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National Training Program on

"Climate Smart Production Technologies to Enhance Soybean Productivity"

Under NFSM-FLD

Training Manual

ICAR-Indian Institute of Soybean Research, Indore (M.P.)

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"Climate Smart Production Technologies to Enhance Soybean Productivity"

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Preface

Soybean is one of the important oilseed crops of India and world. Currently, soybean grown in an area of 12.99 million hectares with production 12.27 million tones. In India soybean mainly grown as rainfed crop (>90%) encounters different production constraints, includes vagaries in monsoon (drought and floods), emerging insect pest, diseases and faulty management practices under changing climate resulted in poor national soybean productivity of around 1059kg/ha. Therefore, understanding and adaptation of soybean climate smart production technologies is need of the hour for different soybean stake holders to uplift soybean yield in the country. Therefore, ICAR IISR, Indore under FLD on soybean scheme, funded by DAC & FW, Govt. of India, New Delhi is organizing 3 days (06-08 February 2023) national training program (Hybrid mode) on "Climate Smart Production Technologies to Enhance Soybean Productivity" to disseminate climate smart soybean production technologies to different extension workers (Input dealers/extension officers/KVK scientists), who are actively involved in transferring soybean related production technologies to farmers across the country.

This training manual consists of different aspects of climate smart production technologies in soybean, recently released soybean cultivars, pest and disease control measures under changing climate. Therefore, authors/course co-ordinates of this training manual putt all efforts to compile whole training session chapters related to Climate Smart Production Technologies to Enhance Soybean Productivity for effective utilization of the soybean climate resilient technologies by the trainees and other soybean stakeholders across the country.

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Foreword

*Soybean is a premier oilseed crop of the country contributes 42.06% of total oilseed area and 34.45% of total oilseed production in the country. The average productivity of the soybean, 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 through 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 2.0 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, Indore, is organizing a national training program (Hybrid-mode) on "**Climate Smart Production Technologies to Enhance Soybean Productivity"** under frontline demonstration (FLD) on soybean scheme funded by DAC&FW, Govt. of India, New Delhi during 6-8 February 2024 with the participation of 100 personnel's who are actively involved in the public extension services viz. state department agriculture, as well as, Krishi Vigyan Kendra's and input dealers of reputed companies located across the country. I am extremely happy that the coordinators of this training programme have been successful in organizing this training programme. Further, the present outcome in the form of training manual 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 training manual particularly Dr B.U. Dupare (Principal Scientist, Agricultural Extension), Dr Raghavendra Nargund, Scientist Sr. Scale (Agronomy), Dr Rakesh Kumar Verma, Scientist Sr. Scale (Agronomy) and Dr Savita Kolhe (Principal Scientist, Computer Application) of this institute 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: 08.02.2023
Place: Indore

(K. H. Singh)

Content

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, 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

Table 2: Zone-wise list of notified and recommended soybean varieties

1. Central Zone: (Madhya Pradesh, Bundelkhand region of Uttar Pradesh, Rajasthan, Gujarat, North-West region of Maharashtra)

S.No.	Variety (Identification year)	Average Yield (quintal/ha.)	Maturity period (days)	Notification year
1.	N.R.C -181	93	16-17	2023
2.	N.R.C. - 188	77	46.72	2023
3.	J.S. 22-12	90	21	2023
4.	J.S. 22-16	91	21	2023
5.	N.R.C. - 165	90	19	2023
6.	N.R.C. – 157 (M.P)	93	16	2023
7.	IS-131/NRC 131 (M.P)*	92	15	2023
8.	IS-136/NRC 136 (M.P)*	105	16	2023
9.	M.A.U.S. 725 (Maharashtra)*	92-96	24	2023
10.	N.R.C -152	89	18	2023
11.	N.R.C -150	91	18	2023
12.	Him Palam Soya -1 (HIMSO 1689)	100	21	2023
13.	PHULE DURVA (K.D.S. 992)* (MH)	101	27	2022
14.	J.S. 21-72	97	21	2023
15.	RVSM-35	98	22	2021
16.	N.R.C -138 (INDORE SOYA-138)	93	18	2021
17.	A.M.S. 100-39 (P.D.K.V AMBHA)	97	21	2021
18.	R.V.S. 76(RAJ VIJAY SOYABEAN)	101	21	2021
19.	N.R.C.- 142 (INDORE SOYA 142)	97	20	2021
20.	M.A.C.S.- 1520	100	22	2021
21.	N.R.C.-130 (INDORE SOYA 130)	92	15	2021
22.	R.S.C. 10-46	102	19	2021
23.	R.S.C. 10-52	101	21	2021
24.	A.M.S.M.B. 5-18(SUVERNA SOYA)	100	20	2021
25.	A.M.S.1001 (P.K.V. YELLOW GOLD)	95-100	22	2021
26.	J.S. 20-116	101	21	2019
27.	J.S. 20-94	97	21	2019
28.	J.S. 20-98	96-101	21	2019
29.	N.R.C. 127	102	18	2018
30.	RAJ SOYA 18 (R.V.S.-18) (M.P)*	92	19	2017
31.	RAJ SOYA 24 (R.V.S. 2002-4)	99	19	2017

*Only for concerenced state

2. Eastern Zone: Chhattisgarh, Jharkhand, Bihar, Orissa and West Bengal
3. North Eastern Hill Zone: Assam, Meghalaya, Manipur Nagaland and Sikkim

S.No.	Variety (Identification year)	Average Yield (quintal/ha.)	Maturity period (days)	Notification year
1.	N.R.C -11-35	107	24	2023
2.	Shalimar Soyabean-2(SKUA-WSB-101) (Jammu Kashmir)*	-	-	2023
3.	UMIYAM SOYABEAN-1 (R.C.S 1-9) MEGHALAYA*	96-105	25	2023
4.	R.C.S. 10-71			2022
5.	R.C.S 10-52			2022
6.	BIRSA SOYA 3(B.A.U.S 40)* JHARKHAND	-	-	2022
7.	HIM PALAM HARA SOYA 1(HIMACHAL)*			2022
8.	CHHATISHGRAH SOYA (R.S.C 11-15)*	101	25	2022
9.	BIRSA SOYA 4* JHARKHAND	105-110	28	2022
10.	M.A.C.S 1407	104	21	2021
11.	M.A.C.S. 1460	97	23	2021
12.	N.R.C.- 132 (INDORE SOYA 132)	105	17	2021
13.	N.R.C- 147 (INDORE SOYA 147)	100	23	2021
14.	N.R.C- 128	106	19	2021
15.	N.R.C- 136	107	17	2021
16.	N.R.C.S.L-1	107	17	2021
17.	R.S.C 11-07	102	21	2021
18.	R.S.C 10-46	98-103	19	2021
19.	A.M.S. 2014-1 (P.D.K.V. PURVA)	105	18	2021
20.	D.S.B. 32	102	19	2020
21.	J.S.20-116	100	21	2020
22.	K.D.S. 753 (PHULE KIMYA)	95-100	30	2019
23.	KOTA SOYA (R.K.S. 113)	100-102	19	2018
24.	CHATTISGRAH SOYA 1 (CHATTISGRAH)*	95-100	24	2018

4. Northern Plain Zone: Punjab, Haryana, Delhi, North Eastern Plains of Uttar Pradesh, Plains of Uttarakhand and Eastern Bihar

S.No.	Variety (Identification year)	Average Yield (quintal/ha.)	Maturity period (days)	Notification year
1.	P.S. 1670	122	23-24	2023
2.	S.L. 1074	124	19	2021
3.	S.L 1028	124	21	2021
4.	N.R.C -128	128	22	2021
5.	UTTARAKHAND KALA SOYABEAN (BHAT 202-UTARAKHAND)*	100-115	16	2020
6.	S.L. 979	127	24	2020
7.	S.L. 955	126	22	2020
8.	PANT SOYABEAN 26 (P.S.1572)	120	20	2000
9.	P.S. 1477	113	26	2017
10.	P.S. 1521 (UTTARAKHAND)*	112-115	19	2017
11.	PANT SOYABEAN 23 (P.S. 1523 UTTARAKHAND)*	113-120	28	2017
12.	PANT SOYABEAN 21(P.S. 1480 UTTARAKHAND)*	123-126	25	2017
13.	S.L. 958	142	23	2015
14.	PUSHA 12	124-131	22	2015
15.	P.S. 1368 (UTTARAKHAND)*	117-125	21	2013

5. Northern Hill Zone: Himachal Pradesh and Hill region of Uttarakhand

S.No.	Variety (Identification year)	Average Yield (quintal/ha.)	Maturity period (days)	Notification year
1.	V.L. SOYA 99	118	24	2023
2.	HIM PALAM SOYA 1(HIMACHAL PRADESH)*	-	-	2022
3.	PANT SOYABEAN 25(P.S.1556)	120	23	2020
4.	SHALIMAR SOYABEAN-1 (JAMMU OR KASHMIR)*	140-145	22	2019
5.	V.L.SOYA 89	116	23	2019
6.	V.L. BHATT 201(UTTARAKHAND)*	117	16	2016
7.	V.L. SOYA 77 (UTTARAKHAND)*	112-127	20	2016

6. Southern Zone: Karnataka, Tamil Nadu, Telangana, Andhra Pradesh, Southern Part of Maharashtra

S.No.	Variety (Identification year)	Average Yield (quintal/ha.)	Maturity period (days)	Notification year
1.	AALSB 50(ADILABAD INDORE SOYA CHIKKUDH-1) TELANGANA*	99	24	2022
2.	M.A.U.S 725 (MAHARASTRA)*	92-96	24	2022
3.	PHULE DURVA(K.D.S. 992) MAHARASHTRA*	101	27	2022
4.	M.A.CS- N.R.C 1667	96	21	2021
5.	KARUNE (K.V.B.S.-1)	68**	106	2021
6.	N.R.C- 142(INDORE SOYA 142)	96	22	2021
7.	M.A.C.S. 1460	89	21	2021
8.	A.M.S.2014-1	105	18	2021
9.	R.S.C 11-07	97	25	2021
10.	N.R.C. -132	99	23	2021
11.	N.R.C -147 (INDORE SOYA 147)	96	24	2021
12.	D.S.B 34	101-106	24	2021
13.	K.D.S.753 (PHULE KIMYA)	95-100	27	2020
14.	K.B.S. 23 (KARNATKA)	85-90	30	2020
15.	D.S.B 28 (D.S.B. 28-3)	95	25	2020
16.	K.D.S. 726 (PHULE SANGHAM)	96-97	35	2019
17.	A.M.S 1001 (MAHARASHTRA)*	95-100	24	2019
18.	K.S.103	91-95		2018
19.	D.S.B. 23 (D.S.B. 23-2)	95	25	2018
20.	M.A.U.S. 612	91-95	24	2018
21.	BASAR (TELANGANA)*	105-115	25	2018
22.	M.A.C.S. 281	96	27	2016
23.	K.D.S 334(PHULE AGRANI)	94	25	2015
24.	D.S.B.21	90-95	26	2015
25.	M.A.U.S 162	100-103	30	2014
26.	M.A.C.S. 1188	101	25	2013

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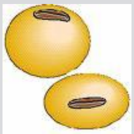

Climate Smart Agronomic Practices for Soybean Production

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Soybean is princiapal oilseed crop of world and India. 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		20^{th} June - 5^{th} July	20^{th} June-5^{th} July	15^{th} June-30^{th} June	15^{th} June - 30^{th} 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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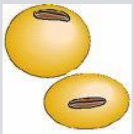

Weed Management in Soybean under Changing Climate Scenario

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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 CO2.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 CO2: Elevated atmospheric CO2 is known to improve the growth of plants due to increased efficiency. The interaction between CO2 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 CO2 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 CO2 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+surfactant 0.2% (Isooctylphenoxyl-poloxenthnanol 12.5%)	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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Management of Soybean Diseases under 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: 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 20-34, JS 20-69, JS 20-98 etc.
iv. Seed treatment with Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25% + Mancozeb 50% WS @3g/kg seed or Penflufen 13.28% w/w + Trifloxystrobin 13.28% w/w FS @ 1 ml/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

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 22-27^{o}C 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 20^{o}C plants exhibit chlorotic spots. Uredinia are formed and by 9 to 10 days they begin 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), kresoxim methyl or 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 of soybean. In addition, it also causes seed rot, seedling rot, root and stem rot. Disease is favored by continuous 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 Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25% + Mancozeb 50% WS @3g/kg seed or Penflufen 13.28% w/w + Trifloxystrobin 13.28% w/w FS @ 1 ml/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 Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25%+ Mancozeb 50% WS @3g/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.

viii. **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.
ii. Seed treatment with Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25% + Mancozeb 50% WS @3g/kg seed or Penflufen 13.28% w/w + Trifloxystrobin 13.28% w/w FS @ 1 ml/kg seed.
i. 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 Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25% + Mancozeb 50% WS @3g/kg seed or Penflufen 13.28% w/w + Trifloxystrobin 13.28% w/w FS @ 1 ml/kg seed.
iii. Removal and burning of crop debris.
iv. Spray of carbendazim or thiophanate methyl @ 0.1% or Fluxapyroxad 167 g/l + Pyraclostrobin 333 g/l SC 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.
iii. Seed treatment with Carboxin 37.5% + Thiram 37.5% @ 3 g/kg seed or Carbendazim 25%+ Mancozeb 50% WS @3g/kg seed.

8. 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.

9. 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 Carbendazim 25%+ Mancozeb 50% WS @ 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.

10. Yellow Mosaic disease

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 observed. 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 Imidachloprid 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.

List of fungicides recommended for soybean crop

No	Fungicide	Approved for the control of	Dose/ha	Brands
A	**Seed Treatment (Fungicides)**			
1	Azoxystrobin 2.5% + Thiophanate Methyl 11.25% + Thiamethoxam 25% FS	Fusarium root rot, Phytophthora root rot, Rhizoctonia seedling blight, Pythium seedling blight	10 ml/kg seed	Electron, Cascade
2.	Fluxapyroxad 333 g/l FS	Rhizoctonia root rot, Cotyledonary spot	1.0 ml/kg seed	Systiva
3	Penflufen 13.28% w/w + Trifloxystrobin 13.28% w/w FS	Seed and Seedling rot disease	1ml/kg seed	Evergol
4	Carboxin37.5%+ Thiram37.5%WS	Collarrot, Charcoal rotand other seedling diseases	3g/kg seed	Vitavax power
5	Carbendazim 25%+ Mancozeb 50% WS	Root rot, Collar rot	3g/kg seed	Samurai

B	**Seed Treatment (Insecticides)**			
1	Thiamethoxam 30 FS	10 ml/kg seed		
2	Imidacloprid 48 FS	1.23 ml/kg seed		
C Sprays: 1st during the initial stage and Second spray after 15 day				
1	Hexaconazole 5% EC	Rust	500 ml	Contaf
2	Kresoxim-methyl 44.3% SC	Rust	500 ml	Ergpn
3	Picoxystrobin 22.52% w/w SC	Rust(Phakopsora pachyrhizi) Leaf spot (Cercospora kikuchii& Alternaria alternata)	400 ml	Galileo
4	Pyraclostrobin 20% WG	Frog eye leaf spot (Cercospora)& Alternaria leaf spot	375-500 g	Headline
5	Tebuconazole 25.9%EC	Anthracnose (pod blight)	625 ml	Orius, exil
6	Tebuconazole 38.39% w/w SC	Leaf spot (Alternaria, Cercospora & Myrothecium)	600 ml	Buonos
7	Tebuconazole 10%+Sulphur 65%WG	Leaf spot & Pod blight	1250 g	Swadhin Haru, Jakuzzi
8	Azoxystrobin 18.2% + Difenoconazole 11.4% w/w SC	Leaf spot & Rust	500 ml	Azozole, Godiwa super
9	Carbendazim12%+ Mancozeb 63%WP	Alternaria leaf spot, Myrothecium leaf spot, Pod & stem blight & Anthracnose	1250 g	Saaf,, Gould
10	Fluxapyroxad 167 g/l + Pyraclostrobin 333 g/l SC	Frog eye leaf spot	300 g	Priaxor
11	Pyraclostrobin 133 g/l + Epoxiconazole 50g/l SE	Cercospora leaf spot	750 ml	Opera

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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 appearance in terms of infestation and damage every year due to frequent climate change. Since last few years' outbreaks of different insect has been occurred. For example, in central region (Madhya Pradesh, Rajasthan and Maharastra) in the year of 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 to farmers and researchers. So, it is very necessary to formulate a stable and wide spectrum Insect-pest's management program to cope up this problem under changing climate scenario. For this purpose, Integrated Pest Management is best suited. The very first component of IPM is to correct identification of the insect-pests. Major insect-pests of 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 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. *Heliverpa armigera* (Gram Pod Borer)

Every year, the soybean crop is reported to be increasingly infested by Gram pod resulting in heavy yield losses. This is found to be polyphagus with more egg laying capacity and recently this has developed resistance to many popular insecticides. Hence, farmers are advised to adopt following control measures:

- Use of recommended seed rate.
- Install insect-specific pheromone trap at 4-5 locations 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 heliothis 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 or Indoxacarb 14.5 SC @ 0.5 l/ha or Flubendiamide 39.35 SC @ 150 ml/ha) or Flubendiamide 20 WG @ 250-300 g/ha using 500 litre of water per hectare.

3. Green Semilooper

Soybean in infested by a complex 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. Farmers are advised to follow control measures as given below:

- Use recommended seed rate. 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.
- Regular monitoring of the field and destruction of egg mass / caterpillar in early stage.
- 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 or Indoxacarb 14.5 SC @ 0.5 l/ha, pre-mix insecticides like Betacyfluthrin 8.49% + Imidacloprid 19.81% OD @ 350 ml/ha or Thiamethoxam + Lambda Cyhalothrin @ 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.

4. Girdle Beetle

1. During recent years, this insect is found to be most commonly seen in major soybean growing states. Generally, its typical infestation is seen after 25-30 days after 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. Following control measures are suggested for management of this insect.

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

6. **White Grub**

7. 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.
8. Installation of light trap or pheromone traps for collection and destruction of white grub adults.
9. Seed treatment with Imidachloprid 48 FS @ 1.25 ml/kg seed.
10. 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.
11. **<u>IPM components</u>**

12. **Summer deep ploughing:** Deep ploughing is essential during summer, after harvesting the *rabi* crop. This facilitates exposing the hibernating insects to extreme heat and predatory birds.
13. **Proper sowing time**: Crop sown during June end escapes damage due to stem fly. However, where girdle beetle is a recurring problem, sowing should be done during first-second week of July.
14. **Optimum/Recommended seed rate, spacing and plant population**: Higher seed rate results in more densely populated soybean crop which attracts more insects. Further, it promotes lodging resulting in yield loss. Hence, farmers are advised to check the germination percentage of their seed before sowing and accordingly use seed rate (60-80 kg/ha) depending on seed size with recommended spacing (45 cm x 5cm).
15. **Selection of insect resistant/tolerant variety:** Varieties recommended for a particular agro-climatic zone, should only be used. More yields should not be the only criterion. Cultivation of marginally

less yielding but insect-resistant or tolerant variety is always remunerative.

16. **Balanced nutrition:** Use of excessive nitrogenous fertilizers leads to more incidence of defoliators and girdle beetle. Therefore, use optimum quantity of recommended nutrients only. Use of potassium improves crop health and provides resistance against insect-pests.
17. **Destruction of infested plants:** Bihar hairy caterpillar and tobacco caterpillar are gregarious feeders at initial stage. At this stage, infested plants are easily spotted in the field. Removal and destruction of such plants prevents larvae to migrate to and damage other plants. Likewise, girdle beetle infested plants are also easily recognized by dried portion above the girdles. Up to 30-45 days, remove the infested plant parts from below the girdles to destroy eggs and grubs of girdle beetle. For spotting and removing the infested plants/plant parts, constant scouting of entire field is very essential.

1. **Light Trap:** Adult moths of most of the defoliating larvae are nocturnal, and are attracted towards light source. These should be collected with the help of "Light Traps" and destroyed. By doing so, adults can be prevented from mating and laying eggs and the crop can be saved. Light traps are also useful for attracting adults of white grubs.
2. **Pheromone Trap:** Infestation by *Helicoverpa armigera* and *Spodoptera litura* can be minimized through specific pheromone traps. These traps not only help in monitoring the incidence but also for mass trapping the adults. Care should be taken that the pheromone septa are not touched with bare hands while fixing on the trap.
3. **Bird Perches:** In order to exploit the potential of insect-predatory birds, 'T' shaped bird perches should be installed in the fields.
4. **Use of botanical insecticides:** Simple water extracts of *Acacia arabica* (leaves or seeds), Custard apple (leaves or seeds), *Datura* (leaves or seeds), *Eucalyptus* (leaves), *Ipomoea* (leaves), Lantana (leaves), tobacco (leaves) and *Pongamia* (leaves) exhibit insecticidal action against defoliators. Different neem products like, neem oil, seed extract, leaf extract etc. act as feeding deterrent for leaf eating insects. Consequently, insects get repelled from the crop. Continuous starvation leads to insect death in a few days.
5. **Use of microbial insecticides**: Application of commercially available microbial insecticides like DiPel, Biobit, Delfin etc (Bt based) or Larvocel, Biosoft, Dispel or Biorin (*Beauveria bassiana* fungus based) @ 1.0 kg/ha can help in controlling defoliating larvae without adverse effect on natural enemies, parasitoids and predators. For control of tobacco caterpillar and gram pod borer, insect specific Nuclear Polyhydrosis Virus like Virin S/Biovirus S or Virin H/Biovirus H can be used for spraying on the soybean crop.
6. **Use of chemical chemical insecticides:** 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. Use of insecticides has been found to be effective

for proper management of insect-pests (Table 1)

Precautions to be followed during use of insecticides

a. **Insecticide and quantity of spray solution:** After selecting appropriate and good quality insecticide, check its expiry date. Then spray it thoroughly on the crop in proper concentration and quantity. 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 will not give desired results.

b. **Time of spray and use of appropriate nozzle:** Insecticides should be sprayed in morning or in evening. Spraying during day time reduces the activities of beneficial insects like parasites, predators, honeybees and causes hindrance in biological insect control, honey collection and pollination. Cone Nozzle is found to be best suitable for spray of insecticides which ensure evenly distribution. While spraying the contact insecticides like Quinolphos/ Triazophos/Indoxacarb, cone nozzle should be used for evenly distribution of the spray. Also, power sprayer as well as boom sprayer are the suitable alternatives for both required quantity of water as well as time and labor.

c. **Repeating insecticide spray:** If appropriate insecticide is sprayed in recommended concentration and quantity in right time, only one spray is sufficient. Insecticides are usually effective for 10-15 days. During this period insect-population is reduced on one hand, and the susceptible stage of crop is also over on the other hand. If at all second spray is required, use different insecticide of the same category (contact or systemic). This is essential to prevent development of insecticide resistance in insects.

d. **Compatibility of insecticides:** Before using any other insecticide or fungicide as mixture, consult the experts for their compatibility. In a compatible combination, both the chemicals should retain their respective efficacy. Synthetic Pyrethroids therefore, should always be used independently. Common fungicides such as Carbendazim, Thirum, Dithane-M-45 are compatible with insecticides. The most suitable and effective combinations of chemical insecticides and post emergence herbicides are given in Table 2. These combinations can be used at recommended doses of individual chemicals according to the prevailing conditions of insects and weeds.

Other measures of insect management: Controlling insect population below economic injury level by employing all possible measures, to part with sole dependence on conventional chemical insecticides, is the aim of integrated pest management. To achieve this objective, scientific research is continuing to evaluate different products helpful in management of insect-pests. Although, not recommended for use in soybean at present, but for the sake of knowledge, information of some potential products is being given, whose practical use in soybean and commercial production is likely in near future:

Table1: 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+ Thiomethoxam	125 ml/ha
White fly	Thiamethoxam 30 FS	10 ml/kg seed
	Imidacloprid 48 FS	1.25 ml/kg seed
	Betacyfluthrin 8.49% +Imidacloprid 19.81% OD	350 ml/ha
Defoliators (Semiloopers, Tobacco caterpillar, *Helicoverpa armigera*)	Chlorantraniliprole 18.5 SC	150 ml/ha
	Indoxacarb 15.8 EC	333 ml/ha
	Profenofos 50 EC	1250 ml/ha
	Quinalphos 25 EC	1500 ml/ha
	Spinetoram 11.7 SC	450 ml/ha
	Betacyfluthrin 8.49% + Imidacloprid 19.81% OD	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
	Profenophos 50 EC	1250 ml/ha
	Betacyfluthrin 8.49% +Imidacloprid 19.81% OD	350 ml/ha
	Thiamethoxam + Lambda Cyhalothrin	125 ml/ha
Pod borer (*Helicoverpa armigera, Cidia ptychora*)	Profenophos 50 EC	1250 ml/ha
	Chlorantraniliprole 18.5 SC	150 ml/ha
	Indoxacarb 15.8 EC 333 ml/ha	333 ml/ha

Table 2: 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

Virus: Some viruses like nuclear polyhedrosis virus (NPV) cause disease in insect-pests and reduce their populations. Viral disease infested larvae stop feeding, become sluggish, limp and flaccid and their integument becomes very fragile. Internal body contents disintegrate and the larvae die. The dead larvae are usually found hanging by their legs from the plants. For the management of *Helicoverpa armigera* and *Spodoptera litura* spray of Ha NPV or Sl NPV @ 250 LE/ha has been found to be effective.

Bacteria: Bacteria kill the insect-pests by causing different diseases. Infected insects cease feeding, become sluggish in movement and exhibit diarrhea and vomiting. The body becomes flaccid and the insect dies within 1 to 3 days. Commercial formulations of *Bacillus thuringiensis* are available in various trade names, viz. Biobit, Dipel, Halt, Delfin etc. They have been found effective against defoliating larvae. Bt formulation is compatible with thiamethoxam, among insecticides and with carbendazim, triademafon and thiophanate methyl among fungicides. Hence a tank-mix formulation of Bt + thiamethoxam + carbendazim / thiophanate methyl can be used for the management of defoliators, stem borers and foliar diseases. If soybean rust is also seen along with defoliators the mixture of Bt + triademafon can be sprayed.

Fungus: Contrary to virus and bacteria (which infect the insects from inside), fungus infects the insects from outside through the integument. On reaching inside the insect body, they develop cottony mycelium. This mycelium again penetrates out through the integument. Finally, the insect body gets covered with white powdery substance, which disperses through wind, to infect other insects also. Naturally occurring fungi like, *Beauveria bassiana*, *Metarrhizium*, *Spicaria*, *Entomophthora* etc. cause different diseases in insects.

Parasitoids and predators: Some insects spend their lives by eating other harmful insects from inside (parasites) or from outside (predators) by predation. Biological control through these beneficial insects has immense value in integrated pest management. Parasites like *Apanteles*, *Elasemus*, *Bracon*, *Brachymaria*, *Trichogramma* etc. destroy the eggs, larvae or pupae of harmful insects. Some predators, such as *Cantheconidia furcellata*. *Rhinocoris fuscipes* etc. consume many larvae during their life period.

Trap crop: *Anethum graveolens* (*Suva*) is excellent trap crop for most of the defoliators. Intercropping of soybean: *Suva* (in 6:1 or 12:2 row ratio) helps in trapping the insects on *Suva* crop and saving the main

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Seed Inoculation in Soybean under Changing Climate Scenario

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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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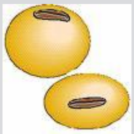

Climate Smart Practice for Seed Treatment in Soybean

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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 enronronment 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.

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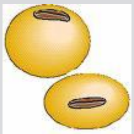

Quality Seed Production in Soybean

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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 30^{o}C 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 20-27^{o}C. 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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Processing Techniques and Food uses of Soybean for Food and Nutritional security

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Soybean (*Glycine max* L. merril), a crop of highest nutritional value has already revolutionized the socio-economic condition of farmers of central India. It is spreading in newer areas while replacing traditionally grown crops and is contributing to vegetable oil economy of the country. Now is a time to take this golden bean to the kitchen of Indian households and exploit the enormous health benefits and capacity to provide nutritional security to those who are deprived of quality protein diet because of poverty. There is a need to create awareness among the population about the health benefits of soybean and its utility for preparation/fortification with popular traditional recipes.

As such, the crop has been contributing to the rural economy of India. However, its potential to contribute in achieving nutritional security has largely been untapped in India even after four decades. Its food uses have found to be negligible except as vegetable oil which is most common Indian households. There is a direct need for popularization and consumption of soybean in the form of various soybean based food preparations as soybean is considered to be a functional food. Beside, 20 percent oil, soybean contain about 40 percent of high quality protein which is full of essential amino acids. Hence, Soybean can be considered as a potential alternative to mitigate a large scale problem of protein calorie malnutrition, a serious concern in rural population. In addition, it has a considerable amount of minerals like calcium, iron and vitamins. Of late, the research did in the past have revealed some interesting facts about the nutraceutical properties of soybean. The health beneficial compounds like isoflavone present in soybean are found to be anti-cancerous in nature. Consumption of soybean is also advisable in order to avoid disorders like anemia, osteoporosis, diabetics, chronic ailments and cancer. Hence, utilization of soybean through different soy based food preparations is one of the most appropriate options for rural population to augment its protein supply which, in addition to other health benefits besides best quality protein at relatively lower cost. It helps people to feel better and live longer with an enhanced quality of life.

The untapped potential regarding health and nutritional security by way of domestic utilization of soybean by Soybean can be used for alleviating the problem of protein calorie malnutrition and also for achieving nutritional security. This can be done using 50g of soybean in the form of any soybean based food preparations or traditional recipes. However, before using soybean for preparation of food preparation, it is advised to go for processing in order to inactivate the bad effects of Kunitz Trypsin Inhibitor (KTI) which is heat labile compound. This can be done either through boiling the raw soybean for at least 30 minutes or through deep frying depending on the nature and utility of the food product. The enormous health benefits of soybean can be exploited using processed soybean in daily diet on regular basis. The ICAR-IISR has recently developed some food grade suitable varieties like NRC-127 (Null KTI), NRC 132 and NRC 181 (Null Lypoxygenase-2), NRC 142 and NRC 152 (Double Null-KTI and Lox2 free) and are recommended for preparation of various soybean based food preparations at domestic level.

Soybean based food preparations

Soy nuts: Roasted nuts can be prepared by blanching the raw soybean with 1% salt solution for 20-25 minute. After the removal of excess moisture, the same can be used for preparation of soy nuts using microwave oven. In absence of oven, it can be roasted in frying pan using salt till the time to soybean changes its original color. Similarly, fried soy nuts can also be prepared using deep fry method. The soy nuts so prepared can be consumed by adding salt and chili powder, chopped onion, chopped green chili, lemon juice etc as per the taste preferences.

Sprouted Soy/Vegetable Soybean: Soybean can be sprouted using wet cloth in the perforated utensil for 3-4 hours and sprinkling of water at the regular intervals. After the sprout initiation, the same can be consumed after pressure cooking/boiling in the form of salad/sprouted soy.

Vegetable Soybean/green pods: Green soybean pods during pod filling/maturity (R6 stage) can also be one of the options for its consumption. Similar to the Pigeon pea pods, soybean pods can also be boiled for 20-25 minutes in salt solution. After draining out excess water the soybean grains from these boiled pods can be directly consumed which are very tasty.

Soy flour: There are three types of soy flour (enzyme active, toasted and untoasted) which is available in the market at present is prepared using de-oiled cake which is produced during oil extraction process at the the solvent extraction units. For enhancing the nutritional qualities of popular traditional recipes, use of untoasted soy flour can be made for fortification (75:25) with major ingredients (wheat/chickpea flour or maida/Rawa-Suji) for the products prepared using the process of deep frying whereas toasted soy flour can be used for the products which needs baking (roti/bakery products). The soy flour can also be prepared at domestic level and can be mixed with wheat/sorghum/pearl millet flour for roti making using 9:1 proportion. For preparation of soy flour, soybean should be boiled for at least 20 minutes after which its husk can easily be removed. The same should be sun-dried for 2-3 days and either mixed with wheat for preparation of chapatti flour or for preparation of soy flour separately which later on can be used during fortification with other soy flour based products in order to enhance the nutritional quality.

Soy flour based food products: Soy flour can be mixed with maida/rawa-suji/chickpea flour for preparation of various traditional recipes (Mathri, biscuits, Shakkarpare, Papad, Sev, Chakli etc) in 75:25 proportion.

Soymilk: 1 kg of soy grains produces on an average about 8 liters of soy milk which if further used can produce about 1.5 to 1.75 kg of soy paneer (Tofu). For preparation of soymilk, required quantity of soy grains are put for steam pressure-cooking along with equal quantity of water using pressure cooker for around 3 minutes. Thereafter, the soy grains are allowed to be kept in lukewarm water for 3-4 hours for soaking. The soaked grains are then grinded in a mixer using lukewarm water. The paste so prepared is added with 6 liters of water and then is boiled for about 10 minutes and filtered. The filtered solution is called soymilk and the solid material, which left while filtering is called Okara. The soy milk can be consumed using desired essence and sugar or can further be used for preparation of milk based products like yoghurt, Lassi, Shrikhand or tofu.

(soy paneer): For preparation of tofu, prepare the soymilk using the process given above. Then add the solution prepared by using 5 gm each of calcium chloride and magnesium chloride or citric acid/lemon juice as per the availability for coagulation process through which the whey and coagulated solids are separated. The coagulated item after removal of excess water is kept under heavy weight is made compact and is called as soy paneer (tofu)

which is ready now for its use in different traditional recipes.

Soy okara based products: *Okara*, the byproduct received during the process of preparation of soymilk can be used for preparation of *Pakora*, *Nuggets*, *Gulab jamun*, *Upama*, *Paratha*, *Halwa* etc.

		
Soy Nuts	**Soy flour**	**Soymilk**
		
Soy Biscuits	**Soy Sev, Papad, Shakkarpare**	**Tofu**
		
Soy Pakora	**Soy Parantha**	**Soy Yoghurt, Shrikhand**

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