Research Project Proposal

Developing Chickpea Cultivars Suited to Mechanical Harvesting and Tolerant to Herbicides

Submitted to

National Food Security Mission (NFSM)
Department of Agriculture & Cooperation
Ministry of Agriculture
Government of India

Participating Institutes

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Hyderabad
Indian Institute of Pulses Research (IIPR), Kanpur
Indian Agricultural Research Institute (IARI), New Delhi
Punjab Agricultural University (PAU), Ludhiana
Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV), Gwalior
University of Agricultural Sciences (UAS), Dharwad
Acharya NG Ranga Agricultural University (ANGRAU), Hyderabad

ICRISAT
Science with a human face

International Crops Research Institute for the Semi-Arid Tropics

This work will be undertaken as part of the

CGIAR RESEARCH PROGRAM ON GrainLegumes

1. Project title: Developing chickpea cultivars suited to mechanical harvesting and tolerant to herbicides

2. Participating institutes

- International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, Hyderabad, AP
- Indian Institute of Pulses Research (IIPR), Kanpur, UP
- Indian Agricultural Research Institute (IARI), New Delhi
- Punjab Agricultural University (PAU), Ludhiana, Punjab
- Rajmata Vijayaraje Scindia Krishi Vishwa Vidyalaya (RVSKVV), RAK College of Agriculture (RAKCA), Sehore, MP
- University of Agricultural Sciences (UAS), Dharwad, Karnataka
- Acharya NG Ranga Agricultural University (ANGRAU), RARS-Nandyal, AP

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6. Project duration: Four years

7. Total cost of the project: Rs 764.24 lakhs

8. Project summary

Chickpea is harvested by hand in India because the available chickpea cultivars are not suited to mechanical harvesting. In developed countries, such as Australia, Canada and USA, chickpea is harvested mechanically and no cultivar can be released which is not suited to mechanical harvesting. With continuously increasing labour cost, manual harvesting has become an expensive field operation for any crop in India and farmers are increasingly opting for mechanical harvesting where it is feasible. Availability of chickpea cultivars suited to mechanical harvesting will reduce production cost and attract farmers to chickpea cultivation. This is particularly important for northern India, where chickpea area has declined by more than 3 million ha due to replacement of chickpea with wheat and other high value crops. Chickpea cultivars with tall and non-spreading plant type are needed for mechanical harvesting. ICRISAT and National Agricultural Research Systems (NARS) in India already have breeding lines with these desired traits. Selected breeding lines will be extensively evaluated in multilocation trials at research stations and farmers' fields and fast tracked for release. Suitable agronomic practices (seed rate, row-to-row and plant-to-plant distances, etc) will also be worked out for the breeding lines suited to mechanical harvesting. One to two elite lines suited to mechanical harvesting will be released/proposed for release by the end of this project. New breeding lines suited to mechanical harvesting and adapted to target regions will be developed through targeted breeding for strengthening the breeding programs for future development of cultivars. Commercial combine harvesters are available for other crops. We will evaluate these and make required adjustments/modifications to customize for chickpea harvesting.

Another area of chickpea production where cost of cultivation can be reduced is by developing herbicide tolerant cultivars. The farmers are not able to use post-emergence herbicides for weed control in chickpea because the available cultivars are sensitive to herbicides. Thus, manual weeding is currently the only option for Indian farmers to manage weeds in chickpea. Herbicides are gaining popularity in India in many crops, including the legume crops like soybean, mungbean and urdbean. Herbicide tolerant chickpea cultivars are needed for reducing cost of cultivation and making chickpea cultivation attractive to farmers. We propose to identify sources of herbicide tolerance from the germplasm and also induce through chemical mutagenesis and use these for development of herbicide tolerant breeding lines. Chickpea cultivars suited to mechanical harvesting and tolerant to herbicides would be more competitive in the farming system and increase profitability of chickpea cultivation to the farmers by reducing cost of production. Such cultivars would have better chances of finding place in cereal dominated cropping systems of northern India.

This project is aimed at (1) developing chickpea cultivars suited to mechanical harvesting, (2) modifying/adjusting combine harvesters to customize for chickpea harvesting, and (3) developing chickpea cultivars tolerant to herbicides.

9. Background and rationale

9.1 Chickpea cultivars suited to mechanical harvesting

Mechanization of farm operations is essential for improving efficiency of agriculture and reducing cost of cultivation. The farmers in India are gradually enhancing mechanization of farm operations. The sowing of many crops, including chickpea, is largely done by seed drills and the use of combine harvesters in crops like wheat and rice is rapidly increasing. The chickpea farmers, particularly in Andhra Pradesh, are demanding chickpea cultivars which are suited to mechanical harvesting. The current chickpea cultivars are not suited to mechanical harvesting because the plant height is not adequate and the branches are close to ground due to semi-spreading growth habit.

Development of chickpea cultivars with 30 to 40% more height than the existing cultivars and semi-erect to erect growth habit will make these cultivars suited to mechanical harvesting. Such plant types can accommodate more number of plants per unit area and can also give higher yield. Another advantage with such plant type is the reduction in buildup of humidity in crop canopy due to more solar light interception, which will minimize damage due to foliar diseases. Mutants with upright growth habit have been identified and used in chickpea breeding to develop improved breeding lines (Dahiya et al. 1990, Sandhu et al.1990, Lather 2000, Gaur et al. 2008). An elite tall breeding line with upright growth habit yielded about 4 t ha^{-1} under high density planting (50 plants m^2 compared to normal planting 33 plants m^2) and was suitable for mechanical harvesting as the fruiting zone started at about 20 cm from the base (Lather 2000).

The chickpea breeding programs of ICRISAT, IIPR, IARI and some of the State Agricultural Universities already have several tall breeding lines with semi-erect to erect growth habit. A set of lines selected from these can be fast-tracked for release by concerted efforts on mutilocation testing and identifying promising lines for release in different geographic regions. The release of cultivars suited to mechanical harvesting will benefit farmers by reducing cost of cultivation and increasing net profit from cultivation of chickpea.

Fig.1: Farmers in Andhra Pradesh using combine harvester for chickpea harvesting. As the available varieties are not suitable for mechanical harvesting, the crop is cut by hand and the plant bundles are thrown to the harvester for threshing and cleaning.

9.2 Modification of harvesting machines for chickpea harvesting

The available commercial harvesters have been designed for crops like wheat and rice. Adjustments/modifications may be required to improve their suitability for chickpea harvesting. The Department of Farm Machinery and Power Engineering of the Punjab Agricultural University has vast experience on designing and customizing farm machineries. The collaborative efforts of plant breeders and agricultural engineers will help in speedy identification of varieties suitable for mechanical harvesting and adoption of harvesting machines.

9.3 Chickpea cultivars tolerant to herbicides

The other chickpea production practice where cost of cultivation can be reduced substantially is by promoting use of post-emergence herbicides in controlling weeds by developing herbicide tolerant cultivars. Chickpea is sensitive to herbicide and manual weeding is currently the only option for weed control. Weeds compete with crop plants for water, nutrients, sunlight, and space and also harbor insect and disease pests. If left uncontrolled, weeds can reduce chickpea yield significantly. Inter-row cultivation is not sufficient for weed control and intra-row hand weeding is necessary under close planting conditions. Thus, the management of weeds in chickpea is becoming expensive and in some cases uneconomical due to high labor cost involve in manual weeding. Herbicide-tolerant cultivars offer opportunity of controlling weeds through need-based applications of herbicides. Weed management through herbicides is not only economical but also facilitate zero-tillage or minimum tillage methods, which help preserve topsoil.

Herbicide tolerant cultivars have been developed in many crops by exploiting already available genetic variability (spontaneous mutations) in the germplasm. For example in wheat, a variety "ND901CL" tolerant to imidazolinone herbicide, which control many difficult-to-manage weeds in wheat production systems, was developed using a combination of modified bulk and pedigree breeding procedures by North Dakota State University, USA (Mergoum et al. 2009). Similarly, a variety "Coromup" in narrow-leaf lupins (Si et al. 2008) and a variety "Tracy-M" in soybean (Hartwig 1987) with improved tolerance to herbicide metribuzin have been developed by screening the advanced breeding lines for herbicide tolerance.

Greater success in development of herbicide tolerant cultivars has been achieved through mutation breeding (chemical mutagenesis). Commercial herbicide-tolerant crops developed from herbicide-tolerant mutants include imidazolinone-tolerant maize, rice, wheat, oilseed rape, sunflower, and lentil; sulfonylurea-tolerant soybean and sunflower; cyclohexanedione-tolerant maize; and triazine-tolerant oilseed rape (Duke 2005). Most of the herbicide-tolerant mutants were developed through chemical mutagenesis followed by herbicide selection (Tan et al 2005). Among the chemical mutagens, ethyl methane sulphonate (EMS) was the most popular one. All mutations used in commercial herbicide-tolerant crops are derived from a single nucleotide substitution of genes that encode enzymes or proteins targeted by herbicides. Thus, once a mutation is induced, the mutant gene (the herbicide tolerance gene) can easily be introgressed in any other cultivar.

A chemical company BASF in Canada has developed varieties in wheat (AP602CL), corn (Clearfield Corn), rice (PWC16) and canola (Clearfield Canola) tolerant to imidazolinone herbicides through a combination of mutagenesis and conventional breeding techniques

(http://cera-gmc.org/docs/decdocs/04-166-002.pdf). Herbicide tolerant varieties have also been developed in some grain legumes. In narrow leaf lupin (*Lupinus angustifolius* L.), two highly tolerant metribuzin mutants Tanjil-AZ-55 and Tanjil-AZ-33 were identified and the tolerance was 4-6 times higher than the original parent respectively (Si et al. 2009). Similarly in lentils RH44, a variety was developed by mutagenesis and cross-breeding that has an increased resistance to imidazolinone herbicides (Slinkard et al. 2007). Hence exploiting the existing variation from stored germplasm and creating variation through mutagenesis are the cost-effective methodologies to identify sources of variation for herbicide tolerance and development of herbicide tolerant cultivars in chickpea.

Limited efforts have been made in breeding for herbicide tolerance in chickpea. A study conducted at University of Saskatchewan in Canada identified several chickpea accessions tolerant to imidazolinone class of herbicides (Imazethapyr and Imazamox) (Taran et al. 2010). Recently, PAU-Ludhiana carried out preliminary screening of a set of 3300 chickpea genotypes, including released varieties and improved breeding lines obtained from various State Agricultural Universities, NBPGR, ICRISAT and ICARDA, for tolerance to herbicide **Metribuzin** (@ 100 g/ha dose) during post-rainy season 2010-11. Wide genotypic differences were observed for herbicide tolerance ranging from 100% killing of the plants (in most of the genotypes) to 80-90% survival of the plants (very few genotypes). A dose of 100 g/ha for herbicide was decided after initial evaluation of five doses (50, 100, 150, 200 and 250 g/ha). The dose of 50 g/ha of herbicide was not effective in controlling the weeds, while the doses of 150 g/ha and more caused 100% mortality of chickpea plants.

Fig 2: Screening for herbicide tolerance in chickpea at PAU-Ludhiana during post-rainy (*Rabi*) season 2010-11. Wide genotypic differences were observed for herbicide tolerance among 3300 genotypes screened.

The results of above studies clearly show the feasibility of using conventional breeding for developing herbicide tolerant chickpea cultivars. We propose to use herbicide tolerant lines identified by PAU-Ludhiana and identify additional sources of tolerance from the germplasm through large scale screening and also induce through chemical mutagenesis. The selected

tolerant lines will then be used in breeding programs for introgressing herbicide tolerance in the selected popular cultivars.

11. Project goal: The overall goal of the project is to reduce cost of chickpea cultivation and increase farmers' income by developing cultivars suited to mechanical harvesting and tolerant to herbicides.

12. Key objectives:

- Develop chickpea cultivars suited to mechanical harvesting.
- Modify/adjust combine harvesters to customize for chickpea harvesting
- Develop chickpea cultivars tolerant to herbicides.

13. Major activities

- Fast-track for release the available breeding lines suited to mechanical harvesting.
- Targeted breeding for development of cultivars suited to mechanical harvesting.
- Evaluate the available commercial harvesting machines and make required modifications/adjustments to customize for chickpea harvesting
- Identify sources of herbicide tolerance from the germplasm and induce mutations for herbicide tolerance through mutagenesis.
- Develop herbicide tolerant breeding lines.

14. Key outputs

- At least one cultivar suited to mechanical harvesting released/proposed for release each in northern, central and southern India.
- New breeding lines suited to mechanical harvesting and adapted to each region developed through targeted breeding.
- Combine harvesters suitable for chickpea harvesting available.
- Sources of herbicide tolerance identified from germplasm/breeding lines or induced through mutation breeding.
- Breeding lines with enhanced herbicide tolerance developed for each target region.

15. Year-wise activities and milestones

Year 1

Activities	Milestones
Organize a meeting of all partners for developing a detailed workplan of the project, including selection of breeding materials/ germplasm for use in the project, procedures for mutagenesis and screening for herbicide tolerance, protocols for conduct of station and multilocation trials and format for recording of observations and reporting of data.	One meeting of all project partners organized during Sep/Oct 2013 by ICRISAT at one of the participating centers.
Select tall and upright breeding lines with adequate seed quantity available and evaluate these in multilocation yield trials.	At least 20 breeding lines with tall and upright growth habit evaluated at all 7 locations.

Evaluate in station trials the tall and upright breeding lines for which seed available is not enough for multilocation trials.	A station trial on available breeding lines (20 to 100) with tall and upright growth habit at 4 main locations (ICRISAT, IIPR, IARI, PAU).
Make crosses for improving selected cultivars for plant height and growth habit required for mechanical harvesting.	At least 4 crosses made at each of the 7 locations for developing breeding lines suitable for machine harvesting.
Select suitable harvesting machines and do their functional testing.	Functional testing of at least 2 selected harvesting machines performed at PAU
Screen a new set of genotypes (germplasm/ cultivars/breeding lines) for herbicide tolerance.	At least 300 genotypes screened for at least one herbicide at 4 locations (ICRISAT, IIPR, IARI, PAU).
Putative herbicide tolerant genotypes selected in the previous year screened again for herbicide tolerance.	30 genotypes screened for herbicide tolerance at all 7 locations.
Screen accessions of wild *Cicer* species for herbicide tolerance.	At least 20 accessions of wild *Cicer* species screened for herbicide tolerance at ICRISAT.
Make crosses for developing breeding lines with enhanced herbicide tolerance.	At least 4 crosses made for improving herbicide tolerance at each of the 4 locations (ICRISAT, IIPR, IARI, PAU)
Screen M_2 populations of JG 11 and KAK 2 for herbicide tolerance.	M_2 populations of JG 11 and KAK 2 screened for herbicide tolerance at ICRISAT.
Mutagenesis with EMS for inducing variability for herbicide tolerance.	Select at least one cultivar at each of the 4 main locations (ICRISAT, IIPR, PAU and IARI) treat with EMS and obtain M_1 generation.
Grow breeding lines/populations for generation advancement in the off-season	Seed of breeding lines/populations advanced during off-season (in the summer season at Patancheru and in the rainy season at Hiriyur and Dharwad in Karnataka).
Prepare and submit Annual Report of Year 1	Annual Report submitted by ICRISAT

Year 2

Activities	Milestones
Organize annual meeting to review the progress of Year 1 and refine the workplan for Year 2.	One annual meeting of the project organized during Jul/Aug 2014 by ICRISAT at one of the participating center.
Construct and conduct a new multilocation trial by selecting promising tall and upright breeding lines from multilocation and station trials of Year 1.	At least 30 breeding lines with tall and upright growth habit evaluated at all 7 locations.
Enter the promising tall and upright breeding lines in Initial Varietal Trial (IVT) of AICRP on chickpea	At least one promising tall and upright breeding lines entered in IVT.
Construct and conduct a station trial on newly identified tall and upright breeding lines at each location.	One station trial on newly identified tall and upright breeding lines conducted at 4 main locations (ICRISAT, IIPR, PAU and IARI).

Grow F2/F3 from 4 crosses at each location for generation advancement and share bulk seed with all partners.	The bulk seed of F3/F4 populations segregating for plant height and growth habit shared among partners.
Make required adjustments/modifications in the harvesting machines and perform testing in the field with selected lines.	Performance of harvesting machines tested after making required changes.
Screen additional genotypes (germplasm/ cultivars/breeding lines) for herbicide tolerance at 4 locations (ICRISAT, IIPR, IARI, PAU).	At least 300 new genotypes screened for herbicide tolerance at 4 locations.
Screen selected herbicide tolerant genotypes at all 7 locations and cross top few lines with selected cultivars for introducing herbicide tolerance.	At least 30 genotypes careened for herbicide tolerance at all 7 locations.
M_3 progenies from selected M_2 plants screened for herbicide tolerance at ICRISAT	At least 100 M_3 progenies screened for herbicide tolerance at ICRISAT.
Screen M_2 for herbicide tolerance to identify herbicide tolerant mutants	At least one M_2 population screened for herbicide tolerance at each of the 4 locations (ICRISAT, IIPR, IARI and PAU).
Grow breeding lines, mutant lines and segregating populations in the off-season for seed multiplication/generation advancement.	Seed of breeding lines/populations advanced during off-season.
Prepare and submit Annual Report of Year 2.	Annual Report submitted by ICRISAT

Year 3

Activities	Milestones
Organize annual meeting to review the progress of Year 2 and refine the workplan for Year 3.	One annual meeting of the project organized during Jul/Aug 2015 by ICRISAT at one of the participating center.
Repeat the multilocation trial of the second year on tall and upright breeding lines.	At least 30 breeding lines with tall and upright growth habit evaluated at all 7 locations.
Enter the promising tall and upright breeding lines in Initial Varietal Trial (IVT) of AICRP on chickpea.	At least one promising tall and upright breeding line entered in IVT from each region (northern, central and southern India).
Construct and conduct new station trial on tall and upright breeding lines at each location.	One station trial on newly identified tall and upright breeding lines conducted at all locations.
Evaluate top 2-4 lines at farmers' fields within each region.	At least 2 breeding lines suited to machine harvesting evaluated on farmers' fields.
Conduct an agronomic trial in each region on selected 1-2 elite lines suited to mechanical harvesting for identifying optimum seed rate and population density per unit area.	An agronomic trial on 1-2 promising tall and upright breeding lines conducted at all locations for establishing optimum seed rate.
Select tall and upright plants with acceptable seed traits from F4 populations at each partner organization.	At least 4 F_4 populations evaluated and tall and upright promising plants selected at each location.
Exhaustive testing of harvesting machine at research station and farmers' fields.	The harvesting machines with desired modifications tested at stations and on farmers' fields.

Evaluate herbicide tolerant mutant lines at 7 locations.	At least 20 herbicide mutant lines screened for herbicide tolerance at all 7 locations
Screen segregating populations (F_2/F_3) for herbicide tolerance.	At least 4 segregating populations screened for herbicide tolerance at each location.
Grow breeding lines, mutant lines and segregating populations in the off-season for seed multiplication/generation advancement.	Seed of breeding lines/populations advanced during off-season.
Prepare and submit Annual Report for Year 3	Annual Report submitted by ICRISAT

Year 4

Activities	Milestones
Organize annual meeting to review the progress of Year 3 and refine the workplan for Year 4.	One annual meeting of the project organized during Jul/Aug 2016 by ICRISAT at one of the participating center.
Repeat the regional multilocation trials within each region with selected entries.	Multilocation trials conducted on selected elite lines suited to mechanical harvesting in each region.
Repeat the agronomic trial in each region aimed at establishing optimum seed rate and population density per unit area for the selected elite lines suited to mechanical harvesting.	Optimum seed rate established for breeding lines suited to mechanical harvesting.
Conduct large number of on-farm trials on selected lines and evaluate these for suitability to harvest with combine harvest.	Selected 2-3 elite tall and upright breeding lines and evaluated at farmers' fields for suitability to mechanical harvesting.
Construct and conduct new station trial on tall and upright lines generated from new crosses.	One station trial on newly identified tall and upright breeding lines conducted at all locations.
Demonstrations of harvesting machine to farmers' fields and transfer of technology to industry.	At least 2-3 demonstrations on harvesting machine conducted on farmers' fields in each region.
Further evaluate selected herbicide tolerant mutant lines in multilocation trials.	At least 20 mutant lines evaluated for herbicide tolerance at all locations.
Evaluate herbicide tolerant F_4 breeding lines in station trials.	At least 100 breeding lines evaluated for herbicide tolerance at each location.
Multiply selected material in the off-season and share the produce with project partners.	Seed of breeding lines/populations advanced during off-season.
Develop and submit proposal for release of top 1-2 elite lines suited to mechanical harvesting in each region based on data available from 3-year evaluation.	Varietal release proposals developed for at least 3 elite lines.
Prepare and submit the Final Report of the project.	Final Report submitted by ICRISAT

16. Role of ICRISAT in the project

ICRISAT being a lead institute will be responsible for providing technical guidance, coordinating the project activities, monitoring of the project activities and submitting the financial and technical reports to NFSM. ICRISAT has the largest collection of chickpea

germplasm (>20,000 accessions). The ICRISAT's chickpea breeding program will be able to select required germplasm and fast track development of breeding lines by taking three crops per year. ICRISAT will supply germplasm and breeding lines to partners in this project.

17. Monitoring and evaluation

A project monitoring committee (PMC) will be constituted with approval from the Agriculture Commissioner. The PMC will have three members – one from NFSM, one from ICAR and one from SAUs. The PMC members will not be from the participating institutes of this project. The PMC will provide guidance and monitor the progress of the project.

18. Adoption pathways and expected impacts

This project will identify for release elite lines of chickpea suited to mechanical harvesting. We would complete mutilocation evaluation of selected lines and also collect data on performance of these lines at farmers' fields in the target regions. The top 1-2 lines each in northern, central and southern India would be proposed for release to the respective State Variety Release Committees or to the Central Variety Release Committee through All India Coordinated Research Project (AICRP) on Chickpea. We expect that at least one cultivar suited to mechanical harvesting will be released or proposed for release in each region (northern, central and southern) within the life of this or project.

Development of herbicide tolerant chickpea is a new area of research and we need to first confirm sources of herbicide tolerance identified at PAU-Ludhiana from a preliminary screening of one year and identify/induce additional sources of herbicide tolerance and then use these in development of high yielding and agronomically acceptable cultivars. Thus, progress in development of herbicide tolerant chickpea will not be as rapid as for the development of cultivars suited to mechanical harvesting, where initial breeding materials already exist. For herbicide tolerance, we expect to generate advanced breeding lines and identify some candidate lines for multilocation evaluation by the end of this project. These lines will be later evaluated in multilocation trials at research stations and also at farmers' fields and the top lines will be released through State and/or Central Variety Release Committee.

Once the herbicide tolerant mutants are identified, these will be used in understanding genetics of herbicide tolerance and identifying molecular markers for herbicide tolerance gene(s) for improving efficiency of herbicide tolerance breeding. The project will benefit collaborating scientists in enhancing their skill and capacity of chickpea breeding programs for herbicide tolerance and suitability to mechanical harvesting. The project would provide opportunities to students and young researchers for improving their knowledge and skills. The salient findings from this project will be published in form of research articles in peer reviewed Scientific Journals/Conference Proceedings and benefit the global scientific community.

The research efforts made in this project would ultimately lead to development of chickpea cultivars suited to mechanical harvesting and improved tolerance to herbicides. Availability of these cultivars will make chickpea cultivation more attractive and remunerative to farmers. The long term impacts of the outcome of this project would be enhanced income of farmers from chickpea cultivation; expansion in chickpea area due to improved competitiveness of chickpea, particularly in northern India; and increased domestic production of chickpea.

19. Summary of Budget (Rs. In lakh)

Particulars	ICRISAT	IIPR	IARI	PAU Part A	PAU Part B	RAKCA	UAS- D	RARS-Nandyal	**Total**
(A) Contractual Staff	40.84	17.46	14.46	13.62	13.62	13.62	13.62	13.62	**140.86**
(B) Equipment	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00	**16.00**
(C) Operational									
Field experiments	113.50	51.85	35.00	35.00	8.65	31.35	31.35	31.35	**338.05**
Greenhouse/ off-season experiments	36.50	8.65	8.65	8.65					**62.45**
Consumables and contingent expenditure	42.00	13.75	11.75	11.75	9.25	9.25	9.25	9.25	**116.25**
Workshops/me etings	13.00								**13.00**
Travel (domestic)	6.00	3.60	2.35	2.35	2.35	2.35	2.35	2.35	**23.70**
Total operational (C)	211.00	77.85	57.75	57.75	20.25	42.95	42.95	42.95	**553.45**
Sub-total (A+B+C)	**253.84**	**97.31**	**74.21**	**73.37**	**35.87**	**58.57**	**58.57**	**58.57**	**710.31**
Institutional overhead charges (10%)	25.38	0.00	0.00	7.34	3.60	5.87	5.87	5.87	**53.93**
Grand Total	**279.22**	**97.31**	**74.21**	**80.71**	**39.47**	**64.44**	**64.44**	**64.44**	**764.24**

Year-wise budget for each collaborating institute (Rs. in lakh)

(1) ICRISAT-Patancheru

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: Special Project Scientist (1) @ Rs 50,000/month with 5% increase every year; Research Associate (1) @ Rs 24,000/month +30% HRA	9.74	10.04	10.36	10.69	40.84
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational					0.00
Field experiments	26.00	27.50	29.00	31.00	113.50
Greenhouse/off-season experiments	8.00	8.75	9.50	10.25	36.50
Consumables and contingent expenditure	9.00	10.00	11.00	12.00	42.00
Workshops/meetings	2.50	3.00	3.50	4.00	13.00
Travel (domestic)	1.20	1.40	1.60	1.80	6.00
Total operational (C)	46.70	50.65	54.60	59.05	211.00
Sub-total (A+B+C)	**58.44**	**60.69**	**64.96**	**69.74**	**253.84**
Institutional overhead charges (10%)	5.84	6.07	6.50	6.97	25.38
Grand Total	**64.29**	**66.76**	**71.46**	**76.71**	**279.22**

(2) IIPR-Kanpur

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: SRF (1) @ Rs 16,000/month for 1st and 2nd yr and Rs 18,000/month for 3rd and 4th yr + 20% HRA; Skilled worker (2) @ Rs 8,000/month	4.22	4.22	4.51	4.51	17.46
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational					
Field experiments	12.00	12.60	13.25	14.00	51.85
Greenhouse/off-season experiments	2.00	2.10	2.20	2.35	8.65
Consumables and contingent expenditure	3.00	3.25	3.50	4.00	13.75
Travel (domestic)	0.75	0.80	0.95	1.10	3.60
Total operational (C)	17.75	18.75	19.90	21.45	77.85
Total (A+B+C)	**23.97**	**22.97**	**24.41**	**25.96**	**97.31**

(3) IARI-New Delhi

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: SRF (1) @ Rs 16,000/month for 1st and 2nd yr and Rs 18,000/month for 3rd and 4th yr + 30% HRA; Skilled worker (1) @ Rs 8,000/month	3.46	3.46	3.77	3.77	14.46
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational					
Field experiments	8.00	8.50	9.00	9.50	35.00
Greenhouse/off-season experiments	2.00	2.10	2.20	2.35	8.65
Consumables and contingent expenditure	2.50	2.75	3.00	3.50	11.75
Travel (domestic)	0.50	0.55	0.60	0.70	2.35
Total operational (C)	13.00	13.90	14.80	16.05	57.75
Total (A+B+C)	**18.46**	**17.36**	**18.57**	**19.82**	**74.21**

(4) PAU-Ludhiana: Component A (Crop Improvement)

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: SRF (1) @ Rs 16,000/month for 1st and 2nd yr and Rs 18,000/month for 3rd and 4th yr + 20% HRA; Skilled worker (1) @ Rs 8,000/month	3.26	3.26	3.55	3.55	13.62
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational					
Field experiments	8.00	8.50	9.00	9.50	35.00
Greenhouse/off-season experiments	2.00	2.10	2.20	2.35	8.65
Consumables and contingent expenditure	2.50	2.75	3.00	3.50	11.75
Travel	0.50	0.55	0.60	0.70	2.35
Total operational (C)	13.00	13.90	14.80	16.05	57.75
Sub-total (A+B+C)	**18.26**	**17.16**	**18.35**	**19.60**	**73.37**
Institutional overhead charges (10%)	1.83	1.72	1.84	1.96	7.34
Grand Total	**20.09**	**18.88**	**20.19**	**21.56**	**80.71**

(5) PAU-Ludhiana: Component B (Farm machinery)

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: SRF (1) @ Rs 16,000/month for 1st and 2nd yr and Rs 18,000/month for 3rd and 4th yr + 20% HRA; Mechanic cum tractor driver (2) @ Rs 8000/month	3.26	3.26	3.55	3.55	13.62
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational (domestic)					
Field experiments	2.00	2.10	2.20	2.35	8.65
	0.00	0.00	0.00	0.00	0.00
Consumables and contingent expenditure	2.00	2.15	2.40	2.70	9.25
Travel	0.50	0.55	0.60	0.70	2.35
Total operational (C)	4.50	4.80	5.20	5.75	20.25
Sub-total (A+B+C)	**9.76**	**8.06**	**8.75**	**9.30**	**35.87**
Institutional overhead charges (10%)	0.98	0.81	0.88	0.93	3.60
Grand Total	**10.74**	**8.87**	**9.63**	**10.23**	**39.47**

(6) RAKCA-Sehore

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: SRF (1) @ Rs 16,000/month for 1st and 2nd yr and Rs 18,000/month for 3rd and 4th yr + 20% HRA; Skilled worker (1) @ Rs 8,000/month	3.26	3.26	3.55	3.55	13.62
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational					0.00
Field experiments	7.00	7.50	8.10	8.75	31.35
Consumables and contingent expenditure	2.00	2.15	2.40	2.70	9.25
Travel (domestic)	0.50	0.55	0.60	0.70	2.35
Total operational (C)	9.50	10.20	11.10	12.15	42.95
Sub-total (A+B+C)	**14.76**	**13.46**	**14.65**	**15.70**	**58.57**
Institutional overhead charges (10%)	1.48	1.35	1.47	1.57	5.87
Grand Total	**16.24**	**14.81**	**16.12**	**17.27**	**64.44**

(7) UAS-Dharwad

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: SRF (1) @ Rs 16,000/month for 1st and 2nd yr and Rs 18,000/month for 3rd and 4th yr + 20% HRA; Skilled worker (1) @ Rs 8,000/month	3.26	3.26	3.55	3.55	13.62
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational					
Field experiments	7.00	7.50	8.10	8.75	31.35
Consumables and contingent expenditure	2.00	2.15	2.40	2.70	9.25
Travel (domestic)	0.50	0.55	0.60	0.70	2.35
Total operational (C)	9.50	10.20	11.10	12.15	42.95
Sub-total (A+B+C)	**14.76**	**13.46**	**14.65**	**15.70**	**58.57**
Institutional overhead charges (10%)	1.48	1.35	1.47	1.57	5.87
Grand Total	**16.24**	**14.81**	**16.12**	**17.27**	**64.44**

(8) RARS-Nandyal

Particulars	Year 1	Year 2	Year 3	Year 4	**Total**
(A) Staff: SRF (1) @ Rs 16,000/month for 1st and 2nd yr and Rs 18,000/month for 3rd and 4th yr + 20% HRA; Skilled worker (1) @ Rs 8,000/month	3.26	3.26	3.55	3.55	13.62
(B) Equipment	2.00	0.00	0.00	0.00	2.00
(C) Operational					
Field experiments	7.00	7.50	8.10	8.75	31.35
Consumables and contingent expenditure	2.00	2.15	2.40	2.70	9.25
Travel (domestic)	0.50	0.55	0.60	0.70	2.35
Total operational (C)	9.50	10.20	11.10	12.15	42.95
Sub-total (A+B+C)	**14.76**	**13.46**	**14.65**	**15.70**	**58.57**
Institutional overhead charges (10%)	1.48	1.35	1.47	1.57	5.87
Grand Total	**16.24**	**14.81**	**16.12**	**17.27**	**64.44**

Justifications for the budget

Contractual Staff	
Special Project Scientist at ICRISAT	He/she will be responsible for statistical analysis of the multilocation data, managing the inventory of seed supply and database of the project, compiling reports from all partner institutions and developing the initial drafts of the research reports. This is a Post-Doctoral Fellow level position to be recruited as per existing rules and regulations of ICRISAT.
Research Associate at ICRISAT and Senior Research Fellow at other locations	He/she will be responsible for implementation of the project activities and recording all field observations and entering the data in excel sheets. These positions will be recruited as per existing rules and regulations of the ICAR.
Skilled workers	They are required to assist in field activities, including assistance in measurements.
Equipment	These include power sprayers, chlorophyll meters, data loggers, data processing system, and other minor non-recurring items.
Operational	
Field experiments	Wages of casual labours and expenses required in field preparations, inter-culture operations, harvesting, threshing, etc.
Greenhouse/ off-season experiments	Includes greenhouse rental charges, charges by the research stations providing land and facilities for off-season crop, wages of casual labours and other expenses during the off-season.
Consumables and contingent expenditure	Includes costs of herbicides, pesticides, fertilizers, EMS, pots, envelops, cloth bags and other

	consumable items.
Workshops/meetings	Expenses incurred in arranging annual meetings of the project.
Travel (domestic)	Includes visits to the off-season nurseries, travel to other locations for monitoring of experiments attending meetings/conferences within India.
Institutional overhead charges	10% overhead charges have been kept for all partner institutes except ICAR institutes.

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