Strategy for Increasing the Soybean Productivity through Frontline Demonstrations and Its Role in Soybean Economy of India in Changed Climatic Scenario

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ABSTRACT

Soybean has shown unprecedented growth during past more than four decades in terms of area and production expansion (Sharma et al., 2016b) and emerged as a leading oilseed crop in India, contributing significantly to the edible oil pool as well as earns considerable amount of foreign exchange for the country through export of de-oiled cake and other products. The crop has also revolutionized India's rural economy through upliftment of socio-economic status of soybean farmers particularly in Central India (Sharma, et al., 2016a). The all time high area under soybean cultivation was recorded at 11.72 million ha during 2013 and the highest production and productivity of 14.67 million tonnes and 1353 kg/ha, respectively, was observed during 2012 (Fig 1). The crop has substantial presence in many states, however, Madhya Pradesh, Maharashtra and Rajasthan contributes to about 90 per cent of total soybean produced in India and cultivation of soybean is fast spreading in the states of Karnataka, Telangana and Gujarat.

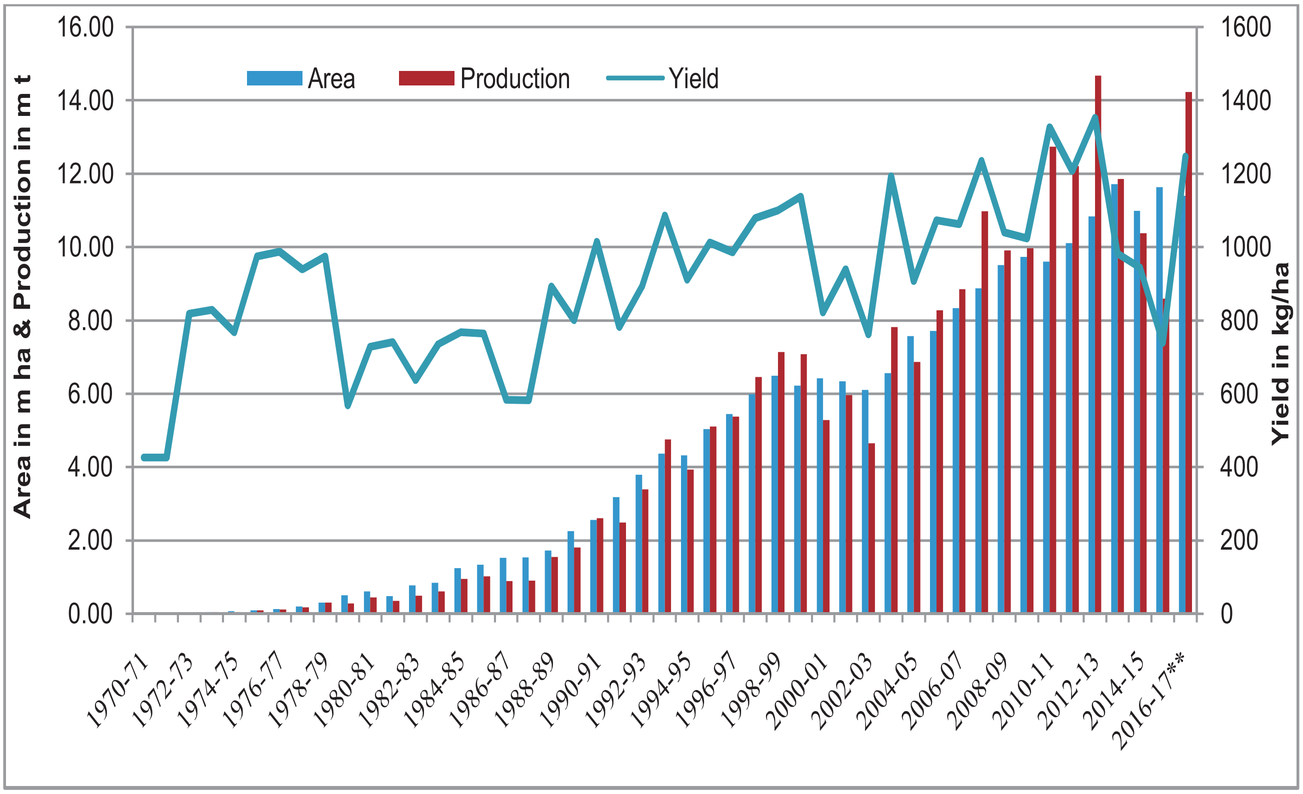

***Figure 1.** Growth in area, production and yield of soybean in India*

The crop is mainly grown under rain-fed conditions, the pattern and intensity of rainfall plays significant role in the yield realization. Over the years, there has been a shift in the behaviour of monsoon and drought is experienced every year at one or other growth stages. Also, once in every 2-3 years drought conditions are experienced in India (Birthal *et al.*, 2015) and soybean production and productivity fluctuates in Madhya Pradesh and other parts of country.

There has been setback to soybean production continuously since *kharif* 2013 wherein the soybean production gone down below 1 tonne/ha. Continuous decline in production of soybean from 2013 onwards is mainly associated with weather aberrations such as late arrival of monsoon, high intensity rains, subsequent drought and high temperature conditions, etc. Excessive rainfall in 2013 and late arrival of monsoon and drought conditions in 2014 (Table 1), particularly in states like Madhya Pradesh, Maharashtra and Rajasthan were the main reasons reported for low productivity of soybean in India. In 2015, the worst year for the soybean production and productivity, very unusual weather conditions comprising long period of drought, heavy rainfall in short span of time (Fig 2a and 2b) and above normal temperatures in the main soybean growing regions has adversely affected the soybean yield. Besides these abiotic stresses, there were biotic factors that have further confounded the problem.

Table-1
Rainfall and departure from normal (%) in central India

Year	Actual Rainfall (mm)					Departure %				
	June	July	August	Sept	June - Sept	June	July	August	Sept	June - Sept
2010	120.9	375.2	323.5	209.2	1028.9	-25.4	12.2	4.7	11.8	3.6
2011	187.1	296	296.1	239.7	1068.7	14	-8.8	13.3	32.2	9.6
2012	99.3	311.9	305.5	218.2	934.9	-39.5	-3.9	0.1	20.3	-4.1
2013	275.9	437.6	299.2	180.7	1193.4	68.1	34.8	-2	-0.4	22.4
2014	64.6	358.5	256.4	201.1	880.5	-60.6	10.6	-15.9	11	-9.6
2015	204.5	267.9	204.8	141.8	818.9	24.4	-17.5	-32.9	-21.8	-16

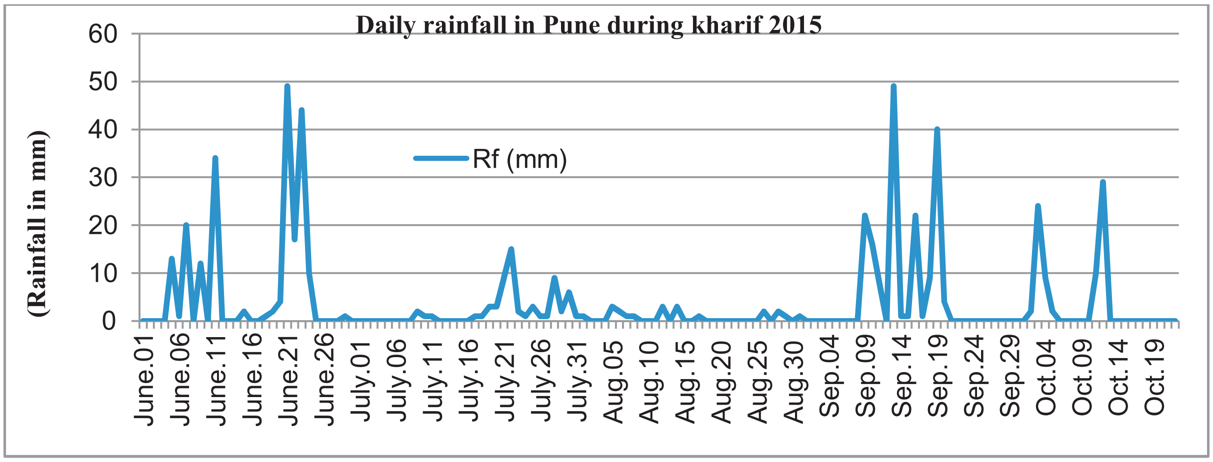

Figure 2 a. *Daily monsoon rainfall in Pune (2015)*

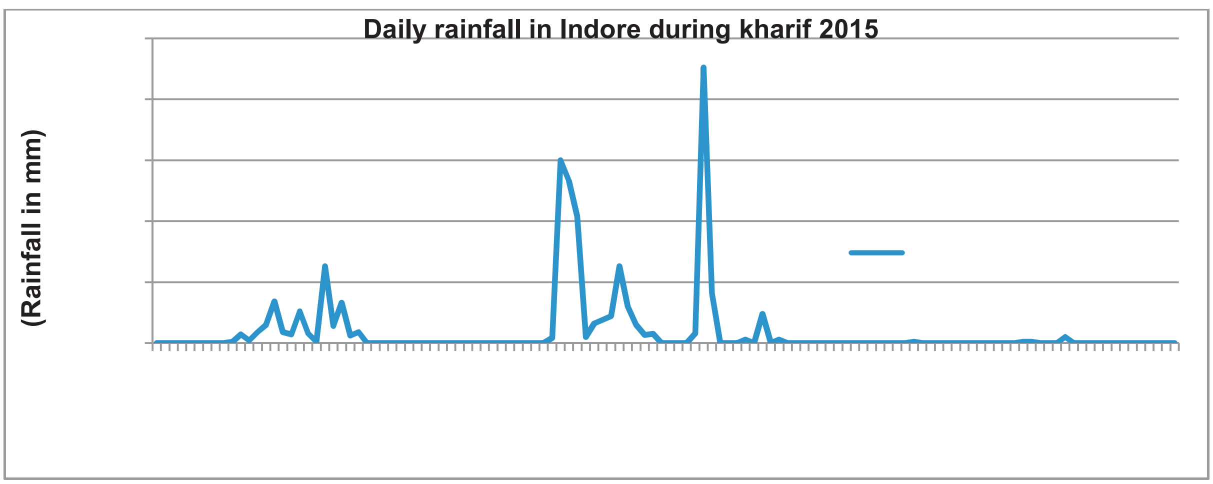

Figure 2 b. *Daily rainfall in Indore (2015)*

Soybean being a low cost input crop offers better options for the Madhya Pradesh farmers for cultivation during *kharif* season and holds a great potential in the state. However, the dissemination and adoption of improved production technology among the farmers appears to be major bottleneck for poor productivity of soybean in India. The productivity can certainly be increased to 1.8 to 2.0 tonnes per ha with judicious use of recommended package of practices which can generate an additional soybean output of about 2.0 to 3.0 million tonnes in the country.

Due to rain-fed nature, the cultivation and productivity realization of soybean crop at farm level depends mainly on the quantum and distribution of monsoon coupled with the level of adoption of the recommended production technology. The intensity and distribution of rainfall varies from year to year leading to dry spell (drought) and excessive water (water logging) condition in the field. Under both these conditions, the productivity of soybean crop is adversely affected (Kumar *et al.*, 2002). The extent of yield reduction due to these stresses depends upon duration of stress and growth stage of crop at which they occur.

Occurrence of water logging conditions for varying period, depending upon the intensity and duration of rainfall, is also a general feature observed in many *kharif* crops in India. Prolonged water logging in the field results in anaerobic conditions in the root zone. The reduction in crop growth and yield due to water logging depends on the duration of the water logging and the growth stage at which it occurs. Therefore, it is necessary to avoid water-logging conditions in the field so that potential of the crop can be harvested.

The impact of adoption of improved package of practices on yield and economics of soybean during normal weather and water stressed years in major soybean producing states have been analyzed and presented in this paper. Data generated through frontline demonstrations (FLDs) conducted across the country have been used for the period from 2010-11 to 2015-16. In order to remove the price effect, the cost and returns data were deflated with the wholesale price index with base 2011-12 as 100. However, before going into details of economic analysis, it is important to know the intricacies of technology development, dissemination and its adoption among the farmers of major soybean growing states in the country.

Research infrastructure for soybean in India

Soybean, a golden crop of prosperity was grown in India before its re-introduction during early seventies. The black seeded soybean of yesteryears was popular among Indians with various names like *Bhat*, *Bhatman*, *Bhatmas*, *Ramkulthi*, *Bhut*, *Kalitur*, *Teliakulth* and *Garryakalay* (Singh and Saxena, 1979, Dupare *et al.*, 2011 and Tiwari, 2014). Also in soy state of Madhya Pradesh, black seeded soybean was traditionally grown among the farmers which they called *Kalitur*. The systematic research & development work on soybean was initiated in the year 1967 consequent to the launch of All India Coordinated Research Project on Soybean (AICRPS) initially from IARI, New Delhi which later on shifted to GBPUA&T, Pantnagar. The varietal development work carried out under AICRPS and their adaptability and multi-location testing among new soybean growing areas led to release of number of soybean varieties superior in yield attributes.

Within a short span of time, the concerted efforts of R&D system, extension personnel, farmers, input suppliers and solvent extraction industry and staff of oilseed federation have been successful in bringing the sizeable area under this crop. The Indian Council of Agricultural Research (ICAR), an apex body of agricultural research in India later on established National Research Centre for Soybean (NRCS) in the year 1987 at Indore while shifting of headquarters of AICRPS to Indore. The crop which initially occupied vast majority of *kharif* fallow available in central India (Bisaliah, 1986) particularly Malwa Plateau, started its horizontal as well as vertical expanding in its area, production and productivity (Chand, 2007) and soon occupied number one position among the oilseed crops grown in India. Soybean is still occupying its premier position among the oilseeds of the country. With the continued progress of the crop, the NRCS was upgraded to the status of Directorate of Soybean Research (DSR) in the year 2009 which further upgraded to Indian Institute of Soybean Research (IISR) in the year 2014 and is continuously striving for development of location specific high yielding varieties and technologies related to different biotic and abiotic stresses, development, validation and dissemination of strategies and integrated approaches for its wider adoption among the farming community.

Technology development

Since the start of AICRPS in 1967, more than 119 varieties of superior characters like high yield, high oil, resistant/ tolerant to biotic and abiotic stresses have been developed by soybean R&D system in India out of which nearly 40 varieties are under seed chain and being grown by the farmers. The system also developed and recommended location specific improved package of practices for soybean and is regularly being validated and disseminated location specific technologies to different soybean growing areas.

Technology dissemination

The knowledge and technologies developed through research programmes have to reach its ultimate user i.e. farmers, majority belonging to small and marginal categories. To cater this need, number of public as well as private extension agencies is working in India. Among the major public funded extension systems existing in India, the major chunk of transfer of technologies in agriculture is being performed by State Led Extension Services through Department of Agriculture of the concerned state and Krishi Vigyan Kendras. This agency has wider network of its multi-level chain of extension professionals (Joint Director at Divisional, Deputy Director at District SDAO at Block and VLW/RAEO at village level) being administered by Director (Agriculture) at State level. They are being trained at units of ICAR institutes/State Agricultural Universities for their knowledge up-gradation in the latest technological advances in package of practices on regular basis.

So far as dissemination of improved soybean production technologies are concerned, the extension professionals of State Agricultural Department of soybean growing states are being trained at ICAR-Indian Institute of Soybean Research, Indore on regular basis through organization of Model Training Courses/Trainers' Training Programmes especially designed for them. These trained participants consequently are supposed to pass on the knowledge to their subordinates thereby ensures its percolation to grass root level. The institute also organizes/participates in various extension programmes like Zonal Workshops/Pre-season workshops, Farm Fairs & Exhibitions, demonstrations, training of visiting farmers, etc.

The other Public Funded Extension System available in the country is ICAR-SAUs extension system performing the mandate of Extension Education. This is also known as Firstline Extension Systems wherein directly scientists are involved in taking their technological finding/package to different stakeholders particularly extension professionals of public extension system, farmers and staff of private companies as well as NGOs. The ICAR institute along with Research Stations of SAUs conducts training programmes as well as refresher courses in various commodities and disseminates the knowledge to the extension professionals. They also impart training programmes for the scientific staff of Krishi Vigyan Kendras which are operated at district level primarily mandated for complimenting the technology dissemination work carried out by State Extension System. The ICAR institutes and SAUs also conduct frontline demonstrations primarily to educate extension professionals and farmers by demonstrating the actual worth of improved technologies for convincing and motivating the farmers of surrounding areas for its adoption.

Frontline demonstrations

The demonstrations conducted in real farm situations under the close supervision of scientists of the ICAR/SAUs are called front-line demonstrations. The technologies under FLD are demonstrated for the first time by the scientists themselves before being fed into the main extension system of the State Department of Agriculture. The main objective of Front-Line Demonstrations is to demonstrate newly released crop production and protection technologies and its management practices in the farmers' field under different agro-climatic regions and farming situations.

ICAR-Indian Institute of Soybean Research is conducting Frontline Demonstration on soybean since 1989-90 in different agro-climatic zones of the country in association with the identified centres under All Indian Coordinated Research Project on Soybean. These FLDs which are conducted on farmers' field on 0.4 ha area covers all the recommended package of practices including newly release cultivars. The yield results of the improved technology (IT) under FLD are then compared with yield realised from farmers own traditional practice (FP) and yield gap II is worked out along with other economic indicators like per cent increase over FP, Gross & Net Returns, Benefit Cost Ratio, etc. The analysis of Frontline Demonstrations in Soybean conducted over the period of 27 years have clearly indicated that these FLDs have been successful in reducing the Yield Gap II from 1050 kg/ha in 1989-90 to nearly 400 kg/ha recently. These FLDs are also useful to understand that there is lot of scope to realize the production potential of improved soybean production technology and its adoption among the farming community.

Adoption of improved soybean production technology

The innovation decision process is the process through which an individual passes from first knowledge of an innovation to forming an attitude towards an innovation, to a decision to adopt or reject, to implementation of the new idea, and to confirmation of this decision. As explained by Rogers (1983), the decision stage in the innovation-decision process occurs when an individual engages in activities that lead to a choice to adopt or reject the innovation. Active rejection involves adopting the new practice(s) initially but later on deciding not to continue it whereas Non-adoption (Passive Rejection) involves decision never considering for its application. Adoption of an agricultural innovation/practice/technology in general is a decision making process on the part of farmers whether to make full use of new practice as the best course of action available. When the farmer is exposed to new technology or practice for example in FLD, he or she may eventually go to decide whether to continue it (adoption) or reject the same. An adoption study conducted recently in the soy state of Madhya Pradesh by Dupare *et al.* (2011) revealed that soybean farmers, in general, have only medium levels of adoption of different improved package of practices of soybean, and some of the practices being over adopted by the farmers. As explained earlier, the firstline extension education system of ICAR/SAUs to some extent supplement the efforts carried out by main extension system of Department of Agricultue of concerned states by educating their officer and middle level staff about the improved technologies through training.

Soybean and weather aberrations

The year-to-year variability in soybean yield is primarily due to the weather during growing season. Rainfall and temperature during the growing season mainly affects crop yields. The growth of soybean from germination to maturity is dependent on availability of moisture (i.e. precipitation under rain-fed conditions) during the season (Kumar *et al.*, 2002). In India, variation in the onset of the monsoon, its intensity and duration are mainly responsible for the relative performance of the soybean crop (Pawar *et al.*, 1997, Lahiri, 1978) and ability of soybean farmers to achieve optimal yield in two ways, i.e. by affecting yield and influencing input allocation by farmers. The extent of yield reduction due to moisture stresses (drought or water logging) depends upon the duration of stress and the growth stage at which they occur. A small stress (about 15% less than minimum moisture availability index) during mid-seedling and end of reproductive stage can reduce productivity by 20 per cent in soybeans.

Climate change happens to be a global phenomenon and is continue to affect the yield of different agricultural commodities world over. Of late, there found to be regional variation in rainfall particularly decrease in rainy days in soybean growing areas. The average temperature during the crop growth period is increased. The instances of heat wave, heavy rainfall and/ or drought have found to be increasing since last decade (Birthal *et.al.*, 2015). As far as soybean is concerned, climatic variation have been noticed particularly by the incidences of delayed onset of monsoon, prolonged dry spells during the crop growth stages coupled with high intensity rains for short period, early cessation of monsoon and sometime damage to the crop produce during maturity period of soybean. There is a need to develop the technologies and production practices like seed/varieties with varying maturity duration fitting in existing cropping systems, changed photoperiod scenario, etc. and make the soybean growers aware about the consequences of these climatic variations while educating them to modify their agricultural practices, follow adaptation strategies accordingly in order to enhance and sustain soybean yields.

Impact of weather variations and role of improved technology

The impact of adoption of improved soybean production technologies (IP) can evidently be seen from the analysis of data of frontline demonstrations over the period presented in Table 2. Results indicated that there was significant reduction in soybean yield across soybean growing states during excess moisture year (*kharif* 2013) and during drought years (*kharif* 2014 and 2015). However, adoption of improved production technology resulted in 15 to 35 per cent higher yield realization in major states (in FLDs with improved practices over farmers practice) and generated 25 to 65 per cent additional net returns from soybean (Table 2 and Figure 3). Thus, proper technology adoption has not only improved soybean yield realization but also generated significant additional net returns even under water stress conditions.

It is noteworthy to observe that yield received through improved technology under FLD has shown around 31% and 33% per cent increase in soybean yield over farmers practice under both the situations. Further, the gross returns of the IT (Rs. 43692 and Rs. 45644/ha) were significantly higher than farmers practice under normal years as well as years experiencing stress condition with marginal cost of Rs 3362/ha and Rs 3119/ha, respectively. If we compare the yield data of FLDs under normal years to those affected by vagaries of climate, the adoption of IP had an edge over all the economic indicators despite yield reduction due to adverse climate. Similarly, considerably high net returns were noted with IP under both normal as well as drought years.

In the soy state of Madhya Pradesh, even during the water stress years the yield obtained by adopting the recommended technologies (IP) was 35 per cent higher than the traditional farmers' practices (FP). The farmers who adopted the recommended package of practices, could save their yield loss to some extent despite the climatic adversaries. Similarly, the economic indicators also reveal that the gross as well as net returns received from adoption of improved technologies certainly had an edge over conventional farmers' practices to a considerable extent. With an additional expenditure of Rs. 3840/ha in adoption of improved practices over farmers practice resulted in additional net returns to the tune of Rs. 6861/ha during water stress years.

Table 2
Impact of technology adoption under normal and water stress years

	Madhya Pradesh		Maharashtra		Rajasthan		Karnataka		All India	
Particulars	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress	Normal	Stress
Yield (kg/ha)										
Yield_IP	1718	1387	2238	1944	1720	1455	1934	1896	1779	1550
Yield _FP	1291	1031	1862	1550	1174	960	1595	1589	1360	1166
Yield _St	1202	914	1446	923	1470	918	940	835	1297	900
Cost and returns (Rs/ha) at 2011-12 prices										
CoC_IT	14493	16194	21465	27871	13821	17794	20367	33011	15827	20363
CoC_FP	10757	12354	18438	26622	11404	16430	18225	29578	12465	17244
GR_IT	41923	41732	55387	56063	47342	41822	44023	51185	43692	45644
GR_FP	31510	31031	46345	44315	31851	27421	36197	42624	33231	34089
NR_IT	27430	25538	33922	28192	33521	24028	23656	18173	27865	25280
NR_FP	20754	18677	27906	17693	20448	10991	17972	13046	20766	16845
Incremental income (%) in IP over FP										
Incr_Yield	33.1	34.5	20.2	25.4	46.5	51.6	21.2	19.3	30.8	33.0
Incr_CoC	34.7	31.1	16.4	4.7	21.2	8.3	11.8	11.6	27.0	18.1
Incr_GR	33.0	34.5	19.5	26.5	48.6	52.5	21.6	20.1	31.5	33.9
Incr_NR	32	37	22	59	64	119	32	39	34	50

In the case of Maharashtra, second largest state in terms of soybean area and production, the results of FLDs followed similar trend. During normal years, adoption of improved technology has shown around 20 per cent increase in soybean yield over farmers practice and farmers could manage to earn of Rs. 6016/ha with a marginal cost of Rs. 3027/ha. If we compare the yield data of FLDs under normal years to those affected by vagaries of climate, the adoption of IT had an edge over all the economic indicators despite yield reduction due to adverse climate. But it is interesting to note that by adopting the improved technology with additional investment of Rs. 1249/ha only farmers could get edge on net returns of Rs. 10499/ha during water stress years.

Similarly in Rajasthan, it is encouraging to know that during normal years, adoption of improved technology has shown around an increase of 46.5% and 51.6% increase in soybean yield over farmers practice (Figure 3). If we compare the yield data of FLDs under normal years to those affected by vagaries of climate, the adoption of IP had an edge over all the economic indicators despite yield reduction due to adverse climate.

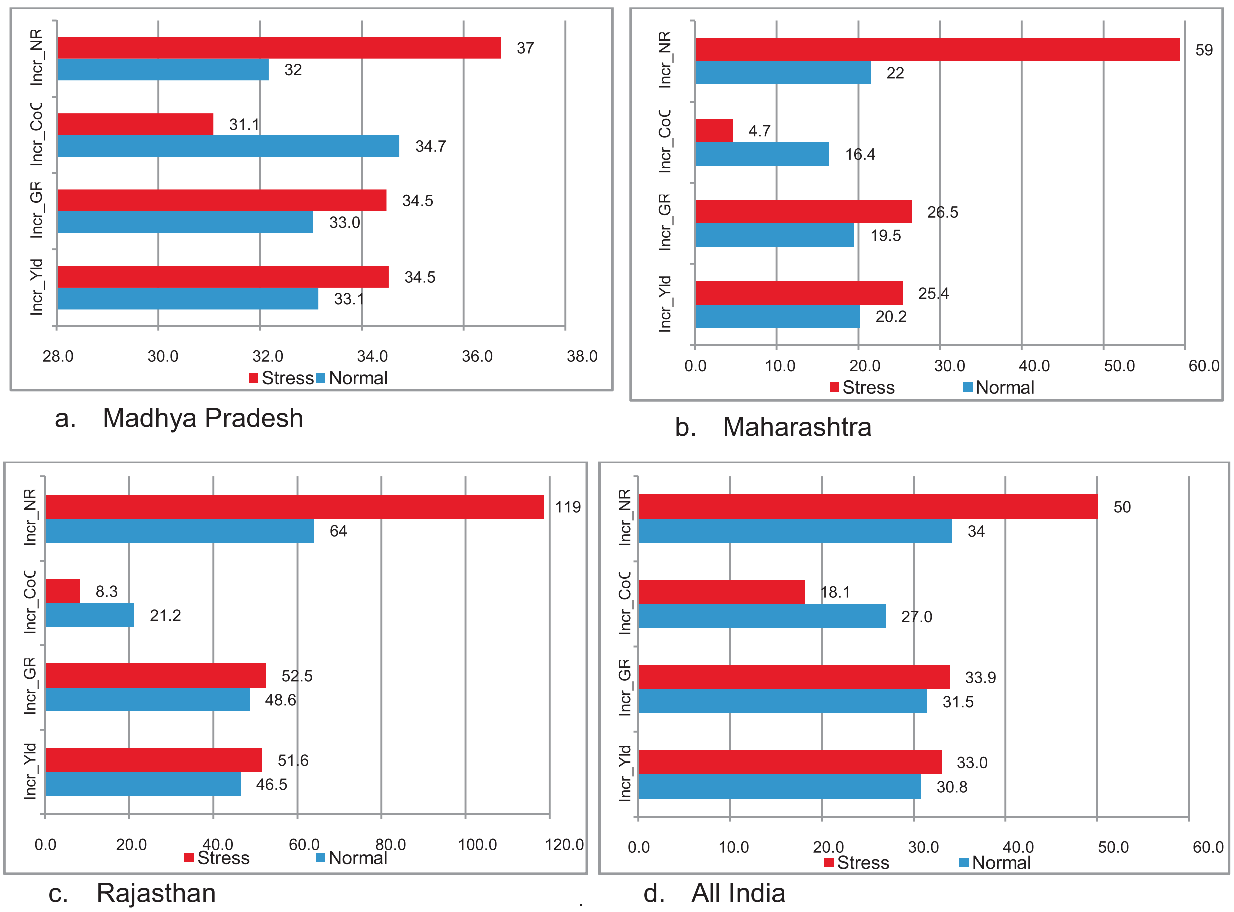

Figure 3. Incremental cost and returns from Soybean cultivation by adopting improved production technology

It is necessary to save the crop from drought as well as from water logging in order to realize the full yield potential. The adverse impact of drought can to a great extent be minimized by proper water management and *in-situ* conservation of soil moisture. It is vital to improve the level of adoption of improved package of practices in order to enhance yield realization and mitigate the effect of weather variations. There is tremendous scope to increase soybean production and productivity by educating the farmers in which frontline demonstrations is playing a very crucial role.

CONCLUSIONS

- The reduction in soybean yield across states during water stress years was observed as compared to normal years.
- However, adoption of improved production technology resulted in 15 to 35 per cent higher yield realization in major states (in FLDs with improved practices over farmers practice) and generated 25 to 65 per cent additional net returns from soybean.
- Thus, proper technology adoption has not only improved soybean yield realization but also generated significant additional net returns even under water stress conditions

Policy interventions required to boost the soybean yield

- It is necessary to save the crop from drought as well as from water logging in order to realize the full yield potential.

- The adverse impact of drought can to a great extent be minimized by proper water management and in-situ conservation of soil moisture.
- It is vital to improve the level of adoption of improved package of practices in order to enhance yield realization and mitigate the effect of weather variations.
- There is tremendous scope to increase soybean production by enhancing productivity.

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