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Climate change impact on pulse in India- A review

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Abstract

Climate change has emerged as one of the major global environmental issues, due to its subsequent impact on food production and food security. The changing climatic conditions have a major impact on rainfed crops including pulses. Since pulses occupy major share in rainfed agriculture, reduction in yields as a result of climate change are predicted to be more pronounced for these crops. The increasing CO$_2$ concentration is posing a serious threat as it leads an increase in the average global temperature but the same has been positively correlated with increased biomass and yield particularly in C$_3$ plants. Pulses are reported to be particularly sensitive to heat stress; a short span exposure of high temperature at flowering stage can cause heavy yield losses through damage to anthers, flower drop and pod damage. The predicted changes in temperature and their associated impacts, water availability, pests, disease, and extreme whether events are likely to affect potential of pulse production. Major pulses such as chickpea, pigeon pea, lentil grown under rainfed conditions are subjected to multiple stresses viz. drought, high and low temperatures, high solar radiation, salinity and waterlogging. If present trend in climate change continues as projected through various weather prediction models, the adverse situation will more pronounce for pulses crops. Global warming is already underway and adapting strategies are now a matter of urging, especially for the most vulnerable poor countries. An appropriate climate policy should be to minimise the effects of climate change at farm, regional, national and international level.

Keywords: Climate change, food security, pulses, adaptation strategies

Introduction

Climate change is any significant long-term change in the expected patterns of average weather of region (or the whole Earth) over a significant period of time. These changes may take tens, hundreds or perhaps millions of year. But increase in anthropogenic activities such as industrialization, urbanization, deforestation, agriculture, change in land use pattern etc. leads to emission of greenhouse gases due to which the rate of climate change is much faster. According to IPCC 2012 [32], it is a change of climate which is attributed directly or indirectly to human activity (Gul Zazai *et al*. 2018) [26] that alters the composition of the global climate atmosphere and which is an addition to natural climate variability observed over comparable time periods. IPCC has also reconfirmed that the global atmospheric stocks of greenhouse gases (GHGS) have increased markedly as a result of human activities since 1750, resulting in significant warming of the climate system by 0.74°C between 1906 and 2005 (IPCC 2007) with most warming occurring over the recent half century however, the warming has neither been steady nor the same spatially and temporally.(Chhagan *et al*. 2019a, 2019b) [10, 11] Climate change has emerged as one of the major global environmental issues due to its subsequent impact on food production and food security (Berg *et al*. 2013) [3]. Climate change scenarios include higher temperatures, changes in precipitation, and higher atmospheric CO$_2$ concentrations. The increased level of greenhouse gases (GHGs) (carbon dioxide (CO$_2$), water vapour (H$_2$O), methane (CH$_4$), nitrous oxide (N$_2$O), hydro fluorocarbons (HFCs), per fluorocarbons (PFCs), and sulphur hexafluoride (SF$_6$) etc. due to anthropogenic activities has contributed to an overall increase of the earth's temperature, leading to a global warming. The atmospheric CO$_2$ concentration has increased from 280 ppm to 395 ppm, CH$_4$ concentration increased from 715 ppb to 1882 ppb and N$_2$O concentration from 227 ppb to 323 ppt for the year 1750 and 2012.

The projected rate of warming is unprecedented during last 10,000 years. More intense and longer droughts have occurred since 1970s. Perpetual snow cover has declined on both area and depth of snow cover. Global mean sea level is projected to rise by 0.18 to 0.59 m by the end of the century. IPCC also predicted that average global surface temperatures will increase by 2.8°C during the twenty first century, with best- guess increases ranging from 1.8°C to

4℃ (IPCC 2007) [31]. During 20th century, global annual mean precipitation showed an insignificant upward trend with large spatial, seasonal and inter-decadal variability (IPCC 2007) [31]. Also solar radiation across the globe declined at a rate of 0.51 W/m^2/ year during last 50 years (Stanhill and Cohen 2001), a phenomenon that is generally termed as global dimming (Wild *et al*. 2005) [63].

In India, mean, maximum and minimum temperatures have significantly increased by 0.51, 0.71 and 0.27 per hundred years respectively during 1901 – 2007 (Kothawale *et al*. 2010) [37] with accelerated warming (0.21 / decade) after 1970s (Kothawale *et al*. 2010) [37]. The warming may be more pronounced in the northern parts of India. The extremes in maximum and minimum temperatures are expected to increase under changing climate, few places are expected to get more rain while some may remain dry. Leaving Punjab and Rajasthan in the North West and Tamil Nadu in the South, which show a slight decrease on an average a 20 per cent rise in all India summer monsoon rainfall over all states are expected. Number of rainy days may come down (e.g. MP) but the intensity is expected to rise at most of the parts of India (e.g. North East). Gross per capita water availability in India will decline from 1820 m^3/ yr in 2001 to as low as 1140 m^3/ yr in 2050. A trend of decreasing rainfall (-6% to -8% of normal over the last 100 years) has been observed in Northeast (NE) India (Gadgil *et al*. 2007) [21]. In addition, decrease of solar radiation and sunshine duration during recent past in India has also been observed (Kumari *et al*. 2007) [42].

Pulses and climate change

Food production, food security and climate change are intrinsically linked. Whether in the form of droughts, floods, hurricanes or soil acidification, climate change impacts every level of food production as well as ultimately, the price instability of food and the food security of affected farming communities (FAO 2016) [17]. Pulses have been recognized as a major source of vegetable protein with needed minerals and vitamins. They play a vital role in maintaining soil fertility by fixing atmospheric nitrogen. India is the largest producer of pulses in the world with 25% share in global production. The IPCC has projected that after 2050 temperatures would rise by 3-4 degrees over current levels with major impacts of climate change on rainfed crops (Mushtaq *et al*. 2020) [46]. Since pulses occupy major share in rainfed agriculture, reduction in yields as a result of climate change are predicted to be more pronounced for these crops, especially in indo-gangetic plains under limited water supply situations since there are no coping mechanisms for rainfall variability. The predicted changes in temperature and their associated impacts water availability, pests, disease, and extreme whether events are likely to affect potential of pulse production. Major pulses such as chickpea, pigeon pea, lentil grown under rainfed conditions are subjected to multiple stresses viz. drought, high and low temperatures, high solar radiation, salinity and waterlogging. If present trend in climate change continues as projected through various weather prediction models, the adverse situation will more pronounce for pulses crops. However, in order to cope up with these adverse abiotic factors, pulses have wide adaptive mechanisms such as very deep rooting system in pigeon pea and chickpea, high degree of dehydration tolerance, phenotypic plasticity, wide ranging sensitivity towards photo thermo periods and higher moisture retention capacity.

The effect of high temperature and water deficit

High temperature and water deficit decrease net photosynthesis during the period of the constraint, resulting in a reduction of plant growth rate. Final seed number and final seed weight depend on plant growth rate during the flowering period and the seed filling period, respectively (Guilioni *et al*. 2003; Pellissier *et al*. 2007) [25, 48]. Thus, high temperature and water deficit indirectly affect seed number and seed weight. Moreover, severe heat stress can cause abortion of flowers, resulting in direct reduction of seed number (Guilioni *et al*. 1997) [27]. However, the indeterminate growth pattern of most legumes provides plasticity to environmental stresses by allowing the development of additional flowers and then seeds under favourable growing conditions. The temperature during seed filling may influence N partitioning. For example, lowering temperature from 23°C to 13°C with maintained radiation results in an increase in C assimilate availability allowing new vegetative sinks to grow. The increase in vegetative growth seems to attract a part of the N available at the expense of filling seeds (Larmure *et al*. 2005) [43]. On the other side, increasing temperature above 23°C results in a decrease in the rate of N remobilization from vegetative parts to growing seeds (Pellissier *et al.* 2007; Ito *et al.* 2009) [48, 34]. Eventually, temperature variations can also affect seed N concentration, one of the main criteria determining the quality of grain legume. Legume plants have the ability to fix atmospheric N2 through symbiosis with soil bacteria (Rhizobia) hosted in specific root organs called “nodules”. Indeed, symbiotic N2 fixation is highly sensitive to environmental stresses (Sprent *et al.* 1988), especially to temperature, water, salinity, sodicity, acidity, and nutrient disorders (Chalk *et al.* 2010; Hungria and Vargas 2000; Jayasundara *et al.* 1998) [7, 30, 35]. As such, climate change may affect symbiotic fixation either directly by impairing Rhizobia survival, Rhizobia competitiveness, nodule formation, growth, or activity, or indirectly by modifying carbon supply to nodules. Still, effects of environmental constraints on those parameters largely remain to be precisely characterized and quantify, also considering the duration, timing, and severity of stress (Chalk *et al.* 2010) [7], and simulation modeling to predict symbiotic nitrogen fixation under different conditions would be quite useful (Liu *et al*. 2010) [44]. As a general rule, severe stresses inhibit both legume dry matter accumulation and the proportional dependence on symbiotic N fixation as a source of N. The symbiosis is resilient to low to moderate stress, but there may still be a penalty on legume dry matter (Chalk *et al.* 2010) [7]. Moreover, nodules compete for carbon use with the roots (Voisin *et al.* 2003) [60]. As such, nodulation can limit root growth. The restricted root development of some legume species (Hamblin and Tennant 1987) [28] may limit water and nutrient uptake, especially at late growth stages when environmental stresses are frequent. Bourgault *et al.,* (2018) [5], found that high temperature applied to lentil at the flat-pod stage reduced yield by 33% under both ambient and elevated CO2..For chickpea, Wang *et al*. (2006) [61] observed that high temperature imposed for10days at pod development caused plants to add fewer pods during post-stress recovery than equivalent stress imposed at early flowering. Controlled experiments on bengal gram under greenhouse conditions (irrigated) indicated that increasing temperatures beyond 21^0 (26/16 ^{0}C day / night) reduce bengal gram yields (Jumrani and Bhatia, 2014) [36] indicating temperature increase more than projected in the Info Crop models might negatively impact this crop and therefore breeding for heat tolerant varieties by improving reproductive efficiency is an essential part of climate change adaptation strategy in this crop.

The reproductive parts and grain-filling process are extremely sensitive to chilling and high temperature. The combined effect of heat and drought is more detrimental than effect of drought and heat alone, as a result productivity further goes down (Basu *et al.*, 2009) [2]. Pigeon pea, in particular, is highly sensitive to temperature fluctuations, causing massive flower drop, forced drying and bending of apical leaves when subjected to cold stress (< 5°C) (Basu *et al.*, 2009) [2]. In green gram, temperature above 42°C during summer causes seed hardening due to incomplete sink development. Field pea is well adapted to low temperature than other winter pulses like lentil and chickpea showing retarded growth below 7°C. Day-time maximum air temperature beyond 40°C during reproductive phase in winter pulses results in complete failure of anthesis, pod setting and induces hardening of seeds. The failure of anthesis at high temperature is primarily caused by poor pollen germination, stigma receptivity, and pollen load on stigma and ovule viability above 35°C (Basu *et al.*, 2009) [2]. Field pea is even more sensitive to high temperature than chickpea and lentil.

Timing and intensity of exposure to high temperature are critical where response varies across pulse crops (McDonald and Paulsen 1997; Egli *et al.* 2005) [45, 15]. Lentil is particularly sensitive to high temperature (>30°C) during the reproductive phase, causing pod and flower abortion and significant reduction in grain yield and quality (Erskine *et al*. 1994; Siddique 1999; Gaur *et al.* 2015; Kumar *et al.* 2016; Sehgal *et al.* 2017; Sita *et al.* 2017) [16, 55, 22, 40, 53, 57]. Several days of high temperature limits many physiological processes including photosynthesis, metabolic pathways, electron flow and respiration rates (Redden *et al.* 2014) [52]. Yield was reduced by 87% for lentils grown in pots under field conditions with high temperature during the reproductive phase (>38°C daytime, 23°C night) (Bhandari *et al.* 2016) [4], and grain set was observed to be the most sensitive yield component (Gaur et al. 2015; Bhandari *et al.* 2016) [22, 4].

Dubey *et al.*, (2011) [14] observed that with every 0.1°C increase in maximum and minimum temperature and temperature differences, the yield of the chickpea, lentil and pigeon pea declined considerably. Results also indicate that there was greater impact of increase in average maximum temperature on yield reduction as compared to increase in minimum temperature and the temperature difference (Table 1). The consequence of rainfall decline was also studied. On an average, the yield reduction for every 10mm average annual rainfall drop for the selected pulse crops was found to be 12.35, 13.05 and 8.05 kg/ha for chickpea, lentil and pigeon pea respectively (Table 1).

Table 1: Consequences of changed weather parameters on the yield of major pulses (adapted from Dubey *et al.*, 2011) [14]

Year	Increase in temperature (℃)	Variation in temperature Difference (℃) from the base year 2001- 2003	Trends in actual and declined rainfall (mm) from the baseline year of 2001 - 2003 (860.07mm)	Actual and decline yield (kg/ha) of major pulse from the base year 2004.		
	Max. Min. Temp. Temp.			Chickpea	Lentil	Pigeon pea
2004	+0.15 +2.45	-3.26	698(162)	1550(-)	1800(-)	1400(-)
2005	+0.16 +2.11	-2.93	680(180)	1500(-50)	1750(-50)	1325(-75)
2006	+1.15 +2.95	-2.55	534(326)	1200(-350)	1525(-275)	1200(-200)
2007	+0.56 +3.03	-3.37	556(304)	1100(-450)	1300(-500)	1105(-295)
2008	+1.81 +1.78	-0.93	600(260)	1075(-475)	1225(-575)	1045(-355)
Average	+0.86 +2.46	-2.60	614(268)	1285(-331)	1520(-350)	1215(-231)
Change in yield with every 0.1℃ increase in max. temperature				-38.49kg/ha	-40.7kg/ha	-26.86kg/ha
Change in yield with every 0.1℃increase in min. temperature				-13.46kg/ha	-14.22kg/ha	-9.39kg/ha
Change in yield with every 0.1℃ increase in temperature differences				-12.73kg/ha	-13.46kg/ha	-2.90kg/ha
Change in yield with every 10mm drop in the rainfall				-12.35kg/ha	-13.05kg/ha	-8.60kg/ha

Delahunty *et al.* (2018) [13] reported the response of three lentil genotypes to high temperature under variable carbon dioxide enrichment. It was observed that there was no significant interaction between temperature, CO_2 and genotypes on any of the lentil yield components measured, although there were significant main effects of temperature and genotype. High temperature caused a reduction of16% for grain set compared with the ambient control, whereas individual grain weight increased by 5% under high temperature (Table 2). High temperature also caused a decrease in harvest index of 10%. For lentil exposed to high temperature, there was no significant effect on biomass accumulation (Table 2). Although there was no significant effect of CO_2 on lentil yield components, CO_2 enrichment corresponded to an increase in biomass accumulation, grain number and yield of 16%, 11% and 4%, respectively (data not shown). However, there was a decline of harvest index and individual grain weight under elevated CO_2 of 11% and 4%, respectively.

Table 2: Effect of high temperature applied at early pod-filling for 3 days (38°C daytime, ambient night) on yield components of three lentil genotypes. (adapted from Delahunty *et al.* 2018) [13]

	High temperature Control Heat	(P=0.05)
Biomass (g pot–1)	8.5 8.4	n.s.
Grain number per pot	99.8 83.6	12.2
Individual grain weight (mg)	50.7 53.6	1.3
Grain yield (g pot–1)	4.9 4.4	0.5
Harvest index	0.59 0.53	0.03

The effect of heat waves

Climate change is expected to raise the frequency of extremes of cold and heat in different parts of the world (Christensen *et al.* 2007; Hennessey *et al.* 2008) [8, 29]. Yet, heat waves are common, and current characteristic of the semi-arid tropics and developing cultivars to withstand supra-optimal temperatures is important. It is well known that plant's reproduction is sensitive to heat stress (Prasad *et al.* 2000, 2002, 2006) [51, 50, 49]. Therefore, it will be important to identify genotypes that are capable of setting seeds at supra-optimal temperatures. In doing so, care should be taken with the experimental approach as simply delaying the date of planting to ensure that reproductive development occurs at high temperatures will also affect the radiation received by the crop. To reliably screen for the ability to set seed at high temperatures, controlled environment conditions will be required. Finally, considering the interaction of heat stress with water stress will be critical in semi-arid regions. There are indeed predictions of yield decrease in soybean in future scenarios, which are due to both moisture and heat stress (Carbone *et al*. 2003) [6].

The compensating effect of CO_2

High intrinsic water use efficiency, i.e., the ratio of photosynthetic and transpiration rates at the leaf level, is achieved by having a low CO_2 concentration in the sub stomatal chamber (Condon *et al.* 2002) [9]. A high photosynthetic rate would contribute to that by driving down the CO_2 concentration in the sub- stomatal chamber. Increasing CO_2 concentrations in the atmosphere would maintain optimal CO_2 concentrations in the sub-stomatal chamber at lower level of stomata opening, resulting in lower rates of transpiration saving water. Therefore, we can expect that the higher CO_2 conditions brought about by climate change will have a beneficial effect on the overall plant water balance and productivity, as has been show previously (Muchow and Sinclair 1991; Serraj 2003) [47, 54]. Reduced stomatal conductance in a higher CO_2 environment will maintain plant water relations, but may have implications for heat stress as leaf temperature rises with reduced transpiration. Warm air temperatures accelerate grain growth rate, reduce the duration of grain filling, and may reduce grain weight (Wiegand & Cuellar, 1981; Sionit *et al.,* 1987; Frederick & Camberato, 1995) [62, 56, 20]. Baker *et al.* (1989) reported the response of soybean yield to elevated CO_2 concentration at three temperatures over the day/night range of 26/19 t0 36/29°C (Table 3). Seed yield decreased as a function of temperature either at normal or elevated CO_2 concentration. This decrease was related to a decrease in seed weight. The data of (table 3) show no tendency for the growth modification factor to increase with temperature for either seed yield or biomass accumulation. In another study with soybean, a decrease in yield at elevated temperature (above 26/20°C daytime/night time) was associated with a decrease in pod number (Sionit *et al*., 1987) [56].

Table 3: Seed yield, components of yield, total above-ground biomass and harvest index of soybean grown at two CO_2 concentrations and three temperatures in 1987(adapted from Baker *et al*., 1989)

CO_2 conc. (μmol/mol)	Day/night temperature (°C)	Grain yield(g/plant)	Seeds/plant	Seed mass(mg/seed)	Aboveground biomass (g/plant)	Harvest index
330	26/19	9.0	44.7	202	17.1	0.53
330	31/24	10.1	52.1	195	19.8	0.51
330	36/29	10.1	58.9	172	22.2	0.45
660	26/19	13.1	58.8	223	26.6	0.49
660	31/24	12.5	63.2	198	27.6	0.45
660	36/29	11.6	70.1	165	26.5	0.44

F-Values

CO_2 conc.	12.3	11.4	2.5	NA	NA
Temperature	NS	8.4	106.2	NA	NA
CO_2 x Temperature	NS	NS	11.2	NA	NA

Adaptation strategies

The impact of climate change is complex and no single strategy will address the issue adequately. A combination technology and policy related interventions are required (Venkateswarlu and Shankar, 2009) [59]. Following are some important adaptation strategies.

Addition of photo- and thermo-insensitiveness

Pulses are considered to be highly sensitive to photo thermo-periods. Sensitivity to photo- and thermo-periods is the major factor responsible for high Genotype × Environment (G × E) interaction, and yield instability of major pulses across different environments. Therefore, development of photo-and thermo-insensitive genotypes had been the primary requirement to address the climate risk. Field studies have been conducted in pigeon pea with different maturity durations (extra-early, early, medium and long durations) in Kenya, to determine the effect of photoperiod and temperature on flowering. It has been found that the extra-short duration genotype 'ICPL 90011' was the least responsive to variation in photoperiod, while the 2 long duration genotypes 'ICEAP 00040' and 'T 7' were the most sensitive to photoperiod. In chickpea, 'ICCV 960029' and 'ICCV 960030' have been identified as photo- and thermo-insensitive (Table 4).

Table 4: Some of the food legume genotypes showing photo- and thermo-insensitivity (Basu *et al*. 2016) [1]

Food Legumes	Photo –thermo- insensitive
Chickpea	'ICCV 92944', 'ICCV 96029', 'ICCV 96030'
Blackgram	'PGRU 95016', 'IPU 99-89', 'IPU 94-1', 'IPU 99-79', 'BGP 247'
Vigna germplasm	V. umbellata ('IC 251442'), V. glabrescens ('IC 251372')
Pigeonpea wild accessions	C. scarabaeoides 'ICP 15761'
Pigeonpea	'ICPL 90011'

Complementing with sources of heat tolerance

Sources of heat tolerance have been identified in some legumes by exposing the crop to high temperatures at reproductive phase. Extensive screening of germplasm for heat tolerance across chickpea germplasm indicates a large genetic variation in heat tolerances (Krishnamurthy *et al.,* 2011) [38] that can be used in the breeding programmes for development of heat-tolerant varieties. Several thermo tolerant chickpea lines, e.g. 'ICC 1205', 'ICC 15614', 'ICC 8950', have also been identified. A heat-tolerant chickpea variety 'JG 14' has been released for late-sown condition in India and Myanmar (Gaur *et al*., 2010, 2014) [23, 24].

Adopting diversification in practice

Diversification of farming is an effective approach to reduce the risk associated with farming in unpredictable environments. Diversification of cropping to reduce risk is especially important under dry land conditions. Crops differ in their response to a given environment and this difference is used to reduce the risk associated with growing one crop. Mixed cropping or intercropping is an example of a successful approach to crop diversification where two or more crops are grown together in various possible configurations. Therefore, efficient utilization of resources by increasing cropping intensities following inter- and multiple-cropping systems. Actually, multiple-cropping systems, such as intercropping or crop rotations with pulses, have a higher soil carbon sequestration potential (FAO, 2016) [17]. Therefore, alternate land-use systems such as alley cropping, agri-horticultural and silvi-pastoral systems, which utilize the resources in better way and stabilizing pulse production. This system withstands climate extremes as pulses are hardier than most crops and help to nourish the soil (FAO, 2016) [17].

Fallow and conservation tillage

The fallow system is designed to conserve soil moisture. The fallow system has advantages like improved availability of soil nutrients and the eradication of certain soil-borne pests. Increasing storage of soil moisture by the fallow system with or without conservation tillage is standard agricultural practice in dry land farming. The benefit of fallow and conservation tillage in terms of increasing available soil moisture to the crop depends on soil water holding capacity, climate, topography and management practices. Conservation tillage is basically meant for minimized tillage operations to conserve soil structure and to maintain ground cover by mulch, such as stubble. These practices reduce water runoff and increase soil infiltration. Conservation tillage is the usual practice under dry land systems.

Maintaining adequate soil organic matter

Under changing climatic scenario, the soil organic carbon (SOC) is under severe attack. The advanced agricultural practices and or adoption of recommended management practices have tremendous potential in sequestering carbon in crop land soils. In other words, several farming practices and technologies can reduce GHGs emission and prevent climate change by enhancing carbon storage in soils, thereby preserving both the existing soil carbon as well as reducing emission of all the greenhouse gases.

Improved crop-specific practices

Agronomic practices such as tillage, sowing time, planting method, ridge-planting of kharif/ rainy-season pulses, crop geometry, plant population, nutrient and water management, seed treatment, weed management and plant protection have major impact on pulse productivity. Crop-specific agronomic practices hold tremendous scope to raise pulse productivity potential in water-stress region under changing climatic conditions. For example, typical practices involves incorporation of the fertilizers in furrows below the seed as limited soil-moisture restricts nutrients availability to plants. Further, judicious use of organic and inorganic fertilizers inputs improves moisture-holding capacity of soil and increase drought tolerance.

Water harvesting and supplemental irrigation

Pulse crops are usually grown in rainfed regions, leading to sub-optimal productivity levels. Hence scientific scheduling of irrigation, an estimate of quantity of water to be applied and deployment of water-saving irrigation methods can lead to enhanced yield, higher water and nutrient-use efficiency and larger area coverage under irrigation (DAC, GoI, 2012) [12]. Similarly, adoption of sprinkler irrigation has tremendous potential in saving irrigation water and expanding area under irrigation. The technique is successfully running in many districts of the country having limited water resources. Further, drip irrigation holds huge potential for widely spaced crops like pigeonpea. Above irrigation technology, can expand irrigation area by 30–50%. Overall, micro-irrigation ensures higher water-use efficiency and in turn water economy (Kumar *et al.*, 2014) [41].

Use of bio fertilizers

The use of certain bio fertilizers, such as arbuscular mycorrhizae (AM) fungi enhances water-use efficiency (11–24%) in rainfed pea (Kumar *et al*., 2016) [40]. Apart from enhancing overall nutrient-use efficiencies particularly of phosphorus, a technology involved is rather simple, very convenient, inexpensive and eco-friendly. The AM fungi do so by extending root-system into the soil through ramifying hyphae, thereby increasing its exploratory area for harnessing water from deeper layers. However, there is a dire need to conduct further researches in this area and generate database. Similarly, pulses need less nitrogen as external input because much of their N requirement is met through biological N-fixation. It is, therefore, important that farmers are encouraged to adopt agronomic practices that facilitate N fixation especially seed treatment with crop-specific Rhizobium strains**.**

Balanced nutrient management

Biological N_2 fixation enables pulse crops to meet 80– 90% of their nitrogen requirements; hence a small dose of 15–25 kg N/ha is sufficient to meet the requirement of most of the pulse crops. However, rotation of pulses with cereal crop requires slightly higher dose of N (30–40 kg N/ha). Besides, pulse crops respond well to 20–60 kg P_2O_5/ha. Widespread deficiency of certain micronutrients, especially of zinc and secondary nutrient, especially of sulphur in pulse-growing pockets of different states and boron deficiency in eastern and north-eastern states having acid soils have necessitated the use of said nutrient fertilizers (DAC, GoI, 2012) [12].

Conclusion

Climate is the primary determinant of agricultural productivity with direct impact on food production across the globe. Agriculture sector is the most sensitive sector to the climate changes because the climate of a region/country determines the nature and characteristics of vegetation and crops. Food production systems are extremely sensitive to climate changes like changes in temperature and precipitation, which may lead to outbreaks of pests and diseases thereby reducing harvest ultimately affecting the food security of the country. Increase in the mean seasonal temperature can reduce the duration of many pulse crops and hence reduce final yield. Improved agronomic practices hold tremendous potential to combat adverse impact of climate change on pulse production. By the adoption of recommended management practices, agriculture contributes not only to soil and water conservation, but also for enhancing the amount of soil organic carbon in soil and mitigating CO2 emission effects on climate change. This step will definitely contribute in stabilizing the Yield of major field crops in future

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