Review Paper

An Overview: Effect of Different Abiotic Stresses on Quantitative Traits of Brassica, Sunflower and Soybean due to Climate Change.

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Abstract: Despite of technological advancement, such as improved crop cultivars, genetically modified organisms, and irrigation systems, weather is still a key factor in agricultural productivity, as well as soil properties and natural communities. The effect of climate on agriculture is related to variability in local climates rather than in global climate patterns. Climate change and agriculture are interrelated processes, both of which take place on a global scale. Climate change is affecting agriculture in a number of ways, including through changes in average temperatures, rainfall, and climate extremes; changes in pests and diseases; changes in atmospheric carbon dioxide and ground-level ozone concentrations; changes in the nutritional quality of some foods; and changes in sea level. Heat and drought are the most injurious abiotic stresses affecting the plant growth and development globally. In oilseed crops, crop germination, plant height, leaf area index, pollination, grain weight, oil and protein content and crop growth rate is affected by high temperature. Increase in the mean seasonal temperature can reduce the duration of many crops and hence reduce the yield. Water deficit stress also caused a reduction in the plant growth due to decline in photosynthesis products which ultimately cause decrease in crop production. The consequences of agriculture's contribution to climate change, and climatic change's negative impact on agriculture, are severe which is projected to have a great impact on food production and may threaten the food security especially in poor countries and hence, require special agricultural measures to combat with. There are many research and management strategies that can reduce the negative impacts of climate change on oilseed crops to safeguard the global food security.

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Introduction:

Climate change is the crucial global issue which is severely effecting crop growth and development and ultimately reducing their production (Mustafa *et al.,* 2017). Change in climate is occurring due to the natural and human activities. From last few years average world temperature is increasing. Changes in the normal weather pattern are due to burning of fossil fuels, emission of greenhouse gases, that affects the Earth temperature since last century (Wewerinke and Vicente, 2010). According to the latest and fourth assessment report (4AR) of the International Panel on Climate Change (IPCC), Global temperature is rising unequally and unpredictably as a result of increasing average air and ocean temperatures and melting of glaciers (IPCC, 2007). Climate variability are expected to cause changes in sea levels, rainfall pattern, and the frequency of extreme high and low temperature events, floods, droughts, and other abiotic stresses (Dhillon and Wuehlisch, 2013). Plants face various biotic and abiotic stresses in the existing situation of climate change. Environmental stresses such as temperature, drought, salinity, cold and elevated CO_2 affect plant growth and development individually and all together. All these stresses cause significant loss of crop yield and quality (Serrano *et al.*, 1999).

Climate change has badly impact on its agriculture. Increase in atmospheric CO_2 leading to increase in temperature and varying rainfall pattern. A minor increase in temperature even 1ºC-2ºC may affect crop yield which is projected to declining crop production (Mall *et al.,* 2017). CO2 concentration has increased by about 30% since the mid-18th century due to increases in combustion of fossil fuels, industrial processes, and deforestation (Houghton *et al.,* 2001). Although increases in atmospheric CO_2 are projected to stimulate growth in some crop species but climate impacts, particularly heat waves, droughts and flooding, will likely dampen yield potential. In peanut

(*Arachis hypogaea* L.), increase in CO_2 enhances the yield by 8% on average of 50 years while 31% yield is decreased by 3ºC increase in the atmospheric temperature. So that increase in mean temperature has a striking effect on yield. (Cooper *et al.,* 2009).

The climate change is very critical for food security in developing countries like Pakistan. Pakistan is an agriculture-dependent country, more than 47% of its population is agriculture based. Agriculture sector contributes 24% to GDP (IUCN, Government of Pakistan). Pakistan is facing severe scarcity of edible oil due to its increasing demand and production gap, thus, edible oil production does not match with growing demand of population (Fazal, *et al.,* 2015). Consequently, a huge volume of foreign exchange is spent every year on its import to gratify the requirement. (Hasan, *et al.,* 2015). During the year 2013-14, the local production of 0.573 million tonnes against the 3.20 million tonnes total need of edible oil and imported 2.627 million tonnes of edible oil worth US$ 2.50 billion (Govt. of Pakistan, 2014-15). The purpose of this paper is to review the studies about the effect of different abiotic stresses on growth, development, and production of Brassica, Sunflower and Soybean caused by climate change. Hence, a precise research strategy may be adapted to mitigate the effects of climatic change on these oilseed crops.

1. Brassica:

Brassica belong s to family *Brassicaceae*. This genus includes 100 species. Brassica is an important vegetable oilseed crop which is at third position after soybean and palm oil worldwide and providing 13% of the total world supply. Brassica species are mainly grown for vegetables, oil, condiments and fodder (Ashraf & McNeilly 2004). Brassica grains are rich source of oil used as cooking oil or lubricating agent and protein in oil free cakes used for livestock feed (Durrani and Khalil, 1990). The optimum temperature for germination and seedling establishment of brassica is 26ºc (Lallu and Dixit 2008). Due to the climate change impact, high temperature, salinity and drought stress mainly affect the brassica crop.

Effects of high temperature stress on Brassica:

Heat stress caused reduction in pollen germination and pollen tube length which resulted in pollen mortality and fruit setting in Brassica (Singh *et al*., 2008). In Brassica High temperature stress caused reduction in germination and survival of seedling (Rathore & Raja 2014). The effects of heat stress at reproductive stage in Brassica are more severe than at other growth stages where temperature stress is being studied (Hall, 1992 and Paulsen, 1994). *B. juncea* was more adaptive in semiarid areas than *B. napus* and *B. rapa* when exposed to heat stress (Rakow 1995). It is reported that high temperature stress affects different stages such as pollination, fertilization, embryogenesis and gametogenesis during reproductive cycle (Angadi *et al.,* 2000; Singh *et al*., 2008). Flowering and flower pattern of Brassica was also affected due to the heat stress. As a result of reduction in flowering, poor fertilization, fruit abortion and post fertilization decrease in the seed production was reported (Young *et al.*, 2004). High temperature stress has severe effects on the silique and seed production but it has no effect on flower production. When Brassica species tested under 35/15ºC day/night temperature for 7 days 50% reduction was reported at early flowering than at silique development (Angadi *et al*., 2000; Young *et al*., 2004). Angadi *et al.,* (2000) and Young *et al*., (2004) also reported 50% reduction in yield. Heat stress has no effect on flower production but it has severe effects on silique and seed production (Young *et al*., 2004).

Effects of cold stress on Brassica:

Low temperature caused reduction in germination rate and seedling emergence of Brassica species (Zheng *et al.,* 1994). Temperature below the 10ºC resulted in significant reduction in canola germination (Nykiforuk and Johnson-Flanagan 1994). Vigil *et al.* (1997) reported in an experiment that 65 to 81 growing degree days (GDD) are required for the emergence of spring canola seedlings. An inverse response was observed among the cultivars between freeze damage seed yield in an experiment conducted by Cebert and Rufina (2007). Marshall *et al*., (2000) reported that low temperature caused reduction in the rate of seed germination and increase in percentage on non-germinators. Low temperature resulted in lower emergence and poor establishment in spring canola grow under cold stress(Blackshaw, 1991). Early spring frosts were found more problematic to canola seeded in fall, which emerges earlier than early spring seeded canola (Willenborg *et al*., 2004). Low temperature also caused reduction in cell wall thickness. Twenty genotypes of winter canola were tested at different growth stages under naturally occurring severe spring frosts by Cerbert and Rufina (2007) experiment showed a decrease in many yield components such as destruction of photosynthetic green tissues due to late spring frosts, destruction of developing pods and primary yield reduction due to falling of fertilized flowers after late spring frosts. Morrison *et al*., (1989) reported that 5ºC was the optimum germination temperature for canola. Low temperature reduces the final percentage and rate of germination, which results in delayed and reduced seedling emergence of canola species (Zheng *et al,* 1994).

Effects of drought stress on Brassica:

Sadaqat *et al.,* (2003) reported *a* significant decrease in the stem height of rapeseed cultivars under water deficit conditions. Less soil moisture resulted in the lessening of a number of branches per plant

(Sadaqat *et al*., 2003; Naeemi *et al*., 2007). Water insufficiency caused a decrease in the plant height which is related to decline in photosynthesis products resulted by water stress conditions which ultimately cause the plant not to attain its maximum genetic potential (Hossein *et al*., 2012). Drought stress has adverse effects on photosynthesis reduction, stomatal exchange, protein synthesis and accumulation of dry matter which ultimately affect different growth stages (Larcher, 2004; Ohashi *et al.,* 2006; Hossein *et al*., 2012). Water deficit conditions results in a reduction in the number of silique per plant by shortening the flowering period, reproductive period and infertility of flowers and their abscissions (wright *et al*., 1996). Sinaki *et al.,* (2007) observed that drought stress during flowering and siliqua formation stage resulted in the reduction of the number of silique per plant through severe flower and silique abscissions. Daneshmand *et al.,* (2008) reported a 59% decrease in the number of silique per plant of rapeseed cultivars when subjected to water deficit conditions.

Nasri *et al*., (2008) reported that water stress resulted in significant decrease in seed yield, number of seeds per siliqua, the number of silique per plant, 1000 seed weight, oil yield and seed oil content in five cultivars of rapeseed. During the flowering stage heat stress caused reduction of biological yield, seed yield and the number of silique per plant while, the number of seeds per siliqua was not affected (Sinaki *et al*., 2007). Zakirullah *et al.,* (2000) reported that under water stress conditions the number of silique in the main stem, the number of branches per plant and the number of seeds per siliqua of drought-sensitive lines of rapeseed had a severe drop however, in drought tolerant lines this reduction was non- significant. *Brassica juncea* cultivars showed more resistant than *Brassica napus* under water deficit conditions was with more number of pods and better yield (Gan *et al*., 2004).

Effect of CO_2 concentration on Brassica:

Reza & Moghadam (2012) stated that high concentration of CO_2 increased leaf soluble carbohydrates, decreasing sugars, glucosinolates concentration ratio in Brassica species. However, proline and chlorophyll contents reduced under increased elevated CO_2. Frenck *et al*., (2011) reported that higher CO_2 increased the vegetative mass but in one cultivar of *Brassica napus* seed yield was enhanced. Chakraborty and Uprety (2012) stated that elevated CO_2 enhanced yield attributes traits such as seed yield, total number of pods per plant, pod dry weight per plant, number of seeds per pod, thousand seed weight and harvest index.

2. Sunflower:

Sunflower (*Helianthus annuus* L.) is an important oil seed crop belongs to family *Compositae*. Sunflower is one of the most important oilseed crops in the world. Sunflower oil is economically important because it is extensively used in human diet and in many industrial applications (Onemli, 2012). Its seed contains 35-55% oil contents. Its oil is rich of linoleic acid and comparable with olive oil used as good quality edible oil (Iqtidar and Amanullah, 2005). Accumulated air temperature is very important factor for determining the rate of physiological development in sunflower. Drought and high temperature are the two important abiotic stresses, which affect both vegetative and reproductive growths of sunflower unfavorably (Beard and Geng, 1982).

Effect of high temperature stress on Sunflower:

High temperature stress commonly occurring during plant growth and development is responsible for major yield losses in crop plants (Burkhanova *et al*., 2001). Heat stress induces decrease in duration of developmental phases leading to less number of organs, smaller organs, reduced light perception, over shortened life cycle and perturbation of the processes related to carbon assimilation (transpiration, photosynthesis and respiration) which are responsible factors for reduction in crop yields.

The reproductive processes are also severely affected due to high stress (Amutha *et al.,* 2007). Prolonged exposure to high temperature causes a decrease in chlorophyll content, increased amylolytic activity, disintegration of thylakoid grana and disruption of assimilate transport (Kozlowska, 2007).

Increasing CO2 and other greenhouse gases are likely to have serious implications for global climate systems and to cause a series of unusual environmental changes, predominantly through anthropogenic activities (Allen 1990, IPCC2001, McMichael 2001, Centritto & Loreto 2005). Increasing CO2, and consequently temperature, effect plant growth development and function (Centritto & Loreto 2005). The combined effect of both heat and drought on yield of many crops is stronger than the effects of each stress alone (Dreesen *et al.,* 2012; Rollins *et al.,* 2013). Heat and drought stress decrease the duration of growth and development of plant, leads to the significant yield losses (Barnabás *et al.,* 2008).

Effect of drought stress on Sunflower:

Water stress is likely the most important factor that adversely affects plant growth and development (Andrade *et al.,* 2013). Water stress is one of the most important factors of abiotic stresses that effect on growth and yield of plants worldwide (Roche *et al*., 2009). A drop in water potential induces different metabolic, morphological, and/or physiological responses, including reduction in the vegetative growth (Mahajan *et al*., 2005). In sunflower (*Helianthus annuus* L.), low water availability in the soil has a negative impact on yield. Like other oil crops, sunflower is sensitive to water deficit at the germination stage (Ahmad *et al.,* 2009). Andrade *et al.,* 2013 reported that water stress is very important factor at initial stages of plant growth and development. At high water deficit, the chlorophyll content decreased to a significant level in sunflower plants (Kiani *et al*., 2008). A common adverse effect of water stress on crop plants is the reduction in fresh and dry biomass production (Farooq *et al.,* 2009). Diminished biomass due to water stress was observed in almost all genotypes of sunflower (Tahir *et al.,* 2001). Low Water stress mostly reduced leaf growth and leaf area in many plant species, such as Populus (Wullschleger *et al.,* 2005), soybean (Zhang *et al.,* 2004) and many other species (Farooq *et al*., 2009). The combined effect of both heat and drought on yield of many crops is stronger than the effects of each stress alone (Dreesen *et al.,* 2012; Rollins *et al.,* 2013).

Effect of low temperature stress on Sunflower:

It has been reported that growth of sunflower seedlings was inhibited to some degree when they were subjected to suboptimal temperatures (Bradlow, 1990). Cold effects with short freezing treatment results in decreased cell wall thickness. Sunflower tolerated chilling stress at high seed moisture content (approx. 22 %) but failed to acclimatize under freezing temperatures. Chilling at(5°C) or freezing at (−5 or −10 °C) stress significantly improved total soluble protein (TSP) content but this stress suppressed seed germination reported by Kumar and Bhatla (2006).

3. Soybean:

Soybean (*Glycine max* L.) belongs to the family *leguminosae*. It is cultivated largely all over the world. It is one of the most valuable crops in the world not only as an oilseed crop and feed for livestock but also as food of great nutritional value for human consumption (Masuda *et al*., 2009). Soybeans are good source of protein, lipids, and other nutrients. Protein contents in soybean are 38-44% which are more than the protein contents of other legumes and cereals. It comprises of all the essential amino acids except methionine, which must be supplied in the diet because they cannot be synthesized by the human body. Soy bean oil provides calories, the essential fatty acids. It is the source of vitamins A and E. (Lokuruka, 2010). The world soybean production increased by 4.6% annually from 1961 to 2007 and reached average annual production of 217.6 million tons in 2005-07. (Masuda *et al*., 2009).

Effects of high temperature stress on Soybean:

Soybean seed yield and yield related components are influenced by temperature. Soybean seed yield is frequently increased when temperature increases between 18/12 °C (day/night) and 26/20°C (day/night), but poorly decreases at temperatures more than 26/20 °C (Sionit *et al*., 1987). During seed filling stage, increasing temperature from 29/20 °C to 34/20 °C (day/night) significantly decreases soybean seed yield (Dornobos and Mullen, 1991). Seeds per pod is the yield contributing parameter which is least affected by temperature (Huxley *et al*., 1976; Sionit *et al*., 1987; Baker *et al*., 1989). During flowering and pod development, temperature rising from 30/25°C (day/night) reduce seed weight irrespective to temperature during seed filling period (Egli and Wardlaw, 1980). Under humid tropical environments, day temperature reaching up to 33°C is common. For Soybean, optimum temperature range was 25-29°C and pod setting is seriously affected at temperatures above 37°C. According to the current scenario, seed yield components are slightly affected at 30°C and extremely affected at 35°C. So if temperature is above 30°C then soybean seed production is significantly reduced (Lindsey and Thomson, 2012). Recent studies showed that 1°C increase in temperature may decline 1.3% yield in soybean (Lobell and Field, 2007). During reproductive growth stage, higher temperature may shorten the time for seed to develop completely before maturity resulting in a decrease in seed size. So a reduction in seed size under high temperature during seed filling period may be related to shorter seed growth period (Duthion and Pigeaire, 1991).

Moreover, during reproductive growth stage heat stress may have negative effect on the cell expansion, cotyledon cell number and thus seed filling rate so resulting in reduced seed size (Munier-Jolain and Ney, 1998). On the other hand, high temperature is responsible for the percentage of aborted pods and lower seed set pods and probably owing to the increased number of non-viable pollens, failure of anther dehiscence, reduced pollen tube penetration into the stigma and collectively deteriorate reproductive mechanism. (Gross and Kigel, 1994).

Effects of drought stress on Soybean:

Water is important for the crop growth and development but its high and low amounts affect the crop growth and its yield badly. Soybean yield is also affected by precipitation, rainfall and subsequent moisture availability. In 65% of the bean-producing area in the region, the mean rainfall exceeds 400 mm during the three months after sowing, while in other areas yield is severely affected by water deficit (Wortmann *et al*. 1998). During the growing season, when precipitation falls below 300 mm, the estimated soybean yield decreases up to 1000kg/hectares (Wortmann *et al*. 1998). Hence, variations in rainfall and soil moisture content, instead of rising temperature are the more critical factors in soybean yield.

Soybean seed yield is affected when drought stress occurs during its growth stages. Soybean seed germination is reduced when moisture deficit

(Drummond *et al*., 1983). According to the Greenhouse studies, the most severe drought stress condition significantly reduced germination by 6 percentage points in one year of the two year study (Dornbos *et al*., 1989). During reproductive growth stages, drought stress is reduced yield and yield components depending upon the severity of the stress and time period that drought occurred (Van Doren and Reicosky, 1987). When drought stress is imposed between reproductive stages of pod development and early seed filling stage, seed vigor is reduced (Rassini and Lin, 1981). Yaklich (1984) conducted an experiment by applying drought stress treatment in different growth stages. He reported that when drought stress is applied at seed filling period, seed vigor is reduced as evaluated by aging (AA) test. He also reported that drought stress during seed filling period has no effect on seedling emergence. Vieira *et al*. (1991) reported that yield reduced by 35% in the severe drought condition. When stress is occurred early in seed development growth stage, seed weight is reduced so yield is decreased. He also reported that there is no effect of drought stress on seed germination. Yaklich (1984) also showed no effect of drought stress on germination. But Smiciklas *et al*. (1989) reported lower germination during seed development growth stage.

Effect of CO_2 concentration on Soybean:

Soybean seed yield is increased with the increase CO_2. The rise in $CO_2$is valuable for soybean, because soybean is a C-3 species that also fixes N_2. Soybean grown in natural soil is responsive to CO_2 that shows about 38% soybean seed yield response to a doubling of CO_2 from 330 to 660 ppm. A doubling of CO_2 may increase leaf photosynthesis, canopy assimilation, biomass and grain yield by34-38% (Ainsworth *et al*., 2002). Soybean seed yield receptive to doubled CO_2 is re-estimated to be 34% (Hatfield *et al*., 2008).

Conclusion:

Abiotic stresses are severely affecting the growth and development of oilseed crops due to global climate change. Oilseeds breeders should plan their breeding program under the scenario of climate change and develop oilseed varieties especially resilient to drought and heat stresses. Agronomists should also design production technologies of oilseed crops with reference to climatic fluctuations. Adverse effects of abiotic stresses can be minimized by using different management practices like planting methods, appropriate sowing time, foliar application of plant growth regulators, balanced nutrients, and well-defined production technology in Oilseed crops. So, there is dire need to adopt the latest production technology, various management techniques, and grow cultivars resilient to climatic change in order to mitigate the adverse effects of different abiotic stresses due to climate change.

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