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MANAGEMENT PRACTICES TO MITIGATE THE IMPACT OF HIGH TEMPERATURE ON WHEAT: A REVIEW

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ABSTRACT

Climate change is a reality and agriculture is highly vulnerable, particularly in the semi-arid and arid regions of India. The climate is changing rapidly through the processes such as CO2 and changed pattern of precipitation resulting in heat and drought stresses, respectively. This changing climate could strongly affect the wheat production worldwide. The effect of increasing temperature during grain filling stage of wheat causes substantial reduction in grain yield. In this review paper are discussed the factors responsible to reduce the grain yield of wheat under the climate change and agronomic management practices as time of sowing, alternative method of planting, mulching, seed priming, foliar spray of salts, use of potassium fertilizer with municipal waste water, use of extra irrigation water and foliar spray of micronutrients to mitigate the high temperature effect on the productivity of wheat. Priming with moringa water extract and ascorbate substantially improved the tissue water status, membrane stability, gas exchange, water productivity of the plant. Timely sowing of wheat crop generally gives higher yield as compared to late sown crop. Late sown wheat crop faces high temperature stress during ripening phase. Late planting reduces the tillering period and hot weather during critical period of grain filling lead to forced maturity thereby reduces the grain yield. Planting of wheat with zero tillage, bed planting and conventional tillage with mulching produced higher grain yield than conventional tillage. Organic mulches provided better soil water status and improved plant canopy in terms of biomass, root growth, leaf area index and grain yield, which subsequently resulted in higher water and nitrogen uptake and their use efficiencies. The foliar spray of KNO3 (0.5%) at 50 percent flowering stage, 1.0 per cent KNO3 during anthesis stage, 2.5 mM of arginine, spray of zinc, extra irrigation water during grain filling stage, use of potassium fertilizers with municipal waste water increased the productivity of wheat under high temperature conditions.

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Climate change; mitigate; Mulching; seed priming; foliar spray; extra irrigation water

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[I] INTRODUCTION

Crop performance and yield depend largely on environmental interaction. So, the knowledge as how to environment influences crop growth, development and yield of great importance. Non-stress environment is ideal for successful cop production. A biological stress can be defined as any environmental factor capable of inducing a potentially injury strains in living organisms [1]. Growth and development of wheat is adversely affected by environmental stresses like high temperature, soil moisture deficit, low light intensity, etc. Among these, temperature plays an important role in growth, development and yield of wheat. Wheat growing in India is a gamble of temperature [2]. High temperature at the both ends of wheat growing season in India is a limiting factor. In case of November sown crop, high temperature at sowing, helps wheat plant to accelerate its growth and thus shortens the tillering phase by inducing the crop to enter the elongation stage more quickly and this result in poor tillering of the crop. In case of delayed sown crop, stages like flowering and grain filling

Table: 1. Effect of dates of sowing on growth and yield contributing characters of wheat

Date of sowing	Plant height (cm)	Dry matter accumulation at maturity (q/ha)	Number of tillers (m^{-1}row length)
25 November	82.4	65.9	84.1
10 December	80.1	43.9	54.1
CD (p=0.05)	1.3	5.9	7.1

Source [27]

coincide with rise in temperature and atmospheric drought during March and April, which causes poor growth and low grain yield.

Continual heat stress affects approximately 7 million hectare of wheat in developing countries, whereas terminal heat stress is problem in 40 per cent of the temperate environments that encompass 36 million hectare. Spring wheat is grown in these areas experience severe heat stress in certain phases of crop growth. In India also almost the entire wheat growing area falls under the tropical and sub-tropical environment. A sudden rise in temperature during grain filling prior to maturity is a widely prevalent phenomenon in almost all parts of India, causing significant reduction in yield [3]. Wheat grown under late sown conditions is exposed to very low temperature up to booting stage, but the later stages face higher temperature that inhibits grain development, resulting into poor grain yield.

Upon exposure to heat stress, development of various growth stages is accelerated to such a degree that the environment cannot supply necessary inputs (radiation, water and nutrient) fast enough [4]. In wheat, period from onset of spike ignition to flowering is very sensitive to temperature acceleration in this phase seems to be the main reason for reduction in sink size under high temperature conditions. Heat stress affects the production of wheat by causing reduction in duration of grain filling phase, kernel size, biomass, tiller number, etc. heat stress adversely affected days to appearance of first node, tiller per plant and spikelet's per plant, thereby resulting in reduction of sink capacity and future sources capability of the plant [5]. An increase in 10C can cause decrease of 4 mg in grain weight [6].

Many investigators have established the effects of temperature at the later stage of the development of wheat crop particularly after the heading stage. Average temperature of 150C during grain filling is optimum for maximum grain weight [7, 8]. High temperature during grain filling period of wheat affects the kernel weight and grain yield through reduction in grain filling [9]. However, an increase of 0.50C temperature resulted in decrease in the duration of wheat crop by seven days, which reduced the yield by 0.5 t ha-1 in north India [10]. In another studies, the effect of high temperature on grain development in wheat and rice studied [11]. It was found that wheat yield decreased by 5 per cent for each 10C rise in post anthesis daily mean temperature in the range between 17.70C and 32.70C. In another investigation was observed that a 20C increase in temperature in wheat and rice resulted in 15-17 per cent decrease in grain yield of both crops but beyond that the decrease was very high in wheat [12]. High temperature has many detrimental effects on wheat. High temperatures after anthesis hastens the leaf senescence shorten the period of grain growth and decrease the grain yield [13]. Under high temperature conditions, tillering and root growth are reduced but heading and maturity are accelerated. High temperature and drought reduced the duration of grain development period, thus reducing the grain size [14]. In this review paper are discussed the factors responsible to reduce the grain yield of wheat under climate change particularly the effect of high temperature during reproductive stage.

[II] FACTORS AFFECTING ON WHEAT UNDER CLIMATE CHANGE

2.1. Effect seed priming

The climate is changing rapidly through the processes such as CO_2 and changed pattern of precipitation resulting in heat and drought stresses, respectively. This changing climate could strongly affect the wheat production worldwide. In study evaluated the role of seed priming with inorganic salts ($CaCl_2$, KNO_3, KCl, plant water extracts (sorghum, moringa) and organic molecules (ascorbate, salicylicate, proline) in improving the wheat performance under heat and drought stresses [15]. For stress treatments, there were four sets in the experiment viz., optimal conditions, drought stress (at 50 % of the field capacity), heat stress (4^0C) higher than the ambient temperature and both drought and heat stress. For priming wheat seeds were soaked in aerated solutions of respective osmotic/plant water extract while water soaked and dry seeds were taken as control. Each of the stresses substantially reduced the wheat performance and the effects were more severe when both the plants were exposed simultaneously to both the stresses. Priming treatments substantially improved the tissue water status, membrane stability, gas exchange, water productivity and plant was better than the other inorganic salts, however, priming with moringa water extract and ascorbate was better than other treatments in the respective group. Seed priming techniques may therefore be employed to improve the wheat performance in changing climate.

2.2. Effect of dates of planting

Time of planting is one of the most important non-monetary inputs for optimizing the growth according to prevailing agro-climatic conditions and genotypes. The performance of wheat varies with different dates of planting.

2.2.1. Growth parameters

Conducted an experiment at Punjab Agricultural University, Ludhiana on loamy sand soil [16] and reported that plant height was maximum of the crop sown on 25 October (81cm), which was at par with crop sown on 4 November (76 cm) and 14 November. It was significantly superior to the crop sown on 24 November (72 cm). Another experiment was conducted at Palampur on silty clay loam soil [17] and noted that wheat crop sown in the 1st week of November had significantly higher plant height (98.1 cm) as compared to crop sown on 1st week of December (82.8 cm) and 1st week of January (75.5 cm). In another studies, the similar findings were reported from Gurdaspur, Punjab [18]. However, other experiments were conducted [19, 20] **[Table–2]** at Punjab Agricultural

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University, Ludhiana on loamy sand soil and reported that plant height was significantly higher of crop sown at November 15 (78.5 cm) as compared to December 20 (71.6 cm). Similar results were reported from Chiplima [21], and from Gurdaspur [22]. However, it was reported that plant height was not significantly affected by the date of sowing [23, 24]. From HAU, Hisar, reported that crop sown on 20 November produced significantly more leaf area index (4.4) than that of 20 December (3.9) sown crop [25]. However, at Ranchi, Bihar conducted an experiment on sandy loam soil [26] and reported that timely sown crop (24 November) produced significantly more leaf area index (4.31) as compared to late sown crop (3.01). Dry-matter accumulation was also significantly higher with timely sown crop (879.9 gm-2) than late sown crop (662.6 gm-2). However, plant height, dry matter accumulation and tillers per meter row length were significantly higher in early sown crop of 25 November than late sown crop of 10 December. So that early sown wheat crop was superior to late sown crop in various growth parameters [27] **[Table-1]**. Another investigation was conducted at Haryana Agricultural University, Hisar on sandy loam soil and noted that planting dates did not affect the dry-matter accumulation significantly. Plant height was significantly higher of 30 November (81.9 cm) sown crop than 1 November (76.5 cm) and 15 November sown crop [28]. However, conducted an another experiment on sandy loam soil and observed that plant height was maximum of crop sown on 1 December as compared to crop sown in December and January at Umerkote [69] and Bathinda [29], respectively.

Conducted an experiment at Pantnagar on silty loam soil and found that a significant reduction in plant height was recorded in late sowing wheat crop [30]. However, from Jharkhand noted that the plant height of timely sown wheat was 11.47, 29.25 and 54.06 per cent higher in the first year [31], while 15.08, 33.44 and 44.06 per cent higher in second year compared to moderately late, late and very late sown wheat, respectively. Dry matter accumulation was decreased with delay in sowing from timely (21 November) to very late (7 January).

In conclusion, delayed sowing caused marked reduction in growth parameters like plant height, dry matter accumulation and leaf area index through the reduction in duration of maturity. There are many factors responsible for reduction in growth factors but high temperature is one of the major factors which play vital role in the reduction of growth parameter.

2.2.2. Grain yield

Conducted an experiment at Gurdaspur (Punjab) on loamy sand soil and found that crop sown on 15 October was produced higher grain yield as compared to crop sown on 25 October, 4 and 14 November. The increase in yield was due to increase in effective tillers and 1000-grain weight of early sown crop [18]. However, from Ludhiana (Punjab), reported that grain yield was significantly higher of crop sown on 25 October as compared to crop sown in November and 5 December on loamy sand soil [19,20] **[Table–2]** . Another studies conducted on silty clay loam [17], loamy sand [35], sandy loam [28, 36, 37, 38] **[Table–3]** and loamy [39] soils found that grain yield was significantly higher of crop sown in the 1st week of November as compared to crop sown in December and January, respectively.

Table: 2. Effect of sowing dates on the grain yield and yield attributes of wheat

Treatments	Grain yield (qha^{-1})	Straw Yield (qha^{-1})	Tiller per meter row length	1000-grain weight (g)	Plant height (cm)
Dates of sowing					
November 15	45.3	69.9	89.4	38.3	78.5
December 20	31.6	49.2	75.1	37.6	71.6
CD (p=0.05)	2.2	3.0	3.2	0.5	0.8

Source: [20]

Table: 3. Effect of sowing dates on the grain yield and yellow berry incidence in wheat

Treatments	Grain yield (qha^{-1})	Yellow berry (%)*
Dates of sowing		
November 3	43.2	33.1 (31.0)
November 15	41.0	30.7 (26.5)
December 15	28.7	18.7 (10.8)
CV (%)	9.4	15.4
CD (p=0.05)	2.0	7.3

Source: [37]

- arc-sine transformed values
- figures in parenthesis are the original values

However, maximum grain yield was recorded from the crop sown on 15 November and significantly differed from crop sown in December and January on silty loam, sandy loam and loamy sand soils of Pantnagar, Kanpur and Ludhiana, respectively [20, 32, 33] **[Table–2]**. Similar results were reported from Chiplima [21]. From Jamalpur, Bangladesh [34] reported that higher grain yield was obtained from the crop sown on 20 November (1795.4 kg ha-1) than 20 October (653.8 kg ha-1), 5 November (895.5 kg ha-1), 5 December (1358.9 kg ha-1) and 20 October (771.2 kg ha-1). However, from Jharkhand [31] noted that grain and straw yield of wheat were significantly affected by the time of sowing. Delay in sowing beyond timely sowing (21 November) reduced the grain yield by 16.2, 37.4 and 59.9 per cent under moderately

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late (7 December), late (21 December) and very late (7 January) sown condition, respectively. The similar findings were reported from Ludhiana, Punjab [20] **[Table–2]**. Timely seeded crop produced maximum spike-bearing tillers m-2, grains per spike and 1000-grain weight. Similar results were reported from Hisar (Haryana and Ludhiana (Punjab) [20,25] **[Table–2]**. The wheat crop sown early consumed more photo-thermal units and helio-thermal units in comparison with late sown crop at physiological maturity. This could be explained by the fact that delayed sowing resulted in forced maturity of wheat because of high temperature prevailed during reproductive phase of the late sown crop. Due to that maximum grain yield was recorded in early sown wheat crop in comparison with late sown crop.

Conducted an experiment at Pantnagar on silty loam soil [30] and found that crop sown on 27 November produced significantly higher yield (36.6 q ha-1) as compared to crop sown on 27 December (33.7 q ha-1). The grain yield was higher due to significantly higher number of seedlings and effective tillers per unit area and more grain weight per spike and 1000- grain weight. Similar findings were reported from Ranchi, Bihar [26], Niphad, Maharashtra [40] and Ludhiana, Punjab [27] **[Figure–1]**, respectively. The grain yield of wheat under early sown crop could be attributed to better basic infrastructural frame work of plants in early sowing as supported by higher taller plants, dry matter accumulation, tillers per meter row length, number of effective tillers per unit area, number of grains/ear, 1000-grain weight, ear length, straw yield and also utilized higher growing degree days and photo-thermal units. Similarly, straw yield was significantly higher in early crop sown might be due to higher growth and development contributing characters such as plant height, dry matter accumulation, tillers per meter row length and number of effective tillers per unit area. However, conducted an experiment on sandy-loam soil and observed that highest grain yield was obtained from the crop sown on 1 December than November, December and January sown crop [29, 41]. Sowing time is one of the most important management factors involved in obtaining higher yield [44]. Timely sowing of wheat crop generally gives higher yield as compared to late sown crop. Late-sown wheat crop faces high temperature stress during ripening phase. Late planting reduces the tillering period and hot weather during critical period of grain filling lead to forced maturity thereby reduces the grain yield. The rate of dry-matter accumulation remains faster at higher temperature than at lower temperature. Spike dry weight increases due to the deposition of grain protein and carbohydrates, which are partially on the expense of, assimilate transfer from stem and root. Whereas, from Udaipur noted that grain yield was significantly higher of normal sown crop (37.7 q ha-1) as compared to early (33.6 q ha-1) and late sown crop (28.2 q ha-1). The grain yield was higher due to increase in effective tillers per meter row and grain weight/ear in normal sown crop [42].

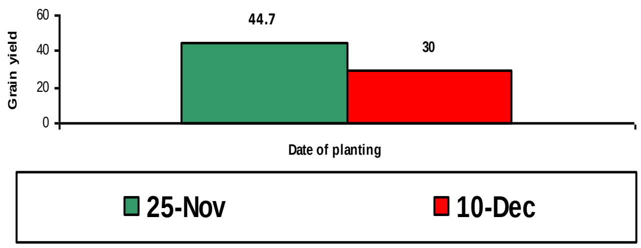

Fig: 1. Effect of dates of planting on grain yield of wheat. Source: [26]

In the end, it can be concluded that late sowing caused substantial reduction in biological and economic yield of wheat through the reduction in number of seedlings and effective tillers per unit area, more grain weight per spike, number of grains per ear head and 1000- grain weight irrespective of location and variety. It may be occurred due to the adverse climate change particularly high temperature during the reproductive stage and low temperature effect on germination.

2.2.3. Quality parameters

The late sown crop had maximum protein, ß-Carotene, gluten content, sedimentation value as compared to normal and early sown crop [28, 36, 38, 42, 43]. The lowest incidence of yellow berry was reported in wheat grains of 30 November sown crop [28, 43]. However, another an experiment conducted at Gurdaspur (Punjab) on sandy loam soil and reported that the incidence of yellow berry decreased significantly with successive delay in sowing from 3 November to 15 December [37] **[Table–3]**. Whereas, other experiment conducted at Jobner (Rajasthan) on loamy soil [39] and reported that sowing dates had no significant effect on grain appearance, test weight and sedimentation value during both the years of study. However ß-Carotene was higher in early sown crop (4.91 ppm) as compared to late sown crop (4.65 ppm). The yellow berry incidence was higher in late sown crop (6.49 %) as compared to early sown crop (5.74 %).

In general, it has been observed that the quality parameters such as protein, ß-Carotene content, gluten content,

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sedimentation value were higher in late sown crop; however, the incidence of yellow berry was lowest.

2.3. Effect of methods of planting

The selection of suitable method of planting plays an important role in the placement of seed at proper depth, which ensures better emergence and subsequent crop growth. Wheat is planted using different planting methods depending upon the available soil water, time of planting, amount of residue in the field and availability of planting machine.

2.3.1. Growth parameters

Conducted an experiment at Punjab Agricultural University, Ludhiana on loamy sand soil and observed that plant height and dry matter accumulation was significantly higher with bed planting method as compared to conventional method [45]. The similar findings were reported from Modipuram, U.P. [46] and Hisar [47, 48]. However, the leaf area index and dry matter accumulation was significantly more in wheat sown with bed planted method with 3 rows as compared to flat planting method [47]. The crop growth rate in bed planting was significantly maximum as compared to flat planting throughout the crop season. In another study from Hisar [49] reported that plant height was significantly higher in bed planted wheat (92.11 cm) in comparison to conventionally sown crop (83.23 cm). However, in another investigation from Hisar, it was observed that furrow irrigated raised bed sowing (FIRBS) resulted in less LAI as compared to conventional flat sowing during both the years [25]. Whereas, from Ludhiana reported that numbers of tillers, effective tillers per square meter and ear length were found to be highest in conventional tillage with mulching which was at par in crop sown with conventional tillage without mulching but significantly higher than zero tillage in standing stubbles after removal of loose straw [27].

It can be concluded that growth parameters such as plant height, dry matter accumulation and leaf area index were found higher in wheat sown with bed planting than conventional method. It shows modification in planting method could alleviate the adverse impact of high temperature during the reproduction stage of wheat.

2.3.2. Grain yield

Conducted field experiment on sandy-loam soil at New Delhi and noted that grain yield was maximum of wheat sown with bed planted method with 3 rows (53.06 q ha-1), which was at par with conventional planting method (50.85 q ha-1) and significantly superior to bed planted method with 2 rows (42.23 q ha-1) [54] **[Table–4]**. Yield of no-tilled sown wheat was poorer than conventional method of sowing, mainly due to failure of herbicide to control perennial and moisture stress [55]. The mean yield of winter wheat sown with direct drilling or shallow cultivation was about 10 and 7 per cent less, respectively, than after ploughing [56]. While from Bukua (Nigeria) reported that wheat grain yield was lower in zero tillage (1.5 t ha-1) than conventional tillage (1.83 t ha-1) sown crop on a sandy soil [57] probably due to low fertility and low water holding capacity of soil. Similarly, two year study conducted at Birsa Agricultural University, Ranchi during 1982-83 and 1983-84 on silty loam soil showed that wheat sown with conventional tillage after puddle transplanted rice gave 7 percent more grain yield than no-tillage [58].

Table: 4. Effect of planting system on grain yield of wheat

Planting system	Grain yield (tha^{-1})
Conventional	5.085
3 wheat rows per bed	5.306
2 wheat rows per bed	4.223
CD (p=0.05)	0.269

Source: [88]

The lower yield of wheat following rice under no-tillage was observed as compared to conventional tillage [15]. In another study found that no-tillage technique gives more grain yield (12.93%) and straw yield (15.84%) than conventionally tilled wheat [107]. This is because no-till planting allows the timely planting of wheat and so, reduce the estimated 1 per cent loss day-1 ha-1 of wheat yield due to late planting. However, 1 per cent increase in wheat yield with reduced tillage was recorded compared to conventional method [3]. Whereas, when early sowing was made more than 30 days before conventional sowing it increased yield by an average of 11 per cent. So, the objective behind introduction of wheat sowing without seedbed preparation was to improve wheat productivity by sowing wheat in time. This technology improves the grain yield by about 20 per cent over farmers practice entirely under farmers' conditions [2].

Zero, reduced and conventional tillage recorded statistically similar grain yield [92, 57, 20, 103]. In rice-wheat system, no-tillage increased wheat yield by 10 per cent over conventional tillage because of better number of tillers, better establishment and lesser weeds [4]. Similarly, recorded significantly higher grain yield under zero tillage [22, 67, 89, 104, 111] as compared with the yield obtained under conventional tillage. This increase was due to significantly higher effective ear head m-2 , grains spike-1 and spikes m-2 in zero tilled wheat crop. The higher yield and its attributes under zero tillage were due to advancement in sowing time offered by zero tillage [95}. In another study planting of wheat with zero tillage in standing stubbles after removal of loose straw, conventional tillage with mulching and conventional tillage without mulching produced the statistically similar grain yield. It might be due to the similar straw as well as biological yield under different planting methods [26] **[Figure-2]**.

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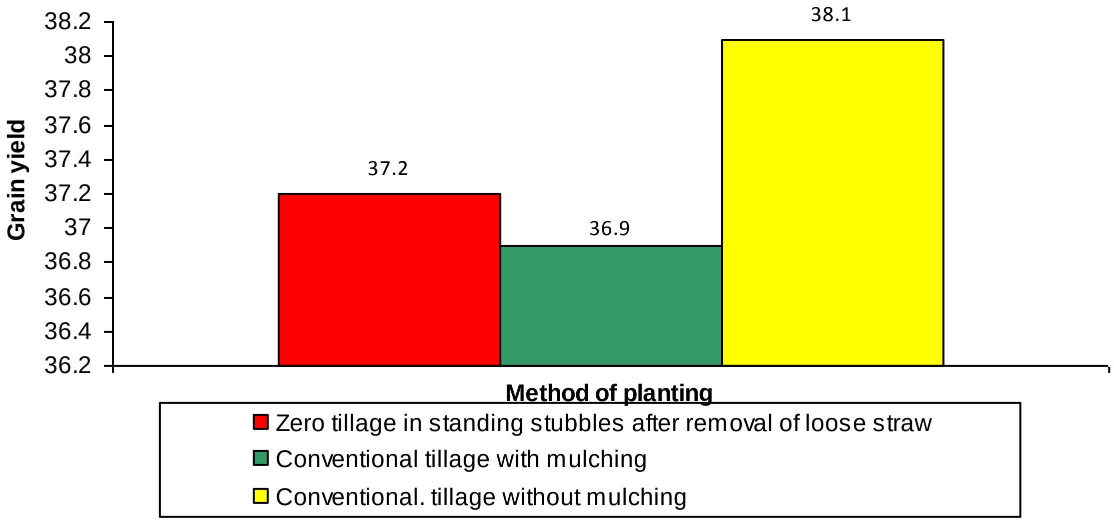

Source: [27]

Fig 2: Effect of methods of planting on grain yield of wheat

In the end it can be concluded that planting of wheat with zero tillage, bed planting and conventional tillage with mulching produced higher grain yield by proving these alternative methods of planting proved to mitigate the effect of high temperature during the reproductive stage of wheat.

2.3.3. Quality parameters

Conducted an experiment at Haryana Agricultural University, Hisar on sandy loam soil and reported significantly higher protein yield in bed planted wheat in comparison to conventionally sown crop [49]. However, the protein content was not influenced significantly due to planting methods. In another study from Hisar, noted that planting system did not affect significantly on protein content of wheat. Also the nitrogen uptake was not significantly affected by the planting methods [48].

From these studies it could be concluded that method of sowing of wheat could reduce the impact of climate change and improve the quality parameters of wheat.

2.4. Mulching

Mulching has been proved to be useful in conserving moisture and increasing productivity in wheat [70, 71, 72, 73, 74] **[Table–5, 6]**. Organic mulches provided better soil water status and improved plant canopy in terms of biomass, root growth, leaf area index and grain yield, which subsequently resulted in higher water and nitrogen uptake and their use efficiencies [75]. Mulching, when catch crop residues are spread and left on the soil surface between successive crops, is well-known and recommended practice for conserving soil and water [76, 77]. The main advantages of mulching are organic matter and nutrient supply.The slow release of nitrogen (N) from decomposing mulch residues is better synchronized with plant uptake than sources of inorganic N, increase N uptake efficiency and crop yield while reducing N leaching losses [78, 79, 80]. Mulched catch crops approach also long-term increases of soil organic matter and microbial biomass [81, 82, 83], further improving nutrient retention and N uptake efficiency. These favorable changes are the main reasons for increase in plant yields [84, 85, 86]. The other benefits are favorable changes in micro-climate within the crop fields and reduction in soil temperatures [87]. Plant residue protects the soil surface against the splash effect of raindrops, crusting and increases aggregate stability measured by wet-sieving. It was confirmed by observing the increase in the soil organic matter content, increased its stability and decreased soil surface sealing [88]. Organic matter addition increased macro porosity and water infiltration rates [89]. Much research has shown that use of surface mulch can result in storing more precipitation water in soil by reducing runoff, increasing infiltration and decreasing evaporation [71, 90, 91] **[Table–6]**. Mulched cover crops also may provide favorable microhabitats for useful insects [92]. Application of plant mulch combined with minimum tillage is known to be effective in reducing soil erosion, maintaining soil structure and conserving soil water in temperate as well as tropical regions.

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Table: 5. Effect of different treatments on biomass yield and grain yield of wheat

Year	Yield (qha^{-1})	Treatments				
		No straw mulch and no irrigation	Straw mulch and no irrigation	No straw mulch and irrigation 15 mm	No straw mulch and irrigation 30 mm	No straw mulch and irrigation 45mm
1997	Biomass	3356±390	4584 ± 350**	4500 ± 364**	4903 ± 510***	5556 ± 493***
	Grain	818 ± 125	1240 + 84**	1250 ± 104**	1384 ± 156***	1650 ± 131***
1998	Biomass	7120 ± 310	8563 ± 439**	9546 ± 480***	10970 ± 570***	12580 ± 520***
	Grain	2061 ± 199	2601 ± 203**	2520 ± 195**	2883 ± 228***	3230 ± 213***

Source: [71]
** statistical significance at p< 0.01 level, when compared to the t1 treatment within the same row and same year
*** statistical significance at p< 0.001 level, when compared to the t1 treatment within the same row and same year

Table: 6. Effect of straw mulch and irrigation on evapotranspiration and soil water depletion

Year	Factor	Treatments				
		No straw mulch and no irrigation	Straw mulch and no irrigation	No straw mulch and irrigation 15 mm	No straw mulch and irrigation 30 mm	No straw mulch and irrigation 45mm
1997	Evapotranspiration	239.2	219.5**	250.6 NS[a]	260.8**	271.1***
	soil water depletion	58.1	38.4***	54.5 NS[a]	49.7***	45.0***
1998	Evapotranspiration	369.6	355.3*	349.9**	338.8***	364.4 NS[a]
	soil water depletion	91.2	76.9***	71.5***	60.4***	85.7 NS[a]

Source: [71]
a statistical significance at p> 0.05 level, when compared to the t1 treatment within the same row and same year
* statistical significance at p< 0.05 level, when compared to the t1 treatment within the same row and same year
** statistical significance at p< 0.01 level, when compared to the t1 treatment within the same row and same year
*** statistical significance at p< 0.001 level, when compared to the t1 treatment within the same row and same year

In conclusion, use of organic mulches provided better soil water status and improved plant canopy in terms of biomass, root growth, leaf area index and grain yield, which subsequently resulted in higher water and nitrogen uptake and their use efficiencies and may reduce expected reduction of economic yield under adverse climate during reproductive stage of wheat.

2.4.1. Foliar spray of chemical

In recent past some encouraging results were obtained with post flowering foliar application of various nutrients on yield of wheat. The higher grain and straw yield of wheat by spraying 0.5 per cent KNO_3 at 50 per cent flowering stage of the crop was reported [93], a number of studies have been conducted [94, 95] confirming the results . The beneficial effect of NO_3- in delaying synthesis of abscisic acid and promoting cytokinin activity [96] and of K+ on photosynthesis, carbohydrate redistribution and starch synthesis in storage organs [97, 98] were presumed to be responsible for higher grain yield. It has been revealed that NO_3- and its counter ions, both K+ and Ca_2+ gave beneficial effect on grain filling and yield of wheat when applied as foliar spray at 50 per cent flowering stage of the crop [99]. Crop sown on 25 November with zero tillage in standing stubbles after removal of loose straw and one foliar spray of KNO_3 (1%) during anthesis was at par in grain yield than those obtained with conventional tillage without mulching + two foliar spray of KNO_3 (1%) during anthesis produced the statistically similar grain yield [27, 100]. However, one foliar spray of KNO_3 (1%) during anthesis gave the highest grain yield followed by two foliar spray of KNO_3 (1%) during anthesis as compared to one extra irrigation during post anthesis and recommended irrigation **[Figure–3]**. A study was designed to explore the role of arginine (0.0, 2.5 and 5.0 mM) in increasing the tolerance of wheat cultivar (Sids-93) to two late sowing (23/12 and 23/1) besides the normal sowing date (23/11) in Egypt [101]. Foliar application of arginine with 2.5 and 5.0 mM on normal or delayed sowing wheat exhibited significant increment in yield and its components in comparison to untreated plants. The magnitude of increments was much more pronounced in response to 2.5 mM of arginine which induce 19.23, 20.53 and 25.51 per cent increases in economic yield per feddan at normally, 30 and 60 days delay, respectively. As well as results show that 2.5 mM arginine treatment induce 8.0 per cent increase in grain yield over the plants sowing late at 23/12 and could reduce the reduction per cent in grain yield from 41.22 to 26.22 per cent at 23/1 sowing

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date.

2.4.2. Foliar spray of micronutrient

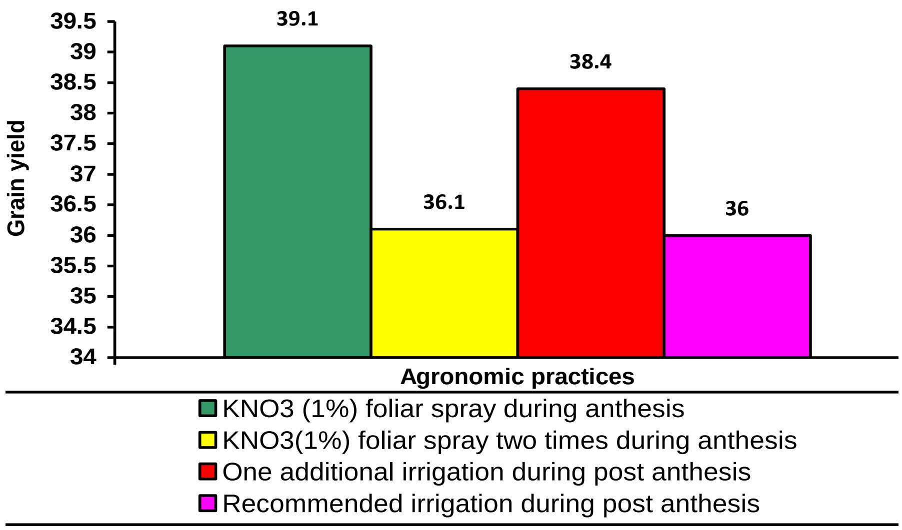
One of the reasons of reduction of crop yield is insufficient supply of micronutrients. Zinc is one of those micronutrients which have an important role in metabolic activities of the most plants. On the other hand, its mobility is low under drought stress conditions, so this element can be sprayed to increase its intake in the plant. It showed that the highest grain and biological yield during the conditions of normal irrigation and spraying with the zinc is 62.40 and 143.00 qha-1, respectively and the lowest of 38.00 and 122.00 qha-in the conditions of discontinuation of irrigation at flowering stage and lack of spraying zinc [102]. On the other hand, application of zinc spraying in drought conditions causes the increase in number of grains per spike, grain weight and harvest index, comparing with the lack of spraying. The spraying the zinc in normal irrigation conditions, especially in drought stress conditions have significant positive effects on yield and yield components of wheat.

2.4.3. Use of extra irrigation water

Additional irrigation over recommended frequencies resulted in increased yields in Sudan and Mexico. In Sudan, increasing irrigation frequency from 14 days to 10 days were increased yields 10 percent, while frequencies of 7 days resulted in an increase of 29 per cent. In Mexico, application of 600 mm of water gave control yields of 3.1 t ha-1, while an extra 150 mm during grain filling gave a 13 per cent yield increase (3.5 t ha-1). Although an extra irrigation did not have any main effect in Bangladesh, extra irrigation with a deep tillage treatment increased yield by 11 per cent. Extra irrigation had no significant effect on plant traits or yield in Bangladesh. In Sudan, increased grain yield in response to extra irrigation was associated with higher harvest index and a tendency for higher 1000-grain weight relative to the control. With extra irrigation in Mexico, yield increases of 13 per cent were associated with similar increases in grains per unit area and biomass at maturity, as well as 2 days delay in maturity [103]. The effects of irrigation on crop production are usually quantified using crop water production functions which relate crop yield to amounts of water applied [104, 105]. The rational irrigation can considerably increase the grain yield [71, 106, 107]. It was also asserted that excessive irrigation delays the maturity, harvesting and decreased grain yield [107]. However, it was also reported that excessive irrigation led to a decrease of crop WUE and that effective deficit irrigation may result in higher production and WUE [108]. On the contrary, it showed that the effect of irrigation on wheat yield was almost solely due to increased transpiration, while WUE and harvest index remained unaffected [109]. It is also indicated that the responses of grain yield and WUE to irrigation varied considerably due to differences in soil water contents and irrigation schedules [110]. It concluded that the impact of limited irrigation and soil water deficit on crop yield or WUE depend on the particular growth stage of the crop [111]. However, the crop sown on 25 November with conventional tillage without mulching with one additional irrigation during post anthesis, conventional tillage with mulching + one additional irrigation during post anthesis and conventional tillage with mulching + recommended irrigation gave the similar grain yield of wheat [27,100] **[Figure–3]**.

2.4.4. Use of potassium fertilizers with municipal waste water

A cadmium level is significant in most urban and industrial waste waters. Hence its accumulation in crops which are irrigated by the urban waste waters is investigable. On the



Source: [27]

Fig 3: Effect of agronomic practices on grain yield of wheat

application of potassium fertilizer reduce cadmium uptake in plants. Conducted an experiment with three levels of potassium fertilizer (0, 200 and 400 kgha-1 potassium sulfate) [112]. The results showed that application of potassium fertilizer on wheat grains has decreased cadmium uptake of 0.57 to 0.18 mgkg-1 and also after using potassium fertilizer on wheat straw, the amount of cadmium was decreased from 0.91 to 0.54 mgkg-1. On the other hand after potassium consumption, the percentage of grain protein was also significantly increased from 10.45 to 12.63 per cent. As consumption a large amounts of potassium causes a significant reduction in grain cadmium concentrations, so although potassium intake may not be economically justified, but its application is justified due to the reduced absorption of cadmium and health of crops.

In the end, it could be concluded that the foliar spray of KNO_3 (0.5%) at 50 per cent flowering stage, 1.0 per cent KNO_3 during anthesis stage, 2.5 mM of arginine, spray of zinc, extra irrigation water during grain filling stage, use of potassium fertilizers with municipal waste water could alleviate the adverse impact of high temperature on wheat.

[III] CONCLUSION

From the investigations of various workers, it can be concluded that the adoption of agronomic practices like Seed priming, timely planting , zero tillage, conventional tillage with mulching and bed planting, one additional irrigation in conventional with and without mulching during post anthesis, Foliar spray of 0.5 per cent KNO_3 at 50 per cent flowering stage or 1.0 per cent KNO_3 during anthesis in zero tillage and conventional tillage, use of organic mulch, foliar spray of zinc in normal irrigation conditions and drought conditions, use of potassium fertilizer with waste water can alleviate the adverse impact of high temperature on wheat.

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