IMPACT OF CLIMATE CHANGE ON WEEDS AND HERBICIDE EFFICACY

Abstract:

Climate change is the change in statistical distribution of weather pattern that lasts for an extended period of time. There are several components of these climate changes occurring globally that includes uneven rainfall, droughts, floods, warming of atmosphere *etc*. These are the most important challenges influencing natural ecosystems, agricultural productivity and food security. Climate change is not only influencing crop plants and forests directly but can also impact the pests of these crops. Weeds respond to climate change by changing the duration of their life cycles, population dynamics and shift to new habitats and become a potential competitor to crop plants thereby reducing the production and productivity of crops. Elevated temperature and elevated CO_2 level in the environment interfere with herbicide activity, which affects the herbicide absorption, translocation and thereby reduces the efficacy of the applied herbicide. Weeds' resistance to herbicides may probably increase due to further aggressive growth of weeds in future climate conditions, which can cause a decline in the efficacy of routinely used herbicides.

Key words: Climate change, Weeds, Weed Invasion, Crop-Weed Competition, Herbicide efficacy

Introduction

Climate is the synthesis of weather conditions in a given area, characterized by long term statistics for the meteorological elements in that area. "Generally, the quantities measured are surface variables, such as temperature, precipitation and wind. More broadly, the "climate" is the description of the state of the climate system" (IPCC, 1995).

"Climate change is the change in statistical distribution of weather pattern that lasts for an extended period of time. It is a tribute, directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time period" (UNFCC, 1994). Since the industrial revolution began around 1750, human activities have contributed substantially to climate change by adding CO_2 and other heat trapping greenhouse gases to the atmosphere (CH_4, NO_2, SO_2 and CFC, *etc)*. "These gas emissions have increased the greenhouse effect and caused earth's surface temperature to rise. Projections suggest 2.4 - 6.4 ^{0}C increase of global average temperature by the end of 21st century" (IPCC, 2007).

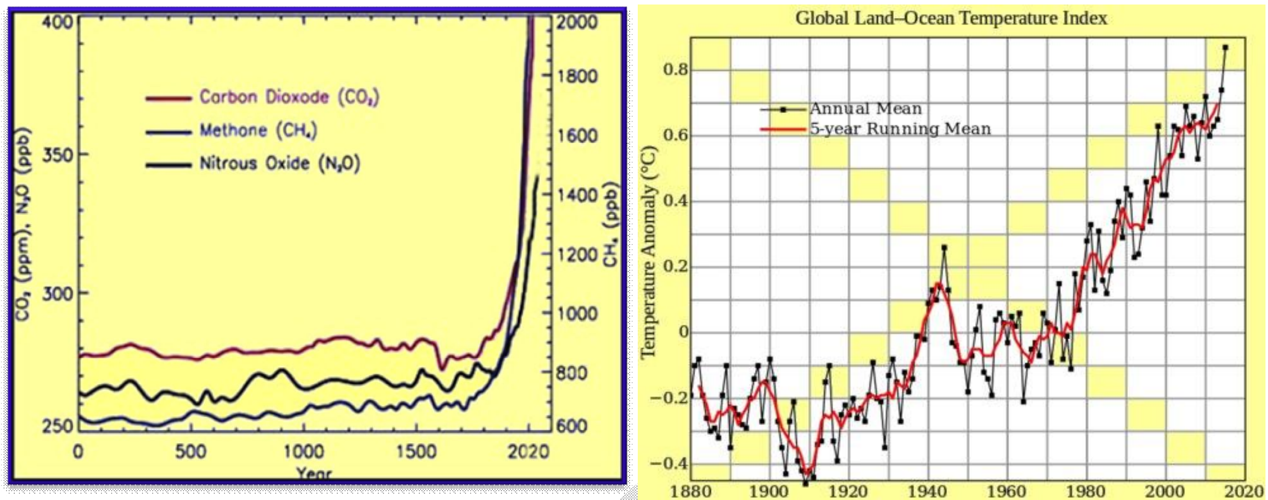

Fig 1. Global Land Ocean temperature index

"Crop production and agronomic practices involving weed management and pest control may be severely affected by these altered abiotic conditions primarily caused by changes in climate and climate variability (Dukes *et al.*, 2009; Singer *et al.*, 2013). Warmer and wetter climates not only affect weed growth but also change the chemical properties of certain herbicides; thereby altering their performance on weeds and their control" (Dukes *et al.*, 2009).

Gas	Current concentration	Annual increase (%)	Contribution to global warming (%)

CO_2	413.2 ppm	1.6	40-50
CH_4	1.86 ppm	1.2	20-25
CFC's	0.24 ppb	3.0	15-20
N_2O	331 ppb	1.0	5-10

Impact of climate change on weeds

Achieving sustainable crop production in unpredictable environments necessitates a holistic approach that focuses on not only increasing crop productivity but also effective management of agricultural pests such as weeds. Hence, to understand the effects of climate change on weed growth and development, Ziska and Goins (2007) conducted an experiment at agricultural research station, Beltsville (USA) to study the effect of different CO_2 concentration on vegetative and qualitative characteristics of poison ivy (*Toxicodendron radicans*) and the results revealed that there was higher leaf area (6,568 cm^2 $plant^{-1}$), leaf weight (43.3 g $plant^{-1}$), stem weight (87.1 g $plant^{-1}$), rhizome length (851 cm), number of rhizomes $plant^{-1}$ (2.25) and urushiol content (78.1 mg) at 600 $\mu mol\ mol^{-1}$ of CO_2 concentration which is much higher than CO_2 concentration of 300 $\mu mol\ mol^{-1}$ condition. Increased CO_2 concentration not only affects crop plants by increasing the weed growth but also affects human health through the secretion of the harmful chemicals like urushiol in poison ivy which is responsible for causing dermatitis in human beings [19,20].

Table 1. Annual increase in global warming

There were 4.2 and 17.6 per cent increase in photosynthetic rate in purple nutsedge and yellow nutsedge, respectively. They/ Ziska and Goins (2007) also observed reduced transpiration and conductance under elevated CO_2 conditions and even studied the response of purple nutsedge and yellow nutsedge growth variables to ambient and elevated CO_2 conditions. Their results revealed that there were 8.1, 4.0, 31.1 and 20.0 per cent increase in number of tillers/plant, number of leaves/plant, leaf area (cm^2/plant) and root length (cm), respectively in purple nutsedge and 7.5, 8.2, 1.9 and 1.2 per cent surge in the number of tillers/plant, number of leaves/plant, leaf area (cm^2/plant) and root length (cm), respectively in yellow nutsedge in the experiment conducted in Auburn University, Alabama (USA) the response of purple nutsedge and yellow nutsedge to ambient and elevated CO_2 conditions (Rogers *et al.* 2008).

Kumar and Varshney (2010) conducted an experiment at ICAR-Directorate of Weed Research, Jabalpur to study the estimated infested area by parthenium in India during different decades since 1955, and there was only 0.5 ha area infestation by parthenium in India during 1955-1960 and up to the end of 2001-2009, the infestation was increased to 18.78 m ha to non agricultural lands and 14.25 m ha to crop lands and 2.0 m ha to forest lands.

Table 2. **Impact of climate change on land**

Period	Infested non-agricultural lands (m ha)	Crop land (m ha)	Forest land (m ha)	Total infested area (m ha)
1955-1960	0.5	0	0	0.5
1961-1970	3.0	0	0	3.0
1971-1980	4.5	0.5	0	5.0
1981-1990	6.0	1.0	0	7.0
1991-2000	7.5	2.0	0.5	10.0
2001-2009	18.78	14.25	2.0	35.0

Lee (2011) conducted an experiment in 2011 at Konkuk University, South Korea to study the effect of photosynthetic rates of *Chenopodium album* under different climatic conditions and the results revealed that there was increased photosynthetic rate in treatment with combined conditions of 4^0C elevated temperature and 750 ppm of CO_2 over 4^0C elevated temperature with ambient CO_2. It clearly indicates that, elevated CO_2 conditions boost up the photosynthetic rate in the weeds or in general plants.

Understanding the effects of climate change on weed growth and herbicide activity is important to optimize herbicide applications for the effective control of weeds in future. Hence, Manea *et al.* (2011) also conducted an experiment at Macquarie University, Sydney (Australia) to study the effect of ambient and elevated CO_2 on grassy weeds. Here they examined 3 different grassy weeds those were *Chloris gayana, Eragostis curvula* and *Paspalum dilatum* and the results revealed that there were increase in total biomass (g/plant) by 39, 83 and 59 per cent, respectively under elevated CO_2 concentration of about 750 ppm.

Jabran (2016) conducted experiment at Adnan Manders University, Aydin (Turkey), to study the effect of normal and elevated carbon dioxide on the fresh weight and dry weight of *Potentilla recta* L. and the results revealed that there was higher fresh weight (3.5 g/plant) and dry weight (1.0 g/plant) of *Potentilla recta* L. was observed under elevated CO_2 (800-850 ppm) conditions over the normal one (400 ppm).

Four different treatments were undertaken to study the effect of different climatic conditions on growth and biomass of *Hordeum murinum* (2 years average data), those includes control or ambient environment (CO_2= 400-450 ppm; temperature 20/10 ^{0}C day/night), elevated temperature (CO_2= 400-450 ppm; temperature 25/15 ^{0}C day/night), high CO_2 + elevated temperature (CO_2= 800-900 ppm; temperature 25/15 ^{0}C day/night) and lastly high CO_2 (CO_2= 800-900 ppm; temperature 20/10 ^{0}C day/night) and the results revealed that there was increased chlorophyll content (47.1), number of leaves (126.0), plant height (72.9 cm), fresh weight (55.1 g/plant), dry weight (7.1 g/plant) and leaf area (4476.5 cm^2/plant) in treatment with high CO_2 + elevated temperature over other treatments in the experiment conducted in Adnan Manders University, Aydin (Turkey) (Jabran *et al*., 2018).

Impact of climate change on Crop-Weed Competition

Since climate change imposes new limitations on resources essential to plant growth, crop weed interactions and crop losses from weeds are likely to be affected. To know what is the impact of climate change on crop weed competition, Kumar *et al*. (2014) conducted an experiment at ICAR-Directorate of Weed Research, Jabalpur to study the effect of CO_2 concentrations on growth and development of chickpea, *Lathyrus sativus* and *Medicago polymorpha.* The results revealed that there was 5.88 and 10.11 folds increase in number of pods/plant and fresh weight of pods (g/plant), respectively in *Medicago polymorpha* under elevated CO_2 over the ambient CO_2. This increase in growth and development of *Medicago* is much higher than Chickpea and *Lathyrus sativus*. Hence, from this we can conclude that weeds gain more advantage from elevated CO_2 than the crop plants and they also studied the effect of CO_2 concentrations on nodulation (80 DAS) of chickpea, *Lathyrus sativus* and *Medicago polymorpha*, and the results revealed that there was 4.24 folds increase in fresh weight of nodules (g/plant) in *Medicago* which was much higher than chickpea and *Lathyrus sativus* under elevated CO_2 condition.

Gozde and Dogan (2015), conducted an experiment at Adnan Manders University, Aydin (Turkey) to study the fresh weight of wheat and weeds as affected by CO_2. Here they have considered four different weed species those were wild oat, canary grass, bedstraw and wild mustard and they have observed 1.7, 3.2, 3.7 and 2.7 folds increase in fresh weight (g pot^{-1}), respectively under elevated CO_2 (750-800 ppm) condition which was much higher than wheat.

Impact of climate change on herbicide efficacy

Successful weed management relies not only on the chemical properties of herbicides but also on its interaction with the plant and the environment. Besides plant morphologic and anatomic characteristics, environmental conditions play a pivotal role in determining the efficacy of herbicides at the time of application. Coetzer (2001) conducted experiment at Kansas State University, USA to study the effect of temperature regimes on efficacy of glufosinate. They reported that since there was an increase in temperature, the visible injuries on weeds have diminished even at higher dosage of chemical that is at 820 (g ha^{-1}). There were only 78, 73 and 70% visible injury upon application of glufosinate at 31/26 for control of palmer amaranth, redwood pigweed and common water hemp, respectively which is much lesser than the temperature regime of 21/16.

Kumar *et al*. (2011) conducted experiment at ICAR-Directorate of Weed Research, Jabalpur to study the effect of elevated CO_2 and temperature on efficacy of sulfosulfuron (25.0 g *a.i.*/ ha) on *Phalaris minor*. They reported that there was 25% survival rate under elevated CO_2, 40% survival rate under elevated temperature and there was 60% survival rate under combined effect of elevated CO_2 and temperature.

In an experiment conducted by Naidu (2015) at ICAR-Central Tobacco Research Institute, Rajahmundry (Andra Pradesh) to study the efficacy of different herbicides at ambient and elevated

CO_2 conditions, there was three, nine, seven and five days delay in complete death of *Chinopodium album, Phalaris minor*, *Avena fatua* and *Amaranthus viridis*, respectively upon application of glyphosate, isoproturon, clodinafop and 2,4-D under elevated CO_2 (550 ppm) over ambient CO_2 (380 ppm) conditions.

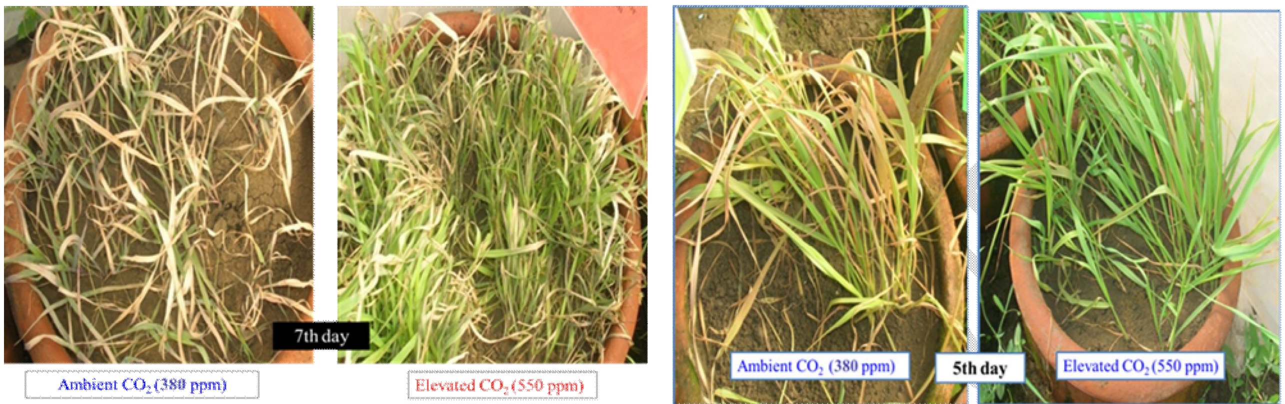

Fig 2. Efficacy of different herbicides at ambient and elevated CO2 conditions

Herbicides have become the major tools for weed management because of their simplicity in use, greater efficacy and more importantly, due to the reduction in control costs by saving labor and time. Herbicide absorption into the target plant largely depends on its interaction with atmosphere, soil or the soil atmosphere interface. Several environmental factors such as temperature, moisture, relative humidity and solar radiation influence a plant's physiologic status and its susceptibility to herbicides. To understand this in a better way, Alizade *et al*. (2021) conducted an experiment at Tarbiat Modares University, Iran to study the effect of different herbicides under drought stress and non drought stressed conditions. The results revealed that ED_{50} of drought stressed weeds was greater than non drought stressed plants that is 24.4 and 15.7 g *a.i.*/ha upon application of sulfosulfuron and sulfosulfuron + metsulfuron-methyl, respectively for control of *Hordeum spontaneum*. There was 13.4 and 8.1 g *a.i.*/ha of ED_{50} value was observed in 60% field condition that is drought stressed condition upon application of clodinafop-propargyl and mesosulfuron-methyl + iodosulfuron-methyl sodium, respectively for control of *Avena sterilis subsp. Ludoviciana*. Hence, from this study it was concluded that less moisture affects the absorption and translocation of herbicides in weeds which ultimately leads to reduced herbicide efficacy.

Conclusion

Photosynthetic rate and competitive ability increase in invasive weeds under climate change, resulting in increased root growth and weed biomass, making it more difficult to control. Herbicides are important tools for weed management and offer several benefits to growers by being cost-effective and more reliable than any other methods of weed control, but the chemical properties of herbicides are as sensitive to climate change as plant growth and development. Hence, adopting some of the possible practices for weed management and improving herbicide efficacy under climate change is must.

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