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MITIGATION TECHNIQUES FOR KHARIF PULSES TO ADDRESS CLIMATE ABNORMALITIES

Sonu Get

Ph. D. Scholar, Department of Plant Breeding, RARI, Sri Karan Narendra Agriculture University, Jobner-303329

Corresponding author's Email- **sonugate79@gmail.com**

Introduction

Pulses are an important source of protein supplementing human diet and are contributing significantly to the nutritional security of the majority population of the country. Productivity of pulses has been almost constant for the last four decades. The average productivity at global level is about 1.00 tonne/ha, while of India is > 0.9 tonne/ha. Similarly, area of pulse crops has not increased much during the past 60 to 65 years. In the World, India is the largest producer, consumer and importer of pulse. In India, pulses are grown in an area of 25.40 million ha with a production of 23.22 million tonne with 914 Kg/ha productivity (Anonyms, 2018-19). In India, Madhya Pradesh is the largest producer of pulses followed by Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh and Karnataka are together contributing 79% area and 80% production. In general, the low production and productivity of pulses are ascribed to crop affected by various forms of abiotic and biotic stresses in different regions of the country. Due to the uncertain low productivity, low income and low input nature, pulses are grown as residual/alternate crops on marginal lands in rainfed areas after taking care of food/income needs from high productivity high input crops like rice and wheat by most farmers. Also, they are grown as rainfed crops with limited application of inputs.

The productivity of Kharif pulses is often affected by high temperatures and drought, mostly during the podding phase. Yield loss is usually greater when legumes experience heat and drought during the reproductive period compared to the vegetative stage. Most pulses growing areas are vulnerable to climate change as the maximum threshold temperature for tolerance of pulses has already reached above 35°C. Reduction in yields in rainfed areas due to change in rainfall pattern during monsoon season and increase in demand for crop water. Early flowering, short duration, faster biomass accumulation, deep root-system, high water-use efficiency and high root proliferation before onset of terminal drought and heat are the morpho-physiological adaptations to escape these abiotic stresses. Under the changing climate scenario, soil organic carbon is subjected to reduction and adoption of resource-conserving technologies and most of these management practices have tremendous potential to sequestering carbon to the soil. Resource-conserving technologies, conservation-farming practices, and improved farming methods can reduce greenhouse gases emissions and increase soil carbon storage. In addition, the organic cultivation of pulses increases the organic content of the soil and reduces the emission of gases due to the exclusion of synthetic fertilizers. However, limited information is available on climatic stresses effect on performance of mitigation technologies to abiotic and biotic stresses on major pulse crops viz. green gram, black gram, pigeon pea and cluster bean crops.

Multiple climatic stresses

Adverse effects of climate change are more pronounced in pulse crops compared to oilseed and cereal crops. Pulse crops are more vulnerable even to the fluctuations of weather conditions. Climate change is affecting our agriculture owing to 0.74°C average global increase in temperature in the last 100 years and atmospheric CO2 concentration increase from 280 ppm in 1750 to nearly 400 ppm up to 2015 (Sankaranarayanan *et al.*, 2010). The increase of temperature of 3° to 4°C could reduce crop yields by 15 to 35%. The frequency of occurrences of extreme weather events such as changes in rainfall patterns, particularly late onset of monsoon, uneven distribution of rain, short-term water logging, mid-or late-season drought, floods, heat stress during flowering, fertilization and grain filling stage and cyclones has rise' in recent years than in the past during kharif. The pulse crop requires cold temperatures during vegetative growth and warm temperatures at maturity; the optimum temperature for growth is 18° to 30°C. Similarly, nitrogen-fixation through symbiotic association of Rhizobium sp. is also virtually declined at temperature exceeding beyond 35 °C. Depending on the intensity, duration, and stage of exposure, heat stress can adversely affect delayed flowering, flower abortion, reduced number and size of flower, deformity of floral organs during flowering stage, embryo abortion, poor fruit set at fertilization period, and like-wise during grain filling stage altered source sink relations, aborted seed. Moreover, drought and high temperature interact together, and the damaging effect of both the stresses together is far more severe than individual effect. Based on physiological studies, major kharif pulse crops are categorized as per thermo tolerance in the order of cluster bean > green gram > pigeon pea > black gram.

Abiotic climatic stress

The major abiotic climatic vulnerabilities are occasionally late onset of monsoon, mid-or late-season drought and water-logging, uneven distribution and untimely rains, frost, etc. The major abiotic stresses are water submergence during early stage of crop, photo-thermo sensitivity, late season drought, heat stress at flowering and pod formation stage affecting all major kharif pulses, excess growth due to high moisture content in soil and drought during reproductive stage of cluster bean, respectively. The water-logging during establishment stage, mid-and late-season drought in short and long duration pigeonpea cultivars, moreover long duration cultivars affected by frost, chilling temperature and heat waves. Drought stress alone may reduce seed yields by 50% in the arid and semi-arid regions.

Biotic climatic stress

Climate change abnormalities have increased the intensity of biotic stresses indirectly. Wilt and root rot increases in dry condition and excess moisture, whereas *Cercospora* rust disease increases due to excess soil moisture and humidity. The climate change abnormalities are one of the factors which regulate the density of insect pests in blackgram ecosystem. Combined infestation of pests and diseases in black gram annual estimated yield lose over 30% in dry land conditions. Similarly, yield losses in black gram by 67% due to yellow mosaic virus in irrigated conditions. Among insect pest, pod borer (*Helicovera armigera*) complex causes the greatest harm, followed by yellow vein mosaic virus, pod fly, wilt and root rot. Pod borer and sterility mosaic virus damage increases due to rise of temperature and prevalence of cloudy weather conditions. Poor drainage/water stagnation during the rainy season causes heavy losses to pigeon pea on account of low plant stand and increased incidence of Phytophthora blight disease. Yellow mosaic virus in green gram and black gram is due to white fly and fly increases under high humidity and slight increased temperature.

Mitigation techniques

Agriculture, particularly in India with nearly 60% rainfed area, has been a highly risky venture with vagaries of monsoon besides the interplay of other abiotic and biotic factors. Climate change is set to compound the daunting complex challenges already being faced by agriculture. Therefore, concerted efforts are required for mitigation and adaptation to reduce the vulnerability of Indian agriculture to the adverse impacts of climate change and making it more resilient. Conservation agriculture involving continuous minimum mechanical soil disturbance, permanent organic soil cover with crop residues or cover crops and diversified, efficient and economical viable crop rotations provides opportunities for savings on inputs, improving resource-use efficiency and mitigating greenhouse gas (GHG) emissions and climate change adaptation. Recent research efforts have attempted to develop conservation agriculture (CA) based crop management technologies, which are more resource-efficient, needless inputs, improve production and income, and reduce GHG emissions compared to the conventional practices (Pathak *et al*., 2011).

A. Mitigation via crop improvement strategies

1. Developing climate-resilient varieties

A large number of genotypes from diverse genetic resources of pulses have been identified as tolerant to multiple stresses. Among these, wild progenitors of diverse pulses have very high tolerance level for drought and heat or to both. For example a number of pigeonpea varieties have been identified which have high osmotic adjustment under drought. Some of these are: ‘VKS11/24-1’, ‘TGT 501’, ‘JKM 7’, ‘ICP 13673’, ‘GRG 2009-1’, ‘ICP 84031’, ‘Bahar’, ‘GRG 815’, ‘BDN708’ etc.

2. Reducing crop duration

Developing cultivars tolerant to heat, salinity, flood and drought stress; modifying crop-, water- and pest-management practices; adopting resource-conserving technologies; crop diversification and better weather forecasting etc.

3. Managing heat stress

Screening for heat tolerance and identification and development of heat-tolerant genotypes will play vital role in genetic advancements of pulses for mitigation of climate change in the future.

4. 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 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.

5. Enabling drought stress

Climate change driven high carbon gain per unit availability of water enables faster dry-matter accumulation, hence water-use efficiency (WUE) of all cool-season pulses may greatly increase. However, benefits of high WUE cannot be derived due to shortening of crop duration and adverse effects of high temperature that induces pollen sterility. Biomass was found to be the most sensitive to water stress.

B. **Mitigation via crop husbandry practices**

There are technologies available for stepping up the productivity and production levels of pulses under changing climatic scenario in the rainfed regions. The role of various management practices from mitigation point of view is given here:

1. Adopting diversification in practice

Diversification of farming is an effective approach to reduce the risk associated with farming in unpredictable environments. 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. Planting of several crop varieties (varietal diversification) offers a better probability for reducing loss due to environmental stress as compared to growing a single variety only. Higher rainfall intensities forecast during cropping season may prohibit planting in situ (under field condition) where certain contingency planning could help compensate the productivity loss (Praharaj *et al.,* 2015; Sankaranarayanan *et al*., 2010).

2. Fallow and conservation tillage

The fallow system has advantages like improved availability of soil nutrients and the eradication of certain soil-borne pests. Increasing soil moisture by the fallow system with or without conservation tillage is standard agricultural practice in dryland farming. Conservation tillage is basically meant for minimized tillage operations to conserve soil structure and to maintain ground cover by mulch, such as stubble. The conservation practices like zero/ minimum tillage practices with mulching, raised bed planting could provide a viable alternative to other land configurations for a remunerative pigeonpea–wheat system (Singh *et al.,* 2015) and in certain soils deep tillage was found very useful in improving soil-moisture storage.

3. 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. Important benefits of SOC in the low input agro ecosystems are the retention and storage of nutrients, increased buffering capacity, better soil aggregation, improved moisture retention, increased cation-exchange capacity. The addition and maintenance of soil organic carbon improves soil structure, texture and tilth (Hati *et al.,* 2008), activates a very large portion of inherent microorganisms.

4. Reducing greenhouse gas emissions

Several reports have highlighted the potential of organic agriculture in reducing greenhouse gases (GHGs) emission. Organic system of pulse production increases soil organic matter levels through the incorporation of composted organic manures and cultivation of cover crops (Suri *et al.,* 2012). These systems obviously lessen the emissions of gases through production and transportation of synthetic fertilizers due to less demand for them. The inclusion of pulses in crop rotation reduces the need for fertilizer inputs. Pulses supply their own nitrogen and contribute nitrogen to succeeding crops (Lemke *et al.,* 2007).

5. 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. Judicious use of organic and inorganic fertilizers inputs improves moisture-holding capacity of soil and increase drought tolerance.

6. Water harvesting and supplemental irrigation

Water-harvesting approach includes collection of runoff from large contributing areas and concentrates it for use in smaller crop area. Presently, basic water-harvesting systems involve an external contributing area to induce runoff. The water is diverted into a receiving area comprising cultivated plots, individual trees or small terraces. Similarly, adoption of sprinkler irrigation has tremendous potential in saving irrigation water and expanding area under irrigation. Micro-irrigation ensures higher water-use efficiency and in turn water economy (Kumar *et al.*, 2014b). Micro-irrigation at critical stages generally considered at flowering through sprinkler or drip may prove beneficial for increasing productivity of pulses.

7. Balanced nutrient management

Biological N2 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. Sulphur application @ 20–40 kg/ ha at sowing and zinc sulphate @ 25–50 kg/ha once in 2 years effectively overcome the deficiency of concerned nutrient, further enhancing pulse productivity.

Future Prospects

The following strategies for futures are essential for sustaining productivity and benefits.

- Provide Timely and long-term weather forecasts are suitable agricultural advice to farmers.
- In rainfed areas, conservation of rain water by in situ and ex-situ rainwater harvesting method and irrigation applied at drought conditions before flowering stage through drip or furrow or check basin or boarder strip method.
- Develop resistant / tolerant varieties of multiple biotic (eg wilt, blight, pod borer, etc.) and abiotic stresses (eg frost, drought, uneven temperature tolerance, etc.) through coordinated research efforts by the public and private sector.
- Promote resource conservation technologies such as permanent beds, traditional beds and ridge furrow sowing to improve productivity, profitability and enhance energy saving and physico-chemical properties of soil.
- With the technical help of university personnel, greater emphasis should be placed on seed production of region specific abiotic and biotic stress resistant / tolerant varieties through group of farmers.
- Seed supply to the user with bio fertilizers and Trichoderma @ 10 g / kg seed for seed treatment.
- Formulate state specific weather based abiotic and biotic stress insurance policies and encourage farmers to adopt widely to reduce losses during extreme climatic events.
- Formulation of policies for efficient use of natural resources, availability of quality inputs in the market and procurement of farmer produce at minimum support price fixed by the government.

Summary

Appropriate area specific climate resilient technologies can help in coping up with the challenge of climatic variability. Some climate resilient technologies such as cultivation of drought, heat, insect pest resistant/tolerant cultivars, slight modification in crop management practices, adoption of water management technologies, conservation agriculture technologies and better pest management, access to weather forecast can help to increase productivity of pulse. The crop established on bed and furrow for irrigation increases productivity and saving of crop from more water submergence. Similarly, insurance policies promoted to combat and minimize losses during extreme climatic events. Some of these technologies for pulse production are already being practiced by farmers in some parts of the country. But there is a need of wide dissemination and adoption of area specific technologies to protect or enhance pulse production. Thus it is concluded that timely adoption of proper technologies and tolerant/resistant cultivars can dilute effect of climatic abnormalities and doubling yield and benefits from rainy season pulse crops.

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