www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating 2017: 5.03
TPI 2017; 6(11): 414-418

www.thepharmajournal.com
Received: 29-09-2017
Accepted: 30-10-2017

Ajit Kumar Mandal
Department of Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Ga Dheebakaran
Department of Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Mahamaya Banik
Department of Plant Breeding and Genetics, Mahatma Phule Krishi Vidhyapeeth, Rahuri, Maharashtra, India

Arun Kumar
Department of Environmental science, G. B. Pant University of Agriculture and Technology, Pantnagar, Uttarakhand, India

Vimal Kumar
Department of Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Correspondence
Ajit Kumar Mandal
Department of Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu, India

Impact of climate change on adaptation capacity of Horse purslane (*Trianthema portulacastrum*)

Ajit Kumar Mandal, Ga Dheebakaran, Mahamaya Banik, Arun Kumar and Vimal Kumar

Abstract
Climate change, such as long drought periods and occasional very wet years may worsen weed invasion. Horse purslane has high reproduction and efficient seed dispersal mechanisms which helps them to take advantage of the expected calamities like cyclones and floods. Weeds have more adaptability to stress conditions than crops. Hence, it's important to understand the thriving capacity of weeds under future projected climate for preparing ourselves to manage during future climate condition. In this context an investigation was carried out at Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, during 2015 -'16 to understand weeds response to climate change in order to manage them during future climate scenarios. Experiment was carried out under pot culture mode in Climate Control Chamber under CRD with 10 treatments. Each treatment was a combination of one temperature and one moisture level. Three temperature levels viz., ambient (0 ^{0}C), +2 ^{0}C and +4 ^{0}C increase over the ambient and two moisture levels viz., supply of moisture at 100% and 60% ET of previous day. The results revealed that, the problematic weed *Trianthema portulacastrum* had high acclimatization capacity and produced more growth under elevated temperature up to +4 ^{0}C, under sufficient moisture. The C_4 pathway of Horse purslane helped the weed to utilise the moisture and temperature more efficiently even during stress and produced higher growth. Moisture stress with increased temperature had negative effect on growth, but induced early flowering and more seed production in *Trianthema portulacastrum*. It is concluded from the study that, in future under elevated temperature the crop production would suffer with *Trianthema portulacastrum* menace under rainy and drought season.Hence, necessary precaution measures against *Trianthema portulacastrum* have to be included in climate change adaptation technologies.

Keywords: Horse purslane, future climate, elevated temperature

Introduction
Agriculture is highly influenced by both biotic and abiotic factors of the region. Weeds are one of the major biotic thread to crop production. They compete with crops for space, water, sunlight, nutrient and air. They become alternate host and harbour pest and diseases during off season. Some of them also produce allelopathic effect on crops growing nearby. The presence of weed in cropped area reduces the efficiency of fertilizer and irrigation, enhances the population of other pest and finally reduces the crops yield and quality (Labrada and Parker, 1994) [13]. The yield losses due to weeds (33%) are more than those from insect pest (20%), diseases (26%), miscellaneous pest (8%), stored pest (7%) and rodent (6%) (Kulshreshta and Parmer, 1992) [12]. In India, weed management consume 30–50 per cent share of the total cost of cultivation (Bhan, 1997) [1]. *Trianthema portulacastrum* popularly known as Horse purslane is an annual indigenous plant of South Africa that is widely distributed in South East and West Asia, Africa and Tropical America. It is one of the problematic terrestrial weed by virtue of its competitiveness as a C_4 species (Khaliq *et al.*, 2011) [10]. It belongs to the Aizoaceae family and is a much branched, fast growing, prostrate, succulent annual herb with ovate green leaves. It is indigenous to South Africa but it is widely distributed in India, Pakistan, Sri Lanka, West Asia, Africa, and tropical America (Saeed *et al*., 2010) [19]. It's prostrate growth and profuse branching capacity helps it to quickly cover the soil surface and form a green carpet (Senthil *et al*., 2009) [20]. It has exclusively vegetative growth for a short time period of 35-40 days after emergence and then both vegetative growth and reproductive growth continue simultaneously (Das, 2008) [4].
Climate change will result in more extreme weather events including an increased frequency of severe droughts and extreme rainfall (Walck *et al.*, 2011) [25].

The recent Intergovernmental Panel on Climate Change (IPCC, 2013) [9] assessment report V indicated that, climate scenarios predict an increase of annual mean temperatures by 1.5 – 4 ^{0}C by the end of 21th century. As a consequence of climate change, plants may be more often subjected to high temperatures and low soil moisture during the growing season in spring and summer (Knapp *et al.*, 2008) [11]. Climate change involves rising temperatures (Tubiello *et al*., 2007 [24]; Gillett *et al.,* 2011[7]) and altered precipitation patterns, which also increase the probability for summer droughts in (Bloomfield *et al*., 2006 [2]; Lobell and Burke 2008[14]; Robinson and Gross 2010[18]).

Weeds are influenced by these altered abiotic conditions (Dukes *et al.,* 2009[5]; Singer *et al*., 2013[21]). Weeds respond to climate change by changes in geographic distribution, changes in the life cycles, changes in the population dynamics, shift in natural habitats and changes in the ecosystem structure and composition (Naidu *et al.*, 2014) [16]. The biological plasticity of weeds and their greater intraspecific genetic variation compared with most crops could provide weeds with a competitive advantage in a changing environment. Controlling weeds is likely to be more difficult and expensive under climate change (Naidu, 2015) [15].

In this context, the study titled "Assessing acclimatization capacity of problematic weeds under future climate scenarios and results pertaining to the "Horse purslane" is alone described in this paper.

Materials and Methods

The study was conducted as pot culture in climate control chamber of Agro Climate Research Centre, Tamil Nadu Agricultural University, Coimbatore, during 2015 – 2016 to estimate the acclimatization capacity of problematic weed (*Trianthema portulacastrum*) under elevated temperature and moisture stress. Location at latitude of 11^{0}N, longitude of 77^{0}E and mean altitude is 426.7 m above mean sea level and Coimbatore comes under Western agro climate zone of Tamil Nadu**.** Coimbatore is climatically categorized as Semi-Arid Tropic (SAT) climate with an average annual rainfall of 696 mm distributed in 46 rainy days. The long period average annual mean maximum and minimum temperatures are 31.7 ^{0}C and 21.3 ^{0}C respectively. The normal annual mean relative humidity is 84.8 per cent during morning 07.22 hours LMT and 49.3 per cent during evening 14.22 hours LMT. The average mean bright sunshine hour is 7 per day and solar radiation is 311.4 cal/cm^2/day.

The study was conducted with 10 treatments and three replication in Completely Randomized Design. Each treatment was a combination of one temperature and one moisture level. The temperature levels were varied as ambient (0 ^{0}C), two degree (+2 ^{0}C), four degree (+4 ^{0}C) increase over the ambient temperature. The moisture levels were, supply of moisture at 100 per cent of evaporation (M_{100}) and 60 per cent of evaporation (M_{60}) occurred previous day. Trial was conducted for three generations of weeds and the temperature and moisture levels were varied generation to generation as per treatment. The treatment detailed in table 1.

Table 1: Treatments details of all the three generation

Treatment	1st Generation	2nd Generation	3rd Generation
T_1	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}
T_2	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	+4 ^{0}C + M_{100}
T_3	+2 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}
T_4	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}
T_5	0 ^{0}C + M_{100}	0 ^{0}C + M_{100}	0 ^{0}C + M_{100}
T_6	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}
T_7	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	+4 ^{0}C + M_{60}
T_8	+2 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}
T_9	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}
T_{10}	0 ^{0}C + M_{60}	0 ^{0}C + M_{60}	0 ^{0}C + M_{60}

Irrigation: Irrigation with good water was done to the pots on the basis of pan evaporation reading as per treatment schedule. The loss of water through evaporation was calculated every day and equal water was poured in the pots for 100 per cent moisture level. In 60 per cent moisture stress treatment, quantity of water equal to 60 per cent of open pan evaporation was poured. The calculation method was as followed. Diameter of pot - 25 cm; Area of pot: 0.049 sqm. 1mm of water in 1square meter =1 litre. Hence, for 1mm in 0.049sq m = 49 ml. If pan evaporation reading is 5 then water required for 100% level pots =5 x 49ml =245ml and for 60% = 147 ml.

Results and Discussion

Growth Parameters

The data observed at 45 planting/Cutting (DAS/C) for the effects of different treatments on *Trianthema portulacastrum* plant height (cm), number of branch and leaf area (sq.cm) are depicted in table 1. The mean values recorded at 45 DAS/C were ranged (plant height- 17.8 to 25.7 cm, 39.7 to 68.0 cm and 32.5 to 62.7 cm), (number of branch- 18.1 to 37.4, 159.3 to 206.3 and 75.0 to 117.3) and (leaf area-307.3 to 1033.4, 1903.8 to 4394.7 and 1135.5 to 3524.2) during 1st, 2nd and 3rd generations, respectively. It was observed that, the treatment T_4 (+4 ^{0}C with M_{100}) had significantly higher plant height (25.7 to 67.9 cm), number of branches (23.2 to 193.6) and leaf area (744.2 to 4394.7sq.cm) than all other treatments. The growth of *Trianthema portulacastrum* was significantly lower in ambient temperature treatment (T_5, +0 ^{0}C with M_{100}) and T_{10} (+0 ^{0}C with M_{60}). There was a decline in plant height in all the treatments during the 3rd generation. The data on leaf, stem and total dry matter production per plant observed at 45 DAP/C are depicted in table 3. The mean values at 45 DAS/C were ranged (leaves dry matter per plant 0.918 to 2.880, 5.744 to 12.744 and 3.460 to 10.332), (stem dry matter per plant 1.123 to 2.651, 2.806 to 4.917, and 1.314 to 4.079) and (total dry matter per plant2.146 to 5.532, 8.770 to 17.661 and 5.068 to 14.402) during 1st, 2nd and 3rd generations respectively. In, general the leaf area per plant was lesser in 3rd generation compared to 2nd generation. It was observed that, the dry matter production per *Trianthema portulacastrum* plant were significantly higher in the treatment T_4 (+4 ^{0}C with M_{100} for all three generations) than other treatments. The treatments that were received 100 per cent moisture (M_{100}, T_1 to T_5) produced significantly more leaf area than the treatments with moisture stress (M_{60}, T_6 to T_{10}).

The results obtained during 1st, 2nd and 3rd generation for the effects of different elevated temperature and moisture stress combinations on *Trianthema portulacastrum* growth parameters were increased with increase in temperatures (+2 ^{0}C or +4 ^{0}C) and the growth was significantly more if the plant had no moisture stress (M_{100}). The maximum growth was observed in treatment number T_4 (+4 ^{0}C +M_{100}, for all the generation) followed by T_3 (+4 ^{0}C +M_{100}, from 2nd generation onwards). Singh (2009) [22], who reported that moderate stress intensities delayed the germination alone and did not affect the other growth parameters of *Trianthema portulacastrum*.

There was significantly lower growth viz., height, branches, leaves, leaf area and dry matter were observed in the treatment number T_5, which was ambient temperature (0 ^{0}C) with 100 per cent moisture (M_{100}) followed by T_{10}, ambient temperature with moisture stress (M_{60}). The results inferred that, the *Trianthema portulacastrum* weed had induced by elevated temperature and produced more growth under no moisture stress conditions. Being a C_4 plant, with sufficient moisture the *Trianthema portulacastrum* will adopt easily and produce more growth under elevated temperature as supported by the earlier studies of Carter and Peterson (1983) [3] and Ziska (1997) [26]. The C_4 photosynthesis is an adaptation of the C_3 pathway that overcomes the limitation of the photorespiration, improving photosynthetic efficiency and minimizing the water loss in hot, dry environments (Edwards and Walker, 1983) [6].

The *Trianthema portulacastrum* had decreased growth under elevated temperature during summer (III generation) as adoptive mechanism. This was supported by Poorter and Navas (2003) [17] and Trumble (2013) [23] that the weeds have greater genetic diversity and adaptability and showed a better growth and reproductive response than that of crops when availability of a resource changes within the environment.

Yield Components

The mean values of number of seeds per plant at 45 DAS/C were ranged from 754 to 1229, 1403 to 2172 and 1926 to 3261 during 1st, 2nd and 3rd generations, respectively. It was observed that, the number of pods per *Trianthema portulacastrum* plant were significantly higher in the treatment T_9 (+4 ^{0}C with M_{60} for all three generations) followed by T_4 (+4 ^{0}C with M_{100} for all three generations) than other treatments. The seeds per plant also followed the same. The results obtained during 1st, 2nd and 3rd generation for the effects of different elevated temperature and moisture stress combinations on *Trianthema portulacastrum* seed production were depicted in figure 1. The results inferred that the seeds production capacity of the *Trianthema portulacastrum* were positively influenced by increasing temperature and negatively influenced by the moisture availability. The *Trianthema portulacastrum* tend to produce significantly more number of seeds under stress condition. This was confirmed earlier by Heschel and Riginos (2005) [8] that the *Impatiens capensis* and other weeds involve rapid phenological development such as early reproduction, flowering and maturity as a drought escaping mechanism.

Table 2: Effect of elevated temperature and moisture stress on plant height, No of branches and leaf area per plant of *T. portulacastrum* on 45 days

Treatment details				I Generation			II Generation			III Generation		
No.	I Gen	II Gen	III Gen	Plant height cm	No. of branches	Leaf area par plant sq.cm	Plant height cm	No. of branches	Leaf area par plant sq.cm	Plant height cm	No. of branches	Leaf area par plant sq.cm
T_1	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	21.98	24.4	617.81	60.33	167.1	3407.0	39.7	81.7	2456.12
T_2	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	22.64	23.8	593.77	62.96	164.7	3544.9	46.24	83.3	2632.71
T_3	+2 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	22.63	24.2	638.81	65.97	159.3	3919.8	55.3	93.3	2967.42
T_4	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	25.74	23.2	744.21	67.99	193.6	4394.7	62.67	117.3	3524.24
T_5	0 ^{0}C + M_{100}	0 ^{0}C + M_{100}	0 ^{0}C + M_{100}	19.23	31.3	517.77	43.2	179.1	2136.5	32.53	75.0	1376.04
T_6	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	21.07	19.2	571.17	54.04	176.3	2665.2	40.53	80.0	1775.25
T_7	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	20.77	18.8	499.75	53.83	170.1	2579.5	46.13	87.3	1919.75
T_8	+2 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	20.67	18.1	532.43	55.19	192.1	2549.7	47.2	92.1	2559.62
T_9	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	23.67	37.4	1033.37	58.94	206.3	3354	54.13	95.7	3019.66
T_{10}	0 ^{0}C + M_{60}	0 ^{0}C + M_{60}	0 ^{0}C + M_{60}	17.77	21.6	307.28	39.73	196.0	1903.8	35.57	78.3	1135.47
		Mean		21.617	24.2	605.637	56.218	180.5	3045.5	46	88.4	2336.63
		SEd		0.995	1.2	29.79	2.648	8.1	118.24	1.42	4.0	107
		CD (P = 0.05)		2.0755	2.4	62.139	5.5235	16.9	246.64	2.962	8.3	223.191

Table 3: Effect of elevated temperature and moisture stress on leaf, stem and total dry matter per plant of *T. portulacastrum* (g/plant)

Treatment details				I Generation			II Generation			III Generation		
S. No.	I Gen	II Gen	III Gen	Stem	Leaves	Total	Stem	Leaves	Total	Stem	Leaves	Total
T_1	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	1.63	1.74	3.37	3.70	9.71	13.41	1.77	7.07	8.84
T_2	+2 ^{0}C + M_{100}	+2 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	1.65	1.69	3.34	3.84	10.19	14.03	2.12	7.65	9.77
T_3	+2 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	1.66	1.80	3.46	3.86	11.17	15.03	2.81	8.54	11.36
T_4	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	+4 ^{0}C + M_{100}	1.84	2.14	3.98	4.92	12.74	17.66	4.08	10.32	14.40
T_5	0 ^{0}C + M_{100}	0 ^{0}C + M_{100}	0 ^{0}C + M_{100}	1.80	1.44	3.25	2.81	6.01	8.82	1.31	3.91	5.23
T_6	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	1.22	1.61	2.84	3.50	7.60	11.10	1.77	5.11	6.88
T_7	+2 ^{0}C + M_{60}	+2 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	1.16	1.39	2.55	3.30	7.23	10.53	2.16	5.43	7.59
T_8	+2 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	1.12	1.49	2.61	3.85	7.20	11.05	2.35	7.30	9.64
T_9	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	+4 ^{0}C + M_{60}	2.65	2.88	5.53	4.41	9.44	13.85	2.79	8.59	11.38
T_{10}	0 ^{0}C + M_{60}	0 ^{0}C + M_{60}	0 ^{0}C + M_{60}	1.23	0.92	2.15	3.03	5.74	8.77	1.61	3.46	5.07
		Mean		1.60	1.71	3.31	3.72	8.70	12.43	2.28	6.74	9.01
		SEd		0.20	0.12	0.28	0.27	0.64	0.86	0.21	0.37	0.57
		CD (P = 0.05)		0.41	0.26	0.59	0.56	1.33	1.79	0.45	0.77	1.18

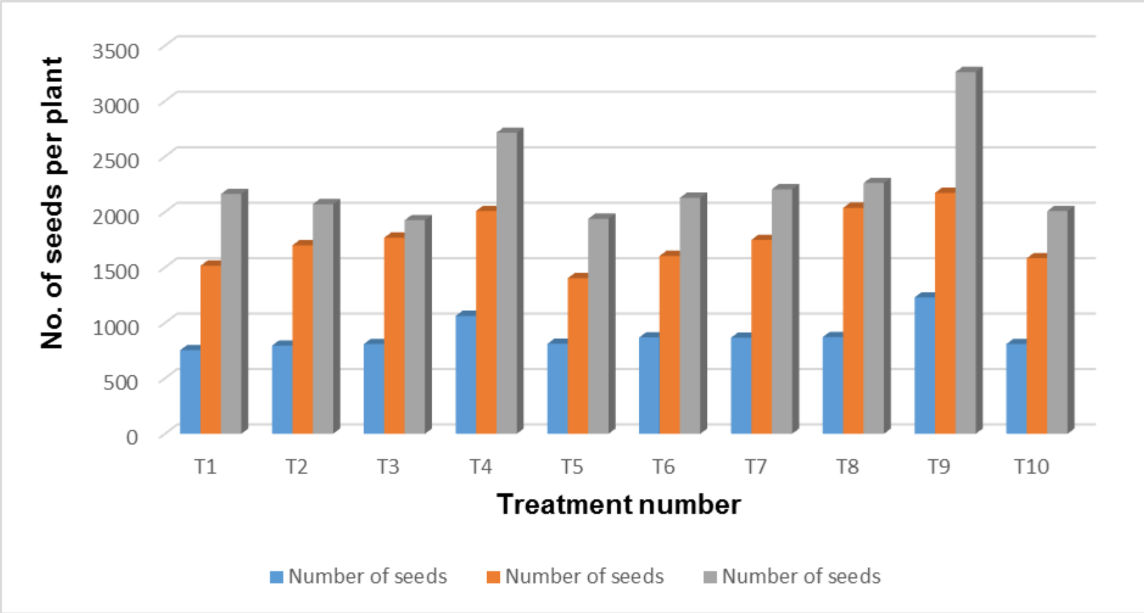

Fig 1: Effect of elevated temperature and moisture stress on number seeds per plant of *T. portulacastrum*

Conclusion

The problematic weed *Trianthema portulacastrum* had high acclimatization capacity and produced more growth under elevated temperature up to +4 ^{0}C, with sufficient moisture. Being C_4 pathway plants, these weed utilise the moisture and temperature very efficiently and produce more growth under elevated temperature without moisture stress condition. During moisture stressed condition, as drought escaping mechanism. It is concluded that, in future elevated temperature condition, during the rainy season, the crop production will suffer with weed menace. The moisture stress had negative effect on growth. On the other hand it induced the early flowering and more seed production. Hence, necessary precaution should be taken up during moisture stressed summer to control the *Trianthema portulacastrum* before seed setting. There is option for genetic engineers to introduce this temperature and moisture stress tolerance capability of *Trianthema portulacastrum* in to agricultural crops.

References

1. Bhan VM. Vision-2020. National research centre for weed science, perspective plan, 1997, 53.
2. Bloomfield JP, Williams RJ and Gooddy DC. Impacts of climate change on the fate and behaviour of pesticides in surface and groundwater. Science of the Total Environment Journal. 2006; 369:163-177.
3. Carter DR, Peterson KM. Effects of a CO_2 enriched atmosphere on the growth and competitive interaction of a C_3 and a C_4 grass. Oecologia. 1983; 58:188-193.
4. Das TK. Basics and applications. New Delhi: Jain Brothers, 2008, 901.
5. Dukes JS, Pontius J, Orwig D. Responses of insect pests, pathogens and invasive plant species to climate change in the forests of northeastern North America. Journal of Research. 2009; 39:231-248.
6. Edwards G, Walker D. C_3, C_4: mechanisms and cellular and environmental regulation, of photosynthesis. Oxford: Blackwell Scientific Publications. 1983; 222(4627):1009.
7. Gillett NP, Arora VK, Zickfeld K. Ongoing climate change following a complete cessation of carbon dioxide emissions. Nature Geoscience. 2011; 4:83-87.
8. Heschel MS, Riginos C. Mechanisms of selection for drought stress tolerance an avoidance in *Impatiens capensis* (Balsaminaceae). American Journal Botany. 2005; 92:37-44.
9. IPCC (Intergovernmental panel on climate change) Climate change 2013 the physical science basis, 2013. (<http://www.ipcc.ch/report/ar5/wg1/>, March 2014).
10. Khaliq A, Riaz Y, Matloob A. Bio-economic assessment of chemical and non-chemical weed management strategies in dry seeded fine rice (*Oryza sativa* L.). Journal of Plant Breeding and Crop Science. 2011; 3:302-310.
11. Knapp AK, Beier C, Briske DD, Slassen AT, Luo Y, Reichstein M. Consequences of more extreme precipitation regimes for terrestrial ecosystems. Bioscience. 2008; 58(9):811-821.
12. Kulshreshtha G, Parmer. In: resource management for sustained crop production souvenir, Indian Society of Agronomy, New Delhi, 1992, 339-343.
13. Labrada R, Parker C. Weed control in the context of Integrated Pest Labrada R and Parker C. Management. Weed Management for Developing Countries. Edited R. Labrada JC, Caseley C. Parker, Plant Production and Protection Paper No. 120, FAO, Rome, 1994, 3-8.
14. Lobell D, Burke MB. Why are agricultural impacts of climate change so uncertain. Environment Research Letter. 2008; 3:1-8.
15. Naidu VSGR. Climate change, crop-weed balance and the future of weed management, Indian Journal of Weed Science 2015; 47(3):288-295.
16. Naidu VSGR, Murthy TGK. Crop-weed interactions under climate change, Indian Journal of Weed Science 2014; 46(1):61-65.
17. Poorter H, Navas M. Plant growth and competition at elevated CO_2: on winners, losers and functional groups. New Phytologist Journal. 2003; 157:175-198.
18. Robinson TMP, Gross KL. The impact of altered precipitation variability on annual weed species. American Journal of Botany. 2010; 97:1625-1629.
19. Saeed M. Interference of horse purslane (*Trianthema portulacastrum* L.) with maize (*Zea mays* L.) at different densities. Pakistan Journal of Botany. 2010; 42(1):173-

179.
20. Senthil A, Chinnusamy C, Kumar G, Prabhakaran NK. Identification of threshold level of horsepurslane (*Trianthem aportulacastrum*) in irrigated cowpea (*Vigna unguiculata*). Indian Journal of Crop Science. 2009; 4(1&2):141-143.
21. Singer A, Travis JMJ, Johst K. Interspecific interactions affect species and community responses to climate shifts. Oikos. 2013; 122:358-366.
22. Singh S. Effect of temperature and water potential on germination of twelve weed species. Indian Journal of Weed Science. 2009; 41(3-4):113-126.
23. Trumble J. Climate change: predicting pest problems and planning for the future. Presented at the California department of food and agriculture climate change adaptation consortium, American Canyon, CA. 2013, 23-27.
24. Tubiello FN, Soussana JF, Howden SM. Crop and pasture response to climate change. Proceeding of the National Academic Science. 2007; 104:19686-19690.
25. Walck JL, Hidayati SN, Dixon KW, Thompson K, Poschlod P. Climate change and plant regeneration from seed. Global Change Biology. 2011; 17:2145-2161.
26. Ziska LH, Bunce JA. Influence of increasing carbon dioxide concentration on the photosynthetic and growth stimulation of selected C_4 crops and weeds. Photosynthesis Research. 1997; 54:199-208.