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Consequences of climate change in weed species in the rice ecosystem

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Abstract
Weeds are benefiting from climate change and will continue to do so because they are more diverse and have more flexibility. Climate change will alter the weed population, and invasiveness threats could rise. Current management techniques' effectiveness could be impacted. For almost 60% of the world's population, rice (*Oryza sativa* L.) is a major food crop. There are a number of biotic and abiotic elements that have an impact on rice production. Weeds are the primary biotic factor in yield loss, and temperature, soil moisture, and Co_2 are the primary abiotic factors. The study recommends that research on weed species, focusing on those weeds that benefited at high temperatures, soil moisture stress situations, and high Co_2 concentrations, is necessary.

Keywords: Climate change, temperature, soil moisture stress and Co_2

Introduction
The term "climate change" refers to a long-term alteration of the climate system caused by the industrial revolution and a rise in the concentration of greenhouse gases. The phenomenon of climate change is now well acknowledged. The majority of climatic modelers appear to agree that the average annual surface temperature of the world would rise by 1.5 to 4.5 °C in the twenty-first century (MacCracken *et al*., 1990; Houghton *et al*., 1992) [28, 19]. In accordance with the latest IPCC Sixth Assessment Report 2021, under a low GHG emissions scenario global warming is quite likely to exceed 1.0 °C to 1.8 °C by the late 21st century. Under the extremely high GHG emissions scenario and the intermediate scenario, respectively, global warming would range from 2.1 °C to 3.5 °C and 3.3 °C to 5.7 °C (IPCC, 2004) [21].
If current emission trends continue, atmospheric CO_2 concentration is predicted to reach levels of 600-700 ppm by the end of 21st century, up from today's around 419.4 ppm (pre-industrial period) levels. Global warming and its attendant changes in climate, such as altered precipitation, wind patterns, an increase in sea level, and more floods and droughts, raise fears that global CO_2 enrichment will have an impact on weeds and crop yields directly or indirectly (Sinha and Swaminathan, 1991; Chauhan *et al*., 2014) [38, 14]. According to Hunt *et al*., 1991 [20] plant competition will change with different responses to high CO_2 and temperature and also reported that an increase in photosynthesis is caused by higher CO_2 concentrations. (Kendal *et al*. 1985) [23].
The weed flora of ecosystems supporting arable crops has seen some noticeable changes in recent decades. (Schroeder *et al*. 1993) [37]. Weeds that rely on vegetative dispersal will not spread as quickly as weeds that have effective seed-dispersal systems (wind, water, and birds). In general, plants with C_3 photosynthetic pathways are predicted to gain more from CO_2 enrichment than plants with C_4 pathways, although the opposite is true with rising temperatures. Given that most weeds are C_4 plants, the difference in how C_3 and C_4 plants react to high CO_2 and temperature have significant effects on crop/weed competition. However, this fundamental notion that most crops are C_3 and most weeds are C_4 and that subsequently weed competition would diminish as CO_2 increases, should not be considered an unquestionable dogma (Ziska 2001, 2003) [43, 44]. In contrast to more subtle changes brought about by actual increases in temperature, CO_2 levels, water availability, and associated weather events, extreme weather events are linked to climate change in many ways, a more serious worry from farmers' viewpoints on crop management. Future development will need to make modifications to technology, managerial techniques, and regulation to handle these drastic shifts (Bhat and Jan, 2010) [5].

The paper aims to discuss the effect of climate change on parameters like Temperature, Moisture conditions (Flooding) and crop-weed competition in the elevation of CO_2 concentration in the Rice Cropping system.

General principles of weeds' reactions by altering in changing climate scenario

Arable weeds are impacted by changing climatic circumstances in a variety of ways. For a species to survive in a particular habitat, it must adapt to environmental changes. (Woodward and Cramer 1996) [41]. These responses result in shifts that have diverse scale effects (see below). Plant species often have three choices to prevent extinction. (Lavorel and Garnier 2002; Pautasso *et al.* 2010) [27, 32].

1. **Migration:** Range shift is the term for the process wherein migration with suitable climate changes the spread of weeds. Weeds must have the proper propagules dispersion mechanisms to migrate. This is typically also given by human activity in arable habitats (Kubisch *et al.* 2013) [25]. Range transitions have a landscape-scale impact (Jump and Penuelas, 2005) [25].
2. **Acclimatisation:** The reaction of organisms within their phenotypic plasticity without evolutionary adaptations is generally referred to as acclimatization to changes in climate conditions. (Pearman *et al*, 2008) [33]. These plasticity changes can be categorized as either tolerating or avoiding climate change. (Grime and Hodgson 1987; Lavorel and Garnier 2002) [16, 27]. As a result, the weeds' competitive capacity and fitness are either increased or decreased (Barrett 2000) [3]. Thus, the realized niche is changing, which causes niche changes. They operate on a local level, and as composition changes, it is possible to identify them visually.
3. **Adaptation:** Adaptation to climate change, is frequently linked to development of new properties or the improvement of existing ones. (Harlan and de Wet, 1965; Carroll *et al*., 2007; Tungate *et al*., 2007) [17, 13, 39]. Thus Natural selection is responsible for these specific biological adaptations of weeds, which lead to phenotypic alterations.

Climate change impact on agriculture weeds

Effects of temperature on weed species in Rice fields

One of the essentials for germination, along with water, oxygen and light, is temperature. (Bidwell, 1979) [6]. For the proper growth and development of embryo before germination, precise temperature control is crucial (Harris *et al*., 1998) [18]. According to (Bewley & Black, 1994) [4], three ways that temperature controls germination in the field by the ability and rate of germination, the removal of primary or secondary dormancy, and the induction of secondary dormancy.

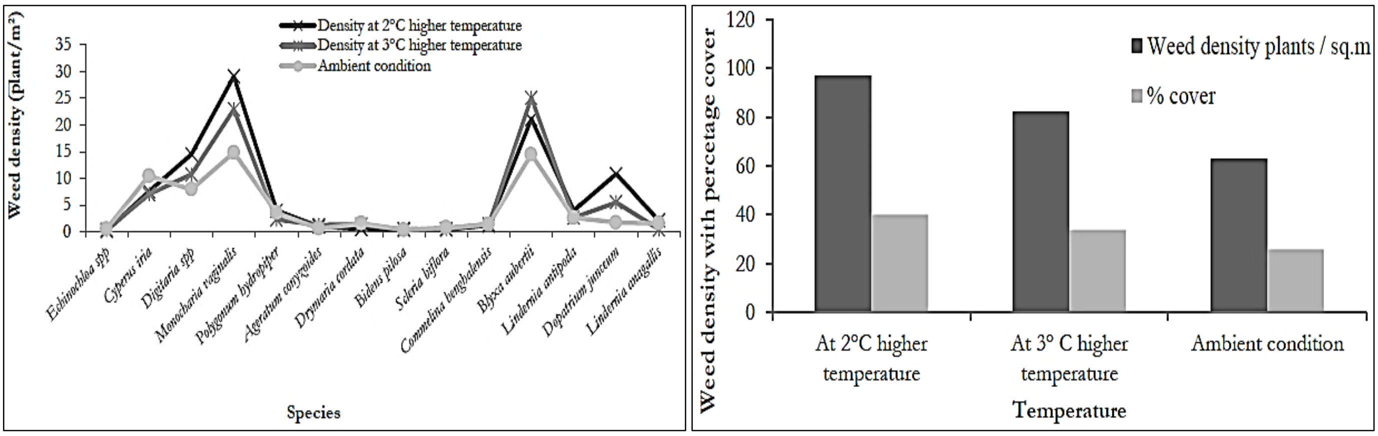
In the transplanted paddy field, a total of 17 weed species from the experiment-four C_4 and 10 C_3 weed species belonging to ten families (nine dicots and eight monocots) were recorded (Table 1).

Table 1: Composition of weeds in rice fields

S.N.	Name of species at varied temperature	Life Cycle	Photosynthesis pathway	Local name	Family	Dicot/Monocot
1	*Ageratum conyzoides*	A/Broad leaf	C_3	Gandhi	Asteraceae	Dicot
2	*Cyperus iria*	A/Sedge	C_4	Mothe	Cyperaceae	Monocot
3	*Drymaria cordata*	A/Broad leaf	C_3	Avijalo	Caryophyllaceae	Dicot
4	*Digitaria spp*	A/Grass	C_4	Banso	Poaceae	Monocot
5	*Echinochloa spp*	A/Grass	C_4	Sama	Poaceae	Monocot
6	*Dopatrium junceum*	A/ Broadleaf	C_3		Scrophulariaceae	Dicot
7	*Polygonum hydropiper*	A/Broad leaf	C_3	Pire	Polygonaceae	Dicot
8	*Lindernia antipoda*	A/Broad leaf	C_3		Scrophulariaceae	Dicot
9	*Scleria biflora*	A/Sedges	C_4		Cyperaceae	Monocot
10	*Bidens pilosa*	A/Broad leaf	C_3	Kalo	Asteraceae	Dicot
11	*Lindernia anagallis*	A/ Broadleaf	C_3		Scrophulariaceae	Dicot
12	*Monochoria vaginalis*	P/Broad leaf	C_3	Nilo Jaluke	Pontederiaceae	Monocot
13	*Commelina benghalensis*	P/Broad leaf	C_3	Kane	Commelinaceae	Monocot
14	*Blyxa aubertii*	A/Broad leaf	C_3		Hydrocharitaceae	Monocot
15	*Lindernia nummularia*	A/ Broad leaf	C_3		Scrophulariaceae	Dicot
16	*Amischophacelus axillaris*	P/Broad leaf	C_3		Commelinaceae	Monocot
17	*Stellaria media*	A/Broad leaf	C_3		Scrophulariaceae	Dicot

*A-Annual, P-Perennial (MoAD, 2016; Rao & Matsumoto, 2017; Caton *et al*., 2010) [30, 35, 12,]

The majority of the weed species responded favorably to temperature rises. *Digitaria species, Monochoria vaginalis, Polygonum hydropiper, Bidens pilosa, Dopatrium junceum, Lindernia species (L. anagallis* and *L. antipoda),* and *Lindernia* spp. all exhibit an increase in weed density at temperatures up to 2 °C higher. At a 2 °C warmer temperature, *Monochoria vaginalis* has the highest density (Caton *et al*., 2010) [12]. It is an aquatic species that thrives in moist to swampy environments and is favored by rising temperatures (Bir *et al*., 2018) [7]. At both the ambient temperature and the 3 °C higher temperature, *Blyxa aubertii* had the highest density. While *Echinochloa* spp. has the lowest density at a 2 °C temperature rise, *Bidens pilosa* has the lowest density at a 3 °C temperature increase and in ambient conditions (maximum average 27.2 °C). (Fig. 1). At an ambient temperature, *Monochoria vaginalis* and *Cyperus iria* have the largest weed densities. A similarity was observed by Rao *et al*. (2017) [36] in the rice field.



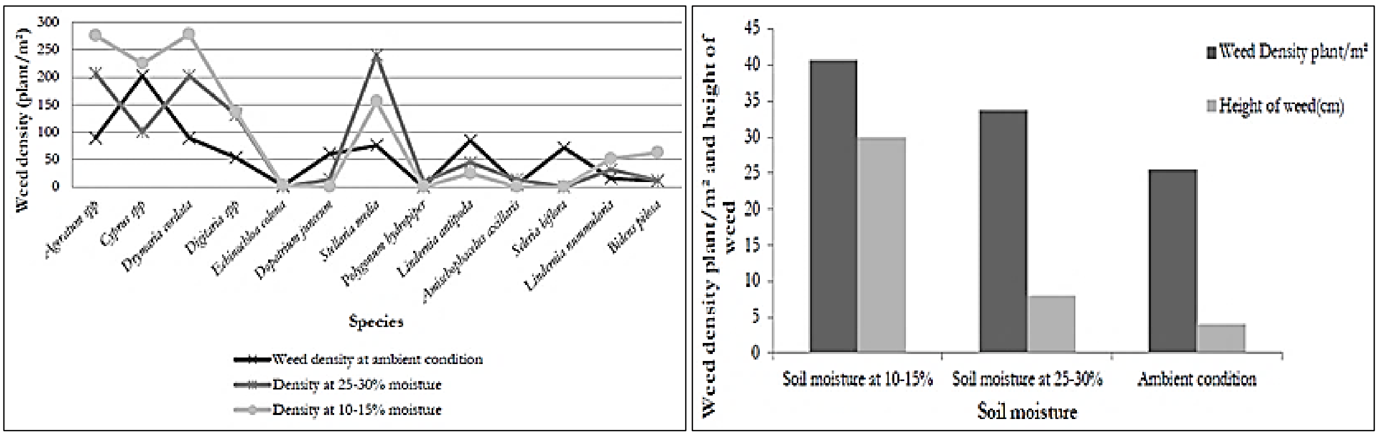
(**Source:** Ambika *et al*., 2022) [2]

Fig 1-2: Density of Weed species at a varied temperature conditions

Effects of Moisture on weed species in Rice field conditions

In Chapagaun's transplanted experimental paddy field, among 17 (Table 1) weed species 13 (Fig: 3) eight dicots and five monocots belonging to seven families were identified. The plot's soil moisture was maintained at 25-30% and 10-15% moisture (Fig. 4). Dicot species dominated the research area's weed flora. *Ageratum conyzoides*, *Drymaria cordata*, *Bidens pilosa*, and *Lindernia nummularia*, weeds that use the C_3 photosynthetic pathway, were commonly observed and have grown in number as soil moisture has decreased. *Ageratum conyzoides, Drymaria cordata*, *Digitaria* spp., *Lindernia nummularia* and *Bidens pilosa* all experienced an increase in weed density when soil moisture decreased. In all treatment settings with the highest weed densities, *Ageratum conyzoides, Cyperus iria* and *Drymaria cordata* were the most often encountered species. In ambient conditions, *Cyperus iria* has the highest density (Kumar *et al*., 2017) [26], because it grows in moist to wet soil, while *Stellaria media* has the highest density when the soil moisture is between 25 and 30 percent. *Ageratum conyzoides* and *Drymaria cordata* have a high density when the soil moisture level is between 10% and 15% because they grow in moist, shady areas to dry (Korres *et al*., 2016; MoAD, 2016) [24, 30]. *Echinochloa* spp., *Lindernia antipoda* and *Amischophacelus axillaris* had the least density in 10-15% soil moisture, 25-30% soil moisture, and the ambient condition.

Weed density was 25.5%, 33.7%, and 40.7%, respectively, at ambient, 25-30% soil moisture, and 10-15% soil moisture (Fig. 4). The maximum weed density was observed at a soil moisture level of 10% to 15%. Furthermore, the height of the weeds was greatest at 10-15% soil moisture and lowest at ambient conditions. Weed has a higher genetic diversity and responds more strongly to changes in resources like moisture, light, CO_2, and nutrients. (Bir *et al*., 2018; Ziska & Dukes, 2011) [7, 47].



(**Source:** Ambika *et al*., 2022) [2]

Fig 3-4: Density of weed species at varied Moisture condition

Effects of flooding on weed species in Rice field: Weed shift

Flooding creates oxygen-deficient conditions that kill weeds. In order to control weeds, flooding, dredging, and other techniques can be used. For instance, *Alhagi camelorum*, a Xerophyte that cannot endure inundation and cannot grow, can be managed Cynodon dactylon and Convolvulus arvensis are wiped out by flooding, and *Ammania baccifera* emerges as the dominant species. The paddy field's surface water was preventing weed development (Manandhar *et al*., 2007) [29]. However, weed species differ in their tolerance to flooding (Table 2).

Table 2: Germination of weed seeds after storage in water

S. No.	Weed species	Duration of storage and germination
1	*Echinochola cruss-galli*	After 2 months, less than 5% germinated After 3 months, less than 1% germinated After 12 months, none germinated
2	*Cirsium arvense*	After 36 months, 50% germinated After 54 months, none germinated
3	*Convolvulus arvensis*	After 54 months, 55% germinated
4	*Agropyron repens*	After 27 months, none sprouted
5	*Amaranthus retroflexus*	After 33 months, 9% still sprouted
6	*Russian Knapweed*	After 30 months, 14% of seeds still sound After 5 years, none germinated

(Bruns and Rasmussen, 1953, 1957 & 1958) [8]

Effects of elevated CO_2 concentration

It is anticipated that plants having C_3 photosynthetic pathways will benefit more from CO_2 enrichment than C4 plants (Patterson and Flint 1980) [31]. Because most weeds are C_4 plants, the difference in C_3 and C_4 plants react to high CO_2 could have significant effects on crop/weed competition. It can be suggested that many C_4 weed species will have a reduced reaction to increased CO_2 compared to crops, which mostly utilise the C_3 photosynthetic pathway (Alberto *et al*., 1996) [1]. However, weeds having both C_3 and C_4 photosynthetic pathways can be found in agricultural settings (Table. 3). Therefore, it is expected that C_3 weed species present in the crop will respond to higher CO_2 concentration more if a C_4 weed species is less susceptible to the increase in CO_2 concentration. In order to create effective weed management strategies for new species under the scenario of a changing climate, it is crucial to evaluate crop/weed competition in cropping systems.

Table 3: Important C_3 and C_4 weed species of rice and wheat crops in India

Crop	C3 weeds	C4 weeds
Rice	Weedy rice, *Scirpus* spp., *Monochoria*, *Eclipta prostrata*, *Ammania baccifera*	*Echinochloa* spp, *Cyperus* spp., *Leptochloa chinensis*, *Bracharia*

Impact on crop/weed competition of C_3 crop (rice) versus C_3 weed (red rice)

(Ziska *et al.*, 2010) [46] had been conducted in United states. They discovered that rice yield did not respond to elevated CO_2, rice biomass increased with an increase in CO_2 from 300 to 400 ppm but did not grow further with an increase in CO_2 to 500 ppm (Figure 5), Whereas Red rice produced seeds and responded linearly in terms of biomass. These findings from (Ziska *et al.*, 2010) [46] imply that red rice will be more competitive than rice crop and will produce more seed than at the current CO_2 concentration under rising CO_2 levels.

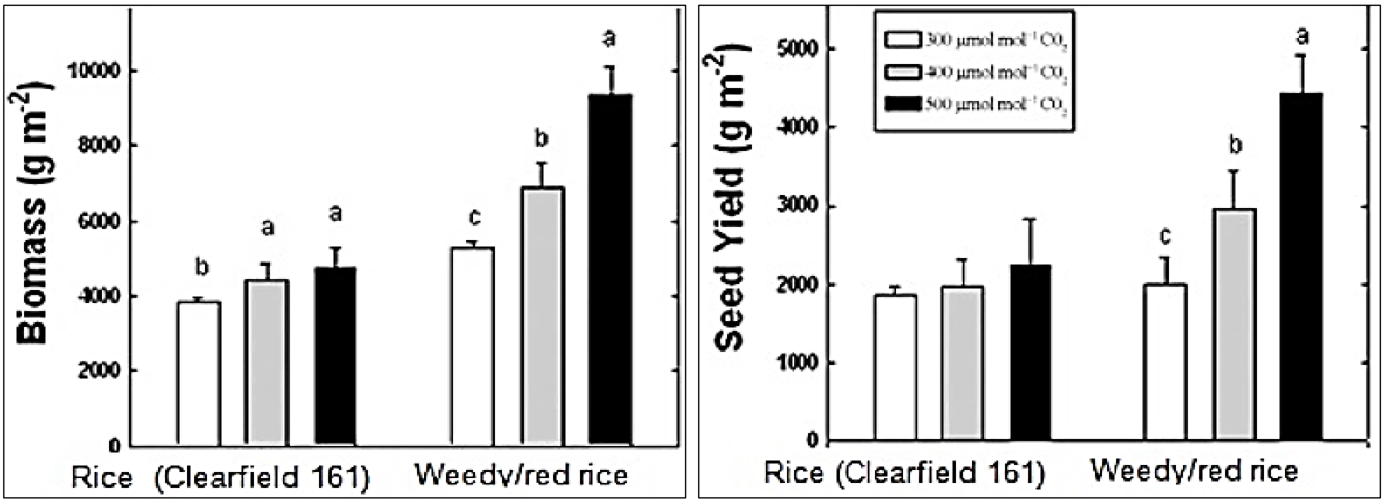


Fig 5: Biomass and Seed yield of rice (C3 crop) and red rice (C3 Weed) under elevated Co2 conditions (Ziska *et al*., 2010) [46]

The crop-weed competition in the elevated CO_2 condition shows that weed species have upper hand over the crops because of their persistence, tolerance, aggressiveness, seed dispersal, regeneration capacity and evolutionary strategies, these superior characteristics make weeds had more favour to the changing climate. However, within the weed species we can able to identify the weed shift by the dominant weed species.

Table 4: Crop/weed competition outcome at elevated CO_2 conditions in rice and other crops (Modified from Bunce, and Ziska, 2000) [11]

Weed species	Crop	Favored under elevated CO_2	References
Red rice (C3)	Rice (C3)	Weed	(Ziska *et al.*, 2010) [46]
Echinochloa glabrescens (C4)	Rice (C3)	Weed	(Wilcove *et al.*, 1998) [40]
Taraxacum and *Plantago* (C3)	Grasses (C3)	Weed	(Poorter, H., 1993) [34]
Amaranthus retroflexus (C4)	Sorghum (C4)	Weed	(Ziska, 2003) [44]
Taraxacum officinal (C3)	Lucern (C3)	Weed	(Bunce, 2000) [11]

Effects of climate change on weed management

It is anticipated that climate change may make present weed control methods less effective. (Ziska *et al*., 1999) [42]. The most popular weed control is the chemical method. The effectiveness of herbicides can be affected by changes in temperature, wind speed, soil moisture and humidity. For instance, dryness can result in the formation of thick cuticles, which can impede the entrance of herbicides into the plant (Ziska *et al*. 1999 and 2004) [42, 45]. It has also been discovered that increasing atmospheric CO_2 concentrations can reduce the efficacy of Glyphosate. for instance, in rice When the field is dry, Cono weeding practises are challenging and Chemicals used during flooded conditions may leach. There are essentially no data on mechanical control as a result of growing carbon dioxide levels. Similarly, Climate change may also affect the growth, morphology, and reproduction of the target bio-agent, which could modify the effective weed bio-control agents, it is evident that climate change or modification in CO_2 will alter weed management. Respectively, combining cultural, mechanical, and chemical methods to control weeds is known as integrated weed management.

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