e-Book on

Climate Smart Technologies and Practices for Increasing the Soybean Productivity

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Climate Smart Technologies & Practices for Increasing the Soybean Productivity

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Dr P Chandra Shekara
Director General, MANAGE

Foreword

Climate change due to increasing temperature leads to frequent occurrence of extreme events with high intensity and it has a profound impact on agriculture in terms of production, productivity and livelihood of the farmers. The changed climatic conditions demand a professional extension system in promoting climate resilient technologies and practices in the farmers' field to minimise the risks of climate change in agriculture. Considering the importance of sensitizing the extension functionaries, MANAGE has proposed a series of collaborative training programme with ICAR institutes and State Agricultural Universities to facilitate in dissemination of climate resilient technologies. This will also strengthen the research and extension linkages. Due to COVID-19 pandemic, a Collaborative Training Programme on "Climate Smart Technologies and Practices for Increasing the Soybean Productivity" was organised through online jointly by ICAR-Indian Institute of Soybean Research, Indore and National Institute of Agricultural Extension Management, MANAGE, Hyderabad during 18-21 May 2021. The e-book titled "Climate Smart Technologies & Practices for Increasing the Soybean Productivity" prepared as part of the training programme covered all the important topics of soybean in terms of climate smart varieties, climate smart agronomic practices, nutrient & weed management in the context of climate change, pest and disease management, abiotic stress management, mechanisation, extension strategies etc., in 16 chapters, which were contributed by the experts.

I am sure that this e-book will be highly useful to the scientists, scholars, researchers and extension professionals of both public and private sectors related to soybean to have a comprehensive understanding about the adaptation strategies in the context of changing climate scenario and help the farmers to achieve the sustainable productivity in soybean.

I would wish to thank Dr Nita Khandekar, Director IISR, Indore for collaboration, and congratulate the Coordinators Dr B. U. Dupare, Principal Scientist (Agril. Extension), Dr Savita Kolhe, Principal Scientist (Comp. Application), ICAR- Indian Institute of Soybean Research (IISR), Indore and Dr N Balasubramani, Director (CCA), National Institute of Agricultural Extension Management (MANAGE), Hyderabad for organising the collaborative training programme and bring out a joint publication in the form of e-book.

I wish this e-Book will better the income of soybean farmers through effective extension by addressing climate change challenges.

Date 24.05.2021
Hyderabad

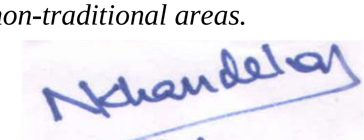
(P Chandra Shekara)
Director General

Preface

The average productivity of the soybean, a premier oilseed crop of the country has been stagnated to around 1ton/ha during the last two decades and is a major concern for the soybean R&D system. This has become more difficult in view of the adverse climatic conditions experienced in most of the soybean growing areas particularly on account of delayed and erratic monsoon, increased frequency of drought at different growth stages of the crop, unwanted rains during the maturity period coupled with increased biotic stress particularly insect-pests and diseases. Nevertheless, it is matter of satisfaction that the ICAR-Indian Institute of Soybean Research, Indore though its nationwide network under AICRP on Soybean has developed and validated technologies and practices which are able to achieve the productivity levels of more than 2.5 ton/ha as evident from reports of the frontline demonstrations.

*The ICAR-Indian Institute of Soybean Research has constantly been supporting the extension systems of state agricultural department as well as the developmental officer at National level through organization of trainers' training programmes on different aspects. These are planned keeping in mind the major objective of dissemination of improved soybean production technologies to the soybean growers as well as other stakeholders for updating their knowledge level and for providing timely solution on the technological issues faced by the farmers. In line with the same, the ICAR-IISR and ICAR-NAARM has jointly organized an online collaborative training programme on "**Climate Smart Technologies and Practices for Increasing the Soybean Productivity**" during 18-21 May 2021with the participation of 152 personnels who are actively involved in the public extension services viz. state department agriculture, as well as, Krishi Vigyan Kendras located across the country.*

I am extremely happy that the coordinators of this training programme have been successful in organizing this training programme in an effective manner notwithstanding the pandemic period experienced by the country due to COVID 19. Further, the present outcome in the form of e-book also needs to be appreciated as it covers detailed information on important technologies and practices which will enable farmers to manage the yield levels even in case of adverse climatic situation. I must congratulate editors of this e-book particularly Dr B.U. Dupare (Principal Scientist, Agricultural Extension) and Dr Savita Kolhe (Principal Scientist, Computer Application) of this institute as well as Dr. N. Balasubramini, Director, Centre for Climate Change, National Institute of Agricultural Extension Management, Hyderabad for all their efforts for bringing this publication in the present form. I also wish that this publication will act as a ready-reckoner for accessing the technologies and practices for the extension workers, as well as, those engaged in the dissemination of technologies and information on climate smart soybean production technologies for increasing the productivity levels and expansion of the crop in the newer non-traditional areas.



Date 07.07.2021
Indore

(Nita Khandekar)
Acting Director, ICAR-IISR, Indore

Content

S. No	Topic	Page No
1.	Climate Smart Soybean Varieties of India *Dr Sanjay Gupta and Dr Mrinal Kuchlan*	1-12
2.	Climate Smart Agronomic Practices for Soybean Production *Dr S D Billore*	13-22
3.	Weed Management in Soybean under Changing Climate Scenario *Dr R.K. Verma*	23-28
4.	Climate Smart Nutrition Management Practices for Soybean Production *Dr A. Ramesh*	29-38
5.	Management of Bacterial & Fungal Diseases of Soybean in the Changing Climate Scenario *Dr Laxman Singh Rajput, Sanjeev Kumar, Dr V. Nataraj, Hemant Singh Maheshwari and Dr Shivakumar M*	39-43
6.	Management of Most Important Insects of Soybean in the Changing Climate Scenario *Dr Lokesh K. Meena and Dr Amar Nath Sharma*	44-47
7.	Climate Smart Pest Management in Soybean *Dr Amar Nath Sharma*	48-60
8.	Role of Micro-organisms in Soybean Production and Seed Inoculation Techniques *Dr Mahaveer Prasad Sharma*	61-64
9.	Management of Viral Diseases of Soybean under Changing Climate Scenario *Sanjeev Kumar, Dr Laxman Singh Rajput, Dr V. Nataraj, Hemant Singh Maheshwari and Dr Shivakumar M*	65-69
10.	Climate Smart Practice for Seed Treatment in Soybean *Dr Punam Kuchlan and Dr Mrinal Kuchlan*	70-75
11.	Extension Strategies for Improving the Soybean Sector against Climate Change Risks *Dr N. Balasubramani and Vincent A*	76-89
12.	Soybean Cultivation vis-à-vis Changed Weather Scenario in Coming Decades *Dr Nita Khandekar*	90-98
13.	Quality Seed Production in Soybean *Dr Mrinal Kuchland and Dr Punam Kuchlan*	99-104
14.	Mechanization for Climate Smart Soybean Production *Dr Dev Vrat Singh*	105-116
15.	Strategies for Management of Abiotic Stresses in Soybean *Dr Maharaj Singh, Dr Subhash Chandra and Dr GK Satpute*	117-127
16.	Use of Social Media and ICT in TOT of Soybean *Dr B. U. Dupare and Dr Savita Kolhe*	128-134

Climate Smart Soybean Varieties of India

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Soybean (Glycine max L. Merril) is the world's most important seed legume which contributes 25% of the global edible oil and about two thirds of the world's protein concentrate for livestock feeding. The cultivation and use of soybean could be traced back to the beginning of China's agricultural age. Chinese medical compilations, dating back 6000 years, mention its utilization for human consumption (Krishnamurthy and Shivashankar, 1975). To the populace of China, Japan, Korea, Manchuria, Philippines and Indonesia, for centuries, soybean has meant meat, milk, cheese, bread and oil. This could well be the reason, why, in these countries it has earned epithets like 'Cow of the field' or 'Gold from soil' (Hovarth, 1926). In India Soybean was introduced from China in 10th century A.D. through the Himalayan routes, and also brought in via Burma (now Myanmar) by traders from Indonesia. As a result, soybean has been traditionally grown on a small scale in Himachal Pradesh, the Kumaon Hills of Uttar Pradesh (now Uttarakhand), the Khasi Hills, Manipur, the Naga Hills, and parts of central India covering Madhya Pradesh. It has also been reported that the Indian continent is the secondary centre for domestication of the crop after China (Hymowitz, 1990; Khoshoo, 1995; Singh and Hymowitz, 1999). Global soybean area and production in 2020 was 127.9 million ha and 379.8 million t and India ranks fifth in the area and production in the world after USA, Brazil, Argentina and China. The contribution of India in the world soybean area is 10-11% but the contribution to total world soybean grain is only 4 to 5% indicating the poor levels of productivity of the crop in India (1.1 t/ha) as compared to other courtiers (World average 2.3 t/ha).

Indian Scenario

Soybean is the numero uno oilseed crop in India. Soybean has become an important oilseed crop in India in a very short period with approximately 10-11 million ha area under its cultivation. India is divided into six agro-climatic zones for soybean cultivation. These are Northern Hill Zone, Northern Plain Zone, Eastern Zone, North Eastern Hill Zone, Central Zone and Southern Zone. There are specific varieties released for each zone which are suited to their agro-climatic conditions. There has been an unprecedented growth in soybean area which was just 0.03 m ha in 1970 and has reached to 14.67 million ha in 2012-13. The mean national productivity has increased from 0.43 t/ha in 1970 to 1.36 t/ha in 2012-13. Soybean production in India during 2020-21 is estimated to be 13.58 million tons from an area of 12.12 million ha and a productivity of 1125 kg/ha as per 1st advance estimates of DAC&FW as compared to production of 11.22 million tons from an area of 11.39 million ha and productivity of 1015 kg/ha in 2019-20. Madhya Pradesh (5.85 m ha), Maharashtra (4.32 m ha) and Rajasthan (1.1 m ha) were the major states for soybean. Karnataka, Telengana, Gujarat, and Chhattisgarh with an area of 0.332, 0.16, 0.15 and 0.08 m ha, respectively, show good promise of expansion in the future.

The major soybean growing states are Madhya Pradesh, Maharashtra, Rajasthan, Karnataka, AP and Chhattisgarh. Soybean is now predominantly grown as rainfed crop in Vertisols and associated soils with an average crop season rainfall of 900 mm which varies greatly across locations and years. Introduction of soybean in these areas has led to a shift in cropping system from rainy season fallow followed by post rainy season wheat or chickpea system fallow-wheat/chickpea) system to soybean followed by wheat or chickpea (soybean-wheat/chickpea) system. This has resulted in an enhancement in the cropping intensity and resultant increase in the profitability per unit land area. Introduction of soybean has helped in improving the socioeconomic conditions of large number of small and marginal farmers probably due to the fact that even under minimum agricultural inputs, management practices and climatic adversities, it fetches profitable returns to the farmers. In fact, soybean is one of the most resilient crops for the rainfed kharif season as despite aberrant weather conditions in recent past, the crop has maintained its performance.

Achieving the higher productivity is the ultimate objective of improved varieties in any crop and soybean is no exception. Unlike, traditional varieties, these varieties are developed with specific characters. They may have higher yields, tolerance to various biotic and abiotic stresses and suitable maturity duration for a particular crop rotation.

Improved varieties, in any crop are essential for achieving higher productivity. Unlike, traditional varieties, these varieties are developed with specific characters like higher yields, tolerance to various biotic and abiotic stresses and suitable maturity duration for a particular crop rotation. Soybean is a short day plant and is highly sensitive to day length. This results in narrow adaptability of individual soybean varieties across latitudes and planting times. The history of development of soybean varieties in India is comparatively new. The introduction of soybean started in 1963 with trials conducted at Pantnagar and Jabalpur agricultural universities, using varieties from USA. Promising varieties in these trials like Bragg, Clark 63 were released for cultivation. During 1980-90, these varieties were used as parent to develop further improved varieties for Indian conditions. The varieties developed after 1990 utilized breeding lines and indigenously developed varieties in hybridization programmes. Genetic enhancement of yield in soybean and its stability under rainfed condition have been the focus. The ideal soybean plant for high yield should have determinate or semi determinate growth habit (suited to short growing season), erect and non lodging, long juvenile period, broad leaves for maximum light interception, rapid LAI development and seed fill duration, and maturity duration of 95-100 days. Most of the improved varieties are capable of yielding 2-3.5 t/ha. The important yield contributing characters are high number of pods per unit area, seeds/pod and seed size.

The total number of released/identified varieties in India till date is 143. Some of these varieties are land races or selections from them and have been known since long. These are (a) a pool of black seeded indigenous varieties such as Bhat or Bhatmash which represent the habitat of northern hill region but are also cultivated in scattered pockets of central India under the names such as Kalitur and Kala Hulga, (b) yellow seeded pool of northern or Tehri-Garhwal region presently represented by JS 2, and (c) a pool of indigenous varieties with small and yellow-seeded varieties represented by Type 49. In Kumaon hills, black soybean locally known as bhat, was grown while in Northeastern India viny type yellow seeded cultigens were grown. These land races have given rise to three varieties viz., Kalitur, JS-2 and Type-49. A majority of Indian varieties have been developed using exotic parents. Depending on their breeding history, the Indian varieties can be grouped into two. The first group comprises varieties viz. Bragg, Lee, Improved Pelican, Hardee, Monetta, Shilajeet, Co 1, Gujarat Soy 1, Gujarat Soy 2, VL Soy 2 and JS 71-05 which owe their evolution to direct selection from exotic and indigenous material. The second group comprises a bulk of the Indian varieties which were developed through hybridization and mutation in/among the varieties of the first group. Soybean breeding programmes across the country have also been successful in developing varieties with specific characters ranging from having resistance to biotic and abiotic stresses, special agronomic niches, important processing requirements and product specific quality traits (Table 3).

The traditional breeding techniques have been used for improvement to yield and other traits. The yields have increased by 60% in the last 60 years and 3900 varieties of soybean have been released world wide. The advent of molecular techniques has speeded soybean breeding. The ability of genome sequence, the use of functional genomics, gene mapping, QTL analysis and transgenic development are accelerating soybean improvement. Glyphosate tolerant Roundup Ready (RR) soybean is the most widely grown GE crop in the world. These molecular techniques the future of breeding programmes. Consequently soybean could become a major crop for producing high quality protein, healthy oil and oil for biodiesel.

The unique features of varieties can be divided into following categories.

Morphological features: The main morphological characters for identification of soybean varieties are leaf shape, flower color, presence/absence of hair, hair colour, seed colour and seed hilum color. Most of the varieties can be distinguished on the basis of these characters.

Agronomic features: These characters include growth habit, plant height, branching pattern, number of pods, seeds per pod and seed size etc. The ideal soybean plant for Indian condition is a medium tall plant with high number of pods, medium maturity (90-105 days) and 100 seed weight of 11-15 gm.

Tolerance to diseases and insects: Many varieties possess genetic resistance to particular disease. Such varieties are specially suited for cultivation in areas where that disease is prevalent. Yellow mosaic of soybean occurs frequently in Northern Plain Zone, the varieties like PS 1347, SL 688, and PS 1225 with resistance to YMV make it possible to cultivate soybean in this zone.

Maturity duration: Duration is important for a rainfed crop like soybean. Farmers prefer early maturing varieties (less than 90 days) which can escape moisture stress of the late monsoon season and fit in the cropping system. Presently a range of maturity from 85-130 days is available in soybean. Varieties are classified as early for maturity period less than 95 day, medium duration for maturity between 95-105 days and late for maturity beyond 105 days. Varieties like, JS 95-60, NRC 7, and JS 93-05 maturing in 85-95 days are very popular among the farmers. Late varieties like NRC 37 and JS 97-52 (105-110 days) give higher productivity but will need irrigation in case of moisture stress. Different features of soybean varieties released/notified in India till date are given in the following table 1.

Six Agroclimatic zones of soybean cultivation are there in India comprising following states

1. **Central zone:** MadhyaPradesh, Rajasthan, Gujrat, Bundelkhand Region of UP, Vidarbh and Marathwada area of Maharashtra
2. **South Zone:** Southern Maharashtra, Karnataka, Telengana, Andhra Pradesh and Tamil Nadu
3. **Northern Plain Zone:** Punjab, Haryana, Delhi, U.P. (except Bundelkhand region)
4. **Northern Hill Zone:** Himachal Pradesh and Uttarakhand
5. **Eastern Zone:** Chhattisgarh, Orissa, West Bengal, and Jharkhand
6. **North Eastern Hill Zone:** North Eastern States

The soybean varietal improvement programme is mainly coordinated by All India Coordinated Research Project on Soybean (AICRPS). The coordinating centre is ICAR-Indian Institute of Soybean Research, Indore. The leading centres under AICRPS for development of improved soybean varieties are as follows

1. Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur, Madhya Pradesh
2. GB Pant University of Agriculture and Technology, Pantnagar, Uttarakhand
3. ICAR-IISR, Indore
4. Punjab Agriculture University, Ludhiana
5. VPKAS, Almora
6. Agharkar Research Institute, Pune
7. ICAR-IARI, New Delhi
8. Rajmata Vijayraje Sindhia Krishi Vishwa Vidyalaya, Gwalior, M.P.
9. Vasantrao Nayek Marathwada Krishi Vidyapeeth, Parbhani, Maharashtra
10. Dr. PDKV, Akola, Maharashtra
11. MPKV, Rahuri, Maharashtra
12. UAS Dharwad, Karnataka
13. IGKVV, Raipur, Chhattisgarh
14. Agricultural University, Kota, Rajasthan
15. Chaudhary Sarwan Kumar Himachal Pradesh Krishi Vishvavidyalaya, Palampur, Himachal Pradesh
16. Punjab Agricultural University, Ludhiana, Punjab

Table 1: The list of soybean varieties released/notified in India during last 10 years for different zones and states is given below

Sl. No.	Soybean variety	Year of release/Notification	Area of adaptability	Maturity (days)	Yield (Kg /ha)	Oil and protein content	Salient features	Reaction to insect - pests & diseases
1.	PRS 1	S.O. 454(E), 11-02-2009	Uttaranchal mid hills	100 (80days in Indore)	2000		Determinate, pink flower colour, 100 seed weight: 13 gm.	-
2.	DSb-1	449(E), 11.02.2009	Karnataka	90-95	2400	18.27 % 38.49 %	Semi determinate, early maturing, white flowers, tawny pubescence on stem and pods and brown hilum	Less susceptible to soybean rust, and resistant to girdle beetle, green and grey semi-looper and stem fly
3.	PS 1225	SO 449(E)/11.2.2009	Tarai and Bhabar Region of UP and Uttarakhand	125	3000-3200	18.0 % 42.0 %	Grey pubescence, light brown hilum, Improved seed longevity. Shattering and lodging resistance.	Resistant to YMV, bacterial pustule, collar rot anthracnose, pod blight and SMV.
4.	VL Soya 65	S.O.211 (E)/ 29.01.2010	Uttarakhand	121	1542		White colour of flower Round seeded, black grain colour, Leaves with 4-5 leaflets, 100 seed weight 14.65 g	Resistant to frog eye leaf spot, pod blight and leaf blight
5.	MAUS 158	2137(E) /31.08.2010	Marathwada region of Maharashtra	93-98	2250	19.7 % 42.46 %	Purple flowers, yellow seeds with black hilum,	Tolerant to Bacterial pustules, *Rhizoctonia* root rot and aerial blight, collar rot and charcoal rot
6.	RKS 24	SO 283(E) 7.2.11	Rajasthan	95-98 days	3000-3500	21%	Determinate growth habit, white flowers, tawny pubescence, dark green leaves and brown hilum.	Moderately resistant to bacterial pustule, collar rot and YMV.
7.	SL 744	456(E), 16.03.2012	Punjab	139 days	2200	20.48% 41.07%	light green leaves, white flowers, brown pubescence, medium sized grains, seeds cream in colour	Resistant to YMV and SMV
8.	Pant Soybean-19 (PS 1368)	S.O. 652(E) 10.04.2013	Uttarakhand	117-125 days.	2121		White flower, tawny pubescence, brown hilum, tall and sturdy plant type.	Resistant major foliar diseases, YMV, Bacterial pustule and *Rhizoctonia* aerial blight.
9.	MACS-1188	S.O.2817 19.09.2013	Southern Zone	101 days	2500	19.10% 41%	Determinate growth habit, medium plant height, brown pod, yellow seed and black hilum	Resistant to Bacterial Pustules, Rhizoctonia aerial blight and Charcoal rot.

10.	Pratap Soya 45 (RKS 45)	S.O. 2815 19.09.2013	Rajasthan	95-98 days	3000-3500	21% 40-41%	Determinate growth habit, white flower, hairy plant type, tawny pubescence on pods at maturity, creamy yellow seed and brown hilum Responsive to high fertility under irrigated condition and suitable for water stress condition	Moderately resistant to Bacterial pustules and YMV
11.	RVS 2001-4	S.O 1146(E) 24.04.2014	Madhya Pradesh	94	2300	21.5 % 42.0%	Semi determinant white flower, glabrous, Brown hilum,	Tolerant to major leaf, pod and root diseases.
12.	JS 20-29	S.O 1146(E) 24.04.2014	Central zone	93-96 days	2125	20.90 % 41.1 %	Semi determinant white flower, glabrous, Black hilum, pointed ovate green leaf, tawny pubescence, brown pod, large seed size	Resistant to YMV and Charcoal Rot;
13.	JS 20-34	S.O 1146(E) 24.04.2014	Central zone	86-88 days	2052	20.30 % 40.8 %	Determinate growth habit, white flower, dark green rounded ovate leaf, pod pubescence absent, yellow pod, black hilum, medium seed size	Extra early (87 days); resistant to Charcoal Rot; moderate to high resistance to girdle beetle;
14.	MAUS 162	S.O. 1919(E) 30.07.2014	Maharashtra	100-103 days	2000-3000	21.37% 41.95%	Semideterminate growth, erect plant type, dark green leaves, purple flower, pubescence absent on pods, yellow seed, brown pod and black hilum	Tolerant against charcoal rot, Rhizoctonia root rot and Rhizoctonia aerial blight
15.	DSb-21	S **S.O. 1228(E) 07.05.2015**	Karnataka **South Zone**	90-95 days	2800	18.2% 38.2%	Semideterminate growth, purple flower, pubescence almost absent on stem and pods, yellow seed coat and brown hilum	Resistant to rust
16.	NRC 86	S.O. 268(E) 28.01.2015	Central zone	95-97 days	2150	19.80 % 40.60 %	Determinate growth habit, purple flower, tawny pod pubescence, Dark Green pointed ovate leaf, brown hilum, round shaped small seed, plant height 55-59 cm	Moderately resistant to Bacterial Pustule, Pod Blight and Collar Rot; highly resistant to Charcoal Rot; Moderately resistant – highly resistant for girdle beetle; moderately resistant to stem fly
17.	KDS 344 (Phule Agrani)	S.O. 268(E) 28.01.2015	Southern Zone	94 days	2600	16.80 % 34.6 %	Semi determinate growth habit, violet flower, rounded ovate dark green leaf, pubescence absent on pod, brown pod, yellow green seed, brown hilum	Tolerant to rust; moderately resistant to stem fly, pod borer and leaf roller
18.	Pusa 12 (DS 12-13)	S.O. 1228(E) 07.05.2015	North Plain Zone	124-131 days.	2300	19.6% 37.8%	Determinate growth habit with average plant height of 76 cm, tawny pubescence, white flower, light green leaves, tawny pubescent on plant and pods, yellow seed and black hilum.	Resistant to YMV, Rhizoctonia aerial blight and Bacterial pustules

19.	SL 958	S.O. 112(E) 12.01.2016	Punjab	142 days	2300	19.8% 42.0%	Semi-determinate growth habit with tall plant height (87cm), light green lanceolate leaves, white flower, tawny pubescence on plant and pods, medium size light yellow oval seeds with black hilum	Resistant to YMV and SMV.
20.	MACS 1281	S.O. 2238(E) 29.06.2016	Southern Zone	96 days	**2500**	18.15% 40%	Determinate growth habit, purple flower, glabrous pods, round yellow seed and black hilum	Moderately resistant to Bacterial pustules and Bacterial leaf blight Moderately resistant to stem fly, defoliators, pod borer and leaf folder
21.	JS 20-69	S.O. 2238(E) 29.06.2016	Madhya Pradesh	93-95 days	**2300**	20-22% 39-42%	Semi-determinate growth habit, white flower, pointed ovate green leaves, tawny pubescent on plant and pods, medium plant height, medium size spherical yellow and shiny seeds with black hilum.	Resistant to Yellow Mosaic Virus (YMV), Charcoal Rot (CR), Bacterial Pustules (BP), *Alternaria* Leaf Spot (ALS), Pod blight (PB) Indian bud blight (IBB), Target Leaf Spot (TLS).
22.	VL Soya 77	S.O. 3540(E) 22.11.2016	Uttarakhand Hills	112-127 days	1970	18.6% 38.91%	Determinate growth habit, green pointed ovate leaf, purple flowers, tawny pubescent, tall plant type (78 cm), bold seeded (100 seed wt. 16.89 g), yellow seed with black hilum. Suitable for rainfed organic condition.	Moderately resistant to frog eye leaf spot and pod blight. Moderately resistant to girdle beetle and stem fly.
23.	VL Bhat 201	S.O. 3540(E) 22.11.2016	Uttarakhand Hills	117 days	**1642**	15.45% 41.02%	Determinate growth habit, green pointed ovate leaf, white flowers, tawny pubescent, brown pods at maturity, black seeds, bold seeded (100 seed wt. 13.12 g) Suitable for rainfed organic condition.	Highly resistant to frog eye leaf spot, target leaf spot and moderately resistant to pod blight. Highly resistant to girdle beetle. Moderately resistant to stem fly.
24.	Raj Soya-24 (RVS 2002-4)	S.O. 1007(E) 30.03.2017	Central Zone	96 days	1905	**21-22.5%** **41%**	Semi determinate, green pointed ovate leaf, white flower, pubescence absent on pod, brown pod at maturity, yellow colour medium size seed, seed lusture shiny, black hilum.	Resistant or moderately resistant to major diseases
25.	Pant Soya 21 (PS 1480)	S.O. 2805(E) 25.08.2017	Uttarakhand	123-126 days	**2057**	19.25 % 40.5 %	Sturdy tall plants (68 cm), determinate growth habit, white flowers, dark green leaves, gray pubescence, yellow	Resistant to Yellow Mosaic Virus (YMV), SMV & Bacterial Pustule

							medium size seeds with black hilum. Resistance to pod shattering.	Tolerant: *Rhizoctonia* Aerial Blight (RAB)
26.	Pant Soya 23 (PS 1523)	S.O. 2805(E) 25.08.2017	Uttarakhand	112-115 days	**1915**	40.5 % 19.8 %	Semideterminate plant type, smooth dark green pointed ovate leaf, white flower, gray pubescence, round yellow seed with black hilum,	Resistant to Yellow Mosaic Virus (YMV), Soybean Mosaic Virus (SMV), & Bacterial Pustule (BP), Tolerant: *Rhizoctonia* Aerial Blight (RAB)
27.	Pant Soya 24 (PS 1477)	S.O. 2805(E) 25.08.2017	North Plain Zone	113 days	2560	20.50 % 40 %	Determinate compact plant, dark green narrow leaflet, purple flower, tawny pubescence, yellow bold seed, brown hilum	Resistant to YMV, Bacterial Pustule, and moderately resistant to *Rhizoctonia* Arial Blight Resistant to lodging and shattering
28.	Raj Soya-18 (Pragya)	S.O. 2805(E) 25.08.2017	Madhya Pradesh	95-100 days			Semi-determinate plant type, dark colour lanceolate leaf, white flower, pubescence absent, yellow seeds with black hilum.	
29.	Chhattisgarh Soybean- 1 (CG SOYA-1)	**S**.O. 1379(E)/ 27.03.2018	Chhattisgarh	95-100 days	24.45	20-23 %.	Short & semi-erect and Semi - determinate plant type, light green Pointed ovate leaves, white flower, brown pubescence of pods. yellow seeds with brown hilum	Resistant to Indian bud blight, Rhizoctonia aerial blight, Myrothecium leaf spot and bacterial pustule disease. Moderately resistant to pod blight (*Collototricum truncatum*).
30.	Jawahar Soybean 20-98 (JS 20-98)	**S**.O. 1379(E)/ 27.03.2018	Central Zone	96-101 days	**2094**	19.3 % 40.9 %	Semi determinate plants with white flower, medium plant height (45,9 cm) Pointed ovate leaf, tawny pubescence present on pods and stem, blackish hilum	
31.	Kota Soya-1 (RKS 113)	**S.O. 1379(E)/ 27.03.2018**	Eastern zone	100-102	1893	20% 38-40%	Determinate plant type, light green pointed ovate leaves, sparse pubescence with tawny colour, Purple flower, elliptical yellow seeds with brown hilum	Tolerant to bacterial pustules, bacterial blight, rust and collar rot. Tolerant to defoliator, stemfly, aphids and leafminer.

32.	MAUS 612	**S**.O. 1379(E)/ 27.03.2018	Maharashtra and South Zone	91-95 days	**2531 (max 2760)**	20.49% 40.50%	Scared Grey Pubescence, Semi determinate with purple flower and blackish hilum	
33.	DSb. 23	**S**.O. 1379(E)/ 27.03.2018	Southern Zone	95	**3900**	18.63% 38.2%	Semi-determinate plants with average plant height(48cm.), purple flower, pointed ovate leaf, light yellow seeds with brown hilum	Moderately resistant to defoliators, stemfly and pod borer. Highly resistant to rust.
34.	KS 103	**S**.O. 1379(E)/ 27.03.2018	NE Zone	91-95 days	**2537**	18.10% 45.56%	Semi-determinate plants with average plant height(65cm.), violet flower, round ovate leaf, grains yellowish white and light brown hilum	Field rust resistance and resistance to pest complex.
35.	Basara	S.O. 6318 (E) 26.12.2018	Telangana		**2663**	19.51%	semi determinate with medium growth habit & cluster bearing habit, white colour flower, Stem and pods covered with tawny pubescence, yellow seeds with Imperfect black hilum,	
36.	NRC 127	S.O. 6318 (E) 26.12.2018	Central Zone	102	**1807.29**	18.5-20% 38.0-40%	Free from Kunitz trypsin inhibitor. Semi-determinate plant with pointed ovate and medium green leaves, white flower, yellow seeds with black hilum, tawny pubescence.	Resistance/tolerance against pest complex, pod borer and lepidopteran defoliators Resistance against YMV, ALS, TLS, SCV and bacterial pastule
37.	KSD 726	S.O. 1498 (E) 01.04.2019	South Zone	96-97	**2442**	18.42% 38.14%	Semi-determinate plants with average plant height(49cm.), violet flower, rounded ovate leaf, yellow seeds with brown hilum	Resistant to rust (K. Digraj) and purple seed stain disease. Moderately resistance to Stem fly and defoliators.
38.	VL Soya 89 (VLS 89)	S.O. 1498 (E) 01.04.2019	Himachal Pradesh and Uttarakhand.					
39.	AMS 1001	S.O. 3220(E) 05.09.2019	Maharashtra	95-100 days	**2173**	18.93% 49.32%	Determinate growth, semi erect, pointed ovate dark green leaves, purple flower, pod pubescence absent, yellow spherical seeds with grey hilum, medium seed size (100 seed weight 10.48g)	Resistant to root rot, YMV, Alternaria leaf spot,

40.	Jawahar Soybean 20-116 (JS 20-116)	S.O. 3220(E) 05.09.2019	Central Zone, Eastern zone, NE Zone	100.9 days	**2122**	16.32%	Semi-determinate with medium plant height (65.81 cm), white flowers, rounded ovate green leaf, glabrous pods and stem, spherical yellow seed with black hilum	Resistant to YMV and Charcoal rot,
41.	Jawahar Soybean 20-94 (JS 20-94)	S.O. 3220(E) 05.09.2019	Central Zone	97.3 days	**2104**	20.35%	Semi-determinate with medium plant height (55.58 cm), violet flowers, rounded ovate green leaf, tawny pubescence, spherical yellow seed with black hilum	Resistant to YMV and Charcoal rot, Rhizoctonia aerial blight and alternatia leaf spot
42.	Shalimar Soybean-1 (AGR/538)	S.O. 3220(E) 05.09.2019	Jammu & Kashmir	140-145 days	**2030-2560**	13.56% 38.00%	Tall plant type (67.5 cm), light purple flower, leaf shape intermediate, leaf colour green, tawny colour dense pubescence on plants and pods,	Resistant to root rot and rust and moderately resistant to yellow mosaic virus as well as Alternaria blight
43.	NRC 128	S.O. 500(E) 29.01.2021	Eastern and Northern Plain Zone	110	**2269 (NPZ) 1871(EZ)**	18.88%	Semi-determinate with Tall plant height (62 cm), purple flowers, pointed ovate green leaf, pubescence on stem, leaves and pods, spherical yellow seed with dark brown hilum	Resistance to pod blight (ct) and moderately resistance to charcoal rot and MYMIV. Tolerance to water logging conditions. Slight antixenosis and good.
44.	NRC 130	S.O. 500(E) 29.01.2021	Central Zone	92	**1515**	17.8%	Erect and determinate with medium plant height (47 cm),, dark green leaves, purple flower, glabrous, light yellow & round and bold seeds with yellow hilum with one brown spot on micropile.	Absolute resistant to charcoal rot and AR. Moderately resistant to TLS & Pod Blight (ct) Moderate Antixenosis against Spodoptera litura under controlled condition and resistant to stem fly, girdle beetle and defoliators in field condition.
45.	NRC 132	S.O. 500(E) 29.01.2021	Southern and Eastern zone	104.6(EZ) 98.55(SZ)	**2288(SZ) 1652(EZ)**	18%&40%(SZ) 19.2&39.3%(EZ)	Semi determinate plant with pointed ovate and medium green leaves, White flower, yellow seeds with black hilum, brown pubescence. first lipoxygenase-2 free	NZ: HR reaction to Indian Bud Blight and MR reaction to pod blight (ct) SZ: highly resistant to purple seed stain (PSS) and moderately resistant to pod blight (ct); moderate antixenosis against S. litura, Girdle beetle
46.	NRC 136	S.O. 500(E) 29.01.2021	Eastern zone	107	**1700**	17.5%	Semi-determinate with Tall plant height (67 cm), White flowers, pointed ovate green leaf, tawny pubescence on pods, spherical yellow seed with dark brown hilum	Highly Resistant to Indian Bud Blight. Moderately Resistant to defoliators.

47.	NRCSL 1	S.O. 500(E) 29.01.2021	Eastern zone	107	**1706**	19.5% 38.5%	Determinate plant with medium plant height (56 cm), pointed ovate & dark green leaf, purple flower, yellow& spherical seeds with black hilum, puberulent, Sparse and small brown hair	Tolerant to YMV and MS to PB(Ct) MR to defoliators (larva/m) at Amravati and Sehore, R to insect pest complex at Sehore, Parbhani, , R to semiloopers and MR to spodoptera litura at Parbhani, MR to stem tunneling at Parbhani and Sehore, and MR to girdle beetle damage at Amravati, Parbhani, Sehore
48.	NRC 147	S.O. 500(E) 29.01.2021	Southern and Eastern zone	96	**2362**	EZ 17%, SZ 19%.	Suitable for irrigated and rainfed conditions during kharif season, The first variety with 42±5 % oleic 49.acid content; it is a germplasm collected from Bihar (IC 210)	
49.	MACS 1460	S.O. 500(E) 29.01.2021	Southern and Eastern zone	97(EZ) 89(SZ)	**2253(EZ) 2085 (SZ)**	17.6-18.9	Suitable for irrigated and rainfed conditions during kharif season, suitable for mechanical harvesting	
50.	MACS 1520	S.O. 500(E) 29.01.2021	Central Zone	98-120	**2207**	19%	Suitable for irrigated and rainfed conditions during kharif season	Resistant to charcoal rot
51.	RSC 11-07	S.O. 500(E) 29.01.2021	Southern and Eastern zone	102(EZ) 97(SZ)	**1916 2515(SZ)**	18-19%	Suitable for irrigated and rainfed conditions during kharif season	Resistant to Indian Bud Blight and Pod Blight (ct), susceptible to rust, HR to purple seed stain
52.	RSC 10-46	S.O. 500(E) 29.01.2021	Central Zone Eastern zone	102	**1947**	18.5% 40%	Medium plant height (54 cm), purple flowers, pointed ovate green leaf, elliptical yellow seed with black hilum	Resistant to stem borers and defoliators. Moderately resistant to Stem fly and girdle beetle. Resistant for biotic stresses like charcoal rot, Bud blights, bacterial pustules, Target leaf spots, stem borers. Moderately resistant to Rhizoctonia aerial blight.
53.	RVSM 2011-35		Central Zone	98	**2200**	19.1% 38.5%	100 seed weight 13.1 g; Semi-determinate; brown pubescence, white flower, black hilum, medium broad pointed leaf, Oval yellow seed	Moderately resistant to PB(ct), YMV and TLS. Susceptible to CR, RAB and MLS, multiple resistant for Stem fly, Girdle beetle and Defoliators
54.	NRC 138		Central Zone	93	**1789**	21.1% 39.4%	100 seed weight 9.9g, determinate, pointed ovate leaf, white flower, brown pod, dark brown pubescence, brown hilum	Moderately resistant to PB(ct), TLS, Resistant to YMV, susceptible to CR, RAB and MLS
55.	NRC 142		Central Zone and Southern Zone	CZ: 97 days SZ:	**CZ: 1999 SZ:**	CZ:22.0% SZ: 21.7% Protein:38.2%	100 seed weight CZ 11g, SZ: 13.7 g; Null lox 2 and Null KTi, purple flower, black hilum, determinate, dark ovate green leaf,	Resistant to YMV, MR to RAB and TLS and S to CR, Pb(ct)and MLS,

							brown pubescence, purple flower, black hilum, oval seeds,	Slight Antixenosis for defoliators and R-HY/S-HY reaction to pest complex
56.	AMS 100-39		Central Zone	97 days	**2087 Kg**	20.5	100 seed weight 11.5g, semi-determinate, rounded ovate dark green leaves, purple flower, yellow pod, spherical light yellow shiny seed, black hilum,	MR to Charcoal rot and MLS and MS to RAB and YMV, S to Pb(ct) & TLS, Antibiosis reaction for defoliators, Resistant to defoliators, stem fly and R-HY/S-HY reaction to pest complex
57.	KDS 992		Southern Zone	101	**2658**	19.3%	100 seed weight 15.8g, semi-determinate, pointed ovate medium green leaves, purple flower, glabrous pod, medium brown pods, elongated yellow seed, brown hilum	HR to PSS, MS to rust and PB, Resistant to defoliators and moderate antixenosis for defoliators
58.	MACSNRC 1667		Southern Zone	96	**2051**	19%	100 seed weight 14.8g, semi-determinate, purple flower, round seed with black hilum,	MS to PB, S to Rust, MS to PSS
59.	Karune (Vegetable soybean)		Southern Zone	Pod harvest: 68 days	**10640 Kg green pods**		Green seed weight 77.8 g, dry seed weight 30-35 g, 4.8 to 6.5 sucrose content, semi-determinate, puckering leaf surface, oval green leaves, white flowers, light green oval seed, white hilum	MR to PB, MS to Rust and MS to PSS, R-HY reaction to pest complex

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Climate Smart Agronomic Practices for Soybean Production

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Soybean is the foremost oilseed crop of the world. The seeds are rich in both oil (16-21%) and protein (36-42%). In recent years, soybean has established itself as a major rainy season crop in the rainfed agro-ecosystem of central and peninsular India. The crop is predominantly grown on Vertisols and associated soils with an average crop season rainfall of about 900 mm which varies greatly across locations and years. Introduction of soybean in these areas has led to a shift in the cropping system from rainy season fallow followed by post-rainy season wheat or chickpea (fallow-wheat/chickpea) system to soybean followed by wheat or chickpea (soybean-wheat/chickpea) system. This has resulted in an enhancement in the cropping intensity and resultant increase in the profitability per unit land area. Besides improving the socio-economic conditions of small and marginal farmers of this region, the crop helps in meeting 20% of the total edible oil requirement of the country and earns substantial foreign exchange by exporting de-oiled cake (DOC).

The mission of increasing foodgrains production and productivity stands somehow achieved, these gains were accompanied by widespread problems of natural resources degradation, which now pose a serious challenge to the continued ability to meet the demand of an increasing population. Issues of conservation have assumed importance in view of widespread resource degradation problems and the need to reduce production costs, increase productivity and profitability and make agriculture more competitive. Indian agriculture has reached a point where it must seek new directions – those by way of strategies, policies and actions which must be adopted to move forward.

The past strategies to increase foodgrains production, however, have resulted in massive exploitation of natural resources, contributing to unsustainable growth; there is need to change this in the future. Over the past three decades or so, internationally, rapid strides have been made to evolve and spread resource conservation technologies like zero and reduced tillage systems, changes in land configuration, inputs management, better management of crop residues and planting systems, which enhance conservation of water and nutrients. Conservation agriculture (CA) which has its roots in universal principles of providing permanent soil cover (through crop residues, cover crops, agro-forestry), minimum soil disturbance and crop rotations is now considered the principal road to sustainable agriculture: a way to achieve goals of higher productivity while protecting natural resources and environment. It is a major step toward transition to sustainable agriculture. Retention of crop residues on soil surface, along with fertilization with organic manure and involvement of legumes in crop rotation coupled with minimum/no-tillage practices play an important role to sustain soil fertility, improving fertilizer/water use efficiency, physical conditions of soils and enhance crop productivity. Thus it is concluded that resource conserving technologies should enhance soil health, water and nutrient use efficiency and form an important component of the regional strategy for food security, rural development, improved profitability, environmental quality and sustainability of natural resources.

Productivity Constraints

The poor performance at the productivity front is mainly attributed to soybean cultivation under rainfed condition by resource poor farmers. The probable reasons for poor yield of soybean at national levels are (i) inherent poor seed longevity, (ii) poor/excess plant population, (iii) mono-variety cultivation, (iv) delayed sowing, (v) sowing of seed without seed treatment and inoculation, (vi) poor water management practices, (vii) timely unavailability of quality inputs, (viii) imbalanced fertilizer application (ix) no/ little use of organic manures (x) inefficient control of insects and pests, (xi), disproportionate use of water in spraying of pesticides, (xii) mixed sowing of seed with fertilizer, (xiii) shattering losses due to delayed harvesting, (xiv) proneness of soybean to field weathering, (xiv) cumbersome process in availing credits.

Field selection

Although, soybean is versatile in respect of soil requirement for remunerative production, a well-drained, sandy loam soil to clay with medium available water holding capacity, reasonable depth, comparatively rich in organic carbon and leveled fields with near neutral pH is ideal for harnessing maximum soybean yield. Soil with excessive salts/ sodium and poorly drained conditions are not suitable for soybean cultivation.

Tillage

One deep ploughing once in 2-3 years otherwise one normal ploughing in summer followed by 2 cross harrowing or cultivation for breaking of soil clods will make ideal seed bed for a good crop of soybean. Now the time has come to go for conservation tillage to achieve sustainability of soybean production.

Land management for moisture conservation

The soils permit only little water to percolate down to enrich groundwater. The runoff losses are high (25%) which trigger soil loss to an extent of 6 t/ha. High intensity rains, a common phenomenon during *kharif* in Vertisols and associated soils adversely affects crop growth. A need thus arises to improve *in situ* soil and water conservation and at the same time provide proper drainage. Broad bed and furrow or ridge and furrow system have been found to satisfactorily attain these goals on deep Vertisols. A very simple technique of making conservation furrows after every 3/6 rows of soybean will facilitate for both to conserve moisture as well drain out excess water from the field.

Selection of varieties

A good soybean cultivar should be high yielding and should exhibit stable performance across a range of environments. It is advisable to grow more than one (preferably 3-4) variety (Varietal cafeteria approach) with different maturity durations particularly when the planting area is quite large in order to achieve sustainability in soybean production and to make an efficient use of harvesting equipment and laborer.

Germination Test

Checking for seed germination is an important aspect of soybean cultivation and management as the final yield depends on the total plant stand. A minimum 70% seed germination must be ensured. A counted seeds are sown in 1x1m plot and it is kept moist. From 5-8 days emergence is counted everyday till the count is stabilized or a simple germination test involving placing 100 seeds in between two newspaper sheets and rolling them with a moist cloth. It has to be seen that the cloth is kept just moist throughout the test. From 5-8 days germination count is taken every day till it is stabilized.

Time of sowing

In northern, north-east, north-west and central part of India, soybean is predominantly grown as sole crop in *kharif* (June-October). However, in peninsular as well as north-eastern region of the country, successful crop of soybean is feasible in *rabi*/spring and summer seasons (November to April) also. Owing to the recent outbreak of rust, however, the cultivation of soybean in two successive seasons is not recommended.

For *kharif* crop, pre-monsoon planting after irrigation in the second fortnight of June have been found to give good results in the terms of desired plant population and good yields. When irrigation is not available, sowing should be effected with the commencement of monsoon rains. Sowing should be completed in last week of June or latest by first week of July because late planting leads to multiple problems like poor plant stand, pod bearing, seed filling and yield. It is not advisable to plant soybean after 20th July.

Plant population

One of the reasons for poor soybean yield in India is sub-or super-optimal plant population. A plant population of about 4.5 lakhs has been found to be optimum with a range of 4 to 6 lakhs plants per hectare. In general, comparatively higher plant population is desirable for determinate varieties. Use of quality seed and good seedbed are pre-requisite to maintain the desired field emergence.

Spacing, seed rate, seed treatment, seed inoculation and depth of sowing: Seed rate is dependent on seed index and germinability.

Small seeded variety	- 60-65 Kg/ha
Medium seeded variety	- 65-70 kg/ha
Bold seeded variety	- 70-75 kg/ha

The required seed rate is generally 65 kg/ha.

A row spacing 30 and 45 cm is recommended for southern, central and northern zones, respectively. The ideal plant to plant distance is 4-5 cm. In case of delayed sowing on account of late onset of monsoon, the yield reductions due to less vegetative growth coupled with early flowering can be compensated to some extent by narrowing the row to row spacing (30 cm) and increasing the seed rate by 25%.

Nearly 20 or even more species of fungi are known to be seed borne affecting soybean plant stand, thus making it essential to resort to fungicidal treatment of seeds. Treating the seeds with Thiram + Carbendazim fungicide (2:1) at the rate of 3 g/kg seed or *Trichoderma viridi* @ 5 g/kg seed has been found to prevent collar rot and ensure good plant establishment. Seed treatment improves the germination of infected seeds, reduces the amount of seed borne inoculum and protects seed and seedling from soil borne pathogens.

In order to save the crop from possible infestation of Yellow Mosaic Virus (YMV), the seed treatment should be carried out using Thiamethoxam 30 FS @ 10 ml/kg seed or Imidacloprid 48 FS @ 1.25 ml/kg seed immediately after the treatment with recommended fungicides.

Seed Inoculation

To facilitate the effective nodulation and fixation of atmospheric nitrogen in root nodules of soybean plants, it is imperative that seed is inoculated with *Bradyrhizobium japonicum* culture @ 500 g/65 kg seed. In recent years, application of phosphate solubilizing bacteria @ 500 g/65 kg seed which is complementary to rhizobia is also recommended for improving phosphorus use efficiency for better yields. In the areas where soybean has not been previously grown an enhanced level (2 to 5 times) of *Rhizobium* is advisable during the initial years of soybean cultivation. Just after seed treatment, seeds should be inoculated with *Rhizobium japonicum* + phosphate solubilizing microorganisms (PSM) each @ 5 g/kg seed. The seed should be placed at the depth of 3-5 cm to ensure good germination and subsequent plant stand.

Nutrition management

In general, energy rich crop are grown in energy starvation conditions. Soybean is considered to be moderately exhaustive crop. Balanced nutrients application ensures better yield performance of soybean. The integration of 5-10 t Farm Yard Manure or 2.5 t poultry manure/ha with the basal application of 25:60-80:40-50:20 N: P_2O_5: K_2O: S kg/ha generally provides balanced nutrition for harnessing the yield potential of soybean.

Weeding and intercultural operations

Although two hand weddings, first at 20 days and second at 40 days after sowing are recommended. It shall be advisable to go for chemical weed control to ensure effective control even during incessant rains. Application of pre-plant incorporation (PPI) or pre-emergence (PE) or post emergence (PoE) herbicides and two hand weeding were found equally effective to reduce the weed load in soybean.

Water management

The critical period for water requirement in soybean is planting to emergence, flowering and pod filling stage. A proper water management at these three stages is essential to optimize yield. Stress on account of excess or deficit soil moisture would be detrimental to yield. Soil moisture of 75 % available soil moisture (ASM) should be preferably maintained during the crop growth period. Only 25 to 30 % of the total water consumed by soybean crop is used before flowering while reproductive stages account for 70 to 75 % of water usage. Considering that the water requirement of soybean for planting and germination is approximately 100 mm, the total water requirement of soybean work out to be around 500 mm.

Drought Management

Drought stress is a complex syndrome, involving several climatic, edaphic and agronomic factors, and is characterized by three major varying parameters, i.e. timing of occurrence, duration and intensity. Drought induces a restriction of water supply which results in a reduction of tissue water content, stomatal conductance, metabolic processes and growth. In response to drought stress, plants develop various adaptive mechanisms including drought tolerance and avoidance strategies. Plants may avoid drought stress by maintaining favorable water status under drought either by increasing the capacity for water uptake of roots or reducing water loss from leaves.

Mitigation of drought stress strategies in soybean are: (i) Plant more than 3 varieties (ii) Plant early maturing varieties if occurance of drought is more frequently experienced (iii) Application of crop straw @ 5 t/ha after field emergence (iv) Application of one anti-tanspirants like KNO3 @ 1% or MgCO3 @ 5% or Glycerol @ 5% in case of drought and (v) In-situ mulching with weeds at 30 days after sowing.

Table 1: Zone wise recommended soybean production technologies

Input/practices	**North Hill Zone** (Himachal Pradesh, North hills of Uttarkhand)	**North Plain Zone** (Punjab, Haryana, Delhi, North-Eastern plains of U.P., Plains of Uttarkhand, Western Bihar)	**Central Zone** (M.P., Bundelkhand region of U.P., Rajasthan, Gujrat, Northern and western parts of Maharashtra and Orissa)	**Southern Zone** (Karnataka, Tamil Nadu, Andhra Pradesh, Kerala, Southern parts of Maharashtra)	**N-Eastern Zone** (Chhattisgarh, Assam, West Bengal, Bihar, Meghalaya)
Varieties	VLS 65, VLS 59, VLS 63, VLS 49, Palam Soya, Hara Soy	PS 1347, PS 1368, PS 1092, PS 1042, PS 1225, SL 744, SL 688, Pusa 97-12, Pusa 12, Pusa 98-14	JS 93-05, JS 95-60, JS 20-34, JS 20-29, JS 20-69, JS 97-52, NRC 7, NRC 37, NRC 86, MAUS 71, MAUS 158, RVS 2001-4, RKS 24, Pratap Soya 45, JS 335	Phule Agrani, DSb 21, DSb 1, MAUS 162, Phule Kalyani, MACS 1188, MACS 1281, RKS 18, KDS 344, DS 228, MAUS 2, MAUS 61, NRC 77	DSb 19, RKS 18, Pratap Soya 1, Pratap Soya 2, JS 97-52, MAUS 71, Indira Soya 9, JS 80-21
Seed rate	55 kg/ha	65 kg/ha	65 kg/ha	65 kg/ha	65 kg/ha
Sowing time		20th June - 5th July	20th June-5th July	15th June-30th June	15th June - 30th June
Seed treatment	Fungicide: Thiophanate methyl (45 %) + Pyraclostrobin (5 % FS) @ 3 ml/kg seed, Insecticide: Thiamethoxam (70 WS) @ 3 g/kg seed, Culture: Bradyrhizobium culture/PSB @ 5 g/kg seed				
Spacing	45 × 5 cm	45-60 × 5 cm	30-45 × 5-8 cm	30-45 × 5 cm	30-45 × 5 cm
Fertilizers (NPKS kg/ha)		25:75:25:37.5	25:60:40:20	25:80:20:30	25:100:50:50
Plant population	4 lakhs /ha	4 lakhs /ha	4-6 lakhs /ha	4-6 lakhs /ha	4-6 lakhs /ha
Depth of sowing	3 to 5 cm	3 to 5 cm	3 to 5 cm	3 to 5 cm	3 to 5 cm

Weed management	Two hand weeding at 20 and 40 days after sowing (DAS) or Pendimethalin (30 EC) + Imazethapyr (2 EC) @ 750 + 50 to 900 + 60 g a.i./ha as pre-plant incorporation or Diclosulam (84 WDG) @ 22 g a.i./ha or Sulfentrazone (39.6 SC) @ 360 g a.i./ha or Pendimethalin (30 EC) @ 1 kg a.i./ha or Metolachlor (50 EC) @ 1 kg a.i./ha or Clomazone (50 EC) @ 1 kg a.i./ha as pre-emergence or Imazethapyr (10 SL) @ 100 g a.i./ha or Propaquizafop (10 EC) @ 50-75 g a.i./ha or Fenaxyprop-p-ethyl (9.3 EC) @ 100 g a.i./ha or Imazethapyr (70 % WG + Surfactant) @ 70 g a.i./ha or Propaquizafop (2.5 %) + Imazethapyr (3.75 % ME) @ 50 + 75 g a.i./ha as post-emergence (15 –20 DAS) in 750 to 800 liters water/ha.
Irrigation	At flowering and pod filling stage, in case of drought
Harvesting	When pods turn black, brown or golden, seed has 15-17 % moisture
Threshing	Operate thresher at low cylinder speed of 400 to 500 rpm at 12-14 % seed moisture
Seed storage	At seed moisture of about 9-10 %, store in moisture proof bags

Harvesting, Threshing and Seed storage

Timely harvesting and proper handling are important for enhancing quality and quantity of soybean production. Delayed harvesting leading to pod shattering is one of the major causes of reduced yields in soybean. Moisture content of the seed is the criterion for seed harvest. Generally the seed moisture at harvest should be 14 to 16 %. In most of the varieties change of pod colour to golden yellow indicates the stage of harvest. Harvesting can be done by cutting the stalks to the ground level by sickles or by tractor driven reapers or combines. The harvested plants should be left on the threshing floor for 2-3 days for drying. The dried produce can be threshed by operating mechanical threshers at a low cylinder speed of 400-500 rpm at seed moisture levels of 14% and at a speed of 300-400 rpm at seed moisture of about 13%. Seed cracking and seed splitting are seen if the seed moisture is below 13% while seed bruising is seen if the seed moisture is above 15%.

If the seed moisture has been brought down to 9 % or less, waterproof bags should be used otherwise jute bags are recommended. Soybean seed being hygroscopic in nature absorbs moisture from atmosphere or loses moisture till the equilibrium is reached. Hence precaution should be taken to see that relative humidity is kept as low as possible and any chance of absorbing moisture is avoided.

Aeration during storage is important, particularly when the moisture content is not low to the desired extent. Proper aeration helps in conditioning the seed, equalizing the temperature within the desired mass, cools the seed to ambient temperature. Generally a relative humidity of 65% or less is preferable. For longer storability of the seed, the relative humidity should be less than 50 %. Temperature in the storeroom has profound effect on seed viability, seed germination and vigour of seedlings. Ideal temperature for maintaining the quality of the seeds for 8-9 months is recommended to be 20^{o} C at a relative humidity of 50 %.

Soybean in cropping systems

The remunerative cropping systems for different zones are shown in Table 1. In addition to sole crop, relay, mixed, companion or intercropping of soybean with other crop(s) appropriate to location and season like pigeon pea, sorghum, maize, sugarcane, cotton, finger millet and plantation crops have been found to be highly remunerative and biologically efficient (LER 1.25 to 1.70).

In Madhya Pradesh, soybean + pigeon pea (4:2 row ratio) intercropping is highly remunerative and is recommended especially for rainfed cultivation. Early maturing pigeon pea varieties are more suitable in the system. Intercropping of soybean with sorghum or cotton is also recommended and practiced in and around Madhya Pradesh. For northern hill and northern-plain zones, soybean-maize and soybean-sorghum is recommended. For southern zone, particularly Tamil Nadu and Karnataka, intercropping with finger millet, maize, pigeon pea and sugarcane is recommended. The other remunerative intercropping combinations viz. soybean + corn (alternate paired rows at 90/30 cm or 45 cm), soybean + sorghum, soybean + sugarcane (1:2 row ratio at 90/45 cm), soybean + pigeon pea (4:2 row ratio at 30 cm) and soybean + finger millet (1:2 row ratio at 45 cm) were also identified in their respective areas of adaptability. In Karnataka, soybean is recommended to be intercropped with finger millet, maize, pigeon pea and sugarcane. The soybean based cropping systems are not only productive but they have been profitable as well energy efficient under various agro-climatic conditions. It is also advisable to farmers that continuous growing of soybean on same piece of land should be avoided. Crop rotation tactics should be followed for sustainable soybean production.

It may be conclude that with the use of appropriate improved production technology, there is great scope to achieve average productivity of 2.0 t/ha. The adoption of the practices outlined above are able to mitigate the biotic as well as abiotic stresses in soybean in order to achieve sustainable and remunerative yield levels.

Conservation Agriculture (CA)/Resource Conserving Techniques (RCTs)

Conservation agriculture has emerged as a new paradigm to achieve goals of sustainable agricultural production. It is a major step towards transition to sustainable agriculture. The term CA refers to the system of raising crops without tilling the soil while retaining crop residues on the soil surface.

Conservation agriculture:

Conservation agriculture is a broad term and it encompasses all conserving techniques that conserve resources any way. It also involves following RCTs: (1) Soil cover, particularly through retention of crop residues on the soil surface; (2) Sensible, profitable rotation; and (3) A minimum level of soil movement, e.g., reduced or zero tillage.

Resource Conserving Technologies:

Resource conserving techniques (RCTs) refer to those practices that conserve resources and ensure their optimal utilization and enhance resource or input use efficiency. These techniques include: (A) Tillage and crop establishment such as Laser land leveling, conservation tillage (zero/minimal tillage), bed planting/(FIRBS), ridge and furrow, rotary tillage, stale seed bed, precision farming, use of leaf color chart (LCC), SPAD meter, green seeker. (B) Crop management such as clean crop seed, sowing (date, method & rate), crop/variety, fertilization (N), water management, crop diversification and crop rotation, integrated crop management (ICM). (C) Mulching and crop residue management; and (D) GMCs/HTCs, deleterious rhizobacteria (DRB), Microbial consortia and allelopathy. Some important RCTs have been discussed here.

Table 2: Remunerative cropping systems for different zones

Zone	Cropping system	Intercropping system
Central (Madhya Pradesh, Bundelkhand region of U.P., Rajasthan, Gujarat, Northern and western parts of Maharashtra)	Soybean-wheat or chickpea soybean-wheat-corn fodder, soybean- potato, soybean- garlic/potato-wheat, soybean- rapeseed or mustard, soybean-pigeon pea or safflower or sorghum	Soybean + pigeon pea, Soybean + corn, Soybean + sorghum, Soybean + sugarcane, Soybean in mango/ guava orchards, Soybean in agro-forestry
Southern (Karnataka, Tamil Nadu, Andhra Pradesh, Kerala, Southern parts of Maharashtra)	Wheat-soybean-finger millet-peas, oat-cowpea-barley-soybean, soybean-finger millet-beans, soybean-wheat-groundnut	Soybean + pigeon pea, Soybean + finger millet, Soybean + sugarcane, Soybean + sorghum, Soybean + groundnut, Soybean in coconut/ mango/ guava orchard and soybean in agro-forestry.
Northern Plain (Punjab, Haryana, Delhi, North-Eastern plains of U.P., Western Bihar)	Soybean-wheat, soybean-potato, soybean-chickpea	Soybean +pigeon pea, Soybean + corn, Soybean + sorghum, Soybean in mango/ guava orchards, Soybean in agro-forestry
Northern hill (Himachal Pradesh, North hills of U.P.)	Soybean-wheat, Soybean-pea, Soybean-lentil, Soybean-toria	Soybean + corn, Soybean + pigeon pea,
North eastern (Assam, Meghalaya, West Bengal, Bihar, Orissa)	Soybean-paddy, paddy-soybean	Soybean + finger millet, Soybean + paddy, Soybean + pigeon pea

Combining the above elements with improved land-shaping (e.g. through laser aided leveling, planting crops on beds, etc.) further enhances the opportunities for improved resource management. In conventional systems, while soil tillage is a necessary requirement to produce a crop, tillage does not form a part of this strategy in CA. Benefits of CA are several folds. Direct benefits to farmers include reduced cost of cultivation through savings in labour, time and farm power, and improved use efficiency resulting in reduced use of inputs. More importantly, CA practices reduce resource degradation. Gradual decomposition of surface residues improves soil organic matter status, biological activity and diversity and contributes to overall improvement in soil quality. CA is a way to reverse the processes of degradation inherent in conventional agricultural practices involving intensive cultivation, burning and/or removal of crop residues, etc. CA leads to sustainable improvements in efficient use of water and nutrients by improving nutrient balance and availability, infiltration and retention by the soil, reducing water loss due to evaporation and improving the quality and availability of ground and surface water.

Laser land levelling

It is a precursor of resource conserving technique and a process of smothering land surface (± 2 cm) from its average elevation using laser equipped dragged buckets. It leveled the surface having 0 to 0.2 % slope so that there is uniform distribution of water may takes place and thus enhance resource use efficiency. Advantages of laser land leveling are as follows: About 4% rise in area under cultivation due to removal of bunds and channels; Saves 10-15% water due to uniform distribution; Increases resource (Nutrient and water) use efficiency; Reduces cost of production and; Enhances productivity.

Minimum/zero Tillage

It involves considerable soil disturbance, though to a much lesser extent than that associated with conventional tillage. Minimum tillage is aimed at reducing tillage to the minimum necessary for ensuring a good seedbed, rapid germination, a satisfactory stand and favorable growing conditions. Advantages of minimum tillage:- Improved soil conditions due to decomposition of plant residues in situ; Higher infiltration caused by the vegetation present on the soil and channels formed by the decomposition of dead roots; Less resistance to root growth due to improved structure; Less soil compaction by the reduced movement of heavy tillage vehicles and less soil erosion compared to conventional tillage. In contrary, disadvantages of minimum tillage are as follows:- Seed germination is lower with minimum tillage; In minimum tillage, more nitrogen has to be added as rate of decomposition of organic matter is slow; Nodulation is affected in some leguminous crops like peas and broad beans; Sowing operations are difficult with ordinary equipment; Continuous use of herbicides causes pollution problems and dominance of perennial problematic weeds.

Zero tillage is an extreme form of conservation tillage (CT) in which mechanical soil manipulation is reduced to traffic and sowing only. It helps in paradigm shift in crop production. The current and potential area is 2.0 m ha and 10 m ha under zero tillage in India, respectively. It is very helpful in the area of intensive cultivation where a turnaround period between two crops is really very less and thus it can facilitate timely sowing. Advantages of the zero tillage are as follows: Saving of fuel and labour cost, reduced cost of cultivation, timely planting gave yield advantage and reduces soil erosion and improves soil health.

Broad-Bed and furrow system

Broad -bed and Furrow method consisted of creation of broad-beds of 135 cm wide and 20 cm high raised beds and separated by 50 cm wide furrows, which are to a depth of 20 cm and graded across the contour to a 0.6 per cent slope. The main purpose of this system is to provide adequate drainage during heavy rainfall and draining excess water into grassland waterways or farm ponds and to provide supplemental irrigation to rainy and post rainy crops, reduces runoff and soil loss, and for conserving moisture in-situ in the furrows. These are semi-permanent structures and are stable for 2 to 4 years and are suitable for planting many upland crops like wheat, chickpea. In NICRA villages in Madhya Pradesh, farmers who adopted broad bed furrow planting method in soybean with BBF planter avoided damage to the crop due to excess rainfall in kharif, 2013 season and realized about 40 % yield advantage compared to flatbed sowing. Broad bed furrow technology for wheat, soybean, and maize saved crop damage due to excess soil moisture by aiding quick drainage and avoiding water stagnation.

Furrow Irrigated Raised Bed (FIRB)/Ridge and furrow systems

The system consists of array of alternating ridges and furrows. The ridges are normally made of 15-20 cm high and 75 cm wide with tractor drawn ridger on less than 1.2 per cent slope. Upland rainy season crops like soybean, maize sorghum and pigeon pea can normally be planted on the ridges. Generally, three rows of soybean, two rows of sorghum, maize, sorghum and pigeon pea can be planted on the crest of the ridges to maintain uniform plant population as recommended for flatbed method of planting. The lower catchments in a field can be used for storage of some of the runoff water from the upper catchments thereby supplementing the storage capacity of the farm pond during the period of continuous rains. Ridge planting facilitates root zone aeration besides favorably influencing the soil moisture relations rendering the ridges better drainable and runoff. The grain yield of all the crops increased between 21 to 106 % depending on the amount and distribution of rainfall. The advantages of FIRB systems are as follows:- It promotes crop diversification, saves irrigation water by 25-35 %, saves fertilizer and seed rate up to 25 %, it helps in decreasing weed infestation as well as easy weeding, it provide easy passage for drainage of excess water and it facilitates easy rouging in the field crops.

Crop residue management: About 400 million tons of crop residues are produced in India alone. In areas, where mechanical harvesting is practiced, a large quantity of crop residues are left in the field, which can be recycled for nutrient supply. About 25% of nitrogen (N) and phosphorus (P), 50% of sulfur (S), and 75% of potassium (K) uptake by cereal crops are retained in crop residues, making them valuable nutrient sources. Mulching with crop residues contribute to the conservation of soil and rainwater.

This method reduces evaporative losses, runoff total and available P and K contents of the soil organic matter, soil N. Unlike removal or burning, incorporation of straw builds up soil from cropped fields. Crop residues modify soil biological activity resulting in improved soil fertility and better soil physical conditions.

Varietal cafeteria approach (Avoid mono-varietal culture)

Due to uncertainty of weather conditions, the planting of 3 to 4 soybean varieties is a viable option to cope up with biotic as well as abiotic stresses. Therefore, to maintain stability in productivity, farmers are advised to grow 3-4 soybean varieties with varying maturity durations. Different varieties possess resistance/tolerance to biotic as well as abiotic stresses. As they mature at different time, it also gives convenience for the farmers during harvesting and threshing too. Genetically, the yield of soybean varieties is inversely proportionate with maturity period. Long duration varieties are able to produce more yields and subject to application of irrigation in the condition of early cessation of monsoon.

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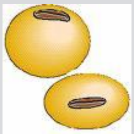

Weed Management in Soybean under Changing Climate Scenario

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Weeds have always been a serious problem on agriculture lands. Man has allowed them to create havoc by growing, spreading and disseminating their seeds at will and thus the weeds are resultant of the fittest in the struggle for existence. Weeds are unwanted and undesirable plants that interfere with the utilization of land and water resources and thus adversely affect human welfare.

Among the causes of low productivity of soybean, weeds are the major factor. It offers severe infestation of a large number of weeds which reduce the yield. This crop is susceptible to weed crop competition during the early growth stage (4-7) weeks. Depending upon the intensity and type of weed flora, the reduction in crop yield may occur to the extent of 25 to 70%. Therefore, it is important to keep the crop weed free as far as possible so as to get higher yields from soybean. Weed control is indispensable in modern crop management because weed cause stresses for light, moisture, space, nutrients and may have some allelopathic effects as well resulting in poor crop growth especially during 40 days after sowing and thereby yields are reduced remarkably.

Soybean is a most dominant raifed crop of India as well as world and has ability to mitigate the protein malnutrition and fulfill the edible needs of country. Soybean being a rainy season crop, the substantial yield erosion may occur due to biotic and abiotic stresses. Among the biotic stresses, a weed causes a serious threat to soybean crop. The soybean yield losses may very between 35 to 80% depending on the kinds of weed, time of infestation and duration of weed persistence in field. Soybean crop normally infested with grasses, broad leaf weeds and sedges. The initial period up to 45-60 days after sowing is considered the most critical period for soybean-weed competition. The presence of mix population of weeds is very difficult to manage it properly and further management problems will appear in climate change scenario.

Impact of climate on weeds

Weeds have a greater genetic diversity than crops. Consequently, if a resource (light, water, nutrients or carbon dioxide) changes within the environment, it is more likely that weeds will show a greater growth and reproductive response.

Weeds are one of the main threats to agriculture and the environment. Their management remains a significant financial, logistical and research challenge. Climate change will require revisiting what we deem appropriate for weed control to keep current and future management strategies efficient and effective. Global warming and other climatic changes will affect the growth, phenology, and geographical distribution of weeds.

The main drivers for climate change impacts on plants, including weeds, will be changed temperatures and rainfall, altered frequency and intensity of extreme weather events and increasing concentrations of carbon dioxide (CO_2) in the atmosphere.

The risk of negative impacts from weeds due to extreme weather events, such as prolonged drought, heat waves, floods and cyclones that occur under today's climate, are similar to the risks associated with average climate change conditions. Thus future climates may further favour weed invasions, which could increase the risk of negative impacts from these species. However, it also means that adaptation responses to reduce the potential impact of weeds may also be just as appropriate to implement today.

Climate change will exacerbate both the threat to biodiversity and the cost to agriculture of weeds. This is because new and changed levels of weed impacts on the environment will arise, requiring new or significantly altered adaptation responses to reduce negative impacts.

General principles of the weeds' reactions: The effects of changing climatic conditions impact arable weeds in various ways. In order to persist in a local habitat, species have to respond to the changes of the environment. . Generally, plant species have three options to avoid extinction. **(1). Migration** with a favorable climate, which leads to alterations of the distribution of weeds—a process called **range shift.** (**2). Acclimation** to changes in climate conditions basically refers to the response of species within their phenotypic plasticity without evolutionary adjustments. These responses can be divided into tolerance and avoidance of climatic changes that lead to performance beyond the species' ecological optimum. This process called **niche shift. (3.) Adaptation** to changes in climate conditions, which is often associated with the evolution of new properties or with the optimization of existing ones. These individual biological adaptations of weeds, which are driven by natural selection, result in **trait shifts**.

Increased temperature: Each plant species has a temperature range that is suitable for survival and growth. Some weeds will also be able to tolerate the projected increase in temperature. C4 weeds that is more efficient than C3 weeds in warmer or drier climates, or at lower levels of atmospheric CO_2.Allow sleeper weeds to become invasive.Increased temperature expandof weeds into higher latitudes or higher altitudes.

Changing rainfall: Like temperature, plant species have a range of soil moistures that are suitable for survival and growth. Most parts of India are characterized by climate that is exceptionally variable in rainfall between years as well as being variable between decades. This variation can affect the recruitment and survival of weeds.

Increasing CO_2: Elevated atmospheric CO_2 is known to improve the growth of plants due to increased efficiency. The interaction between CO_2 and growth is strongly influenced by the mode of energy capture (photosynthesis), with some plants (C4 and CAM), including many grasses and succulents, being more efficient than others (C3 plants).Higher CO_2 will stimulate photosynthesis and growth in C3 weeds and reduce stomatal aperture and increase water use efficiency in both C3 and C4 weeds. Respiration, and photosynthate composition, concentration, and translocation may be affected. Perennial weeds may become more difficult to control, if increased photosynthesis stimulates greater production of rhizomes and other storage organs. Changes in leaf surface characteristics and excess starch accumulation in the leaves of C3 weeds may interfere with herbicidal control. Any direct or indirect consequences of the CO_2 increase that differentially affect the growth or fitness of weeds and crops will alter weed-crop competitive interactions, sometimes to the detriment of the crop and sometimes to its benefit.

Increase in extreme weather events: Extreme weather events include cyclones, droughts and floods, heat waves and frosts. All of these factors can cause great changes in plant abundance, competition between weeds and other plants, and weed distributions at a local scale.

Phenology: The timing of plant growth and reproduction (phenology) will be influenced by changes in seasonal cues, such as temperature and rainfall.

Land Use Change: Human responses to climate change, including deliberate adaptation choices, will be a major contributor to weed problems with climate change. Potential responses include: (i) Changed farming practices as farmers implement climate change adaptation measures (ii) Shifting the distribution of crop species will likely shift the distribution of their associated weeds (iii) Opportunistic cropping to take advantage of years with good rain (iv) The introduction of new crop species better able to tolerate extreme conditions (v) Changes in choice of sown crops (vi) Development of new cropping regions.

Weeds are likely to show greater resilience and better adaptation to changes in CO_2concentrations and rising temperature in competition with crops due to their diverse gene pool and greater physiological plasticity. Weeds with C3 and C4photosynthetic pathways may exhibit differential responses to higher CO_2levels and temperatures, which can affect the dynamics of crop–weed competition. In addition to its positive impact on weed growth, climate change factors could influence the efficacy of many herbicides, making weed management a major challenge for sustainable crop production. Environmental factors such as CO_2, light, temperature, relative humidity, and soil moisture differentially affect the uptake, translocation, and activity of different herbicide chemistries. These changes will likely see a new set of weeds that require ongoing management and investment of resources.

Management of weeds:

Complete mechanical and/or manual weeding may not be possible and cost effective during the critical period of crop weed competition for obvious reasons.

Herbicide considered almost synonymous with modern weed science technology, as they gave a new direction to the farmers to realize the maximum yield potential of at lower production. It is also to be noted that no herbicide is implicated as yet in permanently damaging any useful soil microbial system including Rhizobium microbes. Further, herbicides have found harmless to earthworms, other beneficial bacteria if applied properly. These can however, be temporary fluctuation in microbial populations, but in no way the application of these herbicides are found detrimental to soil health and environment for plant growth, unlike several insecticides. Pre-plant incorporation and pre-emergence herbicide may have a very short persistence in the soil and weed flora may appear again after time span and complete with the crops at later stages. Whereas, post-emergence herbicides kill weeds and keep the hardy uncontrolled weeds under control by arresting there growth through various kinds of deformities in foliage and growing points.

Mechanical control: As mentioned earlier the critical period of weed crop competition in soybean is 30-45 days after sowing (DAS). Therefore, the weeds should be managed during this period. Two hand weeding at 20 and 40 DAS or intercultural operation (hoeing) by hand hoe or bullock drawn implements or tractor drawn implements during critical period is found beneficial.

Agronomical control: In situ mulching of weeds at 30 DAS is also beneficial for controlling weeds as well as to conserve soil moisture and add the organic matter in the soil.

Chemical control: The pre plant incorporation (PPI), pre emergence (PE) and post emergence (PoE) herbicides have been recommended in soybean to manage the weeds. Though the PPI herbicides are not very much popular among the farmers and very limited molecules are available in the market. The details of herbicides are given in Table 1.In view of climate change, any one method of weed control not works effectively and efficiently. Therefore, the integrated weed management is the only option to combat with weeds. Looking to the impact of climate change on weeds, the following are be kept in mind while managing the weeds:

1. Follow integrated weed management strategies (cultural, mechanical and chemical)
2. Follow herbicide rotation
3. Use proper crop rotation
4. Use of only recommended herbicides
5. Do not mix herbicides farmers their own
6. Make solution in 500 l of water for Spray
7. For herbicide spray-use flat fan or flood jet nozzle
8. Use appropriate dose of herbicide and at right time for achieving maximum herbicide efficacy.

Table1: Details of herbicides recommended in soybean

Technical name	**Formu-lation**	**ai/ha**	**Dose/ ha**	**Weed species**
Pre plant incorporation				
Pendimethalin + Imazethapyr	30+2 EC	750+50-900+60 g	2.5-3.0 l	*Echinocloa crusgalli*, *Digera arvensis*,*Commelina benghalensis*, *Amaranthus viridis*, *Portula caoleracea*
Pre-emergence herbicides*				
Diclosulam	84WDG	22 g	26 g	*Cyperus sp.*, *Commilena benghalensis*, *Euphorbia geniculata*, *Digera arvensis*, *Acylipha* sp., *Echinochloa colona*
Sulfentrazone	39.6 SC	360 g	750 ml	*Acalypha* sp., *Commelina* sp., *Digera sp.*, *Cyprus* sp., *Echinochloa* sp., *Brachiaria* sp., *Dinebra* sp.
Clomazone	50 EC	1.0 kg	2.0 l	*Digiteria* sp., *Echinochloa* sp., *Parthenium hysterophorus*, *Commelina* sp.
Pendimethalin	30 EC	1.0 kg	3.30 l	*Echinochloa* sp., *Euphorbia spp.*, *Amarnanthus viridis*, *Portulaca oleracea*, *Trianthema* sp., *Eleusine indica*
Pendimethalin	38.7 CS	580-677 g	1.5 – 1.75kg	*Echinochloa colonum*, *Dinebra arabuica*, *Digitaria sanguinalis*,*Bracharia mutica*, *Dactyloctinum aegyptium*, *Portula caoleracea*,*Amaranthus viridis*, *Euphorbia geniculate*, *Cleome viscose*

Flumioxazin	50 SC	125 g	250 ml	*Commelina benghalensis, Digera arvensis, Euphorbia* sp., *Phyllannthus niruri, Echinochloa crusgalli*
Metolachlor	50 EC	1.0 kg	2 kg	*Echinochloa colonum, Eleusine indica, Digitaria* sp., *Dactyloctonium aegyptium, Panicum* sp., *Cyperus sp., Amaranthus viridis*
Metribuzin	70WP	0.5 -0.5 kg	0.75-1 kg	*Digitaria* sp., *Cyperus esculentus, Cyperus campestiris, Borreria* sp.,*Eragrostis sp.*
Early Post emergence**				
Chlorimuron ethyl	25 WP	9 g	36 g	*Cyperus rotundus, Commelina, benghalensis, Celosia argentea, Digera arvensis,Cucum istrigonus, Cyprus iria, Parthenium hysterophorus, Acalypha indica, Phyllanthus niruri, Trianthema-portula cashurm, Caesulia auxillaris*
Bentazone	480 g/l SL	900 g	2.0 l	*Cyperus rotundus, Achalipha indica,Commelina bengalansis, Echinocloa colanum, Echinocloa crusgalli*
Post emergence***				
Imazethapyr	10 SL	100 g	1.0 l	*Cyperus difformis, Echinochloa colonum, E. crusgalli, Euphorbia hirta, Croton sperrsifeorus, Digera arvensis, Commelina Benghalensis*
Quizalodfop ethyl	5 EC		1.0 l	*Echinochloa crusgalli, E. colomum, Eragrostis sp.*
Quizalofop-ethyl	10 EC	37.5-45 g	375-450 g	*Eragrostsi pilosa,Digitarias anguinalis, Eleusine indica, Dinebra retroflexa, Echinochloa crus-galli, Brachiaria aramosa*
Fenaxyprop-p-ethyl	9.3 EC	100 g	1.0 l	*Echinochloa colonum, Echinochloa crusgalli,Digitaria* sp., *Eleusine indica, Setaria sp,Brachiaria sp.*
Quizalofop-p-tefuril	4.41 EC		1.0 l	*Echinochloa* sp., *Dinebra Arabica,Digitaria sanguinalis, Cynodon dactylon, Hemarthria compressa,Eleusine indica*
Fluazifop-p-butyl	13.4% EC	125-250 g	1 -2 kg	*Echinochloa colonum, Echinolchloa crusgalli, Eleusine indica, Cyanodon dactylon, Dactyloctenium aegyptium, Digitaria* sp., *Setaria* sp.

Haloxyfop R Methyl	10.5 EC	108-135 g	1-1.25 kg	*Brachiaria* sp., *Digitaria sanguinalis. Dinebra arabica*, *Echinochloa* sp., *Eleusine indica, Eragrostis sp., Pnicumi sochmi*
Imazethapyr	70% WG + Surfactant	70 g	100 g	*Cyperus routandus, Echinochloa spp., Dinebra Arabica, Digera spp., Brachiariamutica, Commelina benghalensis, Commelina communis, Euphorbia geneculata, Cyanotis axiallaris*
Propaquizafop	10 EC	50-75 g	0.5-0.75 kg	*Echinochloa colonum, Echinochola crusgalli, Digiteria sanguinalis, Dactyloctenium eigyptium, Eleucine indica*
Combination of herbicides				
Fluazifop-p-butyl + Fomesafen	11.1 +11.1 SL	250 g	1 kg	*Echinochloacolona, Digitaria* sp,*Eleusine indica, Dactyloctenium aegyptium, Brachiaria reptans, Commelina benghalensis, Digera arvensis, Trianthema* sp., *Phyllanthus niruri, Aclypha indica, Dinebra arbica,*
Imazethapyr + Imazamox	35% +35% WG	70 g	100 g	*Echinochloa colonum, Dinebra arabica, Digitaria sanguinalis, Brachiaria mutica, Commelina benghalensis, Euphorbia hirta*
Propaquizafop + Imazethapyer	2.5%+3.75% ME	50+75 g	2.0 l	*Dactyloctnium aegyptium, Echinocloa colonum, Eleusine indica, Digitaria sanguinalis, Commelina benghalensis, Euphorbia hirta, Digera arvensis, Amaranthus viridis*
Sodium Aceflourofen + ClodinafopPropargyl	16.5% + 8% EC	80-165 g	1.0 kg	*Acalypha indica, aegyptium, Alternanthera philoxeroides, Amaranthus* sp., *Celosia argentea, Cleome viscose, Commelina benghalinsis, Dactyloctanium, Digera arvensis, Digitaria sanguinalis, Echinochloa* sp., *Eleusine indica,Euphorbia* sp.,*Parthenium spp.,Phyllanthus niruri, Physalis minima, Stellaria media, Trianthem amonogyna*

* Make solution in 500 litre water and sprayed in between after sowing and before germination of soybean
** Make solution in 500 litre water and sprayed in between 10 to 15 days after sowing
*** Make solution in 500 litre water and sprayed in between 15 to 20 days after sowing

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Climate Smart Nutrition Mnagemetnt Practices for Soybean Production

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The continual use of high input of fertilizers has adversely affected the sustainability of agricultural production and environment. In the year to come, for a system to be sustainable, it becomes imperative for the management of organic matter and the rational use of organic inputs. However, organic manures can not meet the total nutrient needs in intensive cropping systems, an integrated supply of nutrients from fertilizers and organic manures seems to be a need of the time. Even if we utilize the whole of our organic resources presently available for agricultural use, it would be able to meet only one third of the nutrient required for the present level of food grain production.

For harnessing the yield potential of soybean, the sub-optimal and unbalanced nutritional management has been the major impediment. It is estimated that at least 20% yield enhancement for component/sequential crop is likely through balanced plant nutrition. This calls for integrated plant nutrient supply system (IPNS) not only to optimize productivity but also to sustain the farming systems. The basic functions of IPNS are as given below.

- To take care of nutritional needs of the plant for optimum biological productivity and economic gains to the farmer,
- To ensure that the soil is not impoverished and/or degraded, and
- To see that the system is relevant to diversity of environment, soil, cropping systems, local situations, social, geographical, economic situations and farm/farmer specific.

In this context, IPNS should also take following into account:

- Physical, chemical and other constraints in the soil,
- Availability and supply of plant nutrient sources in terms of quantity cost and time,
- Nutrient needs of crops/cropping system.,
- Climate, and
- Farmers' own resources and management capability.

The present day management practices particularly for IPNS are based on the understanding like:

- Organic or biological sources of plant nutrients complement mineral fertilizers in fulfilling the nutrient requirement of crops. This, however, vary between sources, combination of sources and agro-ecological conditions.
- In general, combined application of mineral and organic sources resulted in synergistic effects by increasing significantly the fertilizer use efficiency.
- Application of organic resources should trigger the microbial population dynamics, which directly reflects the transformation of nutrients, improvement in soil physical condition, reduction in soil borne phyto pathogens.
- Under high input agricultural production where the productivity curve has reached a plateau, addition of organic sources

could increase yield due to increased soil productivity and FUE.

- The cost of cultivation is held within the reach of average farmer under IPNS as the crop requirement is partly met from cheaper organic sources.

Majority of soybean area in India is in Madhya Pradesh and is grown on Vertisols and associated soils and by and large the crop is grown under rain fed situations. These soils are potentially productive, if managed properly in terms of overcoming soil, water and nutrient management constraints. Currently, these soils have low and skewed crop productivity. Due to inappropriate soil, water and crop management practices, crop canopy development is slow and poor which result in continuous degradation of soil. The yield gap analysis between improved technology and farmers' managed plots under soybean based cropping system is too wide. It therefore now calls to view the problem in a holistic manner to develop farmers' friendly soil water and crop management technology for bringing sustainability to soybean based production systems.

Rainfed agriculture suffers from a number of hydro-physical and socio-economic constraints, which affect the productivity of rainy and post rainy season crops. These include erratic and undependable rainfall, excess and deficient moisture with in a season, harsh thermal regime, soil loss, low level of input use and technology adoption and resource poor farmers. The inherent characteristics relevant to soil management being low infiltration rate, poor drainage leading to run off and soil loss and a narrow moisture range for optimum tillage operations. These soils are frequently flooded during rainy season creating anaerobic conditions in the root zone leading to oxygen stress thereby decreasing crop productivity. Moreover, the productivity of these soils is also low because of low organic matter content, depletion /loss of nutrients and soil biota. Difficulties also exist in establishment and moisture stress at critical stages of growth in the case of post rainy season crops.

Extreme variations in rainfall both in time and space (spatial and temporal variations) call for in-situ rainwater management strategies for minimizing risk and stabilizing soybean based production systems. In view of the poor infilitrability of Vertisols and associated soils and high cost involved in providing sub surface drainage there have been very few successful attempts to increase the upland rainy season crop yields including soybean. The strategy for soil moisture management is therefore to maximize use of rainfall by increasing infiltration and moisture retention, encourage surface drainage and reducing runoff and soil erosion for optimizing the performance of high yielding improved varieties. In-situ rainwater management can be carried out either through land configuration techniques or adoption of suitable tillage practices or through crop residue management.

Like any other crop, soybean also requires the entire essential, major, secondary and micronutrients for completing its life cycle and yield expression continuous and balanced supply of nutrients through integrated approach may result in sustainable yield of soybean. In this context, the various components of IPNS and moisture management methods are discussed independently below.

Agricultural management strategies affect soil environment such as intensive/conventional systems involving excessive inorganic nutrient addition, tillage and other interventions by modifying soil processes in long term .The conventional inorganic fertilization supplies nutrients to crop plants immediately for plant assimilation for improved crop growth and improving crop productivity. However, fertilizer application has a cascading effect on soil quality and soil degradation and ground water contamination.In conventional agricultural systems the loss of soil organic carbon content is a common phenomenon and resorting to improving soil organic carbon content through proper best management practices involving resource conservation technologies such as reduced tillage/no till/changes in land configurations and organic management is the way forward. Organic management tend increase the concentration of carbon, microbial proliferation and diversity, improve soil physical, chemical and microbiological characteristics of soil and overall environment quality. The main drawback of organic management is that efficiency and nutrient supplies /conservations is attained after a long period of time. Moreover, organic carbon plays a significant role in soil functioning and soil quality parameters linked to carbon cycling have used in soil quality evaluation. However, changes in soil quality indicators changes in a long run and therefore long term experiments are particularly important in soil quality evaluation.

Effect of organic and conventional agricultural management systems on soil soil quality indicators

Intensification of agriculture through excessive tillage, extensive use of inorganic fertilizers and agrochemicals, reduced use of organic manures/crop residues, mono-cropping resulted in the degradation of soil quality and agro-ecosystem functioning. This has resulted in loss of biodiversity, soil productivity, soil erosion and surface runoff mediating soil degradation.Therefore, alternative agricultural management systems such as organic farming has been construed to be environmentally, socially and economically viable options to improve soil quality crop productivity and also quality of produce.Several long term studies have attempted to delineate between organic and conventional agricultural management systems with regards to mainly on soil chemical and biological soil quality indicators and very few studies were carried out to ascertain changes in soil physical properties in an quantified manner. The inherent problem in most studies is the difficulties encountered in assessing soil physical measurements. This chapter tries to review some implications of organic and conventional management systems on soil physical and chemical soil quality indicators:

Conventional soil tillage practices impair the soil quality resulted into negative impacts on erosion, compaction, leaching and runoff, while organic farming is a more sustainable farming system by using manure and control of pests by natural means. Organic amendments are the viable option for the rehabilitation of highly degraded and uncultivable soils because they improve the soil properties in agriculture, mine soils and other disturbed ecosystems by positive response in biological soil properties and formation of soil aggregates, positively influencing plant growth and also improve other physical properties. Several workers have been reported elsewhere an increase in mean weight diameter due to the application of organic amendments in undisturbed soils, urban solid waste compost, manure, and sewage sludge. There are reports that application of farmyard manure and NPK fertilizers increased mean weight diameter, percentage of water stable aggregates as compared to conventional agricultural management systems involving inorganic fertilization. Similar increases in mean weight diameter and aggregate stability was also reported by several researchers.Reduced tillage coupled with organic manure application increases soil structural stability through minimal disruption of soil aggregates and consequently soil organic carbon content may increase through protection in soil aggregates and less exposure to oxygen.Organic management resulted in a decrease in soil bulk density as compared to conventional systems due to increased soil organic carbon content, soil structure and increases in root growth.Integrated use of organic manures and inorganic fertilizers increased soil hydraulic conductivity. The increase in soil hydraulic conductivity was ascribed to decrease in soil bulk density, increase in effective pore space, soil structural stability and also increase in soil organic matter.

Judicious and combined nutrient management is crucial to soil organic carbon sequestration. The best option is integration of farm generated organic manure with inorganic fertilizers or alone application of organic manures to increase soil organic carbon stock, improve productivity and enhances sustainability of agriculture because carbon management is the key to environment safety and sustainability of soil health vis-à-vis agricultural productivity. Aggregate stability of the soils is a widely used indicator for evaluating physical quality and susceptibility to erosion. Moreover, It has also been reported that changes in soil aggregate stability may serve as early indicators of degradation or recovery stages of soils and, more generally, of ecosystems. Soil organic carbon content is one of the main factors controlling aggregate stability of soils. Application of organic amendments enhances soil organic carbon and sequestration rate by replacing labile and very labile organic carbon in soil aggregates with more stable compounds. Soil organic matter is a source of energy and carbon for soil microorganisms which increased the formation of soil micro and macro-aggregates through mucilage. Soil microorganism like arbuscular mycorrhizal fungi produce a protein aceous material called glomalin which is play a key role in aggregation, maintaining soil structure and in carbon sequestration. Soil organic matter binds the primary particles in the aggregates, physically and chemically, and this, in turn increases the stability of aggregates, decreasing erodibility and promoting root development and activity of the soil microbial community. More stable soil aggregates leads to protect organic material from microbial decomposition and prevent soil structure degradation, thereby ensuring high water holding capacity and proper movement of soil water.

In recent years, the role of soil organic carbon in climate change mitigation is well established. Organic management play a vital role in maintaining or sustaining the crops productivity under changing climate scenarios through mitigating the effect of climate change and improve the carbon stock of the soils. While being the storehouse of many plant nutrients, the soil carbon stock also strongly influences the soil physical properties and productive capacity of soils. Over the years, efforts have been made to improve the soil organic carbon stock in continuously cropped soils by integrated fertilization, manuring and residue management practices. Use of organic manures and compost enhances the soil organic carbon pools more than application of the same amount of nutrients as inorganic fertilizers. Improved soil quality through stabilization of carbon in restored soils by different mechanisms (e.g., microbial binding agents, physical protection of organic carbon in soil aggregates, binding of organic carbon with mineral particles) has gained more emphasis due to its contribution to climate change mitigation. On the other hand, mulch or mulch cum manure is also a practice adopted to improve the fertility and productivity of the soil under arid and semiarid climates. Mulches are abating the soil erosion and evaporation, improves infiltration rate, enhancing the establishment of vegetation, as well as root growth. Production of roots exudates in the rhizosphere, which stimulate or enhances the microbial activity and, as a result, production of extracellular polysaccharides and other compounds are increase resulted into increase soil aggregate stability. Similarly, organic management enhances or had a positive effect on soil porosity, biological activity, and resistance to physical stresses, bulk density and hydraulic conductivity compared to conventional.

Long term intensive arable cultivation has negative effects on soil physical properties such as soil structure, with effects on soil erodibility and crop yields, decline in soil organic matter levels and the stability of soil structure. However, several workers found that the clear benefits in total organic matter from manure applications, but no or little differences in soil quality (structure) were reported between organic and conventional management across several different soil types. In contrast, there are reports of greater soil porosity, organic matter content and lower penetration resistance under organic farming. Similarly, reports indicate positive effects on organic matter content and pores from a wider range of sizes under organically managed soils conventionally managed soils. Organically managed farm may have higher soil organic matter content , stable aggregation water supply capacity, increase infiltration rates , increase in the hydraulic conductivity and pore, increased in porosity, lower penetration resistance and decrease bulk density. There are reports that reduced micro porosity can have negative effect on water storage, root development, microbial population activity and crop yield. Water retention at higher suctions affected by soil organic matter and soil texture, because soil organic carbon positively correlated with soil water content at high suctions.

Integrated use of organic manures and inorganic fertilizers is considered as a viable option in relishing improved soil quality and crop yields under low input agro-ecosystems prone to soil degradation. It was reported that conjugation of organic and inorganic nutrient sources ensures continual nutrient supply and minimizes nutrient losses and sustain crop productivity in agro-ecosystems. In a long term experiment involving soybean-wheat cropping system revealed that integrated use of organic manures and NPK fertilizers increased total N, P, Olsen's P and available potassium by 20.8, 30.2,25.0 and 52.7% as compared to application of NPK alone. Similarly, application of FYM +NPK increased total N,P and Olsen's P by 42, 52 and 71% respectively over NPK alone. There are reports that indicated that application of organic manures along with mineral N increased available N, P, K and micronutrients (Zn, Cu, Fe and Mn). There are many reports to indicate increases in soil N content with application of organic manures.

Low availability of native soil phosphorus for plant growth acts as a deterrent to realize increased crop productivity. It is well known that most of the soils contain appreciable amounts of total P; ironically, soil solution P concentration was found to be very low and is an impediment for increased plant P assimilation. This stems from the fact that both applied P and native soil P are rendered unavailable as P is subjected to sorption reactions on soil colloids and/or subjected to precipitation reactions. Owing to this, it has been reported that the fertilizer P use efficiency to be very low. In this context, it has become inevitable that large amounts of fertilizer P is required to be applied to sustain crop productivity, which is not a sustainable solution and also inorganic P fertilizers are costly and mostly out of the reach of resource poor farmers. Therefore, it will be plausible if alternate agricultural production systems are devised which is cost effective, P efficient and sustainable. In this regard, agricultural management systems such as organic management, P fertilization alone or in conjugation with organic manures, tillage interventions, crop rotation are some of the strategies which can mobilize soil P for plant assimilation for increased crop productivity. Organic management systems play a formidable role in agricultural ecosystems as they improve soil physico-chemical and biological properties thereby play an important role in nutrient cycling in general and P in particular. The mineralization of organic manures not only supply plant available P for uptake but also play a significant role in native P mobilization through an array of mechanisms such as release of P from exchange sites through organic anions evolved during organic manure decomposition, metal complexation, dissolution reaction, substrate for microbial proliferation and changing the dynamics of P in the rhizosphere positively affecting root architecture and biological properties such as root released phosphatases or phosphatases of microbial origin or both, or increased dehydrogenase activities an indicator of microbial activity. This can be construed as a synergistic effect on P mobilization, wherein increased P availability for P assimilation. Rhizosphere acidification, release of protons and phosphatase and phytase into the rhizosphere results in increase in soil available P content.

The incorporation of organic materials to soil will not only supply K, but also releases K from the non-exchangeable sites through the production of organic acids through proliferating microorganisms during the course of organic matter mineralization and root exudation. Similar increases in available K.

Many researchers have reported increased soil micronutrient content with organic manure application. The increase in soil micronutrient can be attributed to increased mineralization/decomposition of added organic manure and micronutrients present as organically complexed or recalcitrant sources such as carbonates and hydroxy carbonates to available micronutrients through microbial activity and rhizosphere processes such as root acid excretion, increased microbial metabolic processes during active crop growth phases. This can be due to increases in pertinent soil enzyme activities indicating microbial build-up and a decline in rhizosphere pH resulting in the depletion of organically bound and carbonate bound micronutrients.

Soil organic carbon is an important soil quality indicator as it integrates soil physical, chemical microbiological and biochemical properties. However, large background levels of SOC that exists in recalcitrant pools and natural variability in soils under different climatic situations make it a difficult proportion to gauge the influence of agricultural management practices in short term.Soil organic matter is not a homogenous in nature rather it is composed of materials with varying chemical composition and recycling/turnover rates.SOC exists in different pools such as labile, slow or intermediate and recalcitrant. In terms of pertinent applicability of SOC, labile fractions is recognized as pertinent soil quality indicator as it indicates short term changes in SOC due to various management practices.

The intricate role of soil organic carbon stocks in long term accumulation and carbon sequestration is pertinent in recent times as it impacts the sustainability of agro-ecosystem functioning, mitigation of climate change paradigm, and improves soil nutrient availability for crop plants, reducing soil erosion, nutrient runoff, and improving crop productivity. In agro-ecosystems, it is feasible to increase soil organic carbon stocks through appropriate agricultural management strategies such as appropriate crop rotations, integrated organic and inorganic nutrient management, and reduced tillage and reducing organic carbon decomposition. The soil organic carbon dynamics in agro-ecosystem mainly depends on agricultural management practices.

Soil organic carbon plays a pivotal role in influencing the soil microbiome as it provides substrates for the proliferation of soil microorganisms. This in turn determines the abundance, microbial community structure and diversity and their activities in agro-ecosystems. The activity of soil microorganisms determines nutrient transformation, plant growth/suppression, decomposition of organic residues, and physical soil processes.The microbial activity greatly determines short term dynamics and stability of SOC in the long term. Higher microbial activities results in higher carbon turnover and carbon release and any management strategy should concur to reducing microbial access to organic matter decomposition and aid in soil C accumulation .Therefore, identification of appropriate agricultural management strategies that not only improve soil organic carbon content and also mitigate the negative impact of CO2 emission into the atmosphere is a plausible solution for the way forward. Agricultural management through organic agriculture is a viable option for sustaining agricultural intensification has been well documented.

A number of studies indicate that inorganic and organic management not only increased soil organic carbon content but also improved crop productivity. A meta analysis study of around 74 field trails revealed that soil organic carbon stocks were 3.5 Mg C ha-1 and rate of C sequestration was 0.45 Mg C ha-1 yr-1 higher in organically managed farms as against conventional farms. There were diverse reports on the role of application of inorganic fertilizers on soil carbon content. Application of inorganic fertilizers to increase SOC in a long term experiment, while other researchers reported that inorganic fertilization destroyed soil aggregates and loss in organic carbon. The variance in SOC content under different management systems was attributed soil type, climatic condition and cropping systems followed. Moreover, continuous cultivation without any inorganic fertilization or incorporation of exogenous organic sources can decrease significantly the soil organic carbon content/stock. Crop residue burning has been a traditional method of farm waste disposal and reduces SOC storage and inflicting soil quality and crop productivity .Crop residue and conservation tillage were found to improve soil fertility and aggregate stability.

Management regimes that included organic amendment increased SOC concentrations in the surface soils as was observed in other studies. The increased soil organic content have implications in improving physical (aggregate stability, water holding capacity, porosity and nutrient transformation in soils for improved crop productivity . Studies on the long-term effects of different management practices reveal that in general organic management/biodynamic systems increased carbon storage (carbon sequestration) as compared to conventional systems. This can be attributed to increased net primary production with the intensification of agricultural inputs like the incorporation of crop residues, and manuring. Several studies have shown that intensification of farming systems augments SOC levels mainly by increasing the amount of biomass produced and the amount of residues returned. The increase in SOC storage favors the formation of soil aggregates and protects SOC encapsulated inside these stable aggregates from oxidation and by modifying the edaphic factors such as bulk density, pore size distribution, climate that dither SOC biodegradation and will help in mitigating carbon emission. There are reports that long term application of organic manure significantly increased SOC, increased crop productivity and quality of produce and was in consistent with the findings of other researchers. Reduced tillage integrated nutrient management and agriculturally best management practices in terms of cropping sequence improves soil microbiome by increasing soil enzyme activities, soil microbial respiration and soil microbial biomass.

The annual potential of organic sources in the country generated through excreta of livestock and human beings and from crop residues, compost, sewage sludge, industrial wastes and bio-fertilizer is about 17 million tonnes of NPK. The major contributor is animal dung, which has a potential of 7 million tons of NPK. It is paradoxical that although the country has large resources of organic manures, requisite quantities of the same are not available to farmland. A concerted and comprehensive effort is required to be made to mop up all the locally available organic resources and recycle the nutrients from them efficiently.

Organic manures and composts have been used as a means of maintaining and increasing soil fertility all along the history of farming. The supplementary and complementary use of organic manures and bio-fertilizers, besides improving soil physical, chemical and biological properties, also improve the fertilizer use efficiency. Organic manures stimulates the proliferation of diverse group of soil micro-organisms and play an important role in the maintenance of soil fertility because of then role in bio-chemical transformation and due to their importance as source and S in K for mineral nutrients (nutrient cycling, nutrient immobilization and nutrient uptake by plants). Soil structure and porosity are much influenced by soil organisms. Production of antibiotics and bioactive components and suppression of soil borne pathogens are also related to organic residue recycling. Enriching the soils with organic manures has also been able to mitigate the short supply of micronutrients.

Field studies conducted at Coimbatore indicate that application of FYM registered a significantly higher grain yield in soybean-sunflower system than with no FYM application. A long-term field experiment at Ranchi also indicates a significantly higher grain and straw yield with NPK + FYM + lime under soybean-wheat-potato system. At Dharwad, application of FYM (10 t/ha) + RDF increased yields under both soybean-wheat and soybean-chickpea system. Field experiments were conducted at NRC for Soybean to evaluate the impact of different organic sources (FYM, BGS, Poultry manure and urban compost) on soil physical, chemical and microbiological properties under soybean-wheat system. Application of different sources of organic sources of organic manures increased grain and straw yield of both soybean and wheat. This was much evident in poultry manure treated plots. Growth parameters for soybean (Ht of plants, number of nodes, pods and 100 seed wt.) and wheat (number of tillers, ht. of plants and grain yield/plant) also increased due to its application over control. Increased soil enzymatic activities viz. Urease, acid and alkaline phosphatase, inorganic pyrophosphatase, dehydrogenase, aryl sulphatase, and catalase activities were observed due to different sources of organic manures. Soil enzymatic activities were found to be more pronounced in the rhizosphere soil than the non rhizosphere soils. Among the different sources of organic manures, poultry manure treated plots recorded higher soil enzymatic activities.

Soil respiratory activity, microbial biomass C, N, P and S and their mineralization increased due to application of organic manures. These parameters were found to be higher in rhizosphere soils whilst non rhizosphere soils. Higher microbial activity was observed in soybean than in wheat. Application of different sources of organic sources of organic manures at different rates markedly reduced soil bulk density, increased total porosity, water filled pore space, aggregate stability and slaking resistance, plant available WHC, MWHC, and water retention. The effect being more pronounced in PM treated plots.

Being monsoon crop, weeds if not controlled, may result reductions of soybean yield in the range of 35 to 77%. The resultant reduction in yield is primarity due to the competition of weeds with soybean crop for nutrients. The erratic distribution of monsoon may not permit intercultural operation and hence herbicidal control of weeds is obligatory but is presently very limited. Hence, efficient weed control be promoted to check the nutrient drain to retain fertility of the soil and curtail external addition of chemical fertilizers for enhanced productivity .

Integrated nutrient and water management

i) Land configuration

Some of the efficient land configuration techniques for rainfed agro-ecological regions that encourage surface drainage and recharge of soil profile with rainwater and reducing runoff and soil erosion are discussed below:

a) Broad -bed and Furrow System:

It is one such in-situ rainwater management technique and consisted of creation of broad-beds of 135 cm wide and 20 cm high raised beds and separated by 50 cm wide furrows, which are to a depth of 20 cm and graded across the contour to a 0.6 per cent slope. The main purpose of this system is to provide adequate drainage during heavy rainfall and draining excess water into grassland waterways or farm ponds and to provide supplemental irrigation to rainy and post rainy crops, reduces runoff and soil loss, and for conserving moisture in-situ in the furrows. These are semi-permanent structures and are stable for 2 to 4 years and are suitable for planting many upland crops like wheat, chickpea. The broad –bed and furrow are constructed with the help of two furrow openers and a bed- former attached to a bullock drawn tropi cultor. At National Research center for Soybean, Indore we have developed a tractor drawn implement for simultaneous sowing and creation of broad-bed and furrows. In this implement there exist the provision for changing the width of the broad –bed and furrow. At ICRISAT, crop productivity and resource utilization were studied for soybean-chickpea sequential and soybean+ pigeon pea intercropping under BBF and flat bed system. It was observed that adoption of BBF increased productivity of the system and rainfall infiltration, and decreased runoff and soil loss. Work done at NRC for soybean to optimize crop and soil management strategies of Vertisols and associated soils for enhance water and nutrient use efficiency for sustainable crop production. The studies over the past three years have equivocally established that adopting Broad-bed and furrow method in conjugation with inorganic fertilizers increased seed yield, quality, uptake of nutrients, and economic returns over traditional farmers practice (flat bed) through in situ conservation of moisture, drainage of excess water, ground water recharge and reducing runoff and soil loss. This system is economically viable and sustainable and conserves natural resources.

b) Ridge and furrow systems

The system consists of array of alternating ridges and furrows. The ridges are normally made of 15-20 cm high and 75 cm wide with tractor drawn ridger on less than 1.2 per cent slope. Upland rainy season crops like soybean, maize sorghum and pigeon pea can normally be planted on the ridges. Generally, three rows of soybean, two rows of sorghum, maize, sorghum and pigeon pea can be planted on the crest of the ridges to maintain uniform plant population as recommended for flat bed method of planting. The lower catchments in a field can be used for storage of some of the runoff water from the upper catchments thereby supplementing the storage capacity of the farm pond during the period of continuous rains. Ridge planting facilitates root zone aeration besides favorably influencing the soil moisture relations rendering the ridges better drainable and runoff. The grain yield of all the crops increased between 21 to 106 per cent depending on the amount and distribution of rainfall

c) Conservation tillage:

Conservation tillage practice normally stores more plant available moisture than the conventional inversion tillage practice. The higher retention of soil moisture content under conservation tillage is due to the fact that it improves soil structure, increase infiltration of rainwater as crop residues act as a mulch cover and thereby reducing runoff of rainwater and evaporation loss. Increase in the available moisture content under conservation tillage increase the consumptive use of water by crops and hence improve the water use efficiency.

d) Crop residue incorporation

Mulching with crop residues contribute to the conservation of soil and rainwater. This method reduces evaporative losses, runoff from cropped fields. Crop residues modify soil biological activity resulting in improved soil fertility and better soil physical conditions.

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Management of Bacterial & Fungal Diseases of Soybean in the Changing Climate Scenario

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What is a plant Disease: Stakman & Harrar (1957) defined disease as physiological disorder or structural abnormality that is deleterious to the plant or its part or product, that reduces the economic value of the plant.

Disease in plants defined as the series of invisible and visible responses of plant cells and tissues to a pathogenic organism or environmental factor that result in adverse changes in the form, function, or integrity of the plant and may lead to partial impairment or death of plant parts or of the entire plant (Agrios, 2005).

Field situation for plant Disease: A plant pathologist is often asked by friends or associates the following questions. What is wrong with my plant; followed by, what can I do to get rid of the problem? It may be too late to help the specific plant when the question is asked, but proper diagnosis may be extremely important in preventing the problem on other plants or in preventing the problem in the future.

How does a plant pathologist go about diagnosing plant problems? The diagnostician must have very good observation skills, and s/he also needs to be a good detective. It is important to keep an open mind until all of the facts related to the problem can be collected. The possibility of multiple causal factors must also be considered.

Control measures depend on proper identification of diseases and of the causal agents. Therefore, diagnosis is one of the most important aspects of a plant pathologist's training. Without proper identification of the disease and the disease-causing agent, disease control measures can be a waste of time and money and can lead to further plant losses. Proper disease diagnosis is therefore vital.

Disease in soybean: In India the soybean is grown in 12.22 million hectares with 11.86 million tonnes production in 2014. The average production is about 1.02 tonne /ha, which is very less as compared to the world average i.e. 2.2 t./ha. The low yield in India is due to a number of diseases and insect pests. Soybean crop suffers from diseases at pre and post emergence as well as later stages of crop growth till maturity, which are caused by fungi, bacteria, viruses, nematodes and mycoplasma.

The average losses from these diseases are about 12-20%. Hence, recognition or proper identification of these diseases are very important for their management. Some major soybean diseases and their identification and control measures are described below.

1. Anthracnose or pod blight: Disease is caused by Colletotrichum dematium f. sp. truncatum or Colletotrichum truncatum and occurs in severe form under high temperature and humidity. It is a major disease distributed throughout the India and can cause 16-25% damage but sometimes loss in yield can be up to 100%. Pathogen survives in seed and in crop residues. Crop is attacked at all stages of growth but symptoms are evident in the early reproductive stage on stems, petioles and pods. Inoculum as mycelium from seed and debris may initiate the infection. Besides causing pre-and post emergence damping off of seedlings, mycelium may also become established in infected seedlings without symptom development until plants begin to mature. Conidia produced on infected plant parts under favourable conditions may initiate secondary infection.

Symptoms:

i. Generally, irregular reddish to dark brown areas appear on infected parts.
ii. Later on these are covered by black fungal fruiting bodies (acervuli) with setae (minute black spines), which can be seen by unaided eye. These setae are diagnostic character of the disease.
iii. Foliar symptoms are expressed in the form of laminar veins necrosis, leaf rolling and defoliation but under prolonged period of high humidity.
iv. Owing to infection pods turns yellow to brown, seed formation is also affected as they become shriveled and mouldy, and sometimes seeds do not form in the pods.
v. Pre-and post emergence damping off may occur when infected seeds are planted.
vi. Seedlings may be killed as soon as infected seeds germinate or after the emergence.
vii. Symptoms on cotyledons appear as dark brown sunken cankers.

Control measures:

i. Use of clean and healthy seeds.
ii. Burning of infected plant debris.
iii. Cultivation of resistant varieties like JS 2034, JS 206, JS 2098 etc.
iv. Seed treatment with Thiophanate methyl 45% + Pyroclostrobin 5% FS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed.
v. At initiation of disease, symptom like veins necrosis on lower side of upper leaves appears. During this stage spraying of Thiophanate methyl @ 2 g/L of water or Tebuconazole @ 1.25 mL/L of water or Tebuconazole + Sulphur @ 2g/L of water or Hexaconazole 5% EC @ 1.6 mL/L of water or Pyraclostrobin 20% w/w WG @ 1 g/L of water is recommended.

2. Rust: Phakopsora pachyrhizi is the causal organism of Rust. Earlier it is known to occur in N.E. and around Pantnagar in U.P. Disease is severe at the temperature range of 22-27oC accompanied with 80-90% relative humidity and leaf wetness. A yield loss ranging from 40 to 80% has been reported from recent rust epiphytotics in India. Pathogen survives mainly in collateral hosts but also in crop residues remain with the seed. Urediniospores from collateral host and any other source germinate in presence of free water on leaf surface and penetrate the host mainly directly through corticle and underlying epidermal cells. After 5 days at 20oC plants exhibit chlorotic spots. Uredinia are formed and by 9 to 10 days they begins liberating urediniospores.

Symptoms:

i. Initially chlorotic gray brown spots appear on the leaves, abundantly on lower surface. Slowly spots increases in size to form pustules.
ii. Leaves turn brown with in a short time causing early defoliation and reduction in number of pods, seeds and seed weight.
iii. Presence of loose brown powder owing to rupture of pustules is a characteristic symptom.

Control measures:

i. Deep ploughing during summer.
ii. No summer and *rabi* cultivation.
iii. Roguing and burning of infected plants, crop and crop residues.
iv. Two to three-years crop rotation in rust hot spot areas.

v. Seeds from the rust infected crop should not be used for sowing.
vi. Cultivation of rust tolerant varieties like Dsb-32, DSb-21, Dsb23-2, Phule Kalyani, Ankur, PK 1024, PK 1029, JS 80-21, Indira soybean 9, MAUS 61-2 or early maturing varieties.
vii. Two to three sprays of hexaconazole (Contaf) oxycarboxin (Plantvax) @ 0.1% are found effective.
i. To enable entering soybean field for spray at least after every 15 rows a strip of about 1.50 m be left vacant in the field.

3. Rhizoctonia aerial blight: Rhizoctonia solani causes aerial blight. In addition, it also causes seed rot, seedling rot, root and stem rot. Disease is favoured by continued wet conditions and is a major disease all over the India. It can cause up to 35% or more loss in yield. Severity of disease increases with monoculture of soybean. Pathogen is soil and seed borne and sclerotia serve as primary inoculum.

Symptoms:

i. Reddish brown sunken lesions are formed in roots and basal portion of stem just above the soil line and the plant dies. The lower part of the tap root and the secondary root system are usually killed.
ii. Leaves develop small or large grayish brown to reddish brown spots first on lower leaves which later turns in to dark brown spots first on lower leaves which later turns in to dark brown spots.
iii. Defoliation may also occur, petioles remaining attached to the stems.
iv. Oval to elongated spots also appear on stem, petiole and pods. Dark brown sclerotia develop on petioles and leaves.
v. Seeds also get infected through pod having irregularly shaped tan, sunken lesions.

Control measures:

i. Cultivation of disease resistant/tolerant varieties like PK 262, PK 416, PK 472, PK 1042, SL 295 etc.
ii. Avoidance of excess plant population.
iii. Seed treatment with Thiophanate methyl 45% + Pyroclostrobin 5% FS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed.
iv. One spray of carbendazim or thiophanate methyl (0.1%) is found very effective.

4. Myrothecium leaf spot: It is caused by Myrothecium roridum. Disease is major and distributed throughout the India. 20-40% yield losses found in certain areas. Pathogen survives in seed as well as in crop debris.

Symptoms:

i. Small round brown spots with dark brown or purple margin are very common on the leaves.
ii. These spots are surrounded by a translucent area in concentric rings.
iii. In later stage many spots merge with each other and become of irregular shape.
iv. On maturity spots produce white sporodochia, which turns to black.
v. The necrotic centres of the spots fall imparting a "shot hole" effect.

Control measures:

i. Use healthy and certified seed.
ii. Cultivation of resistant/moderately resistant varieties like Bragg, JS 71-05, JS 335, MACS 13, MACS 124, MAUS 47, NRC 7, PK 564, etc.
iii. Seed treatment with Thiophanate methyl 45% + Pyroclostrobin 5% FS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed followed by spray of carbendazim or thiophanate methyl (0.05% to 0.1% or 400 to 800 g/ha) or mancozeb (0.25% or 2 kg/ha). First spray at 35 DAS is very effective.

5. Alternaria leaf spot and blight: Alternaria tenuissima and A. alternaria have been reported to be the casual agents of this disease. These fungi also causes "pod and seed decay". Disease is favoured by high temperature and humidity. Pathogen survives in seed and crop residues. Disease is more common in late sown crop.

Symptoms:

i. Brown necrotic spots with concentric rings appear on the leaves, which coalesce to form large area. These gradually enlarge and spread inwards from the leaf margin.
ii. Later in the season leaves eventually dry and drop.
iii. Pod and seed infection reduces the viability of the seeds.

Control measures:

i. Cultivation of moderately resistant varieties like PK 327, MACS 124, KHSb 2, NRC 2, PK 327, PK 1042, Himso 1563, JS 80-21, Pusa 37, VLS 21 etc.
i. Seed treatment with Thiophanate methyl 45% + Pyroclostrobin 5% FS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed.
ii. Spray of carbendazim or thiophanate methyl @ 400 g/ha over the infected crop.

6. Frog eye leaf spot: Leaf spot produced by Cercospora sojina is very common under warm and humid conditions. This disease along with anthracnose causes about 22% yield loss. This pathogen also survives on seeds and infected crop residues. Infected crop residues produce conidia, which becomes a source of primary inoculum. Spores produced on cotyledons of infected seedlings (from infected seeds) are also prime source of inoculum and infected seeds are a means of distant dissemination of the fungus.

Symptoms:

i. Disease appears in the field about two months after planting in the form of small light brown circular to angular spots on leaves and other aerial plant parts. Central area of spots becomes ashy grey with purplish to dark brown margin. The absence of yellowing around the spot is a distinguishing symptom.
ii. Heavily spotted leaves may fall prematurely.
iii. Initially water soaked spots appear on pods which later on turns in to slightly sunken reddish brown spots.
iv. The seeds get infected and light to dark grey blotches are formed on the seed coat.

Control measures:

i. Use clean and certified seed and resistant varieties like Bragg, Hardee, MACS 58, PK 1024, JS 79-81, and JS 80-21 etc.
ii. Seed treatment with Thiophanate methyl 45% + Pyroclostrobin 5% FS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed.
iii. Removal and burning of crop debris.
iv. Spray of carbendazim or thiophanate methyl @ 0.1% over the infected crop.

7. Cercospora blight or leaf spot and purple seed stain: Disease is caused by Cercospora kikuchii and becomes severe under high humidity especially at flowering stage on early maturing cultivars, causing 15-30% yield loss. Pathogen survives in seeds and surface crop debris of previous crop. C. kikuchii over seasons in diseased leaves, stem and seeds and infects soybean plants at flowering stage. Secondary infection comes from the infected plant producing conidia. Secondary infection may remain symptom less or may even further produce conidia. The fungus from the pod reaches to seed coat where it produces the characteristic purple stain.

Symptoms:

i. At the beginning of seed set, light to reddish purple angular to irregular lesions appear on both the surfaces of leaves. Sometimes upper leaves have light purple appearance making them leathery and dark.
ii. Numerous infections cause rapid chlorosis and necrosis of leaf tissues, resulting in defoliation from upper young leaves.
iii. Veinal necrosis is common.
iv. Most striking symptom is the blightening of younger upper leaves over large area.
v. Reddish purple to reddish black slightly sunken lesions are also formed on stem, petiole and pod.
vi. Heavily infected stems have a dull gray to dark brown appearance and dry up 7 to 10 days prematurely.
vii. Seeds also develop pink to dark purple colouration fetching low price in market.
i. Viii. Germination of such seeds become low, cotyledons shriveled and discoloured and resulted seedlings may die.

Control measures:

i. Use of clean & certified seeds.
ii. Cultivation of resistant varieties like JS 80-21 & Bragg etc.
ii. Seed treatment with Thiophanate methyl 45% + Pyroclostrobin 5% FS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed.

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Management of Most Important Insects of Soybean in the Changing Climate Scenario

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Soybean is infested by more than 270 insect-pests but 8-10 are most important in Indian conditions. Among these most important insect-pests some are region specific and rests are national significance and considered as national insect-pests. These insect-pests are also now changing their status as minor or major insect-pests every year due to rapid climate change. Since last four-five years outbreaks of different insect has been occurred. For example in central region (Madhya Pradesh, Rajasthan and Maharastra) last year (2020) stem fly outbreak has been happened and in 2019 *Helicoverpa armigera* popularly known as gram pod borer has been occurred. So, it is very difficult to adopt a proper pest management tactics against them I to farmers and researchers. Though, chemical insecticides have proved to be highly successful in insect control, but short- and long-term hazardous consequences of their misuse are evident. Developments of insecticide-resistance in insects have been reported in recent past. Hence, the only way to part with sole dependence on chemical insecticides is Integrated Pest Management. Most important insect-pests and their management components of IPM in Soybean are given in this chapter.

MAJOR INSECT PESTS OF SOYBEAN

1. Tobacco caterpillar, *Spodoptera litura*

Every year, the soybean crop is reported to be increasingly infested by Tobacco Caterpillar resulting in heavy yield losses. They are found to be polyphagus with more egg laying capacity and lay eggs in groups of 200-400 eggs/mass and recently they have developed resistance to many popular insecticides.

Identification: Adults zig-zag lines on forewings and white hind wings, caterpillar dorsally black triangular spot on both sides.

Management:

- Use of recommended seed rate.
- Install Spodolure/litlure pheromone trap at 5-10 pheromone traps/ha in the field for monitoring purpose. Care should be taken to use clean cloth while handling the septa.
- Use bird perches at 8-10 locations in the field facilitating easy access for birds to feed on insect larvae.
- Regular monitoring of the field and destruction of egg mass in early stage.
- Spray the crop with biological pesticides like SlNPV 250 LE/ha or *Bacillus thuringiensis*/*Beauveria basiana* @ 1 l/ha.
- If needed, apply the spray of Chlorantraniliprole 18.5 SC @ (0.150 l/ha or Quinalphos 25 EC @ 1.5 l/ha or Flubendiamide 39.35 SC (@ 150 ml/ha) or Flubendiamide 39.35 SC (@ 150 ml/ha) or Flubendiamide 20 WG (@ 250-300 g/ha) using 500 litre of water per hectare.

2. Green Semiloopers: Soybean is infested by a complex of four types of semiloopers. Differing in colour, shape and size, the young larvae initially cut small holes on foliage and later on completely devour the plants. In the event of heavy incidence they also damage buds, flowers and young pods resulting in non-pod formation situation. Its infestation is found to be more in the areas with less rain coupled with high temperature and humidity and causes heavy yield losses.

Identification: I. *Chrysodeixis acuta*: Adult have two brightly coloured spot in forewing arranged in “8” shape of english number, caterpillar green in colour, on dorsal side one yellow colour longitudinal lines and two white colour line one each on both sides and body become wider from front to back.
II. *Diachrysia orichalcea*: Adult forewings with triangular golden colour spot, caterpillar is very similar similar to *Chrysodeixis acuta* but sparse prominent hairs on body are clearly visible.
III. *Gesonia gemma*: Caterpillar thin, green colour and uniform thickness entire body length.
IV. **Mocis *undata*:** Caterpillar dark colored and 4-5 cm long.

Management:

- Avoid higher plant population as it attracts the insect causing heavy infestation.
- Avoid higher use of nitrogenous fertilizers as it invites more insects.
- Use bird perches at 8-10 locations in the field facilitating easy access for birds to feed on insect larvae.
- Spray of biological pesticides *Bacillus thuringiensis*/*Beauveria basiana* @ 1 l/ha.
- Spray the crop using Chlorantraniliprole 18.5 SC @ (0.150 l/ha 4-5 days before flowering. Alternatively, farmers can use Quinalphos 25 EC @ 1.5 l/ha or pre-mix insecticides like Betacyfluthrin 8.49% + Imidaclorprid 19.81% OD @ 350 ml/ha or Thiamethoxam + Lambda Cyhalothring @ 125 ml/ha) or Flubendiamide 39.35 SC (@ 150 ml/ha) or Flubendiamide 20 WG (@ 250-300 g/ha) using recommended quantity of water ie.500 l/ha.

3. Stem fly, *Melanoagromyza sojae:* During recent years, this insect is found to be most commonly seen in major soybean growing states. Generally, its typical infestation is seen after 25 days from sowing. This is a stem-boring insect, owes its significance due to its intricate life cycle. Insects hatching from eggs laid during July and first fortnight of August complete the life cycle during the same crop seasons itself. But those hatching from eggs laid during second fortnight of August and September over winter as pre-pupa and complete the life cycle only after the onset of monsoon in the following year. The infested plants / plant parts show typical drying due to girdles made by the female for egg laying.

Identification: Adult flies are metallic black colour resembling housefly but smaller in size and maggots are light yellow colour.

Management:

1. Use recommended seed rate. Avoid higher plant population as it attracts the insect causing heavy infestation.
2. Spray the crop with Thichloprid 21.7 SC @650 ml/ha or profenophos 50 EC @ 1250 ml/ha or Betacyfluthrin 8.49% + Imidaclorprid 19.81% OD @ 350 ml/ha or Thiamethoxam + Lambda Cyhalothring @ 125 ml/ha) during the initial infestation of girdle beetle.

4. **Girdle beetle, *Obereopsis brevis:*** During recent years, this insect is found to be most commonly seen in major soybean growing states. Generally, its typical infestation is seen after 25 days from sowing. This is a stem-boring insect, owes its significance due to its intricate life cycle. Insects hatching

from eggs laid during July and first fortnight of August complete the life cycle during the same crop seasons itself. But those hatching from eggs laid during second fortnight of August and September over winter as pre-pupa and complete the life cycle only after the onset of monsoon in the following year. The infested plants / plant parts show typical drying due to girdles made by the female for egg laying.

Identification: Adults body orange, lower part of wings black in colour and antenna longer than its body, larva apodous, yellow in colour.

Management:

1. Use recommended seed rate. Avoid higher plant population as it attracts the insect causing heavy infestation.
2. If possible, plant green manuring crop like Dhencha on the field boundaries which attract the beetle thereby protecting the soybean crop from losses.
3. Destroy the affected plant part during the initial stage of infestation in order to break the life cycle of the insect.
4. Spray the crop with Thichloprid 21.7 SC @650 ml/ha or Chlorantraniliprole 18.5 SC @ (0.150 l/ha or profenophos 50 EC @ 1250 ml/ha or Betacyfluthrin 8.49% + Imidaclorprid 19.81% OD @ 350 ml/ha or Thiamethoxam + Lambda Cyhalothring @ 125 ml/ha) during the initial infestation of girdle beetle.

5. Soybean Pod borer, *Helicoverpa armigera:* Every year, the soybean crop is reported to be increasingly infested by gram pod borers resulting in heavy yield losses. They are found to be polyphagus and more than 184 host plants with more egg laying capacity and recently they have developed resistance to many popular insecticides. It lay egss singly so, it is difficult to natural enemies like egg parasitoids to find out them.

Identification: Adults dark black bands on white hind wings, caterpillar longitudinal lines of several colours.

Management:

- Use of recommended seed rate.
- Install helilure pheromone trap at 5-10/ha for monitoring purpose in the field. Care should be taken to use clean cloth while handling the septa.
- Use bird perches at 8-10 locations in the field facilitating easy access for birds to feed on insect larvae.
- Regular monitoring of the field and destruction of egg mass/caterpillar in early stage.
- Spray the crop with biological pesticides like HaNPV 250 LE/ha for *Helicoverpa armigera* or *Bacillus thuringiensis*/*Beauveria basiana* @ 1 l/ha.
- If needed, apply the spray of Indoxacarb 14.5 SC @ 0.333 l/ha or Chlorantraniliprole 18.5 SC@ (0.150 l/ha or Quinalphos 25 EC @ 1.5 l/ha or Flubendiamide 39.35 SC (@ 150 ml/ha) or Flubendiamide 39.35 SC (@ 150 ml/ha) or Flubendiamide 20 WG (@ 250-300 g/ha) using 500 litre of water per hectare.

6. **White grub, *Holotrichia consanguinea:*** Recently this insect has gained significance in soybean crop in some pockets of Madhya Pradesh. The grubs feed on plant-roots in rows. Consequently, drying of plants in linear patches become visible. The grubs feed voraciously under good soil-moisture conditions.

Identification: Adults browinish black, medium sized and stout body, larvae fleshy, white, with brown head, mandibulate mouth parts and arched body.

Management:

- Installation of light trap or pheromone traps for collection and destruction of white grub adults.
- Seed treatment with Imidachloprid 48 FS @ 1.25 ml/kg seed.
- Soil application of Chlorpyrifos (2.5% granular) @16 kg/ha between the rows at 25-30 days after sowing. This helps to bring the grubs above the soil surface after receipt of rain/application of irrigation. Alternatively, you can use phorate 10G @10kg/ha before sowing and well mix in soil.

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Climate Smart Pest Management in Soybean

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The impact of global climate change on crops grown in India is being increasingly visualised from last two decades. With the effect of increasing atmospheric CO_2 concentration in the atmosphere and enhanced ambient temperature, the trend in monsoon has been vitiated. Due to prevailing uncertainty of timely setting of monsoon, uneven distribution, heavy storms, and longer dry spells along with raise in temperature has been directly affecting the rainfed crops and indirectly to the subsequent crops in the cropping system in the Central India.

The inevitable climatic events of extreme nature like rise in temperature and carbon dioxide concentration, irregular rainfall leading to extremes of moisture conditions etc. are making impact on agricultural development *per se* (Padgham, 2009) including insects and pathogens of all Agri-systems. Although the precise impact is still not certain, but majority of evidences suggest following impact (Petzoldt and Seaman, 2007):

- Shortening of insect life cycle leading to increased population.
- Frequent insect outbreaks and disease epidemics.
- Range expansion of insects and diseases.
- Increase in susceptibility of crops to various pests and diseases.
- Loss of efficacy of pesticides.
- Decrease in populations of bio-control agents for insects and diseases.
- Imbalance in agro-ecosystems.

In view of global climate change, the Food and Agriculture Organization started promoting "Climate Smart Agriculture (CSA)" long back (FAO, 2010). In this document, the reorientation in entire agriculture system was clearly emphasized. With respect to management of insects and diseases, the document recommended adoption of IPM strategies, because the climate change would certainly impact the use of pesticides (Peeples, 2013; Pieter et al., 2014). Nevertheless, to make pest management more focused, relevant and context-specific, a new approach of "**Climate Smart Pest Management (CSPM)**" has been put-forth (Heeb et.al. 2019). Some of the major approaches involved in CSPM are mentioned below:

- ➢ Continuously monitoring the climatic aberrations vis-à-vis pests through effective surveillance.
- ➢ More emphasis on prevention strategies.
- ➢ More reliance on physical, cultural, mechanical and biological control options with chemical control as the last option.
- ➢ Development of dynamic and vibrant 2-way linkages between farmers or extension agencies and the experts for timely action against damaging insects.

In the following text, pest-management interventions in line with CSPM strategies are discussed:

Use of resistant / less susceptible varieties: There is strong need to change farmers' mindset for rushing for a new variety irrespective of the zone it has been developed and recommended. Secondly, high yield is the major criteria for the farmers to prefer a variety. They do not care about its reaction against insects and diseases, thereby spending a lot on pesticides. A clear message should go to the farmers that use of a disease/ insect tolerant variety yielding little less and demanding less pesticides would be a wise step rather than going for a variety which requires lot of investment on pesticides for realizing the high yield. A number of varieties showing resistance/ tolerance either to individual insects and diseases or showing multiple resistance have been identified and recommended for the farmers (Joshi and Sharma, 2003; Dupare and Billore 2021). Soybean varieties released, notified and recommended for cultivation in Central Zone during recent past are given below along with their salient features.

S. No.	Variety (Notification Year)	Duration (Days)	Max. Yield (q/ha)	Important characters
1.	MACS 1520 (2021)	98-102	29	Purple flower, brown pods with tawny pubescence, black hilum. Resistance to charcoal rot, YMV, bacterial pustule, rhizoctonia aerial blight, Alternaria leaf spot and also has high resistance to stem fly, girdle beetle defoliators, leaf hopper, stink bug, bean bugs and pod borer.
2.	NRC-130 (2021)	92	30	Determinate, glabrous pods, light yellow seed with yellow hilum. Moderately Resistant to Charcoal rot, Target Leaf Spot and Pod Blight.
3.	RSC 10-46 (2021)	98-107	25	Semi-determinate, purple flower, absence of pubescence, black hilum. Resistant to YMV, charcoal rot, blights, bacterial pustules, leaf spots, stem borers and defoliators.
4.	RSC 10-52 (2021)	99-103	26	Purple flower, brown hilum. Resistant to bud blights, bacterial pustules, target leaf spots, charcoal rot, stem borer. Moderately resistant to rhizoctonia aerial blight and defoliators.
5.	AMS-MB- 5-18 (2021)	98-102	25	White flower, brown hilum. Resistant to charcoal rot, moderately resistant to YMV, SMV, bacterial pustules, rhizoctonia aerial blight and Alternaria leaf spot. Moderately resistant to girdle beetle, defoliators and stem fly.

6.	JS 20-116 (2019)	95-100	30	Semi-determinate, rounded ovate leaves, white flowers, excellent germination, absence of pubescence, black hilum. Multiple resistance against YMV, charcoal rot, rhizoctonia aerial blight, bacterial pustules, leaf spots, stem fly, stem borers. Suitable for mechanical harvesting.
7.	JS .20-94 (2019)	98-100	27	Semi-determinate, excellent germination, rounded ovate leaves, violet flowers, tawny pubescence, black hilum. Resistant to yellow mosaic virus, charcoal rot, blights, bacterial pustules, leaf spots as well as stem fly.
8.	NRC 127 (2018)	100-104	22	First Kunitz Trypsin Inhibitor (KTI) free variety. Semi-determinate, white flowers, tawny pubescence, black hilum. Resistant to YMV, Soybean Crinkle virus (SCV) and Alternaria leaf spot (ALS) and bacterial pustule. Resistant / tolerant against pod borer and lepidopteron defoliators.
9.	RVS 2002-4 (2017)	92-96	22	Semi-determinate, pointed ovate leaves, white flower, glabrous, black hilum, Resistant to YMV.
10.	RVS -18 (2017) For M.P. State	92-97	24	Semi-determinate, lanceolate leaves, white flower, glabrous, black hilum.
11.	JS 20-69 (2016) For M.P. State	91-97	23	Semi-determinate, white flower, glabrous, black hilum. Resistant to YMV and charcoal rot. Resistant/tolerant to insect-pests.

Crop monitoring, Surveillance and Forewarning: Crop monitoring through regular and frequent surveillance is the key to the success of any crop production system. This becomes all the more necessary in view of climate changes that are influencing insect behaviour. The importance of creating awareness among farmers, early detection of pest problem and timely communication of control measures have been very convincingly demonstrated by the CROPSAP (Crop Pest Surveillance and Advisory Project) running successfully in Maharashtra since 2009 (Vennila *et al.*, 2016). Key to its grand success was a massive network of Scouts for surveillance and timely dissemination of experts' recommendations to the farmers. Huge amount of data generated in the project helped to develop models for forecasting major soybean insects (Pratheepa *et al.*, 2014; Patel *et al.*, 2019 a, b, c; Patel *et al.* 2020). Started with soybean, now the model has been extended to many other important crops in Maharashtra as well as in other states.

In present scenario of weather variability within short distances, the insect and disease incidence also vary considerably. It is therefore very important for an expert to know the ground conditions quickly for suggesting the remedial measures in time. A modest beginning has been made in Madhya Pradesh also for soybean crop through a joint venture of Vodafone-Idea and Solidaridad, Vi Smart Agri Project. Till a wider network is established and more insects and diseases are included in the system, the advisories being issued are deemed to be applicable for distant farmers also in the region.

To make the insect detection and monitoring more precise and efficient, machine learning, Internet of Things (IoT), high-end sensors etc. are now being used. In a recent publication Lima *et al.* (2020) have reviewed various sensor-based techniques for early detection and monitoring of insect pests. The most significant technological breakthrough has been the use of Artificial Neural Networks (ANN) for insect identification up to species level. It is now possible to combine ANNs with varying insect morphological characters. With this approach, Wang *et al.* (2012) were able to identify more than 200 insect species belonging to 64 families of 8 orders with 93 per cent precision. Based on cloud-computing image processing, M/s EFOS, TrapView, Slovenia have produced bucket and funnel type traps suitable for moths like *Helicoverpa armigera, Spodoptera litura* etc.

Use Trap Crops: Trap crops are the tools for habitat-management which influence insect-pests as well as the natural enemies. When grown along with the main crop, there is reduced colonization, reduced adult longevity reduced egg-laying preference on the main crop (Hooks and Johnson, 2003). Among major soybean insect-pests, girdle beetle is attracted towards *Dhaincha* (*Sesbania rostrata*) (Tripathi *et al.*, 2013) whereas most of the lepidopteran defoliators are attracted towards *Suva* (*Anethum graviolens*) (Anonymous, 2016). The research conducted at ICAR-Indian Institute of Soybean Research, Indore has proven the potential of *Suva* as a trap crop for the adults and larvae of lepidopteran defoliators. Among different row combinations tested, soybean:*suva* in either 6:1 or 12:2 row combinations were most effective in reducing the populations of semiloopers and *Spodoptera litura* larvae. Majority of the larvae colonize on the *Suva*, with very less on soybean. The larval population colonized on *Suva* are killed by using appropriate insecticide, whereas those present in soybean crop are taken care by natural enemies. Following table clearly shows markedly less larval population on soybean when grown with *Suva* as compared to sole soybean.

Crop(s)	**Semiloopers / m on Soybean**	***S. litura* / m on Soybean**
1. Sole Soybean	15.5	17.0
2. Soybean + Suva (6:1)	3.5	4.0
3. Soybean + Suva (12:2)	3.0	5.0

It is needless to mention here that the quantity of insecticide required to spray only the *Suva* crop will be much less than the quantity required to spray the soybean crop. This reduced insecticide requirement will certainly be a considerable saving for the farmer.

Use of Traps and Perches: For monitoring and mass-trapping of adults of *Helicoverpa armigera* and *Spodoptera litura* pheromone traps are very effective and economical. A keen observation on adult-catches in a single trap in the field will set an alarm about infestation of a particular insect species in near future. Mass-trapping of adult males based on their seasonality (Punithavalli *et al.*, 2014) with more number of traps (8-10 per ha) installed in the field, will leave the females un-mated and thus will lay only sterile eggs. For success of the pheromone traps, i) never handle the lure with bare hands, always use a piece of clean cloth or cotton while placing it on the trap; ii) make some pin-holes in the plastic bag to prevent collection of water in it and falling down due to the weight. It is important to understand that a pheromone trap should not be installed for the insect which has not been a problem in a particular area before.

Light traps are good devices for attracting nocturnal adults of many insects. For soybean crop, light traps are kept outside the fields as the light would influence the crop adversely. There were certain limitations faced by the farmers with traditional light traps- i) short durability of metal body, ii) frequent damage of bulb due to rains, and iii) some natural enemies also get trapped. The Scientists at ICAR-NCIPM, New Delhi have made certain changes and improvised the light traps. The body of this improvised trap is made up of PVC which gives it longer durability. The light source bulb is also made up of hardened glass which can with stand rain drops even when illuminated and heated. In order to set-free the trapped parasitoids like *Trichogramma*, the collection box is provided with several holes to facilitate their escape back to the fields.

Various types of coloured sticky traps are deployed primarily for monitoring of small flying insects like white fly, aphids, thrips, midges, leaf miners etc. as are attracted to various colours. Although yellow and blue sticky traps are most common, Bashir *et al.* (2014) demonstrated that brown-coloured traps attracted maximum number of insects. However, yellow sticky traps coated with lavender or basil oil attract white flies and thrips, while traps coated with lemon oil or castor oils were suitable for leaf miners (Bayisa *et al.*, 2017). The biggest and practical disadvantage of sticky traps used in open fields is that they attract some potential beneficial insects also like *Trichogramma* spp.

Bird perches are very effective in facilitating the activities of predatory birds. It is estimated that each bird consumes 30-50 larvae in one hour. By providing bird perches in the fields, efficiency of predatory birds increases by more than 20 per cent. Usually, the perches are 'T' shaped simple structure made with bamboo sticks. However, small dried bushes placed in the field also serve the purpose. Care should be taken that the perching place is not more than 2-3 feet above the crop canopy.

Removal of insect infested and disease infected plants: A sound knowledge about the nature of damage by some soybean insect helps in reducing the damage/loss to a considerable extent. With increase in temperature due to global warming the insect life-cycle is going to be shortened and number would be increased (Miyashita, 1971; Rao *et al.*, 2014). The gregarious phases of *S. litura* and *Spilarctia abliqua* (Bihar Hairy caterpillar) are vividly visible on the crop. The leaves or the entire plant harboring the gregarious larvae should be removed from the field and destroyed to prevent them from spreading in the entire field (Natikar and Balikai, 2017). In case of girdle beetle, the very first symptom of its infestation is the drooping of plant-part above the girdles. If these parts are removed from the plant and destroyed, dependence on chemical insecticides can be reduced. Being a laborer intensive operation, this can be performed only by small farmers with small holdings.

Some of the diseases with very distinct symptoms can also be spotted and removed at early stage. Yellowing of plants due to YMV disease can be viewed from a distance. They should be uprooted and destroyed to prevent from serving as the disease inoculum. Development of cottony growth at stem base marks the identification of collar rot disease. Such infected plants need to be removed from the field as later on they develop the fruiting bodies, the sclerotia which flow with the water to other parts of the field and infect the crop.

Exploiting the potential of natural Bio-Control Agents (BCAs): Although, the changing climatic conditions are going to influence both the insect pests (as hosts) and the insect bio-control agents thriving on them, but their association would continue and hence the role of BCAs. There are several potential BCAs in soybean eco-system. They include parasites (*Brachymeria* spp., *Appenteles* spp. and larval parasite *Sturmia* spp.); predators (*Rhinocoris fuscipes*, *Cantheconidia furcellata*, *Chrysopa carnea*, Dragon fly, Spiders) and insect pathogens (*Beauveria bassiana*, *Noumeria* (*Spicaria*) *rileyi*, *Bacillus thuringiensis* and Nuclear Polyhedrosis Virus). These naturally occurring bio-control agents are most active during the month of August and can suppress insect population to the extent of 16-20 percent. Although the efficacy of native strains of insect pathogens would be influenced by high temperature and sometimes by water stress conditions (Devi *et al.*, 2005), under congenial conditions, they can control up to 100 % larval population (Sharma and Ansari, 2007). In view of immense potential, farmers' intervention is warranted for conservation and augmentation of bi-control agents, which could be – i) implementing the concept of IPM by using its various components; and ii) rational use of chemical insecticides (use only when felt utmost necessary, only approved pesticides to be used in recommended dosage, use adequate quantity of water for proper crop coverage, avoid using during peak activity of parasitoids, predators and pollinators).

For self and perpetual multiplication of *Trichogramma* spp., a device has been developed by ICAR-NCIPM, New Delhi. It essentially consists of a PVC box with some coarse grains serving as diet for *Corcyra cephalonica*. The eggs laid by *Corcyra* serve as the host for egg parasitoid, *Trichogramma* spp. After hatching from *Corcyra* eggs the adults fly out of the box and parasitize *Helicoverpa* eggs in the field. Commercial Trichocards consisting of glued, parasitized eggs are now available for ready use in the fields. Placing the cards equivalent to 16000 eggs normally gives about 80 per cent control of *H. armigera* (Abbas *et al.*, 2020).

Use Microbial pesticides: Realizing the potential of microbial pesticides in managing major insect-pests and diseases of soybean (Sharma, 1998; Sharma, 2000; Sharma and Ansari, 2004), some commercial formulations are now available. While *Beauveria bassiana* and *Bacillus thuringiensis* are effective against a variety of insects, the Nuclear Polyhedrosis Viruses are very insect specific. *Beauveria* and *Bacillus* are applied @ 1 kg per ha, while insect specific NPVs are recommended for use in soybean @ 250 LE per ha. These microbial insecticides have better efficacy up to 3rd larval instars. In order to reduce the cost of two separate sprays for insecticides and fungicides, tank mixing was considered as the suitable option. Based on various studies, compatible combinations were recommended (Ansari and Sharma, 2000; 2005). However, there is need to assess the compatibility of microbial pesticides with newly recommended fungicides. As the microbial insecticides are slower than the chemical insecticides in inflicting insect mortality, farmers should be advised to have some patience. It has also been observed that soon after ingestion of sprayed leaves, the larvae stop feeding and become very sluggish. Because of lethargic movement the larvae get exposed easily and get killed even with lower doses of insecticides.

Trichoderma spp. is an excellent antagonist against many soybean diseases. The best way is treating the seed before sowing @ 8-10 g per kg. Sometimes, *Trichoderma* applied faces strong competition from the native micro-organisms. In such cases seed treatment with chemical fungicides becomes inevitable. Farmers should be advised to treat soybean seed with premixed formulation like Penflufen + Trifloxystrobine 38 FS @ 1 ml/kg seed or Carboxin 37.5 + Thiram 37.5 @ 3g/kg seed or 2g Thiram + 1g Carbendazim/kg seed.

Use of Botanical insecticides: With changing climatic conditions, an increased pesticide use is expected in form of higher amounts, doses, frequencies and different varieties or types of products applied. Climate change will reduce environmental concentrations of pesticides due to a combination of increased volatilization and accelerated degradation, both strongly affected by a high moisture content, elevated temperatures and direct exposure to sunlight (Delcour *et al.*, 2014). In this scenario, an alternate and safer strategy of using plant extracts is a ray of hope. Thousands of plant species are endowed with insecticidal properties (Bowers, 1992; Jacobson, 1989; Raheja, 1998; Singh, 2000) which can compete with the synthetic insecticides for their efficacy against insect pests. Contrary to chemical insecticides, which have single active ingredient to act against insects, insecticides of plant origin have a number of active compounds that influence both physiological and behavioural processes. In depth studies were taken up at ICAR-Indian Institute of Soybean Research, Indore with some abundantly available plant species viz. *Acacia arabica* (Babool), *Ipomoea carnea* (Behaya), *Eucalyptus globulus* (Neelgiri), *Annona squamosa* (Sitaphal), *Nicotiana tabacum* (Tambaku), *Datura stramonium* (Dhatura) and *Pongamia pinnata* (Karanj). Results revealed that simple water extracts from seeds of Acacia, Annona and Datura are toxic to *Spodoptera* larvae (Rajguru *et al.*, 2011a). Efficacy of these extracts can further be increased by fortification of *Bacillus thuringiensis* (Rajguru and Sharma, 2012). In an attempt to understand the toxicity symptoms caused by plant extracts, freeze-microtomy was performed with the Cryostat (Rajguru *et al.*, 2011b). Extracts of *Annona* and *Ipomoea* leaves killed the larvae by damaging the integument showing contact mode of action; extracts of *Lantana*, *Nicotiana* and *Pongamia* leaves and seed extracts of *Acacia*, *Annona* and *Datura* damaged microvilli of the alimentary canal suggesting the stomach poisons. Interestingly the leaf extracts of *Acacia*, *Datura* and *Eucalyptus* proved to be both contact as well as stomach poison, disrupting the integument, peritrophic membrane and the midgut epithelial layer.

Simple water extract (100% stock solution) can be made by crushing and filtering 0.2 kg plant material in 1.0 lit water. Thus, for making 100 lit spray solution of 100 % concentration, 20 kg plant material is needed to spray 1 ha crop with power sprayer and 18 kg plant material will be required to make 75% concentration.

Rational use of chemical pesticides: Soybean has capacity to yield normally even with 20-25 per cent foliage loss. Since leaf damage has direct relationship with insect population, it is advisable to use costly chemical insecticides only when insect population increases above "economic threshold level". A number of insecticides have been recommended for the control of soybean insect-pests and use of such insecticides has been found to be effective for proper management of insect-pests.

Chemical insecticides recommended against major insects in soybean

Insect	Insecticides	Dose
Blue beetle	Quinalphos 25 EC	1500 ml/ha
Stem fly	Thiamethoxam 30 FS	10 ml/kg seed
	Lambda Cyhalothrin+ Thiamethoxam	125 ml/ha
White fly	Thiamethoxam 30 FS	10 ml/kg seed
	Imidacloprid 48 FS	1.25 ml/kg seed
	Betcyfluthrin + Imidacloprid	350 ml/ha
Defoliators (Semiloopers, Tobacco caterpillar, *Helicoverpa armigera*)	Chlorantraniliprole 18.5 SC	100 ml/ha
	Indoxacarb 15.8 EC	333 ml/ha
	Profenofos 50 EC	1250 ml/ha
	Quinalphos 25 EC	1500 ml/ha
	Triazophos 40 EC	800 ml/ha
	Spinetoram 11.7 SC	450 ml/ha
	Betcyfluthrin + Imidacloprid	350 ml/ha
	Flubendiamide 39.35 SC	150 ml/ha
	Flubendiamide 20 WG	250-300 ml/ha
	Thiamethoxam + Lambda Cyhalothrin	125 ml/ha
Girdle beetle	Thiacloprid 21.7 SC	750 ml/ha
	Triazophos 40 EC	800 ml/ha
	Profenofos 50 EC	1250 ml/ha
	Betcyfluthrin + Imidacloprid	350 ml/ha
	Thiamethoxam + Lambda Cyhalothrin	125 ml/ha
Pod borer (*Helicoverpa armigera, Cidia ptychora*)	Profenofos 50 EC	1250 ml/ha
	Chlorantraniliprole 18.5 SC	100 ml/ha
	Indoxacarb 15.8 EC	333 ml/ha

Depending upon the crop stage, soybean requires 500 lit spray solution per ha with knapsack sprayer and 120 lit/ha with power sprayer. Spraying with less quantity fails to give desired results. For the benefit and safety of beneficial insects, which are active during peak day time, it would be advisable to perform spray operations in the morning or evening hours following safety measures like covering the face with protective mask as well as wearing the goves.

There is tendency among the farmers for tank-mixing of two or more chemicals, most common being insecticides and herbicides. After systemic research at ICAR-IISR and under AICRP on Soybean, following combinations of insecticides and herbicides were recommended for cost effective management of major insect-pests and weeds.

Compatible combinations of insecticides and herbicides for management of major insects and weeds in soybean

Insect(s)	Weed(s)	Combination(s)
Stem fly	Monocot + Dicot	Chlorantraniliprole + Imazethapyr
	Monocot	Chlorantraniliprole + Quizalofop Ethyl
Semi-loopers	Monocot + Dicot	Chlorantraniliprole + Imazethapyr
	Monocot	Chlorantraniliprole + Quizalofop Ethyl
	Monocot + Dicot	Indoxacarb + Imazethapyr
Tobacco caterpillar	Monocot + Dicot	Chloantraniliprole + Imazethapyr
	Monocot + Dicot	Quinalphos + Imazethapyr
	Monocot	Quinalphos + Quizalofop Ethyl
Girdle beetle	Monocot + Dicot	Chlorantraniliprole + Imazethapyr
	Monocot + Dicot	Indoxacarb + Imazethapyr

Do's	Don'ts
While Purchasing • Purchase pesticides/biopesticides only from registered pesticide dealers having valid Licence. • Take proper receipt of payment made. • See approved labels on the containers/packets of pesticides. • See Batch No., Registration Number, and Date of Manufacture / Expiry on the labels. • Purchase pesticides well packed in containers.	**While Purchasing** • Do not purchase pesticides from foot path dealers or from un-licenced person. • Never take '*kachcha*' receipt for little monetary benefit. • Do not purchase pesticides without approved label on the containers. • Never purchase expired pesticide. • Do not purchase loose pesticides or whose containers are leaking/ unsealed.
During Storage • Store the pesticides away from house premises. • Keep pesticides in original containers. • Pesticides/weedicides must be stored separately. • Where pesticides have been stored, area should be marked with warning signs. • Pesticides be stored away from the reach of the children and live stocks. • Storage place should be well protected from direct sunlight and rain	**During Storage** • Never store pesticide in house premises. • Never transfer pesticides from original to another containers. • Do not store insecticides with weedicides. • Do not allow children to enter the storage place. • Do not allow children to enter the storage place. • Pesticides should not be exposed to sunlight or rain water.
While Preparing spray solution • Always use clean water. • Use protective clothing viz., hand gloves, face masks, cap, apron, full trouser, etc. to cover whole body.	**While Preparing spray solution** • Do not use muddy or stagnant water. • Never prepare spray solution without wearing protective clothing. • Do not allow the pesticide/its solution to fall on any body parts.

• Always protect your nose, eyes, ears, hands, etc. from spill of spray solution • Read instructions on pesticide container label carefully before use. • Prepare the solution as per requirement. • Granular pesticides should be used as such. • Avoid spilling of pesticides solutions while filling the spray tank. • Always use recommended dosage of pesticide.	• Never avoid reading instructions on container's label for use. • Never use left out spray solution after 24 hours of its preparation. • Do not mix granules with water. • Do not smell the spray tank. • Do not use overdose which may affect plant health and environment. • Do not eat, drink, smoke or chew during whole operation of pesticides.
While applying spray solutions • Apply only recommended dose and dilution. • Spray operation should be conducted on cool and calm day. • Spray operation should be conducted on sunny day in general. • Use recommended sprayer for each spray. • Spray operation should be conducted in the wind direction. • After spray operation, sprayer and buckets should be washed with clean water using detergent/soap. • Avoid the entry of animals/workers in the field immediately after spray.	**While applying spray solutions** • Never apply over-dose and high concentrations than recommended. • Do not spray on hot sunny day or strong windy conditions. • Do not spray just before rains and immediately after the rains. • Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer. • Do not spray against wind direction. • Never eat or smoke during spraying. • Containers and buckets used for mixing pesticides should never be used for domestic purpose even after thorough washing.
After Spray Operation • Left over spray solutions should be disposed-off at safer place viz. barren isolated area. • The used/empty containers should be crushed with stone/stick and buried deep in soil away from water sources. • Wash hands and face with clean water and soap before eating/smoking. • On observing poisoning symptoms give the first aid and show the patient to doctor. Also show the empty container to doctor.	**After Spray Operation** • Left over spray solution should not be drained in or near ponds or water lines etc • Empty containers of pesticides should not be re-used for storing other articles. • Never eat/smoke before washing clothes and taking bath. • Do not take the risk by not showing the poisoning symptoms to doctor as it may endanger the life of th

[Source: DPPPQ & S, Faridabad]

Dynamic and 2-way linkages: For faster exchange of information from farmer to the expert and back, it is imperative to have strong two-way digital and dynamic communication system. The farmer should be able to communicate his problems to the expert and get a suitable advice in a very short time. Sending pictures depicting the problems like insects, or insect damage symptoms, weeds, disease symptoms etc. help the experts to provide pin-pointed recommendation to deal with the problem.

These facilities are now available through many mobile Apps. Using the strength of ICT, several organizations have developed mobile-based applications which are available on the web for free download and use by the farmers. '*Soybean Gyan*' by IISR, Indore, '*Soya Guru*' by Farms.com, '*m-Krishi*' by TCS etc. are some glaring examples. A joint venture of Vodafone-Idea, Nokia and Solidaridad Asia Network is taking shape as 'Vi Smart Agri Project'.

References

Abbas SS, Shahzad MF, Iqbal J, Ullah A, Batool A, Nadeem M, Begum HA, Rehman H and Muhammad K. 2020. *Trichogramma chilonis* as parasitoid: An eco-friendly approach against tomato fruit borer, *Helicoverpa armigera*. J Agril Sci., 12(2): 167-176.

Anonymous. 2016. Annual Report 2015-16. ICAR-Indian Institute of Soybean Research, Indore. 112 p.

Ansari, M. M. and A. N. Sharma. 2000. Congruence of *Bacillus thuringiensis* with various insecticides and fungicides. *Pestology*, 24(4): 16-19.

Ansari, M.M. and A.N. Sharma. 2005. Compatibility of *Bacillus thuringiensis* and *Beauveria bassiana* with new insecticides recommended for insect-pest control in soybean. Pestology 29(9):18-20.

Bashir et al., 2014. Effectiveness of sticky traps in monitoring insects. Journal of Environmental and Agricultural Sciences. Volume 1, Article No. 5.

Bayisa NG, Hundesa N and Tefera BN. 2017. Essential oils applied on sticky traps increase trapping sucking pests under greenhouse conditions. Intl J Res in Agril Sciences, 3(1): 1-5.

Bowers, W.S. 1992. Insecticide compounds from plants, pp 227-35. **In** Phytochemical Resources for medicine and Agriculture'. Eds. Niggs HN & Seliglier D Plenum Press New York, USA.

Devi Uma K, Sridevi V, Mohan M Ch and Padmavathi J. 2005. Effect of high temperature and water stress on in vitro germination and growth in isolates of the entomopathogenic fungus Beauveria bassiana (Bals.) Vuillemin. J Invertebrate Pathology, 88(3):181-9.

Delcour I P, Spanoghe P and Uyttendaela. 2014. Literature review: Impact of climate change on pesticide use. Food Research International. DOI: 10.1016/j.foodres.2014.09.030. http://www.sciencedirect.com/science/article/pii/S0963996914006309

Dupare, B.U. and Billore, S.D. 2021. Soybean Production: Package of practices and Technical Recommendations. Extension Bulletin No. 16. ICAR-Indian Institute of Soybean Research Publication. Pp: 50

FAO (2010) "Climate-Smart" agriculture: policies, practice and financing for food security, adaptation and mitigation. FAO, Rome, Italy. http://www.fao.org/docrep/013/i1881e/i1881e00.pdf. Accessed 20 Feb 2018.

Heeb L, Jenner E and Cock MJW. 2019. Climate-smart pest management: building resilience of farms and landscapes to changing pest threats. J Pest Sci., 92:951-69.

Hooks and Johnson, 2003Impact of agricultural diversification on insect community of cruciferous crops. Crop Protection, 22(2):223-238.

Jacobson, M. 1989. Botanical pesticides, past, present and future. **In** Arnason JJ, Philogene, BR, Morand P (eds.) Insecticides of plant origin, ACS Symposium Series 387: 1-10.

Joshi, O.P. and A.N. Sharma. 2003. Newer high yielding and insect resistant soybean varieties. In: Souvenir released on the occasion of 41st All India Convention of Oilseeds and Oil Trade & Industry, Vision 2020 – Self-sufficiency in Oilseeds with improved productivity. SOPA, Indore, India, Nov. 8-9, 2003. Pp 105-109.

Lima MCF, Leandro MED de A, Valero C, Coronel LCP and Bazzo COG. 2020. Automatic detection and monitoring of insect pests – A Review. Agriculture 2020, 10, 161; doi: 10.3390/agriculture10050161

Miyashita K. 1971. Effects of constant and alternating temperatures on the development of *Spodoptera litura* F. Appl. Ent. Zool. 6(3): 105-111.

Natikar PK and Balikai RA. 2017. Present status on bio-ecology and management of tobacco caterpillar, *Spodoptera litura* (Fabricius) – An update. Internat J Plant Protec., 10(1): 193-202.

Padgham J. 2009. Agricultural development under a changing climate: Opportunities and Challenges for Adoption. The International Bank for Reconstruction and Development /The World Bank. Pp. 170.

Patel, R M; Sharma P and Sharma, A N, (2019a). Prediction of girdle beetle (*Oberiopsis brevis*) infestation through pest-weather model in soybean. *Journal of Entomology and Zoology Studies* 2019; 7(4): 718-723

Patel, R M; Sharma P and Sharma, A N, (2019b). Weather-Based Forewarning Model to Predict Semilooper Population in Soybean. *Soybean Research*, 17(1&2):46-53

Patel, R M; Sharma, A N; and Sharma, P, (2019c). Prediction of *Helicoverpa armigera* (Hubner) larval population using weather based forewarning model in Soybean. *Journal of Agrometeorology*, 21(4): 494-498.

Patel, R.M.; Sharma, P. and Sharma, A.N., (2020). Weather based Prediction Model to Forewarn Tobacco Caterpillar, *Spodoptera litura* (Fabricius) Larval Population in Soybean. *Journal of the Indian Society of Agricultural Statistics*, 74(2).

Peeples, L. 2013. Climate change may magnify toxic chemical dangers. http://www.huffingtonpost.com/2013/11/08/climate-change-chemicals_n_4240450.html

Petzoldt, C. and Seaman, A. 2007. Climate Change Effects on Insects and Pathogens. Fact Sheet. http://www.climateandfarming.org/clrcc.php.

Pieter D. I., Spanoghe, P. and Uyttendaele, M. Literature review: Impact of climate change on pesticide use. *Food Research International*. 2014. DOI: 10.1016/j.foodres.2014.09.030.

Pratheepa M, Prasad YG, Jeyakumar P, Vennila S, Prabhakar M, Singh Niranjan, Barkhede UP, Sharma AN and Antony Cruz J. 2014: Decision tree induction model for forecasting the pest *Gessonia gemma* on soybean based on abiotic factors. *Indian Journal of Plant Protection*, 42(4): 343-348.

Punithavalli M., Sharma A.N. and Rajkumar M.B. 2014. Seasonality of common the cutworm *Spodoptera litura* in a soybean ecosystem. *Phytoparasitica***,** 42: 213-222.

Rajguru Monika and Sharma Amar N. 2012. Comparative efficacy of plant extracts alone and in combination with *Bacillus thuringiensis* sub sp. *kurstaki* against *Spodoptera litura* Fab. Larvae. *J. Biopesticides*, 5(1):81-86.

Rajguru Monika, Sharma Amar N. and Banerjee S., 2011a. Feasibility assessment of plant extracts fortified with *Bacillus thuringiensis* Berliner for management of *Spodoptera litura* Fab. *Intl J Trop Insect Sci*., 31 (1-2): 92-97.

Rajguru Monika, Sharma Amar N. and Banerjee S. 2011b. Toxicity symptoms of plant extracts on *Spodoptera litura* Fab. (Lepidoptera: Noctuidae) larvae. ***Soybean Research***, 9:116-122.

Rao Srinivasa M, Manimanjari D, Rao Rama C A and Vennila S. 2014. Prediction of number of generations of *Spodoptera litura* Fab. on Peanut under climate change scenarios. Global J Biol Agri & Health Sci., 31(1):244-250.

Sharma, A. N. 1998. Microbial Pesticides: Scope in the management of insect pests of soybean. Presented in the National Seminar of Entomology in 21st Century. Rajasthan Agricultural University, Udaipur, April 30- May 2, 1998.

Sharma, A. N. 2000. Bio-efficacy of *Bacillus thuringiensis* based biopesticides against *Spodoptera litura* and *Spilarctia obliqua* feeding on soybean [*Glycine max* (L.) Merrill]. Crop Res., 19(2): 373-375.

Sharma, A.N. and M.M. Ansari. 2004. Exploiting the potential of *Bacillus thuringiensis* in the management of lepidopterous defoliators infesting soybean. *Soybean Research*, 2:26-34.

Sharma, A.N. and M.M. Ansari. 2007. Potential of naturally occurring bio-control agents of lepidopterous defoliators infesting soybean. *Soybean Research*, 5: 84-86.

Singh, R.P. 2000. Botanicals in pest management: An ecological prospective, pp 56-112 **In** G.S. Dhaliwal and B. Singh (eds.), *Pesticides and Environment*, Commonwealth Publishers, New Delhi, India.

Tripathi P, Tiwari A, Pandey JP and Agnihotri S. 2013. Evaluation of cultural methods for insect pest complex of soybean [*Glycine max* (L) Merrill] in district Rewa (MP) India. Intl J of Scientific and Res Publications, 3(10): 1-3.

Vennila S., R Lokare, N Singh, SM Ghadge and C Chattopadhyay. 2016. Crop pest surveillance and advisory project of Maharashtra - A role model for an e-pest surveillance and area wide implementation of integrated pest management in India. ICAR-National Research Centre for Integrated Pest Management, New Delhi 110 012 India. 56p

Wang, J.; Lin, C.; Ji, L.; Liang, A. A new automatic identification system of insect images at the order level. Knowl. Based Syst. 2012, 33, 102–110.

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Role of Micro-organisms in Soybean Production and Seed Inoculation Techniques

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Soybean is leading oilseed crop in the world as well as in India. Malwa plateau of Central India is hub for soybean cultivation. It has gained wide acceptability among growers due to high profit and demand of deoiled cake (DOC) in the livestock industry in the European market due to non-genetically modified nature of crop being grown in India. It is named as golden bean or miracle bean because the seed contains about 40% protein and 20% oil and are the cheapest source of dietary protein. When compared to other countries the average productivity of soybean in India is almost 1/3rd. In India, soybean is mainly grown as rainfed crop and its productivity under rainfed conditions is hovering around 1 t/ha despite the yield potential of up to 4 t/ha. The reason for low and static productivity of soybean is mainly due to erratic, uneven, inadequate rainfall and frequent occurrence of varying degrees/magnitude of drought are perhaps the most important abiotic factor limiting the productivity of soybean. The abiotic stresses (drought, salinity, high temperature, flooding, nutritional deficiency etc.,), aggravates conditions (biotic stresses) under which plants were adversely affected due to soil and environmentally borne diseases e.g., anthracnose, Rhizoctonia root rot, Sclerotinia and yellow mosaic virus. Hence, to mitigate biotic and abiotic stresses, the conventional breeding approaches which are required for developing tolerant varieties are long-term and therefore there is a need to look for other alternatives. The potential of promising plant growth promoting microbes (PGPM) and their contribution in alleviating stresses in plants has been a viable solution and increasingly exploited. The role of mycorrhizal fungi, moisture tolerant plant growth promoting rhizobacteria (PGPR) including rhizobia in the alleviation of stresses are being promoted worldwide. Hence the utilization of climate smart PGPMs such as arbuscular mycorrhizal (AM) fungi, rhizobia and bacilli could be a viable solution to cope up plants for alleviating the adverse effects of stresses.

How Plant growth-promoting microorganisms (PGPMs) works?

Plant growth-promoting microorganisms (PGPM), have a direct and indirect mechanism to promote plant growth (Backer et al., 2018). The direct mechanisms include: (i) Phytohormone production- auxins, gibberellins, and cytokinin, (ii) Nutrient acquisition- biological nitrogen fixation, phosphorus solubilization, Zinc solubilization, and potassium solubilization, (iii) Siderophore production- for iron and phosphorus nutrition and disease suppression, (iv) ACC-deaminase enzyme production- for reducing ethylene level against various abiotic stresses (v) exopolysaccharide (EPS) production for moisture alleviation, And the indirect mechanisms are (i) induction of induced systemic resistance (ISR), (ii) accumulation of compatible solute against osmotic stress, (iii) production of antibiotic and antifungal compounds for disease suppression, (iv) synthesis of volatile compounds and lytic enzymes for disease control. AM fungi species like *Rhizophagus irregularis*, *Feneliformis mosseae* and *Gigaspora* sp. improves plant survival in the stressed ecosystem such as heavy metal stresses. AM fungi enhancing water and nutrient uptake particularly P through their extended hyphal networks and extraradical hyphae (Smith et al., 2011), improve root architecture, antioxidant defense system, promote osmotic adjustment and improve soil structure by the production of glycoprotein called glomalin related soil protein (Agnihotri et al., 2021).

What are microbial endophytes and their role in mitigating abiotuic stresses?

Microbial endophytes (fungi and bacteria) which lives inside the plant parts/niches like stem, leaf, seed, root system without showing any visible symptoms and help in improving plant directly and indirectly and biofertilizing the plant. The endophytes aid nutrient availability and uptake, enhance stress tolerance, and provide disease resistance to plants. For example AM fungi has been recognised as potential endophytes associating with roots of more than 80% plants. These fungi helps in providing mineral nutrition to plants particularly phosphorus in which AM mobilizes P and other macro and micronutrients. They also helps in disease suppression of many soil borne diseases, improve soil physical, chemical and biological properties. Besides mineral nutrition of macro and micro nutrients, it also helps in the improvement of soil aggregation, soil structure which helps in increasing porosity, carbon accumulation, building higher proportion of beneficial soil microbes and thereby improve the root system architecture. A compound name glomalin produced by mycorrhizal fungi that helps in carbon sequestration and thereby increasing carbon pool in the soil. At ICAR-IISR, Indore *Rhizophagus irregularis* (*Glomus intraradices*), a native AM fungi recovered from soybean-based cropping system has shown tremendous role in C sequestration evaluated and validated through field as well as microcosm studies. Similarly ICAR-NBAIM, Mau has developed liquid biofertilizer based Kisan mitra and IARI, New Delhi has developed similar products on the name of PUSA *Rhizobium, Azospirillum, Azotobacter* bacterial bioinoculants. At IISR Indore four bacterial (rhizobia, zinc solubilizing and one mycorrhiza helper bacteria) has developed and found to be potential strains for growth and nutritional traits. AM fungi mobilizes phosphorus and trace elements like zinc, iron, copper, magnesium, molybdenum. These fungi is applied in soil @100-125 spores per meter square placed 2-3 cm just below the seeds at the time of sowing.

How to produce arbuscular mycorrhizal (AM) fungi?

Due to the obligate nature of AMF fungi, it is difficult to multiply in laboratories. However root organ culture technology involving *Agrobacterium* transformed hairy roots are utilized for commercial production of AMF. However due to non-acclimatization, frequent contamination this technology is very tedious, highly skilled and hence not gained momentum among the Indian farmers application point of view. To avoid high costs and promote indigenous and native AMFs these fungi can easily be produced-

1. On raised/elevated beds where after sterilization of soil, elevated/raised beds is formed and manure/compost (3:1, soil; manure) is added.
2. The trap host plants depending upon the season (maize, sorghum, methi and marigold) are grown and AMF mother culture taken from a government agency like (ICAR-IISR, Indore) is placed and multiplied. This system makes a

symbiotic association with the roots of plants.

3. Harvesting: after completion of life cycle of trap plant, the tops are cut and roots were harvested. Roots along with adhered soils are taken. The roots are cut into pieces and mixed with harvested soil, this constitutes mycorrhiza inoculum.

Potential microbial strains available for soybean application (ICAR-IISR Indore)

- Nitrogen-fixing soybean rhizobia, *Bradyrhizobium japonicum, B. liaoningense and B. daqingense* (Ind-1, Ind-2 and Ind-10A) developed at ICAR-IISR, Indore. These rhizobial isolates were relatively drought-tolerant and improve nodulation under field conditions. Increase yield upto 15% higher and enhanced nitrogen fixation.
- Soybean rhizosphere isolate, Bacillus aryabhattai strain improved Zn content in seeds and increased soybean plant growth and yields.
- Similarly, soybean native arbuscular mycorrhizal fungi (*R.irregularis*/*Glomus intraradices, Fenneliformis/G. mosseae* and *G. geosporum*) can be multiplied using a suitable host like sorghum, maize, amaranthus and marigold depending upon the season of the crop in raised beds. The root along with soil is harvested and the root is made into small pieces along with soil, packed in a cool place. AMF is phosphorus mobilizer, and help against drought stress in plants.
- Under AICRP-Soybean project, IISR evaluated and identified AM fungi and *Paenibacillus polymyxa* HKA-15 (IARI strain) promoting the soybean yield upto 20% with saving of fertilizer inputs.

Modes of application

Seed treatment: Should be applied after all the treatments (fungicide, insecticide), in general seed treatments with suitable biofertilizer @ 10-15 g per kg seed is sufficient. A sticking agent may be used. The biofertilizer powder and sticking agent should be applied on seeds and dried in a cool and shady place.

Soil application: As per the instructions given on the packet, take 5 kg of biofertilizer and suspend in 10 liters of water and mixed in 200 kg of compost and kept overnight and this mixture can be applied.

Precautions

- Avoid from direct exposure of sunlight and plant-protection chemicals
- Treated seed should be made dry in cool and shady places.
- Whole packet should be used in one go
- Do not use jiggery as sticking agent as it will invite termite during moisture stress.
- Why farmers are not inclined/low acceptability towards the biofertilizers?
- The many products available in markets are spurious and farmers want instant results of the application.
- The region-based biofertilizer is unavailable. So inoculant cannot able to compete with native microflora and even due to different soil chemical properties.
- Due to very low costs (10-15 Rs each), poor formulation (black colour) of charcoal power farmers are not willing to make their hands dirty
- The lack of awareness among farmer and unavailability of biofertilizer at right time.

Future direction of research

Keeping in view of above, the potential of microbes in combating the abiotic and biotic stresses is tremendous. However, a systematic research is needed to harness their potential to stay longer more effectively under the changed climatic conditions. Hence there is need to concentrate on the followings to achieve sustainability in soybean productivity without compromising the ecology and environment-

- Evaluation of niche-based microbes suitable for abiotic and biotic stress conditions.
- Recovering of bacterial endophytes inhabiting in different plant parts of soybean such as seeds, roots, stem etc., for stress alleviation conditions.
- Develop techniques for effective delivery of microbes which can stay longer more effectively as per the changing climatic conditions) (customized formulation technologies)-enhanced shelf life.
- To do away charcoal-based career formulations by replacing with liquid based concentrated bioformulations with enhanced shelf life.
- Identification and quantification of functional genes in the microbial strains responsible for specific traits needed for abiotic and biotic stresses
- Development of effective consortia bearing multi-traits after evaluating compatibility tests.
- Identification of long-term farming systems for recovering microbial strains based on harbouring higher functional genes.
- Enforce the stringent regulations for monitoring and stopping the spurious products in the market.
- Notify/create referral laboratories for testing the quality of biofertilizer products.

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Management of Viral Diseases of Soybean under Changing Climatic Scenario

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What is a plant Disease: Any variation from the normal, as expressed either by the checking or the interruption of physiological activities or by structural changes, which are sufficiently permanent to check development, cause abnormal formations or lead to premature death of a part of the plant or the entire plant (Heald, 1933)

Importance of plant diseases: Plant diseases are important as they cause loss. The loss can occur in the field or in the store and at any time between sowing and consumption of the harvest.

In the history of mankind, plant diseases have connected with a number of events:

1. In 1845 the late blight of potato destroyed the crop in Ireland and parts of Europe causing famine. A large number of people died because of hunger.
2. In 1943 Bengal faced a serious famine due to loss in rice yield, which was attributed attack of Helminthsporium leaf spot.
3. Wheat rust has appeared in epiphytotic form in many countries from time to time. This forced farmers of the world to change cropping pattern.
4. In addition to loss in yield and monetary returns, the plant diseases affect in many ways by production of toxins, etc.

The reduction in yield in India is due to a number of diseases and insect pests. Soybean crop suffers from diseases at pre and post emergence as well as later stages of crop growth till maturity, which are caused by fungi, bacteria, viruses, nematodes and mycoplasma.

- **Fungi:** They are chlorophyll less organisms, Unicellular or multicellular filamentous reproduces by vegetative cells, well defined sexual or asexual spores.
- **Bacteria:** They are typical unicellular organism, lack of definite organised nucleus. Individual cells either spherical, rod shaped or curved and may occur singly, in pairs or in chains. In general these organisms lie within the range of 1 - 5 µm.
- **Phytoplasmas:** They are vector or graft transmissible, in some cases dodder transmission is successful. They can be cultured and Koch's postulate can be proved. They are very small unicellular and highly pleomorphic showing small coccoid, ring forms, and fine filamentous. They are inhibited by tetracycline.
- **Viruses:** Plant viruses are a group of living infectious entities showing absolute obligate relationship with living cells. They are made of nucleic acid and protein. Mostly RNA viruses with few exceptions (colmv, plr). The first plant virus was TMV.

The average losses from these diseases are about 12-20%. Hence, recognition or proper identification of these diseases are very important for their management. Some major soybean diseases and their identification and control measures are described below.

A: Root & Seedling diseases

1. Collar rot: It is a soil borne, caused by Sclerotium rolfsii. Hot and humid conditions favour the disease.

Symptoms:

i) The characteristic symptom is formation of white cottony mycelium with reddish brown to dark brown mustard size sclerotia on the surface.
ii) Pathogen attacks collar region or just below the soil surface and causes damping off in younger and collar rot in older plants resulting drooping or wilting of plants.

Control measures:

i) Seed treatment with vitavax @3g/kg or with Trichoderma @ 5 g/kg seed.
ii) Field sanitation, rouging and burning of infected plants check spread of disease.
iii) Crop rotation with maize or sorghum.
iv) Deep summer ploughing to a depth of 15-20 cm which helps in reducing the pathogen as the sclerotia perpetuate through soil, crop residue and weeds.
v) Use tolerant variety NRC 37.

2. Charcoal rot: It is soil as well as seed borne disease, caused by Macrophomina phaseolina. Dry conditions, less soil moisture and temperature ranging from 25 to 35 ºC favour the disease.

Symptoms:

i) Fungus infects the root and stem base. Infected seedlings become week and die prematurely. The leaves drooped down dry and always attached with plants.
ii) Typical charcoal rot shows brown discolouration of lower stem and upper tap root with chlorotic leaves in the beginning and silvery grey stem later.
iii) Abundant minute black sclerotia beneath the outer skin with silvery grey colour are diagnostic character of the disease.

Control measures:

i) Seed treatment with Thiophanate methyl 45% + Pyraclostrobin 5% FS @ 3 ml/kg seed or Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed.
ii) Irrigation during low soil moisture (drought condition) especially at the time of flowering to pod-fill stage.
iii) Crop rotation with cereals or mixed cropping.
iv) Balanced use of fertilizer and proper seed rate.
v) Use tolerant varieties like NRC 2, NRC 37, JS 71-05, AMS 5-18, JS 20-98, MACS 13 etc. Sowing at raised bed or broad bed with basal application of Zinc Sulphate @ 25 kg/ha along with Boron @ 0.5 kg/ha reduces the infection of charcoal rot.

3. Bacterial pustule: Xanthomonas axonopodis pv. glycines is the causal organism of this disease. The bacterium over seasons in seeds, crop debris and in the rhizosphere of wheat roots. The bacterium spreads through water splashing or wind blown during rains. The first infection generally takes place at 25-30 days after planting and new infection may occur throughout the growing seasons. The bacterium enters through the natural openings and wounds. Warm weather conditions and frequent rains during the cropping season expose the plant for infection.

Symptoms:

i) Small pale green spots with raised centres develop on either or both sides of the leaf. Spots look like a dark centre with a pale green halo or ring.
ii) In severe conditions these lesions merge together and forms irregular mottled brown areas.
iii) Leaves become ragged when dead areas are torn away by wind.
iv) Severe infection results defoliation.
v) Small reddish brown slightly raised spots also develop on pods in highly susceptible cultivars.

Control measures:

i) Use resistant varieties like NRC 2, NRC 7, Ankur, Hara Soy, JS 335, PK 416, PK 472, PS 564, PK 308 and PK 327 etc.
ii) Use disease free seeds.
iii) Seed treatment with vitavax @ 0.2%.
iv) Follow crop rotations with cereals and maize.
v) Use balanced dose of fertilizer specially potash 40-80 Kg/ha
vi) Spray Kasugamycin @ 0.2 % at 15 days intervals.

4. Bacterial Blight: This is caused by Pseudomonas syringae pv. glycinea. Pathogen over seasons in crop residue and seeds. Primary infections of cotyledons are the major source of the inoculum that causes secondary infection. The bacterium enters the plant through natural openings and cuts and multiplies in the intercellular spaces of the mesophyll. Though cool and rainy weather favours the development of disease, but high temperature above 35 0C helps in controlling the disease.

Symptoms:

i) Blight lesions are more conspicuous on leaves abut also occur on stem, petioles and pods.
ii) Small angular translucent water soaked yellow to light brown spots appear on leaves.
iii) The centres soon dry out and turn reddish brown to black and are surrounded by a yellowish green halo.
iv) The centres frequently fall out to form ragged leaves.
v) Young leaves are most susceptible. Large black lesions also develop on stem and petioles.
vi) Pod lesions at first are small and water soaked turn brown to black with age. vii. Infected seeds during storage may shrivel and develop sunken or raised lesions.

Control measures:

i) Use disease free and healthy seeds.
ii) Use resistant varieties like PK 472, JS 335 etc.
iii) Seed treatment with carbendazim.
iv) Spray carbendazim @0.2%.
v) Follow crop rotations with non-host crop.
vi) Use balanced dose of fertilizer specially potash 40-80 Kg/ha
vii) Avoid field operation and intercultural operation when leaves are wet.

5. Yellow Mosaic

Causal organism: Mung Bean yellow Mosaic Virus (MYMIV)

Symptoms: Yellow spots are either scattered or produced in indefinite bands along the major veins. Rusty necrotic spots appear in the yellow areas as the leaves mature. Some time severe mottling and crinkling of leaves are also seen. Leaves of severely infected plants become yellow when they are young. Affected plants bear less flower and pods. The infection results in decrease in oil and increase in protein content. The virus is sap transmitted and spread by white fly Bemesia tabaci. The BYMV has a wide host range, which includes pulses and weeds.

Control measures:

i) Cultivation of resistant varieties like JS 20-29, JS 20-69, JS 97-52 ,PK 416, PK 472, CO-1, MACS 450, PS 564, PS 1024, PS 1029, PS 1092, Shivalik, and SL 295
ii) Seed Treatment with Thiamethaxam 30 FS @ 10 ml/Kg or Imidachlloprid 48 FS 1.25 ml/kg seed
iii) Spray Thiamethaxam 25WG @ 100g/ha at 35 DAS.
iv) Use balanced dose of fertilizer.
v) Rouging and burying of infected plants.
vi) Follow clean cultivation practices.

6. Soybean Mosaic: It is caused by Soybean Mosaic Virus (SMV). It is a seed borne disease, infected seeds may fail to germinate or produce diseased seedlings. Symptoms are less severe at 24-25 oC and masked above 30 oC. Very often the SMV infected plants in the field may also get infected with BYMV. The disease is transmitted with a number of aphid species e.g. Aphis craccivora, Aphis gossypi and Myzus persicae

Symptoms:

i) A yellowish vein clearing symptom appears along the small branching veins of young leaves.
ii) Typical rugosity appears on third trifoliate leaves.
iii) Necrosis, brown discolouration of leaf veins, yellowing of leaves, stunting of the plant and defoliation are the results of systemic infection.
iv) iv. Affected plants produce flattened, stunted and curved pods with less pubescence.

Control measures:

i) Use resistant varities like Hardee, Ankur, PK327, Birsa Soybean 1, MACS 57 etc.
ii) Seed Treatment with Thiamethaxam 70WS @ 3g/Kg
iii) Spray Thiamethaxam 25WG @ 100g/ha at 35 DAS or Metasystox @0.01% at 10 days intervals.
iv) Use balanced dose of fertilizer.
v) Rouging and burying of infected plants.
vi) Follow clean cultivation practices.

7. Bud blight like Symptoms: Causal organism: Bud Necrosis Virus (BNV). BNV can infect all stages of plant growth but susceptibility to virus decreases after bloom. Generally the plants infected while less than 5 week old. Such plant show stunted growth with less number of nodes and internodes. Plants grown at a temperature above 25oC do not show stunting. It is a seed borne and infects the members of family Amaranthaceae, Chenopodiaceae, Compositae, Leguminaceae, Cucurbitaceae, Malvaceae, Solanaceae and Umbelliferae

Symptoms:

i) The most typical symptom is curving of terminal buds to form a crook like structure.
ii) Later other buds of the plant become brown, necrotic, and brittle, such buds fall off at slightest touch.
iii) The pith of stem and branches show a brown discolouration.
iv) Petioles of the youngest trifoliate leaves are often thickened, shortened and curved.
v) Pods are under developed and do not produce viable seeds and drops early.
vi) Maturity is delayed. They remain green until harvest.

Control measures:

i) Use resistant or tolerant varieties like MACS 124, NRC 37 etc.
ii) Use balanced dose of fertilizer.
iii) Rouging and burying of infected plants.
iv) Follow clean cultivation practices.
v) Use pre emergence herbicide to kill or rouge out broad leaves weeds as they harbour the pathogen.

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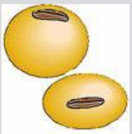

Climate Smart Practice for Seed Treatment in Soybean

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Introduction

Soybean (*Glycine max* L. Merril) is the world's most important seed legume which contributes 25% of the global edible oil, about two thirds of the world's protein concentrate for livestock feeding. Soybean meal is a valuable ingredient in formulated feeds for poultry and fish. At present India ranks fifth in the area and production in the world after USA, Brazil, Argentina and China. The contribution of India in the world soybean area is 10-11% but the contribution to total world soybean grain is only 4 to 5% indicating the poor levels of productivity of the crop in India (1.1 t/ha) as compared to other courtiers (World average 2.3 t/ha). Currently soybean, a leading oilseed crop in India, is grown by millions of small and marginal farmers in rainfed agro-ecosystem. The climatic variability leading to delay in monsoon, drought spells of different duration at various growth stages, water logging conditions and above normal temperatures particularly at seed fill stage are the main reasons of low productivity of soybean in India. Climate change is explicitly accepted as real and become a serious global problem. Poor germination potential of soybean seed and faster deterioration of its seed quality under ambient storage are major problem. The problem of soybean seed germination and field emergence is chronic and should be tackled to some extent by improved seed treating techniques.

Seed Treatmen: Seed treatment is defined as the application of fungicide, insecticide, bio-fertilizer or any other growth regulator either to control the pathogen or insects or to improve the germination potential.

Why Seed Treatment?

- For qualitative improvement in the seed
- Improving the field performance and storability
- Enabling mechanized sowing
- Preventing the infection or predation of seeds and seedlings by pests resident on seed or in the soil
- Low pesticide dosage: Pesticide is applied directly to the "target" in very small dosaes, not throught the enroronment for foliar application
- To transform seed as a carrier of basic inputs such a pesticides, herbicides, nutrients etc., which redefines agriculture as a profit oriented art, business or science.

Advantages of seed treatment

- It protects germinating seeds and seedlings against soil and seed borne pathogens/insects.
- Seed treatment improves Seed germination.
- Helps in early and uniform establishment and growth.
- Enhances nodulation in legume crop.
- Seed Treatment is better than soil and foliar application as very less quantity of chemical is require thus less hazardous to environment.
- Uniform crop stand, even in adverse conditions (less/high moisture).

Evolution of seed treatments

Like many discoveries, seed treatments got their start by accident. In the 1600s, a boat full of grain sank off the coast of England. While the wheat recovered was unfit for milling, some local farmers tried planting it. The seawater-soaked seed produced a crop mostly free of smut, while unsoaked seed produced crops with heavy smut infestations. Thus began the quest for the holy grail of seed treatments. • Some of the first recorded seed treatments are the use of sap from onion (Allium spp) and extract of cypress in the Egyptian and Roman periods. • Salt water treatments have been used since the mid-1600s and the first copper products were introduced in the mid- 1700s

TYPES OF SEED TREATMENT

Seed dressing: This is the most common method of seed treatment. The seed is dressed with either a dry formulation or wet treated with a slurry or liquid formulation. Dressings can be applied at both farm and industries. Low cost earthen pots can be used for mixing pesticides with seed or seed can be spread on a polythene sheet and required quantity of chemical can be sprinkled on seed lot and mixed mechanically by the farmers.

Seed coating: A special binder is used with a formulation to enhance adherence to the seed. Coating requires advanced treatment technology, by the industry. Seed coating Polymers are used in the film coating process. The film coating process consists of the application of a thin water permeable polymer based coating layer onto the seed.

Advantages of Polymers - Better shelf life as a result of less settling out of components. Greater flexibility of dilution at point of use. Less water, resulting in reduced shipping cost and storage costs. Having both hydrophilic and hydrophobic blocks, Wide range of solubility, lack of toxicity and non-interference with enzymatic activity, make them ideal carriers of bioactive materials as well as seed coating agents.

Seed pelleting: The most sophisticated Seed Treatment Technology, resulting in changing physical shape of a seed to enhance palatability and handling. Pelleting requires specialized application machinery and techniques and is the most expensive application.

Occurrence of mycoflora on and in seed has detrimental effect on seed quality at storage. The seed deterioration is accelerated by the infection of storage fungi – namely Aspergillus sp, Penicillium sps. and Rhizopus sps. In the tropical and sub- tropical regions where relative humidity is higher during seed crop maturity, the risk of attack of saprophytic fungi is more. Rains during seed crop maturity may cause devastating loss of seed quality. The infection of storage fungi has cumulative effect on biochemical degradation of seed.

Seed borne Disease of Soybean	**Causal organism**
Purple seed stain	*Cercospora kikuchii*
Phomopsis Seed decay	*Diaporthe phaseolorum and Phomopsis longicolla*
Anthracnose	*Colletotrichum truncatum*
Soybean mosaic	Soybean mosaic virus

Fungicidal seed treatment may be divided into three categories, depending on the nature and purpose of the treatment. These categories are: (1) seed disinfection, (2) seed disinfestation, and (3) seed protection. A given fungicide may serve in one or more of these categories. Seed disinfection - Disinfection is the elimination of a pathogen which has penetrated into living cells of the seed, infected it and become established-for example, loose smut of barley and wheat. Seed disinfestations - is the control of spores and other forms of pathogenic organisms found on the surface of the seed. Seed protection - Seed protection is chemical treatment to protect the seed and young seedling from pathogenic organisms in the soil.

  	
Seeds infected with seed borne diseases-*Cercospora kikuchi* and soybean mosaic virus	**The seedling mortality due to *Sclerotium rolfsi* infection**

Seed treatment materials are usually applied to seed in one of four forms: dust; slurry (a mixture of wettable powder in water); liquids; and planter-box formulations. Based on composition, seed treatment fungicides may be organic or inorganic, metallic or non-metallic, and, until recently, mercurial or non-mercurial. Before the cancellation of the 'volatile mercurials, fungicides for treating seed were generally classified as volatile and non-volatile. Vlith the elimination of the volatile mercurials, most fungicides now approved for use on seed are classified as non-volatile. When using this type material, complete coverage of the seed is necessary to obtain effective control. Some of the systemics, a fairly new class of pesticides, may now be used as seed treatment materials. The desirability of having materials that would move inside the seed or plant and control the pest has long been recognized. Such materials are called "systemic." When used according to the manufacturer's recommendation (see label), a systemic moves through the host plant and controls or retards the growth of certain fungi and insects without affecting the host's metabolic system

The advanced techniques should be followed to produce seeds of better quality and prevent the chances of seed quality loss and seed damage. The measures start with proper seed treatment before sowing to storage of seeds for next sowing season.

	
Polymer coated soybean seeds	Seed Treating Machine

Seed treatment with recommended dose should be followed to improve seed germination and field emergence by protecting the seed from internal as well as external fungal infections. The texture of soybean seed coat is very smooth. Therefore, loss of chemical applied to seed through powder formulations is very high. Seed treatment becomes non-effective if the chemical is not fixed to seeds and it does not enter into the seed to give systemic effect. Soybean seed germination is epigeal type i.e. the seed comes out of the soil due to higher elongation of the seedling hypocotyl. Therefore, most of the powders applied to seed get shed out from seed surface during seedling emergence. Seed polymer coating is most advanced technique to make seed treatment most effective and economical. This polymer coating technique binds the beneficial chemicals on the surface of the seed and does not allow the chemical to get shed out of the seed neither during seed handling, sowing nor during seedling emergence. The chemical gets sufficient time to enter into the seed with the intake of moisture from soil and act systemically and check the growth of internal as well as external fungal infection. Present day seed polymers are manufactured by several firms and being used by private seed companies to improve seed quality as well as improve aesthetic value of high value low volume seeds. The polymer coating technique can be used for all purposes like seed treatment with fungicide and insecticide, application of seed invigorating chemicals, micronutrients (Boron, molebdenum, zinc, iron etc) and bicontrol agents like Trichoderma, etc. The problem of soybean seed germination and field emergence is chronic and should be tackled to some extent by this improved seed treating techniques. Soybean seed can be polymer coated with fungicides-carbendazime, carboxin, thiram; insecticide- thiomethoxam; seed invigorating chemicals – Salicylic acid; micronutrients - boric acid, ammonium molybdate. One of our study has provided evidence for the value of the approach of polymer film coating *Trichoderma sp.* onto the seed using polymer coating technique. Endophytic growth of *Trichoderma* was traced in root, stem, leaf as well as pods. The technique was found successful to improve plant stand by controlling seedling mortality due to Collar rot, to improve plant health and seed yield by controlling foliar diseases - *Sclerotium rolfsi, Rhizoctonia* arial blight, Myrothecium leaf spot diseases. The study reveals that seeds treatment with *Trichoderma* sp. have the potential to highly reduce the disease on soybean. This technique can be followed well before sowing time and seeds can be stored without any adverse effect. The economics of this technique is very viable and cost incurred on chemicals can be reduced by reducing the doses of chemicals due to very high efficiency of application. This modification of doses is still a researchable issue and work is going on for finalization of such recommendations

Drying of polymer coated seeds

Recommended Chemicals and Dose of Seed Treatment in Soybean

Carbendazime + Thiram: 2g + 1g per kg of seeds.
Bio Control agent: *Trichodema viridae* (5g talcom powder/kg seeds) (Spore content 10^7)
Rhizobium culture: 5g per kg seeds.

Climate smart seed treatments for improvement of soybean

Chemical	Mode of application and dose	Beneficial effect
Pyraclostrobin & Thiophenate methyle Trade name (Xelora)	Seed treatment 1 g formulation per kg seed	• Improved germination and field emergence • Increased plant vigour and higher nitrogen metabolism
Molybdenum	Seed Treatment 1.0 g/kg seed	• Higher rate of nodule formation and nitrogenase activity • Higher yield
Rhizobium inoculant strain of *Bradyrhizobium japonicum* WB74	Seed Treatment 1.0 g/kg seed	• Guarantees high nodulation and a maximum level of N2-fixation. • Easy to use and compatible with standard seed treatment applicators • Increased yields and improved crop uniformity • The unique wet granular formulation offers high concentration of bacterial cells within protective capsules giving the products natural sticking properties for seed treatments
Pyraclostrobin & Thiophenate Methyl mixture + Carbendazim	Seed Treatment 0.1g + 0.9ga.i.(2g) + 1g /kg seed	• Improves field emergence, reduces seedling mortality due to collar rot • Improves plant stand with healthy plants seed germination, plant growth, plant health and • Increase yield as plant population maintained
Combination of biomolecule and micronutrient through polymer coating (Salicylic acid, MO B)	Seed Treatment S75 ppm + Mo1g + B200 mg (Treating solution consists of 3g polymer+ 1 g Ammonium Molybdate + 200mg boric acid + 6ml distilled water)for 1 kg seed)	• Increased seed yield, leaf chlorophyll and field emergence

Biocontrol agent through polymer seed coating	Seed treatment 3 g polymer, 3 ml spore suspension of *Trichoderma sp*, and 3.5ml of dw / kg of seeds	• Improves plant stand by controlling seedling mortality due to Collar rot. • Improves plant health and seed yield by controlling foliar diseases -*Sclerotium rolfsi*, Rhizoctonia arial blight, Myrothecium leaf spot diseases.

References:

Cliquet, S. and Scheffer, R.J. (1996). Biological control of damping –off caused by *Pythium ultimum* and *Rhizoctonia solani* using *Trichoderma spp*. applied as industrial film coating on seeds. *Eur. J. Plant Path*. **102**: 247-255.

Jumrani, K., Bhatia, V.S., Pandey, G.P. (2017). Impact of elevatedtemperatures on speciûc leaf weight, stomata density, photosynthesis and chlorophyll fluorescence in soybean. Photosynth Res. **131**: 333-350.

Kuchlan, P., Kuchlan, M.K. and Ansari, M.M. (2019). Efficientapplication of *Trichoderma viride* on soybean [*Glycinemax* (L.) Merrill] seed using thin layer polymer coating. Legume Research. **42(2)**: 260-264.

Kuchlan, P. and Kuchlan, M.K. (2021).Effect of Salicylic Acid on Plant Physiological and Yield Traits of Soybean. Legume Research. DOI: 10.18805/LR-4527. Liu P. (2000). The effect of molybdenum and boron onnutritional and physiological mechanism of yield and quality in soybean. *Ph.D. Thesis. Zhejiang University*, Hangzhou.

Punam Kuchlan and Mrinal Kuchlan **(2016).** Effect of Pyraclostrobin and Thiophenate methyl on seed germination, plant growth and disease control of soybean (Glycine Max (L) Merrill.) ***Bhartiya Krishi Anusandhan Patrika*.** Vol **31**(1): **11-14**

P. Kuchlan and M.K. Kuchlan. (2020). Effect of molybdenum, boron and salicylic acid application to soybean Seeds using poly mer coat ing on field weath er ing and seed yield. *Progressive Research – An International Journal Volume* **15 (3)**:156-159

Punam Kuchlan and M.K. Kuchlan (2021). Intrinsic Factors of Soybean Seed Quality Loss and Practical Approach to Tackle The Problems. *AgroScience Today*. **2(2): 49 – 55**

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Extension Strategies for Improving the Soybean Sector against Climate Change Risks

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According to IPCC, Climate change as defined by Intergovernmental Panel on Climate Change (IPCC) "refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer". Among all the sectors- i) primary (mining, fishing, agriculture etc.,); (ii) secondary (oil refinery, manufacturing, food processing etc.) and (iii) tertiary (financial, education, banking, etc.), agriculture is more vulnerable to climate change.

Climate change – Overview

Climate change alters the production systems, thereby threatens the food security of the billions of population across the globe. Weather is the single largest source of variability that affects farm output drastically. About 20-80 % of the inter-annual variability occurs due to variability in weather parameters. The weather changes bring either direct physiological stress in the crops or indirect pest and diseases or both (PIB, 2019). Further, climate change would be a threat to the livelihood of 36 % or 2.6 million of the global population, because their income source is directly dependent on agriculture and allied activities (Dickie et al, 2014).

Climate change – contributing factors

Greenhouse gases (CO_2, CH_4 and N_2O) in the atmosphere and their variations are the major cause of climate change. India's share of GHG emission to the total emission of the world is about 6.55 %, thereby becoming the third largest GHG emitter in the world (Sapkota et al, 2019). Both natural and anthropogenic activities are contributed to the emission of GHG worldwide. In India, the sectors such as Energy, Agriculture, Industrial process, land use management and wastes release about 68.7 %, 19.6 %, 6 %, 3.8 % and 1.9 % of Green House Gases (GHG) respectively to the climate change. Of the 19.6 % of the Green House Gas emitted from the agricultural sector, about 47 % and 45 % of the gases are released from the use of synthetic fertilizers and enteric fermentation, respectively (WRI CAIT, 2017 as cited in USAID). Cattle production is the most important factor in the GHG emission, followed by rice cultivation, buffalo, small ruminant and wheat production. Of the total crops cultivated in India, over 52 % of the GHG emission is from rice cultivation, followed by wheat, cotton and sugarcane. The burning also results in loss of soil nutrients such as N (nitrogen), P2O5 (Phosphorus), and K_2O (Pottasium Oxide).

Impacts of climate change – Indian experience

About 800 million people in South Asia would be prone to climate change scenario including India. GDP per capita in India is estimated to decline to 9.8 % by 2050 under carbon-intense climate change. Also, India may have to face a loss of 2.5 % GDP by 2050 due to climate change. Similarly, the climate change induced yield loss was estimated to be 4.5 to 9 % in India, which will lead to a loss of 1.5 % of GDP on an annual basis (Vijayan and Viswanathan, 2018). In India, the loss of productivity and increase in food price are the two extremities of climate change, which might push about 42 million population additionally into the poverty trap and cause 0.4 % loss in overall consumption rates. India is likely to face around 10 % rise in cereal price and 3-4 % more poverty after 30 years than the present times due to a rise in temperature and other weather parameters (Jacoby et al, 2011). Indian farmers might have to incur near about 3 % net income loss if the temperature rises by 2^0C and +7 % change in average precipitation (Kumar, 2011). Climate change may cost USD 9 to 10 billion every year. India might have to produce 70 million more food grains by 2030 to feed the growing population (The economic times, 2017). India experiences all kinds of vulnerabilities such as drought, floods, cyclone, heatwaves, cold waves, hailstorms, the occurrence of new pest and diseases, etc. The frequency and intensity of these extreme events are increasing steadily. The Soybean farmers in Madhya Pradesh perceived that climate change has reduced the yield of Soybean up to 50% despite following the crop management practices (Dupare et al, 2020).

Soybean production – An overview

Soybean has an important place in the world's oilseed cultivation due to its high productivity, profitability and vital contribution towards maintaining soil fertility. The major soybean-producing nations are the United States, Brazil and Argentina. The three countries dominate global production, accounting for 80% of the world's soybean supply. India is the fourth-largest producer of Soybean (FICCI, n.d.). The soybean crop is cultivated in 11.8 million hectares with a production of 13.5 million tons (2020-21 estimate). It has been cultivated by farmers since the 1960s in India. The states such as Madhya Pradesh, Maharashtra, Rajasthan, Chhattisgarh, Northern Karnataka, Gujarat and Northern Telangana are the leading Soybean producing states. Presently soybean is contributing 42 per cent share of total oilseed and 22 per cent to total oil production in the country.

There are several weather parameters in a climatic system and any changes in these parameters lead to an adverse effect on agriculture and allied sectors. The following table indicates the changes in weather parameter and their effect on Soybean crop.

Mitigation and adaptation towards climate smart agriculture

Climate smart practices and production technologies will help the farmers to mitigate the emission of GHG emission and adapt agriculture to the emerging agrarian issues of climate change. According to Sapkota et al, 2019, GHG emission from agriculture would be 489 MtCO2e by 2030 without any mitigation measures. However, the emission of GHG would be curtailed to 410 MtCO2e with the mitigation mechanism and adaptation measures. I.e. technical mitigation has the potential of 78.67 MtCO2e per year. There are several extension strategies to minimise the impacts of climate change on soybean and improve production and productivity.

Table 1. Weather parameters and their impact on soybean production

S.No.	Weather Parameter	Impact
1.	Temperature	1^0C increase in temperature would cause yield loss of about 3 to 7% in wheat, soybean, mustard, groundnut, and potato. Soybean crops in Central India are found to be more vulnerable to the increase in maximum temperature than in minimum temperature (Billy and Khanna, 2018). In Madhya Pradesh, Soybean yield is expected to decline by 5% for about 2^0C increase in temperature (cited by Kaur and Kaur, 2018 and IPCC, 2007)
2.	Drought	The risk of drought on soybean yield loss is the highest in the USA, Russian and India (Leng and Hall, 2019). Acute water stress due to prolonged dry spells during the monsoon season could be a critical factor for soybean productivity even under the positive effects of elevated CO2 in the future (Billy and Khanna, 2018)
3.	Rainfall & flood	Most of the area under Soybean are rainfed (Agarwal et al, 2013). A decline in daily rainfall amount by 10% restricts the grain yield of soybean to about 32 % (Billy and Khanna, 2018). The impact of flood is observed on a variety of crop plants, but major grain loss has been observed in soybean (Tewari ad Arora, 2016). It has been estimated that up to a 25% reduction in soy crop yield is due to flooding in Asia, North America, and other regions of the world (Mustafa and Komatsu, 2014).
4.	Incidence of pests and diseases	Like other crops, soybean is also affected by the increasing incidence of pests and diseases. India's soybean output is also impacted due to sporadic virus spread in parts of Madhya Pradesh and pest attacks on standing crops in Maharashtra and Rajasthan (Business Standard, 2020; Directorate of Soybean Research). Farmers in Madhya Pradesh expressed that the cost of cultivation of Soybean has increased due to the increased incidence of pests and diseases (Dupare et al, 2020).

Challenges of soybean production and post-production

According to the Directorate of Soybean Research (n.d.), the gap between lab and land leads to technology mismatch; inadequate government fund to R&D in the soybean sector, fragmented farm holding with diversified technological needs of farmers, lower seed replacement ratio, inadequate transfer of technology, resource-poor farmers etc., pose challenges in the production of soybean as well as Limited entrepreneurship for processing and value addition of Soybean. Moreover, the yield gap of soybean is still a major problem. It is estimated that the rainfed potential of soybean in India is about 2.1 t/ha against the national average productivity of 1.2 t/ha. Moreover, the world average productivity of Soybean stands at 2.76 tonnes/ha. The highest production and productivity of soybean reached 14.67 m tonnes and 1.353 q/ha in 2012. However, it was reduced to as low as 8.57 m tonnes and 0.738 q/ha in 2015 due to climate change (Directorate of Soybean Research) and it will further reduce if there are no adaptation practices. There is also interstate variation in the productivity of Soybean. Maharashtra ranks highest in productivity with 1125 Kg per ha, followed by Karnataka (1124 kg per ha) and Andhra Pradesh (1028 kg per ha). The Soybean yield of the states such as Madhya Pradesh, Rajasthan and Chhattisgarh was estimated to be 714, 780 and 884 kg per ha respectively (The Soybean Processors Association of India, 2020). Hence, large yield gaps exist between the potential and the actual yields harvested by the farmers (Agarwal et al, 2013).

Extension efforts for promotion of soybean as climate smart agricultural option

Extension services play a critical role in agricultural development for food and nutrition security and for improving productivity and livelihoods (FAO 2014). The first step towards adaptation measure to climate change is bringing desirable change among farmers. A number of factors influence the behaviour of farmers, which include externals and internals. Externals such as subsidies, climate finance, incentives, the extent of participation, linkages with the stakeholders, relationship with fellow farmers, friends, neighbours and internals such as education, knowledge, awareness, attitude, farm size, family income, family labour on agriculture, etc. Climate smart technologies have become knowledge-intensive, hence, it poses considerable challenges to farmers regarding adoption and continued adoption. In the absence of relevant extension and advisory services, the adoption of climate smart technologies would be less (Hellin et al, 2014). To respond to climate change, a range of different extension approaches to be kept in mind along with necessary support services and incentives such as preserving indigenous knowledge; conducting climate awareness campaigns, organising training related to climate smart technologies/services, plant health rallies, climate farmers field school, participatory crop planning & water literacy; promoting farmers collectives; the establishment of plant clinics; appointment of climate manager/monsoon manager at the state and district level, providing climate finance and incentive support at farmers level etc. Access to climate information and awareness about climate-associated risks in agriculture is an essential part of mitigation and adaptation. A number of initiatives have been taken by agricultural stakeholders across the globe to address the risks and impacts of climate change. Access to climate information has become a crucial part of farm-level decision making regarding adaptation. Likewise, ICT advisories play a major role in providing timely information to farmers to manage crops against the risks of climate change. ICT supported climate extension services are promoted by various public and private institutes.

Participatory development and adoption of soybean-based climate smart technologies and practices

The increased impact of climate change demands greater participation of stakeholders, including agriculture in the development of technologies that address the risks of climate change. According to the Directorate of Soybean Research, the adoption rate of Soybean production technologies and practices is less, this will affect the adaptation capacity of soybean growers due to mounting risks of climate change such as delayed arrival and uneven distribution of monsoon, long dry spell as well as increased temperature. Therefore, the Extension system needs to identify the vulnerable areas of soybean to different vulnerabilities of climate change with the participation of stakeholders, including farmers. Thereafter, the research system needs to develop and introduce climate smart varieties, production practices and services that effectively address the identified risk of climate change. For example, MAUS-71 (Soybean- non-shattering and high yielding variety when cultivated on Broad Bed Furrow) recorded increased yield than conventional variety grown by the farmers in Kadegaon village of Jalna (Sonune and Mane, 2018). Similarly, the application of KNO3 in soybean etc. is good input management strategies to mitigate the climate change effect on crops. In Central India (Madhya Pradesh), the water-conserving practices like Broad Bed furrows (BBF) has resulted in 35 % increase in yield in Soybean, also the conservation furrows have had a greater impact on the yield (up to 15-20 %) soybean (Bhattacharyya et al, 2016). It is, therefore, the extension system needs to document such climate smart technologies and practices for efficient production of soybean and introduce them to the other soybean cultivated areas. Also, there are several other impactful soybean technologies developed by Agricultural Universities, ICAR-Research Institutes, private sector, NGOs, etc. these improved technologies and services need to be promoted by extension service providers through increased participation of farmers, entrepreneurs, private sectors, etc. As most of the farmers are having small and marginal lands for cultivation, these farmers need adequate incentives and funding support to adopt the recommended technologies and practices of Soybean production. The extension functionaries may also organise Farm Schools, preferably in a cluster of villages to serve as a mechanism for the farmer to farmer extension. It also provides a vital link between the progressive/achiever farmers and neighbouring fellow farmers. This will have the maximum impact on the production of Soybean. There is a funding provision of Rs. 30,000 for organizing each farm school. To ensure, effective extension and scientist linkages, a joint visit may be organised by scientist and extension functionaries as per the guidelines issued under ATMA. In addition, the other provisions under ATMA can effectively be used for delivering extension advisory services for the production and post-production of Soybean. Moreover, the government may provide adequate incentives and funding options to support soybean growers in the adoption of improved technologies.

Effective utilisation of ATMA platform for the pluralistic extension system

All India Coordinated Research Project (AICRP) on Soybean implemented by ICAR-IISR has developed 118 varieties and released. Further, 18 varieties were released during 2012 for different agro-ecological zones and suiting to location specific cultivation requirements. However, there is a need for providing access to these technologies to various extension advisory service providers such as the Department of Agriculture, ATMA, KVK, private institutes, NGOs etc. This will help them to acquire knowledge on these new technologies and popularize among the farmers in their jurisdiction to increase the adoption rate of the improved technologies.

Also, there is a scope for utilizing the provision of ATMA for better convergence and for encouraging Public-Private Partnership for promoting soybean-based technologies and techniques. There is a Farmer Friend (FF) for every two census villages and these FFs can act as a link between extension and farmers. FFs are mostly progressive farmers (Both men and women) are expected to mobilize the farmers for the formation of Farmers Interest Groups and help in the conduct of field demonstration, Kisan Goshties, facilitate in preparation of Village Research Extension Action Plan (VREAP), liaison with Assistant Technology Manager (ATM) for exchange of information related to agri and allied activities at field level. They are also expected to ensure the dissemination of information through multimedia. Hence, the presence of FFs under ATMA may be utilized effectively by the extension functionaries and a close liaison with FFs may be established by extension advisory providers to train them on soybean technologies, and motivate them to disseminate to the fellow farmers in their assigned villages.

Capacity building through ATMA needs to be enhanced. As there is a wide extension gap among soybean farmers, the extension functionaries may use the various provisions available under cafeteria of activity concerning extension activities such as exposure visits of extension functionaries, organizing visits to progressive states, organization of state level exhibition, Kisan Mela, Best Farmer Awards at state and district level, training to the farmers, organizing demonstrations, etc., The funding support of ATMA may be leveraged for capacity building and skill development of soybean farmers.

Promotion of farmer collectives for soybean (e.g. FIGs, FPOs, Commodity Groups etc.)

The scale of soybean production at the individual farmer level is very less due to a smaller area under soybean. In India, the most followed marketing channels for Soybean are Channel I: Producer – village merchant – wholesaler – processor – refiner – oil wholesaler– oil retailer – consumer; Channel II: Producer – cooperative society – processor – refiner – oil wholesaler – oil retailer – consumer and Channel III: Producer – wholesaler in the regulated market – processor – refiner – oil wholesaler – oil retailer – consumer (Chand, 2007). However, the share of return to soya growers is less in the above channels. Hence, the promotion of farmers collective is essential for providing efficient marketing support to Soya growers. The Soybean value chain can be improved by the creation of more farmer collectives such as Commodity Interest Groups (CIGs), Village Producer Organizations (VPOs), Farmers Producers Organizations (FPOs) and Farmer Producer Companies (FPCs) to increase the scale of economics and the efficiency of the group. There are 6000 FPOs (including FPCs) in India. These FPOs were promoted by National Bank for Agriculture and Rural Development (NABARD), Small Farmers' Agri-Business Consortium (SFAC) and state governments (NABARD, 2021). According to SFAC India, out of 897 FPOs promoted by SFAC, only 108 FPOs were promoted for soybean, also, they are not exclusively on soybean, but were formed along with other commodities (e.g. red gram, cotton etc.,). Similarly, only 40 of 2076 FPOs of NABARD were promoted on Soybean, but these FPOs are not exclusively for Soybean as in the case of SFAC except the three FPOs namely, Triveni Javik Evam Udhyaniki Sahakari Sanstha at Ujjain Madhya Pradesh (MP), Tirla Farmer Producer Company Limited at Dhar, MP and Basaveshwara Krushi Utpannagala Utpadakara Sahakar Niyamit Sangha at Dharwad, Karnataka.

However, more such successful FPOs may be promoted for soybean. This will strengthen the soybean value chain, enhance the services related to the provision of inputs for production and post-management, including group marketing. There is a provision for rewards and incentives for the farmers' groups on different enterprises under ATMA. Hence, the extension functionaries due to the insufficient manpower they can form commodity interest groups by utilizing the funding support from ATMA in every block or a cluster of villages, which will facilitate Group led extension and enhance the adoption rates in soybean cultivation and promote value addition in Soybean.

Several commodity-based farmer groups are promoted by both public and private organisations in India and most of these farmers collectives are proven to be effective as the members have better access to technical and market information, improved buying and selling power and enhanced social cohesion and increased income to farmers (Padma and Rathakrishnan, 2012). Such commodity groups may exclusively be promoted for soybean at the village or cluster level. Therefore, the Extension system needs to identify soybean growers to group them under soybean commodity groups and provide them with crop production and protection inputs and innovative technologies, besides facilitating group marketing. They also should ensure transparency and accountability of these institutions for sustainability. There is also a provision for mobilizing 20 farmer groups per block under the cafeteria of activity with funding support for formation, nurturing the groups such as Farmers interest groups/women groups, farmers' organization/commodity organizations, farmers cooperatives, viable groups etc. Also, there is a scope for developing two food security groups on soybean at every block with the funding support of ATMA.

Realizing the importance of Farmers Collectives, MANAGE has recently started an FPO academy to meet the emerging needs related to capacity building and other support services for the establishment and development of FPOs across the country (https://www.manage.gov.in/fpoacademy/fpoacademy.asp). Therefore, the extension functionaries may utilize the services of the FPO academy for the formation and promotion of FPOs on Soybean.

Private sector participation through PPP

The present public extension system is playing a major role in the dissemination of proven technology and is involved in promoting several Climate Smart Agriculture (CSA) interventions to improve the adaptive capacity of farmer to climate change risks. However, the efforts of the public extension system alone are not sufficient. It needs to be complemented by private sectors in pursuit of CSA. In India, the private sector's role in contract farming has benefited a larger number of farmers. Their agro advisory services and other support services such as credit, incentives, provision of quality production and protection materials with marketing support have enabled the farmers to be assured of income. For example, the Public-Private Partnership for Integrated Agriculture Development (PPPIAD) scheme was implemented by the State Department of Agriculture, Archer Daniels Midland Company (ADM) in Maharashtra to improve the value chains for crops as well as developing integrated value chains for specific crops through public-private collaboration and co-investment. One of the beneficiaries is the soybean growers. This PPP has increased the productivity of Soybean through the introduction of new varieties, improvement of farm incomes and created linkages of soybean growers with input and output markets. The present policy framework such as the Farmers (Empowerment and Protection) Agreement of Price Assurance and Farm Services Bill, 2020 also facilitates contract farming. Additionally, the emerging agribusiness companies have innovative technologies, adequate finance and other technical manpower for soybean production. Therefore, the extension functionaries may facilitate the private companies for contract farming on soybean. Further, there is a scope for utilizing the 10% fund earmarked under ATMA for PPP to provide efficient extension advisory services. The public has better backward linkages due to its presence at grassroots level, credibility and network with research organisations. Whereas, the private sector has strength in forward linkages such as input support, credit, insurance, processing and value addition along with marketing. Similarly, NGOs have strength in social mobilization of farmers and farmer collectives. Hence, PPP will help in harnessing the strength of each partner and achieve synergy in providing end to end solution for soybean growers.

Extension services for promoting value addition in Soybean

Value addition plays a major role in generating more income for farmers. There are over 400 soy-based food enterprises in different parts/states of India (Trust for Advancement of Agricultural Sciences, 2014). The value-added products of soybean include Soybean sauce, tofu, soymilk, roasted soy nuts, soy flour etc., and among them, the most popular fermented soy food is soy sauce (Tiwari and Nigam, 2017). Also, as of now Directorate of Research on Soybean through AICRP, soybean has developed a number of soybean varieties giving higher productivity and the SPU, Bhopal has developed processing technology, equipment and pilot plants for 32 soy-based food products such as full-fat soy-flour, soy-fortified bakery products, dairy analogs, roasted/fried/fermented/ extruded soy-snacks, etc., (Trust for Advancement of Agricultural Sciences, 2014). The public and private extension system in soybean cluster areas need to provide necessary infrastructure facilities, incentives and regular training and capacity building to enable them to go for value addition. Further, better marketing facilities have to be arranged for marketing the value-added products of soybean. The extension functionaries may encourage many such entrepreneurs to set up Soybean based industries in the potential areas of soybean, which will ensure marketing for soybean growers.

Capacitating the rural youth on value addition on soybean

The migration of rural youth (men and women) has become a common phenomenon owing to the rising unemployment. Hence, it is the right time to train and involve them in the promotion of soybean based value addition. The Department of Agriculture, ATMA, Krishi Vigyan Kendras (KVKs), private institutes, NGOs, may organise training and capacity development programmes to improve the skills of farmers, both men and women, on the establishment and maintenance of soybean-based value added products. Further, credit and incentive support needs to be provided to these trained youth to establish production and processing plants for value addition. It may also help in reducing the unemployment rate among rural youth.

MANAGE is also implementing a flagship scheme of the Government of India such as Skill Development of Rural Youth (STRY) across the country with the help of various Vocational Training Institutions such as Krishi Vigyan Kendras / Nehru Yuva Kendras etc. It aims to impart skill training to rural youth for free of cost (including food and accommodation) on agri-based vocational areas in agriculture & allied areas to promote employment of rural areas and for creating skilled manpower to perform farm and non-farm operations. Hence, the training institutes working in Soybean areas may utilize this opportunity to train the rural youth on various value addition technologies to create employment opportunities for rural youth, retain them in agriculture and improve the farm income. Further details of the scheme can be accessed from https://www.manage.gov.in/stry&fcac/stryfcac.asp.

Soybean value addition – A way towards doubling Farmers Income

It is learnt from KVK, Kota that the training on soya paneer has encouraged several farmers in Kota to go for value addition. One of the beneficiary farmers of these training programmes was Mrs. Anuradha Meena. She has established a plant of soya paneer processing costing approx. Rs. 8.00 Lakhs. Presently, she is Processing 50 kg of soybean per day. Out of which she is getting 65 kg of soya paneer and it is supplied to the hostels and nearby coaching institutes of Kota city. She also got the FSSAI number for her products. She was awarded by Sh. Om Birla M.P. of Kota for her innovative work. The value addition has enabled her to earn more income (https://kota.kvk2.in/success-stories.html).

The above success story is an encouragement for other fellow farmers to go for value addition. Similar to KVK, Kota, there are some successful cases of value addition in soybean promoted by ATMA. The extension institutes need to promote value addition among farmers, document and replicate the successful cases by adopting various extension methods such as training, exposure visits, demonstration, publicity etc.

Utilizing the Round Table on Responsible Soy (RTRS) for percolating the benefits to the soya growers

The Round Table On Responsible Soy (RTRS) – an international and market-orientated organization – has developed schemes that contain a set of principles, criteria and indicators. These are related to the crop production and control of certified soy and its by-products and are applicable globally to promote responsible soy. In India, the Soy Producer Support Initiative (SOYPSI) is ensuring RTRS.

The overall goal of the SOYPSI is to add value to the soy supply chain by supporting small scale farmers and farmworkers in the soy sector and preparing them for certification. SOYPSI aims to consolidate efforts with existing players in the soy sector to reach a consensus on certifiable and sustainable soy production. It will support the Criteria Development Process on responsible soy production, processing and trading, and make the criteria operational for producers and processing companies involved. In India, the following institutions are supporting soybean growers in RTRS certification.

India Grameen Services / Bhartiya Samrudhhi Finance LTD BASIX: IGS/BASIX provides technical and organisational support to 50 producer groups, covering a total of 10.000 farm households in five districts in Madhya Pradesh, India, to work towards RTRS certification.

Action for Social Advancement (ASA): ASA provides technical and organisational support to soy producer groups, covering a total of 10.700 farm households and 500 farm workers in five districts in Madhya Pradesh, India, to improve production and work towards RTRS certification.

Haritika / Samarth Kisan producers Company Pvt. Ltd: The project aims to support over 6.000 small scale farm households in Madhya Pradesh India, by organizing them in the Samarth Kisan and Khujner Companies, to join the certified and sustainable soy value chain. (https://www.solidaridadnetwork.org/story/soy-producer-support-initiative/). Further details on the principles and criteria for Round Table for Responsible Soy is available on https://responsiblesoy.org/wp-content/uploads/2020/01/Indian-National-Interpretation-for-RTRS-Responsible-Soy-Production-Version-2.0_ENG.pdf.

The extension functionaries may utilize such innovative platforms to encourage and educate more farmers to cultivate Soybean socially and environmentally responsible manner to meet the standards of RTRS, thereby, helping farmers to get additional income.

Accelerating agri start-ups for encouraging soybean cultivation

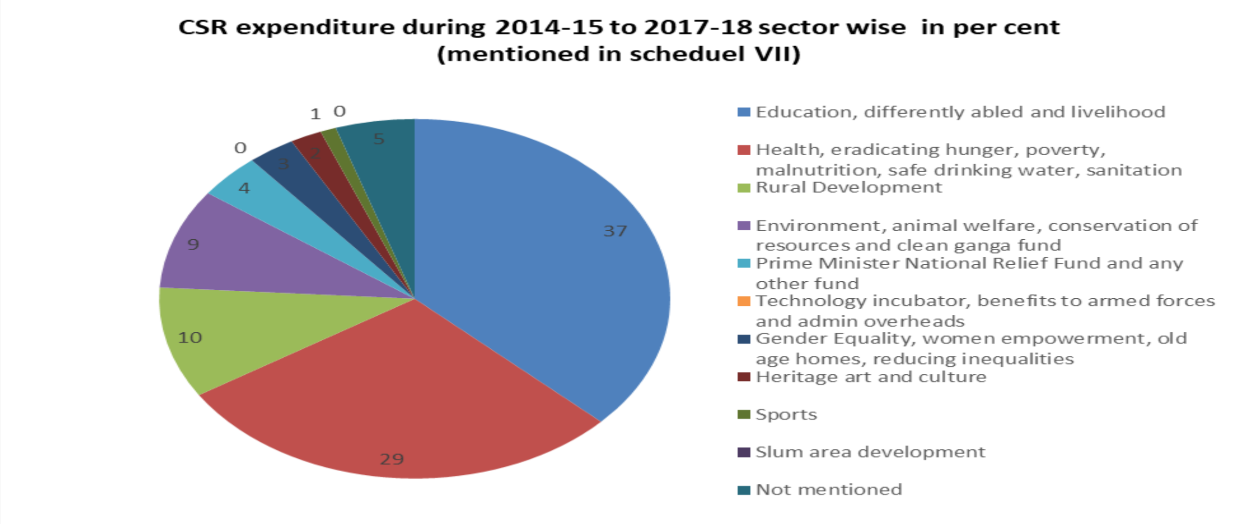
Both central and state governments are creating favourable ecosystem and policy environment for agri startups. Thereby, several start-ups are growing in the agricultural sector. Agri technology start-ups are effective in addressing the existing gaps in extension, technology, marketing, and other services. In India, agri start-ups are focusing on supply chain, infrastructure development, finance and related solutions, farm data analytics and information platforms. A total of 366 agri-based start-ups have come up from 2013 to 2017 (PWC and FICCI, 2018). The strength of the growing agri startups needs to be harnessed for promoting effective value chain management in soybean.

The Entrepreneurship Development Programme (EDP) on Soybean processing was started in the Year - 1995 at ICAR-Central Institute of Agricultural Engineering (ICAR-CIAE), Bhopal to develop the enterprise in the area of soybean processing for the livelihood opportunities, employment generation and production of high-quality protein products at a low cost. According to ICAR, 2019 through EDP on Soybean, 2524 farmers were trained. It was estimated that however, only 14% of them have established Soybean based production units. Also, most of them have closed due to challenges related to marketing.

MANAGE is also one of the knowledge partners for implementing Rashtriya Krishi Vikas Yojana – Remunerative Approaches for Agriculture and Allied Sectors Rejuvenation (RKVY-RAFTAAR) to promote agripreneurship and agribusiness. Hence, under this, MANAGE is providing training and mentorship to ideate and establish enterprises related to agriculture with the grant in aid of Rs. 5 lakhs as seed money and Rs.25 lakhs for a minimum viable enterprise. Further details can be seen from http://cia.manage.gov.in/RKVYSAIP.aspx.
So far, about 200 startups have been promoted by MANAGE under RKVY-RAFTAAR in various innovative areas of agriculture and allied sectors. Hence, the extension functionaries may encourage rural youth, progressive farmers etc., to come out with innovative ideas to address the existing gaps in the soybean sector and utilize the RKVY-RAFTAR initiative of the Government of India.

Leveraging Corporate Social Responsibility (CSR) Funds for the Soybean Sector

The companies act, 2013 has mandated the companies having a net worth of Rs. 500 crore or more, or turnover exceeding Rupees



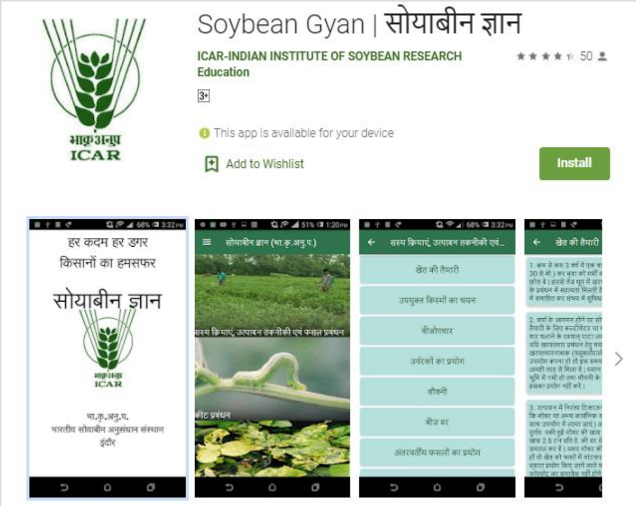
Source: GoI, 2019

1,000 crore or a net profit of Rupees 5 crore or more, to spend at least 2% of its average net profit made during the preceding three financial years. Accordingly, many corporates are involved in the development of the rural economy by improving the education of rural mass, providing better health services, generating livelihood opportunities etc. through CSR funds. The corporates are also spending their CSR funds in the development of watersheds, agricultural technology, extension delivery and establishing better institutional mechanisms to support farmers (Balasubramani and Vincent, 2019). Though more than 60% of the CSR fund was spent on education and health sectors (GoI, 2019), there is an ample opportunity to bring CSR funds for agricultural development with an enabling policy environment and specific regulations. Hence, the research and extension institutes related to soybean sector may encourage corporates to spend a significant portion of CSR funds for Research, extension, entrepreneurship, value addition, marketing, innovations, Climate resilient technologies etc., in the entire value chain of soybean.

Information and Communication Technology (ICT) is extensively used in almost all sectors. Similarly, it can be used in the agricultural sector among soybean farmers. A public extension system or any startups may make a small intervention by developing an ICT platform/app similar to Amazon, Flipkart, Olx etc., this platform can help farmers to source Climate Resilient Inputs and innovative production technologies/practices and market their products. Similarly, the extension system can also use the existing print, electronic and other social media to provide wider publicity about the importance of the soybean production system. The budget earmarked under Farm Information dissemination of ATMA may also be utilized to disseminate the technologies of soybean.

Use of Information and Communication Technology

Further, the Directorate of Soybean Research has developed Soybean Gyan, an android mobile-based application, helps the farmers to access the information related to production technologies and techniques of soybean. So far, more than 10,000 farmers have downloaded this App. Also, a YouTube Channel-IISRSoybean



(https://www.youtube.com/channel/UCNdY5AsfPZqsCO8IxkAuSyQ/featured) was created by the Directorate of Soybean Research in the year 2020 to provide access to farmers, entrepreneurs, academician and relevant stakeholders on agronomic package of practices, control measures for major insect-pest and disease, management of abiotic stresses in soybean etc. This channel also features videos on opportunities for agri startups on Soybean. These videos will be highly useful to those seeking to establish agri ventures in soybean. However, only 1150 people have subscribed to the channel so far with the very minimum views on uploaded videos. This is mostly because most of the farmers in India have little knowledge of the use of modern-day social media technologies and also many of them do not possess smartphones or related ICT gadgets. There is a provision for farm information under ATMA for dissemination of information using social media, printed leaflets, local advertisements and bringing out low-cost publications. In addition, the technology packages may be shared in digital form through IT networks. Hence, the extension functionaries may create awareness among a larger number of soybean farmers to utilize such Apps, other ICT platforms and the provision of ATMA which will supplement their efforts in technology dissemination and will bridge the adoption gap.

Conclusion

To sum up, the agricultural sector is affected adversely due to climate change. It causes a huge loss to farmers owing to its adverse impacts on crop and livestock and in turn affect the livelihood of farmers. However, it is observed that various adaptation and mitigation measures promoted by research and extension system have led to a reduction of the adverse effects of climate change on crop and livestock production and productivity. However, there are several challenges in the adoption of the improved technologies and services by farmers in general, soybean growers in particular. The challenges of climate change such as increasing temperature, delayed rainfall, droughts, new pests and diseases have affected the production of Soybean. Besides, yield gaps, the technology mismatch; inadequate government fund for R&D in the soybean sector, fragmented farm holding with diversified technological needs of farmers are affecting the promotion and adoption of soybean technologies. Though a larger number of technologies, models, innovations, and funding support are available, the adoption rate is rather poor. Therefore, the extension strategies suggested in this paper may enable the extension service providers to promote soybean production and post-production interventions and improve the adoption rate. The extension strategies such as Participatory development and adoption of soybean-based climate smart technologies and practices, pluralistic extension system for promoting the technologies of Soybean, promotion of farmer collectives for soybean (e.g. FIGs, FPOs, Commodity Groups etc.), private sector participation through PPP, extension services for promoting value addition in Soybean, capacitating the youth on value addition on soybean, accelerating agri start-ups for encouraging soybean cultivation, leveraging Corporate Social Responsibility Funds (CSR) funds for soybean growers, use of Information and Communication Technology etc. These extension strategies along with the greater participation of relevant stakeholders (including farmers) would bridge the adoption gaps. It will also address the emerging risks of climate change, improve food and nutritional security, and enhance the income and livelihood of farmers.

References

Agarwal, D. K., Billore, S. D., Sharma, A. N., Dupare, B. U., & Srivastava, S. K. (2013). Soybean: introduction, improvement, and utilization in India—problems and prospects. Agricultural Research, 2(4), 293-300.

Balasubramani. N and Vincent.A. (2019). A workshop on Corporate Social Responsibility (CSR) for Agricultural Development was held on Nov 19- 20, 2018 at National Institute of Agricultural Extension Management (MANAGE), Hyderabad.

Bhattacharyya, R., Ghosh, B., Dogra, P., Mishra, P., Santra, P., Kumar, S., & Sarkar, D. (2016). Soil conservation issues in India. *Sustainability*, *8*(6), 565.

Billy, C., & Khanna, V. K. (2018). Impact of Climate Change in Indian Agriculture: Special Emphasis to Soybean (Glycine Max (L.) Merr.). Open Acc J Oncol Med 2 (4)-2018. OAJOM. MS. ID. 000141. DOI: 10.32474/OAJOM. 2018.02. 000141 179. Environmental Pollution, 126(3), 293-300. https://lupinepublishers.com/cancer-journal/pdf/OAJOM.MS.ID.000141.pdf

Business Standard. (July, 2020). Mosaic virus, pest attacks in three states to hit soybean output this year. https://www.business-standard.com/article/companies/mosaic-virus-pest-attacks-in-three-states-to-hit-soybean-output-this-year-120072301291_1.html

Chand. R. (2007). Agro-industries characterization and appraisal: Soybeans in India. http://www.fao.org/3/ap300e/ap300e.pdf

Dickie, A., Streck, C., Roe, S., Zurek, M., Haupt, F., & Dolginow, A. (2014). Strategies for mitigating climate change in agriculture. *California Environmental Associates/Climate Focus. Online at www. climateandlandusealliance. org/uploads/PDFs/Abridged_ Report_Mitigating_Climate_Change_in_Agricul ture. pdf, accessed on December, 9*, 2014.

Directorate of Soybean Research. (2020). Vision 2050. Directorate of Soybean Research. Indian Council of Agricultural Research. https://iisrindore.icar.gov.in/pdfdoc/vision2050.pdf

Directorate of Soybean Research (n.d.). Strategic Plan 2011-2016. https://iisrindore.icar.gov.in/pdfdoc/strategicplan.pdf

Dupare, B., Sharma, P., Billore, S., & Verma, S. (2020). Impact of Climate Change on Soybean Cultivation in Malwa and Nimar Region of Madhya Pradesh: Farmers' Perspective.

FICCI. (n.d.). Evaluation of the PPPIAD Project on Soybean. http://ficci.in/spdocument/20539/soybean-report.pdf

GoI. (2019). Report of the High Level Committee on Corporate Social Responsibility 2018. Ministry of Corporate Affairs. https://www.mca.gov.in/Ministry/pdf/CSRHLC_13092019.pdf

Hellin, J., Bellon, M. R., & Hearne, S. J. (2014). Maize landraces and adaptation to climate change in Mexico. *Journal of Crop Improvement*, *28*(4), 484-501. Retrieved online from https://www.tandfonline.com/doi/full/10.1080/15427528.2014.921800

Kumar, K. K. (2011). Climate sensitivity of Indian agriculture: do spatial effects matter?. *Cambridge Journal of Regions,* *Economy and Society*, *4*(2), 221-235. Retrieved online from http://indiaenvironmentportal.org.in/files/file/Climate%20sensitivity.pdf

Leng, G., & Hall, J. (2019). Crop yield sensitivity of global major agricultural countries to droughts and the projected changes in the future. Science of the Total Environment, 654, 811-821.

Mustafa, G., & Komatsu, S. (2014). Quantitative proteomics reveals the effect of protein glycosylation in soybean root under flooding stress. Frontiers in plant science, 5, 627. https://www.frontiersin.org/articles/10.3389/fpls.2014.00627/full

NABARD. (2021). Farmer Producers' Organizations (FPOs): Status, Issues & Suggested Policy Reforms. National Paper – PLP- 2020-21. https://www.nabard.org/auth/writereaddata/CareerNotices/2309195308National%20Paper%20on%20FPOs%20-%20Status%20&%20Issues.pdf

Padma. S. R. & Rathakrishnan .D. T. (2012). Promotion of Commodity Interest Groups and Supply Chain Management. https://www.worldwidejournals.com/paripex/recent_issues_pdf/2012/August/promotion-of-commodity-interest-groups-and-supply-chain management_August_2012_9959513665_8504159.pdf

PIB. (2019). Water storage level of 91 major reservoirs of the country goes down by two percent. Ministry of Water Resources, River Development and Ganga Rejuvenation. Retrieved online from http://www.pib.nic.in/Pressreleaseshare.aspx?PRID=1572126

PWC & FICCI. (2018). Agri start-ups: Innovation for boosting the future of agriculture in India. http://ficci.in/spdocument/23049/Agri-start-ups-Knowledge-report-ficci.pdf

Sapkota, T. B., Vetter, S. H., Jat, M. L., Sirohi, S., Shirsath, P. B., Singh, R.,& Stirling, C. M. (2019). Cost-effective opportunities for climate change mitigation in Indian agriculture. *Science of the Total Environment*, *655*, 1342-1354.

Sonune, S. V., & Mane, S. (2018). Impact of climate resilient varieties on crop productivity in NICRA village. Journal of Pharmacognosy and Phytochemistry.

Tewari, S., & Arora, N. K. (2016). Soybean production under flooding stress and its mitigation using plant growth-promoting microbes. In Environmental stresses in soybean production (pp. 23-40). Academic Press. https://www.sciencedirect.com/science/article/pii/B9780128015353000024

The Soybean Processors Association of India (2020): 2020 Soybean Production by State. http://www.sopa.org/statistics/soybean-production-by-state/?search_type=search_by_year&arrive=2020&starting_year_value=&ending_year_value=&submit=Search

Tiwari, A.K., & Nigam. V. (2017). Value addition in soya bean: Production of soya sauce. https://www.researchgate.net/publication/321669256_Value_addition_in_soya_bean_Production_of_soya_sauce

Trust for Advancement of Agricultural Sciences. (2014). Brainstorming Workshop on "Soybean for Household Food and Nutrition Security". https://www.taas.in/documents/pub-activity-23.pdf

Vijayan. I & Viswanathan. P. K. (2018). India's Initiative on Climate Resilient Agriculture - A Preliminary Assessment. Retrieved online from https://acadpubl.eu/jsi/2018-118-7-9/articles/9/44.pdf

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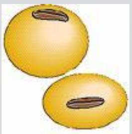

Soybean Cultivation vis-à-vis Changed Weather Scenario in Coming Decades

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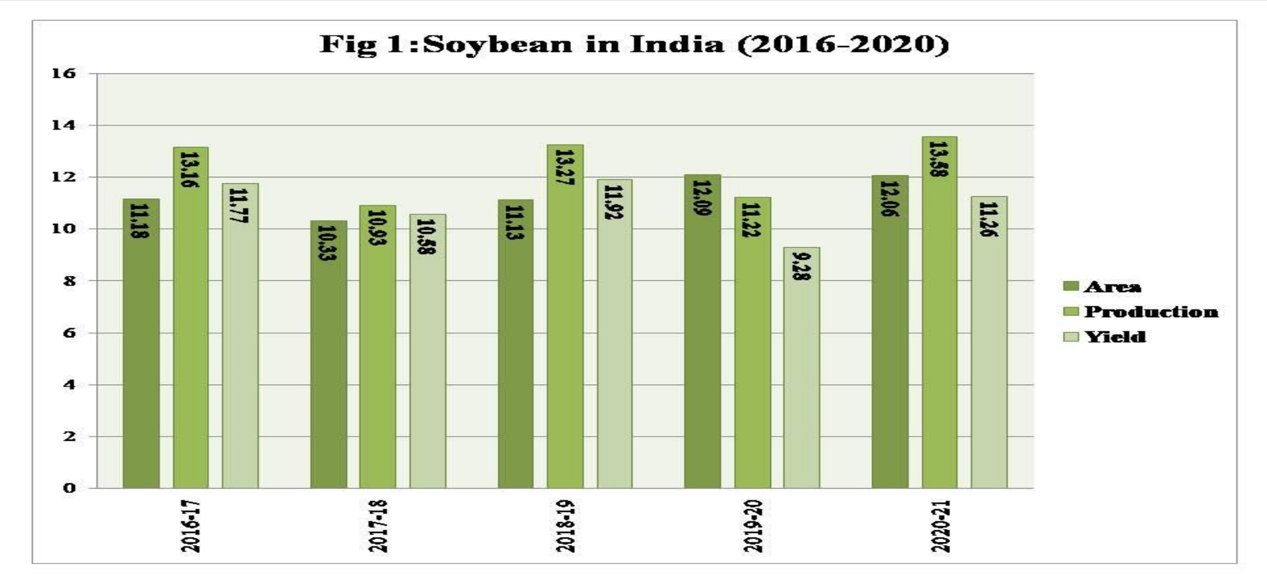
Soybean

Soybean is a temperate origin crop introduced in India in the late sixties. It has a prominent place among modern agricultural commodities as the world's most important seed legume, and contributes about 25% and 65% to the global edible oil and protein concentrate for livestock feeding, respectively. It is also an important commodity for food manufacturers, pharma industry and has many other industrial uses. Soybean is the only complete high quality protein of source vegetable. Soy milk is cheaper than other vegetable sources and has a great scope of use among the increasing vegan population for consumption in various forms with varieties developed having less beany flavour. Tofu is highly nutritious and is complimentary to *paneer*. Soybean also has many therapeutic usages like overcoming problems related to menopause due to presence of estrogen like compound and presence of flavones which protect from cancer.

Soybean holds potential as a vegetable crop to be grown between April to July when green peas are not locally available. Indian Soybean deoiled cake, which is extensively used in feed industry being non-GMO is in high demand and accrued foreign exchange worth Rs.3349 crore during 2019-20.
It is therefore no surprise that global soybean area (127.91 million ha) and production (370.8 million tons) in 2020 has shown an increase of 3.2% in area and 8.3% in production over 2019.million tons) in 2020 has shown an increase of 3.2% in area and 8.3% in production over 2019.

Soybean Cultivation in India

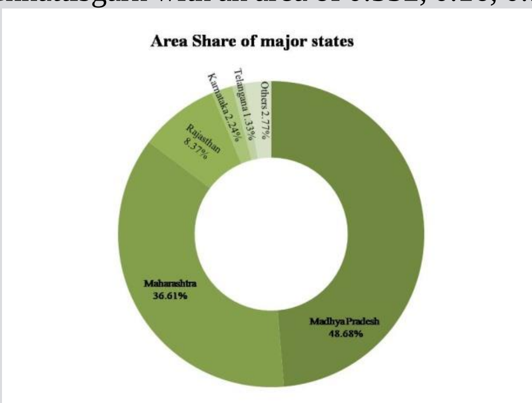
The growth trend of soybean area and production as compared to the decade of its introduction in India has been phenomenal. However, being a *kharif* season crop it does

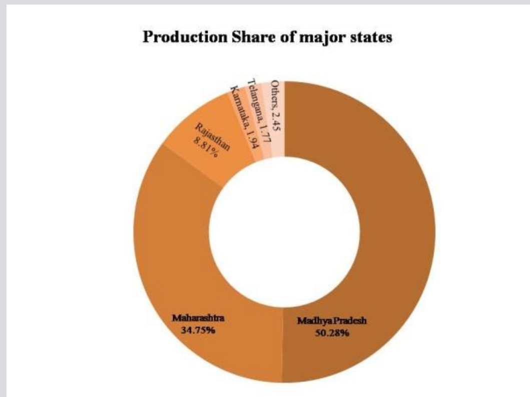


have its challenges. Over the past years there has been more or less stagnation in the area, production and productivity (Fig 1).

The major soybean growing states are Madhya Pradesh (5.85 m ha), Maharashtra (4.32 m ha) and Rajasthan (1.1 m ha). Karnataka, Telengana, Gujarat, and Chhattisgarh with an area of 0.332, 0.16, 0.15 and 0.08 m ha, respectively, show good promise of expansion in the future.

Increasingly farmers of Madhya Pradesh and other states have a demand and mostly prefer early maturing varieties which are affected more climatic variability and the consequent pests and diseases.





Climate change

Climate change is affecting almost all sectors and systems. However, agriculture sector is most vulnerable to it and the impact is likely to be a great threat to the food and livelihood security of the world, in general, and that of India, in particular as rainfed farming is mainstay of the large number of farmers. About 60 per cent of the total cropped in India is still rainfed and large proportion of landholdings are small and fragmented (Jain et al, 2015; Udmale et al, 2014). About 48 per cent area under food crops and 68 per cent under non-food crops is rainfed. The importance of the rainfed agriculture can be measured from the fact that it contributes to 40 % of the country's food production- accounts for 85 %, 83 %, 70 % and 65 % of the national area under coarse cereals, pulses, oilseeds and cotton; and holds 60 per cent of the total livestock populations (Venkateswarlu and Prasad, 2012).

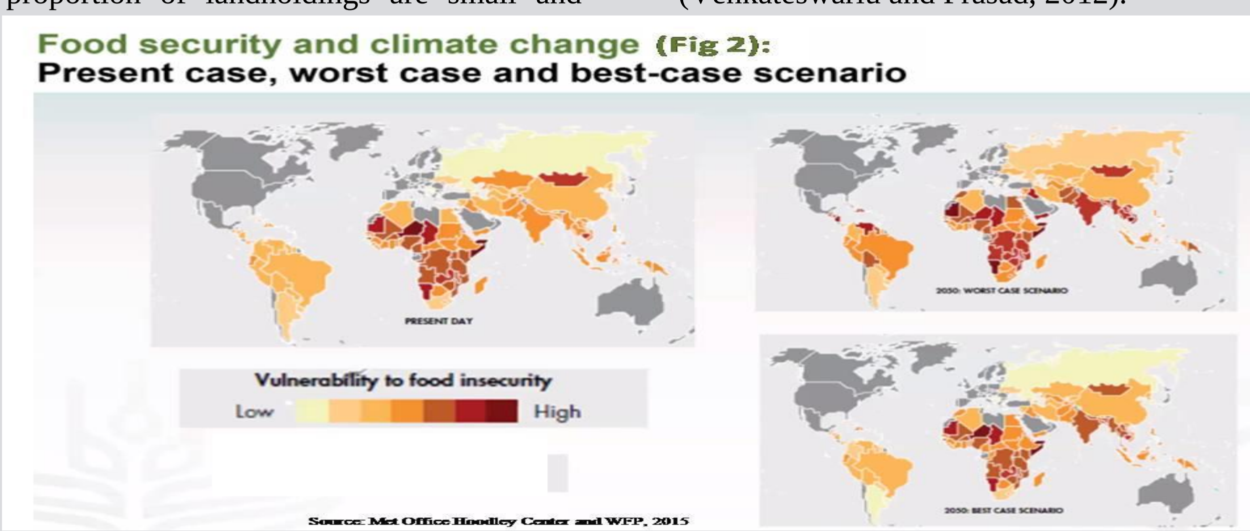


Fig 2 clearly shows the three scenarios with regard to the food security and the climate change. If measures are not taken then by 2050 the situation will be alarming in the developing and under-developed countries including India. Moreover, climate change has been reported to have a significant and generally negative impact on agriculture and growth prospects in the lower latitudes (Vermeulen et al., 2012; Field et al., 2012; Stocker et al., 2013). Increased climate variability in the coming decades is likely to increase the frequency and severity of floods and droughts, and will increase production risks for both, farmers as well as livestock keepers and reduce their coping ability (Thornton and Gerber, 2010). In the past decades, consistent warming trends and more frequent and intense extreme weather events have been experienced across Asia and the Pacific. Ongoing climate change poses a serious threat to food access for rural and urban populations, by way of reducing agricultural incomes, increasing risk and disrupting markets (Vermeulen, 2014). Guiteras (2009) finds that crop yields will decline by 4.5-9% in the short-run (2010-2039) and by a whopping 25% in the long-run (2070-2099) in the absence of adaptation by farmers. Further, Burgess et al. (2014) find that one standard deviation increase in high temperature days in a year decreases agricultural yields and real wages by 12.6 % and 9.8%, respectively, and increases annual mortality among rural populations by 7.3 % in India. Resource-poor producers, landless and marginalized ethnic groups are at more risk.

Vermeulen et al. (2012) also reported that the food systems contribute significantly to global warming and are responsible for 19–29 per cent of global emissions, the bulk of which come directly from agricultural production activities (i.e. N_2O and CH_4) and indirectly from land cover change driven by agriculture CO_2. As a result of global warming phenomenon, it is projected that overall global productivity of crops may decline between 3 and 16 per cent by 2080. Most of the developing countries, particularly those with average temperature near or above crop tolerance levels, are predicted to suffer an average 10 to 25 per cent decline in agricultural productivity in the 2080s.

Sixth assessment report of the Inter-governmental Panel on Climate Change (IPCC, 2018) states that dry land regions and population dependent on agriculture-based livelihoods are disproportionately at a higher risk to the climate variability. The increasing frequency of inter-season variations in rainfall and temperature and other extreme events have significant impact on agriculture production and livelihoods particularly in India. It is increasingly recognized that variations in climate parameters is likely to exacerbate vulnerability of farming and rural communities in semi-arid tropics, which are already disadvantaged due to low and erratic precipitation pattern, lower soil fertility, higher frequency of droughts, weak institutional setup and inadequate access to resources (Bantilan and Anupama, 2006, Singh et al., 2014). Adaptation actions against the adverse effects of climate induced perturbations are pertinent to sustain crop productivity and livelihood of the farmers in short to medium run (Singh et al, 2018). However, understanding the degree of vulnerability to climate change is a prelude for identification and prioritization of vulnerable areas, factors that serve as barriers to effective adaptation and for constructing suitable region–specific interventions to better cope up with current and future climate changes.

Climate change projections suggest that an increase in temperature by 2 to 3.5°C would reduce net agricultural income by 25%. Climate change is likely to aggravate the heat stress in dairy animals and adversely affect their productive and reproductive capabilities. Pests and diseases are highly dependent upon temperature and humidity, and therefore will greatly be influenced by climate change.

To combat the climate change effects there is a need work on the climate smart technologies combining the policies on food security, adaptation and mitigation (Fig 3). Climate smart agriculture (CSA) has been developed and standardized, the need of the hour is its horizontal scaling: replicating technological success in new locations as well as vertical scaling i.e. success through policy and institutional changes. There is a need to directly implement the changes and influence other to implement too at the same time for its wide spread awareness and, adoption and acceptance. There is also a need

Fig 3:*Need for Climate-Smart Agriculture*

to revise the adaptation plan to have greater focus on agriculture, actionable interventions in the plan, a holistic and targeted approach to strengthening resilience of agricultural system through practices, technologies, services, institutions and policies. There is a further need to have agro ecological zone specific actionable plan, participatory approach in the developing the plans, assessment of economic, social and environmental returns on recommended interventions, the investment plans on the interventions too need to be worked out.

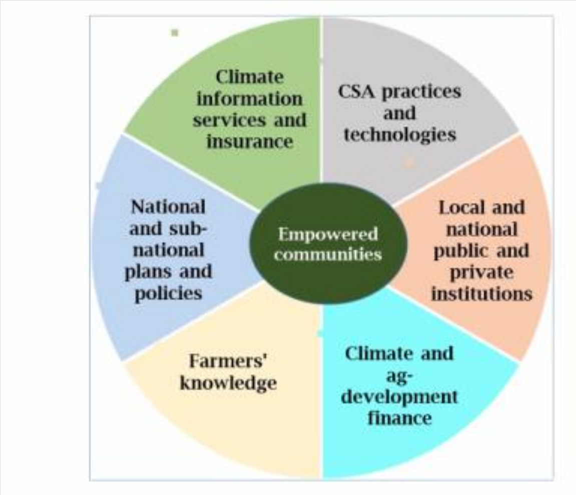
Challenges in soybean production

Soybean by and large the crop is grown on Vertisols and associated soils under rain fed situations. These soils have good production potential provided constraints related to soil, water and nutrient management are taken care of. Being a rain fed crop the challenges of the climate change are multifold in soybean and maybe majorly categorized as:

1. ***Drought***

Due to rainfed nature, the cultivation and final productivity of soybean crop in India depends totally on the quantum and distribution of monsoon. 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. The extent of yield reduction due to these stresses depends upon duration of stress and growth stage of crop at which they occur.

Normally moderate stress occurs in the plant before the visible symptoms appear. Drought stress during the vegetative stage may reduce leaf enlargement, photosynthesis and grain yield. Other consequences are reduced nitrogen fixation, smaller stem size and short plants. If drought stress occurs during flowering, abortion of flowers and pods is likely to increase. At seed formation stage, drought severely affects the dry matter accumulation in seeds and results in number of unfilled seeds and reduced seed size.



In view of above, it is necessary to save the crop from drought in order to realize the full yield potential. The adverse impact of drought can to a great extent be minimized by proper water management at critical stages and in-situ conservation of soil moisture.

Reducing the impact of drought:

a. **Improved soil and water conservation practices and the associated tillage systems**: Utilizing in-situ moisture conservation techniques such as different land configurations (BBF), minimum tillage, and use of mulch can help in minimizing the losses due to drought and excess moisture conditions
b. **Optimization of the fit between crop growth cycle and the available moisture**: Selection of crop/varieties with phenology (flowering, seed fill duration and maturity) best suited to given moisture regime of the region can help in optimization of productivity.
c. **Weed control**: Weeds drain up the available moisture and nutrient in the soil at a much faster rate than the crop. Therefore weeds if not removed can reduce the moisture and nutrient availability to the crop and reduce the productivity of the crop in a given dry land condition.
d. **Timely planting and maintenance of optimum plant population**: Planting of a crop when soil moisture is appropriate for the proper germination and early seedling growth is important for harnessing the good yields under dry land conditions
e. **Selection of drought resistance/ tolerance varieties**: There is a large genotypic variability in response to drought conditions in all the crops. In addition, over the years efforts are being made to use this genetic diversity and develop crop varieties which or resistant/tolerant to drought conditions. Therefore, use of such varieties under drought prone areas can help in improving the productivity of the crop.
f. **Avoidance of mono-cropping and mono-varietal culture**: The multicropping system helps in minimizing the risk evolved in uncertain environmental conditions of rainfed crops. Similarly, planting of more than one variety with of the crop also help in minimizing the risk of total failure of the crop in an uncertain environment
g. **Supplemental irrigation**: Supplemental irrigation is the more common irrigation practice for crops not grown under fully irrigated conditions and where water availability is restricted. It is also known as the "deficit irrigation" since it does not supply the full season crop water requirement. It can be applied to save the crop in case of un-expected drought. The practice may vary extensively with crop and region. In many environments such as chickpea area in MP, if only a single supplementary irrigation is given it is usually more effective if applied pre planting. As such the crop enters the season with stored supply, which can insure growth and productivity of the crop.

2. ***Water logging***

Occurrence of water logging conditions for varying period depending up on the intensity and duration of rainfall is also a general feature in many kharif crops in India. Most plants are highly sensitive to water logging conditions. Prolonged water logging in the field results in anaerobic conditions in the roots. These anaerobic conditions lead to physiological stress and reduced growth and development of the plant. 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. Water logging conditions at seedling stage could lead to seedling mortality and reduced plant stand. In case of legumes, water logging at vegetative stages can result in failure of nodule formation and nitrogen deficiency in the plants. Similarly, water logging occurring at seed fill duration can result in the reduction in grain weight. Therefore, it is necessary to avoid water-logging conditions in the field so that potential of the crop can be harvested.

Reducing the impact of water logging:

Preparation of land and good drainage facilities: While preparing the field in water logging prone areas, care must be taken to provide a slight slope so that water does not stagnate in the fields. There should be good drainage system so that the runoff water is drained out of the fields and collected in water harvesting ponds. Planting of crops on various land configurations such as BBF, ridges, and ridges and furrows etc. have also been found to be very useful in reducing the chances of water logging conditions in the field.

3. *Heat Stress*:

Crop growth and development is highly influenced by the ambient temperature. The optimum temperatures for maximum growth vary from crop to crop and variety to variety. For example, crops grown during rabi season grow well under low temperature conditions whereas crops planted during kharif season can bear relatively high temperatures. Occurrence of high temperatures during one or the other crop growth stages is also a common phenomenon under tropical environments. Increase in ambient temperatures above normal can adversely affect many physiological processes. The high temperature stress usually accompanies with drought conditions and significantly reduces crop growth and yield. High temperatures during planting may adversely affect seed germination in soybean. As the total duration, as well onset of various growth stages are governed by temperature, high temperature conditions may lead early flowering and maturity. High temperatures at reproductive stages may result in flower abortion, reduced grain filling and ultimately reduced yield. The extent of damage due to high temperature stress is dependent on the degree and duration of high temperature faced by a crop.

Reducing the impact of high temperature:

a. Planting time: The planting time of soybean should be such that its growth and development gets the required optimum temperatures.

b. **Multi-variety culture**: Planting of more than one variety of a crop with different maturity can help in reducing the risk of uncertainty of occurrence of high temperature stress and yield losses.

c. **Irrigation**: In case high temperature conditions prevail along with severe soil moisture conditions, the impact will more pronounced. Therefore, under such circumstances providing irrigation could help in lowering the high temperature effects on the crops.

4. *Issues related to Global warming*

Crop growth and yield under normal conditions are largely determined by weather during the growing season. Even with minor deviations from the normal weather, the efficiency of externally applied inputs and food production is seriously impaired. The increasing CO_2 concentration in the atmosphere and the anticipated climate change due to global warming are also likely to affect future global agricultural production through changes in rate of plant growth and transpiration rates.

The instrumental records show that global mean surface temperatures have increased by 0.6 ± 0.2 ^{0}C over the course of the 20th century. Since 1976 a rate of increase of 0.15 ^{0}C/decade has prevailed. In recent decades warming has been most pronounced over the land masses. In the northern hemisphere 1990s constituted the warmest decade of the last millennium. The average global surface temperature in 2005 was 0.46± 0.1 ^{0}C above the 1961-90 average, representing about 0.75 ^{0}C above pre-industrial temperature levels. The warming has been greatest during the winter, spring and autumn seasons (Jones et al., 2001). Minimum temperatures have been increasing at approximately twice the rate of maximum temperatures, a phenomenon confirmed by many national scale studies. Projected warming in Asia is most pronounced in the winter. During winter, precipitation amounts are expected to decline significantly over many monsoon areas although Global Climatic Models (GCMs) do not suggest that the summer monsoon rainfall will decrease in reliability significantly. Extreme events in Asia pose the greatest problem for farmers and there are some indications that extremes are already increasing in frequency.

The current scientific consensus attributes most of the recent warming to anthropogenic activities associated with increasing atmospheric concentrations of greenhouse gases (IPCC, 2001). The primary contribution has been made by CO_2 which has increased from pre-Industrial Revolution levels of 280 ppm to current levels of over 380 ppm.

Conclusion

Present and future climatic change is likely to have substantial impact on the production of all the crops depending upon the magnitude of variation in CO_2 and temperature. Increased temperature significantly reduces the grain yield and performance of a cropping system as a whole due to accelerated development and decreased time to accumulate grain weight. The reductions in soybean yields are found to be about 5-10% and 8-22%, in India and China, respectively. Without CO2 fertilization, effective adaptation, and genetic improvement, each degree-Celsius increase in global mean temperature would, on average, reduce global yields of soybean by 3.1%.

India already is edible oil deficit and is importing nearly of two third of the countries requirement costing heavily to the exchequer. Since farmers are unlikely to change their cropping patter in the coming decade or more and will continue growing soybean as their options for an alternative crop are limited. Therefore, looking into the climate vulnerability of the soybean, there is a need to address the climate change issue before the situation becomes alarming and grave. Climate mitigation technologies need to be propagated, popularized and supported to meet this end.

References

1. Bantilan MCS and Aupama KV. 2006. Vulnerability and adaptation in dryland agriculture in India's SAT: Experiences from ICRISAT's village-level studies. J. SAT Agri Res., 2(1): 1-14.
2. Burgess R, Deschenes O, Donaldson D and Greenstone M. 2014. The unequal effects of weather and climate change: Evidence from mortality in India. Accessed from http://econ.lse.ac.uk/staff/rburgess/wp/WD_master_140516_v3.pdf
3. Chen Shuai, Chen Xiaoguang and Xu Jintao. 2013. Impacts of Climate Change on Corn and Soybean Yields in China. Selected Paper prepared for presentation at the Agricultural & Applied Economics Association's 2013 AAEA & CAES Joint Annual Meeting, Washington, DC, August 4-6, 2013.
4. Field CB, Barros V, Stocker TF, Qin D, Dokken DJ, Ebi KL, Mastrandrea MD, Mach KJ, Plattner GK and Allen SK (Eds). 2012. Managing the risks of extreme events and disasters to advance climate change adaptation: Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press; 2012.
5. Guiteras R. 2009. The impact of climate change on Indian Agriculture. Accessed from http://econdse.org/wp-content/uploads/2014/04/guiteras_climate_change_indian_agriculture_sep_2009.pdf
6. IPCC. 2018. Summary for Policymakers. In: Global Warming of 1.5°C. Masson-Delmotte V, Zhai P, Pörtner H-O, Roberts D, Skea J, Shukla PR, Pirani A, Moufouma- Okia W, Péan C, Pidcock R, Connors S, Matthews JBR, Chen Y, Zhou X, Gomis MI, Lonnoy E, Maycock T, Tignor M, and Waterfield T. (Eds.), World Meteorological Organization, Geneva, Switzerland, 32 pp.
7. Singh NP, Anand B and Khan MA. 2018. Micro-level perception to climate change and adaptation issues: A prelude to mainstreaming climate adaptation into developmental landscape in India. Nat Hazards., 92(3): 1287-1304.
8. Singh NP, Bantilan C and Byjesh K. 2014. Vulnerability and policy relevance to drought in the semi-arid tropics of Asia–A retrospective analysis. Weather Clim Extrem. 3: 54-61.
9. Stocker TF, Qin D, Plattner GK, Tignor MMB, Allen SK, Boschung J, Nauels A, Xia Y, Bex V and Midgley PM. 2013. Intergovernmental Panel on Climate Change: Summary for policy makers. In: Climate Change: The Physical Science Basis. Contribution of Working Group I to the V Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press.
10. Thornton PK and Gerber P. 2010. Climate change and the growth of the livestock sector in developing countries. Mitigation and Adaptation Strategies for Global Change 15: 169-184.
11. Udmale P, Ichikawa Y, Manandhar S, Ishidaira H and Kiem AS. 2014. Farmers perception of drought impacts, local adaptation and administrative mitigation measures in Maharashtra State, India. Int. J. Disaster Risk Reduct., 10: 250-269.
12. Venkateswarlu B and Prasad JVNS. 2012. Carrying capacity of Indian Agriculture: Issues related to rainfed farming. Current Science 102(6): 882–8.
13. Vermeulen SJ, Campbel BM and Ingram JSI. 2012. Climate change and food systems. Annual Review on Environment Resource 37: 195-222.
14. Vermeulen SJ. 2014. Climate change, food security and small-scale producers. CCAFS Info Note. CGIAR Research

Program on Climate Change. Agriculture and Food Security (CCAFS) (https://cgspace.cgiar.org/bitstream/handle/10568/35215/IPCC_info_note3April 14.pdf).

15. Zhang Lixia, Zhu Lili, Yu Mengyang, Zhong Mingxing. 2016. Warming decreases photosynthates and yield of soybean [Glycine max (L.) Merrill] in the North China Plain. The Crop Journal 4: 139–46.
16. Zhao Chuang, Liu Bing, Piao Shilong, Wang Xuhui, Lobell David B., Huang Yao, Huang Mengtian, Yao Yitong, Bassu Simona, Ciais Philippe, Durand Jean-Louis, Elliott Joshua, Ewert Frank, Janssens Ivan A., Lin Tao Li, Liu Erda, Qiang, Martre Pierre, Müller Christoph, Peng, Peñuelas Shushi, Josep, Ruane Alex C., Wallach Wang Daniel, Wu Tao, Liu Donghai, Zhuo, Zhu Yan, Zhu Zaichun, and Asseng Senthold. 2017. Proceedings of the National Academy of Sciences Aug 2017, 114 (35) 9326-9331; DOI: 10.1073/pnas.1701762114

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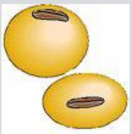

Quality Seed Production in Soybean

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Soybean is the most important oil seed crop in India as well as the world. The soybean has gained a significant position within a very short time of its introduction and commercial cultivation. The popularity of soybean crop still is increasing in different zones and states of our country. Soybean has changed the economic status of the farmers who are growing soybean; still farmers are struggling with the problem of loss of seed quality of soybean. Producing good quality seed is still a challenge in some of the soybean growing areas. Good field emergence is being a problem due to one or other reasons.

Major factors of soybean seed quality loss and poor field emergence
Structural limitations of seed

Soybean seed has structural limitation towards mechanization and large scale handling. The seed coat of soybean is very thin as compared to other leguminous crops. The position of radical axis is also quite raised on the cotyledons. Mechanical damage to an individual seed can include formation of cracks or breaks in the seed coat, cracks in cotyledon, injury or breakage of hypocotyls-radicle axis and complete breakage of seed to the point where it would no longer be classified as part of pure seed fraction. The extreme of mechanical harvesting and threshing is splitting of seed thus producing "Dal' (single cotyledons). The amount of mechanical damage to the seed is inversely related to the seed moisture level. Physical damage increases as the seed moisture decreases below 12%. At higher moisture level (≥ 14%), seeds may be damaged internally and the germination be reduced Singh and Singh, 1981, Prakoboon, 1982). Large seeds tend to be more susceptible to mechanical damage than small seeds. Seeds that have been exposed to field weathering or that have been dried at high temperatures are more susceptible to mechanical damage. The resistance to mechanical damage has been reported to be a genetically governed by mostly seed coat lignin content, seed thickness and structure and distribution of 'Hourglass cells' in seed coat. Seed moisture content is greatly correlated to the seed damage during mechanical harvesting and threshing. The safe moisture for mechanical harvesting and threshing of seed had been recommended to be 13-14%.

Quality loss during storage

The storability of seeds is highly influenced by the storage condition- the relative humidity (RH) and temperature of storage (Justice and Bass, 1978). The tendency of seed to maintain equilibrium moisture in relation to RH of storage is an unavoidable physiological phenomenon. Therefore, high RH of store increases the seed moisture and cause rapid loss of seed quality. In tropical and subtropical regions like India, the development of 'state of the art' facility where storage temperature and RH can be regulated is quite expensive. Lack of such infrastructures forces to store seeds under ambient condition. Soybean seed is being harvested in the month of Oct-Nov and stored for 8 months for next sowing in June-July. The performance of seed in storage varies with areas of storage. The seeds stored in the condition above the safe level of RH (approximately 50-60%) are deteriorated rapidly.

Table 1: The relationship between RH of storage and equilibrium seed moisture content in relation to storage temeperature

Temp. (^{0}C)	**Relative humidity (%) of seed store**				
	50	**60**	**70**	**80**	**90**
15	9.2	11.0	13.0	15.5	19.2
20	9.0	10.7	12.8	15.2	19.0
25	8.7	10.5	12.5	15.0	18.8

Seed health/ seed borne disease

Seed health is an important parameter for determining seed quality. There are reports of as high as 30 seed borne fungi which infect soybean seed (Sinclair, 1982). Most prevalent field fungi associated with soybean seed as seed borne was found to be *Phomopsis sps*. Followed by *Cercospora* and *Colletotrichum sps*. Under Indian condition infection by *Cercospora kikuchii* (Purple stain of seed), *Diaporthe phaseolorum* var. *sojae*, *Myrothecium roridum*, *Macrophomina phaseolina*, *colletotrichum truncatum* are major cause of low seed quality. The incidence of seed borne diseases not only affects the seed crop, it is transmitted through the infected seed to the next crop. Diseases thus disseminated hamper the soybean production. Seed crop should be free from viral diseases like Soybean mosaic viruses.

Occurrence of mycoflora on and in seed has detrimental effect on seed quality at storage. The seed deterioration is accelerated by the infection of storage fungi – namely Aspergillus sp, Penicillium sps. and Rhizopus sps. In the tropical and sub-tropical regions where relative humidity is higher during seed crop maturity, the risk of attack of saprophytic fungi is more. Rains during seed crop maturity may cause devastating loss of seed quality. The infection of storage fungi has cumulative effect on biochemical degradation of seed.

Biochemical deterioration of seed

The biochemistry of seed deterioration has been documented as lipid peroxidation of the phospholipid fraction of cell membrane, disruption of cell membrane, damage to electron transport system in the mitochondrion membrane, inactivation or damage to enzyme system, damage to genetic materials of cell- DNA, mRNA. The production of highly reactive free radicals (superoxide or hydroxyl radicals) during different metabolic pathways triggers the biochemical deterioration of seeds. First and primary site of attack of free radicals are the phospholipids of cell membrane of mitochondria. The lipid peroxidation of phospholipids produces different small chain aldehydes and ketones which attack the genetic material of cell and cause damage to DNA. Damge to the cell membrane cause leaching loss of intra-cellular substances. The antioxidant enzyme system scavenges the free radicals produced in seeds. The expression and activity determine the degree of free radical scavenging. Anti oxidant chemicals like α-tocopherol and ascorbic acids content of seed also determine the level of protection of seeds to scavenge free radicals.

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Critical measures in seed production steps to minimize seed quality loss

The advanced techniques should be followed to produce seeds of better quality and prevent the chances of seed quality loss and seed damage. The measures start with proper seed treatment before sowing to storage of seeds for next sowing season.

Improved methods of seed treatment and its beneficial effect

Seed treatment with recommended dose should be followed to improve seed germination and field emergence by protecting the seed from internal as well as external fungal infections. The texture of soybean seed coat is very smooth. Therefore, loss of chemical applied to seed through powder formulations is very high. Seed treatment becomes non-effective if the chemical is not fixed to seeds and it does not enter into the seed to give systemic effect. Seed polymer coating is most advanced technique to make seed treatment most effective and economical. This polymer coating technique binds the beneficial chemicals on the surface of the seed and does not allow the chemical to get shed out of the seed neither during seed handling, sowing nor during seedling emergence. The chemical gets sufficient time to enter into the seed with the intake of moisture from soil and act

Optimum plant population for proper seed growth and disease and insect management

The recommended 'row to row' and 'plant to plant spacing should be followed. The seed is a living entity and should be properly grown to be able to develop a new healthy plant in the next generation. If the plant population is not maintained or uniform plant spacing is not followed there will be competition for nutrient for growth and seed development. Scarcity of nutrient may cause deficiencies of important and critical biological units e.g. enzymes and mineral co-factors of enzymes with cause failure of germinability of seed produced or abnormal growth of seedling and plant from such low quality seed. Present day improved machineries for soybean seed are developed like soybean seed drill or soybean seed planter where desired plant spacing is achieved properly. Such machines should be utilized for sowing of seed production plots. Proper spacing of plants not only desirable for proper seed development, it also helps in management of insect and diseases. Diseases are becoming alarming and reducing seed yield. Seed borne diseases cause failure of seed production programme as this menace cause loss of germination of seed and seed lots less than standard limit of germination are rejected for further sale.

Water and Nutrient management:

Soybean is mostly grown as rain fed crop. Due detrimental effect of climate change, there are long spell of rainless days during crop growth. Soybean is highly photo and thermo sensitive crop and delay in sowing cause adversely on seed quality. If initiation of rain delays the sowing is also delayed accordingly. But for seed production programme irrigation should be followed for proper time of sowing and protecting the seed crop from long spell of water scarcity due to lack of rain. The drought may hampers quantity of produce but the loss of quality is in much more higher magnitude than loss of quantity.

Similarly, the recommended nutrient doses should be followed for good quality seed production. Among all other mineral nutrients, sulfur and phosphorus are very essential for high protein containing soybean crop. Seed yield was very sensitive to S deficiency occurring during vegetative growth, but not to S deficiency occurring during reproductive growth. The 11S/7S ratio was strongly influenced by S deficiency occurring during reproductive growth, but was relatively insensitive to S availability during vegetative growth (Sexton *et al*., 1998). Phosphorus is specifically important for improving storability of soybean seeds.

Foliar Application of Growth activators and antioxidants for quality seed production

Chemical	**Stages of application**	**Beneficial effect**
Salicylic acid: 100 ppm	i. vegetative stage ii. pod filling stage	• Induce good germination and field emergence • Activate plant internal defense mechanism • Induce abiotic stress resistance: Draught or high temperature • Increase seed vigour and storability of seeds. • Protect seeds from fungal infections
Potassium phosphate 2%	Pod formation or pod filling stage	• Improve cell wall formation and seed quality • Improve seed vigour and storability of seeds
Alpha-Tocopherol 100ppm	i. vegetative stage ii. pod filling stage	Antioxidant act by scavenging radicals in plant system thus improve plant vigour Translocation to seed improves seed yield and seed vigour and storability

Seed Certification Standards for Soybean

S.No.	**Item**		**Foundation**	**Certified**
1.	Pure seed	Minimum	98%	98%
2.	Inert matter	Maximum	2.0%	2.0%
3.	Other crops	Maximum	Nil	10/kg
4.	Weed seed	Maximum	5/kg	10/kg
5.	Other variety of same crop	Maximum	10/kg	40/kg
6.	Germination including hard seed	Minimum	70%	70%
7.	Moisture	Maximum	12%	12%
8.	Moisture (for vapour) proof containers	Maximum	7%	7%

Maintenance of seed quality through seed chain

Nucleus seed→ Breeder seed → Foundation → Certified

Four stages of seed multiplication viz nucleus, breeder, foundation and certified are following in India. In the first two stages, seeds are multiplied and maintained by concerned or designated breeder/ institutions. Later two stags are produced by seed producing agencies and falls under the category of certifies class.

At nucleus and breeder seed stage, the standing crop is inspected by a monitoring team consisting of breeders and officials of central/state seed corporations and seed certification agencies. The requisite care is taken at all stages of production, post harvest handling, processing and storage to maintain high level of quality. Whereas, the standing breeder/nucleus seed crop should have 100 percent varietal purity, the seed of these classes must meet the minimum standard of foundation seed class.

i) **Nucleus seed**: the breeder from breeder stock produces it by selecting line true to type single plant progenies.

ii) **Breeder seed**: Produced from nucleus seed under direct supervision of the breeder and monitored by a team of experts, it provides a source for foundation seed.

iii) **Foundation seed**: This is the first generation progeny of breeder seed. The standards for this class are maintained by thorough periodic inspection by authorized seed certification agencies.

iv) **Certified seed**: This is the progeny of foundation seed. It is accepted only if it meets the prescribed norms at various stages of production.

Standard Seed Production Steps:
Land requirements

Land to used for seed production shall be free of **volunteer plants** (unwanted plants growing from the seed that remain in the field from a previous crop). In addition, the field should be well drained.

Isolation requirements

The dehiscence of anthers takes place in the bud itself before the opening of the flower and hence, normally self pollination takes place. Cross pollination by insects is usually less than one percent. An isolation of **three meters** from other fields of soybean is sufficient to maintain genetic purity**.**

Roguing

At flowering stage remove off type plants on the basis of plant characteristics and flower colour. Do final rouging at maturity stage, to rogue out off types plants on the basis of pod characteristics. If plants affected by yellow mosaic virus and soybean mosaic virus as soon as they appear , so as to check further spread up to first two to three weeks. Continue removal of plants affected by soybean mosaic up to last.

Precautions during harvesting and threshing to minimize mechanical damage to soybean seed

The seed quality of soybean can be maintained by timely harvesting & careful threshing because harvesting at most appropriate time will minimize the effect of weathering & seed damage and careful handling during threshing can prevent mechanical injury to seeds resulting in reduced viability.

1. The crop should be harvested when seed moisture is 15-17%. The stage coincides with fall of leaves and change of pod

colour to yellow/brown/black. Delay in harvesting causes seed losses by pod shattering.

2. The harvested crop should be dried on the threshing floor for bringing down the seed moisture to around 13-15%. At moisture below 12% soybean seed becomes brittle prone to mechanical injury during threshing.
3. Cylinder speed of the thresher should be adjusted between 300-400 RPM. This ensures complete threshing without splitting or breakage of seed when the seed moisture is 14-15%. The speed should be lowered to 300 RPM when the seeds are dry.
4. Seeds should frequently be checked during threshing. If any excessive damage is seen cylinder speed should be adjusted.
5. If the seed has been exposed to weathering strong mechanical force should be avoided.

Drying

After threshing the seed should be finally dried in thin layer on cemented floor or tarpaulin. The moisture should be reduced to 10% or below. In processing plants the seed can be dried either by natural air or hot air of below 30ºC if the moisture content is high.

Cleaning & grading

Seed is cleaned in three steps. A pre-cleaner is used for pre-cleaning of seeds. Pre-cleaning is a fast cleaning process and removes most of the inert matters from seed. A grader is then used to remove the under and over size seeds and soil particles, inert mater etc. Finally specific gravity separator is used for removing foreign matters which have similar size as the soybean seeds of a particular variety.

Packaging & storage

The storage of soybean seed needs special care. Temperature and moisture are most critical factors in storage. Soybean seeds being hygroscope absorb moisture from atmosphere or loose moisture to surrounding air until they reach equilibrium. The relative humidity in the storehouse should be maintained at below 50%. The activity of storage insect & fungi is very low at this level. The temperature in the storage room should be between 20-27ºC. At this temperature and RH of 50% seeds can be stored for 8-9 months safely. If the seed moisture is reduced to 10% or less water proof bags made of thick polythene should be used for storage otherwise jute bags can be used.

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Mechanization for Climate Smart Soybean Production

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Under the present difficult conditions due to climatic changes which is affecting the rain fed vertisols of India adversely on account of erratic monsoon rains. Kharif rainfall is unpredictable in its quantity, duration, intensity and gap of dry spell in between. *Kharif* crop farmers have very short duration for sowing of crop due to above said conditions in vertisols and manage several factors influencing kharif crops. These crops are forced to face and overcome excessive rainwater and drought spells in between which cause major impact on the yields of Kharif crops. Soybean is very sensitive to moisture stress and being epigeal germination of seed needs to have special care for seed depth and safety from birds.

Soybean is crop which is affected the most by the impact of excessive rainfall and spell of drought before and during the crop season. Delayed monsoon, dry spell during the crop period and high intensity rainfall causing inundation of soybean fields are the major causes of major reduction in production of soybean crop. To overcome this critical problem it is need of the hour to use sub-soiler to achieve higher yields of crops such as soybean and other Kharif crops. It is the need of the hour to operate sub-soiler to overcome the vagaries due to climate change for all Kharif crops and save the crop yields from drastically going down.

How and why to use Sub-soiler to mitigate impact of climatic change

Subsoiler is a tractor drawn deep penetrating implement which can be successfully be used in the hardest of the vertisols by 55 PTO HP tractors. The sub-soiler can form firm walled narrow channels of 2.5 inches wide and 30 inches deep in the vertisols

Channels can be formed with the difference of 12 or 15 feet in both the directions of the field plot. Most appropriate time for the operation of the sub-soiler is between 15th of May and 30th May of the year another option to operate the sub-soiler is just after harvest of Rabi crop. Draft encountered by the sub-soiler is lesser when it is operated just after harvest of r*abi* crops as compared to operation in the month of May. It is good to operate sub-soiler with the interval of 12 to 15 feet throughout the field plot in one direction and also in the across direction.

Fig1: Tractor drawn Sub-soiler for vertisols

Benefits of sub-soiler to retain rainwater in the fields

Field preparation with use of sub-soiler in combination with rigid tine cultivator helps to achieve double benefit for the Kharif crop including soybean drill/planter which helps to overcome the adverse impact of high intensity rainfall (in short duration) followed by dry spells for the soybean crop. Excessive rainwater moves down through the narrow channels formed by the Subsoiler in the fields and thus maintains a storage of moisture (70 cm below the soil surface) which can be utilized by the crop during the dry spells

The soybean crop can be irrigated through the furrows formed by the machine of BBF in case of dry spell and also during the regression of the monsoon at the last stage of the soybean crop .Thus the soybean crop can be maintained to near normal condition with the help of this package of technology. Finally the soybean crop yields can be maintained to almost normal.

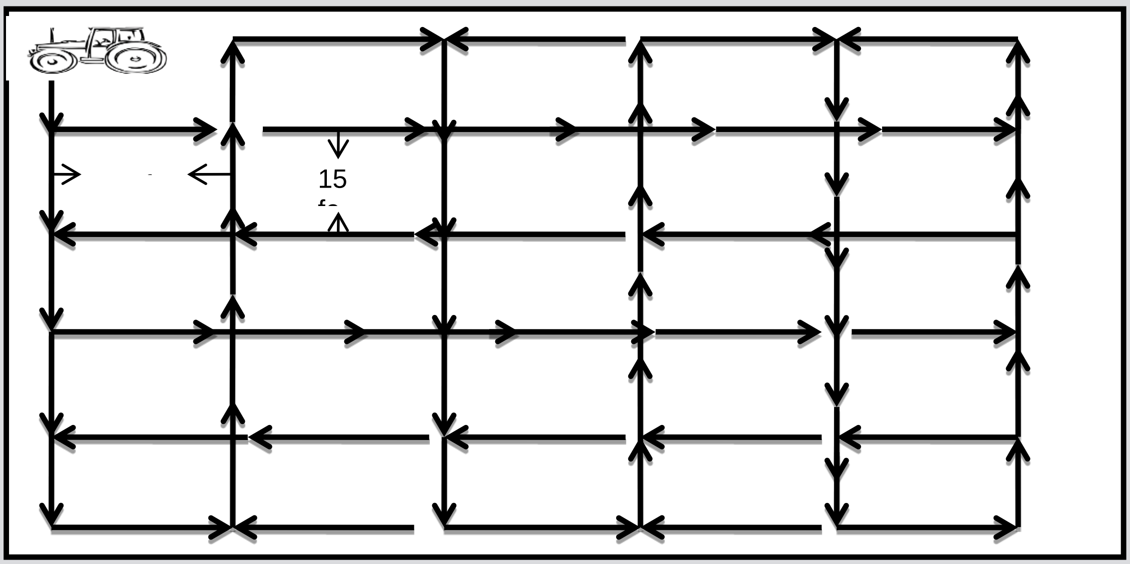


Fig. 1: Sketch to depict mode of operation of Tractor drawn Sub-soiler in the field plot in vertisols

Why to Prepare Land with rigid tine cultivator and not with Duck foot cultivator

Farmers need to understand that field should be prepared preferably by Rigid tine cultivator(with heavy planker/pata) in both the directions of the field plot so that more and rain water enters the deep down in the soil in the forth coming monsoon. Deep tillage with rigid tine cultivator helps better infiltration and percolation of rain water which helps maintain moisture at subsoil which helps the crop in the times of need for the crop. Soybean field which were tilled and prepared with rigid tine cultivators have lesser impact of heavy rains and problems of water logging.

Adverse Impact of Duck foot cultivator (Blade harrow as tillage tools on soil moisture in vertisols

It is important to mention the role of Duck foot cultivator in vertisols. Rigid tine cultivator was a popular tillage machine in vertisols which has been gradually replaced almost completely in vertisols by duck foot cultivator within last 10 year Duck foot cultivator has become dominant tillage tool in vertisols of India .Now rigid tine cultivator is rarely used by soybean growing farmers in Madhya Pradesh and it has replaced by Duck foot cultivator as it eliminates the grasses and weeds in the fields in one pass only whereas rigid tine cultivator needs to be operated for two or three cross passes which results in higher diesel consumption as compare to tillage with Duck foot cultivator. It is relevant here to mention that bullock drawn and tractor drawn Duck foot cultivator was developed for Rabi crops in Vertisols to conserve moisture.

By using Duck foot cultivator rainwater percolates at a very slow rate and at time at negligible rate into the vertisols soils with high content of clay in the soil .In case rigid tine cultivator and avoid using Duck foot cultivator .Because Duck foot cultivator cut the soil up to the depth of 3.5 inches and solid below 3.5 inches remains untilled .In addition to soil below 3.5 inches is compressed by the blade of the which further reduces the percolation of rainwater/irrigation water down below .In other words hard layer which already exists deeper n the vertisols is further added with the help of compaction with the Duck foot cultivator . Duck foot cultivator tilled field face significant amount of soil along with nutrients in the soil .At times the large amount of soil nutrients are removed with the runoff .rain water stagnates in the field plots in short time after rainfall when Duck foot cultivator is used whereas runoff starts after relatively late from the field plot where rigid tine cultivator is used.

On several occasions of high intensity rainfall even seeds are moved out or opened to the air which is damaged by birds and other animals .In certain situations excessive soil is put on the soybean seed which is epigeal seed and its germination is affected thus seed germination does not take place at all. In such situations re-sowing is forced to be done by the farmers.

It has been reported that if rain water is stagnated in field for longer duration nodulation in soybean plant roots are adversely affected with reduced nitrogen fixation.

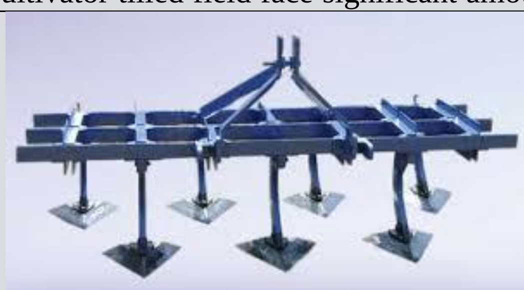


Fig 2 :Duck foot cultivator or "Panja"

Fig 3 :Rigid tine cultivator

Soil compaction, hard layer and its management with proper tillage machines

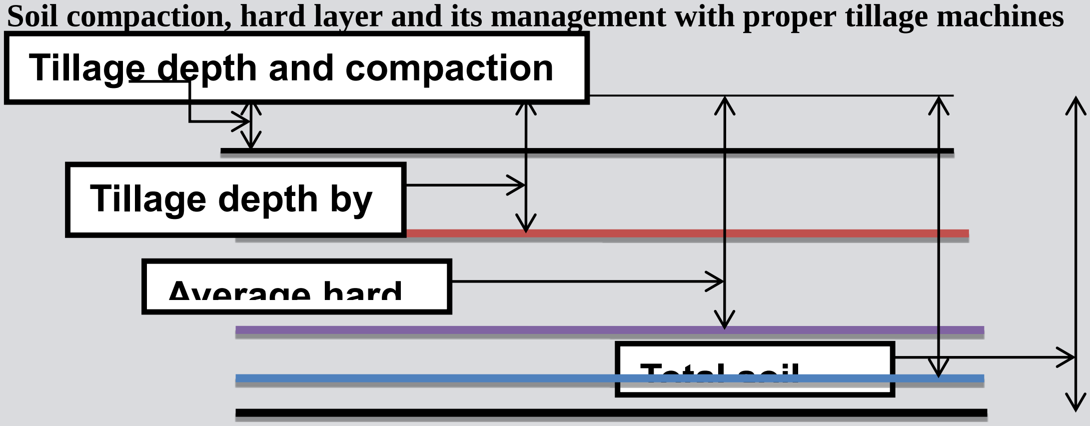


Fig. 4: Sketch to depict tillage and soil layers formed in vertisols with different tillage tools

<u>Adoption of Broad Bed and Furrow to manage moisture to save soybean seed</u>

After the operation of the sub-soiler in the fields should be prepared with the help of rigid tine cultivators (with a heavy planker for high clay containing vertisols) .Broad Bed and furrow machine is then used for the sowing of the soybean crop which simultaneously performs sowing along with forming two furrows/channels. This machine helps the soybean plant to prevent stagnation of water close to the plant roots for longer than desired period. It therefore helps better development of nodules which helps better nitrogen fixation. It is recommended to sow 4 or 5 rows of soybean crop on the bed. Although the machine has several provisions for adjustments for row to row distance but it is found best when distance between two channels is kept at 210 cm with channels 15 cm deep .Farmers have started adopting the BBF /FIRBS sowing machines for several crops including gram. BBF and FIRBS machines are successful in absorbing/holding less rainwater and drain out excessive rainfall in the vertisols.

Fig 5 :Single bottom Broad Bed and Furrow (BBF) seed drill/planter.

The recommended Broad Bed and Furrow seed drill/planter machine for soybean to overcome impact of moisture stress Solution to overcome the problem of drastic reduction of soybean yields in vertisols due to climate change (spells of high intensity rains and dry spells during the soybean cropping period.

Fig. 6: Two in one sowing machine

Fig. 7: Soybean crop sown with BBF seed drill

Desired Package to prevent damage/major reduction in Seed of soybean crop

Combination of three machines ie sub-soiler, rigid tine cultivator and Broad Bed and Furrow seed as a package of tillage for land preparation as a land configuration technique to prevent spells of heavy rains and dry spells in the fields of soybean which has played havoc to the soybean crop this year in vertisols. This practice will help better growth of nodules as well on the roots of soybean plant as this package will avoid long hours/continuous of water stagnation around the soybean plant.

Farmers also agree to the harmful effects of use of Duck foot cultivator (Blade harrow or bakhkhar (in Hindi)) and it has been observed that the fields which have been either been tilled with reversible plow or with rigid tine cultivator have not been affected by the problem of rain water stagnation and have been able withstand the adverse impact of high intensity rains (in short time) and dry spells.

Usage of BBF(Broad Bed and Furrow) seed drill/planters form two channels which help the soybean farmers to apply irrigation water to support the plants during dry spell and at the critical stages when irrigation in needed for better flowering / pod filling .

FIRBS (Furrow irrigated raised bed system) seed drills/planter are very useful for the fields of soybean where soil draft is not high (lesser clay content) .It relevant to mention here that due to facility of subsidy for the tractors (below 35 PTO HP and no subsidy for the tractors available for tractors with 45 PTO HP and above) The tractors (below 35 PTO HP) in vertisols are almost 85% of the total tractors present in vertisols .FIRBS seed drills/planters need higher PTO HP tractors to operate since they are meant to form three or more channels in the vertisols whereas BBF seed drills/planters need to form only two channels which can be formed by 40 PTO HP tractors.

Sowing machines for quality seed production and productivity

Broad Bed Furrow (BBF) seed Planter:-A tractor-drawn broad bed furrow (BBF) planter for soybean [Glycine max (L.) Merrill] was developed to overcome the adverse impact of low and excessive moisture due to shift of climate. It effectively operates in vertisols and associated soils and is attachable to the tractor for facilitating formation of broad bed along with furrows on both the sides of the beds of desired width and depths and subsequent sowing in one go. Plant population mortality in soybean with tractor-drawn BBF seed planter for vertisols was reduced to the range of 16% as compared to flat bed under the vagaries of monsoon which subsequently resulted in yield enhancement to the extent of 18.50%. The BBF seed planter needs to be fabricated for individual tractor so that it performed better in vertisols and other soil conditions.

Features of the machine

1-Name of the tool/ machinery/ equipment- Broad Bed and furrow (BBF) seed planter
2- Capacity-1.0 ha/hr
3-Power Requirement-35 PTO HP tractor
4-Materials used for making-High carbon steel angle iron, MS sheets for seed and fertilizer box, Poly urethane seed roller wheels. Seed dropping pipes
5-Specification-(4,5, or 6 rows for BBF)for soybean crop and 9 rows for wheat and gram as per the need of the crop (for flat sowing method)
6-Cost (2014 cost basis)-Rs 68,100 /- + taxes

Broad Bed and furrow (BBF) seed planter

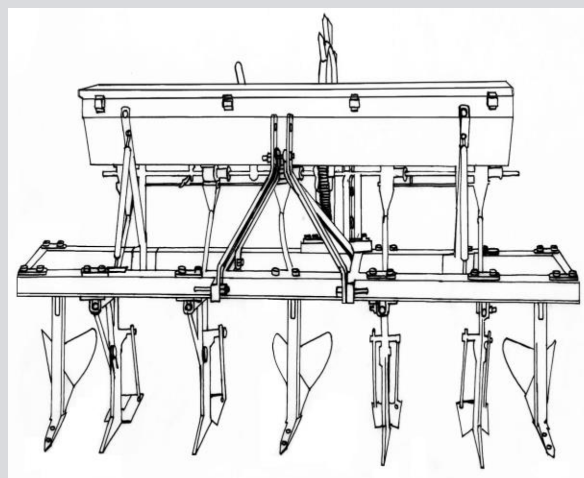
Broad Bed Furrow (BBF) seed drill -2

Broad Bed Furrow (BBF) seed drill**:-**A tractor-drawn broad bed furrow (BBF) seed drill. It effectively operates in vertisols and associated soils and is attachable to the tractor for facilitating formation of broad bed along with furrows on both the sides of the beds of desired width and depths and subsequent sowing in one go. Plant population mortality in soybean with tractor-drawn BBF seed drill/planter for vertisols was reduced to the range of 14–19% as compared to flat bed under the vagaries of monsoon which subsequently resulted in yield enhancement to the extent of 18.65%. Study also indicated that tractor-operated BBF seed drill specifically fabricated for individual tractor performed better in vertisols and under prevailing field draft conditions.

<u>Features of the machine</u>

- Name of the tool/ machinery/ equipment, **Broad Bed and furrow (BBF) seed drill**
- Capacity, 1.0 ha/hr
- Power Requirement, 35 PTO HP TRACTORS
- Materials used for making, high carbon steel angle iron, MS sheets for seed and fertilizer box, Seed dropping pipes
- Specification, (4,5 or 6 rows for BBF) for Soybean crop and 9 rows for wheat and gram as per need of the crop (for flat sowing)
- Cost (2014 cost basis), Rs. 55,300/-+ taxes.

FIRBS (Furrow irrigated raised bed system) seed drill: FIRBS machine has been developed for soybean and other crops as irrigation is needed at the most critical periods during crop growth. The machine is capable of mitigating the effect of dry spells as well as water logging conditions during cropping season of soybean as climatic uncertainties are found in present decade. In addition to holding rain water and draining the excessive rainfall this machines also helps to facilitate supply of irrigation to the formed ridges along the land configuration. Farmers have adopted this machine for sowing soybean and also several other crops including some vegetables. Sowing of soybean using FIRBS seed drill resulted in about 20 % increase in plant population and resultant seed yield by 22 %.



FIRBS (Furrow irrigated raised bed system) seed drill -3

<u>Features of the machine</u>

1. Use of the tool/ machinery/ equipment, Fertilizer placement and sowing in ridges on vertisols
2. Capacity, 1.0 ha/hr
3. Power Requirement, 35 PTO HP TRACTORS
4. Materials used for making, high carbon steel angle iron, MS sheets for seed and fertilizer box, Seed dropping pipes Poly urethane seed roller wheels

5. Specification, (2, or 3 rows per bed) for FIRBS and 9 rows for wheat and gram as per need of the crop
6. Cost (2014 cost basis), Rs 52,250/- + taxes

FIRBS (Furrow irrigated raised bed system) seed drill

Two in one seed drill cum planter -4

Two in one seed drill cum planter: It is a unique machine with provisions for drilling the seeds and also to plant the seeds *ie* to maintain seed to seed distance. Either of the two options can be used just by shifting the plastic pipe from one hole to another. This is a machine which helps farmer to drill or plant the soybean seeds and also other crops with desired adjustments. This unique machine can perform both drilling and planting operations thus saving money of buying two machines.

Features of the machine

- Use of the tool/ machinery/ equipment, sowing in vertisols, and other associated soils
- Capacity, 1.15 ha/hr
- Power Requirement, 35 PTO HP tractor
- Materials used for making, High carbon steel angle iron, MS sheets for seed and fertilizer box, Poly urethane seed roller wheels. Seed dropping pipes
- Specification, 4,5or 9 rows for soybean different rollers as per need of the crop along with seed covering device as option
- Cost (2014 cost basis), Rs. 67,200/-

Two in one seed drill cum planter

Sweep seed drill -5

Sweep seed drill: - The simultaneous tillage and sowing operation by sweep seed drill helps to maintain higher plant population (25.22–34.55%) as compared to flat method of sowing. This also leads to reduction of weeds (59.91– 68.37%) as compared to flat sowing method. Thus, the use of sweep seed drill curtails the cost on post emergence herbicides with the help of the attached sweeps on the frame of the machine. Results of the study with the machine have indicated that crop planted by the sweep seed drill showed yield increase from 7.78 to 16.46% as compared to normal seed drill. The use of developed sweep seed drill leads to saving of one pass tillage and one weeding operation in the initial growth period of the crop. It is suggested to get tractor-operated sweep seed drill manufactured with an adjustable frame which could hold the sweeps at the rear end of the frame of the seed drill and the tines for dropping seeds on the front of the frame of the seed drill to ensure desired field operation.

Features of the machine

1. Use of the tool/ machinery/ equipment, sowing in vertisols alluvial soils and associated soils
2. Capacity, 1.25 ha/hr
3. Power Requirement, 30 PTO HP TRACTORS

4. Materials used for making, high carbon steel angle iron, MS sheets for seed and fertilizer box, Seed dropping pipes
5. Specification, 9 rows for soybean different rollers as per need of the crop
6. Cost (2014 cost basis), Rs 47,600/- + taxes

Fig-Sweep seed drill

Subsoiler for vertisols -6

Subsoiler for vertisols: The Subsoiler was developed to cope with the problem of moisture stress in vertisols due to field inundation by monsoon rain water attributed to climate change in central India. The soil moisture is managed by maximizing the use of rainfall through increased infiltration, moisture retention, reducing runoff and soil erosion. Thus, by employing the machine, performance of high yielding improved varieties is optimized by *in situ* moisture management. Surface runoff and deep drainage water can be exploited as supplemental irrigation to post-rainy season crops like wheat and chickpea. The Subsoiler helps to move the excess water downwards from the field to save the crop from water logging condition also. **This subsoiler can penetrate up to 2.5 feet deep in high clay vertisols of central India.**

<u>Features of the machine</u>

1. Use of the tool/ machinery/ equipment, subsoiling in vertisols alluvial soils and associated soils
2. Capacity, 1.0 ha/hr (depending upon the distance of operation)
3. Power Requirement, 55 PTO HP TRACTORS
4. Materials used for making, high carbon steel flat thick plate, high carbon low wear steel tool. Heavy duty angle iron.
5. Specification, One bottom and can be modified as mole plow.
6. Cost (2014 cost basis), Rs 64,000/- + taxes

Soybean seed planter -7

Soybean seed planter: Soybean seed planter facilitates proper placement of the seeds and maintains seed to seed distance. The soybean seed planter has rotor wheels for different sizes of seeds and hence desired distance of plant to plant is maintained. This machine can be utilized for planting several other crops with specific roller wheels for the seed size and maintain plant to plant distance as desired. This machine can easily be adjusted as per the need such as to change row to row distance also.

Fig- Soybean seed planter

<u>**Features of the machine**</u>

1. Use of the tool/ machinery/ equipment, sowing in vertisols
2. Capacity, 1.15 ha/hr
3. Power Requirement, 35 PTO HP TRACTORS
4. Materials used for making, High carbon steel angle iron, MS sheets for seed and fertilizer box, Poly urethane seed rollers. Seed dropping pipes
5. Specification, 9 rows for soybean different rollers as per need of the crop and additional rollers for other crops as option
6. Cost (2014 cost basis), Rs 47,600/- + taxes

Ridge seed planter -8

Ridge seed planter:-Due to fluctuations of monsoon in Central India, quick seedbed preparation and timely sowing are critical factors to achieve higher soybean [*Glycine max* (L.) Merrill] yield. Therefore, a 'tractor drawn ridge seed planter' was developed, to facilitate formation of ridge of soil along with placement of seeds upon the formed ridge. Planting of soybean using ridge seed planter resulted in 15. % increased plant population and consequently seed yield by 21%**.** The ridge seed planter made by the machine is capable of placing the seed and mitigating the effect of dry spells as well as water logging conditions. The ridge seed planter system of sowing helps to conserve moisture and soil thus saving the plant population for the soybean crop as compared to common practice of sowing on flat crop fields. Besides forming ridges and placing the seeds at the top of the ridges, considerable reduction in weed growth is observed in the field of soybean crop.

Fig-Ridge seed planter

Different stages of the operations of the ridge fertilizer drill cum planter:

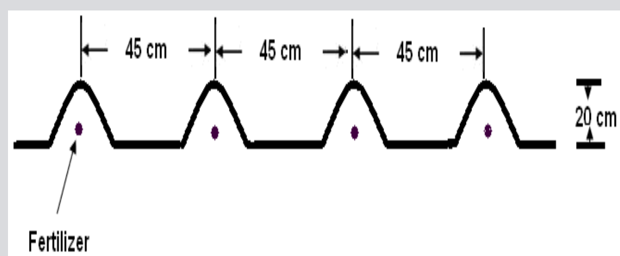


Fig.7 Placement of fertilizer at the ridges formed by Ridge fertilizer cum seed planter

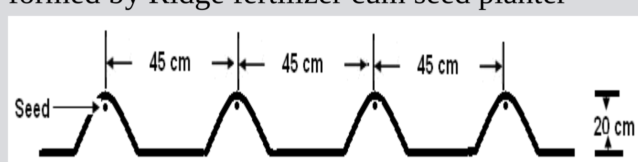


Fig.8 Placement of seed at the top of ridges formed by Ridge fertilizer seed planter

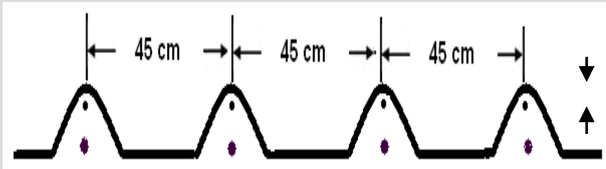


Fig. 9 Placement of fertilizer and seed on ridges formed by Ridge fertilizer seed planter

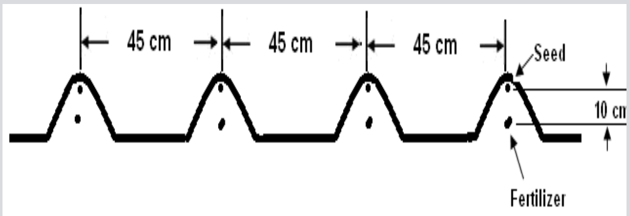


Fig.10. Specification of machine for seed & fertilizer on ridges formed by Ridge fertilizer seed planter

<u>Features of the machine</u>

1. Use of the tool/ machinery/ equipment, sowing in vertisols, alluvial soils and associated soils
2. Capacity, 1.0 ha/hr
3. Power Requirement, 30 PTO HP TRACTORS
4. Materials used for making, high carbon steel angle iron, MS sheets for seed, Seed dropping pipes
5. Specification, 4 row and 5 row and additional rollers as option for other crops as per need
6. Cost (2014 cost basis), Rs 69,100/- (05 tine) + taxes
   Rs 65,250/- (04 tine) + taxes

Ridge fertilizer drill cum seed planter -9
Ridge fertilizer drill cum seed planter:-

Under the unpredictable behavior of monsoon in Central India, quick seedbed preparation and timely sowing are critical factors to achieve higher soybean [*Glycine max* (L.) Merrill] yield. Therefore, a 'tractor drawn ridge fertilizer cum seed planter' hitched to link of three-point linkage system on tractor was developed for facilitating development of ridge of soil along with placement of fertilizer under the ridge and sowing of seeds operations upon it. Planting of soybean using ridge fertilizer drill cum seed planter results in 17.22% increased plant population and consequently increase in seed yield by 31.16 %. The fertilizer drill cum seed planter made by the machine is capable of placing the fertilizer deep as desired below the seed and mitigating the effect of dry spells as well as water logging conditions. The ridge fertilizer drill cum seed planter system of sowing helps to save 44% starter basal fertilizer for the soybean crop below the seed of the plant unlike other methods of starter doze fertilizer application such as common practice of broadcasting starter basal doze fertilizer followed by use of tine tiller to mix the fertilizer. Besides saving fertilizer, there was considerable reduction in weed growth in the field of soybean crop.

Ridge fertilizer drill cum seed planter

<u>Features of the machine</u>

1. Use of the tool/ machinery/ equipment, Sowing and fertilizer placement on the ridges formed by the machine in vertisols
2. Capacity, 1.0 ha/hr
3. Power Requirement, 35 PTO HP Tractor

4. Materials used for making, High carbon steel angle iron, MS sheets for seed and fertilizer box, Poly urethane seed rollers. Seed dropping pipes
5. Specification, 4 row and 5 row and additional rollers as option for other crops as per need along with 4 row and 5 row rollers for fertilizer

6. Cost (2014 cost basis),
Rs 74,800 /- (05 tine) + taxes
Rs 69,100 /- (04 tine) + taxes

iii) **Detailed specification of the developed and commercialized machines along with price**

S. No.	**Name of the Machine**	**Specifications**	**Machine Basic Price ****
1.	Broad bed furrow Seed Drill	09 tines	Rs 55,300/-
2.	Furrow irrigated raised bed system drill /planter	09 tines	Rs 52,250/-
3.	Sweep seed drill	09 tines	Rs 47,600/-
4.	Subsoiler machine	01 tine	Rs 64,000/-
5.	BBF planter *	09 tines	Rs 68,100/-
6.	Soybean Seed planter *	09 tines	Rs 47,600/-
7.(a)	Ridge fertilizer drill cum seed planter	05 tines	Rs 74,800/-
7 (b)	Ridge fertilizer drill cum seed planter	04 tines	Rs 69,100/-
8.	Soybean seed drill cum planter (DSR two in one) *	09 tines	Rs 67,200/-
9.(a)	Ridge seed planter	04 tines	Rs 65,250 /-
9.(b)	Ridge seed planter	05 tines	Rs 69,100/-

*As per demand Rs 8500/- Will be additional for providing the fertilizer box with the machine.
**Taxes will be charged extra by the manufacturer, if applicable.

Conclusion : Combination of three machines ie sub-soiler, rigid tine cultivator and BBF(Broad Bed and Furrow) seed drills/planters as a package of tillage for land preparation (as a land configuration technique) to prevent damage to the soybean crop due to spells of heavy rains and dry spells during the soybean crop season. Flat sowing methods/machines fail to prevent the damage to the crop as this method can't overcome moisture stress caused by moisture stress.

1. It is very important to promote usage of Subsoiler, rigid tine cultivator and BBF seed drill /planters or FIRBS seed drill /planters in place to flat sowing techniques/machines to overcome/manage the risks to the soybean crop sue to climate change. Adoption soybean seed germination test and seed treatment before sowing should be taken up at war footing. It is also critical to advice for desired doze application of recommended fertilizer.

2. Due to fear of poor plant population and also due to poor germination percentage, the farmers invariable go for double quantity of recommended seed rate of sowing.

3. Another prevalent practice is sowing with very small row to row spacing as compared to the row to row spacing of 45 cm .farmers even go as low as 9 cm row to row distance for sowing soybean with seed drills/planters.

4. Several areas have a practice of sowing soybean by seed broad casting in vertisols and associated soils.

List of Licensed Manufacturers of ICAR-Directorate of Soybean Research, Indore, developed machines

1. New Patidar Iron works Rau, 123-124 New industrial Area Rau, Indore (M.P.) PIN45331

2. Rohit steel works, Sector-18, Plot No-92,Krishna-nagar, Chikhali-road, PCNTDA Chinchwad,Pune (Maharashtra) PIN-411019

3. Mahashakti Agro Energy & Innovation Pvt. Ltd, 5 Mohta market, Main Road, Wardha (Maharashtra) PIN-442001

4. S.R. Engineering & Services Sai Mandir Road, Wardha PIN-442001 (Maharashtra

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Strategies for Management of Abiotic Stresses in Soybean

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Introduction

In today‘s climate change sceranios, crops are exposed more frequently to episodes of abiotic stresses such as drought, salinity, elevated temperature, submergence and nutrient deficiencies. These stresses limit crop production. In India, soybean is predominantly grown as a rainfed crop in vertisols and associated soils with an average crop-season rainfall of 900 mm, which varies greatly across locations and years. Along with drought, prolonged flooding/water logging due to heavy rains and low infiltration rate of the soils (Vertisols), in which crop is grown, severely reduces the productivity of this rainfed oilseed in some of the major crop growing regions of India. Around 2-3 Lakh ha area of soybean cultivation covering eight districts of Madhya Pradesh which receive >1200 mm rainfall annually, suffering with water logging and excessive moisture stress. Intergovernmental Panel on Climate Change (IPCC) furtherpredicts that the global mean temperatures may rise by2.6-4.8 ° C by the end of 21st century (IPCC 2013). One of the major challenges for futuresoybean production is to develop technology to reduce risk of yield loss due to abiotic stresses viz., drought, water logging, high temperature etc. in soybean production areas of country. Adaptable measures have been and are being developed to counter the deleterious effects of these stresses. Use of available agro-technologies in terms of mitigating strategies of abiotic stress tolerance needs to be intensified to gain sustainable soybean production by the farmers. In recent years, advances in physiology, molecular biology and genetics have greatly improved our understanding of crops response to these stresses and the basis of varietal differences in tolerance.

Classification of Stresses

It has become traditional for ecologists, physiologists, and agronomists to divide stresses experienced by plants into two major categories: biotic and abiotic. Biotic stresses originate through interactions between organisms, while abiotic stresses are those that depend on the interaction between organisms and the physical environment. Biotic stresses result from competition between organisms for resources, from predation and parasitism, and from the actions of allelopathic chemicals released by one organism and affecting another.

Abiotic Stress: Abiotic stress management is one of the most important challenges facing agriculture. Abiotic stress can persistently limit choice of crops and agricultural production over large areas and extreme events can lead to total crop failures. Abiotic stresses adversely affect the livelihoods of individual farmers and their families as well as national economies and food security. Abiotic stresses include potentially adverse effects of Salinity, Drought, Flooding, Metal toxicity, Nutrient deficiency, High temperature and Low temperature. In addition, abiotic stresses can include Shade, UV exposure Photoinhibition, air pollution, wind, hail and gaseous. In some cases, such as the supply of water, too little (drought) or too much (flooding) can both impose stress on plants. In reality, abiotic and biotic stresses are often inextricably linked.

Drought

Among different environmental stresses, drought is one of the most widely limiting for crop production on a global basis. According to one estimate, around 28 percent of the world‘s land is too dry to support vegetation (Kramer and Boyer, 1995). Severe droughts occur periodically in several major food-producing countries, having far-reaching impacts on global food production and supply. The global production of grain has, in some years, been reduced by 5 percent or more as a result of severe droughts in key countries. It has been estimated that drought causes an average annual yield loss of 17 percent in the tropics (Edmeades et al., 1992), but losses can be much more severe and total crop failures are not unknown.

Effects of drought stress on crops:

- Reduced seed germination and seedling development ·
- Poor vegetative growth
- Reproductive growth is severely affected
- Plant height and leaf area reduced ·
- Significantly reduction in leaf weight ·
- Reduced photosynthesis. ·
- Reduced stomatal conductance
- Significantly reduction in the total dry matter (Fig.1)

Mitigation of Drought Stress

1. Foliar spray of 2% DAP + 1% KCl during critical stages of flowering and grain formation
2. 3% Kaoline spray at critical stages of moisture stress
3. Foliar spray of 500 ppm Cycocel (1 ml of commercial product per litre of water)
4. Mulching with 5 tonnes of sorghum / sugarcane trash, which saves 19- 367 1. 20% of irrigation water by reducing evaporation loss of water
5. Split application of N and K fertilizers as in cotton at 45 and 60 DAS
6. Use of biofertilizers viz., Azospirillum or Phosphobacteria @ 10 packets / ha along with 25 kg of soil or FYM.
7. Seed hardening with 1% KH2PO4 and other salts for 6 – 8 hours (depending upon nature of seed coat) soaked in equal volume of water
8. Spray of 40 ppm NAA (4 ml of Planofix in 4.5 litres of water)
9. Seed treatment + soil application + foliar spray of Pink Pigmented Facultative Methnaotrops (PPFM) @ 106 as a source of cytokinins.
10. In cotton, nipping terminal portion of main stem beyond 15th node (at 70 - 80 DAS) and at 20th node (at 90 DAS) in the case of hybrids and varieties respectively for arresting transpiration loss of water)
11. Foliar spray of 0.5% zinc sulphate + 0.3 % boric acid + 0.5 % Ferrous sulphate + 1% urea during critical stages of moisture stress Application of PGRs namely Cytokinin (10 ppm); Brassinolide (0.5 ppm); Salicylic acid (100 ppm); Ascorbic acid (100 ppm) and CCC (10 ppm).

Flooding stress: Flooding may be defined as any situation of excess water. Sudden inundation following high rainfall events also poses a severe physiological stress on crops. Flooding stress in terrestrial species is referred to as waterlogging and the damage 368 symptoms caused are primarily due to the prolonged exposure of the plants to hypoxia. The effect of waterlogging of roots and lower stems are apparent as a range of symptoms on the shoots, including rapid wilting and severe physiological disruption. Vast areas of rainfed crops, particularly in South and Southeast Asia, are annually affected by flooding. There are two typical kinds of flood. One is short duration over a few weeks and not very deep, termed a ‗flash flood‘ and the other is deep flooding that lasts for a long time, called as _deepwater flood‘. Flash floods are unexpected and uncontrollable, and its flooding water level can reach 50 cm in the rainfed lowlands of the humid and semi humid tropics of South and Southeast Asia.

Effects of flooding stress on plants

1. Decay and death of leaves
2. Wilting
3. Abscission
4. Epinasty
5. Lenticels formation
6. Nutrient deficiency & Toxicity:

Under the anaerobic condition Fe toxicity is high. This leads to increase the polyphenol oxidase activity, leading to the production of oxidized polyphenols. It also causes leaf bronzing and reduced root oxidation power. Iron toxicity symptoms: Tiny brown spots on lower leaves starting from tip and spread toward the leaf base or whole leaf colored orange yellow to brown ¨ Spots combine on leaf interveins and leaves turn orange brown and die. ¨ Leaves narrow but often remain green. ¨ In some varieties, leaf tips become orange yellow and dry up. ¨ Leaves appear purple brown if Fe toxicity is severe. ¨ Stunted growth, extremely limited tillering. ¨ Coarse, sparse, damaged root system with a dark brown to black coating on the root surface and many dead roots. 370 ¨ freshly uprooted rice hills often have poor root systems with many black roots. (Fig.3)

Mitigation of flooding stress

1. Providing adequate drainage for draining excessive stagnating water around the root system.
2. Spray of growth retardant of 500 ppm cycocel for arresting apical dominance and thereby promoting growth of laterals.
3. Foliar spray of 2% DAP + 1% KCl (MOP).
4. Spray of 0.5 ppm brassinolide for increasing photosynthetic activity.
5. Foliar spray of 100 ppm salicylic acid for increasing stem reserve utilization under high moisture stress.
6. Foliar spray of 0.3 % Boric acid + 0.5 % ZnSO4 + 0.5 % FeSO4 + 1.0 % urea during critical stages of the stress .
7. Balance the use of fertilizers (NPK or NPK + lime).
8. Apply sufficient K fertilizer. Apply lime on acid soils, do not apply excessive amounts of organic matter (manure, straw) on soils containing large amounts of Fe and organic matter.

Genetic Strategies

Drought escape allows the plant to complete its life cycle during the period of sufficient water supply before the onset of drought. Farmers can assume measures to reduce the impact of drought by adopting early maturing high yielding varieties through this mechanism. However, early maturing varieties are better generally in the regions of early withdrawal of mansoon, Farmers can use diversified soybean varieties (Table 1) which are tolerant to different abiotic stresses in the areas of adoption accordingly. The second mechanism, drought avoidance, involves strategies, which help the plant maintain high water status during periods of stress, either by efficient water absorption from roots or by reducing evapotranspiration from aerial parts. The third mechanism, drought tolerance, allows the plant to maintain turgor and continue metabolism even at low water potential using mechanisms such as protoplasmic tolerance synthesis of osmoprotectants, osmolytes or compatible solutes.

Table 1: Details of varieties for abiotic stress management

Varieties	Days to maturity (in days)	Seed yield (q/ha)	Traits/Tolerance status
JS 95-60	82-88	20-25	Early maturing, pubescence brown, resistant to defoliators, moderately tolerant to blue beetle semi looper, tolerant to bacterial pustule and Rhizoctonia
JS 20-34	86-88	20-25	Early maturing, determine, resistant to charcoal rot, moderate to highly resistant to girdle beetle and stem fly
NRC 7	90-99	25-35	Early maturing, tolerant to drought and high temperature, determine, resistant to defoliators
JS 71-05	90-95	20-24	Medium days maturing, tolerant to drought and water logging, semi-dwarf, resistant to bacterial pustule
JS 97-52	100-110	25-30	Late maturing, tolerant to water logging, high temperature and drought

For second and third mechanisms, genotypic variation can be exploited through several breeding approaches. Lack of oxygen supply for the plant is the main reason of damage in water logging condition, which hampers nutrient and water uptake, as a reason the plant shows wilting. Plants which can withstand water logging condition have mechanisms such as increased availability of soluble sugar, aerenchyma formation, adventitious root development, stem elongation, greater activity of glycolytic pathway & fermentation enzymes and involvement of antioxidant defense mechanism to cope with the oxidative stress induced by water logging. Ethylene plays an important role, because it induces the genes of enzymes associated with aerenchyma formation, glycolysis and fermentation pathway genes in change of mechanisms of plants.

High temperature negatively affects flower initiation, pollen viability (germination and tube growth), stigma receptivity, ovule viability, ovule size, fertilization, seed/fruit set, seed composition, grain filling, and seed quality. Mechanisms have been identified to minimize heat stress damage during, including heat escape (early morning flowering, less period of flowering), heat avoidance through transpiration cooling and heat tolerance through resilient reproductive processes,

Breeding for abiotic stresses is the most challenging task, because of quantitative inheritance of traits related to particular abiotic stress and their interdependence First step in abiotic stress breeding programme is to identify the diverse trait(s) that are properly defined in terms of the relevant stage of crop development, specific attribute to target environment and their potential contribution in yield. Second step is to develop the proper phenotyping protocol that can screen a large number of genotypes with trustworthy tolerance data in relation to particular abiotic stress. Third step is identification of donor line which having maximum number of contributing traits related to abiotic stress tolerance. So, those donor lines can be used for trait introgression through conventional or molecular breeding strategies (Table 2).

A three tier approach is being used for trustworthy and robust phenotyping in relation to drought tolerance at IISR Indore. In first tier, genotypes (germplasm and breeding lines) are used to exploit genetic variation through carbohydrate remobilization trait via chemical desiccant (potassium iodide) approach at seed filling stage and then identified lines are screened for delayed senescence trait in summer seasons during second tier. In third tier, further identified genotypes are used to phenotype root architecture traits, Drought Resistance Index (DRI) and other physiological traits in relation terminal drought tolerance. Identified donor lines are used for trait introgression in adapted cultivar through bi parental mating & backcrossing, gene/QTL(s) identification, gene expression study at IISR. Water logging tolerant genotypes is being identified using stem elongation trait, chlorophyll retention trait, carbohydrate content and stress yield index at IISR.

Table 2: Relevant traits and donors for different abiotic stress tolerance in soybean

Item	Deficient moisture stress	Excessive moisture stress	High temperature stress
Traits/ Para-meters /Assay	*Agro-morphological:* • Delayed leaf senescence • Plant canopy • Seed size • Stress yield index • Phenology • Early vigour *Root related:* • Root morphology and plasticity • Nitrogen fixation and metabolism under drought *Shoot related:* • Osmotic adjustment • Water use efficiency (Carbon Isotope Discrimination) • Specific leaf area	*Agro-morphological:* • Plant canopy • Stress yield index • Phenology • Early vigour *Root related:* • Root morphology and adventitious roots • Nitrogen fixation and metabolism under hypoxia *Shoot related:* • Stem elongation • Chlorophyll content/SPAD reading *Biochemical:* • Carbohydrate content	*Agro-morphological:* • Delayed leaf senescence • Reproductive efficiency • Seed size • Stress yield index *Root related:* • Root morphology and plasticity *Shoot related:* • Pollen viability and pollen tube length • Specific leaf area • Chlorophyll content/SPAD reading • Chlorophyll fluorescence • Cell membrane stability • Stomatal conductance

	• Chlorophyll content/SPAD reading • Chlorophyll fluorescence • Wax content and leaf pubescence density • Relative water content • Cell membrane stability • Stomatal conductance • Mineral ash content • Canopy temperature differentiation *Biochemical:* • Superoxide Dismutase (SOD) • Peroxidase (POD) • Catalase (CAT) • Ascorbate peroxidase (APX) • Malondialdehyde (MDA) *Molecular:* • Gene identification • Gene expression	*Molecular:* • Gene identification • Gene expression	• Canopy temperature differentiation *Biochemical:* • Superoxide Dismutase (SOD) *Molecular:* • Gene expression
Donor	Jackson, PI 416937, PI 407162, EC 538828, EC 608828, JS 97-52, Young, Davis, Bragg, Hardee etc.	PI 408105A , Archer, JS 97-52, JS 20-38, Hardee etc.	DG 5630RR, AG 4403RR, EC 538828, JS 97-52 etc.

Three stages *viz.*, vegetative emergence stage, V2 stage and R1 stage are being targeted for phenotyping of traits related to water logging tolerance. Identified donor lines are being used for trait introgression and genetic studies for water stagnation traits at IISR. High temperature tolerance has been phenotyped based on canopy cooling, membrane stability and stress yield index at IISR Indore. Resistance for several associated diseases like YMV, Collar rot and Charcoal rot need to be intogressed to developed abiotic stress tolerant varieties.

Salinity stress: However, salinity is predominantly a problem of arid and semiarid regions of the world, where the potential for evapotranspiration exceeds rainfall and there is insufficient rain to leach away soluble salts from the root zone (Miller and Donahue, 1990). In India alone, 7 million hectares of land are salt affected. According to an early Food and Agriculture

Organization (FAO) study (Massoud, 1974), salt-affected soils occupy 7 percent of the world land area, and salinity is also a problem that is increasing rapidly (Pessarakli, 1999), having more than doubled in the past two decades. It is estimated that the world is losing at least 10 ha of arable land every minute and 3 ha of this is lost by salinization. In this way, 1.6 mha of arable land is lost every year. Secondary salinization is widely considered a key process leading to degradation and desertification of the world‘s dry lands. Ironically, much of the loss of land due to salinization is in fact caused by agriculture itself through the adverse effects of irrigation, this occurring in up to 20 percent of irrigated land (Flowers and Yeo, 1995). The ability of plants to survive salinity stress is important for natural distribution of plant species and to agriculture (Flowers and Yeo, 1989). Definition Salinity is defined as the presence of excessive amounts of soluble salts that hinder or affect the normal functions of plant growth. It is measured in terms of electrical conductivity (ECe), with the exchangeable sodium percentage (ESP) or sodium adsorption ratio (SAR) and pH of a saturated soil paste extract. Therefore, saline soils are those that have saturated soil paste extracts with an ECe of more than 4 dSm–1 , ESP less than 15 percent, and pH below 8.5 (Waisel, 1972; Abrol, 1986; Szabolcs, 1994). Saline soils have a mixture of salts of Chloride, Sulfate, Sodium, Magnesium and Calcium ions with sodium chloride often 372 dominant. There are two main sources of salinity: (i) Primary or natural sources Resulting from weathering of minerals and the soils developed/derived from saline parent rocks (Ashraf, 1994) (ii) Secondary salinization Caused by human factors such as irrigation, deforestation, overgrazing, or intensive cropping (Ashraf, 1994). Salinization affects the 1. Chemical properties of soil by changing the cation exchange capacity (CEC) 2. Alter the physical properties: Soil structure is damaged by defloculation of clay particles and hydraulic conductivity is decreased, resulting in a slow movement of irrigation water. 3. Soil salinity also affects the soil microflora that plays important roles in the improvement of soil structure, the decomposition of organic matter and the nitrogen and sulfur cycles (Lal and Khanna, 1994).

Effects of salt stress on plants

1. Osmotic effect or water deficit effect: Reduces the plant‘s ability to take up water, and this leads to slower growth. This is the osmotic or water-deficit effect of salinity.
2. Salt specific effect or Ion Excess Effect: Salts enter the transpiration stream and eventually injure cells in the transpiring leaves, further reducing growth. (Fig.4) · Plants grown in alkaline soils often display a characteristic yellow color on the new growth. Veins remain green, and the yellow color develops between veins. Severe deficiency may cause leaves to be almost white. Deficiencies of other micronutrients such as zinc and copper may produce a similar condition in peanuts. Chemical analysis of the plant tissue is the only sure way to differentiate. · High salts can cause leaf burn, inhibit water uptake, and can interfere with uptake of certain essential elements (e.g., calcium). · Stress at reproductive stages leads to spikelet sterility in cause of rice. · Accumulation of Na+ and Clis toxic to cell in terms of the effect in enzyme activity. 374

Mitigation of salt stress ·

- Seed hardening with NaCl (10 mM concentration) ·
- Application of gypsum @ 50% Gypsum Requirement (GR)
- Incorporation of daincha (6.25 t/ha) in soil before planting
- Foliar spray of 0.5 ppm brassinolode for increasing photosynthetic activity
- Foliar spray of 2% DAP + 1% KCl (MOP) during critical stages
- Spray of 100 ppm salicylic acid · Spray of 40 ppm of NAA for arresting pre-mature fall of flowers / buds / fruits ·
- Extra dose of nitrogen (25%) in excess of the recommended

Split application of N and K fertilizers: Foliar application of ascorbic acid alone increased number of leaves and leaf area, while in combination with zinc sulfate increased the plant height and total plant biomass. · The exogenous application of PGRs, auxins ,gibberellins and cytokinins produces some benefit in alleviating the adverse effects of salt stress and also improves germination, growth, development and seed yields and yield quality · Exogenous application of ABA reduces the release of ethylene and leaf abscission under salt stress in plants, probably by decreasing the accumulation of toxic Clions in leaves. · Post-application with exogenous Jasmonic Acid can ameliorate salt stress, especially the salt-sensitive rather than the salt-tolerant cultivar. 4 mM ascorbic acid and 4 mM gibberellin could increase transpiration rate, relative water content, chlorophyll b, total chlorophyll and 375 xanthophyll content. In general, it was concluded that synergistic interaction between ascorbic and gibberellin could alleviate the adverse · effects of salinity on plants. · Maintenance of high K/Na ratio by applying potash and Ca‘fertilization · Application of PGRs like cytokinin, GA3, IAA, cycocel, thiourea and polyamines (putrescine, spermidine and spermine) either as seed treatment or foliar spray.

Temperature stress: Definition Greaves (1996) defines suboptimal temperature stress as any reduction in growth or induced metabolic, cellular or tissue injury that results in limitations to the genetically determined yield potential, caused as a direct result of exposure to temperatures above or below the thermal thresholds for optimal biochemical and physiological activity or morphological development. High Temperature Stress Levitt (1980) classified plants into psychrophiles, mesophiles, and thermophiles according to whether or not they tolerate low, medium, or high temperatures. Psychrophiles are those plants whose high temperature threshold is 15 to 20°C, mesophiles are those plants whose high temperature threshold is 35 to 45°C, and thermophiles are those plants whose high temperature threshold ranges from 45 to 100°C. Levitt (1980) proposed that the high temperature injury process progresses from a direct reversible strain, i.e., excess respiration over photosynthesis due to elevated temperatures, to an indirect strain, i.e., loss of reserves, or to a direct or indirect injury, i.e., starvation injury. High temperatures may be 376 experienced by plants on a daily or seasonal basis. There is also growing evidence of long-term climatic changes leading to both higher average temperatures, widening the geographic range where high temperatures become routinely limiting to crop production, and increasing the frequency and severity of extreme temperature events. Plants may be as affected by exposure to prolonged periods of moderately high temperature as to short periods of extreme temperature, though the mechanisms for coping with these stresses may differ. Heat stress affects grain quality and yield. Low Temperature Stress Low temperatures can damage plants both by a chilling effect, leading to physiological and developmental abnormalities, and by freezing, causing cellular damage directly and via cellular dehydration. Lyons (1973) described many symptoms of low-temperature injury. Some physiological processes such as flowering in rice are extremely sensitive to low temperatures and damage may occur at temperatures as high as 20°C. Commonly visible symptoms of low-temperature injury to the leaves include wilting, bleaching due to photooxidation of pigments, waterlogging of the intercellular spaces, browning, and eventually leaf necrosis and plant death (Levitt, 1980; Witt and Barfield,1982). Dudal (1976) estimated that 15 percent of arable land is affected by freezing stress. Low temperatures can reduce crop yields in several ways. Chilling and freezing injury can directly affect crop growth by causing physical damage or by interfering with normal biochemical and physiological functions, thus reducing yield. More subtly, low temperatures reduce potential agricultural productivity by limiting the 377 crops or varieties that can be grown in a particular area, with coldtolerant species/cultivars often not those with the highest potential yield. Low-temperature exposure can be both a daily and seasonal factor to which plants must adapt, including, in some regions, prolonged periods of low temperature lasting many months. Effects of Heat stress on Plants ¨ Seedling establishment is hampered ¨ Drying of leaf margins and scorching effect on leaves ¨ Reduction in plant growth ¨ Pollen development is affected ¨ Alteration in photosynthesis ¨ Total biomass is reduced ¨ Spikelet sterility ¨ Grain and fruit development and quality is affected (Fig.5)

Mitigation of high temperature stress

Plants need to be cultivated under shade condition.

- Overhead irrigation to avoid sunburn.
- 378 Application of Gibberellic Acid Stimulate the α – Amylase
- Production for seed germination. BAP reduce the leaf senescence & Lipid peroxidation. Salicylic acid enhances the Thermo tolerance capacity.
- Glycine betaine reduced the leakage of ion.
- Application of Ethylene enhance the seed germination
- Mitigation of low temperature stress Foliar spray of 0.15 % Ammonium molybdate reduces the low temperature stress effect.

Pre-soaking treatment with GA3 and Proline increase the Seed germination. Application of Paclobutrazol increases the activity of Scavenging enzymes. Electrolyte leakage is reduced by the application of Uniconzole (50 ppm). Cryoprotectants also used for reducing the stress effect. ABA has a role in induction of freezing tolerance.

Future Prospectus

Agriculture production has undergone drastic changes in recent years and is being seriously limited by various abiotic stresses. More than 50% of agricultural production loss is due to abiotic stresses, their intensity and adverse impact are likely to amplify with climate change. The major loss is due to high temperature (20%) followed by drought (9%), low temperature (7%), and other forms of stresses (4%). Germplasm improvement, Improvement of stress tolerance through conventional breeding, Improvement of stress tolerance through marker assisted back cross breeding, Improvement of stress tolerance through plant genetic Engineering, hormonal regulation of stress tolerance and improvement biostimulants and bioincolunats are some of the approaches to improve abiotic stress tolerance.

References

1. Abrol. I.P. (1986) .Salt-affected soils: an overview. In: Chopra V. L. and Paroda S. L. (Eds) Approches for incorporating drought and salinity resistance in crop plants. Oxford and IBH Publishing Company, New Delhi, India: 1–23 2.

2. Ashraf. M. (199). Breeding for salinity tolerance in plants. Crit. Rev. Plant Sci., 13: 17–42.

3. Dudal. R. (1976). Inventory of major soils of the world with special reference to mineral stress. – Plant Adaption to Mineral Stress in Problem Soils. Ed. M. J Wright. Cornell Univ. Agric. Exp. Stn. Ithaca, N.Y:3–23.

4. Edmeades., G.O. J. Bolaoos and H. R. Lafitte. (1992). Progress in selecting for drought tolerance in maize. In D. Wilkinson (ed.), Proc. 47th Annual Corn and Sorghum Research Conference, Chicago, December 9ñ10, 1992. ASTA, Washington. Pp. 93n111.

5. Flowers, T.J., Yeo, A.R., (1995). Breeding for salinity resistance in crop plants–Where next. Aust. J. Plant Physiol., 22, 875–884

6. Flowers., T.J and A.R. Yeo. (1989). Effects of salinityon plant growth and crop yields, p. 101–1 19. In: J.H. Cherry (cd.). North Atlantic Treaty Organi-zation Advanced Science Institutes Ser. vol.G19. Environmental stress in plants

7. Greaves, J. A. (1996). Improving sub optimal temperature tolerancein maize—the search for variation. Journal of Experimental Botany. 47: 307–323.

8. GRIME., J. P. (1979). Plant strategies and vegetation processes. Chichester: Wiley and Sons: 222 386

9. Hattori. Y, K .Nagai, M. Ashikari. (2011). Rice growth adapting to deepwater. Curr Opin Plant Biol., 14: 100– 105

10. Kochian., K. V. (1995). Cellular mechanisms of aluminium toxicity and resistance in plant. Annu. Rev. Plant Physiol. Mol. Biol., 46: 237- 260 3.

11. Kramer., P. J and J. S. Boyer.(1995). Water relations of plants and soils. Academic Press. San Diego

12. Lal, B, S.Khanna (1994). Selection of salt tolerantRhizobiumisolates fromAcacia nilotica. World J. of Microbiol. and Biotechnol., 10:637±639.

13. Lerner., H. R. (1999). Introduction to the response of plants to environmental stresses. In: Plant Responses to Environmental Stresses.

14. Marcel Dekker, New York. 6. Levitt, J., (1980). Responses of Plants to environmental stresses. Vol. 1, Acad. Press, 496

15. Levitt, J. (1980). Responses of plant to environmental stresses. 2nd. Ed. Academic press, NewYork.

16. Lyons, J.M., (1973). Chilling injury in plants. Annu. Rev. Plant Physiol., 24, 445–466

17. Massoud., F. I (1974).salinity and alkalinity as soil degradation hazards. FAO/UNDP Expert consultation on soil degradation.FAO Rome.p.21

18. Pessarakli, M. (1999) Response of green beans (Phaseolus vulgaris L.) to salt stress. InPessarakli, M (Ed). Handbook of Plant and Crop Stress 2ed.MARCED LEKKERIN, C.E.E.U.U., pp827-842

19. Plant Responses to Environmental Stresses. Ed. H. R. Lerner. Marcel Dekker, NewYork: 1–26. 387

20. Sanchez., P. A, J. G.Salinas. (1981). Low-inpu t technology for managing Oxisols and Ultisols in tropical America. Advances in Agronomy. 34: 280-407.

21. Singh, G, N.T. Singh and O.S. Tomar. (1993). Agroforestry in saltaffected soils. Technical bulletinNo. 17, CSSRI, Karnal, India. 65 pp

22. Singh., G and N.T. Singh. (1993). Mesquite for the revegetation of salt lands. Technical Bulletin No.18, CSSRI, Karnal:

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Use of Social Media and ICT in TOT of Soybean

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Introduction

Technology dissemination is a vital part of the innovation process, through which the developed technologies are transferred to the targeted communities. Information and Communication Technologies (ICTs) have occupied a greater significance in the extension services in the present era of digital world. Before the digital revolution, television and radio have traditionally been used for disseminating agricultural information for a long time (Purushothaman *et al*., 2003). Consequent to the recent developments in the mobile, computing and networking technologies provide new ways of technology transfer. Increased use of mobile subscriptions and its reach among the common people in the last decade have also increased the use of web based services and applications like web portals and mobile apps.

Social media are forms of electronic communication through which users can create online communities for sharing the information, ideas, personal messages and other contents (Merriam-Webster, 2013). Social media are a contemporary channels of digital communication that is composed of various evolving tools for discussion, interaction and sharing of information among people. World over, the prominent Social media tools used by majority of the population include social networking sites (Facebook, LinkedIn, MySpace, etc.), video and photo sharing websites (Flickr, YouTube, Tumbler, Pinterest, etc.), blogs and microblogs (Blogger, Twitter, Instagram, etc.), forums, discussion boards and groups (Google groups, etc.), Wikis (Wikipedia, etc.), video and podcasts (Skype, etc.), video conferences and web conferences, Email and Instant Messaging (IM), BlackBerry Message (BBM) etc., socially integrated mobile text messaging (Line, WhatsApp, Viber, etc.), websites with social plug-ins and layers, social bookmarking (Delicious, Blink list, etc.), social news (Reddit, Propeller, Digg, etc.) and many more. Simply stated, social media are digitally enabled platform for communication through internet in any form where the content is created and used by the users.

Social media have many advantages when used in agricultural extension as outlined below (Saravanan et al., 2015):-

- Highly cost effective
- Simultaneously reaches large numbers of clients
- Location and client specific, problem-oriented
- User-generated content and discussion among the community members
- Easily accessed from mobile phones
- Increases internet presence of extension organizations and their client reach
- Democratization of information by making it accessible to all
- Brings all stakeholders into a single platform
- Can measure reach and success by tracking number of visitors, friends, followers, mentions, Facebook 'likes', conversation index and number of shares.

In India, the use of social Media and ICTs has gained popularity in the period since last decade consequent to the digital revolution. In line with these developments, the ICAR-Indian Institute of Soybean Research has started use of social media platforms like WhatsApp, YouTube and Facebook etc. for dissemination of information related to the improved soybean production technologies developed by the Soybean R&D system and facilatiating feedback mechanisms among the clients and their interaction with the research system using different ICT tools are discussed in detail in the following sections.

Social Media initiatives in Soybean

With the latest developments in the digitization of the Information and Communication media, the institute has initiated use of some digital media like WhatsApp group far farmers (IISR Soy Farmers) and Insitute Facebook page, Institute Website etc which are regularly being used for disseminating the need based and timely information like weekly advisories on soybean crop during the crop season, organization of various on and off campus extension activities by the institute etc. Accordingly, the ICAR-IISR has started using these social media tools for Transfer of Technology (TOT) purpose since last 3 years (starting from 2017). Further, the institute has launched its YouTube Channel during June 2020 containing informative videos on various topics on soybean technological recommendations.

Farmer-Expert WhatsApp group

Institute created a WhatsApp group viz. IISR Soy Farmers (Fig 1.) for strengthening the strong linkage between soybean growers and soybean domain experts in order to solve farmers queries and problems throughout the year particularly during the cropping season. It was created on 14th May 2017. Presently it has 149 members in the group. Farmers could easily share the images of infected fields and get timely advice by the experts within this group. The creation of WhatsApp group has made the life of farmers easy which earlier was difficult for not getting timely contact with the domain expert at the time of need. The group also have representation of multi-disciplinary team of scientists especially belonging to discipline like Plant Breeding, Agronomy, Plant Pathology, Entomology, Seed Technology, Microbiology, Computer Application and Agril. Extension at present. It is proving to be a very effective platform helping farmers to connect with domain experts throughout the country.

Institute has also launched its Facebook Page (Fig 2) that can be accessible from the link viz https://www.facebook.com/ICAR-Indian-Institute-of-Soybean-Research-Indore-507415769433553/. The Institute on regular basis is engaged in posting relevant useful information about the the events, technological recommendations, varietal release etc on this page. The popularity of the page can be guessed by the fact that as on date 1,859 people like this and 2,141 people follow this page.

Facebook Page

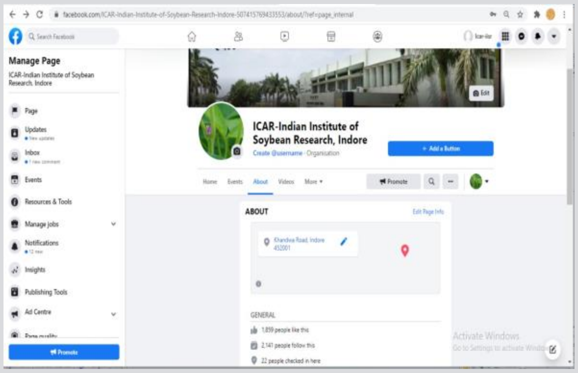


Fig 2. Screenshot of Facebook Page of IISR, Indore

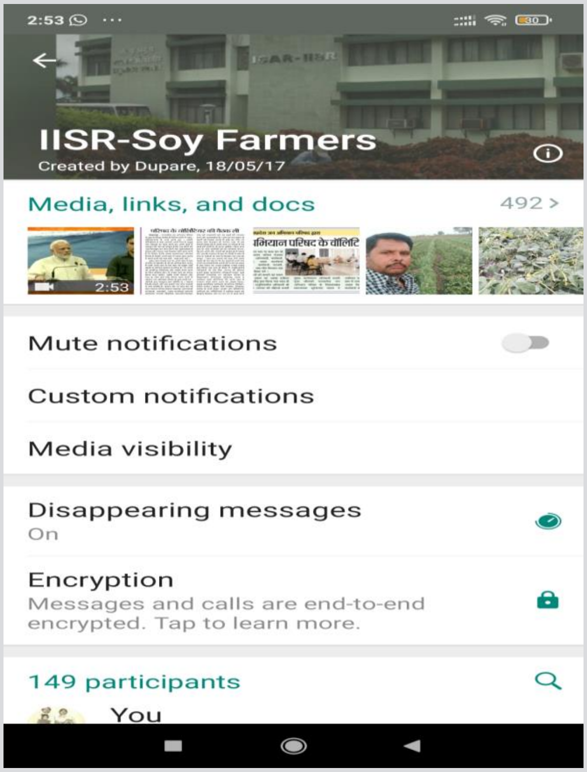


Fig1. Screenshot of institute's Farmer-Expert WhatsApp Group

Large number of internet community is getting benefitted by the information being posted on it from time to time.

YouTube Channel- IISRSoybean Indore: Institute is also running its YouTube Channel since June 2020 for effective dissemination of soybean technologies. The YouTube Channel is accessible from the link https://www.youtube.com/channel/UCNdY5AsfPZqsCO8IxkAuSyQ/videos. There are 45 videos uploaded on the channel uptil now. Videos on different topics that are uploaded are shown in Table 1. The videos contains short and interactive discussion/advice by the institute scientists on various package of practices, management of biotic and abiotic factors like weed, insect-pest and diseases. The comments on these videos are dealt with suitable response by the experts.

Table 1- YouTube videos on different topics with number of views by different visitors

SNo	Video title	Video publish time	Views
		Total	**27870**
1.	सोयाबीन में चक्र भृंग (गर्डल बीटल) का नियंत्रण डॉ अमर नाथ शर्मा Management of Girdle beetle	Jul 3, 2020	6563
2.	सोयाबीन में तना मक्खी के प्रकोप की पहचान Identification of Stem fly in soybean	Aug 7, 2020	3920
3.	सोयाबीन में पीले मोज़ेक रोग का प्रबंधन डॉ.लक्ष्मण सिंह Management of Yellow Mosaic disease in soybean	Jul 27, 2020	2267
4.	सोयाबीन में अंतरवर्तीय फसलो का उपयोग Dr. SD Billore Intercropping in soybean	Jun 20, 2020	1419
5.	सोयाबीन में फली छेदक चने की इल्ली/हेलिओथिस इल्लियों का प्रबंधन :डॉ . अमर नाथ शर्मा	Jun 29, 2020	1303
6.	सोयाबीन में पीले मोज़ेक रोग की पहचान कैसे करे? Identification of YMV in soybean	Aug 5, 2020	1225
7.	सोयाबीन में पीलेपन के कारन एवं निदान डॉ .लक्ष्मण सिंह Causes of Yellowing in soybean	Jul 28, 2020	1084
8.	सोयाबीन में समेकित कीट प्रबंधन :डॉ .अमर नाथ शर्मा IPM in soybean: Dr Amar Nath Sharma	Jun 30, 2020	956

9.	सोयाबीन में रायजोक्टोनिया एरियल ब्लाइट रोग की पहचान Identification of RAB in Soybean	Aug 7, 2020	706
10.	सोयाबीन प्रजाति एनआरसी 127 बाबत कृषक की प्रतिक्रिया Feedback of Farmer on NRC 127	Sep 14, 2020	697
11.	सोयाबीन में तम्बाकू की इल्ली (स्पोडोप्टेरा लिटुरा) का नियंत्रण डॉ .अमर नाथ शर्मा	Jul 24, 2020	665
12.	सोयाबीन में बीजोपचार सही तरीका Dr Laxman Singh Correct sequence for seed treatment)	Jun 9, 2020	579
13.	सोयाबीन में एंथ्रेक्नोज रोग का नियंत्रण डॉ .लक्ष्मण सिंह Management of Anthracnose in soybean	Jul 28, 2020	494
14.	ICAR-IISR में बीबीएफ पद्धति से सोयाबीन की बोवनी Sowing with BBF K2020)	Jun 19, 2020	478
15.	फर्ब सीड ड्रिल का उपयोग कर रिज फरो पद्धति से सोयाबीन की बोवनी	Jun 24, 2020	394
16.	34th Foundation Day of ICAR-Indian Institute of Soybean Research, Indore	Dec 11, 2020	352
17.	सोयाबीन में कीट नियंत्रण हेतु बीजोपचार Dr AN Sharma: Insecticidal Seed treatment)	Jun 9, 2020	338
18.	National Oilseed Brainstorming Meet 23-25 Sep 2020	Sep 23, 2020	289
19.	सोयाबीन में जैविक कीट नियंत्रण हेतु सूक्ष्म जीव आधारित कीटनाशकों का उपयोग डॉ .अमर नाथ शर्मा	Jul 1, 2020	288
20.	सोयाबीन में सफ़ेद सुंडी एवं दीमक का नियंत्रण) Management of white grub and termite in soybean)	Jun 10, 2020	288
21.	सोयाबीन में चारकोल सडन रोग का नियंत्रण) डॉ संजीव कुमार (Management of Charcoal rot in Soybean	Jul 22, 2020	259
22.	सोयाबीन की फसल में अनुशंसित खरपतवारनाशको का उपयोग :डॉ . राकेश कुमार वर्मा	Jun 27, 2020	251
23.	सोयाबीन में गर्दनी सडन रोग का नियंत्रण) डॉ .संजीव कुमार (Management of collar rot	Jul 22, 2020	247
24.	सोयाबीन में प्रारंभिक अवस्था के कीट एवं प्रबंधन :डॉ .अमरनाथ शर्मा	Jun 25, 2020	245
25.	National Oilseed Brainstorming meet Day-2 24 Sep 2020	Sep 24, 2020	204
26.	सोयाबीन में अनुशंसित कीटनाशक एवं खरपतवार नाशकों की संगतता) डॉ सुनील दत्त बिल्लोरे (	Jul 1, 2020	201
27.	सोयाबीन में संतुलित पोषण प्रबंधन :डॉ एस.डी .बिल्लोरे) Balanced nutrition in soybean)	Jun 29, 2020	196
28.	सोयाबीन की बोवनी) डॉ .राकेश कुमार वर्मा (Dr. Rakesh Kumar Verma: Sowing of soybean	Jun 17, 2020	180
29.	सोयाबीन में नमी संरक्षण –डॉ. राघवेन्द्र) –Dr Raghavendra In-situ moisture Conservation)	Jul 20, 2020	177
30.	सोयाबीन में जैविक कल्चर का उपयोग) डॉ महावीर शर्मा (MP Sharma: Bio-inoculation in soybean	Jun 19, 2020	165
31.	सोयाबीन में अनुशंसित बोवनी पूर्व एवं बोवनी के तुरंत बाद उपयोगी खरपतवारनाशक :डॉ .एस.डी .बिल्लोरे	Jun 26, 2020	162
32.	सोयाबीन के लिए खेत की तयारी एवं बोवनी का उपयुक्त समय) Dr SD Billore: sowing time, tillage)	Jun 9, 2020	155
33.	Session II: Opportunities for Agri start-ups and developing linkages	Mar 17, 2021	155

34.	Inauguration Session: Opportunities for Agri-start-ups	Mar 16, 2021	150
35.	National Oilseed Brainstorming Meet DAY-3 25 Sep 2020	Sep 25, 2020	123
36.	Session I: Opportunities for Agri-start-ups	Mar 16, 2021	122
37.	बीज उत्पादन हेतु सोयाबीन की कटाई एवं गहाई में सावधानियां –डॉ . मृणाल कुचलान	Nov 21, 2020	119
38.	Institute Film English	Jan 1, 2021	80
39.	National Oilseed Brainstorming Meet 23 Sept 2020	Sep 23, 2020	73
40.	Institute Film Hindi	Jan 1, 2021	71
41.	Online Meeting Facilitation committee at 4:00PM 21-09-2020	Sep 21, 2020	58
42.	51st Annual Group Meet of AICRP on Soybean- Day1	Mar 12, 2021	46
43.	51st Annual Group Meet of AICRP on Soybean- Day1 2nd half	Mar 12, 2021	32
44.	51st Annual Group Meet of AICRP on Soybean- Day1	Mar 12, 2021	6
45.	51st Annual Group Meet of AICRP on Soybean- Day1	Mar 12, 2021	6

All the videos are technically informative for different clientele groups. The channel is increasing its popularity with presently having 1.14 thousand subscribers in very short time span of eleven months. The contents are also being liked by the users as can be seen by the number of views by users as shown in Table 1.

ICT tools in Soybean

Institute has also developed many softwares to use the potential of Information Communication Technologies in best manner. These ICT tools help the farming as well as scientific community in solving different problems and improve and issues as well as for decision making in real time situations. The following section discusses different ICT tools in Soybean developed by the institute.

1. Soybean Gyan Mobile App

Soybean Gyan Mobile App is developed for Soybean growers to take right decisions in the real time field conditions. It contains comprehensive knowledge on soybean crop management at one platform. The App provides information on – i) Agronomic Practices, Production technology and Crop management, ii) Insect Management, iii) Disease Management, iv) Weed Management, v) Health Benefits and Food Uses vi) Seed treatment and storage vii) Farm Machinery and vii) Important information for Soybean cultivation.

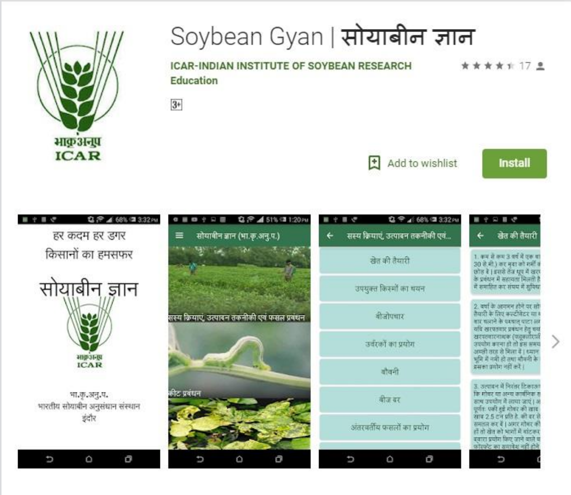


Fig 3. Soybean Gyan on Google play store

This mobile App can be freely downloadable from the link https://play.google.com/store/apps/details?id=com.icar.soyainfo&hl=en from the Google play store. The users of the app, found it as highly useful and a good source of complete soybean crop management information. This is proved from the average review ratings as 4.2 as on date and good review comments written on Google play store. It is very useful for farmers, agricultural advisors, agriculture students or research scholars and agriculture government officials. The users are showing keen interest as shown by more than Ten thousand downloads.

2. Web Applications in Soybean

Institute has developed many web based applications. These applications are accessible from institute website http://iisrindore.icar.gov.in. The IT tools that are useful for farmers and soybean researchers are discussed below-

A **Web-based Soybean Insect Identification and Management** System has been developed for identification and management of Soybean insects. It provides information on different aspects of soybean insects' viz. economic losses, pre-disposing climatic condition for insect attack, seasonal incidence of soybean pests during kharif season, friendly-insects of soybean and insect management recommended practices in Hindi language. It is very useful for farmers in taking right decision at right time in their fields. It served as an effective ICT tool for farmers to take appropriate and timely measures to minimize field losses due to insect attack.

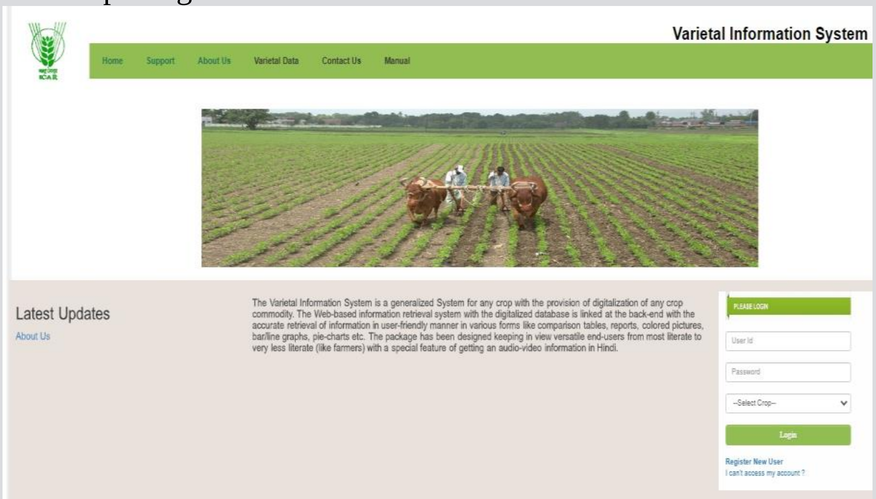
A **Web-based Expert System for disease diagnosis in Soybean** has been developed. It is based on fuzzy-logic Inferencing. It is developed using ASP .NET web technologies. It diagnoses the disease based on the symptoms observed by the user on the field at a particular crop age, applies the appropriate disease rules stored in disease Knowledge base and using the fuzzy-logic based inferencing method, it draws conclusion. It suggests an appropriate control measure based on the diagnosed disease.

A **Knowledge Acquisition System** has been developed as a sub-system of Disease Expert System. It provides a graphical user interface to create the disease knowledge base of any crop. At present, it has disease knowledge on 25 soybean diseases. It is developed using ASP .NET web technology. The Knowledge base is implemented using SQL Server.

An **Intelligent Disease Tutor System** has been developed as a sub-system of Disease Expert System. It acts an Audio-visual training tool to provide complete knowledge on 25 major soybean diseases.

A **Web-based Soybean Germplasm Information System** (WBGIS) has been developed. It provides an easy, efficient and user-friendly tool for the accurate and rapid retrieval of the information on different germplasm accessions. The system is developed using web technologies viz. ASP.NET, Hyper Text Markup Language (HTML), JAVA etc.

Web-based Varietal Information System has been developed to retrieve quickly and accurately the morphological character information of Indian Soybean varieties in a very user-friendly way. It also facilitates DUS testing.



A **Farmer Advisory System** is developed to help the farmers to get the expert advice of the soybean experts. It facilitates sending of expert advice through SMS on farmers mobile phones. Farmers can also send their farm related problems to the soybean crop experts.

Database Management system for AICRPS trials data has been developed with an aim to reduce the processing time and drudgery involved in the compilation of data and preparation of AICRPS Annual Workshop Report.

4. Conclusion

Keeping pace with the digital revolution experienced recently after the successful use of IT tools for their relevance in the process of technology dissemination in agriculture, the increased use of ICT tools are offering variety of solutions to the farming community in real time bsis making the process of technology transfer a more efficient, effective, trustworthy and economically viable to the uses. Looking at its enormous utilities more and more institues, user groups and agencies are now coming up to provide solution to the farmers issues through their mobil apps and ICT tools. The ICAR-IISR Indore is also started providing technical support and guidance to its group of clients through these ICT tools which in future could make a desireable impact among the farmers for adoption of technologies developed by the institute and its package of practices.

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