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Review on climatic abnormalities impact on area, productivity of central India and strategies of mitigating technology on yield and benefits of black gram

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Abstract
The major reasons of fluctuating cost and availability of pulses are climatic abnormalities in India. The climatic abnormalities are more vulnerable on pulse crops compared with oilseeds and cereals. A study was conducted on climatic change abnormalities impact on area and productivity after 3 decades of Madhya Pradesh and Chhattisgarh states of Central India and mitigation technology on yield and benefits of black gram. Absolute and relative changes in average area was slightly increased by 49.2% against base years (1980 to 83) area (532.6 thousand ha), while productivity increased by 40.3% compared with base year yield (217.7 kg/ha). Study showed significant variability in area (CV=17.7%) and productivity (CV=13.8%) of black gram of Central India. The maximum absolute and relative increased in area was 139.1 thousand ha and 146.5% of Malwa plateau, whereas absolute and relative changes decreased in area of Chhattisgarh plain (-13.1 thousand ha) and Bastar plateau (-19.2%) compared with base years, respectively. Maximum absolute and relative change in increase in productivity of Vindhyan plateau was 285.6 kg/ha and 102.8% compared with base year average yield (258.3 kg/ha), while decreasing of absolute and relative change in productivity of Gird region compared of base years.
Results of on farm trials showed that adoptions of mitigation of technologies of climatic abnormalities significantly influenced grain yield of black gram. Study revealed that among abiotic and biotic stresses, major losses in production of grain of black gram by water submergence during rainy season (33.0%) followed by drought during grain filling stage in summer (23.2%) and yellow vein mosaic (34.8%) followed by pod borer (30.1%) compared with control, respectively. Escaping of abiotic and biotic stresses with improved technologies was enhanced grain yield from 21.4-49.2% and 43.0-53.5% compared with control, respectively. 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, variability, climatic abnormalities, technology, impact, area and productivity, black gram

Introduction
Pulses' an important sources of proteins, vitamins and minerals and popularly known as "Poor man's meet" and rich man's vegetable" contribute significantly to the nutritional security of the country [22]. Among pulse crops, India is the world's largest producer as well as consumer of black gram. Black gram (*Vigna mungo* L.) grown in all seasons (rainy, winter and summer) in different parts of India and output accounts for about 10% of India's total pulse production [14]. It contains 24% protein, 3.2% minerals and 59.6% carbohydrate and also has 154 mg calcium, 9.1 mg iron and 38 mg β-carotine per 100g of split grain [4].
The area under black gram cultivation in India is about 3.25 million ha with production of 1.94 million tonnes and productivity 463 kg/ha (Directorate of Economics and Statistics 2012-13), while Madhya Pradesh showed 24% increase in productivity [2]. Although a marked increase in area and productivity of black gram in India during past two decades but the productivity is still very far from satisfactory 800-1200 kg/ha level [20]. Yield gap of black gram in India are due to one or more direct climatic abiotic stresses such as excess soil moisture during rainy season, drought, photo-thermo sensitivity, heat stress during grain filling stage [5, 12, 22] and indirect effect of biotic stresses such as yellow vein mosaic and pod borer complex, *etc* in rainy and summer season crop [9, 18].
The major reasons of fluctuating pulses production are climatic abnormalities. The extreme weather events are more vulnerable on pulse crops followed by oilseeds and cereals [9, 22]. The frequency of occurrences of extreme weather events such as drought, floods, heat waves, cold waves, unusual and unseasonal rainfall, cyclones, frost and hail storm is on the rise in recent years than in the past [18]. Black gram crop requires cold temperature during vegetative growth

and warm temperature at maturity; the optimum temperature for growth is 18 to 30°C [12]. Based on physiological studies pulse crops are categorized as per thermo tolerance in the order of green gram > pigeon pea > black gram > chickpea > lentil > rajmash > fieldpea [5]. Moreover drought and high temperature interact together, and the damaging effect of both the stresses together is far more severe than individual effect [23]. Drought stress alone may reduce seed yields by 50% in Alfisols, whereas in Vertisol, high water holding capacity causes growth reduction up to 5-20% in Central and South India [21, 23].

The study showed weather abnormalities are one of the factors which regulate the density of insect pests in black gram ecosystem. Several researchers reported all over losses of black gram due to insect pests in India conditions, 7 to 35% caused by insect pest complex of different agro-climatic conditions [10], whereas combined infestation of pests and diseases annual estimated yield lose over 30% in dry land conditions [11]. YMV disease of black gram caused heavy yield loss from 10 to 100%, depending upon the crop stage at which the plants get infected, whereas up to 21% yield loss reported by powdery mildew [23]. Study on all insect pests showed negative correlation with maximum temperature while positive correlation with maximum relative humidity and total rainfall. However, climatic stresses effect on area, productivity and comparative performance of mitigation technologies to abiotic and biotic stresses on black gram is completely lacking. Therefore the present study was undertaken to analyse factors affecting changes in area, productivity of states of Central India (Madhya Pradesh and Chhattisgarh) and technological impact on increasing yield and benefits of black gram in changing climatic scenario.

Materials and Methods

The Madhya Pradesh (MP) and Chhattisgarh (CG) states of Central India was studied considering its agricultural zones as unit of investigation because of 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 black gram was collected from directorate of agricultural land records and contingent plan of MP and CG.

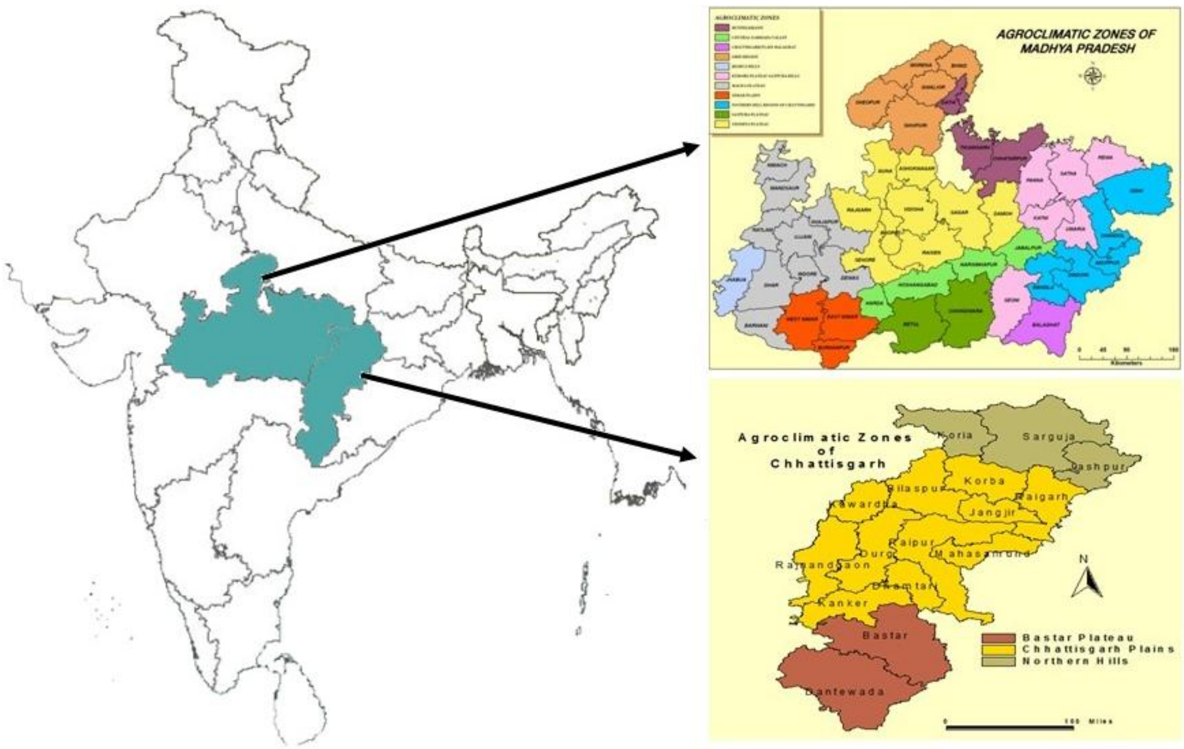

Fig 1: Agro-climatic regions of selected study areas of Central India

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 years. The data on area and productivity of black gram crop 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 for minimize the fluctuations in time series data. The district wise climatic vulnerability was summarises 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 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 (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 black gram 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.

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

For computing the standard deviation, the following formula is used

$$\text{S.D.} = \sqrt{1/N(\sum x^2 - \sum X)^2}/N$$

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 black gram were carried out during two rainy (*kharif*) and summer (*zaid*) 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 26º 32' 15" N latitude and 78º 04' 00" E longitude with altitude 144 m. 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). 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. Average annual rainfall of selected site is 701 mm, mostly concentrated in the months of July and August. Annual rainfall received during 2011-12 and 2012-13 was 875 and 1074 mm, respectively (Fig. 2).

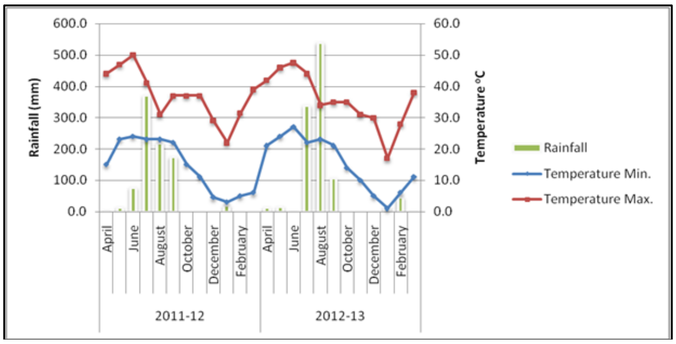

Fig 2: Monthly total rainfall, minimum and maximum temperature during experimentation

Description of soil and analysis

The trials were conducted on alluvial soils. Surface (0-20 cm) soil samples were collected for selected fields and determining initial soil properties. Analysis of soil samples for pH and electrical conductivity (1:2 soil water ratio) was undertaken. Organic carbon [27], available N by Kjeltec-II auto analyzer, P by Olsen method [16], S by Chesnin and Yien method [6], K by NH_4OAc extraction and micronutrient by DTPA extraction was determined. The selected soil of farmers' field was sandy loam in texture and ranges of EC 0.28 to 0.34 dS/m and pH 7.70 to 7.92. The soils were deficient in organic carbon (2.5 to 4.6 g/kg), available N (139 to 184 kg/ha), S (8.9 to 9.8 kg/ha), Zn (0.42 to 0.52 mg/kg), whereas low to medium in available P (8.5 to 11.9 kg/ha) and medium to high in available K (215 to 292 kg/ha). Available Cu (> 0.2 mg/kg), Fe (> 5.0 mg/kg) and Mn (> 2.0 mg/kg) 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 were followed given in table 5 and 6. The sowing methods as conventional on flat land (existing practice), zero tillage, broad bed furrow (Fig. 3) and precision land shaping were adopted as per treatment (Fig. 4). In general sowing and harvesting of crop during 2nd week of July and 1st week of October for rainy season and 4th week of March and 1st week of June for summer season crop in every year, respectively. 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 for black gram 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. 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.

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

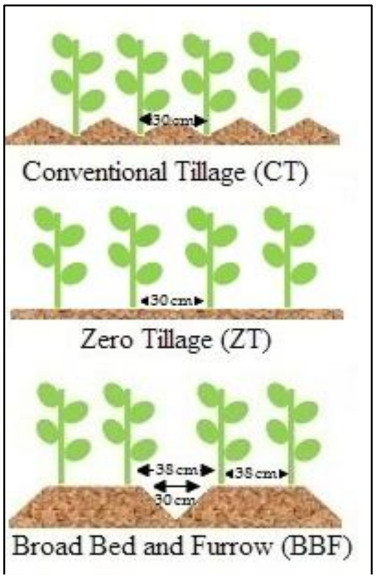

Fig 4: Schematic diagramme of sowing methods

Results and Discussion

Changes in area and productivity

Variations were observed in absolute and relative changes in area of black gram in all agro-climatic zones of Central India (Table 1). Absolute and relative changes in black gram area was increased after three decades by 302.3 thousand ha and 49.2% against total cropped area (532.6 thousand ha) of base year (1980 to 83), respectively. The variability in area was observed by 17.7% in Central India. The maximum increase in absolute changes in area were: Malwa plateau followed by Grid region, Jhabua hills, Satpura hills, Bundelkhand, Nimar valley, Kymore plateau, Central Narmada valley and Vindhyan plateau, while maximum decreased in Chhattisgarh plain followed by Northern and Bastar plateau, respectively. Maximum positive relative changes was observed in Malwa plateau (146.5%) because of shrinking of rainy days and delayed commencement of monsoonal conditions grower shift from soybean to black gram crop, while negative relative change in Bastar plateau (-19.22%) due to longer rain water submergence area shifting in paddy cultivation. Maximum variability was recorded in Satpura plateau (CV=26.7%) due to crop severally affected due to uneven pattern of rains, while minimum variability of Northern hill region of Chhattisgarh and Chhotanagpur plateau (CV=3.3%) because of minimal effect of climatic variability was observed (Table 1 and 2).

Absolute and relative changes in productivity of black gram was increased after three decades by only 76.8 kg/ha and 40.3% compared with productivity of base year (217.7 kg/ha), respectively. The overall variability in productivity was by 13.8% in Central India which may be attributed to abiotic and biotic stresses due to climatic abnormalities (Table 1 and 2). The increase in absolute changes in productivity was in ordered: Vindhyan plateau > Central Narmada valley > Bundelkhand > Satpura plateau > Bastar plateau > Northern hill region of Chhattisgarh and Chhotanagpur plateau > Kymore plateau and Satpura hills > Malwa plateau > Nimar valley > Jhabua hills > Chhattisgarh plain, while decrease in Grid region, respectively. Similarly relative changes were also varied in productivity of different Agro-climatic regions of Central India. Maximum relative changes in productivity was observed in Vindhyan plateau (102.8%) because of favourable climatic conditions, while negative change in Gird region (-34.1%) due to more vulnerability of climatic conditions, respectively. Similarly, higher variability was recorded in Gird region (CV=20.1%) due to crop severally affected climatic variations, while lower variability of Bastar region (CV=7.3%) because of minimal effect of climatic variability's was observed (Table 1 and 2).

Table 1: Absolute, relative changes and variability in area and productivity of black gram 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) (1980-83)	Absolute change	Relative changes (%)
1.	Kymore plateau and Satpura hills	15.2	10.1	66.8 (21.3)*	105.9	72.1	43.5 (13.2)
2.	Vindhyan plateau	9.4	0.6	6.4 (10.5)	258.3	285.6	102.8 (20.0)
3.	Central Narmada valley	9.0	1.2	13.1 (9.5)	215.9	164.7	76.3 (14.9)
4.	Grid region	10.2	89.6	108.8 (25.3)	201.1	-68.5	-34.1 (20.0)
5.	Bundelkhand region	17.6	16.7	94.8 (22.4)	163.1	114.5	68.5 (16.1)
6.	Satpura plateau	37.7	23.0	61.1 (26.7)	281.8	99.4	60.0 (18.2)
7.	Malwa plateau	94.9	139.1	146.5 (25.3)	291.8	52.8	18.1 (11.6)
8.	Nimar valley	83.5	10.7	12.8 (4.1)	324.8	40.7	18.5 (12.1)
9.	Jhabua hills	26.3	30.0	113.7 (25.2)	234.2	36.6	15.8 (11.9)
10.	Chhattisgarh plain	163.8	-13.1	-8.0 (22.8)	154.7	33.7	21.8 (10.6)
11.	Northern hill region of Chhattisgarh & Chhotanagpur plateau	53.2	-3.3	-6.2 (3.3)	146.1	77.6	53.1 (10.5)
12.	Baster plateau	11.8	-2.3	-19.2 (16.3)	316.2	88.4	28.0 (7.3)
	Madhya Pradesh and Chhattisgarh	533.0	302.3	49.2 (17.7)	217.7	76.7	40.3 (13.8)

*Figure in parenthesis variability

Table 2: Climatic vulnerability affecting black gram crop of different Agro-climatic regions of agro-climatic zones of Central India

S.No.	Agro-climatic regions	Climatic vulnerability effects
1.	Chhattisgarh Plain	Water submergence > Uneven distribution of rains > Rains during maturity
2.	Baster Plateau	Water submergence > Uneven distribution of rains > Rains during maturity
3.	Northern Hill Region of Chhattisgarh	Water submergence > Uneven distribution of rains > Rains during maturity > Drought
4.	Kymore Plateau and Satpura Hills	Water submergence > Uneven distribution of rains > Rains during maturity > Drought
5.	Vindhyan Plateau	Uneven distribution of rains > Rains during maturity > Drought
6.	Central Narmada Valley	Water submergence > Rains during maturity > Uneven distribution of rains > Drought.
7.	Grid Region	Uneven distribution of rains > Mid and late season dry spell < Heat during reproductive stage > Drought

8.	Bundelkhand Region	Uneven distribution of rains < Dry spell mid and late season > Drought < Heat stress during reproductive stage
9.	Satpura Plateau	Uneven distribution of rains > Water submergence > Rains during maturity > Drought
10.	Malwa Plateau	Water submergence > Uneven distribution of rains > Rains during maturity
11.	Nimar Valley	Water submergence > Uneven distribution of rains > Rains during maturity
12.	Jhabua Hills	Uneven distribution of rains > Water submergence > Rains during maturity > Drought

Table 3: Effect of climatic vulnerability on abiotic and biotic stress and suggestions for mitigations in black gram

S. No	Climatic vulnerabilities	Effect of vulnerability	Mitigation technologies	References
		A. Abiotic		
1.	Temporary water submergence due to erratic, heavy and uncertain rains	Plant damage at early stage, increase growth and reduced yield.	1. Cultivate crop on upland 2. Sowing of crop on broad bed furrow 3. Drained excess stagnate water	[17, 22]
1.	Mid and late season drought	Suppress growth characters, yield attributes and yield.	1. Cultivation of drought tolerant cultivars 2. Proper plant population and spray of 2% KCl 3. Life saving irrigation	[4, 22]
2.	Heat stress in summer season crop (>44°C)	Adverse effect on reproductive parts	1. Advance planting through ZT 2. Cultivation of short duration cultivars 3. Light irrigation	[7, 12, 22]
4.	Rains during maturity	Sprouting and decay of grains	1. Sowing at 2 or 3rd week of July (Area specific) 2. Broad bed furrow sowing 3. Saving of harvested crop through polythene sheet	[1, 26]
		B. Biotic		
1.	High humidity and temperature in rainy season	Yellow vein mosaic	1. Selection of resistance cultivars 2. Application of organic/inorganic insecticides	[8, 11]
2.	Moist weather condition	Pod borer complex	1. Resistant cultivars 2. Removal of infected and volunteer plants 3. Fungicide spray at ETL level	[11, 17]
3.	Excess soil moisture and humidity	Cercospora leaf spots	1. Timely crop sowing 2. Resistant cultivars 3. Establishment of crop on Bed 4. Fungicide spray at ETL level	[9, 22]
4.	High humidity, temperature, cool and dry weather	Powdery mildew	1. Resistant cultivars 2. Removal of infected and volunteer plants 3. Fungicide spray at ETL level	[1, 26]

Climatic vulnerability effect and mitigation technologies

The cultivation of green gram during *kharif* season is constrained largely due to weather aberrations and their vulnerability to diseases and pests compared with summer season crop. Black gram (*Vigna mungo* L. Hepper) is one of the most important pulse crops of rainfed areas, and facing of multiple abiotic and biotic stresses in the climatic changing scenario grown throughout the country.

Abiotic constraints due to climatic abnormalities

The green gram crop specific major climatic abiotic stresses are water-logging during establishment stage, photo-thermo sensitivity, mid and late season drought for *kharif* season, while heat stress and drought are affecting summer season crop. The excess soil moisture is increasing excess growth, whereas seed germination and vigour index, decreased significantly with increasing temperature [13]. Drought induced changes are mainly related to altered metabolic functions, such as reduced synthesis of photosynthetic pigments, accumulation of osmoprotectants like proline in the cell, decline in the cell membrane stability and alterations in physiological parameters including plant height, leaf area and cell membrane stability in black gram [4]. The optimum temperature for growth is 20-30°C [7] and temperatures above these limits are expected to drastically inhibit its potential yield, while crop thrives best at 30-40°C but above 40°C, there is significant flower shedding [25]. Summer season crop of black gram are frequently exposed to very high temperature above 44°C causing immature seed development. Heat stress affects flowering by reducing flower number and size, and causing deformed floral organs [15] leading to loss of flowers and young pods and hence reduced yield observed in green gram [25]. In addition to heat stress also reduces fertilization efficiency due to increased oxidative stress in the pistil, reduced soluble carbohydrate and ATP content in the pistil, and decreased leaf photosynthesis of green gram [24]. Timely sown of drought tolerant short duration cultivars, light irrigation as per weather forecast by sprinkler or boarder strip irrigation can avoid drought effect. Similarly, establishment of crop on upland by broad bed seed cum fertilizer drill could save crop with excess soil moisture and higher water productivity [17]. Proper plant population, intercultural operations, mulching and spray of 2% KCl enhance resistance to drought [22].

Biotic constraints due to climatic abnormality

Insect pest problem is relatively much less in summer crop due to hot and dry weather conditions as compared to rainy season crop. More than 32 insect species, 38 fungal, 12 viral, 3 micoplasma and 2 bacterial diseases are reported to affect black gram crop in India are considered of major importance in one area or the other [23]. Among these, hairy caterpillars, galeruid beetle, stem fly and white fly, pod borer complex insects and yellow mosaic virus (YMV), crcospora leaf spots (*C. cruenta*) and powdery mildew (*Erysiphe polygoni*) disease are considered of major importance for black gram (Table 4). YMV in black gram increases due to white fly and fly increases under high humidity, slight increases temperature from the normal in temperate region and positive correlated with maximum temperature. The cercospora and powdery mildew increases under high rainfall and humid conditions and temperature. The disease management is quite effective and economic adopting cultural practices, resistant cultivars and judicious use of chemicals [9]. The population of hairy caterpillar increases in slightly humid environment. The pod borer complex increases under moist weather conditions, erratic winter rainfall and increase in minimum temperature [18]. The integrated pest management technology is quite effective to control of pod borer complex/fruit fly [8].

Table 4: Impact of different technological interventions for different climatic stresses on black gram (2 year pooled)

Climatic problems	Interventions	Grain yield (kg/ha)	Stover yield (kg/ha)	Cost of production (Rs./ha)	Net returns (Rs./ha)	B:C ratio
Water submergence during *kharif* crop	I_1- CTS	748	1767	15,810	16,369	2.04
	I_2- BBF	931	2195	15,150	24,892	2.64
	I_3- PLS+BBF	1116	2326	17,278	30,073	2.74
	S Em±	62	93	355	1,617	0.12
	CD at 5%	184	278	1,064	4,852	0.34
Drought at grain filling stage in summer season	I_1- CTS	715	1582	16,915	13,617	1.81
	I_2- ZT	823	1840	14,050	21,134	2.50
	I_3- TC- PU 35+ZT	931	2041	15,115	24,600	2.63
	S Em±	34	76	310	1,062	0.04
	CD at 5%	102	219	932	3,186	0.13
Loss due to rains during maturity stage during *kharif* crop	I_1- Sowing at Ist monsoonal rains	542	2254	16,560	8,588	1.52
	I_2- BBF	650	2198	15,986	13,425	1.88
	I_3- BBF+Sowing at July 3rd week	901	2097	15,986	22,708	2.42
	S Em±	56	26	410	1,708	0.14
	CD at 5%	169	78	NS	5,109	0.41

CTS-Conventional tillage of sowing, BBF- Broad bed and furrow sowing, PLS- Precision land shaping, ZT- Zero tillage of sowing, TC- Tolerant cultivar, minimum support price for grain @ Rs. 33/kg during 2011-12 and Rs. 43/kg during 2012-13, sale price of stover in local market @ Rs. 2/kg during 2011-12 and Rs. 2.25/kg during 2012-13.

Impact of mitigation technologies

The major abiotic climatic vulnerabilities direct affecting black gram crop in rainy season crops are temporary water submergence, rains during maturity, while at summer season faces photo-thermo sensitivity, drought and heat stress during flowering and grain filling stage. Besides under biotic stress increases yellow vein mosaic and pod borer complex are affecting indirectly. The effect of integrated technologies on yield and benefit of black gram crop is given below:

Climatic abiotic stress

Rainy season submergence

During rainy season the crop is often affected by water submergence due to intensive rains. Results of trials showed that sowing of black gram crop grown on bed by broad bed furrow planter (BBF) after precision land shaping (PLS) in *kharif* season significantly higher grain and stover yield was recorded followed by BBF sowing method compared with conventional tillage sowing (CTS) method (Table 5 and Fig. 5). The average grain and stover yield of blackgram was 49.2 and 31.6% higher under sowing of crop with BBF method after PLS, whereas 24.5 and 24.2% increased with BBF sowing method compared with CTS method. Establishment of black gram on raised bed during *kharif* season recorded significantly better growth and yield compared with flat bed planting [17, 20].

Fig 5: BBF sowing method saving of black gram crop from water submergence

Among interventions additional cost production Rs. 1,468/ha for saving of crop from rainy season water submergence, whereas saving Rs. 660/ha with BBF sowing method compared with CTS method (Table 5). The trend of maximum additional returns Rs. 13,704/ha was obtained with sowing of crop by BBF after PLS followed by Rs. 8,503/ha with BBF sowing interventions for saving the crop from submergence compared with CTS (Rs. 16,369/ha). The benefit cost (B:C) ratio was higher (2.74) under by BBF after PLS followed by BBF (2.64) and lower value under CTS (2.04).

Table 5: Impact of different technological interventions for different climatic stresses on black gram (2 year pooled)

Climatic problems	Interventions	Grain yield (kg/ha)	Stover yield (kg/ha)	Cost of production (Rs./ha)	Net returns (Rs./ha)	B:C ratio
Yellow vein mosaic in high humidity and temperature	I_1- Not adopted control measures	662	1562	16,100	12,367	1.77
	I_2- RC- PDU 1	780	1843	16,730	16,826	2.01
	I_3- RC- PDU 1+NSKE 5%	1016	2375	18,110	25,545	2.41
	S Em±	59	135	335	1,196	0.11
	CD at 5%	177	406	1,006	3,589	0.32
Pod borer complex in moist weather condition	I_1- OC T-9	698	1748	16,316	13,923	1.85
	I_2- RC- Shekhar 2	774	2264	16,930	17,293	2.02
	I_3- RC- Shekhar 2+spinosed 170ml/ha	998	2401	18,126	24,900	2.37
	S Em±	51	109	302	1,085	0.09
	CD at 5%	154	326	905	3,254	0.26

CTS-Conventional tillage of sowing, BBF- Broad bed and furrow sowing, ZT- Zero tillage of sowing, OC- Old cultivar, RC- Resistant cultivar, minimum support price for grain @ Rs. 33/kg during 2011-12 and Rs. 43/kg during 2012-13, sale price of stover in local market @ Rs. 2/kg during 2011-12 and Rs. 2.25/kg during 2012-13.

Heat during summer

Delayed sowing after harvest of winter (*rabi*) season crops, summer season black gram crop exposed to higher temperature (> 40°C) at reproductive phase. Photo-thermosensitivity and drought due to high temperature leading to force maturity of black gram crop was suppress by sowing of crop in advance by zero tillage sowing technology. Early sowing of heat tolerant cultivar PU-35 just after harvest of *rabi* crop by zero tillage (ZT) technique increased grain and stover yields by 30.2 and 29.0%, whereas only ZT sowing method increase in yield by 15.1 and 16.3% compared with conventional tillage sowing method, respectively. ZT technique advances the sowing operation by 4 to 10 days and also reduces the cost of production by saving energy [22]. Similar early establishment of green gram gave higher yield and quality compared with late sown crop in summer season [19].

Interventions for saving of crop from heat stress was saved Rs. 2,865 under ZT, whereas Rs. 1,800/ha under heat tolerant cultivar sown with ZT method compared with cost of production under CTS (Rs. 16,915/ha). The trend of maximum additional returns Rs. 10,983/ha was obtained with sowing of heat tolerant cultivar by ZT method for saving the crop from heat stress followed by Rs. 7,517 compared net returns Rs. 13,617/ha with CTS (Table 5). The B:C ratio 2.63 was higher under direct seeding of heat tolerant cultivar through ZT method for escaped crop by heat stress followed by 2.50 under ZT sowing, whereas lower value was 1.81 recorded under CTS method.

Rains during harvesting

Early sowing of black gram crop faces rains during maturity resulting major looses in yield due to facing problem at harvesting, threshing, *etc* and damaging of grains by high moisture, sprouting, *etc*. Under these conditions the crop was saved by adjusting of sowing time. The sowing of crop by both the interventions such as BBF sowing and crop sown in 3rd week of July by BBF method produced significantly higher grain and stover yield as compared to sowing of crop after Ist monsoonal rains. The yield was increased both the treatment of BBF method and sowing in 3rd week of July with BBF method by 19.9 and 66.2% in grain, while decreased in stover yield by 2.5 and 7.5%, respectively, compared with sowing of crop after Ist monsoonal rains. Establishment of green gram during 3rd week of July produced higher yield and also less severity of diseases compared with 1st week sown crop [1, 26].

Adjustment of sowing time saving of crop from loss due to rains at maturity was saved Rs. 574/ha BBF sowing method, whereas nil expender by adjusting of sowing time compared with CTS (Rs. 16,560/ha). The trend of maximum additional returns Rs. 14,120/ha was obtained with BBF sowing in 3rd week of July followed by Rs. 4,837/ha with only BBF sowing method compared with total net returns Rs. 8,588/ha under conventional sowing time (Table 5). The B:C ratio was 2.42 higher under BBF sowing at 3rd week of July followed by 1.88 under BBF sowing, whereas lower value was 1.52 recorded under CTS time.

Climatic biotic stress

Humid conditions

The yellow vein mosaic virus (YMV) disease increases during *kharif* due to favourable weather conditions (high humidity in rainy season and temperature) for white fly. The treatment of management of YMV through resistant cultivar (PDU-1) and resistant cultivar + NSKE-5% spray significantly increased the grain and stover yield compared with control (I_1) (Table 6). The treatments of YMV resistant cultivar and resistant cultivar + NSKE-5% spray was increased by 17.8 and 53.4% in grain and 18.0 and 52.1% in stover yield compared with control, respectively. Use of resistant cultivar and judicious use of bio-controlling agents may contribute substantially in stabilizing the yields of pulse crops [2, 3].

The interventions of improved technologies/resistant cultivar significantly increased net return and benefit cost (B:C) ratio as compared with control (Table 6). Cultivation of YMV resistant cultivar along with spray of NSKE 5% gave highest additional net income (Rs. 13,178/ha) followed by Rs. 4,459/ha with only using YMV resistant cultivar compared with control (Rs. 12,367/ha). Similar trend was noticed in case of B:C ratio under improved technologies/resistant cultivar compared with control.

Moist weather conditions

The pod borer complex infestation due to moist weather condition severely affected yield of black gram. The pod borer complex resistant cultivar (Sekhar-2) and resistant cultivar + spinosed spray significantly increased the grain and stover yield compared with control (I_1) (Table 6). Use of pod borer resistant cultivar and resistant cultivar + spinosed spray was increased by 10.9 and 43.0% grain and 29.5 and 37.4% stover yield compared with control, respectively. Adaptation of modified IPM modules such as use of resistant cultivar, use of insecticides as per ETL time, *etc* according to need is beneficial for sustaining pulse production [3].

The interventions of resistant cultivar only and resistant cultivar along with one spray of insecticide significantly increased net return and B:C ratio as compared with control.

Cultivation of pod borer resistant cultivar along with spray of spinosed gave highest additional net income (Rs. 10,977/ha) followed by Rs. 3,370/ha with only using pod borer resistant cultivar compared with control (Rs. 13,923/ha). Similar trend was noticed in case of B:C ratio under improved technologies/resistant cultivar compared with practices existing practice.

Adaptation strategies

The impact of climate changes are complex and no single strategy will address these issue adequately for black gram crop. A 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.

1. Timely micro level weather forecast includes abiotic and biotic stresses and appropriate agro-advisories for adoption to farmers are essential.
2. Water management is the most crucial part of climate change adaptation. Life saving light irrigation applied at reproductive period through sprinkler, boarder strip or furrow method.
3. Evolving varieties tolerant/resistant to climatic stress of biotic and abiotic multiple stresses through coordinated research efforts by public and private sectors.
4. For increasing yield benefits and energy savings promoting area specific techniques as zero or minimum tillage, ridge bed, broad bed furrow sowing methods and other practices to build soil organic carbon.
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 recommendation for nutrition application.
7. Formulate state specific weather based abiotic and biotic stresses insurance policies and encourage farmers for wider adoption for minimizing losses during extreme events.
8. Strong policy formulated for purchasing of produce of farmers' not less from minimum support price and utilization of natural resources, energy, providing quality inputs to farmers *etc* and its impact should be critically examined.
9. Urgent need to be develop innovative institutional models of marketing like NAFED, Amul, Mother dairy, Parag, Dhara, *etc* and monitoring and executing the value chain of pulse from production to consumption.

Conclusion

Analysis of data from 1980-81 to 2012-13 showed minor growth in area due to challenging climatic vulnerabilities, while productivity of black gram increased by 40.3% from base year productivity (217.7 kg/ha). Results showed that climatic fluctuations were major challenges for enhancing area and productivity. Study reveals that yield loss from 23.2 – 39.8% with abiotic stress, while 30.2 – 34.8% with biotic stress of black gram under trials. Higher yield and benefits by application of technologies is essential to direct effect of multiple abiotic stresses (rainy season water submergence, drought, heat, rains during maturity, *etc*) and indirectly biotic climatic stresses (YMV, pod borer, *etc*). Adoption of improved crop production and establishment technologies (BBF), timely crop established (ZT), resistant/tolerant cultivars sown, use of pesticide at ETL, *etc* increases productivity and benefit. Similarly weather based long term fore cast and insurance policies should be promoted for minimizing losses during extreme climatic events.

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