Abstract

With the change in climate patterns, the world is encountering the threat of drought. Since major wheat-producing countries are situated in drier parts of the world and depend on monsoon rain for wheat cultivation so drought is becoming a serious drawback for wheat production. In this review, previous works were assessed to explore the effects of drought stress on yield and yield-attributing characters of wheat. The plant modifies its physio-chemical processes in response to moisture deficiency so the yield attributing characteristics like plant height, spike length, no. of spikes per unit area, no. of spikelets/spike, no. of grains/spike, biomass yield, harvest index, test weight, etc. are affected ultimately reducing the grain yield. The extent of loss of yield differs among genotypes and the developmental stages of the crop and is characterized by various soil, plant, and environmental factors. Owing to the alliance of yield with the genetic make-up of the crop, drought stress, and its effect are not the concern of only agronomists but rather also of plant breeders. Wheat is the backbone of various food-based and feed-based industries so the enhancement in the production of wheat is a must for the sustainability of the growing population. The article exclusively focuses on the hazards of drought on yield and yield-attributing factors as it is the major concern of many present-day breeders as well as world leaders.

Keywords: Drought, yield, yield components, wheat

Introduction

Wheat is the principal cereal crops cultivated in the world and consists of 1/5th part of the entire human food calories (Ali et al., 2012; Muhammad Farooq et al., 2014; Hawkesford et al., 2013) whereas, in Nepal, wheat is the second most human-consumed food grain after rice and follows rice and maize ranking third in overall consumption (Khatri et al., 2017). According to Ben-ari & Makowski, 2014, wheat production is more distributed than rice and soybean. Wheat is thought to have been domesticated from about 11,000 and 9500 years before (Lev-Yadun et al., 2000; Wang et al., 2017). Derived from South Western Asia (Ali et al., 2012) and extended to major parts of the world, it contributes 30% to the food crops in the world and is taken as the staple food by more than 10 billion people so it is listed as a first cereal crop in the global context (Ali et al., 2012). The wheat has wide use in making bread, cookies, crumpets, flake, flour, people also prefer to consume wheat grain as roasted grain and it is of great importance to feed the livestock due to high nutritional value (Pandey et al., 2020). The wheat production in the world is estimated to be 760.1 million tonnes (FAO, 2020).

The developed nations have a 14% increased yield of wheat than the developing ones due to irrigation provided to wheat. (Shiferaw et al., 2013). According to MIRCA (2000), the total percentage of land irrigated under wheat is only 31.1% (Portmann et al., 2010).

Drought stress is the major abiotic cause for the yield reduction (Budak et al., 2013; Tabassam et al., 2014) in wheat as it is grown under rain-fed conditions in arid and semi-arid regions in major parts of the world (Boyer, 1982). By 2025, around 1.8 billion people are likely to encounter an absolute water shortage, and about 65% of the world population have to survive in water stress environment (Nezhadahmadi et al., 2013). About 32% of wheat is exposed to different types of drought stress during its growth period in developing countries (Keyvan, 2010). Drought stress creates detrimental effects in plants as plants adopt new physio-chemical processes to overcome the stress. The morphology, physiology, biochemistry, and growth of the plants are altered by the drought stress which ultimately causes yield loss. The primary effect of drought is weakened germination which results in the wretched crop stand establishment (Kaya et al., 2006). The
stress, at different developmental stages, can decrease cell expansion and division, alter the opening and closing of stomata, pigment formation, water, and nutrient uptake, protein structure, antioxidant production, hormone composition, cuticle thickness, chlorophyll content, etc. adversely affecting the yield components i.e. plant height, number of plants per unit area, number of spikes per plant and no. of grains per spikes per plant (Mehraban et al., 2019; Nezhadahmadi et al., 2013). Wheat during grain filling, when exposed to drought stress darts leaf senescence (Habuš Jericic et al., 2018; Yang et al., 2003), decrease grain filling period and hence reduces the mean weight of the grains due to remobilization of photoassimilates, nitrogen stored before anthesis (M. Farooq et al., 2009; Giunta et al., 1993; Waraich et al., 2007), and shortened life cycle. The yield and yield-related traits are affected by drought stress due to pollen abortion, reduced food reserves and development of sterile tillers (Qaseem et al., 2019) and reduced shoot biomass (Ashraf & Khan, 1993).

The article focuses on the impacts of drought stress on the yield and yield components of the wheat. Believing that it will help to understand the graveness of the problem, we have tried to entitle the causes of the bleak outcome of yield and yield-related traits. In today's context when the population is rising geometrically; if the crop yield decreases due to climatic factors the hungry population will rise hence the paper outlines some aspects of drought stress on yield-related trait so the energies would be focused on increasing the yield of the wheat from the present land rather than increasing the land under wheat.

Methodology

The latest research papers and review papers suitable for studying effects of drought stress on yield and yield-components of wheat were collected through various national and international journals. Also, the statistical data were collected from international organizations like FAO for more accurate information. All the findings present in this paper are secondary information extracted from above-mentioned sources.

Effects of Drought on Yield and Yield-attributing Traits

Yield is the measurement of product harvested per unit area, generally measured in terms of tons/hectare. The characters or traits of the plants that contribute to the yield of the concerned plant are known as yield-attributing traits of plant. In the context of wheat, plant height, spike length, no. of spikes per unit area, no. of spikelets per spike, no. of grains per spike, biomass yield, harvest index, and test weight are said to be the characters that influence the yield of wheat. The yield attributing traits are inter-related with each other and with the yield hence any variation in the above-mentioned traits causes changes in the yield of wheat.

Plant Height

Drought stress negatively affects plant height of all wheat irrespective of species or cultivars (Kilic and Yagbasanlar, 2010) but the severity is highest in terminal drought followed by tillering drought, pre-flowering drought, and post-flowering drought (Mirbahar et al., 2009; Saleem, 2003). The height of wheat is significantly affected if exposed to drought stress from one-leaf stage to the floral initiation stage which results in the low accumulation of dry matter and finally reduced plant production (Moayedi et al., 2010). The protoplasm is dehydrated and loses its turgidity during a drought so cell elongation, expansion, and mitosis is effected and also the plant sheds its leaves to prevent moisture loss ultimately diminishing the height of the plant (Ghulam et al., 1999; Hussain et al., 2008; Khakwani et al., 2012; Nonami, 1998).

Spike Length

Spike length, though vaguely affected by drought stress as compared to other yield attributing characters (Kilic & Y?basanlar, 2010), it is reduced in all wheat cultivars to some extent depending on the time of application of drought (Saleem, 2003). The lack of moisture regime before flowering causes severe decrement of spike length. The effect of drought on spike length is more pronounced after the 6th week of emergence rather after immediately sown (F. Nawaz et al., 2012). The spike length responds most adversely to the terminal drought followed by drought after the tillering stage, pre-flowering drought and finally post-flowering drought (Mirbahar et al., 2009).

No. of Spikes Per Unit Area

The no. of spikes is one of the major yield components affecting the grain yield which is affected by drought stress (Kiliç & Y?basanlar, 2010). The depressed soil water potential value during stem elongation or degraded survivability of tillers during grain filling is regarded as the cause of the decreased no. of spikes per unit area (Giunta et al., 1993). The utmost serious by drought stress is witnessed during the anthesis stage whereas the drought implied before or after anthesis does not cause graveness as at the anthesis stage (Guttieri et al., 2001; Khan & Naqvi, 2011; Moayedi et al., 2010; Saeidi & Abdoli, 2015) as the potentials of spikes are formed before spike initiation stage (Araus et al., 2002).
No. of Spikelets/spike

The number of spikelets per spike is one of the chief factors determining the total yield of the plant and it is highly affected by drought(F. Nawaz et al., 2012). When Qaseem et al. (2019) exposed bread wheat to drought stress before anthesis, the spikelets per spike was greatly reduced which was also noted by Mirbahar et al., (2009) as he obtained less no. of spikelets per spike from the field of pre-flowering drought than the post-flowering drought. Also, Moustafa et al., (1996) concluded that drought stress at the tillering stage causes less effect to the no. of spikelets per spike than at the heading stage. According to Ghulam et al., 1999 drought stress, either at vegetative or at the reproductive phase show an equal silencing effect on spikelet no. per spike. The drought stress also increases infertile spikelets per spike in wheat(Akram et al., 2004; Den?i´den?i´c et al., 2000).

No. of Grains/spike

The no. of grains per spike in wheat under drought stress is surpassed by the irrigated wheat(Giunta et al., 1993; Kiliç & Ya?basanlar, 2010).Ehdaie et al. (1988) noted that among all the yield components, no. of grains per spike was most intensely affected which was in accordance with Fischer & Maurer (1978), Gutteri et al.(2001) and Zhang et al. (2006). The relative water content of the plant is positively and significantly related to the no. of grains per spike so the cultivar with high RWC has higher tolerance in drought and reduction in grain no. is low. Hence, the no. of grains in a spike is differently reduced in different cultivars(Khakwani et al., 2012). Though the extent of reduction is different, all types of wheat show the reduction in no. of grains per spike if exposed to drought stress(Saleem, 2003). The terminal drought affects the no. of grains held by a spike, the most thereafter the pre-flowering drought and post-flowering drought(Mirbahar et al., 2009; Moayedi et al., 2010; Qaseem et al., 2019). The potentials of spike and no. of spikes per grain is formed before spike initiation(Araus et al., 2002) so drought applied at the heading stage causes significant variation in no. of grains per spike than at the tillering stage (Abid et al., 2018; Moustafa et al., 1996) and no effect after anthesis(Plaut et al., 2004). The lack of fertilization of egg which causes underdeveloped ovule is often credited with the reduced grain number. The drought stress during the pollen development phase produces sterile pollen so the fertilization is disturbed(Manjarrez-Sandoval et al., 1989).

Grain Yield

The yield components like plant height, spike length, effective tillers/m², no. of grains/spike shows a linear relationship with grain yield and hence yield is the most affected factor by drought(Kiliç & Ya?basanlar, 2010; F. Nawaz et al., 2012; Qaseem et al., 2019; Sutton & Dubbelde, 1980; Thompson & Chase, 1992). The taller plant has deeper root penetration so there is the optimal utilization of water and more stored assimilates, both of which lacks during a drought so the yield is reduced(Almeselmani et al., 2011). The grain yield of all the wheat genotypes decrease despite the superiority of the genotypes if exposed to drought(Nouri et al., 2011; Öztürk & Korkut, 2018; Saleem, 2003) but the cultivars are less affected than the landraces obtained from different countries(Den?i´den?i´c et al., 2000). The drought causes more relative decrement in grain weight than the no. of grains and hence the pronounced reduction in the yield of the wheat under drought stress is because of reduced weight of grain rather than less no. of grains(Giunta et al., 1993). Thedrought applied after the anthesis period causes less reduction in wheat yield than the drought at anthesis and graining(Muhammad Farooq et al., 2014; A. Nawaz et al., 2013; F. Nawaz et al., 2012) because of decreased carbon fixation and assimilate translocation(Asada, 2006), decreased grain set and grain filling(A Ahmadi & Baker, 2001; A. Nawaz et al., 2013). The leaf senescence is quickened in the absence of a significant amount of water(Senapati et al., 2019) so the scarcity of water interrupts leaf gas exchange processes which causes the limitation of the size of the source and sink tissues ultimately hampering translocation of assimilates(Anjum et al., 2011; M. Farooq et al., 2009; Jaleel et al., 2009). Grain yield is more affected by water used during anthesis than the total amount of water(Den?i´den?i´c et al., 2000; Passiouura, 1977). The cutback in the grain yield because of drought stress after the anthesis phase is due to the reduction in photo-assimilates production, the ability of the sink to absorb photoassimilates, and grain filling duration. Since the initial grain growth and development phases are least affected under the post-anthesis drought, the reduction of grain yield during this phase reveal that a low amount of photo-assimilates are supplied for grain filling(Ali Ahmadi & Siosemardeh, 2005; Bahman Ehdai et al., 2006; Saeidi & Abdoli, 2015). And, the contraction on yield is profound when stress is applied at the heading stage than at tillering(Moustafa et al., 1996). The drought stress interferes with the growth and photosynthesis processes of the plants which are regarded as the major cause of reduced grain yield(Almeselmani et al., 2011).
Biomass Yield

The inclination of biomass indicates the increment in photosynthetic organs above the ground, stem and yield components that causes increased yield but the leaf expansion and leaf development are hampered by the water deficit (Anjum et al., 2011) so the biomass yield is reduced by drought stress (Alexieva et al., 2001; Taheri et al., 2011). The decrement in grain yield followed by plant height is regarded as the principal cause of biomass reduction in wheat (J. Zhang et al., 2018). Although the biomass yield reduction is different between irrigated and stressed fields, it is not even among the genotypes of the same field (Saleem, 2003). The biomass production is directly proportional to the photosynthesis but the leaf senescence is hastened in lack of water (Senapati et al., 2019) and also, the assimilates production is lower under drought and hence are either absorbed or stored by the source (Abdoli & Saeidi, 2013), so the biomass yield is reduced under drought stress.

Harvest Index

Harvest index is the ratio of grain yield to biological yield which determines the capacity of plants to translocate physiological matters to grains (Moayedi et al., 2010) so the harvest index is substantially affected by the stressed conditions (Giunta et al., 1993; Qaseem et al., 2019). The harvest index shares a positive relationship with grain yield and negative with total biomass. The economic yield of wheat is reduced during stress conditions so the harvest index is reduced when wheat is exposed to drought. The sink size decreases under the stress treatment so the demand for assimilates is reduced causing retention of assimilates in the vegetative organ so the harvest index of wheat under drought stress declines (Giunta et al., 1993).

Test Weight

The test weight is differently affected by drought at different phenological stages; most adversely at drought after tillering, then before flowering, and least by drought after flowering (Akram et al., 2004; Mirbahar et al., 2009; Moayedi et al., 2010; F. Nawaz et al., 2012). The 1000 grain weight is the united effect of length of the spike, fertile spikelet number, grain weight per spike and number of grain (B. Zhang et al., 2006). The negative relationship is found between 1000-grain weight and no. of grains per spike i.e. reduced no. of grains per spike under drought means increased grain weight so the minimum reduction is found in the mean values of 1000 grain weight as compared to other yield components. This may be due to the distribution of the accessible assimilates to fewer amount of seeds resulting in improved grain filling (B. Ehdai et al., 1988; Ghulam et al., 1999; Giunta et al., 1993; Moral et al., 2003). But, sometimes the nutrient uptake efficiency and translocation of photosynthates might be disturbed resulting in the production of shrunken grain because of accelerated maturity forced by stress causing a significant decline in 1000 grain weight of wheat (Khakwani et al., 2012).

Conclusion

Drought is the most serious, yet a most common problem to the global wheat producers and the ongoing climate change is adding fuel to it. Drought stress affects plant height, plant biomass, no. of spikes, no. of spikelets, and ultimately grain yield. Though all the yield components of all wheat genotypes are negatively affected under drought, the intensity of effect varies. The extent of the effect of drought stress on crops relies mostly on parameters such as; phenological stage of crop, intensiveness, and time period of drought stress. The response of wheat to drought stress may also be affected by morphological traits of the plant such as; effective no. of fertile tillers/plant, no. of spikes/m2, no. of spikelets/spike, no. of grains/spike, test weight, spike length, spike weight, and biomass. The crop yield is extremely diminished when drought occurs in the heading or flowering stage. The response of the plant to drought also differs based on the distribution of rainfall, evaporative demands, and moisture storing capacity of soil. Following the water shortage plant responds physiologically to adjust the environment causing the closure of stomata, decreased photosynthesis, low distribution of photo-assimilates so the yield and yield-components of wheat are reduced ultimately by drought stress.

The crop embraces physio-chemical and/or phenological changes to surpass the drought period. The wheat should be well irrigated during the water-sensitive phenological stages. The extent of effects of drought in yield and yield-components of wheat is well known but the agro-morphological changes are the result of physio-chemical modifications on the molecular level. The ground level changes in a plant cell that harms yield and yield-attributes should be identified to cure the effects of drought from the root.
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References


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