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Sudhir Singh
Dept. of Ag. Economics, COA, Gwalior, Madhya Pradesh, India

YP Singh
AICRP-IWM, R.V.S. Krishi Vishwa Vidyalaya-ZARS, Morena, Madhya Pradesh, India

Ravi Gurjar
FFP, R.V.S. Krishi Vishwa Vidyalaya-ZARS, Morena, Madhya Pradesh, India

SS Tomar
AICRP-IWM, R.V.S. Krishi Vishwa Vidyalaya-ZARS, Morena, Madhya Pradesh, India

Correspondence
Sudhir Singh
Dept. of Ag. Economics, COA, Gwalior, Madhya Pradesh, India

Review on climatic impact on area, productivity of Madhya Pradesh, strategies and mitigating technology on yield and benefits of chickpea (*Cicer arietinum*)

Sudhir Singh, YP Singh, Ravi Gurjar and SS Tomar

Abstract
A study was conducted on climatic abnormalities impact on changes in area and productivity after 3 decades of different agro-climatic regions of Madhya Pradesh state of India and mitigation technologies on yield and benefits of chickpea. Absolute and relative changes in area was increased by 627.67 thousand ha and 40.7% against base years (1980 to 83) area 1541.74 thousand ha, while increased in productivity by 178.33 kg ha^{-1} and 37.9% compared with base year yield (471.00 kg ha^{-1}), respectively. All agro-climatic regions showed prominent disparity in area and productivity. Maximum area increased in Malwa plateau (420.03 thousand ha), whereas decreased in Satpura hills (-57.43 thousand ha) compared with base year. Trend of relative changes was obtained in area higher of Jhabua hills (241.18%), while declined in Satpura plateau (-24.55%). Relative changes in productivity was increased of Gird region (128.44%), whereas declined in Vindhyan plateau (-14.40%) compared of base year. Adoption of technologies was neutralized effect of climatic abnormalities. Excess soil moisture through winter rains or faulty irrigation which leads increases plant growth. Under these conditions, crop sown by BBF increased yield by 74.7%, whereas minimum increases in grain yield was using drought tolerant cultivar JG-14 (18.5%) under drought conditions. Adverse effect of terminal heat reduced by advance sowing with ZT just after harvest of *Kharif* crops, resulting increased of grain yield by 22.2%, while root rot effect was diminished by BBF sowing of JG-11 cultivar increased grain yield by 37.7% over control. Wilt infestation under rainfed situations was reduced by summer deep tillage and sowing resistant cultivar JG-11 resulted increased in yield by 37.5%, whereas increase of 38.1% grain yield by crop sown with BBF and spray of Mencozeb 3 g lit.$^{-1}$ water at appearance of *cerecospora* disease. Similarly, using improved techniques for mitigation of climatic abnormalities gave higher net returns and B:C ratio compared to control.

Keywords: relative and absolute change, area and productivity, climatic abnormalities, technological impact, chickpea

Introduction

India's contribution towards global chickpea area and production is about 70% (Gowda *et al*., 2015) [6]. The analysis of 2012-13, shows out of total pulses area 24.7 m ha, highest area was of chickpea (8.7 m ha) followed by pigeon pea (3.81 m ha) in India. In India, Madhya Pradesh (MP) is the largest producer of pulses followed by Maharashtra, Rajasthan, Uttar Pradesh, Andhra Pradesh and Karnataka (Singh and Singh, 2018) [16]. These six states together contribute 79% of pulses area and 80% of pulses production (Chaturvedi and Sandhu, 2016) [2]. The legume crops are grown under rainfed/limited soil moisture conditions under medium and low fertile soils (Singh *et al*., 2018) [14, 17]. In similar conditions, Madhya Pradesh is emerging as a potential source of chickpea because of demand for *kabuli* cultivars for domestic and international market. Extra-large size seed of *kabuli* chickpea fetches premium price in domestic and international markets. Over all, productivity of pulses in MP is quite low 435 kg ha^{-1} against average productivity of Country (1014 kg ha^{-1}) during 2012-13. Moreover, productivity of chickpea remained almost stagnant during last two decades of MP due to crop grown in marginal land, rainfed situations, poor crop management with almost no or little fertilizer application (Singh and Singh, 2016) [13]. The chickpea crop is also highly sensitive to environmental fluctuations (Singh *et al*., 2018) [17]. According to Samra *et al*. (2003) [11] optimum temperature range for chickpea crop is 20 to 25 °C and the lower and higher limits are 5 and 30 °C. The increasing temperature beyond the optimum limit decreases the photosynthetic rates. Studies on chickpea crop showed that anthesis, pollen germination and grain development partially or almost completely terminate when day time temperature exceeded beyond 35 °C which has become a recurrent feature in the entire Northern, Western and Central plains of India (Basu, 2015) [1]. Another important climate fluctuation affecting production of crop are: high night temperature, excess soil moisture, drought appearance in more intense form as a result of high temperature interaction. Unpredictable weather condition coupled with temperature extremities (both high and low) adversely affects reproductive physiology and grain filling in pods, changes in the native flora of *rhizobium* and other useful microbes due to ecological imbalances' (Singh and Singh., 2018) [13, 16].

The major climatic vulnerabilities of this region during winter season are frost, drought, terminal heat and occasional winter rains. The crop specific climatic problems such as terminal heat and drought during reproductive stage and vegetative growth, high moisture content in soil by rain or excess irrigation in pulse crops (Singh *et al*., 2018; Singh and Singh., 2018) [14, 16]. Terminal drought and heat stress results in forced maturity with low yields. More than 80% rainfed pulses face recurrent terminal drought causing substantial yield loss (Basu, 2015) [1]. The winter season crop chickpea is often affected by chilling temperatures especially in North and North-Western India. High moisture availability in soil affects chickpea crop adversely through wilt/root rot and *cercospora* (Singh and Singh, 2016) [13]. The present study was undertaken to analyse factors affecting changes in area, productivity and techniques for increasing yield and benefits of chickpea in changing climatic scenario and results are presented.

Material and Methods

The Madhya Pradesh (MP) state of India was studied considering its agricultural zones as unit of investigation because a marked variation prevails in soil and climate which divides state into 11 agro-climatic regions (Fig 1), which have great variation in farming pattern in area and productivity in different parts of the states. The district wise information on area, productivity and climatic vulnerability of chickpea was collected from directorate of agricultural land records and contingent plan of MP.

Study period and preparation of data

The post period was selected for this study from 1980-81 to 2012-13. The year 1982-83 was selected as the base year, whereas 2012-13 selected as the current year. The data on area and productivity of chickpea crops for each agro-climatic region taken separately for the same period. District figures were summed up to from agro-climatic data regarding area and productivity of each year and each reason separately. Three year moving average were taken minimize the fluctuations in time series data. The district-wise climatic vulnerability is summarised in respective agro-climatic regions of MP.

Analysis of data

Absolute change is one of the methods of studying comparison into change of time/region/crop by an estimation of absolute change. 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

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.

General description of site

On farm trials on chickpea were carried out during two *rabi* (Winter) seasons from 2011 to 2013 to evaluate response of technologies for escaping abiotic and biotic stresses of climatic abnormalities. These trials were conducted at Jigani NICRA village Morena district of MP, India. The study area lies between 23° 15' to 26° 45' N latitude and 70° 30' E longitude with altitude ranging from 150 to 240 m. The Grid agro-climatic region of selected 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 cluster is 701 mm, mostly concentrated in the months of July and August. The weekly minimum and maximum relative humidity was 67 and 98% during first and 48 and 94% during second year, whereas temperature was 3 and 50 °C during first and 1 and 47.5 °C during second year of experimentation, respectively. Annual rainfall received during 2011-12 and 2012-13 was 875 and 1074 mm, respectively (Fig 2). During cropping period of chickpea, 27.7 and 5.8mm rainfall was received during first and second year, respectively.

Description of soil and analysis

The trials were conducted on alluvial soils. Surface (0-20 cm) soil samples were collected for selected fields for determining 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) [19] method; available N by Kjeltec-II auto analyzer, P by Olsen *et al*. method (1954) [8], S by Chesnin and Yein method (1950) [3], K by NH_4OAc extraction and micronutrient by DTPA extraction method. The selected soil of farmers' field was sandy loam in texture and ranges of EC 0.27 to 0.41 dS m^{-1} and pH 7.62 to 7.82. The soils were deficient in organic carbon (2.5 to 4.1 g kg^{-1}), available N (132 to 180 kg ha^{-1}), S (8.1 to 12.6 kg ha^{-1}), Zn (0.41 to 0.55 to mg kg^{-1}), whereas low to medium in available P (8.0 to 11.8 kg ha^{-1}) and medium to high in available K (208 to 295 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 and management

Ten farmer fields for each trial were selected for assessment of effect of each technology compared to existing practices. The interventions for mitigation of climatic effect and existing practices were followed in trials given in table 4. The size of plots was 2000 m^2. The treatment effects were statistically analyzed using randomized block design. Package of practices were followed as per recommendation for different interventions. The sowing methods adopted flat (existing practice) and broad bed furrow sowing adopted as per treatment (Fig 3). Sowing of crop during 4th week of October and harvesting at 4th week of March in each year. The recommended dose of fertilizers for this zone was 20 kg N, 50 kg P_2O_5, 20 kg K_2O, 30 kg S ha^{-1} for chickpea. Full recommended dose was applied as basal application and sources of N, P, K and S were urea, dia-ammonium phosphate, muriate of potash and elemental sulphur, respectively.

Data collection and economic analysis

Grain, 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 grain 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 and productivity of chickpea in all agro-climatic zones of MP (Table 1). Absolute and relative changes in chickpea area of state was increased by 627.67 thousand ha and 40.71% against base year (1980 to 83) total cropped area (1541.74 thousand ha), while changes in productivity by 178.33 kg ha^{-1} and 37.86% compared with productivity of base year (471.00 kg ha^{-1}), respectively. In Malwa plateau the absolute and relative changes in area was highest increased by 420.03 thousand ha and 199.16% against base year area of 210.90 thousand ha. The absolute and relative changes in productivity by 235.08 kg ha^{-1} and 54.68% compared with productivity of base year 429.90 kg ha^{-1}, respectively. Similarly in Nimar valley region chickpea recorded absolute change in area and productivity by 11.47 thousand ha and 114.50 kg ha^{-1}, whereas positive shift in relative changes was recorded in area and productivity by 134.94 % and 24.36% compared with base year data of area 8.5 thousand ha and 279.17 kg ha^{-1} productivity, respectively. Likewise in Jhabua hills - a positive shift of area of chickpea crop was recorded. The relative changes in area was increased by 241.18% compared with base year area 9.77 thousand ha, whereas relative changes in productivity by 53.23% compared with yield of base year 381.08 kg ha^{-1}. The positive shift of chickpea crop in rainfed or limited irrigation water available areas and in low rainfall years resulted increased in area and productivity. Also, the higher profit was incurred from *kabuli* cultivars grown in this region for domestic and international market.

In Chhattisgarh plains increase in area and productivity by 67.06 thousand ha and 41.46 kg ha^{-1}, whereas relative change was recorded in area and productivity by 74.02% and 9.97% compared with base year figures of area 90.60 thousand ha and productivity 415.58 kg ha^{-1}, respectively (Table 1). Likewise in Northern hills region the chickpea crop registered positive shift of area. The relative changes in area was increased 11.25% compared with base year area 70.20 thousand ha, whereas relative changes in productivity by 63.93% compared with yield of base year 321.45 kg ha^{-1}, respectively. The basic reason was of area increasing behind chickpea crop in these regions due to grown in conserved moisture after harvest paddy of rainfed area.

In Vindhyan plateau highly positive shift in acreage was observed by 123.36 thousand ha with the increase of relative change by 44.87% compared with base year area 274.90 thousand ha (Table 1). The absolute and relative change in productivity exhibited decline by -112.51 kg ha^{-1} and -14.40% compared with base year average yield 781.82 kg ha^{-1}, respectively. The decrease in yield due to climatic abnormalities such as winter rains, frost and dry and wet root rot problems were observed. In Central Narmada valley region the relative change in area increased by 36.62% compared with base year area 112.06 thousand ha. It is important to note that, there is very significant positive relative change in their productivity by 78.80% compared with base year data 378.96 kg ha^{-1}. In Bundelkhand region the absolute and relative changes in area was increased by 25.30 thousand ha and 29.46% against base year area of 85.87 thousand ha. The absolute and relative changes in productivity by 381.82 kg ha^{-1} and 72.77% compared with base year yield 524.68 kg ha^{-1}, respectively. The positive increase of area and yield of chickpea crop is more suited in areas of rainfed and limited water available for irrigation.

In Kymore plateau, the area of chickpea crop absolute and relative decreased by -57.43 thousand ha and -20.39% compared with base year data 281.67 thousand ha, whereas absolute change in productivity increased during corresponding years by 153.17 kg ha^{-1} and relative change of 37.41% compared with base year average yield 409.40 kg ha^{-1}, respectively (Table 1). It can be concluded that the area of chickpea crop in this region reduced but productivity increased. In Satpura plateau the relative changes in area of chickpea decreased by -24.55%, while relative change in productivity were enhanced by 41.73% compared to base average productivity 382.15 kg ha^{-1}. Similarly in Gird region absolute change declined in chickpea by -5.20 thousand ha and relative change decreased by -1.61%, compared with base year area 322.87 thousand ha. The productivity reported was increased by 498.81 (128.44%) compared with base year average yield 388.36 kg ha^{-1}. Decrease of chickpea area in these regions was due to increase in irrigated area and chickpea crop replaced by wheat and other higher water requiring crops. Moreover chickpea crop is more susceptible to climatic vulnerability compared to cereal crops and also to losses by blue bulls. In these regions in some areas high soil moisture due to faulty irrigation method (flood) and winter rains leads to excess vegetative growth at reproductive stage and diseases (root rot, wilt and *cercospora*) and terminal heat.

Climatic vulnerabilities

The climatic fluctuations affecting chickpea crop by various vulnerabilities in different climatic regions of MP are given in Table 2. The acute effect of climatic vulnerability on chickpea crop is more pronounced compared with other major *rabi* crops such as wheat and mustard. Occasionally climatic vulnerabilities are drought, heat, cold waves, frost, winter rains affecting chickpea crop in different agro-climatic region of MP. Changes in rainfall patterns, particularly scantly, early withdrawal of rain fall, chickpea crop faces drought, cold waves and frost resulting decrease in yield and benefits. Sometimes untimely winter rains more than once in flowering and pod formation stages also decrease yield (Singh *et al*., 2018) [18]. Chickpea crop is difficult to grow and cannot tolerate even short-term water logging.

Climatic vulnerability effect and mitigation technologies

Abiotic stress

The drought and heat stress effect is more acute in areas of lesser rainfall, early withdrawal of rains, increasing temperatures towards end of the crop season, unavailability of irrigation water and less water holding capacity of soils. Drought and heat are the major abiotic stresses affecting chickpea at reproductive stage, pod setting and grain development adversely affected in North Western, Central and Southern India. Advance planting of early maturing and tolerant cultivars are ways to combat these stress conditions (Table 3). Cold waves (< 10 °C) and frost (< 2 to 3 °C) is affecting chickpea crop in North, North-Western and Central India. Several control measures of cold waves and frost can be adopted for higher yield and benefit (Table 3). The winter rains in semi-arid irrigated and rainfed heavy soil areas affect chickpea crop severely (Singh and Singh, 2016) [13]. The damaging effect through hail storm depends on intensity and stages of crop. The crop is in growth stage more chances of re-growth, however if hail has stripped most of the leaves or has broken the main stem, crop will take much longer time to recover. After hail damage the chances of chickpea crop being affected by *ascochyta* or bacterial blight are enhanced. For better re-growth after damage proper nutrition management is required. Late season hail brings its own set of challenges. Crop insured by insurance companies is better option. Oftentimes, hail will lodge the chickpea crop.

Biotic stress

Among biotic stress under drought conditions dry root rot **(***Rhizoctonia bataticola*) increased with temperature exceed 33 °C and acutely affects chickpea crop in Central and North-Western India. Several management techniques are given in table 3 for suppressing these effects. In contrary, winter rain fall and high amount of irrigation water influences fungal diseases such as wet root rot, wilt (*Fusarium*), collar root (*Sclerotium rolfsii*) and gray mold (*Botrytis scenario*) and *ascochyta* blight on leaf increases with increase in high soil moisture and humid conditions. These diseases may be controlled by crop establishment techniques, selection of tolerant cultivars, proper seed treatment, use of fungicides, etc. Pod borer (*Helicoverpa armigera*) continues to remain a major and challenging insect-pest of chickpea in all growing areas. Pod borer increases with erratic winter rainfall and increase in temperature. Pod borer can easily be controlled by chemical or biological agents.

Impact of mitigation technologies on climatic abnormalities

Impact of abiotic stresses on yield

Occasionally winter rains increase soil moisture and humidity which affect crop-growth during reproductive stage. The crop sown on BBF method significantly increased the grain and straw yields of chickpea over conventional tillage sowing method (CTS). The increase in grain yield was 74.7% but a decrease in straw yield by 20.2% under BBF sowing method compared with CTS (Table 4). Similarly, Singh *et al*., (2018) [15] reported that the seed yield of pigeon pea under the BBF increased by 9.9% compared to the CT. Like-wise, 17% increase in yield was recorded in chickpea under raised bed planting system by Connor *et al*. (2003) [4]. Delayed sowing of chickpea exposed the plants to higher temperatures at reproductive phase. Early sowing of crop just after harvest of *kharif* crop by zero tillage technique increased grain and straw yields by 22.2 and 23.6%, respectively, compared with conventional sowing practice of crop. The sowing of drought tolerant cultivar JG-14 increased the grain and straw yield by 18.5 and 15.1% compared with traditional cultivar (JG-315) and practices followed by farmers.

Impact of biotic stresses on yield

The root rot resistant cultivar JG-11 sown on BBF increased grain and straw yield by 37.7 and 5.3% compared with farmers' practice (cultivar JG-315) adopted (Table 6). Similarly, under rainfed conditions wilt affected chickpea crop. The deep tillage in summer and sowing of resistant cultivar JG-11 increased the grain and straw yield by 37.5 and 47.5% compared to CTS (Prasad *et al*., 2012) [9]. The *cercospora* disease highly infected the chickpea crop due to excess moisture content in soil. Under such conditions, sowing of crop on BBF and spray of mencozeb 3 g l^{-1} water at appearance of disease increased grain and straw yields by 38.1 and 9.1% compared to farmers' practices. Humidity and temperature increases pod borer infestation in this situations at ETL level use of bird perchers 20 ha^{-1} + spray of NPV virus 250 LE ha^{-1} resulted in significantly higher grain and straw yield of chickpea compared to use of only endosulfan @ 1.5 lit. ha^{-1}. The average grain and straw yield of chickpea was 17.71 and 3.28% higher with recommended technique for control of pod borer compared to control (Sharma, 2010) [12].

Impact of abiotic stresses on economics

Among abiotic stresses maximum additional cost of replacement of old cultivar for drought management Rs. 1776 ha^{-1} followed by sowing of crop by BBF sowing method Rs. 460 ha^{-1}, whereas saving of Rs. 3,390 ha^{-1} by advanced sowing of crop by ZT sowing method (Table 5). The maximum additional return (Rs. 25,809 ha^{-1}) was obtained with sowing of crop by broad bed furrow method that saved the crop from excess of soil moisture, whereas Rs. 14,966 ha^{-1} was realized with respect to terminal heat effect through direct seeding by zero till seed cum fertilizer drill after just harvest of *kharif* crop despite drought during reproductive stage by tolerant cultivar JG-14 obtained Rs. 6,654 ha^{-1}.

Impact of biotic stresses on economics

The trend of additional production cost under biotic stress Rs. 3400 ha^{-1} was maximum for control of wilt in rainfed conditions followed by Rs. 1105 ha^{-1} for management of root rot, Rs. 950 ha^{-1} for pod borer and Rs. 735 ha^{-1} control of *cercospora* disease (Table 6). The maximum additional return Rs. 19,792 ha^{-1} under resistant cultivar JG-11 and sowing by BBF treatment for saving from root rot due to excess moisture, while Rs. 14,776 ha^{-1} with control of *cercospora* disease due to excess soil moisture and high humidity through sowing of crop on BBF and spray of mencozeb 3 g $lit.^{-1}$ water at appearance of disease. The saving of crop from wilt in rainfed conditions through deep tillage in summer and resistant cultivar JG-11 gained additional returns Rs. 11,385 ha^{-1}, despite pod borer management by bird perchers 20 ha^{-1} + spray of NPV virus 250 LE ha^{-1} obtained Rs. 6,654 ha^{-1}). The benefit cost (B:C) ratio was higher (3.25) under direct seeding through zero till seeding which escaped terminal heat by advance sowing and minimum (2.12) under deep tillage in summer and resistant cultivar JG-11 for control of wilt in rainfed conditions.

Adaptation strategies

The impact of climate changes are complex and no single strategy will address the issue adequately for chick pea crop. A combination technology and policy related interventions are required. Considering the natural resources, cropping systems, production technologies for changing climatic scenario of the state, the following strategies are important.

1. Adoptions of timely and micro level weather forecast appropriate agro advisories to farmers are essential.
2. Dry sowing and irrigation for germination practices followed in *kabuli* type cultivar cultivation areas. Such practice suppresses germination, root development and growth, yield and increases of diseases. In these areas sowing of chickpea after pre-irrigation or in conserved moisture conditions should be adopted.
3. Water management is the most crucial part of climate change adaptation. Lifesaving light irrigation applied at branching stage through sprinkler, drip or furrow method.
4. Evolving varieties tolerant to climatic stress of biotic and abiotic multiple climatic stresses through coordinated research efforts by public and private sector.
5. For increasing yield benefits and energy savings promoting of minimum tillage, ridge bed, broad bed furrow sowing methods and other practices to build soil organic carbon.
6. More emphasis on need based area specific recommended varieties seed production of abiotic and biotic stress resistant/tolerant varieties through seed societies, farmers groups.
7. Seed supply to end user along with trichoderma @ 5g kg^{-1} seed for seed treatment and sowing of crop on BBF sowing method.
8. Formulate state specific weather based abiotic and biotic stresses insurance policies and encourage farmers for wider adoption for minimizing losses during extreme events.
9. Policy formulated for smart utilization of natural resources, energy, providing quality inputs to farmers etc and its impact on climate change adaptation should be critically examined.

Table 1: Absolute and relative changes in area and productivity of chickpea in current years (2010-11 to 2012-13) compared with base year of different agro-climatic regions of Madhya Pradesh

S. No	Agro-climatic regions	Average area of base years (1980 to 83) in, 000 ha	Absolute Change	Relative Changes (%)	Average yield (kg ha^{-1}) of base years (1980 to 83)	Absolute Change	Relative Changes (%)
1.	Kymore Plateau and Satpura Hills	281.67	-57.43	-20.40	409.40	153.17	37.41
2.	Vindhyan Plateau	274.90	123.36	44.87	781.82	-112.51	-14.40
3.	Central Narmada Valley	112.06	41.04	36.62	378.96	298.93	78.80
4.	Grid Region	322.87	-5.20	-1.61	388.36	498.81	128.44
5.	Bundelkhand Region	85.87	25.30	29.46	524.68	381.82	72.77
6.	Satpura Plateau	74.40	-18.27	24.55	382.15	159.48	41.73
7.	Malwa Plateau	210.90	420.03	199.16	429.90	235.08	54.68
8.	Nimar Valley	8.50	11.47	134.94	279.17	114.50	24.36
9.	Jhabua Hills	9.77	23.54	241.18	381.08	202.86	53.23
10.	Chhattisgarh plain	90.60	67.06	74.02	415.58	41.46	9.97
11.	Northern Hill Region of Chattisgarh & Chhotanagpur Plateau	70.20	7.90	11.25	321.45	205.52	63.93
Madhya Pradesh		1541.74	627.67	40.71	471.00	178.33	37.86

Table 2: Climatic vulnerability affecting of chickpea crop of different Agro-climatic regions of Madhya Pradesh

S. No	Agro-climatic regions	Climatic vulnerability effect
1.	Chhattisgarh plain,	Drought < occasional heat stress < cold waves < frost < hail storm
2.	Northern Hill Region of Chhattisgarh	Occasional drought < heat stress < cold waves < frost < hail storm
3.	Kymore Plateau and Satpura Hills	Drought < occasional frost < hailstorm < cold < heat waves
4.	Vindhyan Plateau	Regular drought < occasional cold < heat waves < frost < hail storm
5.	Central Narmada Valley	Occasional drought < heat waves < hailstorm
6.	Grid Region	Regular Heat and cold waves < occasional drought (mid and late season) < frost < winter rains < hail storm
7.	Bundelkhand Region	Regular drought < dry spell < cold and heat waves < occasional frost < hail storm
8.	Satpura Plateau	Occasional drought < cold and heat waves < hailstorm
9.	Malwa Plateau	Regular drought < occasional heat < cold waves < mild frost < hail storm
10.	Nimar Valley	Occasional drought < heat waves < hailstorm
11.	Jhabua Hills	Drought < heat waves

Table 3: Climatic vulnerabilities on abiotic and biotic stress and suggestions for mitigations for Chickpea

S. No	Climatic vulnerabilities	Effect of vulnerability	Mitigation technologies	References
Abiotic stress				
1.	Drought stress	Suppress growth characters, yield attributes and yield.	1.Cultivation of drought tolerant and short duration cultivars 2.Proper plant population, intercultural operations, mulching and 2% KCl spray	[7, 13]
2.	Heat stress (> 35°C)	Anthesis, pollen germination, partially grain development or almost completely terminate. Degradation of chlorophyll, induce senescence and forced maturity.	1.Timely sowing by direct seeding (Zero tillage) 2.Cultivation of tolerant short duration cultivars	[7, 13, 17]

			3.Light irrigation through sprinkler	
3.	Cold waves (< 10 °C) and frost when temperature falls below 2 to 3 °C	Cold waves, frost, chilling and freezing injury and complete termination of vegetative growth	1. Cultivation of cold/frost tolerant cultivars 2. Light irrigation for high specific heat and relatively warm temperature 3. Plant cover shade through agri-horti/forestry or inter crop of mustard 4. Spray of sulphuric acid or thiourea to enhance resistance 5. Provision of heat by fire creating a air blanket of smoke	[11, 13]
4.	Hail storm	Damaging crop as per intensity	1. Regeneration of early stage crop spray of 2% N with growth regulator 2.Crop insurance	[11, 13]
5.	Winter rains or high soil moisture	Increases growth during reproductive stage.	1. Irrigation as per weather forecast and crop grown on bed	[13, 14]
Biotic stress				
1.	Drought stress and temperature < 33 °C	Dry root rot (*Rhizoctonia bataticola*) at flowering stage in temp.	1.Deep tillage in summer, crop rotation 2.Use of resistant cultivars 3.Seed treatment (thiram 2g + bavistin 1g kg^{-1}) or trichoderma 5g kg^{-1} seed and drenching with Carbandenzim	[5, 9]
2.	High soil moisture or winter rains	Wet root rot, wilt (*Fusarium*), collar (*Sclerotium rolfsii*) and gray mold (*Botrytis scenaria*)	1. Use of resistant cultivars 2.Sowing of crop on BBF + Seed treatment (thiram 2g + bavistin 1g kg^{-1}) or trichoderma 5g kg^{-1} seed	[1, 9, 14]
3.	High humidity	*Ascochyta* blight on leaf	1.Spray of Mancozeb 3 g $lit.^{-1}$ water	[9, 10, 13]
4.	Erratic winter rainfall and increase min. Temperature	Pod borer	2. Bird perchers 20 ha^{-1} + spray of NPV virus 250 LE ha^{-1} or Spray of Trizophos @ 750 ml ha^{-1}.	

Table 4: Impact of different technological interventions for abiotic and biotic climatic vulnerabilities on chickpea

Climatic problems	Intervention	Grain yield (q ha^{-1})	Stover yield (q ha^{-1})	Cost of production (Rs. ha^{-1})	Net returns (Rs. ha^{-1})	B:C ratio
Abiotic stress						
Excess growth due to high soil moisture	FP-CT sowing	10.65	29.7	22,100	18,255	1.83
	IT-BBF sowing	18.60	24.7	22,560	44,064	2.95
	CD at 5%	2.14	3.8	NS	2,941	0.38
Terminal heat infestation	FP-CT sowing	14.57	19.6	22,910	28,860	2.26
	IT-ZT sowing	17.81	24.2	19,520	43,826	3.25
	CD at 5%	1.72	2.7	1,761	3,359	0.25
Drought at reproductive stage	FP-Old cultivar JG-315	13.53	18.6	19,700	26,785	2.36
	IT-Tolerant cultivar JG-14	16.03	21.4	21,476	33,439	2.56
	CD at 5%	1.30	1.8	1,372	3,810	0.20
Biotic stresses						
Root rot due to excess soil moisture	FP-Old cultivar JG-315	16.80	22.9	20,590	37,081	2.80
	IT-Resistant cultivar JG-11 and BBF sowing	23.13	28.2	21,695	56,873	3.62
	CD at 5%	2.25	3.1	NS	2,592	0.29
Wilt in rainfed conditions	FP-CT sowing with old cultivar	11.31	14.1	21,780	16,716	1.77
	IT-Summer deep tillage and resistant cultivar JG-11	15.55	20.8	25,180	28,101	2.12
	CD at 5%	1.65	2.99	2,765	3,114	0.31
Cercospora disease due to excess soil moisture & high humidity	FP-Not adopted any practice	12.92	21.0	22,230	22,945	2.02
	IT- BBF sowing and spray of Mancozeb 3 g $lit.^{-1}$ water at appearance of disease	17.84	22.9	23,465	37,721	2.63
	CD at 5%	3.19	2.6	NS	3,890	0.25
Pod borer	FP- Endosulfan 1.5 lit. ha^{-1}	17.33	24.4	21,500	39,622	2.84
	IP- Bird perchers 20 ha^{-1} + spray of NPV virus 250 LE ha^{-1}	20.40	25.2	22,450	49,410	3.19
	CD at 5%	2.06	2.9	NS	2,846	0.30

FP-Farmers' practice, IP-Improved technology, CT- Conventional tillage, BBF- Broad bed furrow, ZT-Zero tillage

Fig 1: Different Agro-climatic zones of Madhya Pradesh state of India

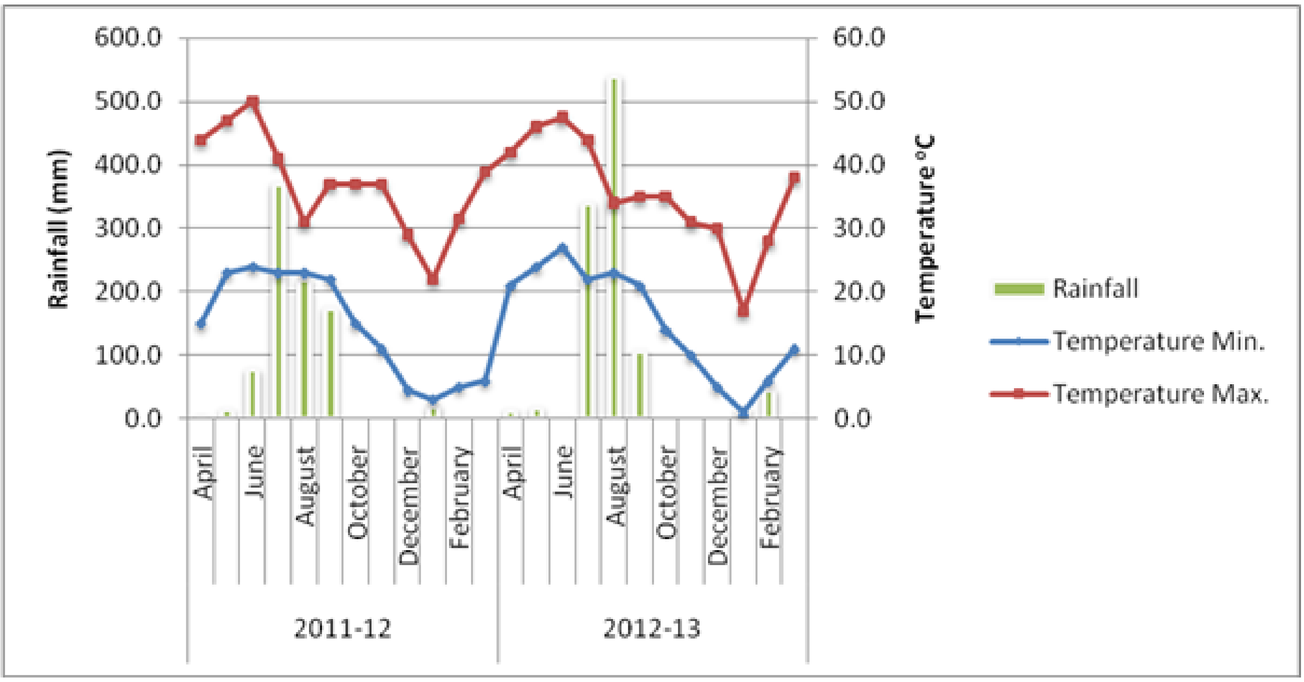

Fig 2: Monthly total rainfall, minimum and maximum temperature during experimentation

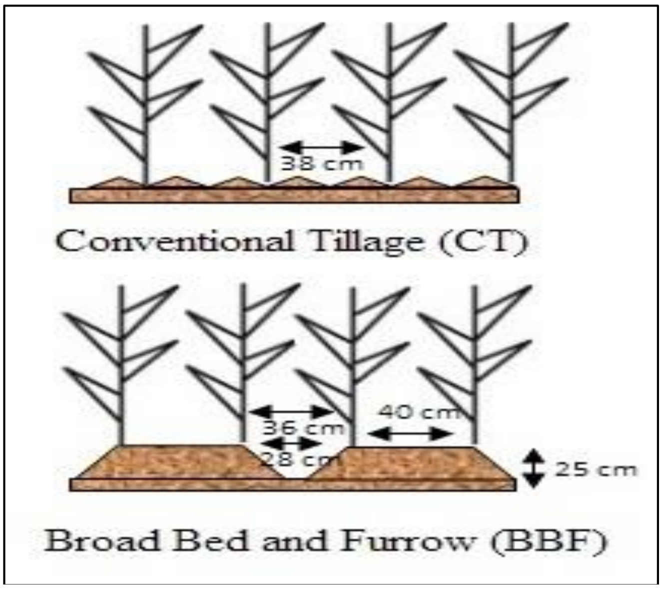

Fig 3: Schematic diagram of different sowing methods

Conclusions

Analysis of data from 1980-81 to 2012-13 showed significant growth in area and productivity of chickpea during the period in Madhya Pradesh, but the climatic fluctuations was a major challenge for sustaining this growth. Higher yield and benefits by adaptation of technologies and tolerant cultivars is essential to multiple abiotic (higher soil moisture, heat, drought, *etc*) and biotic climatic stress (wilt, root rot, *cercospora*, pod borer, *etc*). The crop established through broad bed furrow sowing increases productivity and saving of crop from water submergence. Similarly insurance policies should be promoted for minimizing losses during extreme events.

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