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# Review on climatic abnormalities effect on area, productivity and strategies of mitigating technology on lentil (*Lens culinaris*) in central India

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## Abstract
A study was conducted on climatic abnormalities impact on area and productivity during 3 decades of Madhya Pradesh and Chhattisgarh states of central India and mitigation technology influence on yield and economic benefits of lentil. Statistical analysis showed that absolute and relative changes in average area was slightly increased by 8.0 thousand ha and 0.8% against base years (1980 to 83) area (286.7 thousand ha), while productivity increased by 73.0 kg ha$^{-1}$ and 35.3% compared with productivity of base year (313.0 kg ha$^{-1}$), respectively. Study showed significant variability in area (CV=17.3%) and productivity (CV=23.7%) of central India. The maximum area increased in Vindhyan plateau (35.4 thousand ha), whereas decreased in Kymore plateau and Satpura hills (-25.7 thousand ha), while relative changes were maximum in Gird region (108.8%) and decreased in Satpura plateau (-41.8%) compared with base years. Maximum absolute change in productivity was of Vindhyan plateau (221.3 kg ha$^{-1}$), whereas it decreased in case of Satpura plateau (-17.0 kg ha$^{-1}$) and similar trend was observed in relative changes compared to base years. Results of trials showed that adoptions of technologies were neutralized the effect of climatic abnormalities. Study revealed that seed yield losses of lentil were from 19.6 to 40.0% with abiotic stresses, while 11.6 to 18.8% with biotic stresses compared with mitigation technologies. Escaping of abiotic and biotic stresses with improved technologies enhanced seed yield from 24.3 to 66.7% and 13.2 to 23.2% compared with control, respectively. Similarly, using improved techniques for mitigation of climatic abnormalities gave significantly higher economic benefits compared to control.

**Keywords:** relative and absolute change, variability, climatic abnormalities, area, productivity, economics

## Introduction
Lentil is an important food legume of South and West Asia and North Africa (Ferguson and Robertson, 1999) [8]. Among all pulse crops, lentil is presumably the most ancient legume (Bahl *et al*. 1993) [1]. About 37% of lentil area occurs in India, contributing to 32% of global production (Reddy *et al.* 2013) [15]. Lentil requires a cold climate and it is the 2$^{nd}$ largest growing pulse in *rabi* season after chickpea. It was grown in an area of 1.48 and 1.60 million hectares with an annual production of 1.03 and 0.94 million tonnes during 2010-11 and 2011-12, respectively. The major reasons of fluctuating production are climatic abnormalities. Climate change is affecting our agriculture due to 0.74 °C average global increase in temperature in the last 100 years and increase in atmospheric $CO_2$ concentration from 280 ppm in 1750 to 400 ppm in 2013 (Gautam *et al*. 2013) [9]. According to Gautam *et al*. (2013) [9] climate change is the biggest threat to mankind, and is the cause of nearly 0.4 million deaths a year worldwide and costing the world more than US$ 1.2 trillion. Climatic fluctuations are affecting yield and benefit of lentil by one or more stresses direct or indirectly such as drought, winter rains, hail storm and terminal heat. The more winter rains onwards of flowering to maturity in semi-arid irrigated and rainfed heavy soil areas affect lentil crop by excessive growth during reproductive stage causing severe lodging. Lentil crop is very hardy and can tolerate frost and severe winter but is quite sensitive to heat (Singh and Singh, 2016) [18]. It requires cold temperatures during vegetative growth and warm temperatures at maturity; the optimum temperature for growth is 18 to 30 °C (Kaushal *et al*. 2016) [11]. Flowering period of lentil is very sensitive to changes in external environment especially in temperature and photoperiod (Barghi *et al*. 2012) [2]. Depending on the intensity, duration, and stage of exposure, heat stress can adversely affect developing seeds causing delayed germination or loss of vigour which ultimately reduces emergence, growth rate and development of lentil (Chakraborty and Pradhan, 2011; Wahid *et al*. 2007) [4, 25]. Like-wise during seed filling, heat

stress retards seed growth by affecting all the biochemical events to reduce seed size, accelerate seed filling, thereby reducing the duration of this stage and limiting yield potential of lentil (Barghi *et al*. 2012; Kaushal *et al*. 2016) [2, 11]. Moreover drought and high temperature interact together, and the damaging effect of both the stresses is far more severe than individual effect (Singh and Singh, 2016) [18].

The biotic stresses have been reported to reduce indirectly the productivity of lentil by 20 to 25% (Gowda *et al*. 2015) [10]. Climatic abnormalities have increased the intensity of biotic stresses. Wilt and root rot increases in dry conditions and excess moisture, whereas *cercospora* rust disease increases due to excess soil moisture and humidity (Singh and Singh, 2016) [18]. Similarly, increases in temperature between 19 to 30 °C and humid conditions increases effect of aphid. However information on climatic stresses effect on area, productivity and comparative performance of mitigation technologies to abiotic and biotic stresses on lentil is lacking. Therefore the present study was undertaken to analyse factors affecting changes in area, productivity of states (Madhya Pradesh and Chhattisgarh) of central India and techniques for increasing yield and economic benefits of lentil in changing climatic scenario.

## Material and Methods

The Madhya Pradesh (MP) and Chhattisgarh (CG) states of central India were studied considering their agricultural zones as unit of investigation because a marked variation prevails in soil, climate, cropping pattern, area and productivity which divide states into 12 agro-climatic regions (Fig. 1). The district wise information on area, productivity and climatic vulnerability of lentil was collected from directorate of agricultural land records and contingent plan of MP and CG, respectively.

### Study period and preparation of data

The study period was selected from 1980-81 as base and to 2012-13 as the current year. The data on area and productivity of lentil crop for each district of agro-climatic regions was taken separately for the same period. The district figures were summed up of data regarding area and productivity of each year of each region separately. Three years' moving average was taken to minimize the fluctuations in time series data. Similarly, the district wise climatic vulnerability was summarised in respective agro-climatic zones of central India.

### Analysis of data

Absolute change is one of the methods of studying comparison into change of time/region/crop. Therefore, it was considered proper to take an average of three years, base and end of particular period. The absolute change (AC) of area and productivity was worked out by taking the average of area and productivity of the base year (average of three year 1980-81 to 1982-83) and the average of last current year (average of three years 2010-11 to 2012-13) of the study period and change in area and productivity worked out by: AC = Yn – Yo. Where, Y is used for variant, area/productivity, n and o for average of last three current period and beginning (base) three years.

Relative change (RC) gives a better compression analysis. This measure has been estimated for comparative change among the variable of the crop selected for the study. The comparative change in an area and productivity was worked out as RC = Yn – Yo. Where, Yn is used for current year and Yo for base year data.

Variability gave idea about fluctuations in area and productivity of lentil from base to current years. The base year the common measure of assessing the area variability is coefficient of variation (S.D./Mean x 100) which has been worked out for each region of stated coefficient of variation (C.V.) is defined by the following expression.

$$\text{C.V.} = \frac{6}{\text{x}} \text{ x } 100 = \frac{\text{Standard deviation}}{\text{Mean}} \text{ x } 100$$

For computing the standard deviation, the following formula is used S.D. = $\sqrt{1/N(\sum x^2 - \sum X)^2}/N$

Where, X is used for variable, area, production and productivity and N for number of observations (years).

### General description of site

On farm participatory trials on lentil were carried out during three *rabi* (winter) seasons from 2010 to 2013 to evaluate response of technologies for escaping abiotic and biotic stresses of climatic abnormalities. These trials were conducted at Jigani NICRA (National Initiative Climate Resilient Agriculture) village Morena district of MP, India. The study area lies between 26.5' N latitude and 77.9' E longitude. The agro-climatic region of selected site is Central plateau and hills region and characterized as semi-arid, extremely cold during December-January (-1.0 °C minimum temperature) and hot during May-June (50 °C maximum temperature). Average annual rainfall of this zone is 701 mm, mostly concentrated in July and August in compared to other months. The weekly average of minimum and maximum relative humidity ranged from 25.2 to 81.0% and 41.0 to 92.0% during first, 25.1 to 82.0% and 40.6 to 92.3% during second and 23.4 to 89.6% and 37.2 to 91.1% during third year of experimentation. The temperature and rainfall pattern during study area is given in Figure 2. The daily minimum and maximum temperature ranges were 0 to 49.5 °C, 4.5 to 50 °C and 1 to 47.5 °C, while total rainfall received 558, 875 and 1072 mm, during 2010-11, 2011-12 and 2012-13, respectively.

### Description of soil and analysis

The on farm trials were conducted on alluvial soils. Surface (0-20 cm) soil samples were collected for selected fields to determine initial soil properties. Analysis of soil samples for pH and electrical conductivity (1:2 soil water ratio) was undertaken. Organic carbon was determined by Walkley and Black (1934) [26] method; available N by Kjeltec-II auto analyzer, P by Olsen *et al*. (1954) [12] method, S by Chesnin and Yien (1950) [5] method, K by $NH_4OAc$ extraction and micronutrient by DTPA extraction method. The selected soils of farmers' fields were sandy loam in texture and range of EC was 0.27 to 0.32 dS $m^{-1}$ and pH 7.71 to 7.95. The soils were deficient in organic carbon (2.4 to 4.4 g $kg^{-1}$), available N (135 to 180 kg $ha^{-1}$), S (8.4 to 12.0 kg $ha^{-1}$), Zn (0.41 to 0.55 mg $kg^{-1}$), whereas low to medium in available P (8.1 to 10.9 kg $ha^{-1}$) and medium to high in available K (210 to 272 kg $ha^{-1}$). Available Cu (> 0.2 mg $kg^{-1}$), Fe (> 5.0 mg $kg^{-1}$) and Mn (> 2.0 mg $kg^{-1}$) contents were above the critical limit.

### Treatment details, management and observations

Ten farmer fields for trials were selected for assessment of impact of each technology compared to existing farmers' practices. The size of plots was 2000 $m^2$. The treatment effects were statistically analyzed using randomized block design. The technological interventions for mitigation of climatic effect and existing practices are followed given in table 5 and 6. The precision land levelling and sowing methods *viz*. flat and broad bed planting adopted as per treatment (Figure 3 and 4). Sowing of crop was during 3rd week of October and harvesting in 4th week of March in every year. The recommended dose of fertilizers for this zone was 20 kg N, 40 kg $P_2O_5$, 20 kg $K_2O$, 30 kg S $ha^{-1}$ for lentil and applied as basal. The sources of N, P, K and S were urea, dia-ammonium phosphate, muriate of potash and elemental sulphur, respectively. Package of practices were followed as per recommendation for different interventions. Seed, straw yield, cultivation cost, net returns and cost benefit ratio were calculated to find out the economics of various treatments under study. Different economic indicators of inputs were also calculated based on the existing market prices. Gross returns were calculated by multiplying seed yield with minimum support price of Government of India, and straw yield with prevailing market price. Net returns were calculated as: Net return = Gross return – Total cost of production.

## Results and Discussion

### Changes in area and productivity

Variations were observed in absolute and relative changes in area of lentil in all agro-climatic zones of central India (Table 1). Absolute and relative changes in lentil area was increased after three decades by 8.0 thousand ha and 0.8% against total cropped area (286.7 thousand ha) of base year (1980 to 83), respectively. The variability in area was observed by 17.3% in central India. The maximum increase in absolute changes in area were: Vindhyan plateau followed by Grid region, Bundelkhand, Malwa plateau and Nimar valley, while maximum decrease in Kymore plateau and Satpura hills followed by central Narmada valley, Northern hill region of Chhattisgarh and Chhotanagpur plateau, Chhattisgarh plain and Satpura plateau, respectively. Similar trend was observed in relative changes of central India. Maximum variability was recorded in Northern hill region of Chhattisgarh and Chhotanagpur plateau (CV=28.6%) due to crop being severally affected by climatic variabilities, while minimal effect of climatic effects in Malwa plateau (CV=7.9%) was observed (Table 1 and 2).

Absolute and relative changes in productivity of lentil was increased after three decades by only 73 kg $ha^{-1}$ and 35.4% compared with productivity of base year (313.0 kg $ha^{-1}$), respectively. The variability was quite high in productivity by 23.7% in central India which may be attributed to abiotic and biotic stresses due to fluctuations in climatic conditions (Table 1 and 2). The maximum increase in absolute changes in productivity was in order Vindhyan plateau followed by Nimar valley, Bundelkhand, Chhattisgarh plain, Grid region, central Narmada valley, Malwa, Kymore plateau and Northern hill region of Chhattisgarh and Chhotanagpur plateau, while decrease in Satpura plateau, respectively. Similar trend was also observed in relative changes of productivity of different agro-climatic regions of central India. Maximum variability in productivity was recorded in Nimar valley (CV=76.4%) due to crop being severally affected by climatic variabilities, while minimum effect of climatic effects in Satpura plateau (CV=7.9%) was observed (Table 1 and 2).

### Climatic vulnerability effect and mitigation technologies

Lentil is relatively less tolerant to drought and heat due to shallow, fibrous root system and grown in rainfed or limited irrigated conditions and facing multiple abiotic and biotic stresses in the climatic changing scenario.

### Abiotic stresses and mitigation technologies

The climatic problems such as high moisture content in soil by winter rain or flood irrigation during reproductive stage resulting plant turn to vegetative growth (Singh *et al*., 2018) [19]. Mid and late season drought affecting reproduction and photoperiod, while temperature are the major factors affecting flowering initiation and pod development (Table 3). Terminal drought and heat stress results in forced maturity with low yields (Singh *et al*., 2018) [19]. Another study showed that reproductive stage is more sensitive to high temperatures (30-35°C), resulting in impaired fertilization to cause abortion of flowers and heavy yield losses (Kaushal *et al*. 2016) [11]. Timely cultivation of drought tolerant short duration cultivars, light irrigation as per weather forecast by sprinkler or boarder strip irrigation at branching stage can avoid drought effect (Singh and Singh, 2018) [20]. Similarly, establishment of crop on bed could save crop with excess soil moisture and higher water productivity (Connor *et al*. 2003; Singh *et al*., 2018) [6, 19]. Proper plant population, intercultural operations, mulching and spray of 2% KCl enhance resistance to drought (Singh and Singh, 2016) [18]. The damaging effect through hail storm depends on intensity and stages of crop. The crop in growth stage is more chances of re-growth. For better re-growth after damage, proper nutrition management is required (Samra *et al*. 2003) [17]. Late season hail is more harmful to crop. Under these conditions crop insured by insurance companies is better option.

### Biotic stresses and mitigation technologies

More than 24 insect pest species are reported to affect lentil crop in India (Reddy *et al*., 2013) [15]. Among these, wilt, root rot, rust and aphid cause heavy losses of lentil crop in different parts of the Country (Table 4). Wilt (*Fusarium oxysporum*) is a seed-borne as well as soil-borne fungal diseases, pathogen can survive in soil up to six years even in the absence of the host (Gautam *et al*. 2013) [9]. Wet root rot (*Rhizoctonia solani*) fungal disease generally occurs due to high moisture conditions at seeding stage (Pande *et al*. 2009) [13]. Dry root rot (*Rhizoctonia bataticola*) is a soil-borne fungal disease that mostly appears at the time of flowering, podding and temperature 30 °C or above is favourable for this disease (Gautam *et al*. 2013) [9]. Under these conditions deep tillage in summer, selection of resistant cultivar, seed treatment with fungicides and establishment of crop on bed (Gautam *et al*. 2013; Pande *et al*. 2009; Prasad *et al*. 2012) [9, 13, 14] are good measures. Rust disease of lentil increases under high humidity and cloudy weather conditions with temperature 20 to 22 °C (Basandrai *et al*. 2000) [3]. Rust can easily be controlled by resistant cultivars, removal of infected plants and volunteer plants and selected fungicide spray at ETL level (Pande *et al*. 2009) [13]. Elbakidze *et al*. (2011) [7] observed that most favourable conditions for the growth of aphid populations, the optimum temperature for larval development has been found to be 19 to 30 °C, while 35 °C proved to be lethal. Under these climate conditions, timely sowing of crop and spray of pesticides at ETL level are recommended.

### Impact of mitigation technologies

The major abiotic climatic abnormalities directly affecting lentil crop of Gird region during *rabi* season are early withdrawal of rains creating drought, heat stress during reproduction, occasional winter rains and hail storm. Besides under biotic stress increases wilt, wet and dry root rot, rust and aphid are affecting indirectly. The impact technologies on yield and benefit of lentil crop are given below:

**Abiotic stresses on yield**

Occasionally untimely winter rains or flood irrigation increases soil moisture and humidity which increases crop-growth during reproductive stage. The establishment of crop on bed by broad bed and furrow sowing method (BBF) after precise land shaping (PLS) significantly increased the seed and straw yield of lentil over conventional tillage sowing method (CTS). The increase in seed yield was 58.9%, whereas a decrease of straw yield was recorded in lentil by 6.4% under PLS + BBF sowing method compared with CTS (Table 5). Similar results reported on chickpea under raised bed planting system by Connor *et al*. (2003) [6]. Another vulnerability was exposes the plants to higher temperatures and drought at reproductive phase. The drought and temperature fluctuations during seed filling period cause drastic yield losses. Under such conditions, timely sowing and irrigation at flowering stage increased the yield of lentil seed by 66.7% and straw by 52.1% compared to rainfed practice followed by farmers' (FP). Singh *et al* (1999) [21] reported that irrigation at flowering stage increases yield by 100.5% compared with rainfed lentil. The forced maturity of lentil crop due to terminal heat was avoided by sowing of crop with zero tillage sowing technology just after harvest of rainy season crop, which consequently increased seed and straw yields by 24.3 and 25.9%, respectively, compared to CTS. This technique advances the sowing operation by 10-15 days and increases in yield, also reduces the cost of production by saving energy (Singh *et al*. 2013; Singh *et al*., 2018b)[22, 23].

**Biotic stresses on yield**

The wilt/root rot disease infestation of crop due to dry and excess moisture condition severely affected the yield of lentil. The deep tillage in summer and seed treatment with fungicide for control of wilt/root rot resulted in increased seed and straw yield by 23.2 and 18.7% compared with control (Prasad *et al*. 2012)[14] (Table 6). Similarly, the rust disease under high humidity and cloudy weather conditions affected lentil crop. For escaping rust disease, sowing of resistant variety of lentil Pant L-5 increased seed and straw yield by 13.2 and 19.9%, respectively, compared to existing cultivar JL-1. Singh and Singh (2016)[18] reported that increases in temperature from 23 °C and humidity during cropping period resulted in rapid development of aphid infestation. Under this situations timely crop establishment and at ETL level spray of Trizophos @ 1000 ml ha$^{-1}$ resulted in significantly higher seed and straw yield of lentil compared to control condition. The average seed and straw yield of lentil was 21.1 and 7.0% higher with recommended technique for control of aphid compared to control. Gowda (2015) [10] reported that spray of area specific recommended pesticides at ETL easily control of aphid in pulse crops.

**Abiotic stresses on economics**

Among abiotic stresses higher additional cost for escaping of crop by drought during reproductive stage in lentil was Rs. 1,625 ha$^{-1}$, whereas a saving of Rs. 3,916 ha$^{-1}$ by timely sowing of crop by ZT method and also saving of crop from terminal heat infestation (Table 5). The trend of maximum additional returns Rs. 21,261 ha$^{-1}$ was obtained with sowing of crop by PLS + BBF method for saving the crop from excess moisture followed by management of drought during reproductive stage (Rs. 20,542 ha$^{-1}$) and terminal heat infestation (Rs. 16,264 ha$^{-1}$). The B:C ratio 4.0 was higher under direct seeding through ZT method for escaped crop by terminal heat due advance sowing, whereas lower value was 2.7 recorded under irrigation at branching for control of drought during reproductive stage of lentil.

**Biotic stresses on economics**

The trend of additional production cost recorded under biotic stress was maximum with management of wilt (Rs. 1,747 ha$^{-1}$) followed by control of aphid (Rs. 1,120 ha$^{-1}$) and rust management (Rs. 769 ha$^{-1}$) of lentil (Table 6). The maximum additional return with control of wilt (Rs. 11,442 ha$^{-1}$), while Rs. 8,862 ha$^{-1}$ with aphid and Rs. 7,008 ha$^{-1}$ with control of rust was obtained. The B:C ratio was higher (3.2) under control of wilt and lower (3.1) under control of aphid.

**Adaptation strategies**

The impact of climate changes are complex and no single strategy will address these issue adequately (Singh *et al*., 2018) [19]. Area specific combination of technologies and policy related interventions are required. Adoption of resources management, resistant or tolerant cultivars, production technologies for mitigation in changing/abnormal climatic scenario, the following strategies are important for enhancing productivity.

1. Timely micro level weather forecast of agro-advisories includes abiotic and biotic stresses.
2. Water management is the most crucial part of pulse production, life saving light irrigation applied at branching stage through sprinkler, drip or furrow method.
3. Evolving varieties tolerant to climatic stress of biotic and abiotic multiple climatic stresses through coordinated research efforts by public and private sector.
4. For increasing yield, benefits and energy savings promoting area specific techniques of conservation tillage sowing methods is essential.
5. More emphasis on need based area specific recommended varieties seed production of abiotic and biotic stress resistant/tolerant through seed societies, farmers groups.
6. Seed supply to end user along with seed treatment inputs and nutrient application as per soil test.
7. Formulate specific weather based abiotic and biotic stresses insurance policies and encourage farmers for wider adoption.
8. Policy formulated for smart utilization of natural resources, energy, providing quality inputs to farmers, *etc*.
9. Urgent need to develop innovative institutional models of marketing like Farmer Producer Company, NAFED, Amul, Mother dairy, Parag, Dhara, *etc* from production to consumption.

It was concluded that analysis of data from 1980-81 to 2012-13 showed minor growth in area due to challenging climatic vulnerabilities, while productivity of lentil increased by 35.3% from base year productivity (313 kg ha$^{-1}$). Results showed that climatic fluctuations were major challenges for enhancing area and productivity. Higher yield and benefits by adjusting of technologies is essential to direct impact of multiple abiotic stresses (drought, heat and winter rain) and indirectly biotic climatic stresses (wilt, rust and aphid). Adoption of improved crop production and establishment technologies such as PLS + BBF could save crop with excess soil moisture, timely crop established by ZT, deep tillage in summer, resistant/tolerant cultivars sown after seed treatment, use of insecticide at ETL will significantly improved productivity and profitability of lentil. Similarly insurance policies should be promoted for minimizing losses during extreme climatic events.

**Table 1:** Absolute, relative changes and variability in area and productivity of lentil after 3 decades (1980-83 to 2010-13) of different agro-climatic regions of central India

| S. No | Agro-climatic regions | Average area of base years (1980 to 83) ('000 ha) | Absolute change | Relative changes (%) | Base years average yield (kg $ha^{-1}$) (1980-83) | Absolute change | Relative changes (%) |
|---|---|---|---|---|---|---|---|
| 1. | Kymore plateau and Satpura hills | 71.3 | -25.7 | -36.0(18.7)* | 236.7 | 53.7 | 22.7(10.0) |
| 2. | Vindhyan plateau | 109.0 | 35.4 | 32.5(13.5) | 216.1 | 221.3 | 102.4(41.1) |
| 3. | Central Narmada valley | 22.9 | -11.3 | -49.3(21.3) | 258.8 | 77.5 | 21.6(17.1) |
| 4. | Grid region | 21.3 | 23.2 | 108.8(23.4) | 374.2 | 84.5 | 22.6(35.3) |
| 5. | Bundelkhand region | 11.2 | 3.3 | 30.0(13.6) | 274.1 | 131.6 | 48.0(15.2) |
| 6. | Satpura plateau | 11.0 | -4.6 | -41.8(15.9) | 281.8 | -17.0 | -6.0(7.9) |
| 7. | Malwa plateau | 3.9 | 1.1 | 21.6(7.9) | 286.8 | 69.2 | 24.1(13.9) |
| 8. | Nimar valley | 1.4 | 0.1 | 9.8(15.6) | 324.8 | 184.8 | 56.9(76.4) |
| 9. | Jhabua hills | - | - | - | - | - | - |
| 10. | Chhattisgarh plain | 14.8 | -5.4 | -36.3(14.7) | 173.7 | 84.6 | 48.7(9.2) |
| 11. | Northern hill region of Chhattisgarh & Chhotanagpur plateau | 20.5 | -6.4 | -31.3(28.6) | 275.8 | 34.0 | 12.3(11.1) |
| 12. | Baster plateau Madhya Pradesh and Chhattisgarh | -286.7 | -8.0 | -0.8(17.3) | -313.0 | -73.0 | -35.3(23.7) |

*Figure in parenthesis variability

**Table 2:** Climatic vulnerability affecting lentil crop of different Agro-climatic regions of central India

| S. No | Agro-climatic regions | Climatic vulnerability effects |
|---|---|---|
| 1. | Chhattisgarh plain, | Drought < Occasional heat < Hail storm |
| 2. | Baster plateau | |
| 3. | Northern Hill Region of Chhattisgarh | Drought < Winter rains < Heat stress < Hail storm |
| 4. | Kymore Plateau and Satpura Hills | Drought < Winter rains < Heat waves < Hailstorm |
| 5. | Vindhyan Plateau | Drought < Winter rains < Heat waves < Hail storm |
| 6. | Central Narmada Valley | Occasional drought < Winter rains < Heat waves < Hailstorm |
| 7. | Grid Region | Occasional drought under rainfed conditions (mid and late season) < Winter rains < Hail storm |
| 8. | Bundelkhand Region | Regular drought < Dry spell < Winter rains < Heat waves < Hail storm |
| 9. | Satpura Plateau | Occasional drought < Heat waves < Hailstorm |
| 10. | Malwa Plateau | Regular drought < Occasional heat < Hail storm |
| 11. | Nimar Valley | Occasional drought and heat waves < Hailstorm |
| 12. | Jhabua Hills | Drought < Occasional heat waves |

**Table 3:** Effect of climatic vulnerability on abiotic stress and suggestions for mitigations in lentil

| S. No. | Climatic vulnerabilities | Effect of vulnerability | Mitigation technologies | References |
|---|---|---|---|---|
| 1. | High soil moisture due to winter rains or flood irrigation and humidity | Encourages growth during reproductive stage, decreasing yield and benefit | 1. Sowing of crop on BBF<br>2. Irrigation as per weather forecast | [18, 19, 20, 23] |
| 2. | Mid and late season drought stress | Suppress growth characters, yield attributes and yield. | 1. Cultivation of drought tolerant and short duration cultivars<br>2. Proper plant population, intercultural operations<br>3. Mulching and spray of 2% KCl<br>4. One light irrigation before flowering initiation | [11, 18, 19, 24] |
| 3. | Heat stress (> 30 °C) | Terminated anthesis, pollen germination and seed development partially or almost completely, degradation of chlorophyll, induce senescence and forced maturity. | 1. Timely sowing<br>2. Cultivation of short duration cultivars | [11, 18] |
| 4. | Hail storm | Hail storm damaging crop as per intensity. | 1. Crop insurance<br>2. Damage at early stage spray of 2% N along micronutrient and growth regulators | [16, 18] |

**Table 4:** Effect of climatic vulnerability on biotic stress and suggestions for mitigations in lentil

| S. No. | Climatic vulnerabilities | Effect of Vulnerability | Mitigation technologies | References |
|---|---|---|---|---|
| 1. | Excess moisture, high humidity, temperature > 30 °C is favourable for wet and relatively low temperature (22 – 22 °C) at flowering or podding stage for dry root rot | Wilt (*Fusarium* oxysporum), wet root rot (*Rhizoctonia solani*) and dry root rot (*R. bataticola*) | 1. Deep tillage in summer<br>2. Seed treatment with fungicides<br>3. Selection of resistance cultivars | [9, 13,14, 18, 19]Pande |
| 2. | High humidity and cloudy weather with temperature 20 to 22 °C | Rust (*Uromyces fabae*) | 1. Resistant cultivars<br>2. Removal of infected and volunteer plants<br>3. Fungicide spray at ETL level | [3, 13] |
| 3. | Increase in temperature (>23 °C) and humidity | Aphid (*Aphis craccivora*) | 1. Timely crop sowing<br>2. Growing early cultivars<br>3. Quinolphos 25 EC @ 1000 ml ha$^{-1}$ or Trizophos @ 1000 ml ha$^{-1}$ | [7, 18] |

**Table 5:** Impact of different technological interventions for abiotic climatic vulnerabilities on lentil (3 year mean)

| Climatological problems | Treatment | Seed yield (q ha$^{-1}$) | Straw yield (q ha$^{-1}$) | Cost of production (Rs ha$^{-1}$) | Net returns (Rs ha$^{-1}$) | B:C ratio |
|---|---|---|---|---|---|---|
| Excess growth | CTS | 12.4 | 21.9 | 18150 | 24004 | 2.3 |
| | BBF | 17.6 | 18.3 | 18766 | 39238 | 3.1 |
| | PLS + BBF | 19.7 | 20.5 | 19760 | 45265 | 3.3 |
| | CD at 5% | 0.5 | 1.4 | NS | 2027 | 0.6 |
| Terminal heat infestation | CTS | 15.2 | 17.4 | 19594 | 30090 | 2.5 |
| | ZT | 18.9 | 21.9 | 15678 | 46354 | 4.0 |
| | CD at 5% | 0.3 | 0.9 | 972 | 1826 | 0.2 |
| Reproductive stage drought | RF | 9.9 | 12.0 | 18580 | 13853 | 1.8 |
| | IF | 16.5 | 21.3 | 20205 | 34395 | 2.7 |
| | CD at 5% | 0.8 | 1.2 | 1008 | 1590 | 0.7 |

CTS- Conventional tillage sowing practice, PLS- Precise land shaping, BBF- Broad bed and furrow sowing, ZT- Zero tillage sowing, RF- Rainfed crop, IF- One irrigation at flowering stage, minimum support price of lentil seed Rs 2250 q$^{-1}$, 2,800 q$^{-1}$, 2,900 q$^{-1}$, while straw rate in local marker @ Rs 175 q$^{-1}$, 200 q$^{-1}$ and 225 q$^{-1}$ during 2010-11, 2011-12 and 2012-13, respectively.

**Table 6:** Impact of different technological interventions for biotic climatic vulnerability on lentil (3 year mean)

| Climatological problems | Intervention | Seed yield (q ha$^{-1}$) | Straw yield (q ha$^{-1}$) | Cost of production (Rs ha$^{-1}$) | Net returns (Rs ha$^{-1}$) | B:C ratio |
|---|---|---|---|---|---|---|
| Fusarium wilt/root rot | NA | 16.8 | 20.9 | 19708 | 35468 | 2.8 |
| | DP + ST | 20.7 | 24.8 | 21455 | 46910 | 3.2 |
| | CD at 5% | 1.1 | 1.4 | 979 | 1216 | 0.2 |
| Rust disease | JL-1 | 15.7 | 19.6 | 17940 | 33743 | 2.9 |
| | Pant L-5 | 18.9 | 23.5 | 18709 | 43601 | 3.3 |
| | CD at 5% | 0.9 | 1.4 | NS | 1425 | 0.2 |
| Aphid | NA | 14.2 | 17.1 | 17290 | 26,814 | 2.6 |
| | TCE + IS | 18.3 | 22.5 | 18410 | 38,526 | 3.1 |
| | CD at 5% | 0.7 | 1.2 | 810 | 1347 | 0.3 |

NA- Note adopted any practice, DT- Deep tillage in summer, ST- Seed treatment with cabendazim @ 3g/kg, JL 1- Old cultivar, Pant L-4- Resistant cultivar, TCE- Timely crop establishment, IS- Trizophos @ 1000 ml ha$^{-1}$, minimum support price of lentil seed Rs 2250 q$^{-1}$, 2,800 q$^{-1}$, 2,900 q$^{-1}$, while straw rate in local marker @ Rs 175 q$^{-1}$, 200 q$^{-1}$ and 225 q$^{-1}$ during 2010-11, 2011-12 and 2012-13, respectively.

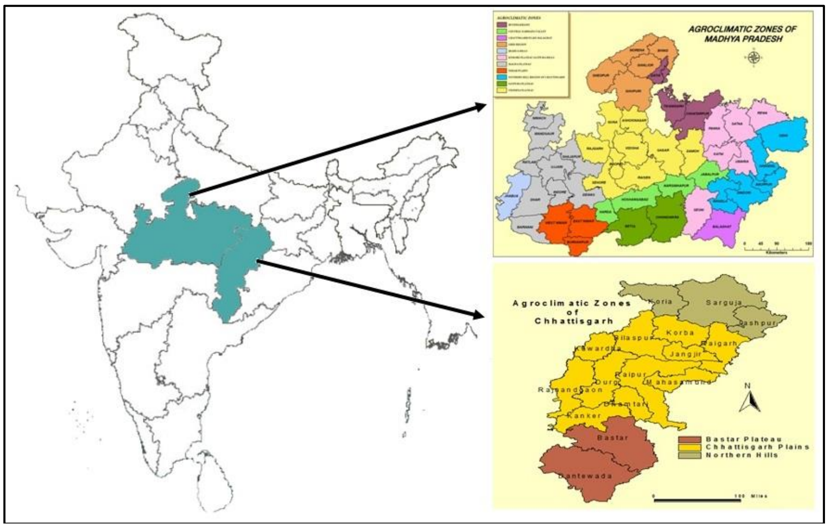


**Fig 1:** Agro-climatic regions of selected study areas of central India

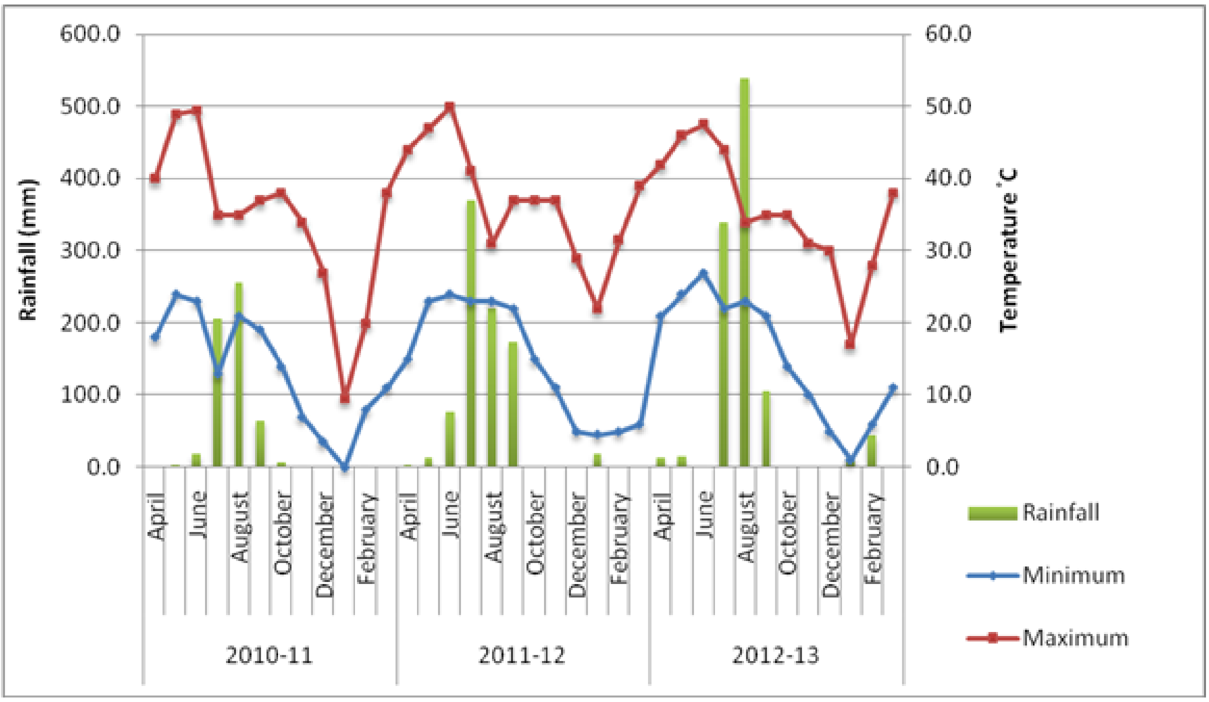


**Fig 2:** Experimentation period monthly total rainfall, minimum and maximum temperature

**Fig 3:** Shaping of field ±2 cm at 100m by laser-assist precision land leveller

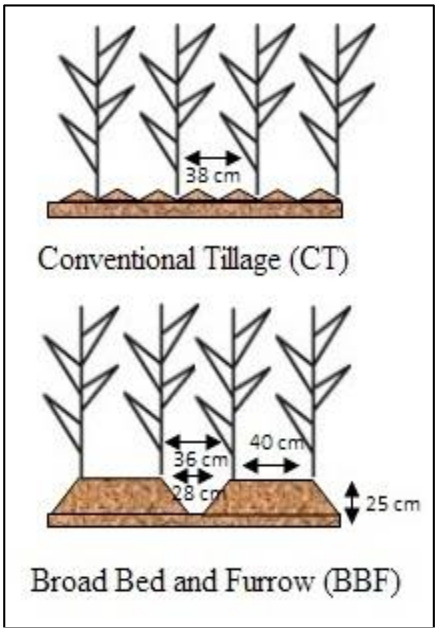


**Fig 4:** Schematic diagram of sowing methods

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