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A study of some weeds of Pakistan and their response to abiotic stress - a review

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Abstract

Weeds are invasive plants that compete the crops and native plant species for space, moisture, and available nutrients in the environment. Weeds are subjected to a variety of biotic and abiotic stresses. Abiotic stresses are inevitable and have resulted in extremely harmful factors influencing weed and crop plants growth and development. Abiotic stresses such as drought, salinity, and temperature fluctuations cause weeds to undergo a variety of anatomical, physiological, morphological, biochemical, and genetic changes as a response to harsh environmental conditions. To cope with these abiotic stress conditions, various weeds employ various strategies such as the production of heat shock proteins, activation of stress genes, antioxidant stress mechanisms, increases or decreases in amino acid metabolism, decreased photosynthesis, membrane leakage, production of super oxides, and so on. In this review article we have mainly focused on the ten most important and aggressive weeds i.e *Cynodon dactylon* (L.) Pers., Phalaris minor Retz., Desmostachya bipinnata (L.) Stapf, Sorghum halepense (L.) Pers., Echinochloa colona L., Cannabis sativa L., Imperata cylindrica (L.) P. Beauv., Sonchus oleraceus L., Carthamus oxyacantha M. Bieb, Fimbristylis littoralis Gaudich invading different areas of Pakistan and their response towards abiotic stresses. Although many studies have been conducted to evaluate the morphological, anatomical, physiological, and biochemical response towards abiotic stress in weeds. However, more research into the main mechanisms behind abiotic stress tolerance is still needed.

Keywords: Abiotic stress, Drought, Salinity, Temperature stress, Weeds

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Introduction

Plants are immobile sensitive organisms that experience different sorts of environmental stresses during their life cycle (Gill & Tuteja, 2010; Pandey & Gautam, 2020; Sachdev et al., 2021). Environmental stress conditions such as heat and cold, salinity, and drought greatly affect the growth and development of plant. Among these abiotic factors, the most important factor is water availability that in broader sense encompasses both salt and drought stress (Basit et al., 2019; Vishwakarma et al., 2019). Drought and salinity are spreading across many regions of Pakistan causing salinization of major portion of arable land (Matloob et al., 2020). Drought, salt stress, high and low temperature are the significant problems faced by plants as these adverse environmental conditions greatly affect the genetic potential of the plants leading to a variety of anatomical, morphological, biochemical, physiological and molecular changes adversely affecting the growth and productivity of plant (Fig. 1) (Bray, 2000; Wang et al., 2000). Salinity, drought, oxidative stress and extreme temperatures are occasionally interconnected and may produce similar effects on plants (Rodríguez et al., 2005; Ashraf et al., 2018; Gull et al., 2019).

Nutrient deficiency may pose a major problem to plants striving to manage and survive in cold, heat, salinity and drought stress. Similarly, restricted availability of crucial elements such as copper, iron, zinc, and manganese which are essential for the proper functioning of defense enzymes including ascorbate peroxidase or superoxide dismutase may result in elevated oxidative stress in plants exposed to abiotic stresses. Therefore, resources and energy are essential for plants adaptation to abiotic stress conditions (Mittler, 2006; Zulfiqar et al., 2020). Weeds are the unwanted plants that invades crops ultimately reducing crop production. In an agricultural ecosystem, crop-weed interaction is the most common biological concern related to the yield and production of a crop (Arshad Javaid & Shoaib; Shabbir et al., 2018; Basit et al., 2019; Butt et al., 2021).

Weeds compete with crops for space, nutrients, light, moisture and growth factors through allellopathy and inter specific competitions. Weeds possess the ability to rapidly disseminate in a vast area, compete and effect the crops and native plant population (Hadi et al., 2014; Inayat et al., 2014). The yield reduction of the crop by weeds depends upon the type of weed, timing of emergence, density, soil characteristics and environmental factors (Chhokar et al., 2007). Similarly,

dynamics of weed population in arable lands are also influenced and regulated by environmental characteristic, soil characteristic, crop rotation and management practices (Koocheki et al., 2009). Major weed flora of the world belongs to the families like Poaceae, Asteraceae, Fabaceae and Amaranthaceae. Weeds also depend on the local climatic conditions of the area. They are associated with clogging water channels, increasing harvesting costs and fire hazards (Rajpar et al., 2010; Ullah et al., 2014). Loss in crop yield and production due to weed competition are much higher than those resulting from the consolidated effect of plant diseases and insects. Weeds may stimulate the development of various plant diseases, act as an alternate host for plant pests and present shelter to plant insects (Marwat et al., 2010; Ullah et al., 2016).

Tillage is a common practice followed in agricultural fields changing the mechanical features of the seedbed that can influence weed and crop emergence. Tillage alters the weed seed distribution in soil affecting the weed population dynamics (Yenish et al., 1992). In spite of the advances in control technologies, weeds have maintained their position as the greatest crop damaging pest as weed communities have tremendous ability to adapt to the new management practices (Sosnoskie et al., 2006; Hashim et al., 2019). Weeds have evolved various complex mechanisms including certain physiological and biochemical changes and processes to tolerate abiotic stress conditions such as chilling and freezing stress, high temperature stress, drought and salinity stress etc. In this article we have summarized the abiotic stress tolerance mechanisms adopted by some predominant weeds of Pakistan.

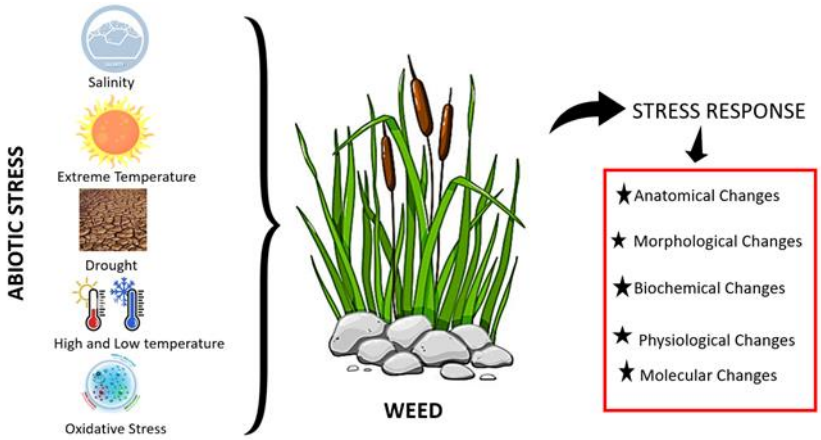

Fig 01: Abiotic Stress response in weeds

***Cynodon dactylon* (L.) Pers**

Cynodon dactylon (L.) Pers also known as Bermuda grass is famous by the name of Dhaka grass, lawn grass or khabbal ghas in Pakistan (Chen et al., 2019). It is a perennial grass that belongs to the family Poaceae. It is widely distributed in warm temperate and tropical areas (Chaudhary, 1989). Bermuda grass has a creeping habit and spreads rapidly by means of seeds, rhizomes or stolons. It may occur around road sides, ditches, arable lands but it is very problematic as a weed in many crops (Rochecouste, 1962). Naturally occurring populations of Bermuda grass have extensive genetic variations for tolerance to abiotic stresses such as soil temperature, drought and salinity (Speranza, 1995). Bermuda grass is known to adapt to the diverse cultivation conditions around the world but knowledge about Bermuda grass stress response is limited due to the lack of genetic information. Drought and salinity are two important environmental stress factors that seriously affect the growth and development of plant. Its growth is encouraged by salinity level and it can tolerate relatively high salinity level (Mass, 1977; Mansoor et al., 2010). Being one of the most widely cultivated warm season grass, *Cynodon dactylon* (L). Pers displays serious natural variations in drought stress resistance in stems and leaves of various varieties. It was revealed by the comparative analysis of these varieties that alteration of water status, antioxidant stress mechanisms and osmolyte accumulation during drought stress might be involved in the natural variation of drought resistant burmudagrass. But the molecular mechanisms behinds the Bermuda grass drought stress response still remains unknown (Shi et al., 2014). As Bermuda grass is tolerant to salinity, drought and heat stress but its growth is seriously affected by chilling and freezing environmental conditions. Low temperatures i.e. cold stress includes chilling temperature i.e. below 20^0C and freezing temperature i.e. below 0 ˚C terribly effects *Cynodon dactylon* (L.) Pers by disrupting cellular hemostasis leading to cellular damage impairing its development and growth (Tester & Langridge, 2010; Varshney et al., 2011). Several metabolic and physiological changes due to cold stress in Bermuda grass such as protein synthesis, dehydrin and chitinase expression, amino acid metabolism etc. have been identified by some research groups previously but the early signal transduction response in Bermuda grass due to cold stress is still unknown (Anderson et

al., 2002; Gatschet et al., 1996; Munshaw et al., 2010; Shi et al., 2014).

***Phalaris minor* Retz.**

Phalaris minor is an herbaceous monocot plant. It is a germinaceous weed that belong to the family Poaceae. It is commonly known as little seed canary grass, Dumbisitti, Mandusi and gullidanda etc. Its propagation occur by seeds (Xu et al., 2019). It grows in winter season and is present in the fields of different plants especially pea field, vegetables, cereals, sugar beet and orchards and is a very aggressive weed of wheat, barley and oat in Pakistan (Singh et al., 1999; Ahmadi et al., 2013). It can also be seen along road side, dairy farms, near water channels, streets and waste lands etc. Its presence can be observed worldwide except North Pole and Antarctica. It resembles a lot to wheat plants until flowering stages and it is very hard to differentiate it from wheat plant during early growth phases (Yasin, 2011; Yasin et al., 2011; Singh et al., 2019). Drought and salinity stress greatly decreases seedling strength, chlorophyll and carotenoid content, total soluble proteins along with a rapid and intensified increase in total soluble sugars and membrane leakage were observed in *P. minor*. However, *P. minor* has evolved in many ways to increase its survival chances under abiotic stress conditions such as by increasing total soluble sugar content in shoots *P. minor* is able to tolerate abiotic stress to some extent (Sethi & Kaur, 2016).

***Desmostachya bipinnata* (L.) Stapf.**

This weed is also known as sacrificial grass belongs to the family Poaceae. It is a serious weed in Pakistan that spreads very aggressively by means of rhizome (Vivekanandarajah & Rajamanoharan, 2021). It is predominant in arid and semi-arid areas of Pakistan (Shakila et al., 2014; Shaltout et al., 2016). Plant growth is greatly inhibited during saline conditions which might be due to the hindrance in the process of photosynthesis that are linked to stomatal limitations decreasing Carbon dioxide assimilation and maintenance of tissue water status (Chaves et al., 2009). Decrease in fresh weight of *Desmostachya bipinnata* (L.) has also been observed in increased saline conditions due to high energy consumption to survive in environmental stress. Shoot xylem pressure and leaf as osmotic potential decreases with increased salinity (Munns & Gilliham, 2015). Biochemical and photochemical reactions along with stomatal obstruction greatly effects the photosynthetic activity of plants (Kosová et al., 2013; Asrar et al., 2017). Decrease in photosynthesis due to reduction in chlorophyll content and chloroplast membrane protein complexes has also been observed in *Desmostachya bipinnata* (L.) in increased saline conditions. Production of Superoxide dismutase is considered as first line defense mechanism against reactive oxygen species in plants. The production of Superoxide dismutase, and total content of proline, soluble sugar and phenol increases in *Desmostachya bipinnata* (L.) during salinity stress (Alscher et al., 2002; Ferrante et al., 2011; Adnan et al., 2016; Asrar et al., 2020).

***Sorghum halepense* (L.) Pers.**

Sorghum halepense commonly known by the name of Johnson grass is a perennial grass that belongs to the family Poaceae. It is considered to be one of the top ten most invasive and aggressive weeds of the world (Paterson et al., 2020; Sakran et al., 2021). It grows rapidly in natural settings and crop fields and suppresses the growth of plants. Excessive seed production, rhizome system and high sprouting ability of fragmented rhizomes with the ability to grow in a wide range of environments plays major role in the invasiveness and competitive success of *Sorghum halepense* (Abdul-Wahab & Rice, 1967; Holm et al., 1977; Majumdar & Sanwal, 2017). Decrease in soil water causes several morphological and physiological changes such as root mass fraction and gas exchange mechanism in *Sorghum halepense* (Heschel et al., 2004; Leguizamón et al., 2011). During water competition *Sorghum halepense* maintains a high rate of leaf gas exchange to absorb more water from its surrounding crops. The photosynthesis rate of *Sorghum halepense* decreases during drought conditions (Acciaresi et al., 2012). Reduced growth of *Sorghum halepense* occurs under high salinity and low water stress effecting the shoot and root growth (Sinha et al., 1986).

***Echinocloa colona* L.**

Echinocloa colona is commonly known as jungle rice or daccan grass. It is the most troublesome weeds around the world and belong to the genus Echinochloa. *Echinocloa colona* infests numerous major corps including rice, corn, cotton, soybean, sorghum and sugarcane (Kraehmer et al., 2016; Heap, 2017; Kaya-Altop et al., 2019). It is the second most important weed after rains due to its maximum density. Increased density and elevated invasion probability is mainly due to the high rainfall rate and standing water during rainy seasons as moisture stimulates its growth (Sumitra & Parul, 2018). Due to its rapid and aggressive growth, elevated seed production, excessive competitive ability and broad ecological range, it causes between 2 to 100% yield loss in rice crops (Motlagh et al., 2011; Tauseef et al., 2012; Zhang et al., 2017; Benedetti et al., 2020). A series of physiological, biochemical, morphological and molecular changes altering the metabolic capacities of weeds under stress conditions has been observed (Simontacchi et al., 2015; Zandalinas et al., 2017). The synthesis and activity of heat shock proteins is activated under stress conditions such as salinity, drought, osmotic and oxidative stress, pesticides, and extreme cold and hot temperature (Wang et al., 2004). During heat stress *E. colona* is observed to elevate its signaling system and stress gene expression to survive in unfavorable conditions (Benedetti et al., 2020).

***Cannabis sativa* L.**

It is a dioecious, anemophilous and annual flowering plant that belongs to the family Cannabaceceae (Kumar et al., 2021). It is native to south and central Asia where it is most commonly used as Marijuana (Gohlke & Doke, 2014; Ocampo & Rans, 2015). It is widely distributed in Khyber Pukhtunkhwa and Punjab. It invades fence rows and waste areas mostly (Marwat et al., 2010). It is widely recognized from ancient times due to its wide spread medicinal and recreational usage (Khalid et al., 2020). Cannabis has a deep rooting system, rapid growth, huge biomass and can be easily cultivated (Hu et al., 2018). A range of biochemical and physiological changes including respiration activation and repression of photosynthesis and cell growth due to down regulation of differently expressed genes has been reported. Along with this, genes involved in amino acid metabolism and biosynthesis of secondary metabolites were substantially down regulated while starch metabolism was elevated during drought stress in *Cannabis sativa*. Thus, drought is an important abiotic stress effecting the growth of *Cannabis sativa* but still the main mechanism behind cannabis sativa tolerance to drought remains unclear (Gao et al., 2018).

***Imperata cylindrica* (L.) P. Beauv.**

Imperata cylindrica is a rhizomatous and aggressive weedy grass that belongs to the Family Poaceae. It is commonly known by the names of Congo grass, baldy grass, jag grass etc. It is widely distributed in tropical and subtropical areas of the world. It is included in the list of seven most worst and troublesome weeds of the world (Cheng & Chou, 1997; Jung & Shin, 2021). It directly competes with native vegetation and crops for nutrients, light and water retarding their growth and development (MacDonald, 2004). Salt stress is an important abiotic stress causing a range of anatomical, biochemical and physiological changes in plant cells. Specific anatomical modifications including cortical parenchyma with large cell area and increased succulence of midribs have been observed in Congo grass as a response to salt stress. During drought conditions, bulliform cells play a significant role in leaf rolling to prevent water loss (Balsamo et al., 2006; Alvarez et al., 2008). Extensive leaf rolling due to the presence of enlarged bulliform cells is an adaptation pattern of *Imperata cylindrica* during water stress conditions (Hameed et al., 2009).

***Sonchus oleraceus* L**

It is commonly known by the names of Common sow thistle, smooth sow thistle, milky tassel etc. worldwide. It a noxious, dicotyledonous weed that belongs to the family Asteraceae (Chauhan et al., 2006; Peerzada et al., 2019). It is a common crop seed contaminant that grows and spreads very rapidly. It produces flowers bearing copious light seeds easily dispersed through wind and water. It is considered as a serious invader that greatly damages the natural and agricultural ecosystem through modification of biogeochemical cycles, habitat alteration, upsetting successional patterns and threatening native plants species etc (Widderick et al., 2010; Hassan et al., 2014; Peerzada et al., 2019). Salt stress is an important abiotic stress effecting the normal functions of the plants. In case of *Sonchus oleraceus* L, under salt stress conditions contents of proline and hydrogen peroxide increases in cell enhancing the activity of antioxidant enzymes. This is an adaptation mechanism of *Sonchus oleraceus* L to tolerate salt stress but the detailed mechanisms is still unknown (Nie et al., 2008; Chen et al., 2015).

***Carthamus oxyacantha* M. Bieb.**

It is a spiny leaf weed that belongs to the family Asteraceae. It is commonly known as wild safflower, or jeweled distaff thistle worldwide (Javaid et al., 2019). In Pakistan the local community recognizes it by the names of Pohli, Kandiari and Peeli Kandiari. It is an annual diploid crop that can easily survive in hot dry conditions with minimal moisture (Shinwari et al., 2014). Seed germination percentage of *Carthamus oxyacantha* increases with increase in temperature while increasing salinity and drought decreases the seed germination capacity of safflower (Tanveer et al., 2012).

***Fimbristylis littoralis* Gaudich.**

It is among the ten most important weeds of Pakistan. It is commonly known as lesser fimbry and belongs to the family Cyperaceae. It is widely distributed in rice fields, on rivers sides and on wet grounds (Ghafoor et al., 1987). Its seeds possess several characteristics that prevent their germination in unfavorable conditions and allow the seeds to survive underground for several years and give rise to huge population of weed when the conditions are favorable. Seed germination is prevented under soil surface as they need oxygen, light and temperature fluctuation (Pons, 1982; Pons & Schröder, 1986). The molecular mechanism behind the prevention of *Fimbristylis littoralis* seeds germination should be explored in detail.

Conclusion

In the natural environment where weeds are considered harmful and useless as they have a serious impact on the crops yield and productivity due to the competition for space, moisture and nutrients but on the other side these weeds are also beneficial as they are used as fodder, provide different kinds of medicinal elements for treating various ailments and used for production of oils etc. Majority of weeds population in Pakistan belongs to the family Poaceae, Asteraceae, Fabaceae and Amaranthaceae. These weeds are exposed to a variety of abiotic stresses in natural environments such as drought, salinity and temperature fluctuations. Different weeds respond

to these stresses in different ways i.e. by decreasing seedling strength and photosynthesis, alteration of water status, preventing and delaying seed germination, production of reactive oxygen species, leaf rolling and activation of stress genes. In most of the cases anatomical and morphological studies have been carried out to identify the changes these weeds undergo during abiotic stress conditions especially focusing on drought and salinity stress. Very few studies have been reported on the response of these weeds towards temperature fluctuation. In future, detailed studies to get the insights into the mechanisms involved behind the response of these weeds towards temperature fluctuation needs be carried out.

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