



Impact of climatic abnormities and mitigating technologies on pigeonpea (*Cajanus cajan*) in central India

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ABSTRACT

A study was carried out on changes in climate; area and productivity of pigeonpea (*Cajanus cajan* L.) over a period of three decades (1982–2016), and impact of climatic abnormalities and mitigation technologies on yield and economic benefits was seen. Long-term data on climate change showed that there is a trend of minimum and maximum temperature rise and a decrease in monthly total rainfall in summer and rainy season, while it increases in winter. Study also revealed the prominent disparity in area and productivity of pigeonpea of all agro-climatic zones of Madhya Pradesh (MP) and Chhattisgarh (CG). The absolute change (AC) and relative change (RC) in area of pigeonpea in MP and CG states increased by 34.66 thousand ha and 16.2% and increased productivity by 243.3 kg/ha and 65.4% compared with base years, respectively. Like-wise maximum AC in productivity was at Central Narmada Valley (CNV) and minimum at CG plains, while RC in productivity was maximum increased in Gird region and minimum in CG plains compared to base years. The crop sowing on bed with broad bed furrow (BBF) increased seed yield by 18.2% compared to flat land sowing method. The Fusarium wilt infestation was reduced with resistant cultivar along with seed treatment with *Trichoderma harzianum* and BBF sowing impacting on yield by 26.2%, whereas increased by 20.7% with control of *phytophthora* blight resistant cultivar sowing on BBF after seed treatment with *Trichoderma viride*, compared with existing practices (EP). Similarly control of pod borer with the use of IPM technology enhanced seed yield by 42.2% compared with EP. Results showed that adoption of improved techniques for mitigation of climatic abnormalities gave higher productivity, net returns and B:C ratio compared to EP.

Keywords: Area and productivity, Climate, Mitigation, Pigeonpea, Relative and absolute change, Yield

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is a major legume (pulse) crop grown in about 50 countries in the tropics and subtropics and accounts for ~5% of total global pulse production (Singh *et al.* 2018). Among major pulses grown and produced globally, Indian share is highest for pigeonpea in area (79.7%) and production (67.3%). Although, India leads the world both in area and production, while productivity has remained almost static during last 50 years (Reddy 2009), due to several biotic and abiotic climatic stresses. Climate change is the biggest threat of the present century (Gautam *et al.* 2013). Ortiz *et al.* (2008) reported that the temperature increases of 3–4°C could reduce crop yields by 15–35% in Asia. Adverse effects of multiple climatic vulnerabilities in the forms of abiotic and biotic stresses are more pronounced in pigeonpea compared to other oilseed, cereal and *kharif* pulses, since crop takes relatively more time to mature (Singh *et al.* 2019, 2020a).

Among pulses, pigeonpea is highly sensitive to water-logging during establishment stage (Singh *et al.* 2019).

Pigeonpea can survive at low temperature to a certain degree but it is highly sensitive to frost damage which causes burn injury and leads to heavy defoliation followed by drastic delay in reproductive phase resulting in negligible pod set (Basu 2015, Singh and Singh 2016). The minimum temperature goes down to 3°C and cold wind is severe enough for the attack of frost in dry condition and more than 80% rainfed pulses face recurrent terminal drought causing substantial yield loss (Singh and Singh 2016). Pigeonpea is highly sensitive to temperature extremities both <7°C and >40°C (Basu 2015). In general, the decrease and fluctuations in total production and productivity of pigeonpea are ascribed to various types of weather abnormalities in different regions of India (Singh *et al.* 2018). The present study was undertaken to analyse factors affecting changes in area and productivity of pigeonpea in central Indian states, MP and CG, and techniques for increasing yield and benefits of pigeonpea in changing climatic scenario.

MATERIALS AND METHODS

The present experiment was conducted in MP and CG states of central India because of a marked variation that

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prevails in soil and climate which divide the states into 12 agro-climatic regions, leads to great variation in cropping patterns in both area and productivity. The district wise information on area and productivity of pigeonpea was collected from directorate of agricultural land records, while climatic vulnerability was collected from contingent plan of MP and CG states.

Study period and preparation of data: The period was selected for this study from 1982–85 (base year) to 2013–16 (current year). The data on area and productivity of pigeonpea for each agro-climatic region taken separately for same period. The district wise figures were summed up from agro-climatic data regarding pigeonpea area and productivity of each year and each region separately. Three year moving averages were taken to minimize fluctuations in time series data. The district wise climatic vulnerability was summarised in respective agro-climatic zones of MP and CG.

Analysis of data: Absolute change is one of the methods to compare the changes in area and productivity of crop by secondary data. Therefore, it was considered proper to take an average of three years, base and end of particular period. The AC was worked out of area and productivity by taking the average of area and productivity of base year (average of three-year 1982–83 to 1984–85) and the average of last current year (average of three years 2013–14 to 2015–16) of the study period and change in area and productivity was calculated as:

$$AC = Y_n - Y_o$$

where AC, Absolute change; Y, Variant, area/productivity; n, Average of last three years current period; o, Average of 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 calculated as:

$$RC = \frac{Y_n - Y_o}{Y_o} \times 100$$

where Y_n, Current year; Y_o, Base year.

On farm trials on pigeonpea were carried out during *kharif* (Rainy) 2013–2016 to evaluate response of technologies for escaping climatic abiotic and biotic stresses. These trials were conducted at Jigani NICRA village Morena district of MP, India.

Treatments and management: Ten farmer fields were selected for trials to assess the impact of each technology compared to existing practices (EP) of farmers. The interventions for mitigation of climatic effect and EP were followed in trials. The size of plots was 2000 m². The treatment effects were statistically analysed using randomized block design. The university recommendations for growing pigeonpea were followed as per different interventions. The sowing methods adopted, flat (EP) and BBF sowing as per treatment (Fig 1). Sowing of crop during

4th week of June and harvesting for short duration cultivar varied as per cultivars.

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. The EC and pH (1:2 soil water ratio), OC, available N, P, K and S were determined as per methods described by Jackson (1973) and micronutrient by DTPA extraction was determined by AAS. The selected soils of farmers' field were sandy loam in texture, and EC and pH ranges from 0.27–0.40 dS/m and 7.62–7.92, respectively. The soils were deficient in organic carbon (2.5–4.3 g/kg), available N (132–184 kg/ha), S (8.1–12.1 kg/ha), Zn (0.41–0.58 mg/kg), whereas low to medium in available P (8.0–10.8 kg/ha) and medium to high in available K (208–75 kg/ha).

Data collection and economic analysis: Seed, stalk yield, cultivation cost, net returns (₹) and benefit cost (B:C) ratio were calculated to find out the economics of various treatments under study. Different economic indicators of inputs were also calculated based on existing market prices. Gross returns, NRs and B:C ratio were calculated by methods adopted by Singh *et al.* (2019).

RESULTS AND DISCUSSION

Climatic changes after three decades: The absolute changes in mean of current over base years in minimum and maximum temperature changes in humidity and rainfall was observed over the time (Fig 2). The hottest

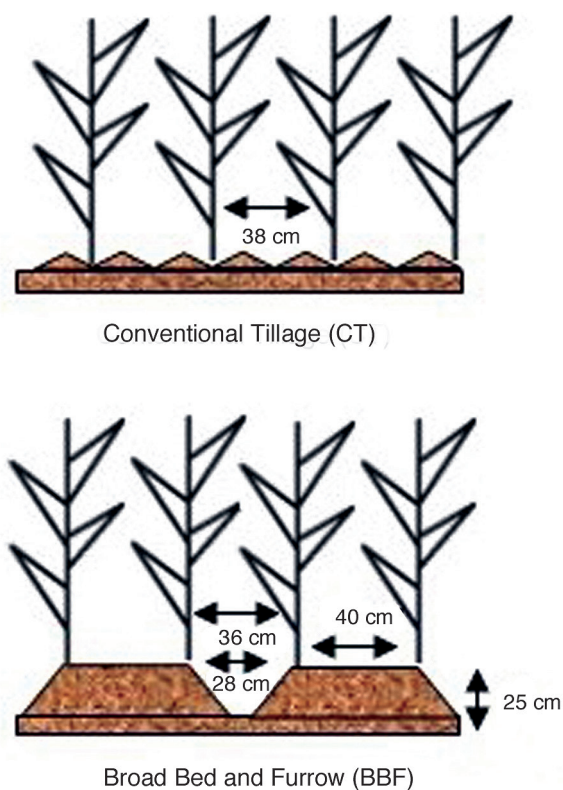


Fig 1 Schematic diagram of different sowing methods.

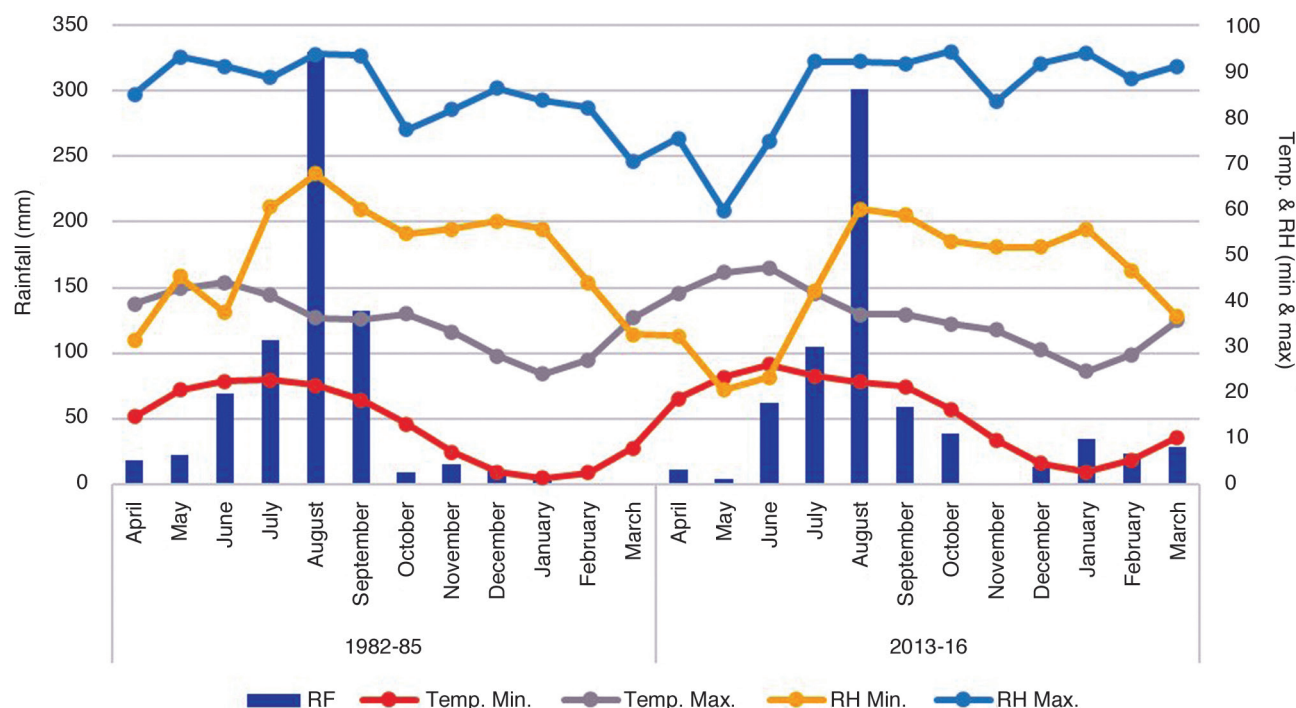


Fig 2 Monthly meteorological average data of base (1982–85) and current (2013–16) years.

month was June, while coldest was January. It was also observed that minimum and maximum temperature had been slightly increased in all months over three decades. The observations recorded that increase in minimum and maximum temperature ranges in current year of 0.7–3.8°C and 0.3–3.4°C than base year, respectively. The minimum temperature was 1.4°C in month of January during base year, while maximum in month of June which was 47.1°C during current year. The trend of temperature indicated that study location gradually became warmer. The total annual rainfall indicated a diminishing pattern and a decrease by

32.2 mm over base year (712.9 mm). This decreasing trend was in total monthly rainfall in summer and rainy season, while erratic and irregular increase in winter months was recorded. In general, the minimum and maximum humidity during summer and rainy season were decreased in current year over base year, whereas reverse trend was seen in winter.

Changes in area and productivity: Variations were observed in AC and RC in area and productivity of pigeonpea in all agro-climatic zones of central India (Table 1). In Central Narmada valley AC and RC in area extended by 16.47 thousand ha and 58.8% against base

Table 1 Area (thousand ha) and productivity (kg/ha) absolute and relative changes in pigeonpea of current compared with base year of different agro-climatic regions of MP and CG

Agro-climatic region	Average area of base years	Absolute change	Relative changes (%)	Base year productivity	Absolute change	Relative changes (%)
Kymore plateau and Satpura hills	55.43	-11.57	-20.9	436	350.5	8.4
Vindhyan plateau	38.46	15.64	40.7	593	132.8	22.4
Central Narmada valley	28.33	16.47	58.8	763	618.9	81.2
Grid region	54.70	-8.24	-15.1	326	535.6	164.2
Bundelkhand	10.23	4.73	46.2	380	287.1	75.6
Satpura plateau	53.57	8.90	16.6	558	529.6	94.9
Malwa plateau	96.77	10.00	10.3	410	299.5	73.0
Nimar valley	34.80	4.13	11.9	470	333.4	74.1
Jhabua hills	4.50	3.36	74.7	349	259.3	74.3
CG plain	40.63	-16.20	-28.5	617	41.5	10.0
Northern hill region	39.67	7.94	20.0	461	239.9	52.0
Bastar plateau	2.50	-0.50	-20.0	846	460.6	54.5
MP and CG	459.59	34.66	16.2	479.33	243.3	65.4

year area, whereas increased in productivity was 618.9 kg/ha and 81.2% compared with productivity of base year, respectively. Similarly, Vindhyan plateau region recorded AC increased in area and productivity by 15.6 thousand ha and 132.8 kg/ha, whereas positive shift in RC was recorded in area and productivity by 40.7% and 22.4% over base year, respectively. Likewise, in Malwa plateau positive shift of area was recorded. As compared with base year data, the AC and RC in area was extended by 10.0 thousand ha and 10.3%, whereas enhanced in productivity by 299.5 kg/ha and 73.0%, respectively. The similar trend was also observed in Nimar valley and Jhabua hills. The positive change of pigeonpea area was due to replacement of paddy with short-duration pigeonpea and crop grown in inter cropping systems with soybean, greengram and blackgram. Also, the higher net profit was observed with pigeonpea due to climatic suitability and crop grown in wheat-based cropping system compared with other *kharif* crops (Singh *et al.* 2020a).

In Bundelkhand region increased in area and productivity by 4.73 thousand ha and 287.1 kg/ha, whereas RC by 46.2% and 75.6% was recorded as compared with base year, respectively (Table 1). Likewise, in Satpura plateau region the crop registered the positive shift of pigeonpea area. The AC and RC in area was increased by 8.90 thousand ha and 16.6%, whereas enhanced in productivity by 529.6 kg/ha and 94.9% than base year, respectively. In Northern hill region of CG and Chota Nagpur plateau acreage was observed positive shift by 7.94 thousand ha with increase of RC by 20.0%, whereas AC in productivity increased during corresponding years by 239.9 kg/ha and RC of 52.0%, respectively. The basic reason of increase in area in these regions is favourable climatic conditions for pigeonpea and higher benefits.

In Kymore plateau the area of pigeonpea crop AC and RC decreased by -11.57 thousand ha and -20.9%, whereas AC in productivity increased during corresponding years by 350.5 kg/ha and RC of 8.4% compared with base year yield, respectively (Table 1). Similarly, in CG plain acreage AC to decline by -16.20 thousand ha and RC decreased by -28.5% compared with base year area. The productivity reported was increased by 10.0% compared with base year average yield during the study period. Pigeonpea crop was replaced by paddy due to climatic unsuitability (high rainfall region crop affected by abiotic and abiotic stresses) and also losses by wild animals. It can be concluded that the area in this region reduced, while increased in productivity was due to timely adoption of package practices. Similarly, in Bastar plateau, AC and RC in area decreased by -0.50 thousand ha and -20.0%, while AC and RC in productivity enhanced by 460.6 kg/ha and 54.5% compared to base average productivity, respectively. In this region pigeonpea area replaced by maize due to climatic unsuitability and maize crop gave higher return and climatic suitability. Similarly, in Gird region acreage AC decline by -8.24 thousand ha and RC decreased by -15.1%, compared with base year area. The productivity reported was increased by 164.2%

compared with base year average yield. In this region farmer grows long-duration cultivar. It has been observed that long-duration pigeonpea cultivars (250–280 days) that occupy fields for nearly whole of the year get damaged by frost and also losses by blue bulls. Now long-duration cultivars replaced by short-duration cultivars of pigeonpea.

Impact of abiotic stresses on yield: The survivability of pigeonpea at early stages is often affected by temporary water submergence that may vary from hours to a few days. The establishment of crop on bed by BBF method significantly increased seed and stalk yield over conventional tillage sowing (CTS) method. The increase in seed and stalk yields was 18.2% and 16.8% under BBF sowing method compared with CTS (Table 2). Similar results were also reported by Singh *et al.* (2018, 2019).

Long-duration maturity cultivars of pigeonpea are known to suffer from frost in north-western and central India. On other hand, short-duration cultivars mature before probable time of frost which generally falls between last weeks of December to whole of January (Singh *et al.* 2018, 2019). Short-duration cultivar produced significantly higher seed and stalk yield compared to long duration cultivar. The average seed and stalk yields were 34.1% and 31.2% higher in case of short-duration compared with long-duration cultivar. Results of trials showed that technique of drought management through advance sowing of extra early maturing variety influenced average seed and stalk yield which were 21.0% and 14.0% higher respectively. In addition to higher yield, short-duration cultivars have additional advantage of early vacate of field unlike long-duration cultivars and do not delay the sowing of succeeding crop (Singh *et al.* 2019).

Impact of biotic stresses on yield: Results of Fusarium wilt management recommended technique (seed treatment with *Trichoderma harzianum* @10 g/kg of tolerant cultivar and BBF sowing) significantly increased average seed and stalk yield compared to control. The average seed and stalk yield was 26.2 and 40.3% higher with improved technology compared to control (Table 2). The BBF sowing field have soil with less water content, more porous and less humid. Biological pesticides such as *Trichoderma* have potential to replace or augment conventional plant disease management (Patel *et al.* 2011).

Control of *phytophthora* blight through use of resistant cultivar (after seed treatment with *Trichoderma viride* @10 g/kg of tolerant cultivar and crop establishment on bed) significantly increased seed yield compared to EP. The average seed and stalk yield was increased by 15.2 and 23.4% with improved technology compared to EP. The recommended technology for control of pod borer/fruit fly (Use of *pheromon trap* @20 + HaNPV 500LE + *quinolphos* 25EC @1000 ml/ha at economic threshold level) produced significantly higher seed and stalk yields as compared to control (Table 2). The average seed and stalk yield was 42.2% and 5.8% higher with recommended technique for control of pod borer compared to control, respectively. Similar results were also reported by Singh *et al.* (2020b) in pigeonpea.

Table 2 Impact of different technological interventions for abiotic and biotic climatic vulnerabilities on pigeonpea

Climatic problem	Intervention	Seed yield (q/ha)	Stover yield (q/ha)	Cost of production (₹/ha)	Net returns (₹/ha)	B:C ratio
<i>Abiotic vulnerabilities</i>						
Temporary water logging during <i>kharif</i>	EP- Line sowing	13.66	64.4	20,200	48905	3.42
	IT- BBF sowing	16.15	75.2	20,450	61063	3.99
	CD at 5%	1.78	2.53	NS	2598	0.16
Frost attack on long duration variety	EP- Long-duration cultivar JA-3	17.30	80.5	22110	65197	3.95
	IT- Short-duration cultivar Pusa-992	23.20	105.6	20050	96561	5.82
	CD at 5%	2.18	4.10	1004	3914	0.22
Drought	EP- Long-duration cultivar Gwalior-3	18.51	82.25	22884	69753	4.05
	IT- Extra early cultivar ICPL-88039	22.78	99.76	24110	89605	4.72
	CD at 5%	1.49	2.99	1380	5771	0.20
<i>Biotic vulnerability</i>						
<i>Fusarium</i> wilt increases with increasing of soil moisture and temp. >25°C	EP- Not adopted any practice	17.83	74.7	23450	64870	3.77
	IT- Resistant cultivar Pusa-992 + <i>Trichoderma harzianum</i> @10 g/kg seed treatment + BBF sowing	22.50	104.4	24460	89030	4.64
	CD at 5%	2.41	5.51	980	5524	0.29
<i>Phytophthora</i> blight infestation increase with high rainfall and humid condition	EP- Local old variety UPAS-120	17.89	82.28	21810	68281	4.13
	IT- Resistant cultivar Pusa-2002 + <i>Trichoderma viride</i> @10 g/kg seed treatment + BBF sowing	21.60	101.5	22570	86636	4.84
	CD at 5%	2.62	4.89	NS	3362	0.21
Pod borer complex increases with erratic winter rains and increase of minimum temp.	EP- <i>Quinolpos</i> 25 EC @750 ml/ha	15.12	94.2	19,800	61274	4.10
	IT- <i>Pheromon trap</i> @20 + HaNPV 500 LE + <i>Quinolpos</i> 25 EC @1000 ml/ha	21.50	99.7	23,100	85334	4.69
	CD at 5%	2.56	3.49	2815	3846	0.31

EP, Existing practice; IT, Improved technology.

Impact of abiotic stresses on economics: Among abiotic stresses maximum additional production cost was recorded with BBF method for saving of crop from temporary water logging (₹250/ha), followed by saving of crop from frost by using short-duration cultivar (₹2,060/ha) and escaping of drought by using extra early drought tolerant cultivar (₹1,226/ha) compared long-duration cultivar (Table 2). The maximum additional return (₹31,364/ha) was obtained with escaping of crop by frost, followed ₹19,852/ha by minimized drought effect by using extra early maturing cultivar and ₹12,158/ha by sowing of crop by BBF method that saved crop from excess of soil moisture. The BBF sowing of pigeonpea fetched higher net returns due to higher yield over flat sown crop. Research on long-duration genotype reported requirement of more energy and inputs for producing seed and stalk compared to short-duration cultivar of pigeonpea (Singh *et al.* 2018). The B:C ratio was higher (5.82) under short-duration cultivar which escaped winter frost by advance sowing and minimum B:C ratio was recorded (3.99) under sowing of crop with BBF for saving of crop from temporary water logging.

Impact of biotic stresses on economics: Maximum

additional production cost under biotic stress was ₹3,300/ha for control of pod borer followed by ₹1,010/ha for management of wilt and ₹760/ha of blight disease compared with control (Table 2). The maximum additional NRs was recorded ₹24,160/ha from management of wilt, while ₹24,060/ha with pod borer by integrated pest management technology and ₹18,355/ha from control of blight disease due to excess soil moisture and high humidity compared with EP plots. The B:C ratio was higher (4.84) under control of blight disease and minimum (4.64) under control of wilt.

Analysis of data showed all over growth in area and productivity of pigeonpea in MP and CG state of India after three decades, but climatic abnormalities is a major challenge for sustaining this growth. Our study showed that adaptation of improved technologies reduced effect of climatic abnormalities. The crop established on bed and furrow irrigation also increased the productivity and saving of crop from more water submergence and drought phases. Thus, it can be concluded that timely adoption of proper technologies and tolerant/resistant cultivars is essential to mitigate multiple abiotic (water logging, frost, drought, heat)

and biotic climatic stress (wilt, blight, pod borer/pod fly) of pigeonpea as well as to produce higher yield and benefits.

REFERENCES

- Basu P S. 2015. Environment and pulse. *Pulse Hand Book* 48–53.
- Gautam H R, Bharadwal M L and Kumar R. 2013. Climate change and its impact on plant diseases. *Current Science* **105**: 1685–91.
- Jackson M L. 1973. *Soil Chemical Analysis*, Prentice Hall of India Pvt., Ltd., New Delhi.
- Ortiz R, Sayre K D, Govaerts B, Gupta R and T Reynolds. 2008. Climate change: Can wheat beat the heat? *Agriculture, Ecosystems and Environment* **126**: 46–58.
- Patel S I, Patel R L, Desai A G and Patel D S. 2011. Bio-control of *fusarium udum* through trichoderma. *Journal Pharma Bio-Science* **2**(4): 215–22.
- Reddy A. 2009. Pulses production technology: Status and way forward. *Economic and Political Weekly* **52**: 73–80.
- Singh A K and Singh Y P. 2016. *Impact of weather abnormalities and mitigation techniques for pulse production in Central India*. 81st annual Convention of ISSS and special symposiums on Sustainable pulse production from less for more held at RVSKVV, Gwalior. SOUVENIR p. 1-13.
- Singh Y P, Singh S and Singh A K. 2019. On farm abiotic stress management in pigeonpea and its impact on yield, economics and soil properties. *Legume Research* **42**: 190–97.
- Singh Y P, Singh S, Nanda P and Singh A K. 2018. Impact of establishment techniques and maturity duration of pigeonpea cultivars on yield, water productivity and properties of soil. *Agricultural Research* **7**(30): 271–79.
- Singh Y P, Tomar Sandeep S, Singh S and Nanda P. 2020a. Effect of precise levelling and crop establishment options for wheat-based systems on soil quality, system- and water productivity in scarce irrigated areas. *Archives of Agronomy and Soil Science* **67**: 1327–40.
- Singh Y P, Tomar S P S and S Singh. 2020b. Impact of biotic stress management technologies on yield, economics and energy indices of pigeonpea grown in Central India. *Legume Research* **43**: 61–67.