

Review Article

<http://doi.org/10.20546/ijcmas.2017.603.272>**Weed dynamics under changing climate scenario: A Review**

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Weeds are ubiquitous in nature and invade both crop and non-crop lands. When present in crop fields, weeds compete with the crops for nutrients, soil moisture, solar radiation and space; hence reduce their productivity and quality. But, they have been the most underrated crop pests despite the fact that these are weeds which cause heavy loss in crop yield rather than other pests. It has been reported that, out of total loss of agriculture production from several pests in India, weed account for about 37%, insect for 29%, diseases for 22% and other pests for 12%. Under changing climate scenario, the levels of weed menace and consequent crop-weed competition are expected to change. Weeds have been conquers and will remain dominant in climate change conditions also since, they have vast adaptive capacity and greater diversity. Climate change may aggravate the weed density, their phenology and invasiveness. Elevated CO₂, rising temperature, changing in rainfall pattern are the distinct consequences of climate change, which leads to deleterious changes in the crop-weed competition, photosynthetic pathway and ultimately growth, density and expansion of weeds. Under climate change scenario, plants with C₄ photosynthetic pathways are expected to benefit more than C₃ from rising temperature but inverse is true with CO₂ enrichment. This differential response of C₃ and C₄ plants to elevated CO₂ and temperature can have important implications on crop-weed competition as most of the weeds are C₄ and most of the crops are C₃ plants.

Introduction

Climatic changes and increasing climatic variability are likely to aggravate the problem of future food security by exerting pressure on agriculture. For the past some decades, the gaseous composition of earth's atmosphere is undergoing a significant change, largely through increased emissions from energy, industry and agriculture sectors; widespread deforestation as well as fast changes in land use and land management practices. These anthropogenic activities are resulting in an increased emission of greenhouse gases (GHG's), such as methane (CH₄), nitrous oxides (N₂O), sulfur dioxide (SO₂), ozone (O₃), carbon dioxide (CO₂), and gaseous

water (IPCC, 2014). These GHG's trapped the outgoing infrared radiations from the earth's surface and, thus, raise the temperature of the atmosphere. There are concerns that climate change will affect weeds and crop yields directly or indirectly through global warming and its associated changes in climate, such as alteration in precipitation, wind pattern, rise in sea level and more floods and droughts. Weeds are the major pests that cause largest yield reductions. If not interrupted, co-occurrence of weeds with crops continues (Dass *et al.*, 2017) that leads to 37% of total losses in agricultural production against 29% losses

caused by insects, 22% by diseases and 12% by other pests (Yaduraju, 2006). However, the particular cropping system adopted, and the agronomic practices used, influence weed species composition under specific agro-climatic conditions (Shekhawat *et al.*, 2017).

Climate change also influences weeds indirectly by enforcing adaptations of farming methods such as choice of crop, sowing time, harvesting date, and other agronomical practices to these alterations (Fleming and Vanclay, 2010). The effect of increased levels of CO₂ on plants has been intensively studied (Zangerl and Bazzaz, 1984; Ziska, 2003; Rogers *et al.* 2008). In brief, C₃ plants benefit from rising CO₂ levels physiologically; however, rising temperatures can override the stimulating effects of CO₂ on photosynthesis of C₃ plants (Batts *et al.*, 1997; Morison and Lawlor, 1999). In contrast, photosynthesis of C₄ plants is more effective compared to that of C₃ plants at higher temperatures, but C₄ photosynthesis is usually not affected by atmospheric CO₂ enhancement (Carter and Peterson, 1983; Ziska and Bunce, 1997). This differential response of C₃ and C₄ plants to elevated CO₂ and temperature can have important implications on crop-weed competition as most of the weeds are C₄. But, this fundamental idea that most crops are C₃ and most weeds are C₄, and hence weed competition will consequently decrease as CO₂ increases, should not be viewed as universal axiom (Ziska 2001, 2003). Climate change may bring changes in weed population and their phenology. Many weed species may expand their range and spread to new areas.

Literature suggest that invasive species may become more of a threat in changing climate because of their strong response to elevated CO₂ and changing climate compared to other native species. Rising atmospheric CO₂ is likely to alter the competition between weeds and crops; the outcome depends on the

individual set of conditions. On one hand, some weeds may be able to evolve successful attributes more rapidly than crops due to their high genetic variation and plasticity (Baker, 1965). On the other hand, breeding of CO₂-efficient crops, such as wheat, maize, or soybean is likely to advance in the future (Ziska *et al.*, 2005; Tokatlidis, 2013). Elevated CO₂ levels and warmer and wetter conditions can also alter the efficiency of certain herbicides by influencing the physiology of plants (Poorter and Navas, 2003; Dukes *et al.*, 2009). Very fewer studies have been done on the effect of climate change on weeds in India. Hence, the aim of this review paper is to address the changes in weed dynamics under changing climatic scenario.

Weed flora in major cropping systems of India

Climate change will provide the environmental opportunity for weeds to invade new ecosystems. Climate change is likely to trigger differential growth in crops and weeds and may have more implications on weed management in crops and cropping systems. There are more than 250 cropping system being followed throughout the country. But, it is estimated that only 30 major cropping systems (Table 1) are most prevalent, excepting the area under mono-cropping owing to moisture and thermal limitations (ICAR, 2009). Most common weed species prevalent in India (Tables 2 & 3), such as *Phalaris minor*, *Avena fatua*, *Chenopodium album*, *Convolvulus arvensis*, *Cirsium arvense* and *Plantago lanceolata* having C₃ photosynthetic pathways will show enhanced photosynthesis due to increased CO₂ level in atmosphere, whereas, weed species with C₄ photosynthetic pathways like, *Amaranthus viridis*, *Dactyloctenium aegyptium*, *Echinochloa crusgalli*, *Leptochloa chinensis*, *Trianthema portulacastrum*,

Cynodon dactylon and *Cyperus spp.* will show a smaller response in photosynthesis to increased CO₂ level in atmosphere (Patterson, 1995). However, in case of rising temperature C₄ weed species will be benefited more as compared to C₃ weeds (Jinger *et al.*, 2016).

Impact of climate change on weeds

Elevated CO₂ concentration

Increased CO₂ concentration and temperature will alter a plant's ability to grow and compete with other individuals within a given environment. There is also evidence (IPCC, 1996; Parry, 1998; Bunce 2001) that increased CO₂ would enable many plants to tolerate environmental stresses, such as drought and temperature fluctuations. Increased tolerance of environmental stress is likely to modify the distribution of weeds across the globe, and their competitiveness, in different habitats. Plants with C₃ photosynthetic pathways are expected to benefit more than C₄ from CO₂ enrichment (Patterson and Flint 1980). This differential response of C₃ and C₄ plants to elevated CO₂ can have important implications on crop-weed competition as most of the weeds are C₄. Therefore, it can be argued that because of C₄ photosynthetic pathway of many weed species, they will show smaller response to elevated CO₂ relative to crops which are mostly C₃. But in agricultural setting, weeds with both C₃ and C₄ photosynthetic pathways are present. Hence, if a C₄ weed species is less responsive to elevated CO₂ concentration; it is likely that C₃ weed species present in the crop will respond more to elevated CO₂. Several observations on the response of growth of C₃ and C₄ species to elevated CO₂ support the general expectation that the C₃ species are more responsive than C₄ species. For a C₃ crop, such as rice and wheat, elevated CO₂ may have positive effects on crop competitiveness with C₄ weeds (Yin and

Struik 2008, Fuhrer 2003). To date, for all crop–weed competition studies, where the photosynthetic pathway is the same, weed growth is favoured as CO₂ is increased. Therefore, C₃ weeds like *P. minor* and *A. ludoviciana* in wheat (C₃) would aggravate with the increase in CO₂ due to climate change. Photorespiration is one reason why C₃ crops exhibit lower rates of net photosynthesis than C₄ crops, at ambient CO₂. However, due to the same reason, C₃ species will respond more favourably to elevated CO₂ levels, because CO₂ tends to suppress photorespiration. In C₄ plants, the internal mesophyll cell arrangements are different to those of C₃ plants, making efficient transfer of CO₂ possible, and this minimizes photorespiration and favours photosynthesis (Drake *et al.*, 1997). Under present CO₂ levels, C₄ plants are more photosynthetically efficient than C₃ plants. Given that they are already efficient at harnessing CO₂, they are likely to be less affected by further CO₂ increase. It is also possible that in a CO₂ enriched atmosphere, important C₄ crops of the world may become more vulnerable to increased competition from C₃ weeds.

Ziska *et al.* (2010) found that in case of rice, rice biomass increased with increase in CO₂ from 300 to 400 ppm but did not increase further with increase in CO₂ to 500 ppm, whereas rice yield did not respond to elevated CO₂. Red rice responded linearly in terms of biomass as well as seed production. These results suggest that under elevated CO₂ concentrations, red rice will be more competitive than rice crop and will produce more seed than at current CO₂ concentration. Ziska (2000) that reported soybean biomass (32%) and yield (23%) increased at elevated CO₂ (ambient + 250 ppm) when grown in mono-culture (Figure 1). But when soybean was grown in competition with *Chenopodium album* (C₃ weed), soybean biomass and yield reduction increased from 23% and 28% at

ambient CO₂ to 34 and 39% at elevated CO₂, respectively due to 65% increase in *C. album* dry weight. Conversely, soybean yield diminished from 45% to 30% at elevated CO₂ compared to ambient CO₂ when grown in competition with *A. retroflexus*. These results suggest that under elevated CO₂, *C. album* would be benefited more than soybean and could become more dominating weed. In contrast, *A. retroflexus* would be less benefitted with rising CO₂ and soybean will likely have competitive edge when grown in competition with this species.

In general, under elevated CO₂, it is likely that only when weed is C₄ and crop is C₃, crop is likely benefitted, whereas in all other cases weeds will get competitive advantage over crop (Table 4).

Due to the ongoing increases in atmospheric CO₂ there would be stimulation in leaf photosynthesis in C₃ plants by increasing the CO₂ level in the leaf interior and by decreasing the loss of CO₂ by photorespiration. The C₄ plants, however, have internal biochemical pump for concentrating the CO₂ at carboxylation site that reduces the oxygenase component of the rubisco, thereby eliminating the carbon loss by photorespiration. Because of this differential response of the plants to the CO₂, it has been postulated that with higher CO₂ levels in the atmosphere, there may be significant alterations in the competitive interactions and certain genotypes or species may become extinct after several generations of altered competition. Elevated CO₂ has been shown to increase growth and biomass accumulation of the C₄ weed *Amaranthus viridis* (Naidu, 2013). As high temperatures would also create increased evaporative demand, with its high water-use efficiency (WUE) and CO₂ compensation point, C₄ photosynthesis is better adapted to high evaporative demand (Bunce, 1983).

Developing leaves of C₄ plants use C₃ photosynthetic pathway until 'kranz anatomy' is fully differentiated (Nelson and Langdale 1989). During this early period a large proportion of the leaf area of these plants use C₃ photosynthetic pathway and therefore, they get benefited from elevated CO₂ condition.

It is evident that an increased CO₂ concentration leads to partial closure of stomata that reduces transpiration per unit area, thereby reduces the plant's water requirement while promoting photosynthesis. Reduced water requirement and enhanced photosynthesis improve WUE. Kimbal and Idso (1983) reported improvement of WUE in 70-100% for both C₃ and C₄ plants. Under the condition of high CO₂ concentration, C₃ plants are likely to become more water-efficient, potentially allowing C₃ weeds to move into drier habitats (Kriticos *et al.* 2003). With high CO₂ fixation rates and with characters like shorter life cycle, vegetative reproduction or easily disseminated seeds, the weeds would become very competitive (Patterson and Flint, 1990; Acock and Allen, 1985). It had been reported that doubling ambient CO₂ levels stimulated biomass yield of C₃ plants by 40% and data for C₄ plants indicated a stimulation of 11% (Kimball, 1983). In C₃ weeds, leaf area generally responds less than biomass to CO₂ enrichment. However, in C₄ weeds, leaf area and biomass responses to CO₂ doubling are similar (Table 5).

Elevated temperature

Under rising temperature, plants with C₄ photosynthesis pathway (mostly weeds) have a competitive advantage over crop plants possessing the more common C₃ pathway (Yin and Struik, 2008). Most of the weeds in rice are of C₄ type in India. For instance, incidence of *Ischaemum rugosum* was a common weed of rice in tropical areas, but

has become a common weed with significant presence in northern states (Singh *et al.* 1991). Similarly, the incidence of *Rumex spinosus* in wheat in north-west India has increased (Kathiresan, 2005). The most potential invasive feature of the species is typical that a greater portion of assimilates is partitioned towards root, leading to extraordinary enlargement in the root mass with rich food reserves, aiding rapid and robust regeneration after mechanical lopping or after revival of ecological stress conditions, such as drought or inundation. The annual increase in root biomass is greater in areas where the mean annual temperature is higher than that in areas of lesser mean annual temperature. The increase in root biomass largely contributes for the weed's ability to tolerate climatic extremes, such as a peak summer associated with high temperature and water scarcity and a peak monsoon winter with water inundation and flooding. This adaptation favors the weed to predominate over other native floras that are susceptible to any one of the two extremes. Tunget *et al.*, (2007) studied the effect of temperature on soybean, *Sida spinosa* (prickly sida) and *Cassia obustutifolia* (sicklepod) and reported that there was an increasing trend in root: shoot ratio in all species with increasing temperatures, however, the weeds consistently had higher root: shoot ratios. At temperatures where maximum growth occurred, the root: shoot growth ratio of soybean (at 32/27°C) was 0.8, and it was 1.3 and 1.6 for *Sida spinosa* (at 36/31 °C), and *Cassia obustutifolia* (at 36/31 °C), respectively (Figure 2).

Elevated CO₂ and temperature

Plant response to the interaction effect of CO₂ and temperature may be complex (Bazzaz 1990). Some studies have shown that low or high temperatures reduce or eliminate the high CO₂ growth enhancement (Hofstra and

Hesketh, 1975; Coleman and Bazzaz, 1992) whereas; others have shown that CO₂ enrichment may increase the plant tolerance to temperature extremes (Sionit *et al.*, 1981; Potvin, 1985; Baker *et al.*, 1989). Based on the differences in temperature optima for physiological processes, it is predicted that C₄ spp. will be able to tolerate high temperature than C₃ spp. Therefore, C₄ weeds may benefit more than the C₃ crops from any temperature increase that accompany elevated CO₂ levels. High CO₂ levels have been shown to ameliorate the effects of sub-optimal temperatures (Sionit *et al.*, 1987) and other forms of stress (Bazzaz, 1990) on plant growth. Tremmel and Patterson (1993) have reported that high CO₂ ameliorated the high temperature effects on quackgrass (*Agropyron repens*). Carter and Patterson (1983) obtained similar results. Data from the results of the experiments by Alberto *et al.* (1996) suggest that competitiveness could be enhanced in C₃ crop (rice) relative to a C₄ weed (*Echinochloa glabrescens*) with elevated CO₂ alone but simultaneous increases in CO₂ and temperature still favor C₄ spp. O'Donnell and Adkins (2001) revealed that wild oat plants grown at high temperature 23/19 °C (day/night) completed their development faster than those grown at normal temperature 20/16°C. If the maturation rate is faster relative to the crop, more seeds may be deposited in the soil seed bank with a consequent increase in the number of wild oat plants. The wild oat plants grown at 480 ppm CO₂ produced 44% more seed than those grown at 357 ppm.

Changes in rainfall pattern

Weeds constrained by rainfall may also find new habitats under new climatic conditions. *Lantana camara*, for example, could expand if rainfall increased in some areas (McFadyen, 2008). The meteorological data available at the Annamalai University showed that in the

tail end of Cauvery river delta region of Tamil Nadu state, the average annual rainfall during the period of 1991 to 2000 has increased by 129 mm compared to the period during 1981 to 1990. The record also revealed that the annual evaporation has reduced by 255 mm from the period between 1981 to 1990 and 1991 to 2000. Further, wet years (years with excess average annual rainfall of 10 %) are also more frequent during 1991 to 2000 than during 1980 to 1990. Phyto-sociological survey of floristic composition of weeds in this region reveals that rice fields were invaded by alien invasive weeds *Leptochloa chinensis* and *Marsilea quadrifolia*. These two weed species dominated over the native weeds such as *Echinochloa* spp. and others by virtue of their amphibious adaptation to alternating flooded and residual soil moisture conditions prevalent during this period in this region (Yaduraju and Kathiresan, 2003; Kathiresan, 2005).

Weed habitat

Climate change is expected to increase the risk of invasion by weeds from neighboring territories. With the competitive ability, weeds often find an opportunity to establish

new populations when natural or desirable plant species decline. Climate change may also favor expansion of weeds that have already established, but are currently restricted in range. The range expansion can be attributed to evolutionary adaptation (Clements and Ditommaso, 2011; 2012). Weeds with have higher spread and establishment potential have the potential, to invade new areas and increase their range. Extreme weather events create conditions congenial for weeds to extend their range and invade new areas or out-compete native species in their existing range. Under drought, the competitiveness of native vegetation gets reduced and new weeds get the opportunity to invade. Flood assist in spreading weeds to weed-free areas; provide opportunity for new weed invasion by washing away the vegetation and exposing the areas of disturbed soil. Warmer temperature will force some species to relocate, adapt or perish. Species that are active in summer will develop faster. Warmer climate restricts temperature sensitive species to high altitudes. In plains, this effect on distribution range is magnified because species without the ability to move to higher elevations must relocate further in the same altitude.

Table.1 Major cropping systems of India (ICAR, 2009)

Rice-wheat	Cotton-wheat	Sorghum-sorghum
Rice-rice	Cotton-safflower	Groundnut-wheat
Rice-chickpea	Cotton-gram	Sorghum- groundnut
Rice-mustard	Cotton-sorghum	Groundnut- rice
Rice-groundnut	Cotton-groundnut	Sorghum-wheat
Rice-sorghum	Maize-wheat	Sorghum-gram
Pearlmillet-sorghum	Maize-gram	Pigeonpea-sorghum
Pearlmillet-gram	Sugarcane-wheat	Groundnut-groundnut
Pearlmillet-mustard	Soybean-wheat	Sorghum-rice
Pearlmillet-wheat	Soybean-gram	Groundnut-sorghum

Table.2 Weed species (C₃ pathway) and their characteristics (Singh *et al.*, 2011; Jinger *et al.*, 2016)

C ₃ weeds	Common name	Family	Characteristics
<i>Agropyron repens</i>	Quack grass	<i>Poaceae</i>	Perennial grass herb
<i>Argemone mexicana</i>	Mexican poppy	<i>Papaveraceae</i>	Annual broad-leaved herb
<i>Ageratum conyzoides</i>	Billgoatweed	<i>Asteraceae</i>	Annual broad-leaved herb
<i>Avena fatua</i>	Spring wild oat	<i>Poaceae</i>	Annual grass herb
<i>Abutilon theophrasti</i>	Velvet leaf	<i>Malvaceae</i>	Annual broad-leaved herb
<i>Ammania baccifera</i>	Red stem	<i>Lythraceae</i>	Annual broad-leaved herb
<i>Commelina benghalensis</i>	Day flower	<i>Commelinaceae</i>	Annual broad-leaved grass herb
<i>Chenopodium album</i>	Common lambsquaters	<i>Chenopodiaceae</i>	Annual broad-leaved herb
<i>Cassia obtusifolia</i>	Sicklepod	<i>Fabaceae</i>	Annual broad-leaved herb
<i>Cirsium arvense</i>	Canada thistle	<i>Asteraceae</i>	Perennial broad-leaved herb
<i>Convolvulus arvensis</i>	Field bind weed	<i>Convolvulaceae</i>	Perennial broad-leaved twining stem
<i>Datura stramonium</i>	Thorn apple	<i>Solanaceae</i>	Annual broad-leaved under-shrub
<i>Eclipta prostrata</i>	False daisy	<i>Asteraceae</i>	Annual broad-leaved herb
<i>Eichhornia crassipes</i>	Water hyacinth	<i>Pontederiaceae</i>	Aquatic broad-leaved grass herb
<i>Lolium perene</i>	Rye grass	<i>Poaceae</i>	Perennial grass herb
<i>Plantago lanceolata</i>	Buckhorn	<i>Plantaginaceae</i>	Annual broad-leaved grass herb
<i>Phalaris minor</i>	Little seed canary grass	<i>Poaceae</i>	Annual grass herb
<i>Poa annua</i>	Blue grass	<i>Poaceae</i>	Annual grass herb
<i>Rumex acetosella</i>	Red sorrel	<i>Polygonaceae</i>	Annual broad-leaved herb
<i>Striga asiatica</i>	Witch weed	<i>Scrophulariaceae</i>	Parasitic weed herb
<i>Solanum nigrum</i>	Black nightshade	<i>Solanaceae</i>	Annual broad-leaved herb

Fig.1 Soybean biomass and yield at ambient and elevated CO₂ when grown in monoculture and in competition with C₃ (*Chenopodium album*) and C₄ weed (*Amaranthus retroflexus*) (Ziska, 2000)

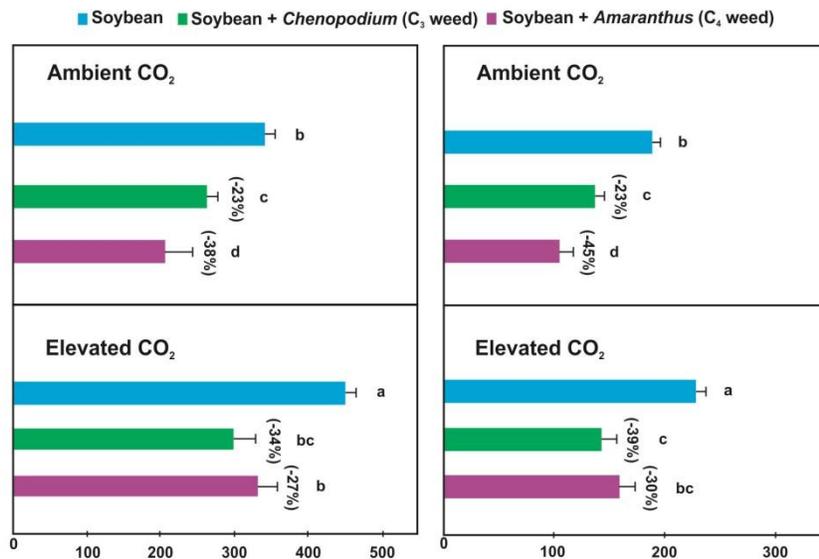


Table.3 Weed species (C₄ pathway) and their characteristics
(Singh *et al.*, 2011; Jinger *et al.*, 2016)

C ₄ weeds	Common name	Family	Characteristics
<i>Andropogon virginicus</i>	Broom sedge	<i>Poaceae</i>	Monocot grass weed
<i>Amaranthus retroflexus</i>	Redroot pig weed	<i>Amaranthaceae</i>	Annual broad-leaved herb
<i>Atriplex spongiosa</i>	Saltbush	<i>Amaranthaceae</i>	Annual herb/sub-shrub
<i>Boerhavia diffusa</i>	Hogweed	<i>Nyctaginaceae</i>	Perennial broad-leaved herb
<i>Cyperus rotundus</i>	Purple nutsedge	<i>Cyperaceae</i>	Perennial herb
<i>Cyperus iria</i>	Flatsedge	<i>Cyperaceae</i>	Annual herb
<i>Cynodon dactylon</i>	Bermuda grass	<i>Poaceae</i>	Perennial herb
<i>Dactyloctenium aegyptium</i>	Crowfoot grass	<i>Poaceae</i>	Annual herb, creeping/erect branches
<i>Digitaria ciliaris</i>	Large crabgrass	<i>Poaceae</i>	Annual spreading grass herb
<i>Eleusine indica</i>	Goose grass	<i>Poaceae</i>	Annual erect tufted grass
<i>Euphorbia hirta</i>	Garden spurge	<i>Euphorbiaceae</i>	Annual herb, deep rooted
<i>Echinochloa crusgalli</i>	Barnyard grass	<i>Poaceae</i>	Annual grass herb
<i>Imperata cylindrica</i>	Congo grass	<i>Poaceae</i>	Perennial grass
<i>Leptochloa chinensis</i>	Sprangletop	<i>Poaceae</i>	Annual grass herb
<i>Monochoria vaginalis</i>	Monochoria	<i>Pontederiaceae</i>	Annual aquatic broad-leaved grass
<i>Portulaca oleracea</i>	Common purslane	<i>Portulacaceae</i>	Annual herb
<i>Rottboellia cochinchinensis</i>	Itch grass	<i>Poaceae</i>	Annual grass herb
<i>Setaria glauca</i>	Yellow foxtail	<i>Poaceae</i>	Annual grass herb
<i>Saccharum spontanium</i>	Tiger grass	<i>Poaceae</i>	Perennial grass/under-shrub
<i>Sorghum halepense</i>	Jhonson grass	<i>Poaceae</i>	Perennial grass
<i>Trianthema portulacastrum</i>	Horse purslane	<i>Aizoaceae</i>	Annual broad-leaved herb

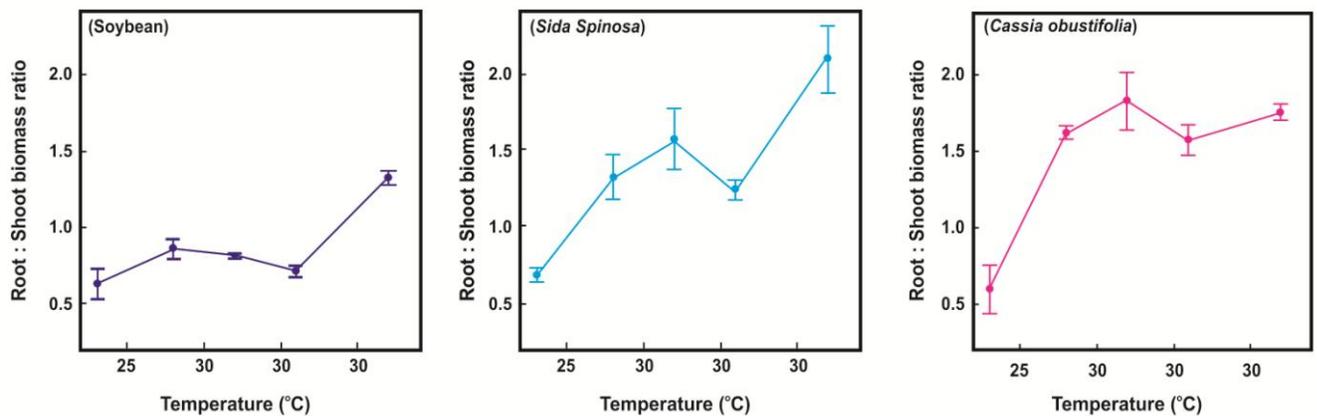
Table.4 Crop-weed competition at elevated CO₂ conditions (Ziska, 2000)

Weed species	Crop	Favored under elevated CO ₂	References
<i>Amaranthus retroflexus</i> (C ₄)	Soybean (C ₃)	Crop	(Ziska, 2000)
<i>Amaranthus retroflexus</i> (C ₄)	Sorghum (C ₄)	Weed	(Ziska, 2003)
<i>Chenopodium album</i> (C ₃)	Soybean (C ₃)	Weed	(Ziska, 2000)
<i>Abutilon theophrasti</i> (C ₃)	Sorghum (C ₄)	Weed	(Ziska, 2003)
Red rice (C ₃)	Rice (C ₃)	Weed	(Ziska <i>et al.</i> , 2010)

Table.5 Effects of doubling CO₂ concentration on biomass of C₃ and C₄ weeds (Patterson, 1995 and Singh *et al.*, 2011)

Range of response (% of growth at ambient)					
Weed (C ₃)	Leaf area	Biomass	Weed (C ₄)	Leaf area	Biomass
<i>Abutilon theophrasti</i>	87-117	100-152	<i>Andropogon virginicus</i>	88-129	81-117
<i>Agropyron repens</i>	130	164	<i>Amaranthus retroflexus</i>	94-125	96-141
<i>Chenopodium album</i>	122	100-155	<i>Cyperus rotundus</i>	92	102
<i>Cassia obtusifolia</i>	104-134	130-160	<i>Digitaria ciliaris</i>	104-166	106-161
<i>Datura stramonium</i>	146	174-272	<i>Echinochloa crusgalli</i>	95-177	95-159
<i>Phalaris minor</i>	131	143	<i>Rottboellia cochinchinensis</i>	113	121
<i>Poa annua</i>	-	100	<i>Sorghum halepense</i>	99-103	56-110

Fig.2 The effect of temperature on root: shoot biomass ratios at 24 days for: soybean, *Sida spinosa* (prickly sida) and *Cassia obtusifolia* (sicklepod) (Tungate *et al.*, 2007)



Weeds with efficient dispersal mechanisms are better equipped to shift their range, while species with short life-cycles are better equipped to evolve and increase their tolerance to warmer temperatures. Weeds that are well-suited to adapt the impacts of climate change may not only fill gaps left by more vulnerable native plants, but they may have an even greater effect by altering the composition of ecosystems and their integrity. In fact, climate change may favour certain native plants to such an extent that they become weeds. Land management practices such as, land clearing, habitat fragmentation and over grazing that clear native vegetation and degrade its condition adversely affect the biodiversity and favour weed invasion by providing opportunities for them to colonise new areas and by reducing the ability of

native vegetation to compete with and suppress invading species.

Alien weeds are usually non-native, whose introduction results in wide-spread economic or environmental consequences (e.g. *Lantana camara*, *Parthenium hysterophorus*, *Eichhornia crassipes*, etc. in India). These weeds have strong reproductive capability and are better dispersers and breeders. With these characteristics, they are benefitted from climate change. Studies indicate that these weeds may show a strong response to recent increase in atmospheric CO₂ (Ziska and George, 2004). *Parthenium hysterophorus* had shown splendid growth response to rising CO₂ and there is possibility that the recent increase in CO₂ during 20th century may have been a factor in the invasiveness of this

species (Naidu and Paroha 2008, Naidu 2013).

In conclusion, rising temperature, elevated CO₂ and changing rainfall pattern are the important aspects of changing climate with pronounced impacts on agriculture ecosystems in general and weed species specifically. In all the studies it is revealed that both crops and weeds respond to changing climate scenario, however, weeds flourish more due to better adaptation strategies. Management of weeds under changing climate scenario is very uphill task and sometimes it becomes too expensive. Hence, there is need to adopt an integrated or inclusive approach to cope-up with the weed problems under state of climate change scenario.

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