AICRP-CHICKPEA

Objectives

- Collection, maintenance, evaluation and characterization of chickpea germplasm
- Development of Desi and Kabuli high yielding varieties with early to medium maturity for timely and late planting conditions suitable for mechanical harvesting with resistance / tolerance to *Botrytis gray* mould, wilt and pod borer along with acceptable seed size and colour,
- Development of high yielding varieties resistant for multiple stresses and races having stable performance,
- To create a wide range of variations through varietal and inter-specific hybridization and induced mutations,
- Genetic investigation on various aspects to generate basic knowledge in the area of genetics and plant breeding,
- Evaluation of elite lines developed at other centers and
- Production of nucleus and breeder seed of released varieties.
- Development of suitable agronomy of newly developed varieties of chickpea for normal and late sown conditions,
- To quantify the magnitude of weed competition and to develop suitable weed management schedule,
- To screen out herbicide suitable for post emergence application in chickpea alongwith its appropriate dose and time of application, and
- To study the agronomic feasibility of coriander intercropping with chickpea and its nutrient management strategies.
- Isolation and characterization of multiple traits *Mesorhizobium* sp. for improving biological N_2 fixation.
- Isolation and characterization of potential Rhizobacteria for improving chickpea-*Mesorhizobium* symbiosis.
- Improving the efficiency of *Mesorhizobium* inoculants in pulse crops through synergistic rhizobacteria.
- Intensive field screening in sick nursery of available indigenous and exotic germplasm to find out sources of resistance against BGM.
- To find out the efficacy of plant extracts and bio- agents having property of inducing resistance against BGM and Ascochyta blight.
- To develop and recommend suitable management modules including integrated disease management for BGM, Ascochyta blight and wilt/root rot diseases.
- Biology and Ecology
- Host Plant Resistance
- Development and evaluation of safe and economic integrated pest management options against major insect pests

A. Chick Pea breeding:

Chickpea

1.Significant Achievements:

Sl. No.	Variety Name	Release agency	Year of release	Recommended areas	Description (q/ha)	Yield	Pedigree
1.	Pant G 114	CVRC	1979	U.P., plains of UK, Punjab, Haryana, H P, Delhi, Rajasthan, Bihar, W B and North eastern states of India	Medium tall, semi-erect, fairly tolerant to wilt and blight, maturity 155-165 days	25	G 130 x G 154
2.	Pant G 186	SVRC	1996	U.P. and Uttarakhand	Desi type, suitable for late sown conditions, brown seeds, resistant to wilt and blight disease, matures in 140-145 days	20-25	ILC 613 x Pant G 114
3.	WCG 1 (Sad bhawana)	SVRC	1997	U.P. and plains of Uttarakhand	Semi spreading, growth habit, dark pigmentation on stem and branches, thick stem and broader leaves, maturity 135, 100 seed wt. 20g., resistant to dry rot and foot rot, moderately resistance to stunt, wilt/root rot and pod borer, protein content 23.7%	20.2	Mutant of C 235
4.	WCG 2 (Surya)	SVRC	1999	U.P. and plains of Uttarakhand	Semi spreading growth habit, foliage of light green color, flower color white, early vigor, maturity 135, plant height 55 cm, 100 seed wt. 15g., resistant to foot rot, moderately resistant to stunt, wilt dry root rot, collar rot and pod borer, protein content 22.8%	20.2	Mutant of G 130
5.	WCG 10	SVRC	1999	U.P. and plains of Uttarakhand	Semi spreading growth habit, bold pod with bold seeds, plant height 55 cm, days to maturity 147, 100 seed wt. 25.4g., moderately resistant to wilt/root rot, collar rot, stunt virus, dry root rot, moderately resistant to pod borer. Protein content 22.3%	21	Mutant of G 130
6.	Pant Kabuli Chana 1	SVRC	2007	Plains of Uttarakhand	Large (32.68 g/100seeds) and attractive seeds, matures in about 140 days, resistant to botrytis grey mould	25-30	PG 92-105 x Pusa 362

7.	Pant G 3	SVRC	2017	Plains of Uttarakhand	Tolerant to wilt and botrytis grey mould diseases and also tolerant to pod borer. It has 1-2 seeds/pod, pods/plant 24-75 with 140-150 days to maturity.	22-25	K850 (LM) x Avrodhi
8.	Pant G 4	SVRC	2017	Plains of Uttarakhand	Tolerant to wilt and botrytis grey mould diseases and also tolerant to pod borer. It has 1-2 seeds/pod, 23-78 pods/plant with 145-150 days to maturity.	22-25	PG92-97 x *C. reticulatum*
9.	Pant Kabuli Channa 2	SVRC	2017	Plains of Uttarakhand	It has beige colour seeds. Tolerant to wilt and botrytis grey mould diseases and also tolerant to pod borer. It has 1-2 seeds/pod, 19-65 pods/plant with the 145-150 days to maturity.	20-22	BG 1053 x PKC 1
10.	Pant G 5	CVRC	2017	North West Plain Zone of India (Punjab, Haryana, Delhi, North West & Central Rajasthan, Western UP and Plains of Uttarakhand and J & K)	Suitable for late sown rainfed / irrrigated conditions of rabi season. Flower colour violet blue, erect plant type with profuse branching. Moderate resistance to wilt, dry root rot, collar rot and stunt diseases	20-25	PG035 X HC 5

Crop varieties released (yet to be notified)

Sl. No.	Variety Name	Release agency	Year of release	Recommended areas	Description	Yield (q/ha)	pedigree
1.	Pant G 6	SVRC	2018	Plains of Uttarakhand	Tall and semi erect plant, Foliage colour is green, Flower colour is violet blue, Seeds are medium sized with 18.10 g/100 seed weight, Tolerant to wilt and botrytis grey mould diseases.	20-25	PG035 xHC1

B. Agronomy

1. Significant Achievements:

Tillage

- Zero tillage did not prove beneficial in chickpea grown after rice. Results of three years study revealed that conventional tillage (3 harrowings + planking) recorded 22.3 and 4.8 per cent increase in yield of chickpea (BG 256) over zero and reduced tillage practice respectively. Reduced tillage was able to increase the yield to the tune of 16.7 per cent over zero tillage.

Date of planting

- First fortnight of November has been found to be the optimum time of planting of chickpea. Sowing done on 25 November, 10 December and 25 December showed significant yield reduction with delay in planting.
- Under late planting condition, chickpea yield decreased significantly beyond December 2 planting. One week delayed sowing done on December 9 caused reduction in grain yield @ 74 kg/ha/day. However, the pace of reduction was more conspicuous (113 kg/ha/

day) as the sowing was delayed for further next week (16th December). The varietal differences between any of the varieties viz., Pant G 186, Pusa 256 and PBG 1 were non-significant.

- Under normal planting (November 25), GNG-2171 being on par with PG186 produced significantly higher chickpea yield over the remaining genotypes. However, under late planting (December, 15) GNG-2171 out yielded remaining genotypes.

Seeding density

- A row spacing of 30-45 cm in chickpea has been found to be optimum. Plant spacing of 10 cm was found suitable.
- Under late planting conditions (December 10 and 25) a spacing of 22.5 cm × 10 cm produced significantly higher yield than 30 cm × 10 cm.
- Varying seed rate from 75 to 125 kg/ha did not cause significant increase in grain yield of *desi* chickpea. However, increasing row width from 30 to 40 cm led to 19% reduction in grain yield of chickpea..
- Grain yield of bold seeded *Kabul* chickpea increased significantly with increase in seed rate up to 125 kg/ha.
- Higher plant population (5 lakh plants/ha) gave significantly more yield of *kabuli* chickpea than that of lower plant population (3.33 lakh/ha).

Nutritional requirement

- Application of FYM @ 5 t/ha did not increase the yield of *Kabuli* chickpea. Use of P_2O_5 @ 40 kg/ha registered significantly higher grain yield than 0 and 20 kg P_2O_5/ha. Seed inoculated with PSB also yielded significantly higher than without PSB inoculation.
- Application of 40 kg P_2O_5/ha increased the grain yield of *kabuli* chickpea by 23% and the response was observed as 9 kg grain/kg/P_2O_5/ha. Inoculation of chickpea seeds with PSB (*B. megaterium*) only recorded an increase in the grain yield by 11% which was equivalent to increase in grain yield with the application of 20 kg P_2O_5/ha.
- Application of sulphur @ 20 kg/ha was found to increase the yield significantly over control under light textured soil having low organic carbon. However, different sources (elemental S, gypsum, single super phosphate and pyrite) remained at par among themselves.
- Nitrogen application @ 40 kg/ha produced significantly higher yield than 30 kg N/ha under late planted condition.
- Two foliar sprays of 2% solution of urea, DAP and MOP at the initiation of flowering and 10-15 days after first application being on par, gave higher yield of chickpea than control. Out of these, 2% urea spray was superior to others. Basal application of DAP @ 100 kg/ha yielded 9.3% higher than that of no DAP.
- Grain yield of *kabuli* chickpea increased significantly with the application of 30 kg P_2O_5/kg. Further increase in Phosphorus to 60 kg P_2O_5/ha led to the marginal reduction in yield. Decrease in seed rate below 100 kg/ha reduced the yield significantly.

Weed management

- Weed control came out to be the most crucial in chickpea production as missing of only weed control from full package of production resulted drastic reduction in grain yield.
- Two hand weedings in chickpea at 25-30 and 45-60 days after sowing were enough to control the weeds.
- Application of Fluchloralin @ 1.0 kg/ha as pre plant soil incorporation or Alachlor @ 1.5 kg/ha as pre-emergence or Pendimethalin @ 1.0 kg/ha as pre-emergence can control the weeds effectively.
- Pre-emergence application of Pendimethalin @ 0.75 kg/ha + one hand weeding at 45 days after sowing also controlled the weeds effectively.
- Under late planting conditions, one hand weeding

at 60 days after planting was found most effective for controlling the weeds.

- Post emergence application of chlorimuron ethyl (CME) @ 4g/ ha at 20 and/or 30 DAS proved toxic for chickpea. However, imazethapyr reduced weed and crop growth irrespective of dose (25-55 g/ha) and time of application (25-35 DAS). At higher dose it brought deformations in morphology of chickpea plants. In contrast to imazethapyr, quizalofop ethyl worked as growth promoter for dicot weeds and chickpea plants but controlled *Phalaris minor* very effectively.
- Pre emergence application of pendimethalin 30 EC + imazethapyr 2 EC (ready mix) @ 1.0 kg/ha + one hand weeding 30 DAS being at par with pendimethalin CS formulation 1.0 kg/ha, PE + HW 30DAS, pendimethalin EC formulation 1.0 kg/ha PE + HW 30DAS yielded significantly higher than remaining treatments.

Water Management

- Response of chickpea to irrigation was variable during different years. During wet winter (Rainfall > 60mm) irrigation response to different irrigation treatments was negligible. During dry winters, one irrigation phased at branching stage, being at par with 2 irrigations (branching + pod filling stages) yielded significantly higher than no irrigation On an average, increase in yield under one and two irrigations was to the tune of 16.2 and 27.8 per cent, respectively over no irrigation.

Cropping system

- Under rainfed condition, intercropping of wheat, toria and coriander with chickpea came out to be more remunerative than either of the component crops taken as pure.
- Intercropping of mustard with chickpea in 5:1, 6:1 and 6:2 row ratio (Chickpea : Mustard) had almost equal chickpea equivalent yield, net return, LER and benefit cost ratio which were higher than any other treatment.
- Rice-chickpea-fodder (Maize + cowpea) and Rice-wheat-fodder (Maize + Cowpea) cropping system were found to be superior in *tarai* conditions of Uttarakhand. Among 200 per cent cropping intensity rotations, rice-chickpea gave the highest rice equivalent yield. Incorporation of green manure either in from of *Dhanicha* or mungbean registered its superiority over rice-wheat alone.
- Intercropping of two rows of chickpea in between two paired rows of sugarcane (2:2) was found more remunerative than that of fieldpea, lentil and sole sugarcane.
- Sole cropping of chickpea being on par with chickpea + coriander (4:2) gave significantly higher chickpea yield than that of chickpea + coriander (3:1). However, sole cropping of coriander out yielded intercropping patterns in terms of coriander yield. Yield of coriander did not differ significantly under both the intercropping patterns (3:1 and 4:2). Intercropping of chickpea + coriander (4:2) computed significantly higher chickpea equivalent (CEY) than remaining cropping patterns.
- Application of 30 kg P_2O_5/ha + PSB recorded significantly higher chickpea yield than remaining phosphorus levels. 45 kg P_2O_5/ha out yielded remaining P levels in terms of coriander yield. However, application of 45 kg P_2O_5/ha, being at par with 30 kg P_2O_5/ha + PSB gave significantly higher chickpea equivalent yield than those of control and30 kg P_2O_5/ha.

C. Microbiology:

1. Significant Achievements:

Nodulation status at farmer's field

Root nodulation survey on farmers field in Bulandshahar, Badaun, Bareilly and Rampur districts revealed that chickpea in general was poorly (0-10 nodules/plant) to moderately nodulated (10-20 nodules/ plant). Nodule number and dry weight did not correlated with soil texture, pH, organic C and total phosphorus content of the soils.

Role of edaphic factors

- Soil temperature around 20-22°C was found to be the best for root nodulation, nitrogenase activity

and chickpea growth. Soil temperature 33°C did not allowed nodulation. Native strains performed relatively better at 27 ± 2°C while inoculated strains did best at 22 ± 2 °C.

- Chickpea did not nodulated in sandy loam soil at 0.1 % moisture content. Efficiency of the inoculated strains with respect to nodule dry weight increased significantly with increase in soil moisture from 0.2 to 0.5 kg/kg soil. however, it did not significantly influenced the shoot dry weight. Soil moisture also influenced the efficiency of inoculated strains, G-3 being more efficient at low moisture levels than TAL 620.
- One irrigation in chickpea, sown on residual moisture in silty soil, at early stage increased nitrogenase activity from 91 to 115 µ mole C2H4/ g nodule/ h. The competitive ability of inoculum strains also increased from 18-25 % (no irrigation) to 26-38 % (with one irrigation).
- Response to inoculation was about 6 times more in acidic soil of Bhowali (pH, 5.7; total N, 0.11%, organic C, 1.5%) than in neutral soil of Pantnagar (pH, 7.1; total N, 0.08%, organic C, 0.90%). However, in neutral soil inoculated strains showed better competitive ability and effectiveness. Alkaline soil of pH 9.2 did not support chickpea growth.

Inoculum load

- Increasing inoculum load on seed increased the efficiency and competitive ability of inoculated strains tremendously. Generally at normal rate of inoculum a seed carries 10^3-10^4 cells. Different inoculated strains at 10 times of the normal inoculum rate produced 234 to 434 kg/ha more chickpea yield over the control. These inoculants at 100 times of the normal rate produced significantly more yield of 17.1 to 22.5% than their respective normal inoculum doses. The 100 times inoculum rate of the inoculated strains also gave an average increase of 10.6 % over their 10 times rates.
- Competitive ability of inoculated strain G-3 increased from 39 to 59 % when inoculum load on seed increased from 2.5 X 10^4 to 2.3 X10^4 cells/seed.

N_2 fixation and N contribution of *Rhizobium* inoculation

- N_2 fixation by chickpea due to inoculation with different strains ranged between 21.4 to 33.0 kg/ ha.
- N_2 fixation computed with ^{15}N dilution technique indicated fixation of 94.3 and 103.8 kg N/ha in chickpea with *Rhizobium* alone and *Rhizobium* + *Azotobacter*, respectively in chickpea-rice sequence.
- Inoculated rice-chickpea sequence added 188 kg N/ha showing 28 kg/ha as the contribution of *Azotobacter* in rice and 40 kg/ha contribution of inoculated *Rhizobium* in chickpea. Uninoculated rice-chickpea sequence saved nearly 90 kg N/ ha over rice barley sequence.
- *Rhizobium* alone inoculation in chickpea showed residual effects equivalent to 20 kg fertilizer N/ha in succeeding maize and sorghum. The residual effect of *Rhizobium* with 40 kg P_2O_5/ha was equivalent to 30 and 40 kg N/ha in succeeding sorghum and maize respectively.

Isolation, identification and evaluation of Chickpea endophytes

- Ten chickpea endophytes having various PGP traits were isolated and identified by the direct sequence analysis of 16S rRNA gene. Using BLAST search among 16S rRNA gene sequences of the isolates and other closely related bacterial genera existing in GenBank, per cent identities were determined. The isolated endophytes were R4 (*Microbacterium testaceum*), R5 (*Strenotrophomonas malphilia*), NE2 (*Bacillus subtilis*), NE3 (*Lysinibacillus fusiformis*), NE5, NE10, NE17, (*Bacillus cereus*) NE12, (*Bacillus stratosphericus*), NE14 and NE17 (*Bacillus* sp.).
- Performance of these endophytic bacteria in terms of nodulation, plant growth, yield and soil properties was evaluated in pot and field

experiments with *Mesorhizobium* sp.. Endophytic bacteria NE10 recorded significantly more grain yield chickpea of 18.4% and straw yield of 26.1% over *Mesorhizobium* sp. alone. The co-inoculated endophytic bacteria significantly improved N uptake and P uptake by chicpea, soil microbial biomass and dehydrogenase enzyme activity at 45 DAS and at harvest of crop

Inoculants formulation

- Standardized the broth medium for preparation of liquid inocuant of *Mesorhizobium ciceri* and PGPR (*Pseudomonas* sp.). YEM broth containing 1.0 g Mannitol, 0.5 g K_2HPO_4, 0.2 g $MgSO_4.7H_2O$, 0.1 g NaCl, 1.0 g Yeast extract, 1.0 g Glucose, 0.5 g Arabinose, 20.0 g PVP-40, 2.0 m*M* Trehalose; 200 µ*M* Fe-EDTA, and 4.0 ml Glycerol per L distilled water was found best for *Mesorhizobium ciceri* (LN 7007) and Nutrient broth containing 3.0 g Beef extract, 5.0 g Peptone, 1.0 g Glucose, 1.0 g Arabinose, 20.0 g PVP-40, 200 µ*M* Fe-EDTA, 1.0 ml Glycerol/ L distilled water was observed optimum for PGPR *(Pseudomonas diminuta*-LK-884).
- Survival of *Mesorhizobium* sp. on chickpea seed was found better following inoculation with liquid inoculant than carrier inoculant. Irrespective of intervals of observations, the mean viable count of *Mesorhizobium* sp. on seed was significantly more, by 8.4 per cent, as compared to carrier based inoculants. Highest mean population on seed was recorded after 10 days of inoculation.
- Liquid inoculant of *Mesorhizobium* sp. by recording 12.3 and 19.1 per cent more mean viable counts under refrigerated than room conditions at different intervals indicated better shelf life than their carrier inoculants. Liquid inoculants of *Mesorhizobium* sp. and PGPR were found slightly better or at least comparable to their carrier based inoculants for performance in chickpea under field conditions.

***Mesorhizobium* sp. and PGPR interaction**

- Seed inoculation with *Rhizobium* (G 567 SMR) in chickpea recorded 16.7 % more, averaged over 2002-03 to 2003-04, grain yield over uninoculated control. Combined inoculation of *Rhizobium* + PSB + PGPR further increased the grain yield of 8.4 % over *Rhizobium* alone inoculation.
- In a field study on chickpea during 2005-06, inoculated *Mesorhizobium* sp. alone gave only numerical increases in various symbiotic traits, yield and nutrient uptake. However, different rhizobacteria recorded significant increases of 3.5 to 86.4 % in nodule number, 34.0 to 282.0 % in nodule dry weight, 1.4 to 57.4 % in grain yield and 10.0 to 52.9 % in straw yield over no rhizobacteria treatment. Dual inoculation of different rhizobacteria with *Mesorhizobium* sp. Further increased the nodulation, grain and straw yield, N and P uptake over *Mesorhizobium* sp. Alone inoculation. Dual inoculation treatment of *Mesorhizobium* sp. + PUK-171 was found to be the best for most plant growth and yield parameters of chickpea.
- Field trials conducted during 2007-08 to 2009-10 revealed that seed inoculation with *Mesorhizobium* sp. (G 567 SMR) in chickpea gave marginal increase of 14.2 % in nodule dry weight and 9.36 % in grain yield as compared to the control. Co-inoculation of PGPRs *viz.* CRB-1, RB-2, PUK-171 (*Pseudomonas* sp.) and LK-884 (*Pseudomonas diminuta*) with *Mesorhizobium* sp. Further increased the nodule dry weight, ranging from 11.9 to 17.6 % and grain yield from 3.6 to 10.0 % over Mesor*hizobium* alone, however, the increases were not statistically significant.

Improving *Mesorhizobium* sp. efficiency by nutrient management

- Application of 40 kg P_20_5 along with inoculation gave significant increase of 28.3% in chickpea grain yield than phosphorus alone treatment at Modipuram. Similarly at Nagina during 1989-90 and 1990-91, application of 40 and 60 kg P_20_5 along with inoculation gave average increases in grain yield of 15.8 and 18.4 % over *Rhizobium*

alone and 10.5 and 24.2 % over respective P doses alone application, respectively.

- In a field trial during *Rabi* season of 2006-07, treatments of *Mesorhizobium* sp. + 25 kg $ZnSO_4$/ha and *Mesorhizobium* sp. + 5 kg Borax/ha were found superior in nodulation, plant dry weight, nutrient uptake and yield parameters of chickpea compared to application of *Rhizobium* + 10 kg $ZnSO_4$/ha or *Mesorhizobium* sp. + 10 kg Borax/ha. Similarly, an application of 0.5 kg $NaMoO_4$/ha with *Mesorhizobium* sp. with was found better than *Mesorhizobium* sp. Alone

Effect of *Mesorhizobium* inoculation on soil biological properties

- *Mesorhizobium* sp. inoculation in chickpea has been found to increase the bacterial and fungal population in soil by 50.8 and 38.2 per cent and dehydrogenase activity by 42.16 per cent over the uninoculated control, respectively after crop harvesting. Similar increases in microbial population as well as in dehydrogenase activity were also observed due to combined application of *Mesorhizobium* sp. and micronutrients.

- In a field study during *Rabi* 2005-06, inoculation of *Mesorhizobium* sp. In chickpea did not influence the available N and P content, microbial biomass C and phosphatese activity in soil significantly. However, inoculated rhizobacteria alone showed increases of 18.7 to 130.7 kg ha^{-1} in available N, 3.56 to 5.25 kg ha^{-1} in available P, 5.9 to 60.8 % in dehydrogenase activity, 17.9 to 112.5 % in alkaline phosphomonoesterase activity and 10.5 to 35.2 % in acid phosphomonoesterase activity over the control after crop harvesting.

- In another field study during 2007-08, inoculation with liquid and carrier inoculants of *Mesorhizobium* sp. and *Pseudomonas* sp. showed increases in soil available N of 19.8 to 57.3%, P of 4.8 to 19.0 %, dehydrogenase activity of 4.8 to 16.1 %, Acid phosphatase activity of 8.6 to 21.3 %, alkaline phosphatase activity of 9.1 to 41.1 % and microbial biomass C of 12.0 to 36.9 % over the uninoculated control. Dual inoculation of these organisms showed better effect on these soil properties than their inoculation alone.

D. Plant Pathology:

1. Significant Achievements:

***Botrytis* gray mould (BGM):**

Screening of germplasm: during the period 1043 germplasms were screened against BGM, the resistant and moderately resistant germplasm are as follows:

BDNG-2010-1, JG 24, Phule G 0215-2, RVSSG-9, GNG-2065, GJG 0906, H08-13, BG3004, IPC 08-11, JG 23, GJG 922, H08-25, BCP 60, GJG0814, CSJ 513, GJG 0904, IPC 08-68, IPCK 07-62, BGD 1079, CSJK 27, GNG 2171, H 09-96, Phule G 0405, Phule G 0511, JG 38, H 10-05, RSG 931, IPCK 2009-164, HK 09-206, JGK 1, BGDC1079, CSJK 27, Phule G 0609-15, Phule G 0611, NBeG 47, H 11-22.

Effect of different media: the colony of the fungus on potato dextrose agar (PDA) was flat with sparse mycelium, initially white later turning grey with the powdery mass of spores. The radial growth of the fungus was significantly different on media tested. PDA medium was found the best for the radial growth followed by Richard's agar medium.

Effect of pH and temperature: the growth of the fungus was significantly different at pH range tested. Maximum radial growth of the fungus recorded at pH6 followed by pH7. It was thus clear that the pathogen preferred slight acidic medium for its growth. Maximum radial growth was recorded at 25°C followed by 20°C. the minimum radial growth was recorded at 35°C.

Management of BGM

***Effect of fungicides*:** Out of 09 fungicides tested *in vitro*, among the systemic fungicides carbendazim and propiconazole proved the best fungicide at 25 ppm conc. The completely checked the growth of test

fungus. The among the non systemic fungicides, Thiram completely checked the growth of fungus. In field experiments, seed treatment with carbendazim followed by three spray of carbendazim (0.1%) was found most effective in reducing the disease severity and increasing grain yield.

***Effect of oils*:** Among the nine plant oils evaluated peppermint was found best antifungal compound, followed by palmarosa, citronella and geranium, while til and winter green oil were least effective in inhibiting the fungal growth. Foliar spray of peppermint oils and citronella oil resulted in low disease severity and high grain yield.

Effect of bio agents: All 12 isolates of *Trichoderma harzianum* inhibited the growth of test fungus. Maximum inhibition of mycelial growth was recorded with isolate TH-41 followed by TH-34. Ten isolates of *Pseudomonads fluorescence* tested, all the isolates significantly inhibited the growth of test fungus. Maximum inhibition of mycelial growth was recorded in case of isolate FLP-4 followed by FLP-18. In field condition, three bio-agents evaluated in which the seed treated with a mixture of *Trichoderma harzianum* (TH-41) + *Pseudomonads fluorescence* (FLP-4) showed lowest disease severity and highest grain yield

Modules for the management of the BGM

- Seeds treatments with carbendazim + thiram (1:2) @3g/kg seed.
- Delayed sowing November 20 - 25
- Row to row spacing 30 cm
- Erect type cultivar (ICCL 87322, PG-186, BG-261)
- Three spray of carbendazim 0.1% as soon as disease appear.

Ascochyta blight diseases

Screening of Germplasm: Fifty germplasm were screened in which 09 germplasm i.e. C1121, ICC637, PGR024, IILL10302, PG014, PG040, PG052, PG055 and ICCV11112 were found resistant and eleven i.e C1009, CSG8962, DC2-92-3, GNG1581, GNG1581+PK V 4, KPG 59+HK 4, PC PGR 9, PGR 021, RSG-963+BG 1003, PG 045 and IC 269715 were showed moderately resistant reaction.

***Effect of different media pH and temperature*:** Among five media taken for selecting basal media for *Ascochyta rabiei* (Pass.) Labr., chickpea dextrose agar medium was found best supporing a mycelial growth of 73.34mm followed by oat meal agar (66.92 mm), potato dextrose agar (57.17 mm) and Richard's medium (43.17mm). While, least being in Czapek's Dox agar medium (28.70). Among different temperature and pH tested 20°C and 6.5 was found excellent for mycelial growth of the fungus respectively

Management of BGM

***Effect of fungicides*:** Among 10 fungicides tested against the mycelial growth of *Ascochyta rabiei* (Pass.) Labr. metiram+pyraclostrobin, pyraclostrobin, azoxystrobin and tebuconazole were found most effective and provided 100 per cent growth inhibition at all tested concentration (50 µg ml^{-1}, 100 µg ml^{-1} and 200 µg ml^{-1}). Mancozeb was found least effective at all three concentration viz. 50, 100, and 200 µg ml^{-1} by giving 42.33, 38.67 and 20.33 per cent mycelial growth inhibition, respectively

***Effect of botanicals*:** All the 5 tested botanicals were found to inhibit the fungal mycelia growth over check. Among the five tested botanicals, Jamun extract was proved to be most effective botanicals by inhibiting 100 per cent mycelial growth of *Ascochyta rabiei* (Pass.) Labr. at all concentration (5%, 10%, 15%) followed by Neem and Garlic only at 15% concentration. Tulsi extract was found least effective in inhibiting the mycelial growth of the fungus followed by Bhang extract at all concentrations

***Effect of bio agents**:* Among the tested bioagents, 100 per cent mycelial growth inhibition was observed in all *Trichoderma harzianum* strains (Th2, Th31 and Th9), followed by *Pseudomonas fluorescens* strains Pf2, Pf4 and Pf6 0.6 showing 27.08, 33.33 and 23.33 per cent mycelial growth inhibition respectively. The lowest radial growth inhibition was observed in Pf6 strain of *P. fluroscens.*

Modules for the management of the Ascochyta

blight

- Use of resistant cultivar (C 1121, ICC 637, PGR 024).
- Optimum date of sowing November 20-25
- Seed treatment with carbendazim + thiram (1:2)
- Three foliar sprays of Metiram 55 + Pyraclostrobin 5 WG @ 963+88 g a.i. ha^{-1} at 15 days interval as soon as disease appeared.

Wilt/root rot diseases

- It was found that the seed treatment with Penflufen15.4 + trifloxystrobin 15.4-30.8 FS @ 80ml/100 kg seed was highly effective against the diseases as compared to other treatment.

E. Entomology:

1. Significant Achievements:

Biology and Ecology

- Gram pod borer, *Helicoverpa armigera* is the most economic pest at flowering and podding stage of the crop.
- The minor pests like Semilooper, *Thysanoplusia orichalcae;* aphid, *Aphis craccivora* and leaf miner, *Chromatomyia horticola* also be found in certain years.
- The peak period of *Helicoverpa* adults occurred during mid March to early April. Two flush of eggs were found one during mid March and second flush during first week of April. There are two generations of *H. armigera* on chickpea crop.
- First appearance of eggs and larvae of *Helicoverpa armigera* was noticed during 4th standard week. Thereafter the egg and larval population increased and reached to the maximum of 15.00 eggs /m^2 and 28.00 larvae/ m^2 areas. During the 10th standard week and 13th standard week respectively.
- The egg and larval population of *H. armigera* was correlated with different environmental factors and indicated that there was a positive correlation between egg and larval population and mean temperature and sunshine days. Whereas mean RH and total rainfall (m.m.) showed a negative correlation.
- Appearance of the moths of *H. armigera* started from 4th standard week. The highest number of moth catch was recorded during 13th standard week (154.62per week per trap). The flowering, pod formation and pod maturation stage of crop coincided with the higher population of the moths.
- Highly significant positive correlation was observed between the population of moths and mean temperature, wind velocity. Whereas non-significant positive correlation was observed between the population of moths count and sunshine days.
- Moth's population showed a negative correlation with relative humidity and rainfall.
- The highest orientation behavior of *Helicoverpa armigera* towards Bathuwa *Chenopodium album* was observed because of the compounds Hexacosane followed by Tetracontane and least active compound for attraction was Germacrene B.
- The bruchid infestation on chickpea does not initiate in the field and if the storage container and the store do not have prior bruchid inoculum, the chickpea seeds can be stored free of bruchid infestation. The data on ovipositional preference, per cent adult emergence, developmental period, growth index of *C. chinensis* and per cent loss in seed weight indicated that the PBG 1, BGM 547 and PG 114 were found moderately tolerant as this recorded lowest growth index of pulse beetle and least per cent seed weight loss.

Host Plant Resistance

- In antibiosis, leaf detach assay experiment, significantly lower leaf feeding was observed on the ICCV097105 followed by ICCV92944.

- Antibiosis pertaining under podding stage, the lowest pod damage recorded in ICCV92944 and significantly lower pod feeding was observed on the ICCL86111, ICCV092944, ICCV097105 and ICC14872 (DR 5) while lower weight gain recorded on ICCV08108.
- The cultivars having higher biochemical parameters viz., protein (ICPL 86111), phenol (ICCL 86111), flavonoids (ICCV10), trypsin inhibitor activity content (TIA) (ICCV097105) in their seeds offered resistance against pod borer attack in chickpea and the best cultivar can be further used for breeding programme to develop tolerance to pod borer menace in chickpea.
- The biochemical parameters revealed that significant differences among the chickpea varieties occur. The varieties which were having biochemical parameters viz., higher phenol (PG 4, PBG 1 and PG 114), flavonoids, tannin and trypsin inhibitor content in their seeds offered resistance against *C. chinensis* attack in chickpea under storage conditions. But having higher protein content variety (PKG 2) indicating that more preferred by the *C. chinensis*. PBG 1, PG 114 and BGM 547 are very promising varieties against pulse beetle, *Callosobruchus chinensis* L.

Integrated Pest Management

- **Insect Pest Monitoring:** The occurrence of *H. armigera* adult moth in pheromone trap catches occurred during 4th to 18th standard week. Maximum is recorded during 13th SW-14th SW.
- **Effect of Dates of Sowing**: Lower percent pod damage was recorded in normal sown (mid november) crop than on late sown crop which resulted in higher grain yield in normal sown crop than on late sown crop.
- **Biological Control:** Limited natural enemies were found on *H. armigera*. Mainly larval parasitoid, *Campoletis chloridae* was recorded. First appearance of *C. chloridae* was recorded on the 4th standard week on chickpea crop and parasitized 80.00 per cent larval population of *H. armigera* persisted till mid –April with peak parasitization (90.93 per cent) of larvae during 6th standard week (February, 5-11). Parasitization by *C. chloridae* ranged from 37.74-90.24 per cent. This paved a way for the formulation of control schedule in area that *C. chloridae* should be conserved itself in the field during this period.
- In sole crop, mean parasitism by *C. chlorideae* on larvae of *H. armigera* was 52.64 % while it was 71.82 % in chickpea- coriander cropping system and the higher parasitism was recorded during 11th SW of March.
- A significant positive correlation was observed between parasitoid population, mean Relative humidity and rainfall. Whereas a negative correlation was observed with mean temperature, sunshine days and wind velocity.

Chemical Control

Neem soap 5% + acephate 75 SP,(750 g. a.i./ha) followed by chlorantraniliprole 18.5 SC (18 g a.i./ha) alone followed by indoxacarb 15.8 EC (62 g a.i./ha) . For pulse beetle lavender oil @2.5 ml/kg seed showed the minimum percent seed damage, minimum percent adult emergence and highest percent hatching inhibition rate. The highest fumigant toxicity and mortality was recorded in citronella oil. The percent repellency was recorded in lemongrass oil.

IPM module for *H. armigera*

Module-1: First spray of chlorantraniliprole 18.5 SC @ 30g a.i./ha followed by second spray of Spinosad 45 SC @ 56g a.i./ha at 15 days interval

Module-2 : First spray of chlorantraniliprole 18.5 SC @ 30g a.i./ha followed by second spray of neem oil 3% .