SALIENT RESEARCH ACHIEVEMENTS

Research has been conducted at the station for three distinct farming situations prevalent in the region viz. (a) rainfed condition, (b) brackish water and restricted irrigation condition, (c) sufficient irrigation with good quality water. In the present day context, the traditional crops like wheat in *Rabi* and pearl millet in *Kharif* have failed to pay sufficient dividend to the farmers due to low price and high cost of cultivation. In the quest for diversification, the farmers are looking for suitable and remunerative alternates. The scientists engaged in research activities have developed technology for the cultivation of crops like clusterbean, sesamum, mungbean, cotton, castor and cowpea in *Kharif* and Indian mustard, chickpea, barley, fenugreek and fennel in *Rabi* for commercial value, which can serve as suitable alternate under different farming situations. The research achievements pertaining to crop improvement, production, plant protection, horticulture, agro-forestry and animal nutrition are summarized and depicted below:

CROP IMPROVEMENT

- **Development of varieties:** The research station has developed two Indian mustard varieties i.e. RB 24 and RB 50

Characteristics of RB 24

- First tetralocular Indian mustard variety.
- Higher yielder than check (25 q/ha rainfed) and (30 q/ha irrigated)
- Long main raceme (104 cm)
- More seed number (18-20/ siliqua)
- Suitable for rainfed conditions
- Moderately resistant to white rust

Characteristics of RB 50

- Suitable for rainfed conditions
- Long and bold siliquae
- Long main raceme (103 cm) and bold seed size (5.7 g)
- More seed number (18) per siliquae
- Higher yielder (32 q/ha) than Laxmi

♦ Contribution in development of varieties

Crop	Varieties
Wheat	**WH 283, WH 416, WH 533, WH 542, WH 711, Sonak, WH 1025, WH 1080, WH 1105, WH1124 and WH1142** **Duram wheat: WHD 896, WHD 912 and WHD 948**
Barley	**BH 393, BH 902, BH 946, BH 959 and BH 885**
Indian mustard	**Laxmi, RH 9304, RH0406, RH 0749, RH 1424 and RH 1706** **Yellow sarsaon - YSH 0401**
Chickpea	**HC 3 and HC 5**
Pearl millet	**HHB 68, HHB 94, HHB 117, HHB 67 (improved), HHB 67 (improved 2), HHB 146, HHB 197, HHB 216, HHB 223, HC 10, HC 20 and HHB234**
Clusterbean	**HG 563, HG 365, HG 884 and HG 870**
Mungbean	**Muskan, Satya, Basanti, MH 318 and MH 421**
Cowpea	**HC 98-46**
Fieldpea	**HFP 9426, HFP 9970B ,HFP 529 and HFP 715**

♦ **Registration of tobacco variety**

Characteristics of C 304

- The only Hookah variety of tobacco from Haryana registered with National Bureau of Plant Genetic Resources, New Delhi as C-304
- Average number of leaves (15) with size of leaf (34.85 cm x 21.50 cm)
- Average plant height (97.15 cm) with average plant stem girth (9.65 cm) and total plant weight (590 g.)
- Days to 50 per cent flowering (90) and average seed yield/plant (15 g.)
- Nicotine content (3.26per cent)

CROP PRODUCTION

Technologies evolved for dryland agriculture

- Pearl millet and cluster bean among *Kharif* crops and Indian mustard and chickpea during *Rabi* are the efficient and productive rainfed crops. Brown sarson and barley could be efficient crops with one protective irrigation. Further, with improved dry farming technology, the production of these crops could easily be enhanced by 2-3 times over farmers practice.

- All dry land crops should be spaced at 45 cm with population of 1.0 to 1.25 lac/ha. The castor crop, however, should be spaced at 120 cm apart. No dry land *Kharif* crop should be sown before 21 June and *Rabi* crops before 21 September. If there is any choice, *Rabi* crops should be sown around 15 October.

- In *Kharif* fallow land, 2-3 harrowings are required for conserving of rain water. At last harrowing, the land should be compacted with a plank. It is essential to keep open the land by ploughing with local plough/harrow immediately after harvest of the crop.

- Mixed cropping of clusterbean in pearl millet in the proportion of 2:1 gives an additional yield of clusterbean without any detrimental effect on the main crop of pearl millet.
- Two rows of mung bean or cluster bean can be intercropped with castor for improving the overall productivity and economy.
- The manifold increase in the yield of dry land pearl millet can be obtained by seeding with ridger seeder. The ridger seeder could also be used for dry sowing of pearl millet before normal onset of monsoon
- Fertilization in dry land *Rabi* crop chickpea revealed that phosphorus should be not mixed with chickpea seed / applied below seed but should be drilled at last ploughing of land preparation. The crop responded favourably up to application of 40 kg P_2O_5/ha.
- In good rainfall years with adequate rains during second fortnight of September, chickpea; Indian mustard and taramira can be taken as a second crop depending upon moisture in the soil profile at sowing time of these crops which should be 200; 175 and 150 mm/m, respectively.
- On the basis of performance of various fruit crops grown under rainfed conditions, ber and aonla were found most successful and economic fruit for dryland region. Besides ber and aonla, other fruits like bael and karonda performed better. Phalsa can also do well in the years of good winter rains.
- Soil application of "Pusa Hydrogel" @ 5 kg/ha in Indian Indian mustard was found adequate for achieving maximum seed yield, net returns, benefit: cost and water use efficiency (WUE) but it was most economical under rainfed conditions.
- To mitigate moisture stress in rainfed cluster bean, seed soaking in thio-urea solution (500 ppm) for 30 minutes + foliar spray of 1per cent NPK (20:20:20) fertilizer at flowering and pod formation stage super imposed over recommended package of practices (RP) increased the grain yield by 27.6 per cent over RP.

Technology developed for use of sodic water

About 68 per cent of ground waters in different districts of this zone are of poor quality i.e. either saline, sodic or saline-sodic, while only 20 per cent are good for crop cultivation. The importance of water in the zone is so great that farmers have no other option except to harness these poor quality waters for irrigating crops because of inadequate availability of canal water facilities coupled with low, erratic and ill distributed rainfall. Sodic water which is characterized by their low EC (< 4 dS m^{-1}), high SAR [>10 (m mol $l^{-1})^{1/2}$] and high RSC (>2.5 me l^{-1}) levels may become a potential source of supplemental irrigation provided they are used judiciously and

carefully. The continuous and indiscriminate use of these waters influence crop growth due to excessive accumulation of sodium in rhizosphere which in turn, adversely affects the physico-chemical characteristics of soil causing nutritional disorders associated with high pH / ESP of soil.

- Long term application of gypsum on the basis of water requirement (RSC 12 and 16 me/l), reduced the moisture retention and improved infiltration rate and hydraulic conductivity
- Addition of gypsum @ 50per cent gypsum requirement of soil irrigated with sodic water (12 me/l) was found appropriate for growing pearl millet, mungbean, urdbean, cowpea and pigeon pea. However in cluster bean, the maximum grain yield was obtained when gypsum was applied @100 per cent gypsum requirement of the soil.
- The best time for gypsum application was found to be before start of monsoon followed by before pre-sowing irrigation of *Rabi* crops as depicted in.
- The major crops, tested under 12 me/l RSC tubewell water showed the relative tolerance of crops as barley>wheat>Indian mustard>field pea>chickpea in *Rabi;* and pearl millet>cluster bean>cowpea>urdbean>mungbean>pigeonpea in *Kharif* season.
- Wheat crop responded upto 25 kg ferrous sulphate /ha in light textured iron deficient sodic soil (pH_2 9.47) and sodic water (RSC 12 me/l) conditions. Foliar spray of ferrous sulphate @ 0.5per cent at 40 and 60 days after sowing was at par to 25 kg ferrous sulphate/ha soil application.
- Application of sodic waters of RSC 12 me/l with gypsum as amendment can safely used in pearl millet, desi cotton, sorghum, wheat, Indian mustard, sugarcane, sonamukhi, chandersur and kalmegh. Sodic water of 16 me/l RSC even with gypsum as amendment was not found suitable.
- The performance of different trees studied under sodic water conditions after two years of transplanting revealed that *Eucalyptus* hybrid was found to be most resistant to soil sodicity for survival whereas *Alianthus excelsa* and *Albizia lebbek* had relatively low survival but after their establishment their growth was good under gypsum application.
- Summer ploughing increased the infiltration characteristics viz. hydraulic conductivity, sorptivity and cumulative infiltration to check runoff and to conserve more soil moisture in sodic (high RSC 12 me l^{-1}) irrigation water than low (RSC 2.8 me l^{-1}) irrigation water in problematic sandy soils.
- Indian mustard needed more N and P under sodic soil and water conditions with gypsum (100 kg N+37.5 kg P_2O_5/ha) application based on 100per cent GR of sodic irrigation water and without gypsum (120 kg N+45 kg P_2O_5/ha) as compared to recommended dose of N and P (80 kg N+30 kg P_2O_5/ha) for normal soil-water conditions.

- Sodicity delayed sprouting, flower initiation and affected the growth of cut flowers (tuberose and gladiolus) adversely. However, application of gypsum at the rate of 100 per cent neutralization of RSC of irrigation water (8.2 me/l) enhanced their growth and production.
- Under sodic soil (pH 9.25) and water conditions (12 me/lRSC), continuous and alternate manuring with dhaincha during *Kharif* is effective in increasing crop yield and soil organic carbon content. While soil pH decreased during initial six to seven years only. Thereafter, soil organic carbon content decreased and soil pH increased.
- Neutralization of RSC with gypsum @ 100 per cent neutralization RSC of water above 2.8 me/l was found to be more effective than FYM @ 10 t/ha per year in decreasing soil pH and ESP and improved infiltration rate irrigated with high RSC water of 12 me/l. A significant increase in $CaCO_3$ build up in soil was observed with gypsum application and its content further increase with soil depth. The adverse effect of sodic waters on soil properties and crops yield was more pronounced in high water requiring cropping system (pearl millet- wheat) as compared to low water requiring cropping system (pearl millet-Indian mustard).

Water management in field crops

In South–Western zone of the Haryana, more than 68 per cent of net irrigated area is covered by tube-well irrigation. The main source of irrigation in this zone is tubewell ground water and about 70 per cent of these tubewells water are brackish in nature. In recent years climate change due to global warming total sharp reduction in annual rainfall in S-W zone of Haryana led to dying of water table and discharge of the well reduces. Under such conditions, efficient management of water becomes most vital component of package of practices.

- Application of five irrigations each of 5 cm depth in wheat variety WH 147 and C306 at crown root initiation, tillering, flowering, milking and dough stages are essential for reaping good harvest of the crop.
- Scheduling of irrigation (each of 6 cm depth) applied in barley at tillering and earing stage of the crop resulted in optimum yield yields. The crop was raised after giving 7.5 mm pre sowing irrigation.

- Under drip irrigation in cotton, the alternate day irrigation schedule was found optimum in terms of seed cotton yield and water use efficiency. Planting of hybrid cotton at a spacing of 1 m x 1 m yielded significantly higher than 1 m x 1.5 m planting pattern in drip irrigation system. Alternate day drip irrigation schedule with double plant per hill at 1 m x 1 m spacing was more promising in hybrid cotton.

- Application of three irrigations at 35 (seedling), 65 (square formation) and 130 (boll opening) days after sowing (DAS) were found optimum for higher seed cotton yield and economic

returns in light textured soil of southern Haryana. Application of first irrigation at 35 DAS produced 8.62 per cent higher yield than irrigation applied at 45 DAS.

- The grain yield of pearl millet and wheat increased significantly with increase in depth of irrigation and gypsum application. The grain yield of both crops in 6 cm depth of sprinkler irrigation was higher than 4 cm and 5 cm depth of sprinkler irrigation. The grain yield of pearl millet and wheat also increased significantly with each successive increase in the neutralization of RSC with gypsum. The mean increase in mean yield of pearl millet was 14.29, 42.97 and 47.06 percent and in wheat was 7.66, 13.68 and 16.53 per cent with G_{50}, G_{75} and G_{100} over G_0. Application of gypsum @ 75 percent neutralization of RSC of irrigation water was found to be optimum for both crops in all depths of sprinkler irrigation.
- In cotton, drip irrigation at 0.8 ETc with 75% dose of recommended fertilizer was found the best in terms of yield and profit in loamy sand soils, which was superior to conventional irrigation method. There was 25 % saving of irrigation water under drip irrigation at 0.8 ETc as coimpared to conventional irrigation method.
- Split application of irrigation water (120 mm) through drip in 12 splits at an interval of 6 days starting from 30 days after sowing increase water-use efficiency by 15 % thereby resulting into 16 % higher seed yield of mustard.

Nutrient management in crops

- In iron deficient light textured soil, application of 20 kg ferrous sulphate ($FeSo_4$)/ha in pearl millet was found optimum. Two sprays of 0.5 per cent ferrous sulphate at 20 and 40 days after sowing proved equal beneficial as that of soil application of 20 kg ferrous sulphate/ha.
- Application of 5 kg borax/ha in boron deficient soil increased the grain and seed yield of pearl millet and Indian mustard, respectively. However, two sprays of 0.2 per cent borax at 20 and 40 days after sowing were at par with soil application of 5 kg borax/ha.
- The *Azotobacter* inoculation increased the forage yield of oat by 7.8 per cent compared with no inoculation and the beneficial effect of *Azotobacter* was more pronounced at lower N levels (control and 30 kg N/ha) compared with that at higher levels (60, 90 and 120 kg 4N/ha.
- Fertilizer response in chickpea showed that maximum seed yield was observed with application of 30 kg N/ha and 40 kg P_2O_5/ha over control and other combinations.
- Application of FYM @ 10t/ha in *Kharif* fallow produced significantly higher seed yield of Indian Indian mustard than sown only after *Kharif* fallow on conserved moisture
- Cluster bean responded significantly to application of 20 kg P_2O_5/ha and 20 kg S/ha. The gum content and gum yield also increased with P and S application.

- Sesame crop responded significantly to application of 45 kg N/ha and 20 kg S/ha. The application of both nutrients increased the seed yield, oil content and iodine content. Whereas in another study, sesame responded significantly to phosphorus and sulphur application upto 10 kg $P_2O_5$and 15 kg S/ha, respectively and corresponding increase in seed yield was 39.7 and 42.8 per cent, respectively over control on mean basis of three years.
- In sandy loam soil deficient in nitrogen and medium in P, application of 100 kg N and 150 kg K_2O/ha was found optimum for higher yield in tobacco var. C 304.
- Castor responded to application of 80 kg N + 60 kg P_2O_5 + 30 kg S/ha (33.0q/ha) in comparison to control (29.3q/ha).
- Co-inoculation with *Azatobactor chroococcum* and PSB at 100 per cent recommended dose of fertilizer in wheat increased its yield by 5.59 per cent over control.
- The Indian mustard hybrid DMH-1 proved better over PAC 432, NRCHB 506, Kranti and Laxmi and all hybrids and varieties responded up to 100 kg+37.5 kg P_2O_5 + 50 kg S/ha under irrigated conditions.
- In coarse textured soil medium in available potash, pearl millet crop responded significantly to K application up to 30 kg K_2O/ha . The increase in mean grain and straw yield over control was 9.55 and 9.75 per cent at 30 kg K_2O/ha, respectively. The K uptake, B:C and available K status also increased with K application. The Additional return per rupee invested on K was maximum (Rs.15.30) with application of 30 kg K_2O/ha.
- In coarse textured soil, medium in available potash, application of 20 kg K_2O/ha in cluster bean was found optimum.
- Post-sowing application of half N either before or after first irrigation in wheat yielded at par.
- In coarse textured soil, medium in available potash, Indian mustard crop responded significantly up to 20 kg K_2O/ha. The increase in Indian mustard seed and straw yield was 8.36 and 7.72 per cent at 20 kg K_2O/ha, respectively over control.
- In coarse textured low P status soil (8.58 kg P/ha), pearl millet (HHB 197) mean grain yield increased by 46.24, 40.25, 10.91, 20.90 and 28.24 per cent over control with the application of 60 kgP_2O_5/ha at sowing, 30 kgP_2O_5/ha at sowing+30 kg P_2O_5/ha at 21 DAS, 30, 45 and 60 kg P_2O_5/ha at 21 DAS, respectively. The P uptake, P-use efficiency and soil mean available P status also increased with P application. The results of three years study revealed that the optimum level and time of phosphorus application is 60 kg P_2O_5/ha and 30 kg P_2O_5/ha at sowing+ 30 kg P_2O_5/ha at 21 DAS. But application of 60 kg P_2O_5/ha at 21 DAS was found to be more beneficial, if phosphorus was not applied at sowing.
- Indian mustard crop responded significantly to application of 30 kg P_2O_5/ha whereas the residual effect of P in Indian mustard (applied in pearl millet) was significant at 60 kg P_2O_5/ha in pearl millet-Indian mustard cropping system in coarse textured low P status soil.

Pearl millet responded significantly to direct and residual application (applied in Indian mustard) up to 60 kg P_2O_5/ha in pearl millet-Indian mustard cropping system. The residual effect of increasing level of P applied in preceding crop led to gradual decrease in crop yield and PUE of succeeding crop. The study revealed that application of 60 kg P_2O_5/ha was found to be optimum for pearl millet-Indian mustard cropping system in terms of crop yield and soil phosphorus fertility status whether the phosphorus is applied in Indian mustard or pearl millet.

- The *Jatropha curcas* seed yield increased from 163.71 kg/ha (control) to 472.5 kg/ha (90 kg N and 60 kg K_2O/ha) with two irrigations. Application of one irrigation at sprouting (May) and two irrigations one each at sprouting and seed formation (May & Oct.) increased the *Jatropha* seed yield by 62.81 and 105.59 percent respectively, over no irrigation. *Jatropha* seed yield increased significantly up to 60 kg N/ha with no irrigation whereas its yield increased significantly up to 90 kg N/ha with one and two irrigations. There was no significant effect of potassium application on seed yield in the absence of irrigation but its effect was significant at 60 kg K_2O/ha application with one and two irrigations, respectively.

- In medium potash status soil, castor responded significantly up to 40 kg K_2O/ha. The increase in seed yield was 6.50 and 13.66 per cent with application of 20 and 40 kg K_2O/ha, respectively. The highest seed yield of 29.30 q/ha, net returns (Rs. 71677/-) and B:C as 2.98 were obtained with application of 40 kg K_2O/ha.

- The maximum seed yield of chickpea was recorded in the treatment having *Mesorhizobium* +CNE-II (Chickpea Nodule Endophyte) but it was non-significant when compared with CNE-II inoculation alone. Nodule endiphytic bacteria positively affected the seed yield. The per cent increase in yield due to inoculation over control varied from 10.90 to 20.90.

- The study on effect of time and mode of bio-fertilizer application in wheat revealed that foliar application of bio-inoculants at 40 DAS in wheat was at par with seed inoculation. However, soil treatment with foliar application was found to be better over seed treatment or foliar application alone.

- In coarse textured medium K status soil (Av. K 169.9 kg/ha), applicaation of 20 kg K_2O/ha in mung bean was found optimum.

- Application of 20 kg S/ha in mungbean and cowpea was found optimum in terms of additional returns per rupee invested and sulphur use efficiency.

- In coarse textured medium K status soil (mean Av. K 170.4 kg/ha), chickpea responded significantly upto 20 kg K_2O/ha

- In coarse textured low S status soil, application of 30 kg S/ha in chickpea yielded significantly higher over lower levels (0,10,and 20 kg S/ha) and recorded higher S use efficiency.

- Application of 30 kg K_2O/ha in peagion pea was found optimum.
- Sowing of castor in June to 15 July was found more economical than sown in late July and August in south-Western Haryana.
- Sowing of groundnut genotype GNH 804 at plant geometry of 25 cm x 10 cm with application of 125per cent RDF (18.75 kg N + 62.5 kg P_2O_5 + 31.25 kg K_2O/ha) was found most economical.

Nutrient management in various crop sequences

- Indian mustard crop responded to N and P application upto 120 kg N + 40 kg P_2O_5 kg/ha when grown after pearl millet. The interaction effect of N and P levels revealed that at lower levels of N (0 and 40 kg N/ha), seed yield of Indian mustard increased significantly upto 20 kg P_2O_5/ha, but at higher levels of N (80 and 120 kg/ha), Indian mustard responded upto 40 kg P_2O_5/ha.
- In light textured medium potash status soils, application of 40 kg K_2O/ha was found optimum for cluster bean-Indian mustard and 60 kg K_2O/ha was found to be optimum for pearl millet-Indian mustard and wheat-pearl millet cropping systems, respectively
- Application of 75 per cent of the recommended fertilizer alongwith 10 t FYM/vermicompost/ha with or without bio fertilizers was found to be optimum for cluster bean –wheat cropping system
- The residual effect of 50 and 60 kg P_2O_5/ha applied to irrigated Indian mustard was significant on yield of pearl millet at 0 and 10 kg P_2O_5/ha levels applied to pearl millet. Application of 30 to 60 kg P_2O_5/ha to un-irrigated Indian mustard have statistically similar residual effect on grain yield of pearl millet. In general, pearl millet yield increased significantly up to 20 kg P_2O_5/ha. And it was statistically at par with 30 and 60 Kg P_2O_5/ha.

Intercropping/mixed cropping systems

- Growing of two rows of mung bean after each row of castor was found to be more remunerative over the pure crops of castor and moong.
- The broadcasting of chicory seed @ 5 kg/ha just before first irrigation in Indian mustard (40 days after sowing) had statistically no adverse effect on seed yield of Indian mustard (14.24 q/ha) compared to pure planting of Indian mustard (14.51 q/ha), but produced an additional yield of 2.20 q/ha seed and 19.73 q/ha green fodder of chicory. The broadcasting of chicory seed at sowing or mixing the seed of chicory with Indian mustard can also be sown.
- Planting of clusterbean in 30:60 cm paired row planting system increased the seed yield of clusterbean by 5.24 and 4.24 percent over clusterbean planting at 30 and 45 cm row spacing, respectively. In paired row planting of clusterbean, intercropping of one row of moong and pearl millet enhanced net returns.
- The intercropping of cluster bean or moth bean in castor had no effect on castor seed yield. Intercropping of cluster bean or moth bean in 1:2 or 1:3 ratio resulted in higher castor–

equivalent yield and net returns. Intercropping of castor with cowpea was not found profitable.

- In high density planted Apple Ber pearl millet and mungbean during *Kharif* and during *Rabi* season Oat crop can be successfully grown up to age of six years. Among different Agri-horti systems Ber+Mungbean+Oat was found most remunerative with highest net returns under 5x3 m planting density.

Agro-Production Technology for different crops

- In peral millet, beside application of fertilizer, seeding of crop with ridger seeder was also found to be useful to get good stand of crop and mitigating weed infestation problem and ultimately boosted crop yield.
- Sowing of Duram wheat in last week of October and first week of November produced significantly higher seed yield than sowing in third week of November.
- Spacing of 20 x 15 cm was optimum for fennel cultivation.
- Sowing of field pea in second week of November was economical than sowing in last week of October and 1st week of November.
- The mungbean varieties MH421 and MH 318 were found to be at par in terms of yield but superior to Satya and Asha. Seed rate of 15kg/ha was found optimum.
- Sowing of pigeonpea in 3 rd week of June was found economical than June 1, 10 and 30 sowings.
- Sowing of soybean between June 20 and 1st week of July than early sowing was found optimum under south-wstern part of Haryana.
- Line sowing of chicory at 30 cm row spacing with 10 kg seed/ha was found optimum for green fodder production.
- For achieving higher yield of Karan rai (*Brassica carinata*), it should be sown at a spacing of 45x10 cm.
- Application of 5t FYM over planted rows and sowing in north-south direction significantly produced 37 and 33per cent higher grain yield of pearl millet as compared to compaction behind plough after sowing.
- Adoption of low monetary agro-techniques in Indian mustard i.e. sowing in north-south direction, removal of 4 permanent leaves at 55-60 days stage, detopping at bud initiation stage (40-50 days to and thinning at15 and 25 days after sowing) caused increase in seed yield of Indian mustard to the tune of 7.3, 7.6, 9.8 and 9.8 per cent as compared to east-west sowing, non-removal of 4 permanent leaves at 55-60 days stage, without detopping at bud initiation stage and no thinning, respectively.
- Soaking of sesame seed in water for three hours before sowing and then drying in shade recorded 23.2 per cent higher germination as compared to unsoaked seed under field conditions. It is essential for achieving optimum plant stand in field under rainfed conditions.

- Clipping of terminal bud in til at 30 days after sowing (DAS) alnogwith application of 40 kg N/ha gave 31.2 percent higher seed yield as well as monetary returns than no clipping.
- Mechanized interculture operations with tractor drawn cultivator at 30 and 60 DAS in chickpea sown at 60 cm wide row spacing produced statistically similar seed yield to recommended practice of two manual interculture with kasola at 25-30 and 45-50 DAS and was found more profitable fetching higher net returns and B:C (₹ 40997/ha and 2.15) than recommended practice of two manual interculture with kasola (₹ 32720/ha and 1.68).
- In pearl millet sown at row spacing of 60 cm, mechanized interculture operations with tractor drawn cultivator at 15 and 25 DAS gave statistically similar seed yield and higher net rturns than recommended two manual intercultural practices with kasola or wheel hand hoe at 3 and 5 weeks after sowing.
- Planting of cluster bean under zero tillage sowing was better in terms of net return and B:C. The highest net return and B:C ratio was recorded with zero tillage sowing as compared to other planting methods.
- Sowing of wheat at row spacing of 17.5 cm with recommended seed rate was found economical than recommended row spacing of 20 cm under timely sown conditions.
- Sowing of barley from from last week of October to first week of November at row spacing of 20 cm with recommended seed rate was found more profitable than recommended time of sowing (15 -30 November) and row spacing (22.5 cm).
- Foliar spray of 1per cent KNO_3 or NPK (20 : 20 : 20) 1 per cent at 50 per cent flowering and 50 per cent grain filling stage of wheat can help in mitigating the adverse effect of moisture stress.
- Among various land configuration in Indian mustard under rainfed condition; Broad bed and furrows (90 cm) gave significantly higher seed yield (20.87 q/ha) as compared to Ridge and furrow (45 cm) and Conventional sowing i.e. 18.42 and 18.35 q/ha, respectively. Similar trend was found in case of stover yield, net return and B:C ratio.
- Foliar spray of zinc sulphate (0.5%) + ferrous sulphate (0.5%) + urea (2%) along with RDF at 30, 45 DAS and 85 DAS recorded statistically higher green fodder yield. It improves quality of fodder and was also found most economical.

Weed control

- Field studies carried out for control of *Kherjal* indicated that application of glyphosate @ 2 to 3 per cent (product) at peak vegetative growth stage in summer resulted in about 85 to 95 per cent control. No harmful effect of the chemical on succeeding peral millet and cluster bean crop was noticed.
- For the control of parasitic weed *Orobanche aegyptiaca* in Indian mustard crop, two sprays of Round Up/Glycel (glyphosate 41per cent SL) @ 25 ml/acre at 30 days after sowing and 50 ml/acre at 55 days after sowing of Indian mustard should be made by using 150 litres of water/acre through flat fan nozzle, which provides 65-90 per cent control of this weed without any crop suppression. However, care should be taken that the crop should not suffer from any moisture stress at the time and immediately after spray of glyphosate, so irrigate

the crop 2-3 days before or after spray. Use of higher than recommended dose may cause injury to the crop.

- Pre-emergence application of pendimethalin 1 kg a.i./ha in association with one inter-culture at 40 DAS (32.54 q/ha) yielded at par with weed free conditions (33.37 q/ha) and farmers' practice (3 interculture) in castor :mung bean was distinctly superior to other treatments and control.

PLANT PHYSIOLOGY

- For higher grain yield of barley irrigations at tillering and earing stage should be applied each of 5 cm depth. The pre sowing irrigation was 7.5 cm depth. The total water requirement of barley crop was worked out 23.5 cm.
- As follier application of ameliorants (per cent KCl or cycocel) in cotton at boll formation stage enhanced water status and cycocel improved chlorophyll content alongwith reduction in boll drops which ultimately increased seed cotton yield under rainfed conditions. KCl was more effective than cycocel under water stress. Boll formation stage in the cotton is most sensitive to water stress.
- April sowing of cotton in South-Western Haryana (American and desi) had better flower and boll retention, water status and higher yield than May sowing. However, desi cotton (HD 107 and HD 123) performed superior in terms of plant water status and yield over American cotton under Bawal conditions.
- Indian Indian mustard var. RH 30 and wheat var. WH 283 found tolerant upto 60 ESP level by maintaining high water status, chlorophyll and membrane stability alongwith grain yield as compared to other tested varieties. Flowering stage in Indian mustard and milking stage in wheat was observed most sensitive to sodicity under por experiments.
- *Khejri* performed better in terms of root length, water relations, chlorophyll content and cell membrane stability than other tree species i.e. rohira, neem and bakain under rainfed condition beside poor shoot growth and dry matter accumulation.

PLANT PROTECTION

- The *Rabi* crops of wheat /barley rotated with Indian mustard or chickpea for 2-3 years suppressed the nematode population. Wheat/barley crops could be successfully grown for the following 3-4 years. Additionally, some other vegetable *Rabi* crops like carrot, coriander etc. was also found suitable for crop rotation to effectively manage the menace of the nematode.
- Population of adults largely determined the intensity of the ber fruit fly incidence in subsequent period and also the incidence of fruit fly increased with the maturity of fruits.
- The pearl millet crop sown in the second and third week of July contracted more smut than earlier (last week of June to mid-July) or later (last week of July onwards) sowings. The

higher smut incidence in mid sowings was due to occurrence of rain 36-43 DAS that coincided with the flowering.

- Spray of Bavistin (0.1 per cent) was comparatively more effective and resulted in minimum disease intensity 11.3 percent and 77.8 per cent control of the sooty mould disease of ber. The next efficacious fungicide in descending order of significance was Blitox-50 (0.3 percent) which could provide 69.7 per cent disease control. The efficacy of other fungicidal treatments ranged from 38.6 to 62.2per cent. Neem leaf extract and its commercial preparation proved least effective. The response of Dithane M-45, Captan and Dithane Z-78 was comparatively poor, though, found superior to control.

- The stepwise regression analysis for powdery mildew of ber showed the variation between 61-88 per cent during five years using maximum temperature and relative humidity. The result indicated negative and significant correlation with temperature during all the years. Logistic transformation provided better fit than other modules.

- Epidemiology of Fig rust had negative and significant correlation with temperature during all the years. Stepwise regression analysis showed that much of the variations can be explained (71-87 per cent) using temperature as one of the independent variables.

- Amongst thirty three ber varieties, infestation of fruit fly (Nov. to Mar.) in BS1 was lower (0.6 per cent) and highest in Gola (46.2 percent) As per rating scale, BS 1, Banarsi Karaka, Sanaur No.3 and Illachi were the varieties which were categorized as resistant whereas rests of the varieties were either moderately resistant or susceptible.

- Sowing in first fortnight of November with normal spacing (30 cm) and three irrigations (pre-sowing, flowering and pod formation stages) resulted in less incidence of disease of wilt and higher yield of field pea.

- Early sowing (October 20 to 30) escaped infection of powdery mildew in fenugreek and ultimately higher yield. The stage of the crop played an important role in the spread of disease and magnitude of losses.

- The Indian mustard crop sown between fourth weeks of October to first week of November had minimum white rot severity of 9.5 per cent while the incidence was higher (49.2per cent) in sowing between second to third weeks of October. Varied response was observed in different cultivars. The percentage of white rust affected plants was observed under fallow-Indian mustard rotations was 13.7. The disease incidence was more (24.6per cent) in fields given only pre sowing + one irrigation.

- Under field conditions, soaking of clusterbean seeds in pure neem extract resulted in least dry root rot disease incidence (4.7 per cent) and highest grain yield (6.64 q/ha). The low yield levels are because of jassid and bacterial blight attack.

- The cross inoculation of powdery mildew pathogen from ber to weed and vice-versa resulted in failure of establishment of disease on either of the hosts thereby indicating a negative role of collateral/alternate hosts in disease dissemination and further disease development.
- Sixteen species of whitegrub beetle were identified from RRS, Bawal and most prevalent species is *Holotrichia consanguinea.* The insects were collected from the orchard of ber, aonla, bael, lasora and pomegranate. Besides this, intensive survey was conducted in some parts of South-Western Haryana upto 2011. The insects specimens were got identified from IARI, New Delhi and HAU, Hisar. Fix plot survey and roving survey revealed that the major parts pests of ber crop were white grub (*Holotrichia consanguinea. H. serrata, Anomola bangalensis, Adorsalis corsalis, Schizonycha ruficolis, Maladera* spp.), fruit fly (*Carpomyia vasuviana*) and bark eating caterpillar (*Inderbella wistoni*). During 2011, fruit borer and flying fox were also encountered causing considerable damage to ber crop. The shoot gall maker (*Betousa stylophora*) and bark eating caterpillar (*Inderbella* spp.) were recorded as common pests in aonla. In lasora, leaf gall mite and leaf miner were the major pests. Root borer, leaf miner and citrus caterpillar were the pests observed on bael. Leaf mite (*Eustranycha orientalis)* and anar butterfly (*Virachola isocratus*) were the common pests in pomegranate.
- Seed treatment with chlorpyriphos @ 15 ml/kg seed provided maximum protection against termite in chickpea variety HC-1.
- Identification of different micro-organisms causing post harvest spoilage.Microsopic examination revealed eight fungi associated with post harvest decay viz. *Botryodiplodia theobromae, Fusarium* sp., *Alternaria alternata, Aspergillus niger, Aspergillus flavus, Penicillium expansum and Phoma eupyrena.* The overall incidence of these fruit rots ranged between 2-3 per cent. All the fungi were found to be the weak parasites.
- Seed treatment with chlorpyriphos @ 20 ml/kg was most effective in controlling whitegrub infestation in pearl millet followed by imidacloprid, cypermethrin and fenvalerate @ 10 ml/kg seed each. However, 15 and 20 ml/kg seed of chlorpyriphos, quinalphos, cypermethrin and imidacloprid were better than 5 and 10 ml in controlling whitegrub in groundnut.
- Ber varieties Banarsi Karaka, Reshmi, Sanur-7 and Nauki were comparatively less susceptible to fruit fly.
- The percentage of plant mortality due to whitegrub in pearl millet was found lowest when phorate 10 G @ 8 kg/acre was applied as pre-sowing application.
- Seed treatment with *Pseudomonas maltophilia* @ 20 ml/kg seed and ethion 50 EC @ 5 ml/kg seed were found superior in controlling termite in wheat.
- The seed treatment with carbendazim 50 WP @ 2g/kg followed by two sprays of 0.1 per cent carbendazim at 45-50 and 65-70 DAS is recommended for effective control of stem rot of Indian mustard.

- Seed treatment of imidacloprid 17.8 SL @ 5 ml/kg seed and spray of Malathion 50 EC @ 1 ml/litre of water were found effective for the control of painted bug in Indian mustard during initial 7-10 days after sowing.

- The major insects species of castor recorded during the period (2012-15) were castor semilooper (*Acanthodelta janata* Linnaeus), castor hairy caterpillar (*Euproctis lunata* Walker), castor capsule borer (*Dichocrosis punctiferalis* Guenee) and castor leaf hopper (*Empoassca flvescens* Fabr.).

- Root borers (110-120 mm) were found associated with dried bael plants. The mortality of one plant was observed in soil application of *Trichoderma* + Phorate against seven in control.
- The 15th October was observed to be the best time under spray schedule with NSKE 5per cent (1st spray), acephate 75 SP @ 1 g/l (2nd spray) and NSKE 5per cent (3rd spray) at 15 days interval for sprays initiation to minimize the infestation of ber fruit borer, *Meridarchis scyrodes* Meyrick in South West Haryana.
- Myclobutanil 10 percent WP (0.04per cent) and Hexaconazole 5 percent EC (0.1per cent) stood at first place in curtailing the ber powdery mildew incidence and offered 92.2 percent control of the disease.
- Studies on the management of ber fruit fly with new molecules carried, revealed that two foliar sprays of dimethoate 30 EC@ 1 ml/ l or malathion 50 EC @1ml/ l of water at 15 days interval can effectively control the damage of ber fruit fly.The spray should be started at pea nut size of fruits.The spinosad 45 SC (2.11per cent infestation), dimethoate30 EC (2.84per cent infestation) and malathion 50 EC (3.43per cent infestation) were statistically at par in reducing the fruit fly infestation. The maximum yield was obtained in spinosad 45 SC followed by dimethoate 30 EC and malathion 50 EC as compared to control. The cost benefit ratio was maximum in dimethoate (1:2.25) followed by Malathion (1:2.34) and NSKE 5per cent registered lowest cost benefit ratio (1:1.82).
- In guava, the castor capsule borer, C*onogethes punctiferalis* caused considerable damage to guava fruits and peak level of infestation (8.0 per cent) was recorded in second fortnight of October during 2018 when temperature ranged from 14.7 to 33.3 ^{o}C and relative humidity from 32. 5 to 82.5 per cent.
- Two native Isolates of *Trichderma asperellum*, HST-1 (ITCC No. 9071) and HMT-2 (ITCC No. 9072) were found best against Fusarium wilt and were submitted to ITCC, Division of Plant Pathology, IARI, New Delhi for open assess.
- A phytoplasma disease was first time reported in *Meilia dubia* (Agro forest tree) in Haryana at RRS Bawal in Feb, 2023. Pruning of infested portion was done followed by foliar spray of streptocycline @1gm per ten liter plus copper oxychloride @3 gm per liter of water which stopped further infestation and spread to other trees.
- A total 2673 (100 ml each) Bio-fertilizer was produced and sold during the year 2022-23.

MICROBIOLOGY

- Nature of waste material and type of vermicomposting affected the availability of nutrients. The C : N ratio was lowest in the vermi-compost prepared from cattle waste + Indian mustard crop residue in ridge system. The initial C : N value of Indian mustard residue + cattle dung was 82.59, this value decreased to 59.56 and 53.16 after 30 days and 35.86 and 21.9 after 60 days. The total P was not affected by method of composting.
- About 9 per cent increase in pearl millet grain yield at 75 per cent recommended fertilizer with vermi-compost.
- Residue of crops incorporated with 75 per cent RF treatment in clusterbean-Indian mustard cropping system not only increased the yield of both crops but decreased soil pH and increased available P and K.
- The *Rhizobium* cultures isolated from nodules of cluster bean collected from South-West Haryana were screened for drought tolerance and other biological traits under lab conditions observed that seed yield under different *Rhizobium* cultures varied from 12.09 q/ha to 14.47 q/ha. The per cent increase in seed yield varied from 6.05 to 15.21 due to inoculation. Maximum seed yield was recorded with GB14c; followed by GH2b. Nodule fresh weight varied from 10 mg to 28 mg; while nodule no. ranged from 0.8 to 3.7. Three drought tolerant isolates namely GB14c, GH2b and GB32a out yielded the uninoculated 75per cent RDF by more than 10 per cent.
- Chickpea *rhizobial* isolates CK 15 and CK 16 were selected as promising multi-trait rhizobia to be used as efficient bioinoculants over commercial chickpea *Rhizobium* strain. The maximum seed yield was observed with 75per cent RDF+CK25; closely followed by 75per cent RDF+CK16. These values were 10.36 per cent and 10.16 per cent higher over 75per cent RDF alone. Two bioinoculants CK15 and CK16 consistently performed better over the reference strain 1233.
- A total 2673 (100 ml each) Bio-fertilizer was produced and sold during the year 2022-23.

HORTICULTURE

The Regional Research Station, Bawal is one of the coordinating research centres under All India Coordinated Research Project on Arid Zone Fruits. The fruit crops covered in the project are ber, aonla, pomegranate, bael, datepalm, lasora and fig. The major focus of this coordinating centre is to evolve high yielding varieties of fruit crops in rainfed conditions and to develop suitable production, protection, post harvest and processing technologies for arid fruits.Fruit trees like ber, aonla, bael, lasora, phalsa, etc have been found well suited for arid environment. Significant advances have been made in recent times towards providing technology support for their cultivation. Important fruit crops and their varieties suited to arid regions of Haryana are depicted in below:

Important fruit crops and their varieties suited to arid regions of Haryana.

Fruit crop	Varieties
Ber	Gola, Kaithali, Mudia Murhara, Umran, Goma Kriti, CIAH Sel-1, CIAH Sel-2, Narendra Ber Sel-1
Aonla	Chakaiya, Banarsi, NA 6, NA 7, NA 10, NA 20, Kanchan, Krishna, BSR-1
Bael	Gonda Selection, NB 5, NB 9, NB 16, NB 17, Pant Aprana, Pant Sujata, CISH-1, CISH-2
Karonda	Pink, Green, White
Phalsa	Tall, Dwarf
Lasora	Local selection (Bold fruit), Thar Bold, Karan Lasora,

- Extensive germplasm surveys of ber orchards were conducted to identify superior and promising genotypes in various parts of Haryana, Rajasthan and Uttar Pradesh in collaboration with NBPGR, New Delhi. More than 100 varieties/ strains of ber are being maintained by Regional Research Station Bawal (Rewari), Haryana. Powdery mildew resistant Ber varieties like Darakhi No. 1, Darakhi No. 2, Gulli, Villaiti and Seedless from Rahuri centre and fruit fly resistant varieties Tikadi and Khirni from CAZRI Jodhpur and Bhusawar (Rajasthan) were collected. The following genotypes of different fruit crops are being maintained and evaluated for growth and yield characters as given below :

Available germplasm at Regional Research Station, Bawal

S/No.	Name	Scientific name	Number
1	Aonla	*Emblica officinalis*	12
2	Bael	*Aegle marmelos*	24
3	Ber	*Zizyphus mauritiana*	102
4	Phalsa	*Grewia subinaegualis*	03
5	Fig	*Ficus carica*	01
6	Karonda	*Carissa carandus*	03
7	Lasora	*Cordia myxa*	12
8	Guava	*Psidium guajava*	07

9	Pomegranate	*Punica granatum*	13

- Amongst 25 years old seedlings of Aonla germplasm, a seedling (BA-19) with light pink colour fruits, having good fruit size and weight (23 g) was identified. Fruits from this seedling may have carotene like additional medicinal constituents. Although the yield from this seedling was less as compared to commercial varieties even than this may be used in future breeding programme to enhance the medicinal and nutritional qualities of the present aonla varieties.
- The compatibility of two scions of ber i.e. Gola and Kaithali with four different root stocks for growth, yield and quality revealed that maximum plant height was recorded in cv. Kaithli budded on *Zizyphus rotundifolia* followed by cv. Gola budded on the same root stock. Stock girth was also maximum in cv. Kaithali budded on *Zizyphus rotundifolia* and least was observed when Gola/Kaithali cvs. budded on *Zizyphus nummularia* root stock. Similar pattern was observed in scion girth. In general, *Zizyphus nummularia* recorded poor plant height, stock and scion girth and its ratios on both the scion cultivars. Fruit weight and yield were also higher in cv. Kaithali budded on *Zizyphus rotundifolia*. However, least yield was observed in *Zizyphus nummularia*/Gola combination.
- Spacing trial on ber cv Gola revealed that a spacing of 8 x 8 meter (row to row and plant to plant) was found optimum for higher yield and quality of ber.
- Optimum time of pruning in ber was found between 25th May to 5th June for higher yield and quality.
- Pruning of ber trees after 6 secondary branches on one year old shoots proved to be the best in improving the fruit yield and quality.
- In bael, spray of borax @0.1per cent followed by zinc sulphate @ 0.6 per cent was the most effective in checking fruit drop, increasing the fruit weight and yield. Borax @ 0.1per cent has been found the most effective in checking the fruit drop and cracking and in improving the yield and fruit quality, immediately followed by 2,4-D @5 ppm.
- Application of phosphorus in ber (cv.Umran) partly through Single Super Phosphate (SSP) and partly through Farm Yard Mannure (FYM) resulted in higher total soluble solids and fruit weight as compared to phosphorus applied through SSP only.
- Amongst five mulches (black polythene, sand mulch, a local weed sarkanda (*Saccharum munja*), pearl millet straw and groundnut shell) in ber orchard, black polythene mulch gave the highest yield and was found the most effective in checking the weed growth and conserving the moisture at all depths of sampling.

- For rejuvenation of old and unproductive ber orchards the plants should be headed back at 5' height from ground level and pruning of sprouted shoots retaining 3' length from the main trunk during the subsequent year is recommended.
- BS 1 a promising germplasm of ber found resistant to fruit fly and powdery mildew [fruit weight (24.6 g), yield (135 kg/tree), TSS (18.6 ^{o}B), acidity (0.54 per cent), ascorbic acid (96.2 mg/ 100 g)] and ripned during last week of February.
- For vegetative propagation of lasora T-budding during middle of July has been found superior. The LBS 1 a promising lasora germplasm fruiting twice a year (June –July and September – October), large fruit size and excellent for pickle have also been identified.
- Twenty two germplasm of various arid zone fruits maintained in germ plasm collection block at RRS, Bawal have been characterized (Lasora-4, mulberry-5, karonda-2, phalsa-4, aonla-2, ber-2, guava-1, bael-1 and nimbu-1) and allocated I/C numbers by the National Bureau of Plant Genetic Resources (ARIS Cell), New Delhi.
- Rejuvenation of ber orchard: Heading back at 5' height from ground level and pruning of sprouted shoots retaining 3' length from the main trunk during the subsequent year is recommended.
- Propagation by T-budding in jamun: Propagation of Jamun is successful by T-budding method in the month of August. Rootstocks can be prepared according to method explained in patch budding.
- High density planting in bael: For High density planting, bael plants can be planted at a distance of 8m x 5m.

- **POST-HARVEST TECHNOLOGY**
- **Utilization of processing wastes of bael (*Aegle marmelos* Correa)**

- Bael peel and pomace are the two processing wastes left over in abundance constituting 35-40 per cent of the total fruit weight. Palatability of these wastes was adjudged by feeding to the cows after mixing with cattle feed in a ratio of 1:3. Peel contained 27.34 per cent crude fibre, 31.85 per cent crude protein, 1.0 per cent calcium and 0.14 per cent phosphorus whereas, pomace contained 9.98, 10.50, 1.20 and 0.10 per cent of crude fibre, crude protein, calcium and phosphorus, respectively. After mixing with the cattle feed in 1:3, the wastes were readily acceptable to the cows, which confirmed that it can be used as animal feed. *In vitro* digestibility for different components of the wastes, it was observed that upto 40.1per cent of the total peel and 69.6 per cent of the pomace was acceptable. Use of these wastes as animal feed not only reduce the feeding and processing costs but also prevent health hazards and environmental pollution.

- Processing and preparation of new products Bael RTS, Bael Vinegar and Bael Wine was carried out. The recipe for standardization of bael RTS were tried and the final recipe was standardized as:

- **For one litre RTS**
- Bael pulp = 100 g
- Sugar = 100 g
- Citric Acid = 2.5 – 3.0 g
- Water = 800 ml

- Preparation of bael vinegar and wine was also taken up, using *Saccharomyces ellipsoideus* yeast for the fermentation of the clarified bael juice. The resultant wine was not acceptable to the panel of judges because of higher acidity and unpalatable taste. The vinegar was moderately acceptable.

- Ambient storage of bael RTS product pasteurized at 85^{o}C for 20 minutes could be stored for 11-12 weeks only without any undesirable changes whereas the unpasteurized bottles could not be stored for more than five weeks. There was a slight increase in TSS for 1-2 weeks, after which the TSS as well as the acidity declined gradually till the spoilage of the product. Acceptability of the bael wine decreased progressively with the increased storage period; however, there was no change in the bael vinegar.

FORESTRY

Agro-forestry Systems

- The green fodder yield for all the crops (pearl millet, cowpea, cluster bean and anjan grass), was more in association with trees (*Khejri*) as compared to sole cropping except anjan grass.

- Performance of poplar *(Populus deltoides*) interplanted with crops under different levels of spacing and irrigation was studied and it was found that poplar is not suitable for this region.
- Fifteen years old top feed tree species (Mopane, Anjan and Acacia) significantly reduced the fodder yield of cowpea, pearl millet and clusterbean. Minimum yield reduction was found in cow pea under all the tree species and cow pea + mopane agroforestry system was found suitable for fodder production as only 27.7per cent reduction was recorded under this system as compared sole cropping.
- The silvi-horti systems of aonla + mahaneem (*Ailanthus excelsa)* and guava+ mahaneem significantly reduced the green fodder yield of dhaincha, cowpea and bajri after 15 years of establishment when compared with sole cropping. Maximum green fodder yield (487.50

q/ha) was recorded in bajri sole cropping. Maximum yield (196.25 q/ha) was also recorded in bajri under guava+ mahaneem system among silvi-horti systems.

- The CO_2 sequestration in *Mahaneem* under different densities varied from 3.83 to 15.90 t/ ha/yr after 6 years of plantation. Maximum carbon sequestration (15.90 t/ha/yr) was recrded under sole plantation.
- The *Mahaneem* plantation done in both the directions (N-S and E-W) on bunds of field did not affect the yield of crops raised during 3 rd year of plantation but crop yields were significantly reduced near tree row in both the directions (N-S and E-W) during 6 th year of plantation. Maximum and significant reduction was recorded from 0 to 3 m followed by 3 to 6 m in both directions when compared with 15 to 18 m distance from tree row.

- Significant reduction in green fodder yield of dhaincha, cowpea and bajri was recorded under silvi-horti agroforestry models of aonla + *Mahaneem* and guava + *Mahaneem* after 19 years of establishment when compared with sole cropping. Sole bajri produced maximum fodder yield. Among agroforestry models, maximum yield was also recorded in bajri under guava+ *Mahaneem*. During *Rabi*, barley also showed similar trend under different agroforestry models. Maximum barley yield was recorded in Dhaincha - Barley + Guava + *Mahaneem* agroforsrty model. *Mahaneem* sequestered more carbon as compared to aonla and guava.
- From preliminary observations the performance of Melia dubia is very satisfactory in terms of growth parameters of tree height and girth at breast height in south west Haryana

RECOMMENDATIONS INCLUDED IN PACKAGE OF PRACTICES, CCS HAU, HISAR

Based on the research work done at the station, following recommendations have found place in package of practices:

1. Clusterbean variety HG 365 should be sown at a spacing of 30 cm using a seed rate of 15 kg/ha.
2. Short duration variety of clusterbean should be sown in the end of June for higher seed yield,
3. Application of sulphur @ 20 kg/ha for higher seed and gum yield of clusterbean,
4. Developed agronomy in relation to sowing time, spacing and seed rate for variety HG 563 of clusterbean.
5. Inoculation of oat seed with *Azotobacter* is beneficial for better returns.

6. Developed entire package of practices of the crop fenugreek for the region particularly in relation to sowing time, seed rate, spacing, and fertilizer requirement and irrigation management.
7. Sodic waters upto RSC 12 me/l EC less than 4000 µ mhos/cm can be successfully used in light textured soil for pearl millet-wheat, pearl millet-Indian Indian mustard, fallow-wheat, fallow- Indian Indian mustard, sorghum (fodder)-wheat, sorghum- Indian Indian mustard, desi cotton- Indian Indian mustard and dhaincha-wheat rotation.
8. Gypsum has been found to be better amendment than FYM for reclamation of sodic soil and water.
9. Application of 50 per cent of recommended amount of gypsum on the basis of soil test before sowing of *Kharif* crops is recommended.
10. Application of 100 per cent of recommended amount of gypsum on the basis of soil test in *Rabi* crops if sodic field is kept fallow in *Kharif* season is optimum.
11. Application of 100 per cent of recommended amount of gypsum on the basis of RSC of irrigation water before sowing of *Rabi* crops is recommended.
12. Instead of keeping the field fallow in *Kharif*, green manuring with dhaincha (35-40 days) in *Kharif* is recommended before sowing of *Rabi* crops.
13. Seed treatment with Raxil 2 DS @ 1g/kg seed controls loose smut of wheat.
14. Sowing of fenugreek around October 30 escapes powdery mildew.
15. For the control of *Kherjal* (*Pluchea lanceolata*), recommendation of Glyphosate has been included in the package.
16. Two sprays of borax @ 0.1per cent at full bloom and after fruit-set were found the most effective in checking the fruit drop and cracking and in improving the yield and fruit quality of bael, immediately followed by 2, 4-D @ 5 ppm.
17. Pearl millet Hybrid HHB 216, HHB 223, HHB 226, HHB 234 and HHB 256 at National level were released during reporting period.
18. Release of Indian mustard varieties RH 0406 and RH 0749 at National level during reporting period.
19. In coarse textured low to medium potash status soils, K fertilization @ 30 kg K_2O/ha is recommended to maintain soil K fertility and harvest optimum pearl millet yield.

20. In coarse textured low to medium potash status soils, K fertilization @ 20 kg K_2O/ha is recommended to maintain soil K fertility and harvest optimum cluster bean yield.
21. In coarse textured low to medium potash status, K fertilization @ 20 kg K_2O/ha is recommended to maintain soil K fertility and harvest optimum Indian Indian mustard yield.
22. Use of biomix (*Azotobactor* + *Azospirillium* + PSB) @ 100 ml as a seed inoculants alongwith recommended dose of fertilizer in pearl millet crop.
23. Castor hybrid DCH-177 has been found the best one under Haryana conditions.
24. In south-Western Haryana, first fortnight of July is the optimum time for castor sowing to get higher seed yield and higher profits.
25. Hybrid castor should be sown keeping the row spacing from 90-120 cm and plant to plant spacing of 90 cm. Seed requirement is 4.0 to 5.0 kg/ha.
26. In irrigated castor, apply 80-120 kg N, 60 kg P_2O_5 and 30 kg K_2O/ha. Apply 40 kg N, full dose of P and K at the time of sowing and rest of N in splits each of 20 kg with irrigation after each picking of mature spikes.
27. Two rows of clusterbean or mothbean should be sown in castor having 120 cm row spacing.
28. Apply 30 kg S/ha through gypsum as basal to castor for higher seed yield.
29. For the control of parasitic weed *Orobanche aegyptiaca* in Indian mustard crop, two sprays of Round Up/Glycel (glyphosate 41per cent SL) @ 25 ml/acre at 30 days after sowing and 50 ml/acre at 55 days after sowing of Indian mustard should be made by using 150 litres of water/acre through flat fan nozzle, which provides 65-90per cent control of this weed without any crop suppression. However, care should be taken that the crop should not suffer from any moisture stress at the time and immediately after spray of glyphosate, so irrigate the crop 2-3 days before or after spray. Use of higher than recommended dose may cause injury to the crop.
30. Application of Oxadiargyl @ 0.15 Kg/ha as pre-emergence in irrigated Indian Indian mustard against annual weeds is recommended for effective weed management in Indian Indian mustard under Bawal conditions.
31. The two sprays of chlorothalonil (0.2 per cent) for the control of aonla rust ie recommended The spray should be initiated at the initiation of the disease and be repeated after 15 days
32. Two sprays (1st at the appearance and 2nd after 15 days) of Karathane (0.1per cent) are recommended for control of powdery mildew of ber. The bio-control agents (*Pseudomonas*

fluorescens and *Trichoderma viride*) were not effective in the control of ber powdery mildew.

33. The *Fusarium solani* alongwith root borer is the cause of drying in bael plants. However, deficiency of N, P and Zn may be the predisposing factor.
34. The seed treatment with carbedazim 50 WP followed by two sprays at 45-50 and 65-70 DAS is recommended for the control of stem rot of Indian Indian mustard.
35. Application of 20 kg K_2O/ha in mung bean in coarse textured low to medium potash status soils of Haryana has been recommended and included in package of practices.
36. In rainfed Indian Indian mustard, foliar spray of agro-chemicals i.e., thio-urea (0.05 per cent) or urea (1per cent) at 50 per cent flowering and 50 per cent pod filling stage superimposed at recommended dose of fertilizer ((40 kg N + 20 Kg P_2O_5 + 30 Kg S/ha) is recommended for enhancing productivity under Bawal conditions .
37. Developed *Mahaneem* based agroforestry system for arid and semi-arid Haryana
38. Application of 20 kg K_2O/ha in chick pea in coarse textured low to medium potash status soils of Haryana is recommended.
39. Application of 30 kg S/ha in chickpea in coarse textured low Sulphur status soils of Haryana has is recommended.
40. For rejuvianation of old and unproductive ber orchards the plants should be headed back at 5' height from ground level and pruning of sprouted shoots retaining 3' length from the main trunk during the subsequent year is recommended.
41. Lasora germplasm fruiting twice a year has been identified and being multiplied. Superior germplasm of mulberry and phalsa have been identified and being multiplied for detailed studies.Germplasm of seedless jamun have been collected and transplanted in germplasm collection block for further studies. Powdery mildew and fruitfly resistant germplasm of ber have been identified and is being multiplied for further use.

Recommendations finalized at National level (All India Coordinated Research Project Group Workers Meetings)

1. For higher yield and economic returns clusterbean should be supplied with 25 kg $ZnSO_4$/ha as basal application, where soils are deficient in Zn. In case the Zn is not given at sowing, it can be supplemented by one foliar spray of 0.5per cent $ZnSO_4$ at 25 to 35 DAS.

2. Adoption of recommended practices alongwith thinning and detopping at bud initiation stage in Indian mustard proved to be the most remunerative practice under low monetary input technology.
3. Spreading of 5 t FYM/ha over planted rows of pearl millet was found beneficial for better plant stand establishment under rainfed condition in Zone A-1.
4. Adoption of clusterbean-Indian Indian mustard sequence and application of 40 kg S/ha to Indian mustard was more remunerative over all other cropping sequences at Bawal. Therefore, this sequence is recommended for South-Western parts of Haryana.
5. In pearl millet- Indian Indian mustard sequence, application of recommended dose of fertilizer (80 kg N +30 kg P_2O_5/ha) alongwith 10 t FYM + 40 kg S + 25 kg $ZnSO_4$/ha in the Indian mustard crop is recommended for southern parts of Haryana.
6. Carbendazim or thiophanate methyl spray @ 0.1per cent along with chlorothalonil as a substitute controls *Graphiola* leaf spot of date palm. First spray should be initiated after the pruning of infected twigs in September at the start of the disease followed by three more sprays at an interval of 15 days.
7. Spray chlorothaonil (Kavach) @ 0.2 per cent and copper oxychloride (Blitox-50) @ 0.3 per cent for the control of fig rust disease. First spray is to be applied at the initiation of the disease followed by three more sprays at 15 days interval.
8. On the basis of six years data, two sprays of Karathane (dinocap) or Bayleton (triademefon) at an interval of 15 days were recommended for the control of powdery mildew of ber.
9. Two sprays of Bavistin @ 0.1 per cent at 15 days interval along with Blitox- 50 (copper oxychloride) as a substitute gives promising control black leaf spot of ber.
10. For the concomitant control of powdery mildew and fruit fly in ber, spray two to three times with monocrotophos (0.04 per cent) + dinocap (Karathane) (0.1 per cent) at 15 days interval.
11. Three alternate sprays of monocrotophos 0.03, fenthion 0.05 and carbaryl 0.1 per cent controlled the fruit fly infestation effectively. Digging the soil under tree canopy during summer and mixing with carbaryl dust @ 25 kg/ha also effectively controlled fruit fly.
12. In rainfed Indian Indian mustard foliar spray of agro-chemicals i.e. thiourea (0.05 per cent) or urea (1per cent) at 50per cent flowering stage + 50per cent pod filling stage superimposed at recommended dose of fertilizer (RDF) is recommended for enhancing productivity under Bawal conditions. In: Proceedings of "21st Annual Group Meeting of AICRP on Rapeseed-

Indian mustard" held at BCKV, Nadia, (West Bengal) on August 20-22, 2014. Session-III: Planning and Technical Programme Formulation: Agronomy, p. A-1 to 2.

13. Application of 20 kg P_2O_5 + seed treatment of castor with biophos @ 600g/kg seed in irrigated conditions of Haryana and UP for enhancing the seed yield and economic returns. Approved in Annual Group Meet of Research workers' on castor held at Davangere from May 14-16, 2015.
14. Pre-emergence application of pendimethalin (1.0 Kg/ha) + hand weeding at 40DAS for realizing higher weed control efficiency, seed yield and economic returns under irrigated conditions of Karnataka and Haryana. Approved in Annual Group Meet of Research workers' on castor held at Davangere from May 14-16, 2015.
15. The *Fusarium solani* alongwith root borer is the cause of drying in bael plants. However, deficiency of N, P, Zn and Fe may be the predisposing factor in it. Concluded during XIX Research Workers Annual Meet 2014 held at Sri Karan Narendra Agriculture University, Jobner from December 12 to 14, 2014.
16. For rejuvianation of old and unproductive ber orchards the plants should be headed back at 5' height from ground level and four strongest shoots be retained. Pruning level leaving 3' feet from the main trunk resulted in proper canopy, higher yield and quality of fruits in AICRP, Arid zone Fruits at Anant Pur, AP.
17. Indian Indian mustard hybrid DMH-1 and PAC-432 were found superior to check (Kranti) acroos the Zone 11 (including Bawal). Hybrid should be sown at a spacing of 45 cm x 15 cm and 125 per cent of the recommended dose of fertilizers (100 kg N + 37.5 Kg P_2O_5 + 50 Kg S/ha) is recommended for higher production under Bawal conditions.

Projects sanctioned/sponsored by external funding agencies:

S.No.	Name of scheme	Year of start	Year of termination	Funding agency
1.	Raising yield ceilings in oilseed: through physio-logical approaches and resistancebreeding (taramira)	2000	2003	NATP (ICAR)
2.	Water requirement and irrigation scheduling of different agri-silvi-horti Systems	2000	2004	NATP (ICAR)
3.	On farm research for enhancing productivity of pearl millet in arid regions	2000	2004	NATP (ICAR)
4.	Residue management options in rapeseed Indian	2004	2007	ICAR

	mustard based cropping system Farmers' participatory approach			
5.	Studies on potash response in field crops in light textured soils of Southern Haryana	2002	2010	IPI
6.	Studies on potash responses to Jatropha in light textured soils of Southern Haryana. (2010 to 2012)	2010	2012	IPL
7.	Identification of elite trees, standardization of nursery and agro-techniques in Jatropha curcas and Pongmia pinnata	2004	2012	NOVOD
8.	Promotion of castor based cropping systems for raising farm income in South-West Haryana	2013	2015	RKVY
9.	Promotion of Zero tillage technology for wheat (*Triticum aestivum*) crop in Rewari district of South-West Haryana	2013	2015	RKVY
10.	Strengthening of seed production programme at CCS, HAU. RRS, Bawal	2013	2015	RKVY
11.	Plus tree selection and development of *Ailanthus excelsa* based agro-forestry systems for south-west Haryana	2012	2016	DST
12	Promotion of castor for crop diversification and higher system productivity in South-West Haryana	2017	2019	RKVY
13	Promotion of potassium fertilization in field crops of South-West Haryana	2017	2019	RKVY
14	Strengthening of biofertilizer production lab. at Regional Research Station, Bawal	2017	2019	RKVY

12.0 Awards/Distinctions won by scientists individually/Team

Name of Scientist (s)	**Name of Award/ Distinction**	**Conferred by**	**Work for which Award/ Distinction/ Conferred (only 4 or 5 lines)**
R.A.S. Lamba Yogender Kumar	Best team award	AICPMIP	Outstanding contribution in the field of Pearl millet improvement on 14.03.2014 at RARI, Durgapura (Jaipur) in the 49th Annual AICPMIP Workshop as member of the team
J. S. Yadav	Best worker award	AICRP Castor	For notable work on castor Agronomy
Sushil Sharma, Ram Karan Gaur and S.S. Yadav	Best poster paper award	Directorate of Research, CCS Haryana Agricultural University, Hisar	Integrated approach for the management of collar rot and white grub in ground nut in South West Haryana,"National seminar on reorientation of agricultural research to ensure national food security" from Jan. 6-7, 2014: 215.
Abha Tikkoo, SSYadav and N Kaushik	Best poster paper award	CCS HAU, Hisar	Effect of irrigation, nitrogen and potassium on seed yield and oil content of *Jatropha curcas".* on 27-28 th March 2012.

P.K.Yadav, S.S.Yadav and Abha Tikkoo	Best poster paper award	CCS HAU, Hisar	"Long term effect of sodic water, FYM and gypsum on physico – chemical characteristics of a light textured soil.
Kumar, V.; Yadav, A. and Rathee, S.S.	Best poster paper award	CCS HAU, Hisar	Nitrogen and phosphorous management of different barley genotypes.
Y.P.Yadav	AICPMIP Best Scientist award	AICRP,Pearl millet	Pearl millet research
Bikram Singh Y.P.Yadav	Best Performing Sub-Centre	AICRP,R&M	Breeding material generated, conduct of trials and overall support to the AICRP-RM programme
R.A.S. Lamba Yogender Kumar	Team award	AICPMIP	Pearl millet research for the year 2011
RAS lamba & Y.Kumar	Best performing Sub centre	AICPMIP	Breeding material generated, conduct of trials and Overall support to the AICRP-RM programme
S.S.Yadav, Abha Tikkoo & Sultan Singh	FAI Annual Award-2010	FAI-IPI	For best research and Field Work in balanced fertilizationwith emphasis to potassium management in field crops.
R.A.S. Lamba Yogender Kumar	Appreciation certificate as Team Members	Society for Millets Research (Indian Institute of Millets Research), Rajendranagar, Hyderabad	For outstanding contribution in the field of Pearl millet Improvement on 24.04.2015 at TNAU, Coimbatore in the 50th Annual AICPMIP Workshop.
Ram Karan Gaur	Second best poster presentation	Society for Advancement of Human and Nature (SADNA)	National Symposium on Modern Agrotechnology for Nutritional Security and Health held at Dr. Y. S. Parmar UHF Nauni Solan from 21-23 April, 2015.
J.P. Singh K.S. Grewal R.S. Antil S.S. Yadav and Abha Tikkoo	IPI-FAI Award, December, 2015	FAI, New Delhi	Promoting balanced and integrated fertilizers use with emphasis on potassium
Yash Pal Yadav	National Award-SRMR Fellow 2017	AICRP, R&M	For significant contribution towards the advancement of Rapeseed – Indian mustard Research and Development

13.0 Book (s) published and research publication (s) other than publications from student's thesis in reputed scientific journals

About 750 research papers, 528 articles, 77 bulletins, 215 booklets, 12 books and 16 manuals have been published.

Name of Publications	Numbers

Books	**12**
Book Chapters	**06**
Research Papers	**750**
Paper Abstracted	**155**
Popular Articles	**528**
Bulletein	**77**
Pumphlets	**25**
Manual	**16**
Booklets	**215**
Total	**1569**