# RESEARCH HIGHLIGHTS 2015


JAWAHARLAL NEHRU KRISHI VISHWA VIDYALAYA
JABALPUR 482004 (MP)

# Research Highlights
# 2015

Jawaharlal Nehru Krishi Vishwa Vidyalaya
Jabalpur, Madhya Pradesh

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# Foreword

Jawaharlal Nehru Krishi Vishwa Vidyalaya, Jabalpur is engaged in agricultural research, education and extension for growth and development of agriculture sector since five decades. Keeping in view, the emerging problems of sustainable agriculture development, agricultural research in basic, applied and strategic fields are carried out as an important mandate of the University. The researchers of agricultural and allied sciences are continuously working for solving the problems of farming community for enhancing agricultural production. The research activities are planned after receiving feed-back from field extension agencies. The major thrust on agricultural research is to enhance total factor productivity (TFP) through efficient utilization of resources on sustainable manner. Such efficient system will ultimately help in enhancing profitability from farming for overall socio-economic development of the peasants.

The major research thrust areas are development of improved varieties of crops and vegetables for yield and quality traits, resistance to biotic and abiotic stresses, and suitability to different agro-climatic conditions and cropping systems; development and collaboration of production and crop management technologies; technologies for dry land  high tech horticulture and integrated farming systems for food, nutritional and income security of small and marginal farmers; organic farming; climate change, conservation agriculture and secondary agriculture for value addition of agricultural produce etc.

It is my immense pleasure that the scientists of the university have done praise worthy research work during 2013-14 and 2014-15 for sustainable agricultural development of the state.  Discerns of research is presented in the form of "Research Highlights 2015". The efforts made by Director Research Services and his team to bring this publication is highly appreciated.

(V.S. Tomar)

**Dr. Dhirendra Khare**
Director Research Services

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# Preface

Agriculture is an important sector of Indian economy as it contributes about 14% to the total GDP and provides employment to over 60% of the population. Indian agriculture has registered impressive growth over last few decades. The food grain production has increased from 51 million tons in 1950-51 to 252.68 million tons during 2014-15. The production of oilseeds (nine-major oilseed) has also increased from 5 million tons to 26.68 million tons during the same period. The rapid growth has helped Indian agriculture to feed growing population and compete in international trade.

Jawaharlal Nehru Krishi Vishwa Vidyalaya has made stride efforts for ensuring food and nutritional security through development of varieties of important crops and development of their matching technologies. The problem oriented location specific research in agriculture is carried out through Zonal Agricultural Research Stations, Regional Research Stations and Agricultural Research Stations covering seven agro-climatic zones and twenty five district of the State under the jurisdiction of JNKVV, Jabalpur.

Some of the landmark research achievements of the University are development of JS series of Soybean varieties which helps in breaking monoculture of JS 335, early rice hybrids which brought rabi fallow under cultivation, improved chickpea varieties helps in enhancing acreage under chickpea not only in Madhya Pradesh but this has brought chickpea revolution in southern part of India. Looking to the predominance of rainfed area and large chunk of small and marginal farmers in the state, there is an urgent need to strengthen agricultural research on soil and water conservation, development of varieties of various crops resistant to biotic and abiotic stress, farming system diversification, biodiversity conservation as gene pool, development of dry land horticulture, organic farming, farm mechanization for conservation agriculture, low cost post-harvest technology, development of sustainable integrated farming system modules specially for small and marginal farmers and development of mitigating and coping strategies to climate change.

I hope, the valuable information contained in the "Research Highlights 2015" will be of enormous interest to all those engaged in the agriculture development in the country and I congratulate all the staff members of the Directorate for bringing out this important publication.

(Dhirendra Khare)

# 1. Introduction

Jawaharlal Nehru Krishi Vishwa Vidyalaya is engaged in agricultural research, teaching and extension for growth and development of agricultural sector since last five and half decades. Looking to emerging problems and needs of the farming community, agricultural research in basic, applied and contemporary fields are carried out as an important mandate of the University. Scientists of agriculture and allied subjects are working to solve the problems of farming community. The major thrust of agricultural research is to increase productivity so that the production system can be made more efficient and sustainable. Such improved systems will ultimately help in enhancing socio-economic sustainability and security of peasants of the state. JNKVV has made stride efforts for ensuring food and nutritional security through development of crop varieties of soybean, chickpea, millets, rice, wheat and many other crops and their matching technology. The problem oriented, location specific research is carried out through Zonal Agriculture Research Stations, Regional Research Stations and Agriculture Research Stations covering seven agro-climatic zones and twenty five districts of the State.

**Zonal Agricultural Research Stations**

1. Head quarter - Directorate of Research Services, JNKVV, Jabalpur
2. Powarkheda, Hoshangabad
3. Kundeshwar Research Farm, Tikamgarh
4. Chandangaon, Chhindwara

**Regional Agricultural Research Stations**

1. Kuthulia Research Farm, Rewa
2. Bamhori Research Farm, Sagar
3. Murjhar Research Farm, Waraseoni, Balaghat
4. Tribal Agricultural Research Station, Dindori

**Agricultural Research Stations**

1. Betelvine Research Station, Nawgaon, Chhattarpur
2. Dryland Horticultural Research Station, Ranguan, Garhakota, Sagar
3. ARS, Tendani, Chhindwara
4. ARS, Sausar, Chhindwara

Multi-disciplinary research of applied nature is being conducted on natural resource management, crop improvement, crop production, crop protection, horticultural crops, allied enterprises, post-harvest technology, farm machinery, soil and water conservation, energy utilization and socio-economic aspects in all the ZARS, RARS and ARS. Well-equipped modernized farms, workshops, laboratories with all necessary electronic modern equipment, Agro-met centre, glass and net houses, e-library, ARIS-Cell with latest information and communication technology are strengthening the research activities of the University. JNKVV is implementing research projects funded by ICAR All India Coordinated Research projects, ICAR Network projects, *ad-hoc* research projects, State Plan, State Tribal Plan and Non Plan projects, Madhya Pradesh Agricultural Marketing Board (Mandi), Madhya Pradesh Council of Science and Technology, Madhya Pradesh State Biodiversity Board, Department of Farmers Welfare and Agriculture Development (RKVY), Department of Science and Technology, Bhabha Atomic Research Centre, Central Biodiversity Board, Agro-Economic Research Center, Cost of Cultivation Scheme, Rashtriya Krishi Vikas Yojna, National Food Security Mission, National Horticulture Mission etc. along with internationally funded projects *viz.,* Japan International Cooperation Agency, Japan, International Rice Research Institute, Philippines, CIMMYT, Mexico, ICARDA, Syria/ Morocco , ICRISAT, India, etc. to carry out the research work in agriculture and allied fields. The consultancy processing cell facilitates testing of products developed by MNC's and Indian corporate sector, promotes agri-business development through the services of technology commercialization, public private partnership as well as capacity building programme. This centre also establishes Agri-clinics and Agri-business Centres to promote the entrepreneurship opportunities among the graduates of agriculture and allied sector.

The thrust of research continues to be on the development of improved crop varieties resistant/ tolerant to biotic and abiotic stresses as well as need based location specific improved crop production and protection technologies. New research program are also formulated to work on the changed scenario of new economic policies and climate change. Presently the University is catering to the research need of the farmers of the following Zones and districts in its jurisdiction

1. Chhattisgarh Plain (Balaghat)
2. Northern Hill Zone of Chhattisgarh (Mandla, Dindori, Shahdol, Anuppur and Umaria)
3. Kymore Plateau and Satpura Hills (Jabalpur, Katni, Seoni, Panna, Rewa, Sidhi, Singrauli and Satna)
4. Vindhyan Plateau- Partially (Sagar, Damoh, Raisen and Vidisha)

**Table 1:Production of pulses and oilseeds in India and Madhya Pradesh (2014-15)**

| Crop | India | | | Madhya Pradesh | | | Rank in Production |
|---|---|---|---|---|---|---|---|
| | Area million ha | Production million tons | Yield Kg/ha | Area million ha | Production million tons | Yield Kg/ha | |
| Chickpea | 8.19 | 7.17 | 875 | 2.86 (34.92) | 2.96 (41.28) | 1039 | I |
| Lentil | 1.34 | 1.02 | 758 | 0.53 (39.55) | 0.34 (33.33) | 638 | I |
| Pigeonpea | 3.71 | 2.78 | 750 | 0.52 (14.02) | 0.51 (18.3) | 981 | II |
| Pulses | 23.10 | 17.19 | 744 | 5.36 (23.20) | 4.79 (27.86) | 877 | I |
| Mustard | 5.79 | 6.31 | 1089 | 0.71 (12.26) | 0.72 (11.41) | 1006 | II |
| Soybean | 11.09 | 10.53 | 950 | 5.58 (50.31) | 6.35 (60.30) | 1139 | I |
| Oilseed | 25.73 | 26.67 | 1037 | 7.09 (27.55) | 7.72 (28.95) | 1090 | I |
| Wheat | 30.97 | 88.94 | 2872 | 5.56 (17.95) | 14.18 (15.94) | 2551 | III |
| Total food grains | 122.07 | 252.68 | 2070 | 14.83 (12.15) | 25.49 (10.09) | 1719 | III |

*Source: Agricultural Statistics at a Glance 2015 (GOI)*
*Figures in parentheses show percentage contributions at national level.*

5. Central Narmada Valley (Narsinghpur, Hoshangabad and Harda)
6. Bundelkhand Zone - Partially (Tikamgarh and Chhatarpur)
7. Satpura Plateau (Betul and Chhindwara)

The state has made tremendous efforts for increasing agricultural production and this reflects in confirmation of **Krishi Karman Award** at national level. At national level Madhya Pradesh has crowning position (Table 1) in production of chickpea, soybean, lentil, total oilseeds and total pulses (Fig. 1). The State ranks second in mustard and pigeonpea and third in wheat and total food grain production at national level.

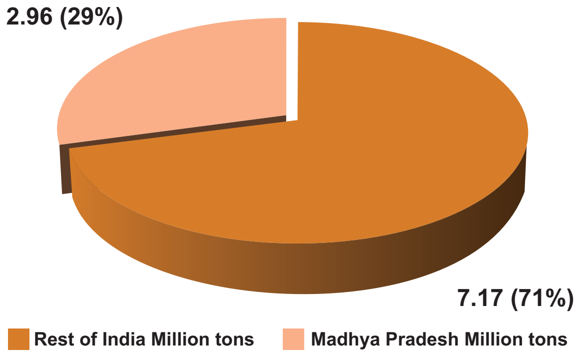



**Fig. 1A: Contribution in Chickpea**

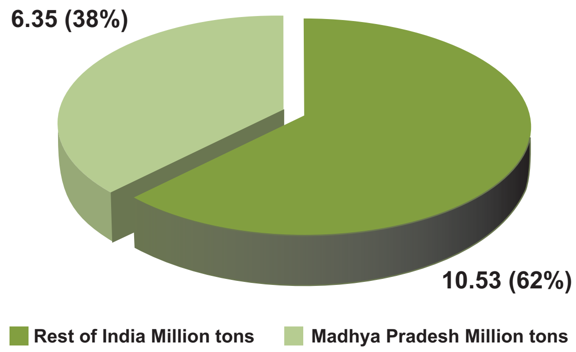



**Fig. 1B: Contribution in Soybean**

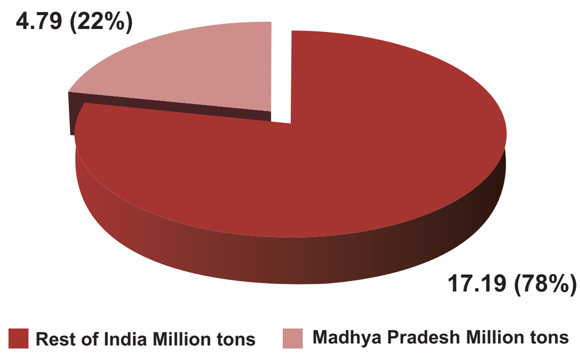



**Fig. 1C: Contribution in Pulses**

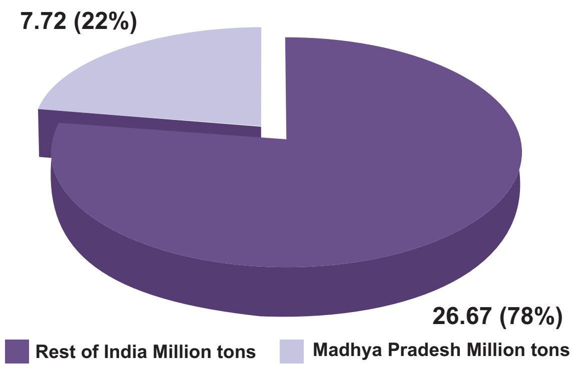



**Fig. 1D: Contribution in Oilseeds**

**Fig. 1: Contribution of the State of Madhya Pradesh at national level**

# 2. Agriculture

## 2.1 Crop Improvement

### 2.1.1 Genetic improvement of cereals

**Wheat**

**MP 3382:** An early maturing (105-110 days), dwarf, tolerant to terminal heat, non-lodging, rich in protein, iron, zinc and copper and other quality attributes is suitable for cultivation under irrigated timely sown condition of Madhya Pradesh. It is rich in chapatti making quality, wet dry gluten content, and gluten index. The variety is resistant to black and leaf rusts.


**MPO 1255:** The high yielding (41-45 qha$^{-1}$) variety matures in 119 days. It is rich in iron, zinc and suitable for pasta making and export.

**MP 3336:** Early maturing, high yielding (42-57 qha$^{-1}$) variety is suitable for irrigated late sown (December-January) area of central zone.


- Out of six identified nutri-rich wheat varieties (MPO 1215, JW 3211, JW 1202, MP 4010 and HI 8663) at national level, five are of the University.
- Water and nutrient efficient wheat variety JW 3211 gave 40 qha$^{-1}$ yield with one irrigation and 50% RDF whereas JW 1202 up to 50 qha$^{-1}$ with two irrigation.
- The highest grain yield was recorded by genotype HD 2687 (88.5 qha$^{-1}$) and HD 2733 (51.0 qha$^{-1}$) in timely as well as late sown thermal stress condition.

**Rice:** JRH 19 an early maturing (108-112 days) rice hybrid with high yield potential (65-70 qha$^{-1}$) and resistance to stem borer suitable for entire rice growing area of the State is developed.

**Physiological efficiency and productivity parameters**

- Kodo millet variety JK 137 performed well in the rainfed situations of Madhya Pradesh demonstrating distinct yield superiority over the national check RBK 155 and GPUK 3 with average increase of 22.64 and 10.63%, respectively. The erect and medium maturing varieties is responsive to application of NPK with tolerance against drought, lodging and shoot fly, moderate resistant to head smut and suitable as sole as well as inter/ mixed cropping.

- Maize genotype Kaveri 25-K60 was identified for quantum efficiency (0.0125) and photosynthetic rate (14.96 µmol$m^{-2}s^{-1}$); Kaveri 25-K45 for carboxylation efficiency (0.057 µmol $m^{-2}s^{-1}$(µmol $mmol^{-1})^{-1}$); HPQM for water use efficiency (4.74 µmol $mmol^{-1}$), mesophyll efficiency (1523.60 (mol $mol^{-1}$(mol $m^{-2}s^{-1})^{-1}$) and harvest index (40.15%) with low stomatal conductance (0.19 mol $m^{-2}s^{-1}$), and transpiration rate (3.15 mmol $m^{-2}s^{-1}$).

- Maize genotype Kaveri super 244 is high yielder (48.39 g $plant^{-1}$ and 6452 kg $ha^{-1}$) owing to its high chlorophyll index (21.40), dry matter production (101.87 g $plant^{-1}$), carboxylation efficiency (0.049 µmol$m^{-2}s^{-1}$(µmol $mmol^{-1})^{-1}$) and water use efficiency (3.57 µmol $mmol^{-1}$). It is also reflected (Table 2) by its high plant height (153.98 cm), number of cobs $plant^{-1}$ (2.0), number of grains $cob^{-1}$ (227.84), cob length (25.19 cm ) , cob girth (39.10 mm) , biological yield (127.65 g $plant^{-1}$ and 17019 kg $ha^{-1}$).

**Table 2: Expression of yield and its contributing traits among genotypes of maize**

| Genotypes | Plant height (cm) | Cobs /plant | Grains /cob | Cob length (cm) | Cob girth (mm) | 100 grain weight (g) |
|---|---|---|---|---|---|---|
| 3110 | 147.88 | 1.00 | 152.66 | 23.66 | 32.10 | 20.51 |
| KAVERI SUPER 244 | 153.98 | 2.00 | 227.84 | 25.19 | 39.10 | 21.44 |
| KMH 3696 | 149.47 | 1.33 | 132.82 | 24.96 | 33.52 | 29.39 |
| KMH 2589 | 146.86 | 1.00 | 122.40 | 22.9 | 33.43 | 20.45 |
| KMH 3712 | 146.5 | 1.00 | 162.28 | 24.72 | 33.20 | 25.86 |
| KAVERI 25-K60 | 147.7 | 1.67 | 157.60 | 23.67 | 33.26 | 24.38 |
| KAVERI 25-K45 | 153.5 | 1.00 | 162.86 | 25.01 | 33.97 | 21.69 |
| HPQM | 138.9 | 1.00 | 142.26 | 23.03 | 31.90 | 18.81 |
| SEm ± | 0.3508 | 0.1606 | 0.7408 | 0.2190 | 0.1338 | 0.5763 |
| CD at 5% | 1.0617 | 0.4861 | 2.2421 | 0.6629 | 0.4049 | 1.7442 |

### 2.1.2 Genetic improvement in pulses

**Chickpea :** Bold seeded Fusarium wilt and root rot resistant *Kabuli* type chickpea variety JGK 5 matures in 100-110 days with 8-10 q$ha^{-1}$ yield.



**Pigeonpea:** Genotypes ICPB 2039, JKM 7 and KPBR 80-2-1 attained the highest survival percentage after seven days; genotype ICPH 2431 maximum chlorophyll content, relative water content, root capacitance and total dry matter production; and JKM 7 maximum plant height after 14 days of water-logging.

## 2.1.3 Genetic improvement of oilseeds

### Soybean

**JS 20-29**: An early maturing (95 days), high yielding (25-30 qha$^{-1}$), multiple biotic stress resistant variety possesses excellent germinability and longevity. Being an early maturing variety, it is suitable for double cropping in rainfed situation, whereas semi-erect growth habit made it most suitable for inter-cropping.

**JS 20-34:** It is an extra early variety (87 days) with high yield potential (22-25 qha$^{-1}$), multiple biotic resistance, suitable for low and medium rainfall, light to medium soils and upland conditions. Its erect growth habit made it suitable for intercropping. It possesses excellent germiniability and longevity.

**JS 20-69:** A high yielding (25-28 qha$^{-1}$), early maturing (93-95 days) resistant to biotic stresses *viz.,* yellow mosaic virus, charcoal rot, blights, bacterial pustule, leaf spots, stem fly, stem borers and defoliators is suitable for double cropping under rainfed situation.

### Screening for physiological efficiency

- Soybean genotype JS 20-91 had the earliest flower initiation (37.75 days), pod emergence (46.25 days) and days to seed formation (56 days), however JS 20-82 was associated with longer reproductive phase (56 days) and JS 20-89 attained physiological maturity at the earliest (81.50 days).
- Soybean genotype JS 20-79 was identified for high dry matter production in pods (21.13g plant$^{-1}$), average maximum LAI (5.02), LAD (16674.16 cm$^2$ days) , water use efficiency (3.71 μmol/mmol), protein (43.15%) and fat (22.25%); JS 20-91 for chlorophyll index (34.77 g m$^2$) and quantum efficiency (0.020); JS 20-88 for transpiration rate (6.94 mmol m$^2$ s$^{-1}$) and stomatal conductance (0.795 mol/m$^2$s$^{-1}$); JS 20-89 for photosynthetic rate (23.26 μmol/m$^2$ s$^{-1}$) and carboxylation efficiency (0.077 μmol/m$^2$/s-$^1$ (μmol mmol$^{-1}$)$^{-1}$); and JS 20-53 for mesophyll efficiency (582.42 (μmol mmol$^{-1}$(mol m$^{-2}$s$^{-1}$)$^{-1}$.

**Table 3: Bio-chemical constituents among soybean genotypes**

| Genotypes | Protein % | Fat % | Fibre % | Carbohydrate % | Ash % |
|---|---|---|---|---|---|
| JS 20-53 | 40.76 | 20.07 | 3.62 | 18.35 | 4.25 |
| JS 20-74 | 38.42 | 18.83 | 4.08 | 21.13 | 5.23 |
| JS 20-79 | 43.15 | 22.25 | 3.77 | 19.19 | 3.90 |
| JS 20-82 | 38.61 | 19.46 | 4.47 | 20.80 | 4.63 |
| JS 20-86 | 39.77 | 21.41 | 3.91 | 18.25 | 5.16 |
| JS 20-88 | 38.92 | 18.76 | 4.29 | 19.90 | 5.41 |
| JS 20-89 | 41.35 | 20.50 | 3.71 | 17.54 | 3.91 |
| JS 20-90 | 39.43 | 19.81 | 3.87 | 20.01 | 4.23 |
| JS 20-91 | 39.78 | 19.73 | 4.05 | 19.64 | 4.83 |
| JS 97-52 | 40.32 | 21.67 | 3.70 | 18.73 | 4.17 |
| SEm± | 0.0586 | 0.0298 | 0.0379 | 0.0317 | 0.0404 |
| CD at 5% | 0.1699 | 0.0866 | 0.1099 | 0.0920 | 0.1172 |

- High physiological efficiency of soybean genotype JS 20-79 (Table 3) resulted in high magnitude of plant height (112.94 cm.), number of seeds/pod (3.25), seed index (13.45 g), pod length (44.91 mm), pod girth (4.58 mm), pod width (8.06 mm), number of pods/ plant (180.00) which in turn had reflected in highest grain yield (10.61 g plant and 2611.90 kg ha$^{-1}$) followed by JS 20-86.

### 2.1.4 Genetic improvement of fodder

**Rice bean:** Variety JRB-1 a high yielding (56 q ha$^{-1}$), bold seeded multiple resistant to diseases and insect-pests matures in 120-125 days with tolerance to lodging under high nitrogen use (150 kg ha$^{-1}$).

## 2.2 Seed technology

### 2.2.1 Seed production and certification

- *Rabi*-summer season at Balaghat located in Chhattisgarh Plains and *Kharif* at Seoni located in Kaymore Plateau and Satpura Hills zone of MP are identified for seed production of hybrid rice. Pigeonpea hybrid seed can be produced commercially in Kaymore Plateau and Satpura Hills and Bundelkhand agro-climatic zones.
- 8.71% more quantity of quality processed seed of soybean in Vertisols under heavy rainfall (2660.74 mm, 53 rainy days) were harvested from ridge and furrow and broad bed furrow methods in comparison to conventional flatbed system.
- Treatment of soybean seed with ammonium molybdate @ 1 g kg$^{-1}$ of seed enhanced the seed yield significantly in molybdenum deficient soils.
- Alternate method planting of pollen parent of hybrid rice (JRH 5) at 5 days interval was significantly superior in terms of yield, 100 seed weight, and vigour index over mixed method of planting for both unprocessed and processed seed.
- The treatment S + Zn followed by Mo (1g kg$^{-1}$ of seed) was significantly superior for processed seed yield, 100 seed weight, seed recovery, germination percent and vigour index of soybean.
- For optimization of seed production technology of Mung bean during *Kharif*, date of sowing (1$^{st}$ August) at 30 X 10 cm spacing with recommended dose of fertilizer + seed treatment with Rhizobium and PSB + spray of Borax (100 ppm) at flower initiation stage was found to be significantly superior for seed yield ha$^{-1}$.
- In all 12 SSR markers linked with distinguishing morphological traits in soybean were identified (Table 4).

**Table 4: Identifications of SSR marker for distinguishing morphological traits in soybean**

| Character | Marker |
|---|---|
| Flower colour | Satt 309, Satt 125 |
| Pubescence colour | Satt 207, Satt 367, Satt 557 |
| Presence of pubescence | Satt 309 |
| Leaflet forms | Satt 369, Satt 270, Satt 268 |
| Hilum colour | Satt 070 |
| Seed coat colour | Satt 207 Satt 493 |
| Presence of four seeded pod | Satt 270 |

### 2.2.2 Seed pathology

- *Alternaria carthemi* associated with safflower seeds was not recorded in seeds treated with Copper oxychloride (0.25%), Carbendazim (0.20%), Carboxin (0.20%), Thiram (0.30%), Thiram + Carbendazim (0.30 + 0.20%) and Thiram + Carboxin (0.30+0.20%).
- Germination of safflower seed enhanced upto 92-96% with Copper oxychloride (0.25%), Thiram + Carbendazim (0.30+0.20%) and Thiram + Carboxin (0.30+0.20%) seed treatment.
- At initial stage, maximum 44.0 CFU of *Trichoderma viride* was recorded in the seed treated @ 8 g $kg^{-1}$ that reduced gradually up to 11.3 after 120 days. Minimum CFU count was in seed treated @ 2g $kg^{-1}$seed with reduction from 21.9 to 5.0 up to 120 days.
- At initial stage, maximum 22.4 CFU of *Pseudomonas fluorescens* was recorded in the seed treated @14 g $kg^{-1}$ seed of urid bean and it reduced up to 4.6 after 120 days. Minimum CFU count was recorded in seed treated @ 8 g $kg^{-1}$ with reduction from 11.8 to 1.3 up to 120 days.
- Standard blotter method is the most convenient technique for detection of seed borne mycoflora of soybean. However, specifically modified deep freezing blotter method is the best for detection of *Colletotrichum dematium;* modified agar plate method for *Macrophomina phaseolina;* 2, 4 - D blotter soaked method for *Phoma medicaginis* and standard blotter method for *Fusarium oxysporum*.
- Soybean seed dressing with Thiram (0.25%), Thiram + Carbendazim (0.2%), Thiram+Carboxin (0.2%) exhibited 62.5%, while *Trichoderma viride* (6 g $kg^{-1}$) controls 47.9% of pre and post mortality caused by *Macrphomina phasolina, Colletotricum dematium, Fusarium oxysporum* and *Aspergillus* spp.
- Application of propioconazole 0.1% at 35 and 25 days after transplanting effectively managed kernel smut in rice.
- Dressing of maize seed with Flowable-Thiram @ 2.5ml $kg^{-1}$ of seed or Vitavax 200 (containing Thiram 37.5% and Carboxin 37.5%) @ 2g $kg^{-1}$ seed effectively reduced the association of *Aspergillus flavus, Aspergillus niger, Helmintho sporium* sp., *Curvularia lunata, Fusarium oxysporum* and *Rhizopus* sp. as compared to control.

### 2.2.3 Seed physiology

- Expression of distinguishable characteristics *viz.,* spikelet arrangement at rachis and sheath base pigmentation at the time of flowering in the varieties of Kodo millet was verified. The expressions of these characteristics were stable and uniform in expression.
- Pre-harvesting sprouting of mung bean can be checked by spray of 100 ppm maleic hydrazide at green pod stage.
- Seed of soybean (moisture 10%) can be stored for longer (up to 210 days) period after seed dressing with Thiram + Carbendazim (1:1).
- Seedling vigour of the parents of hybrid rice enhanced significantly with the seed treatment of Thiamethoxim + Thiram + Carbendazim (0.15%).
- A mean reduction of 14-62% germination was observed in soybean with maximum 87% germination in the first month to 43% in the ninth month under ambient condition. The crop achieved less than 70% germination after 6 to 7 month storage.
- Longevity of small seeded genotypes of soybean is more than the bold seeded because of its high compression strength due to low electrical conductivity, wrinkled and cracked seed coat

(Fig. 2), hydration and swelling coefficient; high hull percentage, testa thickness and phenol and tannin content. These traits exhibit high variability along with high heritability (>62%) and significant association and direct effect on seed longevity.

**Fig. 2: Seed coat bursting in soybean**

**Table 5: Expression of seed surface in vegetable pea variety Arkel**

| Location | Node | Seed surface (%) | | |
|---|---|---|---|---|
| | | Wrinkled | Smooth | Dimpled |
| Upper | 13-18 | 100.00 | 0.00 | 0.000 |
| Middle | 7-12 | 99.998 | 0.00 | 0.002 |
| Lower | 1-6 | 99.540 | 0.17 | 0.290 |
| Total | 1-18 | 99.84 | 0.056 | 0.096 |
| Sugar | (%) | 11.81 | 6.8 | 7.89 |

**Expression of seed surface in vegetable pea:** Smooth and dimpled seeds may be formed at the lower node of the variety Arkel of vegetable pea with low percentage of sugar (Table 5). Grow out Test of these seeds show no correctness of association with genetic purity at seed level.

**Effect of Paclobutrazol foliar application on growth and yield of soybean and pigeon pea:** Application of Paclobutrazol 40 SC @ 75 ml ha$^{-1}$ recorded significantly high seed yield (9.75 q ha$^{-1}$) due to enhancement in the expression of yield contributing morpho-physiological traits resulting in maximum economic productivity. Foliar application of Paclabutrazol 40SC @ 90 ml ha$^{-1}$ at 60 DAS enhanced seed yield by 24.41% over control.

**Influence of silicon solubilizers on stress tolerant rice genotypes:** Application of carrier molecule imidazole solubilizes makes silicon available to rice plant that increases LAI, leaf and culm weight during tillering to flowering stage (LAI 2.61 to 2.86 and 5.55 to 5.71, respectively) with average increase of 10 panicle m$^{-2}$ and 10 grain panicle$^{-1}$.

**Effect of sea weed extract application in soybean:** Soil application of sea weed extract granules @ 12.5 kg ha$^{-1}$, followed by foliar spray of sea weed extract @ 120 ml ha$^{-1}$ at 25.40 and 60 DAS significantly enhanced the physiological determinants *viz.,* LAI, CGR and LAD during flowering and pod fill stages (60-80 DAS) along with morpho-physiological structural yield components and seed yield of soybean (10.08 q ha$^{-1}$) as compared to control (8.44 q ha$^{-1}$).

## 2.3 Resource management

### 2.3.1 Water management

**Wheat:** Two irrigations, first at crown root initiation and second at boot leaf stage recorded significantly higher yield over one and no irrigation. Seed yield (3908 kg ha$^{-1}$) and WUE (108 kg ha$^{-1}$cm) under FIRBS method with irrigation at 1.0 IW/CPE ratio was considerably higher than the yield (3711 kg ha$^{-1}$) and WUE (102.6 kg ha$^{-1}$) under conventional method.

**Water productivity under drip irrigation:** The emission uniformity of built-in drippers with discharge of 4 lph at 1.0 bar operating pressure was more than 80 per cent with <10% manufacture's coefficient of variation in wheat. In drip irrigation, grain yield of wheat was 11.84% and test weight was 9.52% more as compared to flood irrigated. Water productivity of drip irrigated wheat was 44.52% higher as compared to flood irrigated due to high overall irrigation efficiency of drip (80-90%) as compared to flood irrigation system (30-35%). It was the maximum in dripper spacing of 40 and 30 cm with lateral spacing of 60 cm (one line for three rows).

**Water productivity improvement:** The achieved water productivity of 1.48 kg$^{-1}$ m$^{3}$ was very well comparable to the water productivity obtained in border irrigation (1.52 kg$^{-1}$ m$^{3}$). But, the yield recorded in border irrigation was 2.36 times more than the rainfed irrigation. In supervised irrigation water application was 1.81 times more but yield reduction was 36.2% lesser than border irrigation. The test weight in border irrigation was recorded as 23.1% and 13.2% more than sole irrigation and supervised flooding, respectively. Border irrigation (5 numbers) has high irrigation efficiency that gave 36.2% more wheat yield with saving of 44.9% of water. Grain – straw ratio of drip irrigation was 20.2% and test weight 14.1% more than sprinkler irrigation with 3.6% increase in crop yield and 9.75% higher water productivity.

**Rice:** Average seed yield of rice under SRI was (48.8 q ha$^{-1}$) 9.77% more than the yield of transplanted with 1 DADPW (44.5 q ha$^{-1}$) and 28.21% more yield (38.1 q/ha$^{-1}$) in comparison to continuous submergence condition (farmers' practice).

**Response of irrigation in deep Vertisols:** Seed yield was the maximum (3249 kg ha$^{-1}$) under direct seeding with irrigation at 1$^{st}$ day after disappearance of ponded water. Water use efficiency (20.4 kg ha$^{-1}$cm$^{-1}$), net monetary returns (Rs.31015 kg ha$^{-1}$) and B:C ratio (1.51) were maximum under direct sown rice. Under adverse weather conditions (low rainfall) properly managed direct sown rice crop yielded better than transplanted.

**Irrigation in chickpea under late sown condition:** Seed yield of 15$^{th}$ and 30$^{th}$ November sowing was significantly higher (2105 and 2135 kg ha$^{-1}$, respectively) as compared to 15$^{th}$ sowing of December (1579 kg ha$^{-1}$). Seed yield (2274 kg ha$^{-1}$) with three irrigations *i.e.,* branching, pod formation and grain development was at par with two irrigations (2176 kg ha$^{-1}$).

**Linseed:** Dry sowing of linseed with planking (12.43 q ha$^{-1}$) and without planking (11.80 q ha$^{-1}$) followed by come up irrigation gave slightly higher grain yield over seeding after pre sowing irrigation (11.65 q ha$^{-1}$). Among different varieties, JLS 66, JLS 73, JLS 67 and T 397 yielded in descending order.

## Effect of drip irrigation and fertigation

**Turmeric:** Maximum rhizome yield (317.73 qha$^{-1}$) was obtained with drip irrigation at 1.0 PE, followed by at 0.8 PE (304.73 qha$^{-1}$). Both the treatments yielded significantly higher yield as compared to surface irrigation at 1.0 IW/CPE ratio (224.79 q ha$^{-1}$). The net monetary returns (Rs. 2,88,822 ha$^{-1}$) and B:C ratio 2.85 were maximum with drip irrigation at 1.0 IW/CPE ratio.

**Coriander:** The crop with four irrigations and one cutting gave 7.67 q seed and 39.00 q green leaf yield per ha which resulted in wheat equivalent yield of 59.12 q ha$^{-1}$ as against 39.32 q ha$^{-1}$ yield of wheat (Fig 3). The net monetary returns of Rs. 65,469 ha$^{-1}$ and B:C ratio 3.85 with coriander were substantially higher than wheat *i.e.,* Rs. 36,980 ha$^{-1}$ and B:C ratio 2.68. Water productivity was higher in coriander (29.48 kg ha$^{-1}$ cm) as compared to wheat.


**Fig. 3: Crop of coriander with two cuttings and without cutting**

### 2.3.2 Nutrient management

- Integration of chemical fertilizers with organic manure was quite promising in improvement of soil fertility status and enhancing productivity of crops. The notion that application of chemical fertilizers deteriorates available soil organic carbon is disapproved as there is 33% increase in organic carbon (7.6 g $kg^{-1}$) with 100% NPK over initial level of 5.7 g $kg^{-1}$.
- Application of 50% N (urea) + 50% N (compost) + Azotobacter was the 2$^{nd}$ best in rice- wheat with a net income of Rs 6,730 + 6,556 $ha^{-1}$ and B:C ratio of 1.60 + 1.50. In Urid bean-chickpea with Rs 10170 + 13,318 $ha^{-1}$ and in rice + Urid bean, wheat - chickpea Rs 8,900 + 16,636 $ha^{-1}$ and B:C ratio of 2.02 + 2.26 , 1.26 + 4.08 and 1.41 + 4.00, respectively.

**Soybean:** The long term fertilizer application caused significant improvement in physiological, biochemical and yield attributing characters along with seed yield. Application of 15 tons FYM $ha^{-1}$ + 100% NPK (20:80:20 kg $ha^{-1}$) showed significant improvement in LAI-LAD, CGR-SLA-net photosyntheticrate, PAR absorption, stomatal conductance, leaf chlorophyll a and b, total seed protein, oil and seed yield (1488 kg $ha^{-1}$).

**Soybean-wheat:** Integrated use of fertilizer maintained soil fertility and productivity of soybean-wheat in a vertisol (Fig. 4). The maximum build-up of OC content (9.9 g $kg^{-1}$) recorded in 100% NPK + FYM treatment over initial values (5.7 g $kg^{-1}$). Major proportion of added P is fixed in vertisols. Thus, its continuous additions indicate a build-up (34.2 kg $ha^{-1}$) against initial status (7.6 kg $ha^{-1}$). The depletion of soil K was observed (349 kg K $ha^{-1}$) as against initial status (370 kg $ha^{-1}$).

Imbalance use of fertilizers *i.e.,* application of N alone or NP had adversely affect the yield sustainability. However, the role of P in crop production is clearly observed as the yield in NP treatment was significantly higher over N alone.


**Fig. 4: Integrated nutrient management in soybean- wheat system**

**Rice-wheat:** Productivity of individual crop components and cropping system as a whole (WEY) were maximum (rice 30.55 q ha$^{-1}$, wheat 30.62 q ha$^{-1}$ and WEY 51.34 q ha$^{-1}$year$^{-1}$) with the application of 50% NPK through fertilizer + 50% N through green manuring to rice and 100% NPK to wheat (Fig 5). The same treatment also produced the maximum system productivity (19.01 kg ha$^{-1}$day$^{-1}$) and SYI (0.74), followed by application of recommended dose of fertilizer to both the crops (29.33 q ha$^{-1}$, 30.11 q ha$^{-1}$, 49.66 q ha$^{-1}$ yr$^{-1}$, 18.39 kg ha$^{-1}$day$^{-}$ and 0.73, respectively), while the NMR (Rs. 44,089 ha$^{-1}$yr$^{-1}$) and B:C ratio (2.09) were the highest by the earlier than the later treatment (Rs. 42,880 ha$^{-1}$ yr$^{-1}$ and 1.79, respectively).

100% NPK to both rice & Wheat

50% NPK + 12t FYM to rice
& 100% NPK to Wheat

50% NPK + 12t WS to rice
& 100% NPK to Wheat

50% NPK + 12t GM to rice
& 100% NPK to Wheat

**Fig. 5: INM in rice- wheat system**

Application of 120:60:40 Kg ha$^{-1}$ NPK + Zn to both rice and wheat crops resulted in maximum REY (111 q. ha$^{-1}$year$^{-1}$), net monitory return (102381 ha$^{-1}$ year$^{-1}$) and B:C ratio (2.60), followed by 120:60:40 NPK kg ha$^{-1}$ to rice (10328 kg ha$^{-1}$year$^{-1}$) and monitory return of Rs. 92300 ha$^{-1}$year$^{-1}$ with BC: ratio of 2:4.

**Sesame:** Significantly high yield of sesame was obtained under 100% RDN 60:40:20 (737 kg ha$^{-1}$), followed by 75% RDN + 25% RDN through vermin-compost (734 kg ha$^{-1}$) and 75% RDN + 25% RDN through FYM (635 kg ha$^{-1}$). The maximum NMR (Rs. 48,173 ha$^{-1}$) and B:C ratio (4.32) was computed in 100% RDN.

High yield of sesame over 100% RDF was obtained under treatment 100% RDF+75% N through FYM (25%)+vermi-compost (25%) +oil cake (25%) (660 kg ha$^{-1}$), followed by 100% RDF+FYM +vermi-compost+oil cake (30:30:30% N, respectively) + *Azotobactor* (643 kg ha$^{-1}$). The maximum

NMR was obtained in 100% RDF + 75% N through FYM (25%) +vermi-compost (25%)+oil cake (25%) (Rs. 31,410 ha$^{-1}$). The maximum B:C ratio was computed in 100% RDF (2.98).

**Sugarcane :** Germination percentage and cane yield increased significantly with the treatment of cattle dung, cattle urine and water in 1:2:5 ratio for 15 minutes (59.92%, 86.73 t ha$^{-1}$, respectively) as compared to conventional 3 bud sett planting (49.06%, 80.25 t ha$^{-1}$, respectively).

Application of FYM/compost @ 20 t ha$^{-1}$+100% RDF gave 116.36 t ha$^{-1}$ yield in sugarcane. Whereas, FYM/Compost @ 20 tha$^{-1}$+inorganic nutrient application based on soil test gave yield of 116.87 tha$^{-1}$.

**Kodo millets:** Among the fertility gradients tested on Kodo millet, application of 100% RDF (40:20:10 NPK kgha$^{-1}$) gave significantly higher grain yield (1209 kg ha$^{-1}$) as compared to 50 per cent recommended dose of fertilizer (1027 kg ha$^{-1}$) and no fertilizer (744 kg ha$^{-1}$).

## Soil test crop response correlation

- Targeted yield of rice set for 45, 55 and 65 q ha$^{-1}$ was achieved (±12%) with nutrients doses applied on the basis of soil test values using fertilizer adjustment equations.
- In garlic, yield target of 100, 150 and 200 q ha$^{-1}$ were achieved under STCR-IPNS mode. Actual yields 99.5, 132.2 and 171.0 q ha$^{-1}$ experienced against targeted one were achieved with 0.5, 11.9 and 14.5% deviation, respectively.

## Micronutrient, secondary nutrients and pollutant elements in soil and plants

- The DTPA soil test for Zn proved better than other extractant for predicting available Zn status of soils. Ammonium bicarbonate DTPA extractant was also equally efficient for predicting availability of Zn phosphorus and potassium in soil.
- Significantly high soybean yield was achieved with application of 5.0 kg Zn ha$^{-1}$. Zn content in soybean increases with increasing levels of Zn from 36.9 (control) to 50.7 mg kg$^{-1}$ at 10 kg Zn ha$^{-1}$. Alternate year application of 5 kg ha$^{-1}$ Zn gave the significantly superior yield of soybean over single year application and at par with each year application. To ameliorate Zn deficiency, application of 10 kg Zn ha$^{-1}$ to heavy clay soil and 5 kg Zn ha$^{-1}$ to light textured soils have been recommended.
- Application of 5 kg Zn and 40 kg S ha$^{-1}$ significantly increased yield of rice, wheat, soybean, and chickpea over recommended dose of NPK under farmers' field.
- The residual effect of 10 kg Zn ha$^{-1}$ persisted up to 6$^{th}$ crops in soybean- wheat sequence giving the response at 51.3, 34.3 and 17.9% in soybean and 11.4 to 13.6% in wheat. Response reduced to 5% in 8$^{th}$ crop. Available Zn increased from 0.26 to 2.45 mg kg$^{-1}$ after 1$^{st}$ crop and then decreased gradually to 0.40 mg kg$^{-1}$ after 8$^{th}$ crop.
- Zinc and iron deficiency in standing crops can be corrected by the foliar spray of 0.5% and 2% of $ZnSO_4$ and $FeSO_4$, respectively at an interval of 10 to 15 days.
- Under low cost input technology, yield of wheat, pulses and oilseed increased by 23, 26 and 27%, respectively over control due to application of 200 kg FYM enriched with 5 kg Zn ha$^{-1}$ by incubating for 30 days which was at par with the yield obtained at 10 kg Zn ha$^{-1}$.
- Application of 1 kg Boron significantly increased the yield of soybean and wheat and B content of soybean. Seed yield of soybean increased significantly from 1.36 to 1.75 t ha$^{-1}$ at the same time alternate year application was significantly superior over single year and at par with each

year application. The residual effect of B application increased the wheat yield over control, while the maximum wheat yield (4.40 t $ha^{-1}$) was obtained with application of 1.0 kg B $ha^{-1}$.

- Yield of cauliflower increases with the application of 1.25 kg $ha^{-1}$ boron with higher net income over other doses of boron application.
- Coating of soybean and chickpea seed with Ammonium Molybdate @ 1.0 $gkg^{-1}$ seed significantly increased the yield (21.8%) over control in Vertisols.
- Sulphur deficiency in soils is corrected by application of 20 to 40 kg S in maize, sorghum, soybean, urid bean, wheat and chickpea and by application of 40 to 60 kg S in mustard.
- In both Zn and S deficient soils, application of 5 kg Zn + 40 kg S $ha^{-1}$ is recommended along with the recommended dose of NPK to most of the crops as they gave 28 and 39% higher yield of pulses and oilseeds, respectively.
- Maximum biological yield was recorded with the foliar spray of 0.50% $ZnSO_4$, 1.0% $FeSO_4$, 0.25% Boron and 0.50% $MgSO_4$ with highest 1000 grain weight.

## Liquid formulations of bio-fertilizer consortia on chickpea

- Liquid formulations of screened actinomycetes isolates (B6, B10) individually and mixed consortium (CRP) of *Rhizobium* (R40, R56) and PGPR (P3, P10, P25) were evaluated separately and in combination on chickpea (JG 16) along with 20:80:20 without inoculum) and UFUI. Combination of fertilization + B6 + B10 + CRP gave the highest yield of chickpea (2,538 kg $ha^{-1}$), which was 48% more over FUI (1,805 kg $ha^{-1}$).

## Population behavior of soybean-rhizobia

- Soybean rhizobia exhibited PGPR effect to wheat. MPN counts of soybean rhizobia in soil inoculated with and fertilized plots were high. MPN counts of soybean rhizobia in soil varied significantly among different cropping sequences (rice-wheat; maize-wheat; soybean-chickpea; maize-chickpea; and soybean-wheat) under different treatments (control, 100% NPK, 100% and NPK + FYM).

## Nutrient management in organic farming

- Rice-Egyptian clover system is better than rice-wheat system for productivity and economics under organic farming system. Application of FYM, VC and NC, each equivalent to 1/3rd of the recommended N was more remunerative than other combinations of organic manures. Gradual improvement in OC content and microbial population of soil was noted over initial status of the soil.

## 2.3.3 Cropping systems

## Tillage system and irrigation scheduling

- Seed yield of wheat under soybean – wheat sequence (3794 kg $ha^{-1}$) is significantly higher than the yields under rice-wheat sequence (3396 kg $ha^{-1}$). Zero tillage sowing method proved efficient as compared to conventional tillage system. Zero tillage system of sowing of rice-wheat crop sequence may register an advantage of 20-25 days early sowing along-with cost saving in field preparation after rice. Further, the net monetary return from wheat is the maximum with FIRBS tillage in soybean– wheat (Rs. 33,276 $ha^{-1}$) closely, followed by zero tillage (Rs. 32,020 $ha^{-1}$). Similar pattern was observed in rice – wheat cropping sequence.

- Sorghum performed better than other crops with maximum seed yield (3333 kg $ha^{-1}$), NMR (Rs.15,523 $ha^{-1}$) and B:C ratio of (1.45) under BBF sowing method. Sorghum –wheat crop sequence gave maximum wheat equivalent yield (Rs. 7,773 kg $ha^{-1}$), net monetary returns (Rs. 49,343 $ha^{-1}$) and B:C ratio (1.73).
- The maximum seed yield of wheat (4030.6 kg $ha^{-1}$) was obtained in FIRBS tillage under soybean-wheat crop sequence. The maximum seed yield of wheat (3768.3 kg $ha^{-1}$) was obtained with irrigation at 1.0 IW/CPE ratio among irrigation levels. Maximum water use efficiency (157.8 kg $ha^{-1}$ $cm^{-1}$) was recorded in FIRBS tillage practice under soybean-wheat crop sequence. Rice – wheat system proved more remunerative with the wheat equivalent yield of 106.8 q $ha^{-1}$ net monetary return of Rs.86330.5 and B:C ratio of 2.16.
- Rice-garlic and rice-Egyptian clover cropping systems gave maximum net profit (Rs.1,66,943 and 1,66,267 $ha^{-1}$) followed by rice-pea-wheat (Rs.1,32,133 $ha^{-1}$). These cropping systems were superior to the existing rice-wheat and rice-chickpea cropping systems.

## System based high value crops

- Application of 100% NPK + Zn in scented rice (Pusa basmati) - wheat (MPO 1101) produced the maximum REY (42.86 $q^{-1}$ $ha^{-1}yr^{-1}$), followed by 50% NPK through fertilizer and 50% N through FYM to both the crops (40.76 $q^{-1}$ $ha^{-1}yr^{-1}$). 1/3 N each through FYM, VC and NEOC + intercropping of mustard fetched the maximum NMR of Rs. 60,381 $ha^{-1}$ $yr^{-1}$ and B:C ratio 2.27. The total uptake of nutrients was higher under 100% NPK through fertilizers along with zinc (Fig. 6).

**Fig. 6: Rice- wheat system**

## Intercropping

**Soybean + pigeonpea:** Intercropping of soybean with pigeonpea in 4:2 row ratio yielded maximum pigeonpea equivalent yield of 2860 kg $ha^{-1}$, net income of Rs. 81,982 $ha^{-1}$ and B:C ratio 5.53. Soybean + pigeonpea intercropping (4:2) gave maximum soybean equivalent yield (5356 kg $ha^{-1}$) and B:C ratio of 5.60 under drought mitigation (Fig. 7).

**Fig. 7: Soybean + Pigeonpea intercropping and sole crop of pigeonpea**

**Millets + pigeonpea:** Intercropping of kodo millet and pigeonpea (4:2); little millet and pigeonpea (4:2) and opening a conservation furrow between paired rows of pigeonpea was a remunerative practice to enhance productivity under skeletal soil conditions.

**Linseed + chickpea :** Intercropping of linseed with chickpea in the ratio of 4:2 under irrigated ecosystem gave the maximum LEY of 2480 kg $ha^{-1}$ and found most economical technology (B:C ratio 5.44) over sole crop.

**Sugarcane + wheat:** The autumn planted sugarcane + wheat in 1:2 ratio proved significantly profitable (98.58 t $ha^{-1}$, B:C ratio 1.28) as compared to autumn planted sugarcane + wheat in 1:3 ratio (96.76 t $ha^{-1}$, B:C ratio 1.25).

**Wheat+ chickpea/linseed:** Intercropping of wheat + chickpea and wheat + linseed (5:2) produced higher wheat equivalent yield as compared to wheat alone under limited irrigation and irrigated conditions. The WUE, net return and LER were also higher with intercropping system**.**

## Integrated farming system

- The cropping component gave production of 13.11 t $ha^{-1}year^{-1}$ in terms REY with NMR of Rs 118840 $ha^{-1}year^{-1}$. Dairy component which includes three cows and one calf gave production of 19.20 t $ha^{-1}$ $yr^{-1}$ in terms of REY with NMR of Rs. 99,758 $ha^{-1}$.
- Mushroom + vermi-compost unit gave 0.947 t production in terms of REY with NMR Rs. 4793 and vegetable component gave 0.735 t production in terms of REY with NMR of Rs. 55,414 $ha^{-1}$.

## 2.4 Crop protection

### 2.4.1 Disease management

**Rice:** Trifloxystrobin + Tebuconazole @ 0.4g $l^{-1}$ controlled leaf blast of rice (13.73%) and increased grain yield (69.50q $ha^{-1}$) followed by Propiconazole (16.7%). Propiconazole 25 EC @1ml $l^{-1}$ at 50% PE gave most promising results for controlling false smut of rice (3.5%) followed by Trifloxystrobin 25% +Tebuconazole 50% @ 1ml $l^{-1}$ at 50% PE (4.1%) and increased grain yield (Fig 8).

**Fig. 8: False smut of rice**

**Seedling growth and vigour:** Seed treated with Thiomethoxam + Vitavax grown in soil and vermi-compost medium gave maximum initial seedling growth which is best for SRI system (Fig. 9).

**Fig. 9: Effect of Thiomethaxam + Vitavax on seed seedling growth and vigour**

**Soybean:** Seed treatment with thiomethoxam 70 WS @ 3 g $kg^{-1}$ seeds + spray of Imazethapyr 100 g a.i. $ha^{-1}$ at 25 DAS + Barrier crop of sorghum/maize + yellow sticky traps 15 days after sowing + spray of Quinalphos @ 2 ml $lit^{-1}$ at 30-35 days after sowing had reduced white fly count and disease intensity of YMV with increase in yield. Reduction in population of nematode *P. thornei* and increase in yield due to *T. harzianum* (2.5 kg $ha^{-1}$) + *P. chlamydosporia* @ 10kg $ha^{-1}$ talc formulation is recorded. Maximum yield was recorded with combination of neem cake @ 10g/$m^2$ and *T. viride* @ 2.5 kg $ha^{-1}$ (12.64 q $ha^{-1}$) with nematode population 204 N/ 200 cc soil.

**Millets:** Seed treatment with carboxin @ 2 g $kg^{-1}$ seed is highly effective in controlling head smut of little millets with high seed yield. Seed treatment with Carboxin and Carbendazim @ 2 g $kg^{-1}$ seed controls (72.2 to 74.6%) the grain smut of little millet effectively. Sheath blight of kodo and little millet is managed economically and effectivity by seed treatment with Validamycin followed by Hexaconazole @ 2ml $kg^{-1}$ seed. One foliar spray of non-conventional chemical namely Salicylic acid and Sodium fluoride @ 200 ppm induced resistance in little and Kodo millet against sheath blight.

**Onion:** Mancozeb (0.25%) at 30DAT, 0.1% Propiconazole at 45 DAT and 0.25% COC at 60DAT reduces incidence of Stemphyllium blight (8.61), purple blotch (17.12), anthracnose (5.22) and help in increasing yield (34.47 t $ha^{-1}$).

**Tomato:** Carbofuran @ 10g/$m^2$ reduced nematodes (142.75 N) with maximum yield (340.8 q) and 3.10 gall index. *Paecilomyces lilacinus* (@ 50 $gm^{-2}$) + *P. lilacinus* (@ 5 kg $ha^{-1}$) along with FYM reduced nematode (145.5) with 3.45 gall index and 337.65 q yield.

**Okra:** Maximum yield (20.09 q $ha^{-1}$) was recorded with seed treatment of Carbosulfan @ 3% a.i. with 192.7 nematodes of ***M. incognita***.

**Betel vine:** Sanitation + one soil application of 1% Bordeaux mixture at pre monsoon + application of *T. viride* one month after application of Bordeaux mixture + second application of Bordeaux mixture, two month after the first application of Bordeaux mixture has been recommended for management of diseases and better leaf yield.

**Onion and Garlic:** Application of 0.25% Mancozeb at 30 DAT, 0.1% Propiconazole at 45 DAT and 0.25% COC at 60 DAT was most superior with regard to minimum incidence of Stemphyllium blight (8.61), purple blotch (17.12), anthracnose (5.22) and the maximum total yield.

**Mango:** Three sprays of carbendazim (12%) + mancozeb (63%) @ 0.2% (2.0 g $l^{-1}$) or carbendazim @ 0.1% (1.0 g $l^{-1}$) starting from appearance of initial symptoms on new flush at 10 days interval is recommended for management of foliar anthracnose and blossom blight diseases.

### 2.4.2 Insect management

**Soybean:** *Beauveria bassiana* is the most effective against Lepidopteran defoliator complex (94-98% larval mortality) followed by *Metarhizium anisopliae* (92-98% larval mortality) and *Verticillium ecanii* (94% larval mortality).

**Rice:** Application of Bifenthrin 10% EC @50 g *a.i.* $ha^{-1}$ and WCPL 240 @1250 ml $ha^{-1}$ were found to be most effective against Lepidopteran pest complex of rice (leaf folder and yellow stem borer) and also registered highest grain yield without any phytotoxic effect on the crop.

**Urid bean:** Application of Novaluron 8.8 SC @ 62.5 g *a.i.* $ha^{-1}$ and Novaluron 5.25% + Indoxacarb 4.5% SC @ 825 ml $ha^{-1}$ were highly effective against thrips and aphids infesting urid bean and recorded maximum grain yield without any phytotoxic effect on the crop.

**Chickpea:** Application of Novaluron 5.25% + Indoxacarb 4.5% SC @ 825 g $ha^{-1}$ and Novaluron 5.25% SC @ 62.5 g a.i.$ha^{-1}$ are highly effective in reducing the infestation of gram pod borer without any phytotoxic effect on the crop.

**Small millets:** Shoot fly was controlled effectively by seed treatment with imidachloprid 0.3 ml $l^{-1}$ followed by spray of chlorpyriphos 2ml $l^{-1}$ is small millet.

**Sugarcane:** Six pheromone traps $acre^{-1}$ from 2$^{nd}$ fortnight of February and change of lure every two months reduced the early shoot borer infestation by 14.62%. The pheromone traps can be used as monitoring tool for early shoot borer and timely implementation of IPM. Soil application of chlorantraniliprole 0.4 G @ 22.5 kg $ha^{-1}$ at planting and 60 DAP is effective in reducing the early shoot borer infestation (2.84%) significantly and increasing the cane yield (107.52 t $ha^{-1}$, 14.26 %) as compared to control (18.32 % and 94.10 t $ha^{-1}$).

**Chilli:** Application of NC-512 @ 250 ml $ha^{-1}$ is most effective against insect pest complex of chilli.

**Okra and tomato:** Oxymatrine 0.5% EC @ 500 ml $ha^{-1}$ is most effective against insect pest complex of okra and tomato and also registered highest fruit yields.

### 2.4.3 Weed management

**Wheat:** Clodinofop + metsulfuron- (60+4 g a.i. q $ha^{-1}$) recorded highest grain yield of wheat which was significantly at par with phenoxaprop + metribuzin (120 + 210 g a.i. q $ha^{-1}$), sulfosulfuron + metribuzin ( 32 g a.i. $ha^{-1}$ ) and mesosulfuron + Iodosulfuron (14.4 g a.i. $ha^{-1}$).

**Linseed:** Post emergence use of clodinofop @ 80 g a.i. $ha^{-1}$ +2, 4-D @ 0.50 kg $ha^{-1}$ at 30-35 DAS proved an alternative to the practice of hand weeding twice at 20-25 and 40-45 DAS. This treatment gave comparatively higher seed yield (2110 Kg $ha^{-1}$), NER (Rs 30,201) ,B:C ratio 1:2.76, WCE 88% and WI 8.0%. Integrated weed management using pre-emergence application of Isoproturon @ 0.5 kg a.i. $ha^{-1}$ along with one inter culture gave significantly higher grain yield (1,370 kg $ha^{-1}$) in linseed.

**Integrated weed management in aerobic rice:** Application of butachlor (50 EC) @ 1.5 kg a.i. $ha^{-1}$ (3-4 DAS)+ bispyribac-sodium (10 SC) @ 35 g a.i $ha^{-1}$ (15-20 DAS) found superior in terms of yield (6.42 t $ha^{-1}$) and WCE (91.07%).

**Herbicides for direct seeded rice:** Application of flucetosulfuron 10% WG (25 g a.i. ha$^{-1}$) + bispyribac sodium 10% SC (25 g a.i. ha$^{-1}$) was found superior in terms of yield (7.55 t ha$^{-1}$) and WCE (96.87%).

**Potato:** Spray of metribuzin @ 0.75 kg ha$^{-1}$ at 10% of plant emergence found more effective to control weeds and recorded higher yield of potato 37.7 t ha$^{-1}$ against weedy check (24.5 t ha$^{-1}$) with maximum economic returns. This is also effective as pre emergence to control weeds and getting yield of 35.9 t ha$^{-1}$.

## 2.5 Horticulture

**Vegetables:** Application of poultry manure @ 2.5 t ha$^{-1}$ + half dose of NPK (60:40:30 kg ha$^{-1}$) at the time of final field preparation in Broccoli cv. Green Magic grown during *Rabi* season on medium black soil gave maximum head yield 205.02 q ha$^{-1}$ with B:C ratio (4.58). Application of Azospirillum @ 5kg ha$^{-1}$ along with the recommended dose of NPK (100:60:50 kg ha$^{-1}$) gave highest yield in brinjal cultivar Jawahar 64.

**Onion and garlic:** Maximum plant height, neck thickness, 'A' grade bulbs, 'C' grade bulbs, per cent bolters and doubles and the minimum thrips count were observed in foliar application of salicylic acid. The foliar application of salicylic acid at 30 DAS and 2$^{nd}$ spray at 30 DAT and 3$^{rd}$ spray at 45 DAT recorded the maximum equatorial diameter (42.470 mm), polar diameter (40.550 mm) and total bulb yield (28.33 t ha$^{-1}$) of onion. Application of zinc @ 2.0 kg ha$^{-1}$ recorded the maximum average bulb weight (40.58%) and total bulb yield (42.08 t ha$^{-1}$) while, foliar application of zinc @ 0.5% at 30 and 45 DAT recorded the highest marketable bulb yield (42.21 t ha$^{-1}$). Application of 75:40:40:40 kg NPKS + 5 t FYM + 2.5 t PM + 2.5 t VC ha$^{-1}$ was superior for plant height (53.93), number of leaves (10.37), equatorial diameter (3.72), polar diameter (3.77), neck thickness (0.83), average bulb weight (188.80), marketable yield (44.40 q ha$^{-1}$) and total yield (55.34 q ha$^{-1}$) of garlic.

**Potato :** The growth regulator Mepiquat Chloride 5**%** AS @ 2500 ml ha$^{-1}$ sprayed evenly on crop of potato at 45 DAS gave better crop yield, highest tuber width (39.21 mm) and tuber weight (57.08 g tuber$^{-1}$) in comparison to control.

**Fruits:** Heading back upto crowded branch-lets and centre opening with paclobutrazol application is recommended for rejuvenation of over-crowded orchard of mango to increase the productivity and quality of mango fruits. Double hedge row system (888 plants ha$^{-1}$) is recommended for commercial adoption in mango for high yield with quality of fruits. Significantly higher net profit (Rs. 43,161 ha$^{-1}$) was recorded under 1.5 m deheading of guava at par with no deheading and was significantly superior to deheading at 2.0 m height (Rs. 40,495 ha$^{-1}$) and 1.0 m height (Rs. 40,290 ha$^{-1}$).

## 2.6 Medicinal and aromatic plants

### 2.6.1 Germplasm conservation

Thirteen germplasm of Satavari (Fig. 10) and seven of Gudmar (Fig. 11) are maintained at the University for further utilization in crop improvement programme. Maximum survival of Gudmar cutting was recorded in the month of August with 500 ppm IBA treatment.

Fig. 10: Germplasm of Satavari

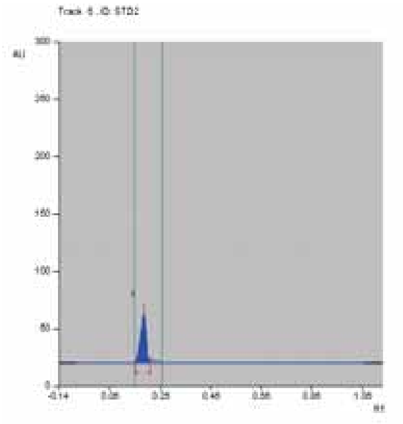
Fig. 11: Germplasm of Gudamar

### 2.6.2 Cultivation

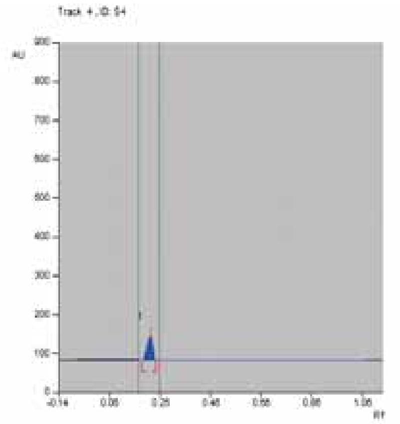
- Maximum number of roots plant$^{-1}$, fresh root yield and dry root yield was recorded in 50% RDF+50% N through FYM treatment in satavari.
- The maximum yield plant$^{-1}$ was recorded with RDF+PSB+AZB. The maximum net return Rs.43953/- and B: C ratio (3.59) was recorded with 50% recommended dose of fertilizer + PSB.
- Ashwagandha as a host of *Sclerotinia sclerotiorum* causing Sclerotinia stem rot is the first report from Madhya Pradesh.
- Nimbecidine (0.15% Azadirachtin) x *T. asperellum* @ $10^6$cfu ml$^{-1}$ + *P. fluorescens* @ $10^6$cfu ml$^{-1}$ was the best treatment for reducing Alternaria leaf blight and enhancing root and seed yield of *Withania somnifera*.
- Vermi-compost @ 2.5 t ha$^{-1}$+ *T. asperellum* @ $10^6$ cfu ml$^{-1}$ + 3 spray of mancozeb 75% WP at 15 days interval is recommended for management of *Cercospora* leaf spot of sarpgandha.
- *Trichoderma* fortified FYM + *Azatobacter* + 2 spray of Nimbecidine (0.15% Azadirachtin) is the best treatment for reducing Alternaria leaf blight and enhancing seed yield of *Lepidium sativum*.
- Combination of plant spacing (60 x 20 cm) and nitrogen (60 kg ha$^{-1}$) significantly improve various physiological parameters and growth determinants, physiological properties, nitrogen content, proximate parameters, forskolin content in roots and morphological yield attributing parameters which finally resulted in maximum dry root yield of Coleus (18.94 q ha$^{-1}$).

### 2.6.3 Processing

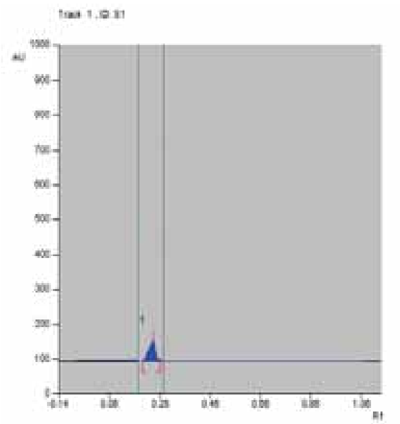
Forskolin content was maximum (0.40%) under shed drying followed by cabinet and oven drying, while sun drying caused a significant reduction in forskolin in roots of Coleus (Fig. 12).



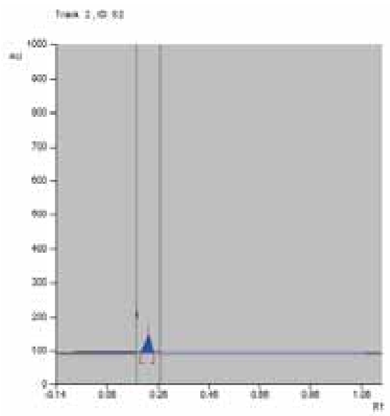
Forsklolin standard



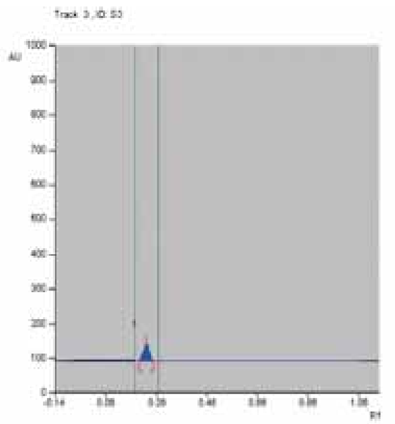
Cabinet drying



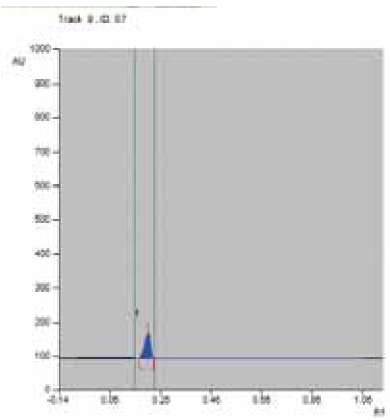
Shed drying



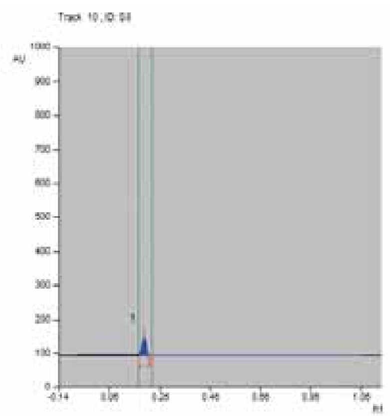
Sun drying



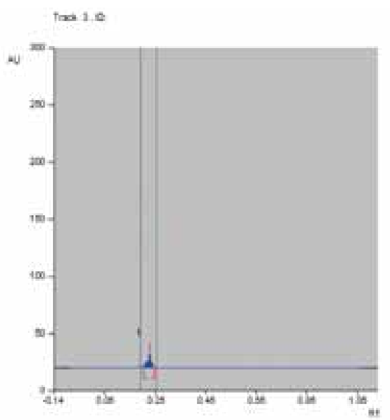
Oven drying



Maximum Open polythene



Minimum Open polythene



Minimum airtight polythene

**Fig. 12: Forskolin content in coleus**

## 2.7 Agro-forestry

**Block plantation of MPTs for biomass study:** At the age of 21 years eucalyptus in 2 x 2 m spacing and Shisham in 3 x 3 m spacing produced maximum above ground biomass of 856.1 t and 203 t $ha^{-1}$ respectively.


**Shisham (3 x 3 m) Eucalyptus (2 x 2 m)**

**Guava based agri-horticulture system:**

- Open condition recorded significantly high grain yield (647 kg $ha^{-1}$) as compared to different pruning management and no pruning. Among different pruning intensities, heavy pruning intensities (*i.e.,* 60 cm pruning) recorded significantly high grain yield (574 kg $ha^{-1}$)
- Managed agro-forestry system is more profitable (Rs. 30,416 $ha^{-1}$) than growing of crop alone (Rs.15,009 $ha^{-1}$) and unmanaged agro-forestry system *i.e.,* no pruning (Rs. 24,475 $ha^{-1}$) .
- Under managed agro-forestry system *i.e.,* cultivation of crop with different pruning intensities, wheat + Sissoo in 25% pruning is more profitable (Rs. 32,460 $ha^{-1}$) as compared to 50% (Rs. 30,485 $ha^{-1}$) and 75% pruning (Rs. 28,305 $ha^{-1}$).

**Babul:** At the age of 4½ year Firojpur (Haryana) provenance of Babool recorded significantly high plant height (338 cm), collar diameter (60 mm), whereas Bilaspur provenance CG recorded significantly highest number of branches (53) per plant.

**Babul + rice based agri-silviculture system:** Rice variety JR 201 gave higher yield (1505 $kgha^{-1}$) than variety JR 199 (cultivation 1012 kg $ha^{-1}$) under agri-silviculture system. Performance of ten year old babul provenance revealed that the cultivation of rice crop with babul (Bilaspur prove.) under alley cropping is economical as it gave an average return of Rs. 5414 $ha^{-1}$, whereas rice alone gave a return of Rs. 4,764 $ha^{-1}$. Hence, there is an additional income of Rs. 650 $ha^{-1}$ under alley cropping (babul + Rice) over arable crop (*i.e.,* rice alone). It has been estimated that babul felled at the age of 10 years will provide fuel wood/small timber @ 22 tons $ha^{-1}$ in addition to rice yield.

**Bamboo based agri-silviculture system:** Moong bean cultivated with bamboo recorded significantly higher net profit (Rs 10,612 ha$^{-1}$) followed by sesame (Rs. 4,976 ha$^{-1}$). Soybean + bamboo (Rs 2,825 ha$^{-1}$) and rice+ bamboo (Rs. 2,761 ha$^{-1}$) gave significantly lowest monetary return.

**Bamboo based silvo-pastoral system:** Napier grass produced significantly higher green fodder yield during first cutting (3040 kg ha$^{-1}$) as compared to Guinea grass (1 577 kg ha$^{-1}$) and Anjan grass (1093 kg ha$^{-1}$). Dicanthium recorded lowest green fodder yield (629 kg ha$^{-1}$) which was at par with Anjan and Guinea grass. Growth of Dicanthium grass was suppressed by stylo during first cutting.

**Progeny of Karanja:** Provenance Bahoripar, Bargi recorded significantly highest pod (432.0 kg ha$^{-1}$) and seed yield (222.6 kg ha$^{-1}$). Highest oil content 41.83% was recorded in provenance Maihar-1 and lowest 35.10% in provenance Bandol-1 Seoni (Fig. 13).

**Fig. 13: Progeny of Karanja**

**Shisham:** At the age of 4 ½ years provenance NRC, Jhansi recorded significantly taller plant height (263 cm) and collar diameter (48 mm) as compared to other provenance.

**Sisoo-based agri-silviculture system:** Rice-wheat with *D.sissoo* gave significantly higher monetary return (Rs. 78,209 ha$^{-1}$) than crop alone (Rs. 63,405 ha$^{-1}$), and no pruning *i.e.,* unmanaged agro forestry (Rs. 66,247 ha$^{-1}$). In managed agro-forestry system (Fig 14) Rice-wheat + *D. sissoo* in 50% pruning gave higher monetary return (Rs. 81,672 ha$^{-1}$) than crop alone (Rs. 60,405 ha$^{-1}$), tree alone (Rs. 33,224 ha$^{-1}$) and unmanaged agro-forestry system (Rs. 66,247 ha$^{-1}$).

**Fig 14 *D. sissoo* based agri-silvi-culture system**

**Horti-pastoral system:** Significantly higher yield of oat fodder (2 cuttings) was recorded in open condition (457 q ha$^{-1}$) which was at par with de-heading of guava at 1.5 m height (Fig. 15). Significantly lowest green fodder yield was recorded under no pruning. Oat variety JO-93 recorded significantly higher fodder yield (439 q ha$^{-1}$) as compared to variety J2 and JO-3.

**Fig. 15: Guava+oat horti-pastoral system**

## 2.8 Food science and technology

- Nutritious porridge was prepared from the grits of wheat, soybean, and mung bean in the ratio of 80:10:10. It is excellent and nutritious with all the essential nutrients.
- The Nutritious nuggets with excellent consumer acceptability are made from soybean + urid bean +potato in the ratio of 32:48:20 and can be commercialized.
- 1.25 kgy gamma radiation treatment in combination with LDPE could be successfully utilized for shelf-life extension of tofu up to 15 days.
- *Chakli* made from 40% sorghum + 30% chickpea + 20% urid bean + 10% soybean; and other product based on pearl millet containing 50% pearl millet + 25% chickpea + 15% urid bean + 10% soybean are superior in nutritional quality with high acceptability.
- *Idli* made of 75% kodo millet + 15% urid bean +10% soy flour had good cooking quality, acceptability, storability and high nutritive value and may be recommended for diabetic persons as it controls glucose level of blood.
- An acceptable Pizza base could be developed by wheat flour with fresh fenugreek leaves / carrot shreds up to the level of 30% with good acceptability. Being rich in fiber, this product has therapeutic value for the persons suffering from constipation, high plasma cholesterol and high blood glucose level.
- The nutritious *dhokla* mix could be developed from Kodo or little millet flour in combination with soy flour similar to rice and chickpea flours. It contains high amount of protein, fibers and minerals. Hence, these products could be considered as therapeutic foods and may be used for the patients suffering from diabetes, constipation and other nutritional disorders.

**Extrusion cooking of little millet and defatted soy flour blend:** Flour of little millet and defatted soy flour blended in 60:40, 70:30, 80:20, 90:10 and 100:0 ratio were extruded at screw speed 60, 80, 100, 120 and 140 rpm and different barrel temperature *i.e.,* 60, 80, 100,120 and 140°C. The moisture content of the feed was kept at 8, 10, 12, 14 and 16% wet basis for preparation of extrudates. The blend prepared with 80% little millet + 20% soy flour at mc 12% (wb)

and extrudate at 100°C barrel temperature and screw speed of 100 rpm gave the most desirable product with maximum crispness.

## 2.9 Socio-economic studies

**TMOP and ISOPOM programme:** The study comprises of 240 soybean growers of Chhindwara, Khandwa and Narshinghpur districts and 120 mustard growers of Mandla, Morena and Chhatarpur districts of Madhya Pradesh revealed that oilseeds production has increased tremendously due to successful implementation of TMOP and ISOPOM programme in the State. Cultivation of soybean and mustard were found more profitable over competing crops maize and wheat.

**Impact of NFSM in Madhya Pradesh:** The study comprises 300 beneficiaries and 100 non-beneficiaries respondents of districts Harda and Balaghat, respectively. The impact of NFSM in Madhya Pradesh was excellent. The seed societies has to be constituted in each district for effective and timely supply of seed to the farmers and the programme should be designed to ensure that every farmer has an equal opportunity to get benefit from it, and more numbers of farmers are able to get benefit from at least one intervention.

**Adoption of recommended doses of fertilizer on soil test basis:** The study comprises 240 soil test and 120 control respondents of districts Shajapur, Ujjain, Hoshangabad and Vidisha for soybean and wheat in the state of Madhya Pradesh. The positive impact of soil testing on productivity of soybean and wheat was observed. Average farmer obtained 24.4 and 20.2% more income and 20.2 and 15.4% more yield than the control farmers in production of soybean and wheat crop, respectively. The yield of soybean and wheat at overall level was increased by 10.20 and 8.30%, respectively after adoption of recommended doses of fertilizer by soil test. The increase in yield was found maximum in marginal (17.9%) followed by large (10.5%), medium (10.0%) and small (2.5%) farmers in soybean, while in wheat, it was maximum in marginal (17.0%), followed by small (6.1%), medium (5.7%) and large (4.8%) farmers.

**Price forecast of major crops in Madhya Pradesh:** The Market Intelligence Centre analysed the likely prices to prevail at harvest period of selected crops using econometric analysis (ARIMA, ARCH, GARCH etc.) of the model prices of the important markets in Madhya Pradesh. Market survey and the results of forecasts along with the present market sentiments revealed that the prices at harvest are likely to be around for maize Rs. 1200-1300 $q^{-1}$, for soybean Rs. 4000-4150 $q^{-1}$, for pigeonpea Rs. 3350-3550 $q^{-1}$, for chickpea, Rs. 2400-2550 $q^{-1}$ and for mustard Rs. 2950-3050 $q^{-1}$. Ten forecasts were made during the agricultural year 2014-15 with reliability of 90% and above. The information was disseminated through newspapers, Kisan Call Centre, ATIC, and Krishi Vigyan Kendras.

**Market integration and volatility of soybean price in Madhya Pradesh:** The monthly time series data (2001-02 to 2013-14) on arrivals and prices of soybean were collected from five major soybean markets (Ashtha, Dewas, Indore, Mandsaur and Shajapur) of Madhya Pradesh based on the highest arrivals. For studying market integration, Nagpur and Sangli markets of Maharashtra and Kota of Rajasthan were selected. Seasonality analysis, ADF unit root test, Johansen's multiple co-integration test and / Granger causality test between markets techniques were used to analyse the collected data. The price indices of soybean in different markets of Madhya Pradesh showed that lower price values were observed during the month of October to March, while the highest value of price indices was observed during lean period from May to September. The model variables had a long run equilibrium / Co-movement among the Ashtha, Dewas, Indore, Mandsaur and Shajapur market price series during the period under study. The price signal of market is transmitted from market of Mandasur to Astha and Dewas.

# 3. Agricultural biotechnology

**Metagenomic analysis of 1-Aminocyclopropane-1-Carboxylate deaminase gene (*Acds*) diversity of rhizospheric and endophytic bacterial population associated with wheat:**

Eleven ACC deaminase producing bacteria and DNA were isolated from soil samples of wheat rhizosphere. 16S rRNA gene was amplified using gene specific primers to provide polygnic affiliation. The representative eleven bacterial strains belonged to different genera of class Gammaproteobacteria and Flavobacterium *viz., Klebsiella* sp*, Acinetobacter bereziniae, Acinetobacter calcoaceticus, Acinetobacter baumannii, Enterobacter* sp.*, Pseudomonas putida, Klebsiella pnemoniae, Enterobacter ludwigii* and *Chryseobacterium* sp. 16S rRNA gene sequences were deposited in the Gene Bank database under the accession numbers KP721464- KP721474.

**DNA Fingerprinting of Foxtail millet:** DNA fingerprinting of 48 accessions of Foxtail millet (*Setaria italica*) carried out using 42 RAPD markers amplified a total of 247 alleles with 97.57% polymorphism. Out of 64 RAPD markers, 38 were found to be polymorphic among 50 genotypes of *Echinochloa frumentacea*. Out of amplified 256 alleles 238 (92.97%) were polymorphic.

**Morpho-physiological and biochemical changes and expression of *Dreb* and *Rubisco* genes in wheat under drought stress:** GW 273 a highly susceptible genotype to drought showed down-regulation of dreb1 and rbcl genes whereas, rbcs showed up-regulation under stress condition. Genotype HI1077 and Sujata were identified as drought tolerant by up-regulated genes (*dreb1*, *rbcl* and *rbcs*).

**Molecular marker evaluation of soybean cultivars for gene based cultivar selection:** Out of total 54 SSR marker used to differentiate MYMY resistant and susceptible soybean cultivars only one SSR Satt 501 was able to differentiate MYMV resistant and susceptible cultivars of soybean.

**Development of direct regeneration protocol for rice bean:** BAP (5mg/l) was found superior over all treatments for multiple shoot induction with stem segment & axillary meristem explants is rice bean.

**Studies on Agrobacterium-mediated transformation in oat:** *Agrobacterium tumefaciens* GV3101 with binary vector pCAMBIA 1305.1 carrying a reporter gene (gus) was used for transformation. GUS staining and molecular analysis employing polymerase chain reaction indicates the integration of the transgenic from the T-DNA region of Agro bacterium to the oat genome.

**Studies on effect of cytokinin in combination with auxins on micro-propagation efficiency of pomegranate:** MS medium containing 0.5 mg $L^{-1}$ of $GA_3$ was found to be the best for shoot elongation in pomegranate variety Bhagva. MS media fortified with 0.1 to 0.5 mg $L^{-1}$ of NAA and 0.1 to 0.5 mg $L^{-1}$ of IBA did not responded for root initiation up to 25 days.

**Molecular diversity analysis of whitefly *(Bemisia tabaci)* collected from different regions of Madhya Pradesh:** Specific mtCOI primer CI-J-2195 and L2-N-3014 showed the presence of ~880bp bands and confirmed the presence of B biotype in whitefly collected from different geographical regions of East Madhya Pradesh. Total 8 monomorphic bands were scored by RAPD markers that stats no variation among collected whitefly samples.

**Genome recovery percentage for O*paque 2* introgressed in backcross population for marker assisted selection of quality protein maize:** Foreground selection of plants using *opaque 2* specific markers in $BC_2F_1$ and $BC_3F_1$ populations showed average genome recovery of 0.983.

**Wine production from over ripe guava fruits using *Saccharomyces cerevisiae:*** To get maximum recovery of alcohol yield, initially incubation period was optimized at standard TSS of 20°Brix, incubation temperature of 30°C and pH of 3.76 (original pH of guava fruit juice) with different ranges of incubation period viz. 24, 48, 72, 96, 120, 144, 168 and 192 hr. The sensory quality evaluation of guava fruit wine revealed that guava fruit wine sample with alcohol yield of 13.2% was found to be more acceptable with respect to all the sensory attributes in comparison to other samples of guava wine.

**Amplification of *phy* gene from *Bacillus spp.* isolated from soils:** The analysis of open reading frame and deduced amino acid sequences showed that the complete ORF of *phy* gene of amplified fragments with one site start codon and two sites of stop codon.

**Molecular screening of soybean germplasm resistant to *Rhizoctonia* root rot:** Polymorphism revealed by 10 SSR primers demonstrated that the alleles are putatively associated with *Rhizoctonia* resistance genes. The polymorphisms revealed between the genotypes provide additional support for a few key loci; specifically Satt 281, Satt117, Satt 246 (240 bp allele) and Satt 245 are putatively associated with *Rhizoctonia* resistance and are present in *Rhizoctonia* root rot resistant genotypes and absent in the susceptible.

**Multiple shoot regeneration of sugarcane from meristem tip, leaf roll and auxiliary bud culture:** Among different concentrations and combinations of growth regulator for shoot multiplication, best performance was observed on MS medium supplemented with BAP (4mg/l) followed by MS medium supplemented with BAP (6mg/l).

**Multiple shoot regeneration from nodal explant of Aswagandha:** The nodal explants cultured on MS basal medium without growth regulators failed to induce shoot proliferation. All the concentrations of BAP (0.5-1.5 mg $l^{-1}$) alone or in combination with IAA (1.5 mg $l^{-1}$ ) promoted adventitious shoot buds via direct organogenesis after five weeks of culture.

**Studies on organogenesis from seedling derived callus in maize:** Highest callus formation appeared in whole embryos cultured on MS (Murashige and Skoog) medium supplemented with 1mg/L 2, 4-D + 3 per cent sucrose.

**Molecular characterization of Mungbean Yellow Mosaic Virus and white fly for control of soybean disease:** DNA from sample of YMV infected leaves and whiteflies were treated from samples of soybean and other host crop such as, okra, tomato, urid and mung bean, including some weed. Sequence alignment and phylogenetic analysis of the samples showed that whiteflies belong to B-biotype except the sample collected from Narsinghpur, Piparia and Chhindwara and all the YMV samples belong to group Mung Bean Indian Yellow Mosaic Virus (MIYMV).

**Development of transgenic oat over-expressing fungal Phytase gene:** Out of eight phytase producing fungal isolates of *Aspergillus* sp. isolate IG 3 (0.46 U $ml^{-1}$) and IG 1 showed high phytase activities (0.39 U $ml^{-1}$). The phy gene was cloned and inserted in pCAMBIA vector. The pCAMBIA+phy construct was transformed in *Agrobacterium tumefaciens* and then in oat using vacuum infiltration assisted *Agrobacterium*-mediated transformation method.

# 4. Agricultural engineering

## 4.1 Soil and water engineering

### Ground water pollution

- The pH value (7.37 to 7.94) of water samples from Narshingpur, Chhindwara, Shahdol and Hoshangabad districts are within permissible limit but of District Seoni is towards alkaline (7.12 to 8.14).
- The EC value (252 to 953µS $cm^{-1}$) of Hoshngabad and Shahdol districts are within desirable limit at 25$^{0}$C. But, it exceeds BIS limit (1000 µS $cm^{-1}$) at some villages of district Narshinghpur and Chhindwara.
- The nitrate concentration exceeds 45 mg $l^{-1}$ at Seoni, Chhindwara, Narshingpur, Shahdol and Hoshangabad districts due to localized pollution effect.
- District Shahdol, Narshingpur, Hoshangabad and Seoni do not have any problem of fluoride and arsenic, since fluoride level is less than 1.5 ppm of BIS (1990) permissible limit. But most of the part of district Chhindwara is affected by fluoride problem.
- Concentration of Sodium (6 to 178 mg l-1) in water samples of Narshingpur, Chhindwara, Shahdol and Hoshangabad districts is within permissible limit.

### Water quality of tribal areas

- Bicarbonate values are increasing under the safe limit in all the tribal districts except Mandla. Chloride values are increasing beyond the permissible limit in block Bichhiya district Mandla, all the blocks of district Dindori, block Kundam of district Jabalpur and block Keolari and Ghansore of district Seoni.
- pH values of ground water samples of all the tribal blocks do not fall within the permissible range of 6.5-8.5.
- The average value of Ca is 226.73 ppm in block Bajag of district Dindori and 384.13 ppm in Mohgaon, and 366 ppm in block Bichhia of district Mandla. The recommended safe limit for Ca + Mg according to BIS for irrigation water is 200 mg $l^{-1}$ and 70 mg $l^{-1}$, respectively.
- Sodium concentration falls under the safe limit in all the blocks of district Seoni with maximum concentration in block Keolari (77.36 ppm) and minimum (5.86 ppm) in block Chhappra. Concentration of Calcium carbonate is 382.2 and 22.5 ppm in block Keolari and Ghansore, respectively whereas in rest of the blocks it was in traces.
- Maximum concentration of potassium is obtained in ground water sample of block Keolari (120.69 ppm), followed by Kundam (25.48 ppm), Bichhia (15.42 ppm), Ghansore (12.91 ppm), Bajag (3.60ppm), Karanjia (2.73 ppm), Kurai (1.15 ppm) and Chhappra (0.85 ppm).
- Concentration (0.02 to 0.07) of Nitrate is lower in ground water samples of all the blocks. Concentration of phosphorus is the minimum in block Bajag (15.68 ppm) and maximum in block Keolari (60.96 ppm).

- Concentration of trace elements (Zn, Cu, Mn and Fe) is within the desirable toxic limit of heavy metals (Cd, Pb, Ni and Cr).
- The maximum Water Quality Index (WQI) for pollution (200.59) is found in village Sarekha of block Keolari, which can be considered as poor water. The minimum values were found in village Karanpur (22.46) and Bichuwa (22.41) of block Kundam.
- The correlation matrix among the eighteen selected water quality parameters revealed strong correlations (r >0.85) between $CO_3$ with Fe and good (r 0.70) between $CO_3$ with Mn in district Seoni and Dindori.
- Ground water quality is continuously deteriorating every year as per the increasing concentration of parameters. Based on WQI ground water quality is good for irrigation purpose in all the districts except block Keolari. 66 % poor ground water quality was observed in district Seoni. District Dindori was good with increase in concentration of EC under the safe limit in block Bajag and Karanjia.

## Demarcation of groundwater potential zones using RS and GIS techniques

In Narmada basin 75.4% of the area (3870.2 km$^2$ out of 5133 km$^2$) comes under excellent and very good ground water potential zone (Fig 160. The producer's accuracy for poor class and excellent class was found as 100%. For very good and good potential, the accuracy was 66.67%. The user's accuracy for the poor class was 75% for very good and for good it was 86.67% and for the excellent class it was found 100%. The overall accuracy of the classification of these classified zones was estimated as 88%.

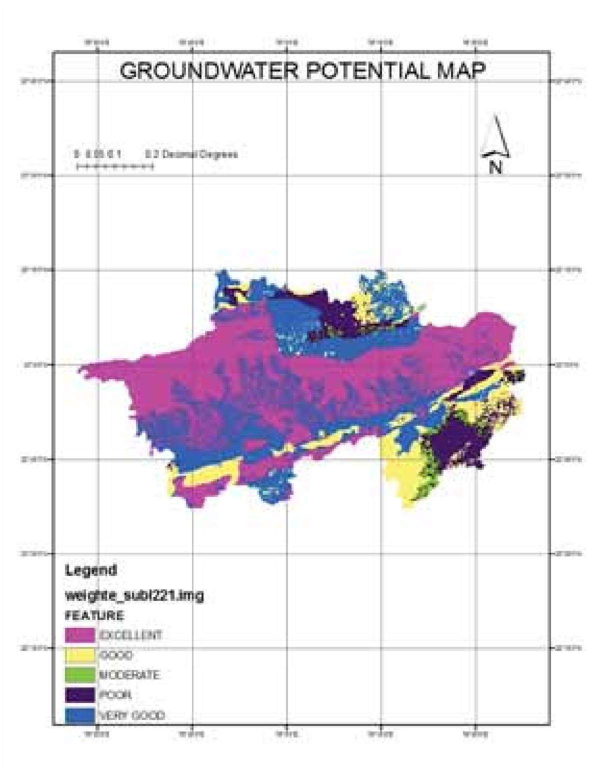
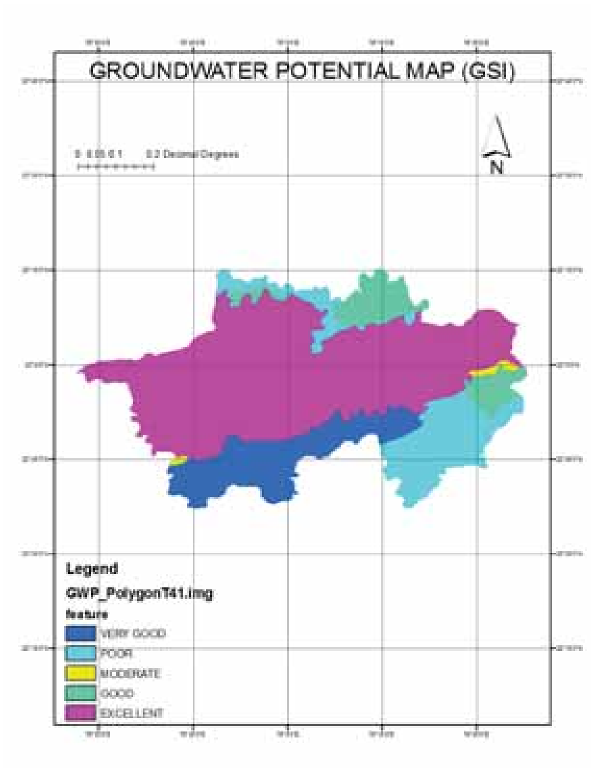



**Fig. 16:Demarcation of groundwater potential zones**




**Simulation of groundwater system**

- District Narsinghpur covers an area of 5133 $km^2$ of which 388415 ha falls under cultivation. Length of boundary is 541 km and total 1300 grids were formed using Visual Modflow software. Well yields are ranging from $2\times 10^{-4}$ to $5.3\times10^{-2}$ $m^3$/sec per m drawdown.
- Well strata of the area shows four to five layers of aquifer material namely soil (0.33 m to 1m), alluvial strata (35 m to 176 m), coarse sand (5 m to 35 m) and gravel (15 m to 91 m). Observation shows declining water table at a rate of 20 cm $year^{-1}$.
- Water table is ranged from 4.30 to 22.50 m depth from ground surface during pre-monsoon and at 2.80 to 20.72 m during post monsoon season.

## Ground water assessment in alluvial areas of upper Narmada basin

- Boundary of district Narsinghpur was digitized in ArcGIS software using topographical map 2.4 km x 2.4 km, with 1300 overlaid grids on the map. The aquifer parameters were obtained for three layers conceptualized for the model, upper 7 m, middle 16 m, and bottom 12 m thick layer depending on well log available for the area. Recharge values were obtained using annual rainfall of different blocks. Flow boundaries were defined using conditions prevailing in the study area.
- After ten years calibration the head values are varying from 305 m to 463 m with coefficient of multiple determinations ($R^2$) as 0.84. The ground water withdrawal rate considered for this situation was 216004 $m^3 day^{-1} km^{-2}$ areas. The model was accepted for prediction after validation with rate of 28.667$m^3 day^{-1} km^{-2}$.

## Water productivity of wheat under drip irrigation

- Progressive increase in plant height remains constant in reproductive phase and then slightly decreases towards maturity due to conversion of manufactured food material. It was recorded that plant height in all the critical stages increases with the decrease in both lateral and dripper spacing.
- Number of tillers and effective tillers $MRL^{-1}$ in all critical stages increases with the decrease in lateral and dripper spacing. 30 cm, 40 cm and 50 cm dripper spacing recorded 11.9%, 8.6% and 7.4% higher grain yield, respectively as compared to control (39.82 q $ha^{-1}$).
- The data pertaining to second order interaction clearly indicated that grain yield under 60 cm lateral spacing with 30 cm dripper spacing was maximum (47.16 q $ha^{-1}$) among all the combinations followed by 60 cm lateral spacing with 50 cm dripper spacing (46.36 q $ha^{-1}$).
- 60 cm lateral spacing (Fig 17) recorded significantly higher water productivity (1.08 Kg/$m^3$) as compared to 80 cm (1.01 Kg/$m^3$) and 100 cm lateral spacing (0.97 Kg/$m^3$). The per cent reduction in water productivity when lateral spacing increases from 60 cm to 80 cm, 80 cm to 100 cm and 60 cm to 100 cm was 7.0%, 4.0% and 11.0%, respectively. The percent increase in water productivity under 30 cm, 40 cm and 50 cm dripper spacing was 29.5%, 26.7% and 26.0%, respectively as compared to control (0.74 Kg/$m^3$).

**Fig. 17: Wheat under drip irrigation**

## 4.2 Farm machinery and power

- Field capacity of Power Weeder (Fig 18) in rice was 0.71 h day$^{-1}$ in clay loam soil with field efficiency of 76-80%; weeding efficiency of 84% with plant damage of less than 1% and fuel consumption 0.67 – 0.76 lit hr$^{-1}$.
- Pperformance of 6-row CIAE inclined plate planter was satisfactory for sowing of vegetable-pea, chickpea and soybean. Field capacity for different crops was 0.46 to 0.54 ha h$^{-1}$ with fairly uniform row to row and plant to plant distance.
- Field capacity of Rice Drum Seeder (TNAU Design) was 0.18-0.20 h ah$^{-1}$ with field efficiency of 74% and saving of Rs. 6000-7000 ha$^{-1}$ in sowing cost as compared to traditional method.

Rice power weeder

CIAE inclined plate planter

Rice drum seeder

**Fig. 18: Testing of farm machineries**

## 4.3 Post harvest processing

**Groundnut testa remover:** Shelling efficiency of 1 min flash heat treated kernel of 87% was obtained with Jute strip on roller and nylon fiber mat on concave of groundnut testa remover (Fig. 19). Shelling efficiency of groundnut testa remover with groundnut kernels dipped in water for 1 min and then heat treated with kurled roller and nylon fiber mat on concave was 72. 24%. Capacity of the machine is 40 kg h$^{-1}$ with processing cost of Rs. 0.80 kg$^{-1}$.

**Multistage grinding of spices:** Volatile oil content of the spice powder (turmeric, coriander and red chilli) obtained by double stage grinding was higher and change in colour of spice power fineness and modules lower as compared to single stage grinding (Fig. 20).

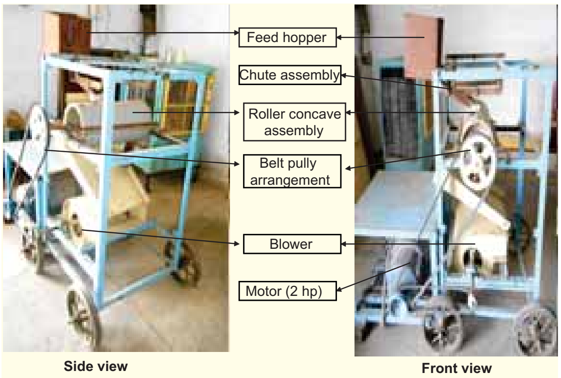



**Fig. 19: Groundnut testa remover**

Rotating hammer in Double stage hammer mill

Rotating hammer in Double stage hammer mill

**Fig. 20: Multistage grinding mechanism**

## 4.4 Renewable sources of energy

### Agro-waste based gasifiers

- A 3.5 kW rice husk gasifier operated to run 5 hp diesel engines save 60% diesel under long term operation at the average rice husk consumption of 8.5 kg $h^{-1}$. About 13 to 15 kg rice husk is required to save 1 liter of diesel.
- A 10 kW wood-based gasifier system operated to run a 10 hp diesel engine save 68% diesel under long term operation at an average wood consumption of 7.2 kg $h^{-1}$. About 6 kg of wood is required to save 1 liter of diesel. The cost of the 10 kW gasifier plant is approximately Rs. 15000/-
- The conversion efficiency of 65% to 76% is observed at gasifier fuel consumption rate of 11 to 16 kg $h^{-1}$. It is suitable for substituting fuel oil or electricity. About 3 to 3.5 kg of processed biomass is required to save 1 liter of fuel oil.
- The system is operated using processed fire wood, lantana and Ipomoea stalks, and briquetted fuel in laboratory and in an *amla* processing industry. Conversion efficiency of 76% to 82% is observed at specific gasification rate of 105 to 140 kg $m^2$ $h^{-1}$ with maximum flame temperature of 860°C. The estimated cost of the system is Rs. 50,000/-. About 3 kg of fuel is required to save 1 liter of fuel oil.

### Bio-gas plant

- Modified Janta type biogas plant after stabilization of the plant operation over a period of two months, the plants were charged daily with fresh cattle dung of 16-18% total solid content without mixing water at the feed rate of 25 kg $m^{-3}$ of plant capacity. The increase in gas yield by 30% and reduction in water requirement by 75% is observed as compared to conventional designs. The total cost of the construction of 10 $m^3$ biogas plant was Rs. 1.10 lakh.
- The biogas generation started after 7 days of first initial charging of the plant. The plant is meeting cooking energy need of 2 families each comprising of 6 members and lighting 4 lamps.

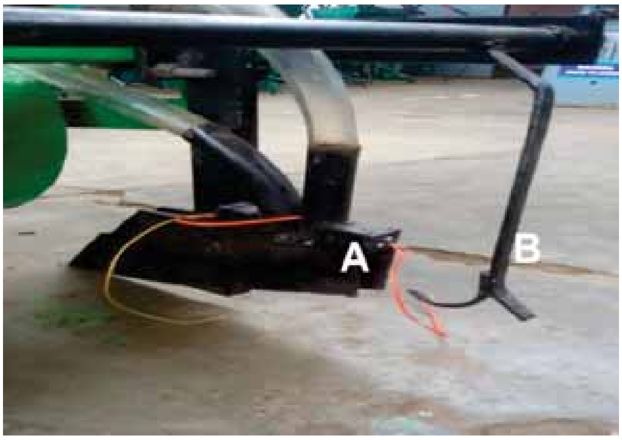
## 4.5 Instrumentation

### An improved seed cum fertilizer drill choke indicator

The improved seed cum fertilizer drill choke indicator is an attachment to the seed cum fertilizer drill available in the market. Optoelectronics is used for detecting the choking instantaneously (Fig. 21). Photo-transistor near IR has been selected as a source. Sensors are mounted just above the furrow opener to detect the choking immediately. The indicator panel consists of several red LEDs corresponds to respective channels and yellow LEDs to indicate the status of seed and fertilizer boxes. The whole implement is compact, economical, durable, efficient and easy to maintain. Flat iron finger is used to remove the choking from the furrow opener. The motion of flat iron finger (back and forth oscillating motion) generated on the principle of crank-rocker four bar mechanism consists of four rigid links connected end to end creating a closed loop.

A - Sensor mounting on furrow opener

B - Choke removing flat iron finger




C - Sensor mounting on furrow opener


D - Choke removing flat

D -Hand operated lever
E -Ground wheel
I -Crank gear
H -Flat iron finger
J1&J2 -Coupler
K1&K2-Rocker
L1&L2 –Shaft

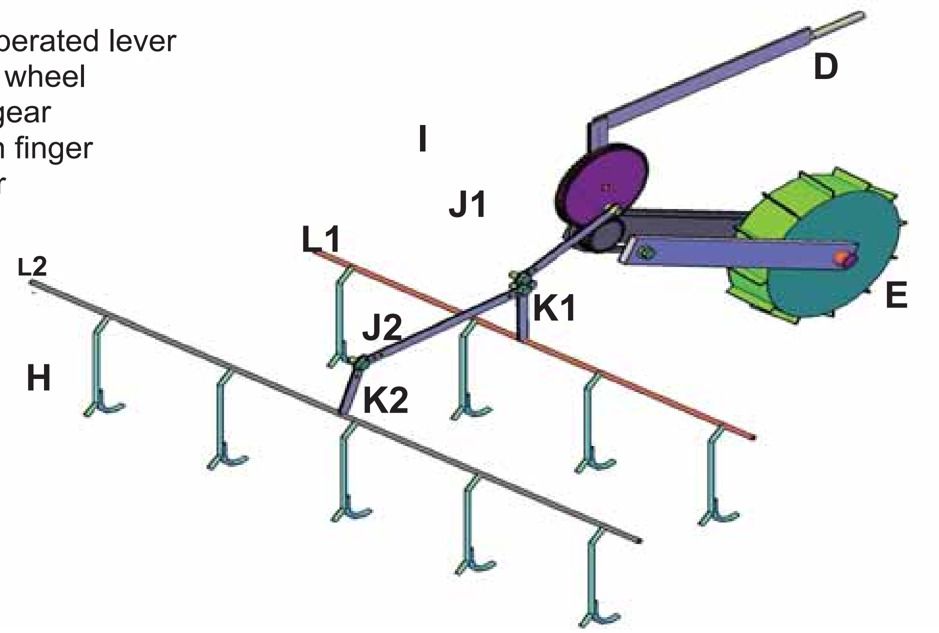



Fig. 21: Choke removing mechanism

## 4.6 Agro-meteorology

### Departure from mean rainfall of South-West Monsoon

South-west monsoon of Chhatisgarh plains, Northern hill zone of Chhattisgarh and Bundelkhand zones of east Madhya Pradesh is receiving deficit rains in the last 11 years while Jhabua hills and Malwa plateau of west Madhya Pradesh is receiving more rainfall (Table 6 and Fig. 22 ).

**Table 6: Departure (%) in different Agro-climatic Zones of Madhya Pradesh (11 years)**

| Agro-climatic zone | 2004 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | Average |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Chhattisgarh Plains | -29 | 29 | 3 | -17 | -5 | -22 | -4 | -10 | -16.6 | 5.2 | -29.7 | -8.7 |
| Northern Hill Zone of Chhattisgarh | -21 | 20 | -14 | -22.3 | -13 | -36 | -18 | 12.6 | -15.8 | 6.2 | -24.2 | -11.4 |
| Kymore Plateau & Satpura Hills | -9 | 29 | -20 | -39 | -19 | -38 | -22 | 19.6 | 17.6 | 50.0 | -30.1 | -5.5 |
| Vindhyan Plateau | -18 | 14 | 11 | -26 | -13 | -31 | -30 | 27.2 | 3 | 77.7 | -26.1 | -1.0 |
| Central Narmada Valley | -7 | 17 | 9.5 | -24 | -18 | -6 | -29 | 5.1 | 15.6 | 91.4 | -22.7 | 2.9 |
| Gird Zone | -28 | -10.3 | -35.3 | -40.8 | 8 | -39 | -10 | 36.4 | 5.3 | 63.5 | -23.8 | -6.7 |
| Bundelkhand Zone | -29 | -21.3 | -43.7 | -50.7 | 28 | -30 | -30 | 18.3 | -8 | 46.2 | -31.2 | -13.8 |
| Satpura Plateau | -17 | -3 | -3 | 8 | -36 | 6 | 4 | 10.7 | 40.7 | 85.5 | -8.8 | 7.9 |
| Malwa Plateau | -3 | -21 | 62 | 1.5 | -26 | -19 | -17 | 46.4 | 17.6 | 76.4 | -16.5 | 9.2 |
| Nimar Valley | -17 | -30.5 | 18.5 | 0 | -35 | -23 | 3 | 7.7 | 23.2 | 69.1 | 19.4 | 3.2 |
| Jhabua Hills | 11 | -25 | 61 | 48 | -19 | -16 | -6 | 7.6 | 17.4 | 62.2 | -2.9 | 12.6 |
| Average of II Zones | -15.4 | -0.2 | 4.5 | -14.8 | 13.5 | -2.3 | -14.5 | 16.5 | 9.7 | 57.6 | -17.9 | 3.3 |

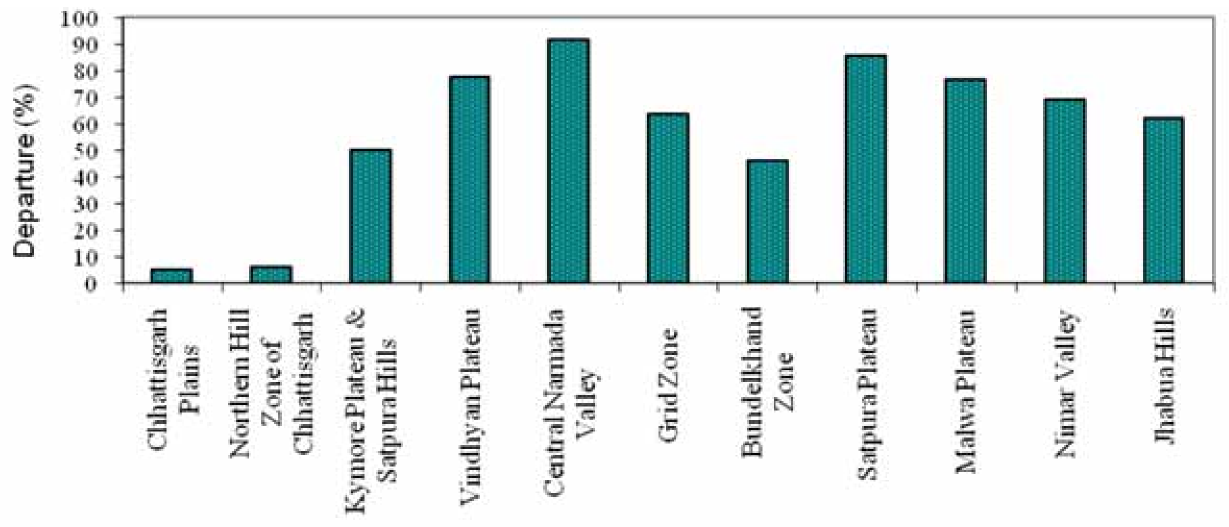



**Fig. 22: Departure from mean rainfall of South-West Monsoon**

### Crop-weather relationship

**Chickpea:** Evaporation, sunshine hours, maximum temperature and mean temperature (average of both maximum and minimum) had a positive correlation (Table 7) at all phenological stages whereas wind speed, morning and evening relative humidity and rainfall and rainy days at vegetative and flowering stages had negative correlation with grain yield.

**Table 7: Pearson's correlation coefficient between seed yield and weather parameters at different phenological stages in chickpea**

| Stages | MAX | Min | Menat | GDD | HTU | PTU | SS hrs | RHm | RHe | Winds | Eva | Rainfall | RD |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Branching | .823** | .770** | .808** | 0.193 | .453* | 0.174 | .770** | -.784** | -.807** | -.742** | .804** | -.811** | -.811** |
| Flowering | .711** | -0.16 | .573** | 0.289 | .516* | 0.205 | .740** | -.587** | -.750** | -.772** | .680** | -.766** | -.711** |
| Podding | .754** | 0.263 | .698** | .705** | .698** | .685** | .650** | -.757** | -.755** | -.605** | .603** | -0.362 | -0.366 |
| Maturity | .754** | 0.263 | .698** | .705** | .698** | .685** | .650** | -.757** | -.755** | -.605** | .603** | -0.362 | -0.366 |

**. significant at 0.01 level and *at the 0.05 level (2-tailed).

Grain yield was 659 to 1122 kg ha$^{-1}$ in *kabuli* type; 802 to 1145 kg ha$^{-1}$ in *gulabi* ; and 459 to 1538 kg ha$^{-1}$ in *desi* varieties. Total crop biomass were in the range of 2145 kg ha$^{-1}$ to 3432 kg ha$^{-1}$ in *kabuli*, 2789 to 3196 kg ha$^{-1}$ in *gulabi* and 2360 to 3647 kg ha$^{-1}$ in *desi* varieties suggesting *desi* proved superior among species. Similarly, second date of sowing observed higher crop total biomass than the other sown dates (Table 8).

**Table 8: Crop biomass and seed yield of chickpea varieties sown at different dates**

| Date of sowing | JGK 1 | JG 315 | JGK 3 | JG 11 | JGG 1 | JG 322 | JG 74 |
|---|---|---|---|---|---|---|---|
| **Grain yield (kg ha$^{-1}$)** | | | | | | | |
| D1- 14 Nov. 2014 | 1122 | 1336 | 1032 | 1562 | 802 | 1538 | 1459 |
| D2- 22 Nov. 2014 | 1137 | 1081 | 1105 | 1270 | 1145 | 1534 | 1390 |
| D3- 10 Dec. 2014 | 774 | 987 | 659 | 459 | 573 | 579 | 576 |
| **Crop biomass (Kg ha$^{-1}$)** | | | | | | | |
| D1- 14 Nov. 2014 | 2145 | 3432 | 2360 | 3432 | 2789 | 3003 | 3239 |
| D2- 22 Nov. 2014 | 3432 | 3003 | 3218 | 3432 | 2574 | 3647 | 3432 |
| D3- 10 Dec. 2014 | 2252 | 2360 | 2896 | 2317 | 3196 | 2574 | 2896 |

## Crop-weather modeling in direct-seeded rice

Direct-seeded rice cultivars were established with an aim to develop genetic coefficients and assess validation, sensitivity analysis and the effect of climate change on projected seed yield. The performance of CERES-Rice was tested and evaluated using the above determined coefficients with their dates of sowing (thermal regimes). The observed and simulated phenological parameters and yield levels for evaluating genetic coefficients was done with the help of statistical indices (RMSE and D-value) for testing the model performance. The variety wise performance is as follows:

**Sahbhagi** (early maturing 90-100 days**)**: RMSE and D-value of anthesis and physiological maturity days were in a range of 1.34-2.7 and 0.92-0.99, respectively. Similarly, LAI (90 DAS) is in a range of 0.1 and 0.91. The grain and total biomass yield showed RMSE at a range of 328-547 and D-value 0.82-0.90. Similarly, harvest index was 1.34 - 0.9%.

**Kranti** (medium maturing at 110-120 days**)**: RMSE and D-value of anthesis and physiological maturity days were in a range of 2.82-4.83 and 0.98-0.99 respectively. Similarly, LAI (90 DAS) is in a range of 0.082 and 0.92. The grain and total biomass yield showed RMSE at a range of 181-639 and D-value 0.90-0.1. Similarly, harvest index was 2.62 and 0.98% (Table 9).

**Table 9: Observed and simulated phenological parameters for testing genetic coefficients in rice varieties**

| Parameters | Sahbhagi | | | | Kranti | | | |
|---|---|---|---|---|---|---|---|---|
| | OBS | SIM | RMSE | D-value | OBS | SIM | RMSE | D-value |
| Anthesis (days) | 84.00 | 85.00 | 1.34 | 0.92 | 97.00 | 100.00 | 2.82 | 0.98 |
| Physiological maturity (days) | 105.00 | 107.00 | 2.70 | 0.99 | 110.00 | 115.00 | 4.83 | 0.99 |
| Maximum LAI (90 DAS) | 3.91 | 3.97 | 0.10 | 0.91 | 5.0 | 5.59 | 0.082 | 0.92 |
| Total biomass (kg $ha^{-1}$) | 8000.00 | 8132.00 | 547.18 | 0.90 | 8010.00 | 9982.00 | 639.12 | 0.91 |
| Grain yield (kg/$ha^{-1}$) | 2708.00 | 3029.00 | 328.59 | 0.82 | 2858.00 | 2927.00 | 181.00 | 0.90 |
| Harvest Index (%) | 33.85 | 34.47 | 1.34 | 0.99 | 35.64 | 36.07 | 2.62 | 0.98 |

## Validation of model

Performance of model proved better when rice is planted in June as compared to July because of less deviation *i.e.,* 8.5-13% in June as compared to 10.5-19 % in July (Table 10).

**Table 10: Validation of model calibrated from 2014 and compared with 2013 grain yield values of direct seeded rice cultivars**

| Cultivars | Sowing dates | Grain yield (kg $ha^{-1}$) | | % Deviation |
|---|---|---|---|---|
| | | 2013 | 2014 | |
| Sahbhagi | June 21, 2013 | 2618 | 2864 | -8.59 |
| | July 9, 2013 | 2401 | 2684 | -10.54 |
| Kranti | June 21, 2013 | 2831 | 3190 | -11.25 |
| | July 9, 2013 | 2418 | 2844 | -14.98 |

Sensitivity of CERES-Rice model using systematic changes in maximum and minimum temperatures in DSSAT indicates that maximum and minimum temperatures are responsible to determine seed yield. Increase in temperature by 1°C predicted yield levels among all tested varieties. However, simulated yield levels decreases with an increase in maximum temperature. Similarly, if temperature decreases by 1°C yield levels increase with minimum temperature up to 2°C in all the varieties (Table 11). After this, further decrease in minimum temperature results in decreased predicted yield levels of all the tested varieties. Maximum reduction in yield was simulated from scenario of increasing temperature by 4°C and decreasing solar radiation (1 MJ/day/$m^2$).

**Table 11: Variation in temperature scenario for sensitivity analysis of yield of rice cultivars**

| Temperature description | Sahbhagi | | Kranti | |
|---|---|---|---|---|
| | Simulated (kg $ha^{-1}$ ) | % Deviation | Simulated (kg $ha^{-1}$ ) | % Deviation |
| A1: +1°C | 2942 | 8.64 | 3090 | 08.12 |
| A2: +2°C | 2604 | -3.84 | 2674 | -06.44 |
| A3: +3°C | 2412 | -10.93 | 2520 | -11.83 |
| A4: +4°C | 2281 | -15.77 | 2311 | -19.14 |
| A5: +5°C | 2084 | -23.04 | 2180 | -23.72 |
| A6: -1°C | 3094 | 14.25 | 3250 | 13.72 |
| A7: -2°C | 3240 | 19.65 | 3391 | 18.65 |
| A8: -3°C | 2582 | -4.65 | 2754 | -3.64 |
| A9: -4°C | 2314 | -14.55 | 2554 | -10.64 |
| A10: -5°C | 2146 | -20.75 | 2331 | -18.44 |

The predicted levels of different rice varieties sown at different dates of the years 2020, 2030, 2040, 2050 and 2050s using weather data from MARK Sim ECHam5 model suggest reduction in yield. It was more in rice sown during month of July among all tested varieties. The predicted yield levels declined with increased number of years. Rice sown in the month of June observed increased grain yield from the current scenario with more yield levels of rice sown during early June as compared to late June. The yield levels increase till 2030 and decrease after 2030, suggest a change in recommended practices as per the climate change conditions. Thus, the climate change could not only cause significant reduction in rice yield, but could also make yield more sensitive to planting time (Table 12).

**Table 12: Predicted yield for direct seeded rice cultivars for the year 2020, 2030, 2040, 2050 and 2080 and their percent deviation from year 2014**

| Varieties | Grain Yield (kg $ha^{-1}$) | | | | | | | Change in Yield (%) | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Sowing Dates | 2014 | 2020 | 2030 | 2040 | 2050 | 2080 | 2020 | 2030 | 2040 | 2050 | 2080 |
| Sahbhagi | June 10 | 2864 | 3201 | 3108 | 2810 | 2638 | 2333 | 11.7 | 8.5 | -1.9 | -7.9 | -18.5 |
| | June 25 | 2684 | 2884 | 2784 | 2590 | 2401 | 2004 | 7.5 | 3.7 | -3.5 | -10.5 | -25.3 |
| | July 10 | 2577 | 2312 | 2280 | 2201 | 2009 | 1891 | -10.3 | -11.5 | -14.6 | -22.0 | -38.3 |
| Kranti | June 10 | 3190 | 3540 | 3418 | 2990 | 2714 | 2514 | 11.0 | 7.1 | -6.3 | -11.8 | -17.7 |
| | June 25 | 2844 | 3010 | 2964 | 2711 | 2608 | 2441 | 5.8 | 4.2 | -4.7 | -15.3 | -23.3 |
| | July 10 | 2538 | 2311 | 2201 | 2110 | 2000 | 1891 | -8.9 | -13.3 | -16.9 | -21.2 | -41.3 |

**Climatic variability and moisture availability**

- The trends in evapo-transpiration components (i.e. energy balance and aerodynamic component) were estimated using the FAO Penman-Monteith software. The energy balance and aerodynamic components are generally in the ratio 75:25 in Jabalpur region. Proportion of reference Evapo-transpiration and its components are computed from 1983-2013. During first two decades from 1983 to 2002, annual ETo is decreasing from 1390 to 1300 mm, but during last decade from 2003 to 2013, it is increasing from 1340 to 1390 mm.

- Aridity Index shows a clear trend of increasing values. In this case climate is sub-humid in the years 1989,1996 and 1998 and in the remaining years 1983-1988, 1990-1995,1997 and 1999-2013, index values comes under humid climate (Fig. 23).

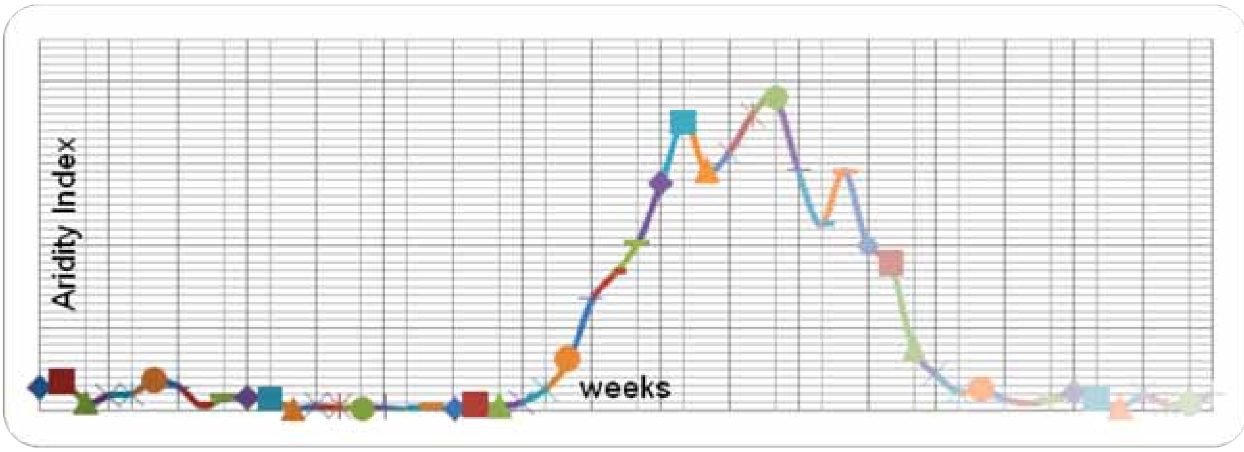



**Fig. 23: Trend of aridity index on weekly basis**

# 5. Status of breeder seed production

**Quantity of Breeder Seed produced (in q) during (2013-14 to 2014-15)**

| S.No. | Crop / Variety | 2013-14 | 2014-15 |
|---|---|---|---|
| | **Kharif** | | |
| 1 | Soybean | 596.74 | 1173.07 |
| 2 | Rice | 5773.98 | 5158.76 |
| 3 | Maize | 12.20 | 14.00 |
| 4 | Pigeonpea | 63.96 | - |
| 5 | Moong bean | 47.61 | 15.70 |
| 6 | Urid bean | 12.19 | 6.60 |
| 7 | Niger | 6.16 | 2.00 |
| 8 | Kodo millet | 12.60 | 10.61 |
| 9 | Little millet | 4.50 | 4.12 |
| 10 | Sesame | 7.95 | 92.40 |
| 11 | Groundnut | 2.00 | 3.00 |
| 12 | Cotton | 1.50 | - |
| | Total | 6541.39 | 6480.26 |
| | **Rabi** | | |
| 1 | Wheat | 6755.93 | 7303.59 |
| 2 | Barley | 90.15 | 39.69 |
| 3 | Chickpea | 1165.91 | 1435.68 |
| 4 | Mustard | 3.68 | 6.50 |
| 5 | Niger | - | 0.13 |
| 6 | Linseed | 47.84 | 54.92 |
| 7 | Lentil | 84.56 | 24.07 |
| 8 | Egyptian clover | 12.00 | 5.00 |
| 9 | Oat | 50.40 | - |
| 10 | Groundnut | - | - |
| 11 | Pea | 31.61 | 67.79 |
| 12 | Maize | - | - |
| 13 | Sugarcane | - | - |
| 14 | Sesame | - | - |
| | **Total** | **8242.08** | **8937.37** |
| | **Grand total** | **14783.47** | **15417.63** |

# 6. Research projects in operation during 2014-15

## All India Coordinated Research Projects

(Rs. in lakhs)

| S.No. | Project | Location | Total Outlay 2014-15 | Funds in tribal area sub project |
|---|---|---|---|---|
| 1 | P-2 Maize Improvement | Chhindwara | 25.249 | 0.0 |
| 2 | P-5 Micro, Secondary Nutrients and Pollutant Elements in Soils | Jabalpur | 46.50 | 4.0 |
| 3 | P-8 Soil Test Crop Response | Jabalpur | 44.36 | 7.25 |
| 4 | P-16-18 Integrated Farming Research | Multi campus | 116.66 | 17.98 |
| 5 | P-20-A Water Management | Powarkheda | 162.66 | 16.78 |
| 6 | P-57 Optimization of Ground Water through Wells & Pumps | Jabalpur | | |
| 7 | P-22 Rice | Rewa | 73.803 | 0.0 |
| 8 | P-23-A Niger | Chhindwara | 20.00 | 1.0 |
| 9 | P-23-A Sesame | Tikamgarh | 46.00 | 1.0 |
| 10 | P-23-C Linseed | Sagar | 41.413 | 00 |
| 11 | P-23-H Sesame | Powarkheda | 24.00 | 00 |
| 12 | P-23-I Linseed | Powarkheda | 1.266 | 00 |
| 13 | P-24-B Soybean | Jabalpur | 39.20 | 00 |
| 14 | P-28-B Millet Improvement | Dindori | 45.76 | 7.55 |
| 15 | P-28-C Millet Improvement | Rewa | 27.71 | 0.0 |
| 16 | P-29-A Wheat Improvement | Powarkheda | 54.65 | 0.0 |
| 17 | P-29-B Wheat Improvement | Sagar | 59.65 | 0.0 |
| 18 | P-30 Vegetable Improvement & NSP | Jabalpur | 90.00 | 1.5 |
| 19 | P-31-B Dryland Agriculture | Rewa | 78.93 | 0.0 |
| 20 | P-32 Forage Crops | Jabalpur | 64.00 | 0.0 |
| 21 | P-34 Sugarcane | Powarkheda | 78.31 | 0.0 |
| 22 | P-37 Potato Improvement | Chhindwara | 33.58 | 0.0 |
| 23 | P-39 Long Term Fertilizer Experiment | Jabalpur | 24.00 | 9.0 |
| 24 | P-43 Harvest & Post Harvest Technology | Jabalpur | 111.33 | 0.0 |
| 25 | P-71 Nematode Pests & their Control | Jabalpur | 55.00 | 0.0 |
| 26 | P-72 Farm Implements & Machinery | Jabalpur | 27.06 | 0.0 |
| 27 | P-73-A Breeder Seed Production | Jabalpur | 67.84 | 0.0 |
| 28 | P-73-B Seed Technology Research | Jabalpur | 99.98 | 0.0 |
| 29 | P-78Soil Biodiversity-Biofertilizer | Jabalpur | 28.85 | 0.0 |
| 30 | P-98 Sub Tropical Fruits | Rewa | 41.10 | 0.0 |
| 31 | P-106 Medicinal, Aromatic Plants and Betelvine | Jabalpur | 14.73 | |
| 32 | P-114 Barley Improvement | Rewa | 21.65 | 0.0 |
| 33 | P-127 Agro-meteorology | Jabalpur | 33.413 | 5.0 |
| 34 | P-148 Agro-Forestry | Jabalpur | 0.0 | 0.0 |
| 35 | P-152 Renewable Energy Sources | Jabalpur | 18.80 | 0.0 |
| 36 | P-286-A Chickpea | Jabalpur | 77.89 | 0.0 |
| 37 | P-289B MULLaRP | Sagar | 23.70 | 0.0 |
| 38 | P-374 Spices | Jabalpur | 2.47 | 0.0 |

| S.No. | Project | Location | Total Outlay 2014-15 | Funds in tribal area sub project |
|---|---|---|---|---|
| 39 | P-375 Arid Zone Fruits | Jabalpur | 24.44 | 0.0 |
| **100% Financed by ICAR** | | | | |
| 40 | P-324 AINRP on Organic Farming | Jabalpur | 7.80 | 1.0 |
| 41 | P-373 AINP on Onion and Garlic | Jabalpur | 8.53 | 0.0 |

## Ad-hoc projects

| S. No | Title | Amount (in lakhs) | Duration | Name of PI |
|---|---|---|---|---|
| **GOVERNMENT OF INDIA** | | | | |
| 1. | Marker assisted breeding of abiotic stress tolerant rice varieties with major QTLs for drought, submergence and salt tolerance at Rewa | 48.60 | 1.11.2010 31.10.2015 | Dr. P. Perajju Principal Scientist (PB), Rewa |
| 2. | Preservation of water chestnut *(Trapa ispinosa Roxburg* ) by gamma radiation | 17.55 | 1.4.2011 31.9.2015 | Dr. S.S. Shukla Principal Scientist (PB), Jabalpur |
| 3. | Seed Production in Agricultural Crops (Mega Seed Project) | 111.50 | 2011-12 Continued | Director Farms JNKVV, Jabalpur |
| 4. | Molecular breeding selection strategies to combine and validate QTLs for improving WUE and Heat tolerance in wheat | 33.75 | 15.5.2011 14.5.2016 | Dr. P.C. Mishra Principal Scientist ZARS, Powarkheda |
| 5. | Selection and utilization of water logging tolerance cultivars in pigeonpea | 68.53 | 2011-12 2016-17 | Dr. S.K. Rao Dean Faculty of Agriculture, JNKVV |
| 6. | Effective waterlogging in Pigeon pea | 2.48 US$ 4000 | 2014 Continued | Dr. S.K. Rao Dean Faculty of Agriculture, JNKVV |
| 7. | Human Resource Development in Medicinal Plants through Facilitation Centre | 27.00 | 1.12.2013 30.11.2016 | Dr. S.D. Upadhyaya Professor (Plant Physiology), College of Agriculture, Jabalpur |
| 8. | Development of an improved choke indicator | 18.38 | 1.11.2013 30.10.2015 | Dr. A.K. Rai Professor, IDSC JNKVV, Jabalpur |
| 9. | Shelf life enhancement of maize and small millets based food products prepared from local varieties of MP using Radiation process | 23.815 | 7.5.2014 6.5.2016 | Dr. (Smt.) Alpana Singh, Assoc. Prof (Home Science) |
| 10. | Web enabled weather based decision support system for forewarning and management of important pest-disease of soybean and chickpea in Bundelkhand zone of MP | 25.804 | 1.12.2014 30.11.2016 | Dr. A.K. Srivastav Assistant Professor (Agro-meteorology) CoA, Tikamgarh |

| S. No | Title | Amount (in lakhs) | Duration | Name of PI |
|---|---|---|---|---|
| **INDIAN COUNCIL OF AGRICULTURAL RESEARCH (ICAR)** | | | | |
| 11. | Network project on Biotic Stress (Rusts) of wheat, Powarkheda | 5.05 | 1.12.2009 continued | Dr. P.C. Mishra, Principal Scientist Powarkheda |
| 12. | Technology Mission Citrus | 284.06 | 18-1-2011 Continued | Dr. S.R. Dharpure Principal Scientist ZARS, Chhindwara |
| 13. | Network project on harvest, processing and value addition of Natural resin and gums | 61.15 | 1.10.2008 31.3.2017 | Dr. Moni Thomas Sr. Scientist (Ent.) College of Agri., Jabalpur |
| 14. | Network project on hybrid rice research | 9.00 | 1.7.2010 30.6.2013 Continued | Dr. G.K. Koutu, Principal Scientist (PB), Jabalpur |
| 15. | Network Centre on National initiative on climate change resilient agriculture - AICRPDA-NICRA (ICAR) | 30.25 | 2010-11 Continued | Officer in charge Dryland Agriculture, Rewa |
| 16. | Weather based agro advisories and assessment of vulnerable areas of major food crops production zone. AICRPAM-NICRA (ICAR) | 13.05 | 2010-11 Continued | Dr. Manish Bhan Scientist, JNKVV, Jabalpur |
| 17. | National Initiatives on Climate Resilient Agriculture (NICRA) Real time pest surveillance in Pigeon pea | 5.00 | 2010-11 Continued | Dr. S.B. Das, Principal Scientist (Entomology), JNKVV, Jabalpur |
| 18. | Marketing intelligence | 35.94 | 01.07. 2013 31.03.2017 | Dr. P.K. Awasthi Professor (Agri. Economics), JNKVV, Jabalpur |
| 19. | Metagenomic analysis of the 1-Aminocylopropane-I-Carboxylate Deaminase gene (AcdS) diversity of population associate with wheat | 24.50 | 1.7.2013 30.6.2016 | Dr. Iti Gontia Mishra Research Associate Biotechnology Centre, Jabalpur |
| 20. | Genetic improvement of non toxic Jatropha varieties for bio-fuels and animal feeds (DARE-ICRAF) | 6.00 | 1.4.2014 1.3.2016 | Prof. V.K. Gour, Senior Scientist (PB), Jabalpur |
| **INTERNATIONAL FUNDED** | | | | |
| 21. | Exploration, collection and characterization of lentil germplasm in Madhya Pradesh (ICARDA, Morocco) | 6.30 | 2013-14 | Dr. Suneeta Pandey Scientist (PB) JNKVV, Jabalpur |
| 22. | Maximization of soybean production in Madhya Pradesh (India) MP-JICA Collaborative project | 72.52 | 2013-14 | Director Research Services, Project Manager |

| S. No | Title | Amount (in lakhs) | Duration | Name of PI |
|---|---|---|---|---|
| | | **STATE GOVERNMENT** | | |
| 23. | Development of farm equipments and machinery testing, training and demonstration facility at JNKVV. Jabalpur | 490.00 | 2012-13 30.9.2015 | Dr. Atul Shrivastav Professor (FMP), Principal Scientist, JNKVV, Jabalpur |
| 24. | Collection, evaluation and utilization of elite lines of wheat from different parts of MP | 7.82 | 3.7.12 2.7.15 | Dr. R.S. Shukla Principal Scientist (PB), Jabalpur |
| 25. | Survey, collection and conservation of wild and traditional cultivars of Vindhyan Plateau of MP | 7.70 | 5.10.2013 4.10.2016 | Dr. Gynendra Tiwari Associate Professor, CoA, GanjBasoda |
| 26. | Studies on promotion of nutraceutical small millets among the peoples of MP for food and nutritional security | 9.94 | 1.9.2014 31.8.2016 | Dr. R.P. Joshi Senior Scientist (PB),College of Agriculture, Rewa |
| 27. | Conservation through rejuvenation of old mango orchards in Rewa | 9.50 | 1.9.2014 31.8.2017 | Dr. Rajesh Singh SMS (Horticulture), KVK, Rewa |
| 28. | Dissemination and validation of location specific cost effective IPM technology through farmers participation approaches for increasing farmers income in major crops of Vidisha District of MP | 5.267 | 1.1.2015 31.12.2017 | Dr. Yogesh Patel Associate Professor (Entomology), College of Agriculture, GanjBasoda |
| 29. | Promotion of low cost precision farming technology for diversification of livelihood option and poverty alleviation among small and marginal farmers | 8.30 | 1.1.2015 30.6.2016 | Dr. Vijay Agrawal, Scientist (Horticulture), JNKVV, Jabalpur |
| 30. | Impact of water stress on secondary metabolites production of medicinal plants used as memory enhancer | 4.68 | 1.2.2015 31.1.2017 | Dr. S.D. Upadhyaya, Prof. (Crop Physio.), Jabalpur |
| | | **AGRICULTURAL ENGINEERING DIVISION** | | |
| 31. | Madhya Pradesh Water Sector Restructuring Project (MPWSRP) | 1301.00 | 2006 to 2015 | Dr. R.K .Nema Principal Scientist (SWE), Jabalpur |
| | | **OTHER AGENCIES** | | |
| 32. | Evaluation and utility of direct application of Gypsum and its mixture with low grade rock phosphate, feldspar, vermi compost, poultry manure and cow dung in different crops of Vindhya Plateau of Madhya Pradesh | 13.59 | 31.8.2013 31.8.2016 | Dr. S.R.S. Raghuwansi Associate Professor (Soil Science), College of Agriculture, Ganjbasoda |

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