sowing was significantly superior to December or January sowing in respect of plant height, effective tillers/ plant, grain and straw yield.

Maliwal et al. (1992) observed that sowing at 09\textsuperscript{th} November produced significantly highest grain yield.

Singh and Uttam (1994) observed that the sowing dates significantly influenced the number of spikes/m\textsuperscript{2}, 1000 grain weight, length of spike (cm), number of grains/spike, grain and straw yield. The crop sown on 10\textsuperscript{th} December gave all these attributes significantly higher than that sown on 10\textsuperscript{th} January but it was at par with crop sown on 25\textsuperscript{th} December.

Das et al. (1996) reported that maximum growth parameters were found on November 30 followed by 15\textsuperscript{th} November and minimum was recorded in crop sown on 15\textsuperscript{th} December.

Kumar and Kumar (1997) observed significant difference in dry matter accumulation due to different sowing times. The crop sown on 30\textsuperscript{th} November accumulated the highest dry weight which was closely followed by sowing on 15\textsuperscript{th} November and both were significantly higher that sown on 01\textsuperscript{st} November.

Subedi et al. (1997) found that sterility increased when wheat sown on 21\textsuperscript{st} December, which had also lowest 1000 seed weight and grain yield and almost 50 \% grain yield reduction compared to the crop sown on 21\textsuperscript{st} November.

Kumar et al. (1998) observed that wheat sown on 18\textsuperscript{th} November favorably influenced the yield attributing characters as well as overall performance of the crop.

Sardana et al. (1999) reported that sowing dates significantly influenced grain yield. Grain yield was 1780 and 2390 kg/ha when sown on 27\textsuperscript{th} October and 11\textsuperscript{th} November, respectively.

Lathwal and Thakral (1999) recorded the decreasing trend in plant height with the delay in sowing. The maximum height of the crop was recorded on 05\textsuperscript{th} when sown November followed by 15\textsuperscript{th} November and 25\textsuperscript{th} November and lowest at 5\textsuperscript{th} December.

Behera et al. (2000) reported that sowing dates significantly influenced the 1000 grain weight, the maximum 1000 grain weight (50.08 gm) was obtained with
01\textsuperscript{st} November followed by 15\textsuperscript{th} November sowing which was also superior to both 15\textsuperscript{th} December sowing and 01\textsuperscript{st} December sowing. This difference caused significant reduction in grain yield under delayed sowing.

Nainwal and Singh (2000) reported that with one month delay in sowing after 27\textsuperscript{th} November, there was significant reduction in 1000 grain weight. Immature and shrieveled grains are produced in late sown crop, which remain in the milk stage during the period of high temperature. On the other hand, the timely sown crop gets an advantage because after having completed its vegetative growth satisfactory, it comes in the earing stage when the temperature is quite favorable.

Ghosh \textit{et al.} (2000) reported that the highest number of ears/m\textsuperscript{2} and test weight was obtained from 16\textsuperscript{th} November sown crop, but it was at par with those of the crop raised on 26\textsuperscript{th} November and gradually decreased with delay in sowing. The lowest value of the grains/ear was found in late sown crop on 06\textsuperscript{th} December.

Singh and Jain (2000) observed that mid-November sown crop gave significantly higher grain yield than the early and late sown crop and the extent of increase was 12.3 and 33.6 \%, because of more number of effective tillers.

Li \textit{et al.} (2001) found significant effects of different sowing dates and varieties on development stages of wheat. The results showed that the emergence of tiller was mainly regulated by the ecological factors rather than the genetic factors.

Negi \textit{et al.} (2003) reported that sowing dates significantly affect the effective tillers/m\textsuperscript{2} and grain yield. Higher number of effective tillers/m\textsuperscript{2} was recorded in crop sown on 28\textsuperscript{th} November (245.6) than in crop sown on 28\textsuperscript{th} October (186.8).

Mishra \textit{et al.} (2003) reported significant difference due to date of sowing in leaf, stem and spike dry weight. Delayed sowing resulted in significant reduction in leaf dry weight. Low temperature experienced by late sown crop during early growth or immediately after seedling emergence might have resulted in poor leaf development. Significantly higher stem dry weight was recorded under normal sown crop (normal temperature). The crop sown on 22\textsuperscript{nd} November produced significantly heavier spike than crop sown on 22\textsuperscript{nd} December due to favorable temperature.

Kumar and Sharma (2003) reported that sowing time significantly affects the height of plant. The crop sown on 30\textsuperscript{th} November (89.0 cm) produced significantly taller plants than the crop sown on 16\textsuperscript{th} (83.3 cm) and 31\textsuperscript{st} December (83.3 cm).

Kulhari \textit{et al.} (2003) revealed that early sown crop failed to record significant grain yield over normal sowing. However, both early and normal sown crop produced
significantly higher grain and straw yield over late sown crop. Thus as consequence of favourable climatic conditions, improvement in growth and yield components under early and normal sowing resulted in realization of higher yield compared to late sowing.

Dhaka et al. (2006) found that the numbers of tillers/plant reduced by 4.8 % when sown on 25th December (3.9 tillers/plant) instead of 20th November (4.1 tillers/plant) and the number of grains/spike reduced by 12.0 % when crop sown on 25th December (43.8 grains/spike) instead of 20th November (49.8 grains/spike). It was also observed that 1000 grain weight reduced by 18.5 % when wheat sown on 25th December (30.3 gm/1000 grain) instead of 20th November (37.2 gm/1000-grain).

Abdullah et al. (2007) reported that delayed sowing adversely affects the straw and grain yield and maximum yield was obtained from sowing on 25th October and minimum yield was obtained from sowing on 10th January.

Shahzad et al. (2007) reported that the plant height decreased with delay in sowing. The crop sown on 15th November produced significantly taller plants (88.73 cm) than that sown on 30th November (86.77 cm) and 15th December (85.41 cm).

Shripurkar et al. (2007) reported that maximum 1000 grain weight, ear heads/m² and number of grains/ear were recorded in 11th November sown crop in comparison to 27th November sown crop.

Shripurkar et al. (2008) found that the early sowing on 08th November gave significantly more ear head/m² (407.39) than the mid sowing on 30th November (402.44) and late sowing on 20th December (377.56), significantly more number of grains/ear head (42.44) than the mid sowing (39.16) and late sowing (37.47) and more 1000 grains weight (48.01 g) than the mid sowing (47.93 g) and late sowing (44.13 g).

Hussain et al. (2008) found that sowing on 25th October, 25th November and 25th December regulated in to a consistent decrease in grain yield. As a result early sowing on 25th October gave maximum yield.

Qasin et al. (2008) concluded that grain yield, straw yield, number of tillers/plant, number of grains/spike and grain weight were significantly affected by date of sowing. Sowing on 15th November gave maximum plant height (79.81 cm), grains/spike (44.14), 1000 seed weight (39.17 gm), grain yield (4165.7 kg/ha) and straw yield (6814.2 kg/ha) compared to that with sowing on 30th November and 15th December.
Tahir et al. (2009) reported that maximum grain yield (4289.54 kg/ha) was obtained when sown on 01\textsuperscript{st} December and minimum grain yield (2109.50 kg/ha) obtained when sown on 30\textsuperscript{th} December.

Khokhar et al. (2010) obtained maximum grain yield of 5904 kg/ha when sown on 15\textsuperscript{th} November and minimum grain yield of 4756 kg/ha when sown on 15\textsuperscript{th} December. Due to reduction in tillering period and increased risk of hot weather during grain filling, late planting results in linear reduction in wheat grain yield.

Baloch et al. (2010) found that sowing on 25\textsuperscript{th} October and 10\textsuperscript{th} November produced the highest number of tillers, plant height, spike length, 1000 grain weight and grain yield, which decreased with successive sowing dates.

Ali et al. (2010) reported that higher grain yield (3826 kg/ha) was obtained from 10\textsuperscript{th} November followed by 20\textsuperscript{th} November (3731 kg/ha) sowing.

Seleiman et al. (2011) reported that sowing date on 15\textsuperscript{th} November surpassed the other sowing dates (01\textsuperscript{st} November, 01\textsuperscript{st} December and 15\textsuperscript{th} December) in all of yield parameters, grain filling rate and flour percentage.

Singh et al. (2011) revealed that late planting reduces the tillering period and hot weather during critical period of grain filling leading to forced maturity thereby reducing the grain yield.

Hariram and Mavi (2012) found that crop sown on 25\textsuperscript{th} October took maximum calendar days, growing degree days, photo thermal unit, and helio-thermal unit for maturity which got reduced with delay in sowing. The grain yield recorded with sowing at 25\textsuperscript{th} October was statistically at par with sowing on 5\textsuperscript{th} November.

Aslani and Mehrvar (2012) found optimum sowing date 01\textsuperscript{st} November and got higher grain, biomass yields, 1000 grain weight and spikes/square meter.

Kumar et al. (2013) reported that sowing at 15\textsuperscript{th} November gave more total tillers (420 tillers/m\textsuperscript{2}), higher dry matter accumulation (1190 gm/m\textsuperscript{2}), higher crop growth rate (19.30 gm/m\textsuperscript{2}/day) at maturity and leaf area index (3.60) resulting in 14.7 % higher spikes/m\textsuperscript{2} (400 spikes/m\textsuperscript{2}), 26.43 % higher spike length (10.40 cm), 15.15% higher number of grain/spike (39 grains/spike), 45.20 % higher grain yield (5100 kg/ha) than 01\textsuperscript{st} November and 30\textsuperscript{th} November sowing with same variety (WH 896) and delayed sowing beyond 15\textsuperscript{th} November reduced yield attributes and grain yield.

Alam et al. (2013) reported that sowing on 25\textsuperscript{th} November produced more total tillers (420 tillers/m\textsuperscript{2}), higher dry matter accumulation (1190 gm/m\textsuperscript{2}), higher crop growth rate (19.30 gm/m\textsuperscript{2}/day) at maturity, and leaf area index (3.60) and resulted in
14.7 % higher spike/m² (400 spikes/m²), 26.43 % higher spike length (10.40 cm), 15.15 % higher number of grains/spike (39 grains/spike), 45.20 % higher grain yield (5100 kg/ha).

Islam et al. (2013) evaluated that late planting exposes plant to the high temperature during grain filling phase causing significant yield loss and reduce plant height. The genotypes were significantly influenced by late sowing with respect to grains/spike, plant height, 1000 grain weight and yield.

Jat et al. (2013) observed highest plant height, number of tillers, dry-matter accumulation/plant, ear length, grains/ear (52.47), ear weight and test weight with sowing on 20th November followed by 06th December.

Sokoto and Singh (2013) recorded highest spike/m², grain yield and harvest index with sowing on 21st November and 05th December and lowest with 19th December and 02nd January sowing.

Kamani and Singh (2013) found that delayed sowing further causes heat stress at reproductive phase which results in forced maturity and high temperature stress at reproductive phase results in poor yield due to reduced number of grains/spike and shriveled grains with poor quality.

Kumar et al. (2013) found that sowing on 25th November resulted in 14.7 % higher spikes/m² (398 spikes/m²), 15.15 % more number of grains/spike (38 grains/spike), 45.16 % higher grain yield (5104 kg/ha).

Lak et al. (2013) took five date of sowing viz., 31st October, 15th November, 30th November, 15th December and 30th December and found highest yield with 15th November and lowest yield with 30th December sowing.

Dagash et al. (2014) reported that crop sown at mid November produced higher grain yield, total dry matter, plant height, 1000 seed weight and harvest index than early November and early December sowing.

Suleiman et al. (2014) reported highest number of grains/spike and grain yield when sown on 01st November, 15th November than 01st December and 15th December sowing.

Rahmat et al. (2014) reported highest seed yield at 31st October and lowest seed yield at 30th December among five date of sowing viz., 31st October, 15th November, 30th November, 15th December and 30th December.

Sanghera and Thind (2014) observed that delay in sowing adversely affects the wheat growth due to high temperature during grain filling period. Exposure to
high temperatures during grain development reduced the yield and yield attributing parameters. High temperature (>31° C) can decrease the rate and duration of grain filling period in wheat. Late sowing reduced the total duration of vegetative phase and decreased the dry matter accumulation in growth period.

Singh and Dwivedi (2015) recorded that number of leaves, net assimilation rate (NAR), crop growth rate (CGR), relative growth rate (RGR) and leaf area index (LAI) was higher on early sowing at 20th November compared to late sown at 10th December and 30th December, because late sowing of wheat results in exposure to high temperature during reproductive phase (seed filling).

Mumtaz et al. (2015) reported that sowing at 11th November followed by 01st November and 21st November gave maximum growth and yield attributes and maximum reduction in growth and yield was observed by sowing on 21st December and 11th December.

Meena and Verma (2015) studied effect of different sowing dates and found highest grain yield (5000 kg/ha) on 14th November followed by 04th December and 24th December (3340 kg/ha) sowing.

Hussain et al. (2015) observed that sowing dates severely influence protein and carbohydrate contents in grain. Among four dates of sowing 10th November and 25th November gave better grain protein, carbohydrate content and yield as compared to 10th and 25th December.

Hussain et al. (2015) observed that late sown wheat faces terminal heat stress, which not only reduces grain yield but also affects the grain development processes and quality.

Hassan et al. (2016) found that among six dates of sowing, sowing on 15th November produced maximum yield and 1000 grain weight and sowing on 27th December and 10th January gave minimum yield.

**Effect of variety on productivity:**

Subedi et al. (1997) found SW 41 and BL 1022 having higher pollen sterility at all sowing dates while BL 1249 had pollen sterility over all sowing dates and gave maximum yield.

Shivani et al., (2001) reported that yield and yield attributes and water use efficiency was significantly higher with HUW 234 and K 9006 sown on 21st November.
Patil and Itnal (2002) obtained maximum yield with DDK 1001 and NP 200 varieties when sown on 20th November.

Tahir et al. (2009) found that variety Inqlab 91 gave maximum number of fertile tillers/m², plant height, number of spikelets/spike, 1000 grain weight and maximum yield (3550.44 kg/ha) while minimum yield (2932.59 kg/ha) was obtained with AS 2002 at similar dates of time sowing.


Aslani and Mehrvar (2012) found that when sown on 01st November DN 11 gave higher number of grains/spike, 1000 grain weight, grain yield, and biological yield over DM 81-6, DM 82-1, Bahar, DN 7, Pishtaz, WS 82-9 and C 85-6.

Patel et al. (2012) observed that GW 322 gave higher yield as compared to GW 496 when sown at 30th November and 10th December.

Alam et al. (2013) found that K 0307 variety had significantly higher total tillers (492 per m²), dry matter accumulation (1120.60 gm/m²) and grain yield (4540 kg/ha) over other four varieties i.e. Raj 4229, K 0906, HD 2733 and DBW 39.

Lak et al. (2013) reported that variety Parsi gave highest grain yield (10.23 t/ha) among five varieties viz., Pishgam, Parsi, Bahar, Sivand and Pishtaz with sowing on 15th November.

Kota et al. (2013) found that DL 893, DL 901, DL 966 and PBW343 varieties exhibited higher performance in terms of grain yield under timely sowing conditions whereas DL 880, DL 882, DL 886, DL 92 and DL 927 gave better performance under late sowing conditions.

Fayed et al. (2014) recorded maximum yield with variety Gemmeiza 9 when sown crop on 15th November as compared to Misr 1, Sakha 93 and Giz 168.

Rahmat et al. (2014) reported that variety Sivand gave highest number of grains/spike, grain yield, and HI with 31st October sowing than Pishgam, Parsi, Bahar, Sivand and Pishtaz variety.

Silva et al. (2014) observed that CD 105 and Safira variety gave highest grain yield from 01st to 15th June sowing than BRS 179, BRS, Guamirim, BRS Guabiju, BRS Umbu, Safira, CD 105 and CD 115 variety.

Suleiman et al. (2014) found that Imam and Wad el Neil variety scored highest number of grains/spike and grain yield than Sasaraib and Debiera variety when sown on 01st November and 15th November.
Deshmukh et al. (2015) found that AKAW 4647 gave higher number of tillers/m², dry matter accumulation, number of grains/spike, grain yield, straw yield and test weight with sowing during first week of November among a set of twenty varieties.

Meena and Verma (2015) reported significantly higher yield and yield attributes with UP 2565 as compared to PBW 17, RAJ 3765, UP 2526, UP 2572 and UP 2584.

Mishra et al. (2015) reported that GW 322 was more vulnerable to increased minimum temperature whereas, GW 366 was least sensitive.

Singh and Dwivedi (2015) observed that number of ears per 20 cm row length, number of grains/ear, grain yield, 1000 grain weight and harvest index was significantly higher in HUW 510 followed by HUW 468 at 20th November sowing.

Hassan et al. (2016) recorded test weight, yield, and protein and gluten content significantly higher in El Nilein and Debeira varieties compared to El Nilein, Wadi Elneel, Giza 168, Debeira, Sasaraibe and Condorin Selaimand.