Weeds and their management under changing climate

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SUMMARY

Weeds are a major constraint for improving agricultural productivity in all ecosystems. Owing to their natural evolution and with certain unique adaptive characteristics like dormancy, shorter life cycle, abundant seed production, vegetative reproduction potentials, variable dispersal mechanisms etc., these unwanted weeds are a challenge to agricultural production and biodiversity as they out-compete crops and native species. It is feared that predicted changes in climate, especially increased atmospheric CO_2, temperature and precipitation will have serious impacts on crop-weed competition. The dynamics of competition between weed and crop plants are affected by environmental conditions, and have been shown to change with atmospheric CO_2 concentration, temperature and precipitation. Climate change may favour certain native plants to such extent that they become weeds. Invasive weeds like *Lantana camara* and *Parthenium hysterophorus* are likely to be more aggressive under climate change especially due to increases in atmospheric CO_2. Increased temperatures have the potential to result in more invasive species introductions through expanded habitat range. There is a possibility that weed populations in arable land will evolve new traits in response to climate change and non-climate selection pressures. Climate change induced morphological and physiological changes in weeds would necessitate finding out alternative strategies for managing weeds.

Keywords: Elevated CO_2, Global warming, Greenhouse gases, Invasive weeds, Weed shift

INTRODUCTION

Changes in the average weather conditions of a region for long-term is considered as climate change. Rapid global industrialization and associated anthropogenic activities have led to production of greenhouse gases, which is continuing at an alarming pace. Climate change will affect many elements of the future crop production. CO_2 in atmosphere, average temperature and tropospheric ozone concentration will be higher, extreme climatic events will be more frequent and severe, more intense precipitation events will lead to increased flooding leading to many direct adverse effects on soil and crops. Direct effects of climate change influence not only the performance of individual organism but of other organisms also at various stages through changes in physiology, morphology and chemistry. CO_2, being one of the major contributors of greenhouse gases, has significant impact on metabolism and performance of plant species. Rise in temperature is the phenomenon associated with the greenhouse effect, which is also termed as global warming. It is generally believed that in comparison to crops, associated weeds in a cropping system may have better plasticity and adaptability to the changing environment by virtue of greater genetic diversity and climate resiliency. Photosynthetic pathway, phenological and developmental aspects of crops and weeds need attention of researchers in order to understand and predict the impact of climate change on crop-weed interactions. At the same time, it is also important to study the biology and behaviour of weed species under futuristic climate change scenario.

GREENHOUSE GASES AND THEIR EFFECT

Greenhouses are made of glass and are designed to hold heat inside. On a cold winter day, it might be cold outside, but inside the greenhouse green plants flourish in the warmth weather and sunshine. *Earth's atmosphere traps energy just like a greenhouse. Energy from the sun can enter the earth's* atmosphere, but not all of it can easily find its way out again. Unlike a greenhouse, the earth does not have a layer of glass over it. Instead, gases in our atmosphere called greenhouse gases absorb the heat. The concentration of greenhouse gasses (% of total, except water vapour) include CO_2 (99.4), methane (0.47), nitrous oxide (0.084), chlorofluorocarbons (CFCs) and other miscellaneous gases (0.007). A greenhouse gas is called so because it absorbs infrared radiation emitted by the earth's surface (this radiation originally comes from solar radiation), in the form of heat, which is circulated in the atmosphere and lost to space.

Greenhouse effect is not a bad thing as long as it is in limits. Greenhouse gases are actually crucial for keeping our planet at a habitable temperature; otherwise, the earth would be too cold to live. But today everybody is concerned about it because the earth's atmosphere is warming up very rapidly. This is happening because we are currently adding more greenhouse gases to our atmosphere, causing an increased greenhouse effect (Figure 1). Anthropogenic or human release of CO_2 contributes to the current enhanced greenhouse effect. The CO_2 released from the burning of fossil fuels is accumulating as an insulating blanket around our planet, trapping more of the sun's heat energy in our atmosphere. The increased greenhouse effect is causing changes in our planet that can affect human, animal and plant lives. The effects have become particularly obvious over the last three decades and it will affect all forms of life at all levels from the individual to community and ecosystem to the eco-region level (Lepetz et al. 2009).

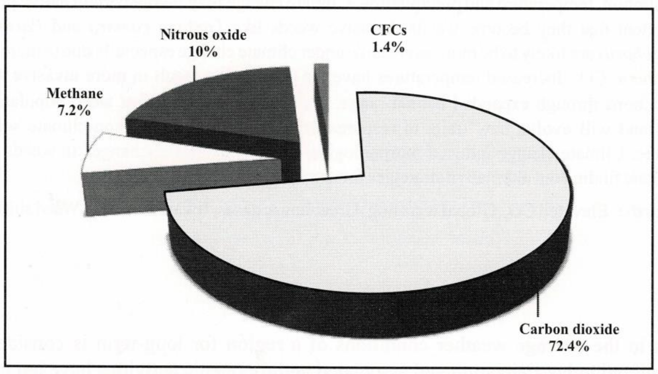

Figure 1. Contribution to greenhouse effect (% of total) except water vapour
Source : www.geocraft.com

Global warming is attributed primarily to increasing atmospheric CO_2 concentrations. Climate change projections suggest that the CO_2 concentrations approaching 750 ppm with no sign of stabilizing and 1.1–5.4°C increase of global average temperature by the end of 21st century (Prinn and Reilly 2014). Studies indicate that significant warming is inevitable regardless of future emission reductions.

Plant response to climate change

CO_2 in the earth's atmosphere is essential for plants as a source of carbon for the synthesis of food through photosynthesis. If the climate change projections are realized, plants are likely to experience significant changes in their growth and development. The uptake of minerals, nutrient and water, canopy exchange of plants, absorption of light energy for photosynthesis reactions as well as the breakdown and burning processes of carbohydrate for growth and development of the plant (respiration) is highly dependent on the atmospheric CO_2 concentration and ambient temperature. There are many processes in plant growth which are affected by interaction of both enhanced temperature and CO_2, that determine carbon balance in the shorter term from the long time scales of development and growth, which together lead to accumulation of biomass and yield. The processes of transpiration (affected by the opening and closure of stomata), and evaporation from surface of plants are determined by the level of temperature and CO_2.

Effect of climate change on weeds

Changes in temperature, precipitation and increasing atmospheric CO_2 have potentially important consequences for crops and cropping systems. Weeds are influenced by these altered abiotic conditions.

Climate change is likely to trigger differential growth in crops and weeds, and may have implications on weed management. As the crop-weed interactions are balanced by various environmental factors, local changes in these factors may alter the balance towards either crop or weed. The effects of climate change on crop-weed interactions are likely to vary with region and crop type. Changes in CO_2 and temperature are likely to have significant effect on weeds and that would affect crop-weed interactions. These effects can be assessed by understanding the response of the physiological mechanisms to such factors i.e. CO_2, temperature and their interaction with other factors.

CROP-WEED INTERACTIONS

Effect of high atmospheric CO_2

Exposure of plants to high atmospheric CO_2 results in increased growth and productivity under favourable nutrient regimes (Kimball et al. 2002). Such changes in plants are attributed to enhanced photosynthesis and improved respiration efficiency (Idso and Idso 2001). In C_3 plants enhancement in photosynthesis occurs because of the saturation of the carboxylation reaction of the enzyme rubisco. Secondly, the high CO_2 suppresses the oxygenation reaction of rubisco in the photorespiratory pathway. The second effect of high CO_2 on the photorespiratory pathway is of great importance as it results in increased net photosynthesis without receiving additional inputs like light, water or nutrients and makes leaf more resource use efficient.

C_4 plants represent nearly 5% of the total higher plant species. These plants have adapted to newer environments including moderate climate. C_4 plants, mostly grasses, are well adapted to dry, hot and highly irradiated environments. Unlike C_3 plants wherein the CO_2 fixation process take place in one cell type i.e. mesophyll cells, in C_4 plants, the process of carbon fixation takes place in two cell types i.e. mesophyll cells and bundle sheath cells. In C_4 plants, photosynthetic metabolism concentrates CO_2 at the site of rubisco carboxylation and renders them relatively insensitive to increase in atmospheric CO_2 concentration.

Table 1. Important crops and weeds and their photosynthetic pathways

Photosynthetic pathway	Crops	Weeds
C_3	*Triticum aestivum*	*Phalaris minor*
	Hordeum vulgare	*Chenopodium album*
	Oryza sativa	*Convolvulus arvensis*
	Cicer arietinum	*Avena fatua*
	Vigna radiata	*Tridax procumbens*
	Vigna mungo	*Bidens pilosa*
	Cajanus cajan	*Rumex dentatus*
	Glycine max	*Asphodelus tenuifolius*
	Allium cepa	*Ageratum conyzoides*
	Allium sativum	*Eichornia crassipes*
	Solanum tuberosum	*Physalis minima*
	Solanum lycopersicum	*Striga asiatica*
	Solanum melongena	*Alternanthera sessilis*
	Brassica oleracea var. capitata	*Commelina benghalensis*
	Brassica oleracea var. botrytis	*Phyllanthus niruri*
	Capsicum annuam	*Eclipta prostrata*
	Beta vulgaris	*Ammannia baccifera*
	Gossypium hirsutum	*Anagallis arvensis*
	Carica papaya	*Chromolaena odorata*
	Mangifera indica	*Cyperus difformis*
	Psidium guajava	*Abutilon theophrasti*
		Ipomoea spp.
		Xanthium strumarium
		Euphorbia geniculata

contd.

Photosynthetic pathway	Crops	Weeds
C_4	*Saccharum officinarum*	*Cyperus rotundus*
	Zea mays	*Cyperus esculentus*
	Sorghum bicolor	*Cyperus iria*
	Pennisetum glaucum	*Cynodon dactylon*
	Panicum sumatrense	*Echinochloa colona*
	Echinochloa frumentacea	*Echinochloa crus-galli*
	Eleusine coracana	*Eleusine indica*
	Setaria italica	*Sorghum halepense*
	Paspalum scrobiculatum	*Portulaca oleracea*
		Digitaria sanguinalis
		Amaranthus spinosus
		Amaranthus viridis
		Amaranthus retroflexus
		Rottboellia cochinchinensis
		Leptochloa chinensis
		Saccharum spontaneum
		Paspalum distichum
		Boerhavia diffusa
		Dactyloctenium aegyptium
		Imperata cylindrica
		Ischaemum rugosum
		Fimbristylis dichotoma
		Fimbristylis miliacea
		Trianthema portulacastrum
		Euphorbia hirta

The differential response of C_3 and C_4 plants to higher CO_2 is specifically relevant to crop-weed competition because most of the crops are C_3 plants while most of the weeds are C_4 plants. For a C_3 crop such as rice and wheat, elevated CO_2 may have positive effects on crop competitiveness with C_4 weeds (Yin and Struik 2008). But this is not always true. To date, for all crop-weed competition studies, where the photosynthetic pathway is the same, weed growth is favoured as CO_2 is increased. Therefore, the problem of C_3 weeds such as *Phalaris minor* and *Avena ludoviciana* in wheat (C_3) would aggravate with increase in CO_2 due to climate change.

Several observations on the response of growth of C_3 and C_4 species to elevated CO_2 support the general expectation that the C_3 species are more responsive than C_4 species. However, elevated CO_2 has been shown to increase growth and biomass accumulation of the C_4 weeds also (Naidu and Paroha 2008). Developing leaves of C_4 plants use C_3 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 C_3 photosynthetic pathway, and therefore, they get benefited from elevated CO_2 condition.

Effect of increased temperature

In contrast to the high CO_2, the high temperature reduces the net photosynthesis by stimulating photorespiration and loss of fixed carbon. However, photosynthetic metabolism responds more to rise in CO_2 than increase in temperature because the relative inhibitory effect of CO_2 on photorespiration is more (Bunce 1998). Increase in air temperature may also increase the transpiration by increasing leaf to air vapour pressure gradient and affects the leaf energy balance. However, the plant response to increase in temperature depends on their interactive effects with high CO_2. Thus, it is important to study the interactive effect of both elevated CO_2 and temperature in order to assess the possible impacts of the climate change on plants.

If the ambient temperature is below optimum for the photosynthesis, a small increase in temperature will result in photosynthetic enhancement. If the increase in temperature is near maximum for plant growth and development, then there would be down regulation of photosynthesis through reduction in the growth and development of carbon sinks and may lead to loss of photosynthetic capacity. Based on the differences in temperature optima for physiological processes it is predicted that C_4 species will be able to tolerate high temperatures than C_3 species. Therefore, C_4 weeds may benefit more than the C_3 crops from any temperature increase that accompany elevated CO_2 levels. At mid-day when light intensity and temperature both reach at peak values, the weed species like red root pigweed (*Amaranthus retroflexus*, C_4) and Johnson grass (*Sorghum halepense*, C_4) are expected to fix CO_2 at higher rate than the crops like soybean (C_3) and cotton (C_3). As high temperatures would also create increased evaporative demand, with its high water-use efficiency and low CO_2 compensation point, C_4 photosynthesis is better adapted to high evaporative demand. Alberto et al. (1996) suggested that competitiveness could be enhanced in C_3 crop (rice) relative to a C_4 weed (*Echinochloa glabrescens*) with elevated CO_2 alone but simultaneous increases in CO_2 and temperature may favour C_4 species. An increase in temperature with accompanying soil moisture stress will offset the positive effect of the CO_2 fertilization; the net effect depends on the level of moisture stress.

Increased temperatures have the potential to result in more invasive species introductions through expanded habitat range and greater potential for destructive outbreaks (Butler and Trumble 2012). As mean temperatures increase, weeds expand their range into new areas. Higher temperatures and other factors are likely to increase insects breeding cycles and thereby populations that play greater role in weed pollination. As animals, including invasive species, move into new areas in response to climate change, they are likely to spread weeds or create disturbance advantageous for weeds.

Interaction effect of CO_2 and temperature

Partial stomatal closure in plants due to increased CO_2 results in decreased stomatal conductance and transpiration. Such reductions in stomatal conductance and enhanced photosynthesis under high CO_2 may improve the transpiration efficiency. Increase in air temperature may increase the rate of transpiration and may offset the elevated CO_2 mediated stomatal closure and transpiration. Both temperature and CO_2 affect plant biomass production by altering the rate of net photosynthesis and respiration. Elevated CO_2 enhances rate of photosynthesis and temperature accelerates respiratory losses and net carbon gain of above processes result in increase in plant biomass. There are reports on increased biomass in plant species grown under high CO_2 environment. However, the magnitude of response depends on the stage of the growth exposed to CO_2. At high temperature, elevated CO_2 caused shortening of growth duration in rice (Lin et al. 1997). In the absence of drought and high temperature stress, exposure of elevated CO_2 during flowering and anthesis in rice increased biomass and yield under field conditions (Baker and Allen 1993).

Biological properties of the soil have often been proposed as early and sensitive indicators of soil ecological stress or other environmental changes. In a study, soil samples were collected from weeds associated with rice-wheat cropping system from open top chambers to assess the effect of elevated CO_2 and temperature on soil enzymes. It was found that CO_2 enrichment significantly increased the activities of soil enzymes like dehydrogenase, fluorescein diacetate (FDA) hydrolysis and urease in weeds rhizosphere, however it was not so in the rhizosphere of crops. It suggests a competitive advantage in favour of weeds (Sarathambal et al. 2016)

Weed shift and invasion

In arable ecosystems climate change causes shifts in species habitation. With climate change, plant species are expected to track the climate favourable to their growth (Jump and Penuelas 2005). Opportunistic weed species possess the ability to track climate change by means of sophisticated dispersal and superior adaptation capabilities (Bergmann et al. 2010). In order to sustain a new habitat, weeds try to persist after they have become established (Smith et al. 2011). As a result, range shifts are often accompanied by natural selection leading to genetic and evolutionary adjustments to the new environments (Richardson et al. 2013). In the Cauvery river delta of Tamil Nadu, phyto-sociological survey of floristic composition of weeds in this region revealed the invasion of rice fields by alien weeds like *Leptochloa chinensis* and *Marsilea quadrifolia*. These weed species dominated the native weeds such as *Echinochloa* sp. by virtue of their amphibious adaptation to alternating flooded and residual soil moisture conditions prevalent in this region (Yaduraju and Kathiresan 2003).

Climate change may also favour expansion of range of weeds that have already established but are currently restricted in range. The first responses to climate change will come from intensification of resident invasive species that are favoured by changes in temperatures, rainfall and CO_2. *Lantana camara*, for example, could expand if rainfall increased in some areas. Weeds which have higher spread and establishment potential have better chances to invade new areas and increase their range. It was observed that the invasive weed *Parthenium hysterophorus* has shown tremendous growth and reproductive response to elevated CO_2. Despite having C_4 rosette leaves, the main vegetative part of the *Parthenium* is C_3, which helps in attaining higher growth and biomass production under a elevated CO_2 concentration compared with the ambient concentration. It suggests the possibility that increase in CO_2 concentration during 20^{th} century may have been a contributing factor in the invasiveness of this species, and further points towards the growing concern about its invasiveness in future (Naidu 2013; Bajwa 2016).

In fact, climate change may favour certain native or introduced plants to such an extent that they then become serious weeds. *Prosopis juliflora*, which was introduced in 1877 in arid and semi-arid zones of India from Central America as a drought-tolerant species suitable for afforestation, has invaded nearly 5.55 million ha of land occupying 1.8% of geographical area of the country. Remote sensing data has predicted the expansion of the species in Gujarat State of India at the rate of 25 km^2 per year. The most potential invasive feature of the species is typical greater assimilate partitioning 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 root enlargement in *Prosopis* is greatly influenced by the temperature regime. The annual increase in root biomass is greater in areas where the mean annual temperature is higher than in areas of lesser mean annual temperature. Increase in shoot biomass due to increasing temperature, though observed is not as significant as the increase in root biomass. The increase in root biomass largely contributes for the weed's ability to tolerate climatic extremes such as peak summer associated with high temperature and water scarcity and flooding. This adaptation favours the weed to predominate over other native flora that are susceptible to any one of the extremes.

Water hyacinth (*Eichhornia crassipes*), an aquatic plant, made its entry into India as an ornamental plant and now occurs throughout the country as a weed in fresh water ponds, pools, tanks, lakes, reservoirs, streams, rivers, irrigation channels and paddy fields. This weed is challenging the ecological stability of freshwater water bodies (Khanna et al. 2011), out-competing all other species growing in the vicinity, posing a threat to aquatic biodiversity. Temperature is one of factors determining water hyacinth with growth rates maximal at 29–30°C. As temperature rises with climate change, higher growth rates will occur leading to faster spread within a habitat and opportunities to invade habitats that were too cool for the weed survival before. According to climate change models, its distribution may expand into higher latitudes as temperatures rise, posing problems to formerly hyacinth free areas (Rahel and Olden 2008).

CLIMATE CHANGE AND WEED MANAGEMENT

Cultural weed management

Mechanical or manual removal is most widely used means of controlling weeds. Stimulation of below-ground growth is higher than that of shoot growth under elevated CO_2 conditions. Therefore, enhanced root or rhizome growth in such species makes the manual removal a difficult task. In weed species with asexual reproduction, higher CO_2 may promote additional plant propagation from below-ground structures and will have negative effects on weed control (Ziska and Goins 2006). Altered growing seasons in crops and weeds induced by changes in climate may affect the cultural practices including weeding operations. Climate extremities like precipitation or drought could also limit the opportunity for field operations. For example, shifting the rice cultivation from transplanting to direct seeding under limited water availability necessitates post-emergence weed management in order to keep the yields high.

Chemical weed management

Increased temperature and uncertain rainfall situations may influence the effectiveness of herbicides. Drought and increased temperatures can cause reduction in herbicide uptake, increase in volatility, structural degradation and thereby reduce its effectiveness. Weeds exposed to elevated CO_2

would experience anatomical, morphological and physiological changes that could affect the uptake rates and translocation of herbicides and its overall effectiveness (Table 2). Stimulation of below-ground growth under elevated CO_2 may lead to abundance of perennial weeds. (Manea et al. 2011) showed that three of four C_4 grass species displayed increased tolerance to glyphosate under elevated CO_2. The reasons for the reduced efficacy of the herbicides might be that increasing CO_2 causes increase in leaf thickness, reduction in stomatal number and conductance that limits the uptake of foliar-applied herbicides. Greater increases in biomass could result in dilution of applied herbicide and thereby reducing its efficacy. Higher starch deposits especially in C_3 plants grown under CO_2 enrichment might interfere with herbicide activity (Patterson et al. 1999). In general, protein content reduced with increasing CO_2, which can result in less demand for aromatic amino acids, thereby reducing the efficacy of glyphosate, a non-selective herbicide which inhibits the aromatic amino acid production through shikimic acid pathway. Decreasing stomatal conductance with increasing CO_2 could also reduce the transpiration and thereby the uptake of soil-applied herbicides. If the growth of the weeds is stimulated by the future levels of atmospheric CO_2, the efficacy of the post-emergence herbicides would be reduced because the time spent by the weeds at seedling stage i.e. the stage of greatest herbicide sensitivity would be shortened (Ziska et al. 1999). At this situation, further applications or additional concentrations of the herbicides may be needed to control such weeds. Drought-stressed weeds are more difficult to control with post-emergent herbicides than plants that are actively growing. For example, systemic herbicides that are translocated within the weed need active plant growth to be effective. Pre-emergence herbicides or herbicides absorbed by plant roots need soil moisture and actively growing roots to reach their target species.

Table 2. Effect of elevated CO_2 on the efficacy of different herbicides

Weed species	Herbicide	Dose	No. of days taken for complete death		
			Ambient CO_2 (360±20 ppm)	Elevated CO_2 (550±50 ppm)	Mortality delayed by (days)
Chenopodium album	Glyphosate	0.2 kg/ha	7	10	3
Phalaris minor	Isoproturon	1.5 kg/ha	6	15	9
Avena fatua	Clodinafop	60 g/ha	8	15	7
Amaranthus viridis	2,4-D	0.5 kg/ha	8	13	5

Source: Naidu (2011)

Biological weed management

Biological weed management is cost-effective, self-sustaining and environment-friendly when compared to other methods of weed management. However, the success depends on several factors. Natural and manipulated biological control of weeds and other potential pests could be affected by increasing atmospheric CO_2 and by changes in other climatic factors. Growth, development and reproductive changes in the selected weedy target due to changing climate could alter the efficacy of the biocontrol agents. Elevated CO_2 and temperature directly alter morphology and reproduction of weeds. Change in C:N ratio may alter the feeding habits and growth rate of herbivores. Direct effects of CO_2 on increasing starch concentration in leaves and lowering nitrogen contents could also affect the biocontrol by altering the behaviour and growth rate of herbivores.

CONCLUSION AND FUTURE LINES OF WORK

Projected changes in atmospheric CO_2 concentration, temperature and precipitation may have potential impact on weeds and crop-weed interactions. There may be a shift in the existing weed flora, which necessitates changes in planning and implementation of weed control programmes. Range expansion of weeds due to climate change would be another serious problem leading to invasion of weeds into new areas. Therefore, increased CO_2 and concomitant increase in temperature may make some of the tropical and sub-tropical weeds to extend their range towards poles and become troublesome in areas where they are not currently a problem. Almost all the studies indicate that both crops and weeds respond to climate change, but the balance will tilt towards weeds since they are naturally evolved with better adaptation strategies. Owing to their greater genetic variation and physiological plasticity, weeds would have a competitive advantage over crops in a changing environment.

Management of weeds is likely to be more difficult and expensive under changing climate especially under high atmospheric CO_2 concentration and associated high temperature. Stimulation of below-ground growth, early vegetative growth and decreased stomatal conductance under elevated CO_2 make the weeds to resist the mechanical and chemical control measures. The changes in CO_2 concentration in the presence or absence of temperature have also been found to alter the herbicide efficacy. In order to get the assured yields in predicted future climatic conditions and extreme weather events, adoption of intensive management practices is inevitable. However, most of these arguments are speculative and warrant further intensive investigations under stimulated conditions. Moreover, climate is not the only factor that will be changing in future. Other factors like population growth, socio-economic and technological changes will have effect no less than climate change. Efforts at molecular level are required in order to get insights into mechanism involved in plants' responses to changing climate. Further, research must be based on holistic approach involving all factors instead of just single factor based studies. However, success of such approaches requires integration and collaborative efforts from all the corners of science to bring together expertise in weed science. Following strategies can be beneficial to fight with the problem of climate change:

- A thorough study on weed dynamics under multi-factorial climate change conditions
- Crop cultivars resilient to climate changes
- Early planting of crops can be effective means of avoiding the high temperature. However, scope of such strategy is limited as it depends on the maturity of the preceding crop also. Adoption of resource conservation agriculture may be viable option which also permits the early planting.
- Most viable and dynamic strategy is to engineer the crop plants which can perform better under futuristic climate change conditions.

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QUESTIONS

I. Subjective type questions (answer in not more than 300 words)

1. What is the greenhouse effect and what are its consequences?
2. How the CO_2 benefit and harm us?
3. How will increased CO_2 affect weed growth?
4. What effect does increased temperature have on weeds?
5. How the crop-weed interactions are affected by climate change?
6. Describe the weed shift and invasion under climate change with suitable examples.
7. What are the weed management constraints under climate change?

II. Objective type questions

(a) Mention whether the following statements are True or False

1. Green house gases are essential for keeping the earth habitable. **(True)**
2. Plant transpiration is determined by the level of CO_2 and temperature. **(True)**
3. High CO_2 enhances photorespiration. **(False)**
4. Increasing temperature will offset the positive effect of CO_2 on plants. **(True)**
5. Temperature is one of the factors determining the invasive potential of the aquatic weed water hyacinth. **(True)**

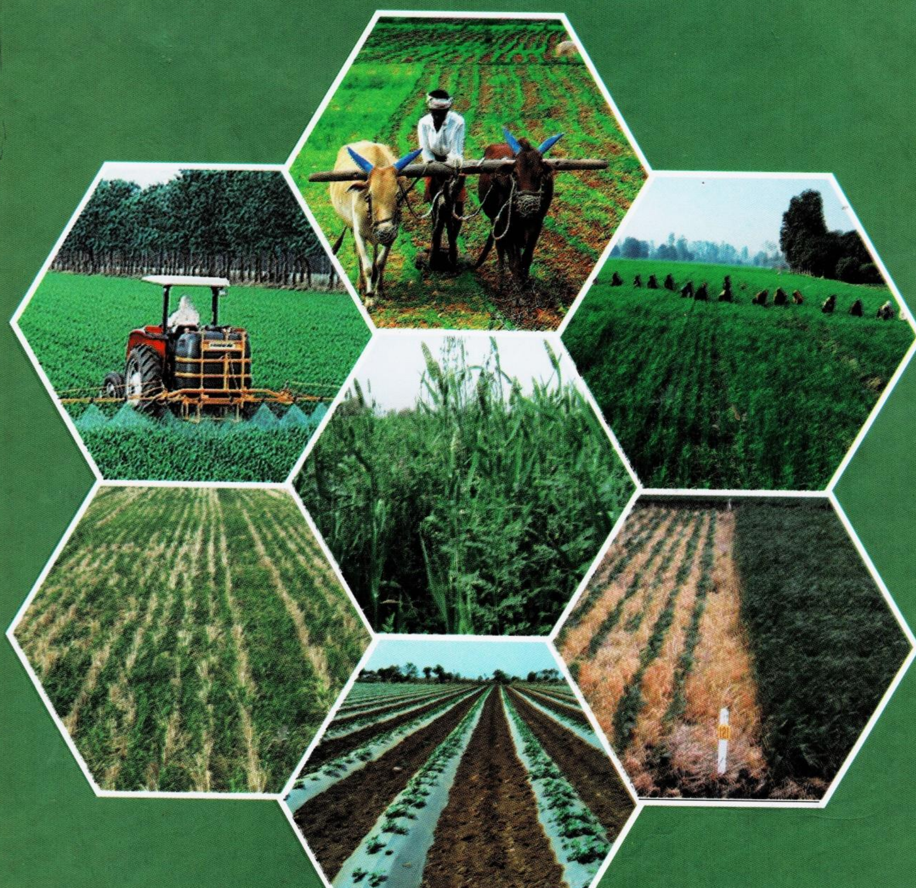
(b) Fill in the blanks

1. CO_2 and temperature affect the plant biomass production by altering the _______ and _______. **(net photosynthesis, respiration)**
2. Elevated CO_2 reduces transpiration by ___________. **(partial closure of stomata)**
3. Reduction in uptake of soil applied herbicides under elevated CO_2 is due to ___________. **(reduced transpiration)**
4. C_4 plants use C_3 photosynthetic pathway until ___________ is fully developed. **(Kranz anatomy)**
5. _____________ under elevated CO_2 makes the manual or mechanical weed control a difficult task. **(Increased root : shoot ratio)**

(c) Multiple choice questions

1. Which one of the following is not a greenhouse gas?
   a) Carbon dioxide b) Methane c) Nitrous oxide d) **Hydrogen**
2. Which one of the following green house gases is major contributor to the green house effect?
   a) **Carbon dioxide** b) Methane c) Nitrous oxide d) CFCs
3. Carbon dioxide is called a greenhouse gas because:
   a) It emits visible radiation b) **It absorbs infrared radiation**
   c) It is used in photosynthesis d) Its concentration is higher than other gases
4. How the greenhouse gases contribute to temperature raise of the earth's surface ?
   a) Allow both incoming sunlight and outgoing infrared radiation.
   b) Stop both incoming sunlight and outgoing infrared radiation.
   c) **Allow incoming sunlight and stops outgoing infrared radiation**
   d) Stop incoming sunlight and allows outgoing infrared radiation.
5. Alien weeds which have become invasive in India are:
   a) *Lantana camara* b) *Parthenium hysterophorus*
   c) *Eichhornia crassipes* d) **All of the above**

Weed Science and Management



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