Short Duration Chickpea Technology: Enabling Legumes Revolution in Andhra Pradesh, India

Final Report

by

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ICRISAT Science with a human face
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List of Acronyms

ACIAR	Australian Centre for International Agricultural Research
ANA	Anantapur district
ANGRAU	Acharya N G Ranga Agricultural University
AP	Andhra Pradesh state
APSSDC	Andhra Pradesh State Seed Development Corporation
AY	Actual Yields
BC	Back-ward castes
BCR	Benefit-cost-ratio
CGIAR	Consultative Group on International Agricultural Research
COC	Cost of Cultivation
COP	Cost of production
CP	Chickpea
CVRC	Central Varietal Release Committee
DIIVA	Diffusion and Impact of Improved Varieties in Africa
ED	Elasticity of Demand
ES	Elasticity of Supply
FC	Fixed cost
FF	Fellow Farmer
FGDs	Focus-Group Discussions
FGMs	Focus Group Meetings
GE	Government Extension Agency
GIS	Geographical Information system
GOI	Government of India
HH	Household
HYV	High Yielding Variety
IAS	Impact Assessment Study
IBPGR	International Bureau of Plant Genetic Resources
ICAR	Indian Council of Agriculture Research
ICARDA	International Centre for Agricultural Research in the Dry Areas
ICRISAT	International Crops Research Institute for the Semi-Arid Tropics
IRR	Internal Rate of Return
KA	Karnataka state
KAD	Kadapa district
KUR	Kurnool district
LGP	Length of growing period
LS	Local Seed Traders
MAHA	Mahabubnagar district
MC	Marginal Cost
MED	Medak district
MH	Maharashtra state
MIT	Massachusetts Institute of Technology
NA	Non-Adopters
NARS	National Agricultural Research System
NIZ	Nizamabad district

NPV	Net Present Value
NRM	Natural Resources Management
NSC	National Seeds Corporation
NY	Normal Yield
PDS	Public Distribution System
PE	Production Environment
PRM	Prakasam district
Qtl	Quintal
SAT	Semi-Arid Tropics
SC	Scheduled Castes
SD	Short Duration
SFCI	State Farm Corporation of India Ltd
SPIA	Standing Panel on Impact Assessment
SSEA	South and South East Asia
ST	Scheduled Tribes
SW	Switchers
ATC	Average Total Cost
TC	Total Cost
TL	Tropical Legumes
TRIVSA	Tracking Improved Varieties in South Asia
UCR	Unit cost reduction
UC	Unit Cost
VC	Variable cost
VLS	Village Level Studies

<u>Conversions used</u>

$ US = Rs.55
Qtl = 100 kg
M ton = 1000 kg
Acre = 0.404 ha

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1 Introduction

This study presents the success story of the adoption and diffusion of improved chickpea short duration varieties in Southern India. The experience in the state of Andhra Pradesh particularly exemplifies evidences that adoption of technologies significantly enhanced agricultural productivity and total welfare gains in both traditional and non-traditional chickpea growing regions. As part of a global initiative to assess the impacts of legumes research in the CGIAR, this study supported by SPIA contributes to generating more reliable information on key aspects of adoption and diffusion as well as gaining better insights and deeper understanding of the impacts of varietal change.

This study conducted a comprehensive adoption survey to generate reliable data on adoption and better understand the diffusion process as well as quantify the direct impacts on productivity, unit cost reduction and welfare gains from chickpea research. The focus of this study is to measure the economic impact of improved short duration chickpea varieties, at the same time achieve a deeper understanding of the underlying adoption and diffusion process.

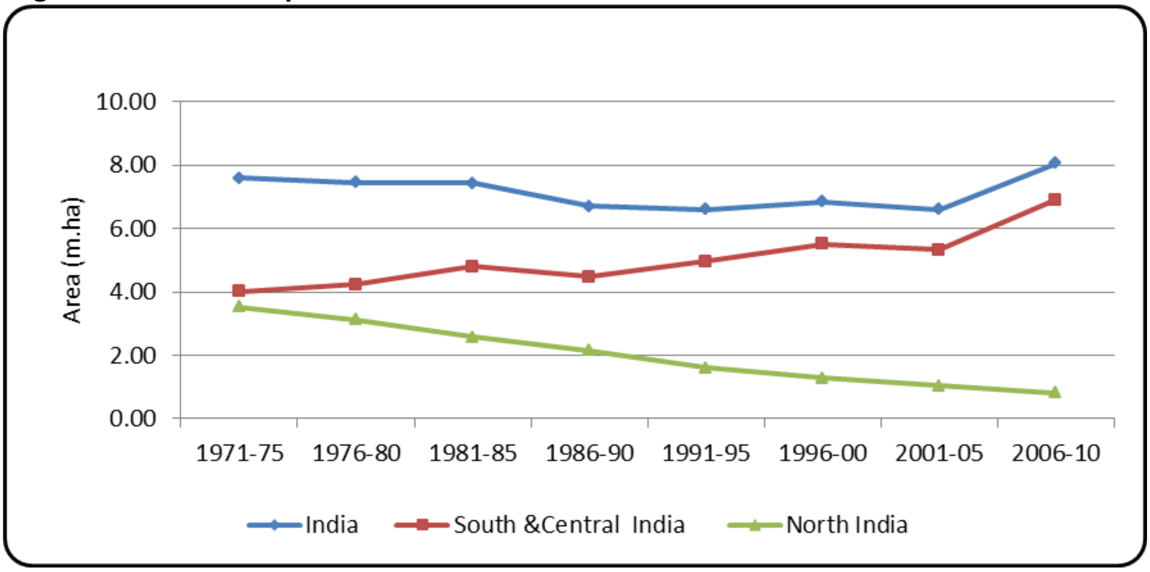
Study Rationale

The last five decades saw chickpea production undergoing tremendous change in terms of area shift from Northern India (cooler, long-season environments) to Southern India (warmer, short-season environments) particularly beginning the period of 1975-1990 on expansion of wheat and rice industry. New chickpea varieties adapted to warmer, short-season environments are bringing increasing prosperity to Southern India and offer hope for farmers elsewhere in the Semi-Arid Tropics (SAT). To appreciate the chickpea revolution in Southern India, we need to go back a few decades.

Northern India, with its long winters, has suitable climate for chickpea cultivation but the expansion of irrigation in the Indo-Gangetic Plains, the development of wheat and rice varieties (HYV) during the green revolution period, and accompanying high input agriculture gradually displaced the chickpea crop to marginal rainfed areas and led to chickpea cultivation being largely replaced by wheat and other cash crops.

Now large area of chickpea crop exists in the semi-arid tropics which most often experiences the short winters, terminal moisture stress and heat stress, wilt disease and pod borer problem at the reproductive stages, particularly in Southern states of India. During the 1964-65 cropping season, chickpea was planted on 5.14 million hectares in Northern India; it is now planted on only 0.73 million hectares (2010-11). During the same period down in Southern India, the cropped area has gone up significantly from 2.05 m ha to 5.56 m ha. This tremendous shift in cropped area happened due to introduction of high yielding short duration chickpea varieties that are resistant to Fusarium wilt disease (see Fig 1.1).

Fig 1.1 Shifts in chickpea area from North to South and Central India



In the above context, it is compelling to systematically document the adoption, diffusion and impact of improved chickpea technologies in Southern India. This specific success story is positive evidence that adoption of technologies can enhance production of chickpea in other regions of South Asia and sub-Saharan Africa, where currently yield levels remain low. A comprehensive quantification of the research benefits at farm level is timely, particularly in Andhra Pradesh as the outcome of the analysis would showcase the impact of chickpea improved technology in India.The chickpea revolution in Andhra Pradesh will be a suitable case to answer many inter-linked issues in technology adoption and agricultural intensification. Some relevant issues that can be further investigated using this data are socio-economic, institutional and policy drivers for technology adoption, farm-level responses (input use, land allocation, soil and water conservation, crop and NRM technologies, mechanization etc.), household welfare and sustainable intensification of SAT agriculture.

Objectives of the study

The overall objective of the present study is to document the 'silent chickpea revolution in Andhra Pradesh.' Specifically, the study aims to address the following three major objectives:

1. Develop and apply new advances in methodology for assessing adoption and impacts of improved agricultural technologies;
2. Track the adoption of chickpea high yielding short duration improved cultivars in AP ;
3. Assess the farm-level benefits of adoption of chickpea improved technologies; and estimate the welfare impacts for the state of Andhra Pradesh and India

Scope of the study

This comprehensive impact assessment study (IAS) has a detailed adoption study and on-farm survey to fully understand the various dimensions of impacts and generate the best possible data for the IAS. The study has been designed to understand and measure the adoption, diffusion and impact of chickpea short-duration improved cultivars in the state of Andhra Pradesh through a representative primary survey and suitable decision tree protocol. Quantification of farm-level welfare benefits experienced by chickpea growing farmers are determined by examining various scenarios of technology adoption: namely a) replacement of old improved cultivars (Annigeri) to adoption of new improved cultivars (like JG 11, KAK 2, and Vihar among others); as well as b) switching over by non-chickpea growing farmers (e.g. farmers traditionally growing other crops like cotton, tobacco, sorghum, groundnut, chillies and others) to new improved short duration chickpea cultivars. Overall, the study aims to understand the substantial preferences for chickpea cultivation over other crops in this state, the pattern of chickpea varietal adoption and replacement, productivity gains at farm-level, unit-cost reductions and its impact on welfare. The influence of socio-economic, institutional and policy variables on the extent of adoption will also be studied. Further, the behavioural changes in own land allocation, leasing-in land, soil and water management, input-use application and mechanization etc. will be documented in relation to technology adoption.

Plan of the study

This report is organized in 11 chapters. The first two chapters introduce and give a background on the chickpea industry in India and Andhra Pradesh. It discusses the importance of chickpea in the world and in India and its historic trends using a temporal analysis covering more than four decades of data on chickpea area, production and productivity. Chapter 3 introduces the global chickpea research domains used in targeting chickpea research. This is complemented by the spatial analysis of bio-physical data - soil, rainfall and length of growing period regimes -which may be influencing chickpea productivity and the diffusion of chickpea short-duration cultivars across various agro-ecologies. It also systematically documents the research and development process and research timeline with specific focus on chickpea short-duration cultivars. Corresponding research and development costs from research started in 1978 up to the releases and dissemination of the new short duration cultivars in southern India are systematically documented. Chapter 4 elucidates on the methodology for estimating the welfare benefits and the conceptual framework underlying it. This gives the theoretical basis of the welfare estimates which encompasses a multi-country perspective and captures the direct benefits from technology adoption in targeted regions as well as the spillover research benefits globally. The tools and methods used to better understand and document technology adoption are discussed in the following chapter to fully understand the impacts including a number of specific testable hypotheses linking the introduction of the new early maturing varieties in southern India to insightful dimensions of impact. This component of the study illustrates some innovative approaches of getting best possible data for the impact assessment study.

Chapter 5 describes the survey details including the sampling framework for the comprehensive study. The process of development of varietal identification protocols and survey instruments are discussed.

The results of the adoption study are presented in Chapters 6. The primary survey results are first featured to reflect the socio-economic profile of chickpea traditional and non-traditional growers in Andhra Pradesh. Deeper insights of the adoption and diffusion process is achieved by disaggregating the data further to analyse the diverse diffusion patterns across cultivars and across districts and more critically to incorporate in the impact analysis the welfare gains and losses of adoptors and non-adoptors and analyse the benefits of various types of adoptors. Chapter 7 presents the summary of the key parameter estimates drawn from chapter 6 and other sources of the minimum data set for assessing welfare gains. In particular, the summary list draws from the field insights on costs and returns in crops cultivation and unit-cost reductions due to adoption of new technology. The estimated welfare benefits are quantified and presented for Andhra Pradesh and India. Finally, chapter 8 presents the summary and conclusions about the study. Chapters 10 & 11 contain the references and appendices for the study.

2 Background to Research

2.1 Chickpea Industry Context

Chickpea (*Cicer arietinum L.*) is the largest pulse crop grown in India and the second largest food legume in the world. It occupies around 15 per cent of total pulse area globally and is cultivated in almost 52 countries (FAOSTAT, 2012). South and South East Asia (SSEA) alone contribute about 88 and 86 per cent shares in global area and production respectively (see Table 2.1). Chickpea, like other pulse crops traditionally grown in many parts of the world, has multiple functions in the traditional farming systems especially in many developing countries. As well as being an important source of human food and animal feed, it also helps in the management of soil fertility, particularly in drylands (Sharma and Jodha 1984).

India ranks first in terms of chickpea production and consumption in the world (both at almost 70%). Currently, chickpea covers 35 per cent of total pulse area and produces nearly 47 per cent of total pulse production in India (GOI, 2012). The long term macro trends (1980-2010) in India indicate that the cropped area has slightly increased and registered a growth rate of 0.25 per cent (see Fig 2.1). But, the production and productivity have increased significantly with exhibited growth rate of 1.3 and 1.04 per cent respectively during the same period (see Table 2.2).

Table 2.1 Chickpea regional distribution, 2012

Region	No. of countries	Area (m ha)	%share	Production (m ton)	%share	Productivity (kg/ha)
World	52	11.98	100.00	10.92	100.00	911.20
Asia	16	10.65	88.92	9.36	85.76	878.82
Africa	14	0.53	4.44	0.52	4.73	970.98
Australia	1	0.50	4.17	0.60	5.51	1204.00
America	7	0.24	1.97	0.36	3.29	1523.28
Europe	14	0.06	0.51	0.08	0.71	1280.70

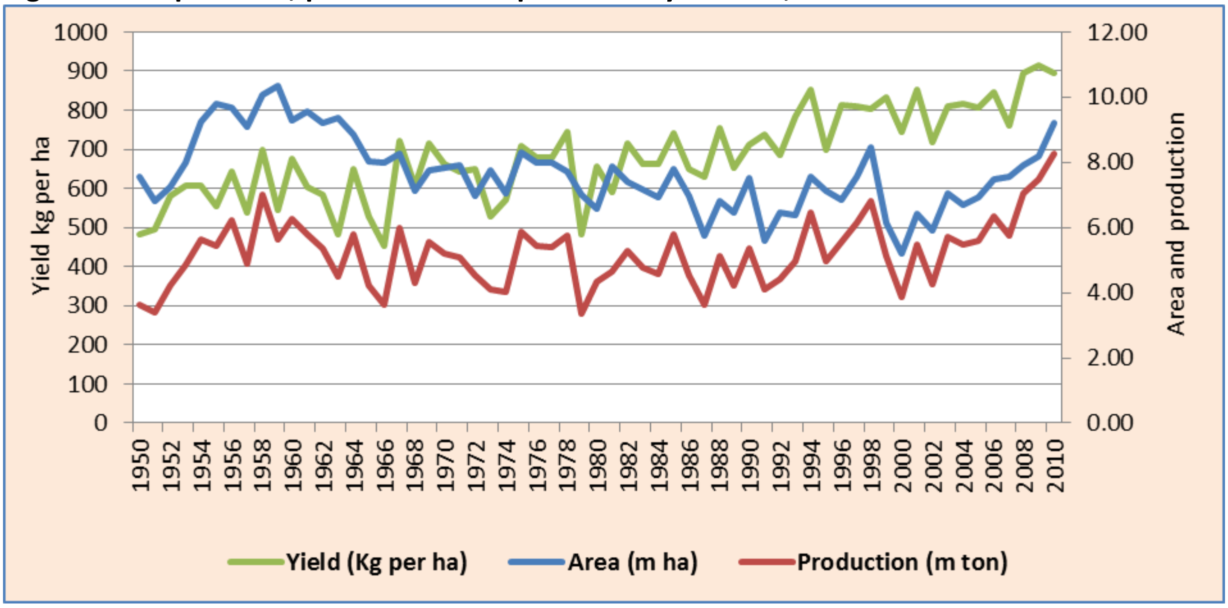
Source: FAOSTAT, 2012.

Table 2.2 All India Chickpea area, production and yield growth rates (%)

Period	Total area	Total production	Yield
1980-85	1.23	3.76	2.53
1985-90	2.67	4.99	2.24
1990-95	6.65	7.85	1.13
1995-00	-7.33	-8.73	-1.49
2000-05	2.84	3.06	0.20
2005-10	3.60	8.25	4.29
1980-10	0.25	1.30	1.04

Source: Ministry of Agriculture and Cooperation, 2012

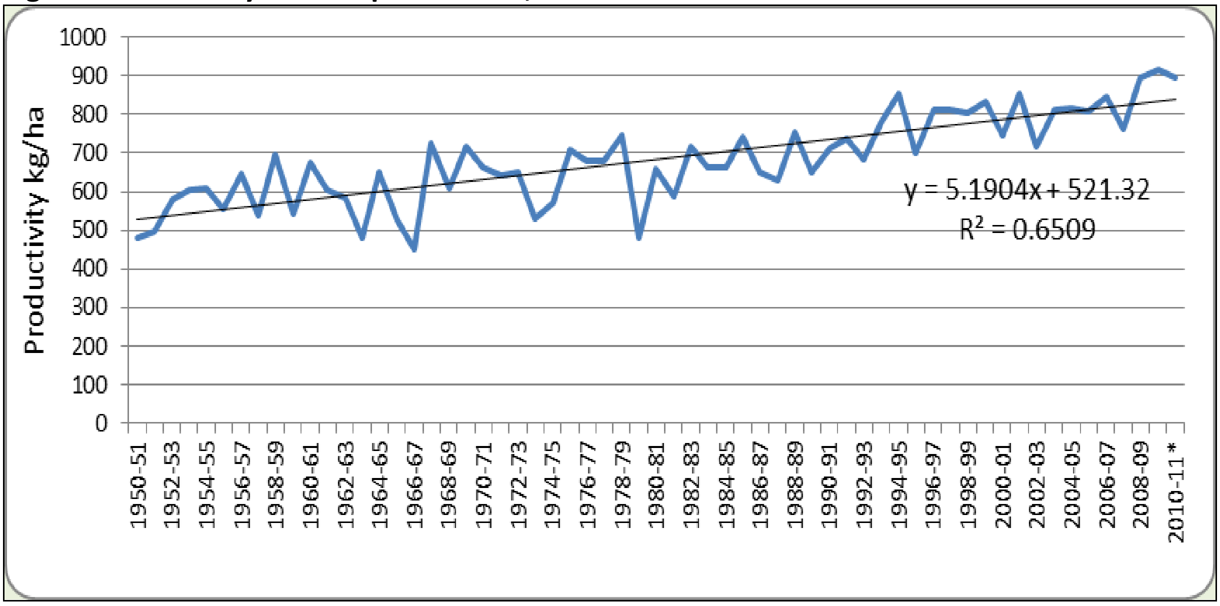
Fig 2.1 Chickpea area, production and productivity in India, 1980-2010



Source: Ministry of Agriculture and Cooperation, 2012

The major six states of Madhya Pradesh, Rajasthan, Maharashtra, Uttar Pradesh, Karnataka and Andhra Pradesh together contribute more than 90 per cent of area and production of chickpea in India (see Table 2.3). However, the growth rate in area during the last four decades (1970-2010) in area, production and productivity is distinctly higher in Andhra Pradesh when compared with other states. The productivity in Andhra Pradesh has increased enormously from 853 kg per ha in 1996-97 to 1308 kg per ha by 2009-10 due to the widespread adoption of improved high yielding short-duration cultivars. While the linear trend line computed for productivity for the period, 1950-51 to 2010-11, for the whole country indicated the productivity increased by about 5 kg per year (Fig 2.2).

Fig 2.2 Productivity of Chickpea in India, 1950-51 to 2010-11



Source: Directorate of Economics and Statistics, GOI

Table 2.3 Performance of chickpea across major states in India, 1966-2010

States	Area in '000' ha		Production '000' tons		Productivity (kg/ha)	
	1966-68	2008-10	1966-68	2008-10	1966-68	2008-10
Andhra Pradesh	77.0 (0.99)	614.6 (7.27)	18.3 (0.40)	810.0 (10.64)	238	1317
Maharashtra	366.3 (4.70)	1289.3 (15.33)	112.3 (2.42)	1060.0 (14.00)	305	815
Madhya Pradesh	1569.7 (20.15)	3014.0 (35.79)	733.0 (15.82)	2925.3 (38.56)	469	972
Gujarat	45.7 (0.59)	162.0 (1.91)	14.0 (0.30)	170.0 (2.20)	337	1032
Punjab	503.5 (6.46)	2.66 (0.03)	398.7 (8.61)	3.16 (0.04)	775	1197
Uttar Pradesh	2297.3 (29.49)	580.0 (6.90)	1387.5 (29.94)	533.3 (7.04)	607	923
Bihar	289.2 (3.71)	209.33 (2.01)	173.0 (3.73)	60.1 (0.77)	598	1042
Rajasthan	1144.7 (15.40)	1307.7 (15.56)	722.3 (15.58)	1036.7 (13.70)	620	760
Karnataka	176.7 (2.52)	886.33 (10.52)	73.0 (1.83)	533.7 (7.05)	430	600
India	7788.3 (100.00)	8420.0 (100.00)	4630.0 (100.00)	7590.0 (100.00)	594	902
Note: Figures in the parenthesis indicates percentage to the column total						

Source: Ministry of Agriculture and Cooperation, 2012

Temporal analysis of chickpea area, production and productivity

As highlighted earlier, the state-wise growth in chickpea area, production and productivity during the last four decades (1970-2010) are presented in Table 2.4. The highest growth in chickpea area was observed in Andhra Pradesh (see Fig 2.3) followed Karnataka, Maharashtra and Madhya Pradesh from 1970 to 2010. Rajasthan and Uttar Pradesh exhibited negative growth trends in the area during the same. Similar patterns were also experienced for chickpea production in these states. The productivity enhancement was much conspicuous in Andhra Pradesh when compared to other states in India. However, the increase in yield was significant during last two decades due to peak adoption of improved cultivars (Fig 2.5). On average the productivity has increased only 8.2 kg per ha per annum from 1970 to 1990 while the same increased at 46.5 kg per ha per year between 1991 and 2010 in Andhra Pradesh (see Fig 2.4 & 2.5).

Table 2.4 Long-term chickpea trends in major states, 1970-2010

(Area '000' ha, Production '000' tons and Yield kg/ha)

State	Item	1971-1980	1981-1990	1991-2000	2001-2010	1971-2010
Andhra Pradesh	Area	64.7	58.2	125.7	490.8	184.9
	Prod	22.2	26.0	95.0	616.9	190.0
	Yield	339.5	434.6	744.2	1242.5	690.2
Gujarat	Area	60.8	97.2	101.2	149.3	102.1
	Prod	41.6	73.6	71.5	136.3	80.7
	Yield	683.0	735.4	669.8	853.5	735.4
Karnataka	Area	158.9	196.6	315.9	622.0	323.4
	Prod	61.7	74.1	157.3	343.4	159.1
	Yield	383.7	381.5	485.3	541.3	448.0
Maharashtra	Area	417.8	544.5	716.6	1072.6	687.9
	Prod	141.0	237.3	414.8	771.1	391.1
	Yield	330.0	423.2	570.3	691.6	503.8
Rajasthan	Area	1571.2	1513.6	1510.4	1081.9	1419.3
	Prod	1073.9	1018.0	1082.5	759.2	983.4
	Yield	672.4	664.8	695.2	694.9	681.8
Madhya Pradesh	Area	1843.9	2219.4	2453.8	2706.7	2305.9
	Prod	1065.8	1512.8	2125.5	2455.1	1789.8
	Yield	583.1	680.0	862.6	902.3	757.0
Uttar Pradesh	Area	1731.8	1415.8	957.7	687.2	1198.1
	Prod	1510.9	1180.1	832.5	619.3	1035.7
	Yield	850.7	834.8	870.4	895.7	862.9
Bihar	Area	230.1	177.5	122.5	128.9	119.1
	Prod	136.2	145.1	115.9	79.0	832.2
	Yield	596.8	819.1	951.7	961.1	832.2
Punjab	Area	320.0	103.3	16.7	4.4	111.1
	Prod	268.5	66.0	13.7	4.2	88.1
	Yield	825.2	674.0	848.7	993.4	88.1

Fig 2.3 Chickpea area ('000' ha) and production ('000' tons) in Andhra Pradesh, 1970-2010

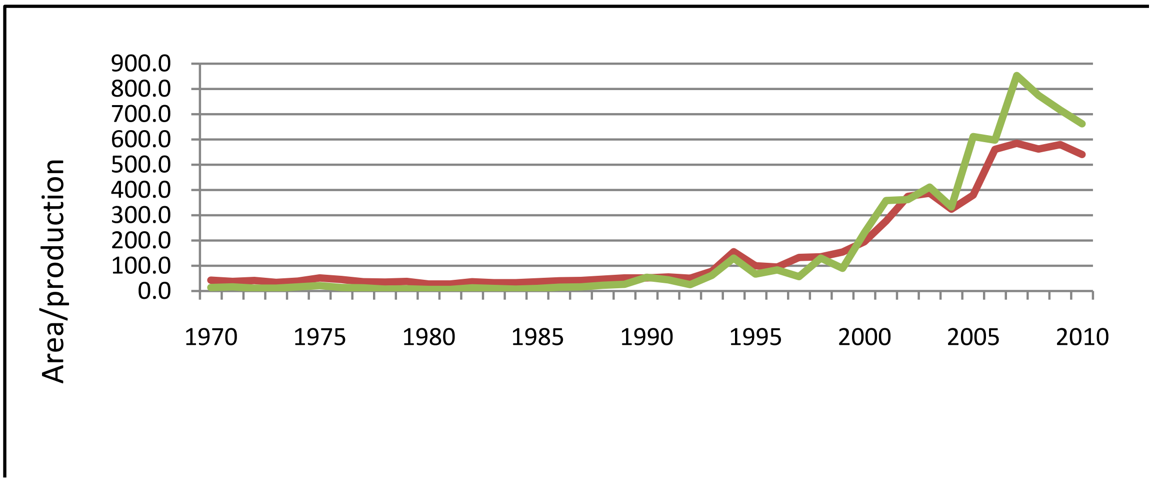


Fig 2.4 Average productivity growth (kg/ha) in Andhra Pradesh, 1970-1990

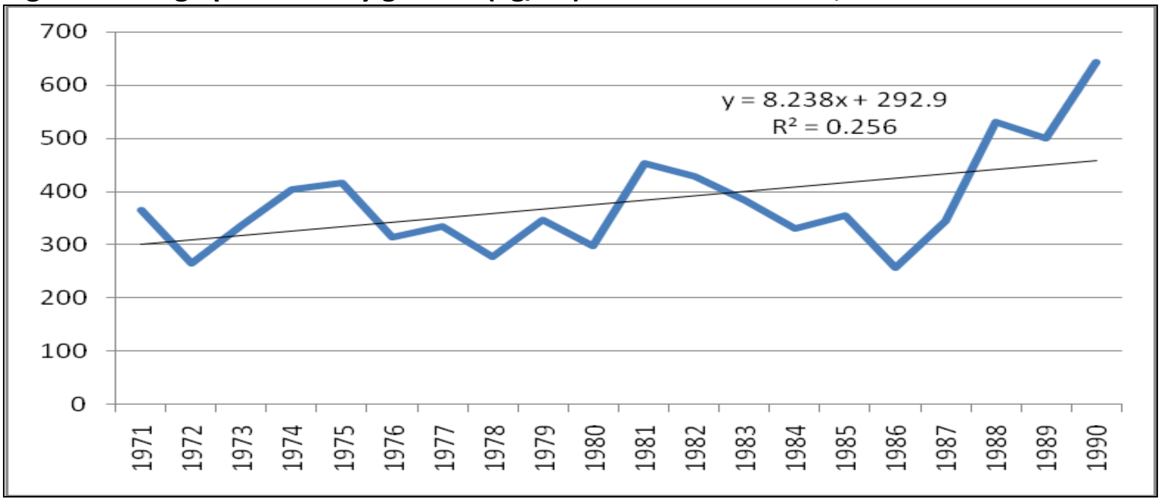
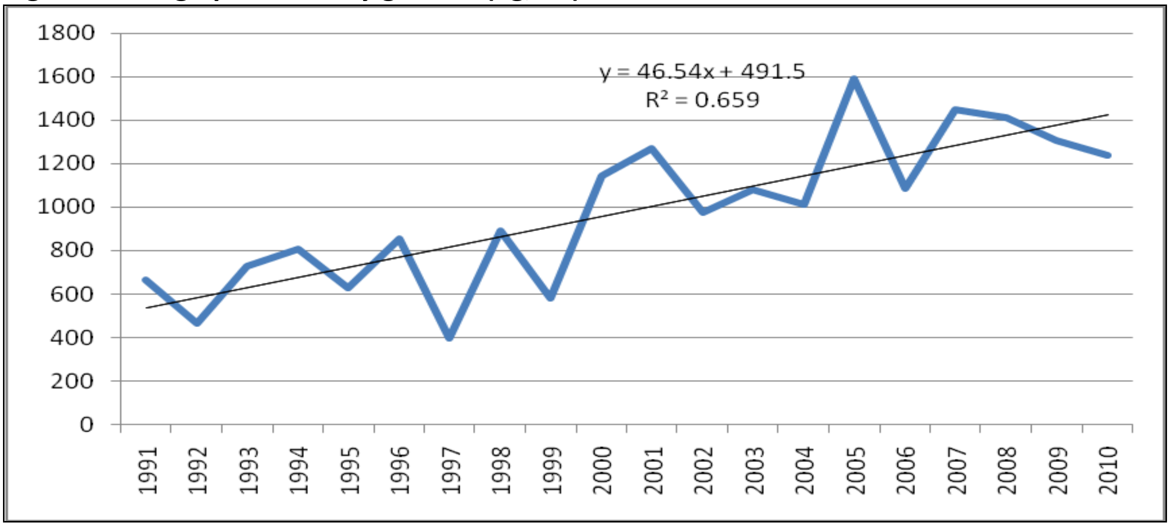


Fig 2.5 Average productivity growth (kg/ha) in Andhra Pradesh, 1991-2010



District-wise performance of chickpea in Andhra Pradesh

The historical trends (1990-2010) in district-wise area and production trends are summarized in Figs 2.6 and 2.7. Kurnool followed by Prakasam holds the lion share of cropped area in the state. Anantapur and Kadapa are in expanding mode rapidly since 2005. Overall, all the major study districts are stagnated in their cropped area or even exhibited the slight down-ward trend during 2010. Similarly, the production trends are much higher in case of Kurnool followed by Prakasam and Anantapur districts. More erratic pattern in production was observed in case of Kadapa, Nizamabad, Medak and Mahabubnagar districts.

Fig 2.6 Chickpea area (000 ha) in districts of Andhra Pradesh: 1990-2010

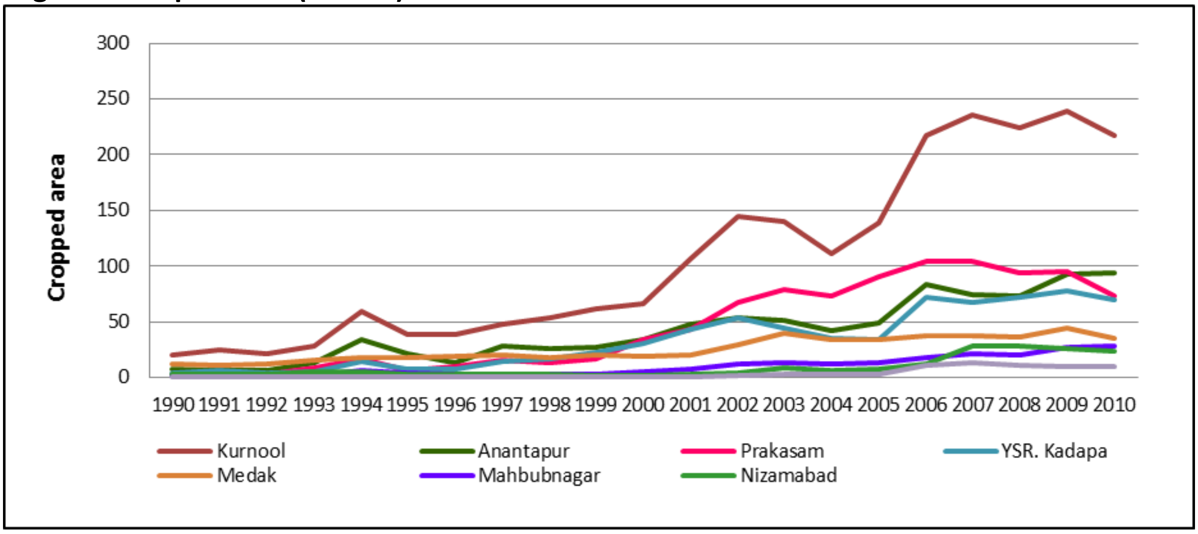
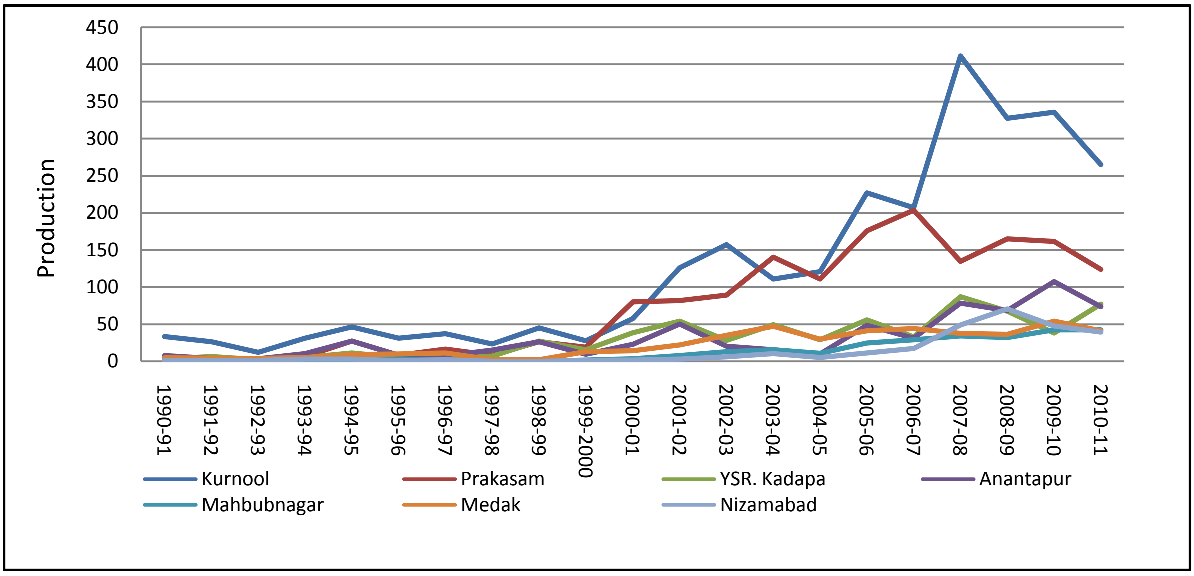


Fig 2.7 Chickpea production (000 t) in districts of Andhra Pradesh: 1990-2010



Long term trends of chickpea area show the pace of increase in seven major districts in Andhra Pradesh, and even indicating new up-coming areas in the vertisols in the northern districts where further diffusion of improved chickpea cultivars in the state is observed (see Table 2.5). Overall, the area expansion was much faster during 1991-2000 when compared to the last decade i.e., 2001-2010. Major districts like Kurnool, Prakasam, Anantapur and Kadapa exhibited little slower growth rates in the latest period than the previous. However, new districts like Nizamabad, Mahabubnagar, Adilabad and Nellore expanding their area under chickpea significantly. The growth rates in production also much higher in during 1990s than the latest period.

Table 2.5 District-wise historical trends of chickpea in Andhra Pradesh

District	Area growth rate (%)		Production growth rate (%)	
	1991-2000	2001-2010	1991-2000	2001-2010
Adilabad	8.36	17.06	-	20.44
Nizamabad	-4.46	30.17	-	38.81
Karimnagar	-6.03	0.55	-	-2.06
Medak	5.98	4.99	2.08	4.99
Hyderabad	-	-	-	-
Rangareddy	4.30	3.26	11.59	4.16
Mahbubnagar	7.58	14.50	-	20.30
Nalgonda	-4.39	-	-	-
Warangal	-	2.26	-	-1.64
Khammam	-	-	-	-
Srikakulam	-	-	-	-
Vizianagaram	-	-	-	-
Visakhapatnam	-	-	-	-
East Godavari	-	-	-	-
West Godavari	-	-	-	-
Krishna	-	-	-	-
Guntur	-3.74	8.65	6.45	8.90
Prakasam	24.75	5.76	31.63	5.90
SPS. Nellore	-	31.13	-	25.16
YSR. Kadapa	21.65	7.47	20.57	6.03
Kurnool	12.17	9.53	5.74	13.61
Anantapur	18.47	8.79	17.46	18.87
Chittoor	-	-	-	-
Total AP	12.40	8.90	15.63	11.40

Table 2.6 summarizes the district-wise recent chickpea trends in Andhra Pradesh for the period 2009-11. Kurnool district has major chunk of area and production share in the state followed by Prakasam, Anantapur and Kadapa districts. Medak, Nizamabad and Mahabubnagar are the upcoming districts where the rapid diffusion of short-duration chickpea cultivars has been taking place. Crops like sorghum, sunflower, coriander and groundnut have been replaced by chickpea because of higher returns and stability in productivity. Among the major players, the productivity was significantly higher in Prakasam

district followed by Kurnool district. This is because of innovative nature of Prakasam farmers as well as better crop management and climate. Historically Prakasam farmers are migratory, hardworking people and always look for new opportunities in agriculture. Because of availability of better soils and rainfall patterns they replaced labor intensive tobacco crop with short-duration *kabuli* types. However, Nizamabad also exhibited the highest productivity levels within new districts group.

The detailed discussions about broad shifts in cropping pattern at India level, major chickpea growing states in India and major districts in Andhra Pradesh are presented in Appendix 1.

Table 2.6 Performance of chickpea in major districts of Andhra Pradesh, 2009-11

District	Area (000 ha)	Production (000 tons)	Yield (Kg/ha)
Kurnool	227.0 (37)	309.5 (38)	1363.3
Prakasam	87.2 (14)	150.1 (18)	1721.6
Anantapur	86.7 (14)	83.1 (10)	957.7
Kadapa	72.8 (12)	60.8 (7)	835.5
Medak	38.6 (6)	43.7 (5)	1134.0
Nizamabad	26.2 (4)	52.5 (6)	2000.5
Mahabubnagar	25.3 (4)	38.7 (5)	1525.9
Andhra Pradesh	612.3 (100)	807.7 (100)	1319.0

Note: Figures in the parenthesis indicates percentage to column total

Historical pattern of chickpea across major districts of Andhra Pradesh

Fig 2.8 depicts the historical pattern of chickpea expansion in major chickpea growing districts of Andhra Pradesh. The quin-quennial average shows the steep expansion of chickpea in Kurnool district in early 1980s following by Anantapur, Kadapa and Prakasam districts (also see Table 2.7).

Fig 2.8 Trends in district level area grown to chickpea in Andhra Pradesh, 1966-2011

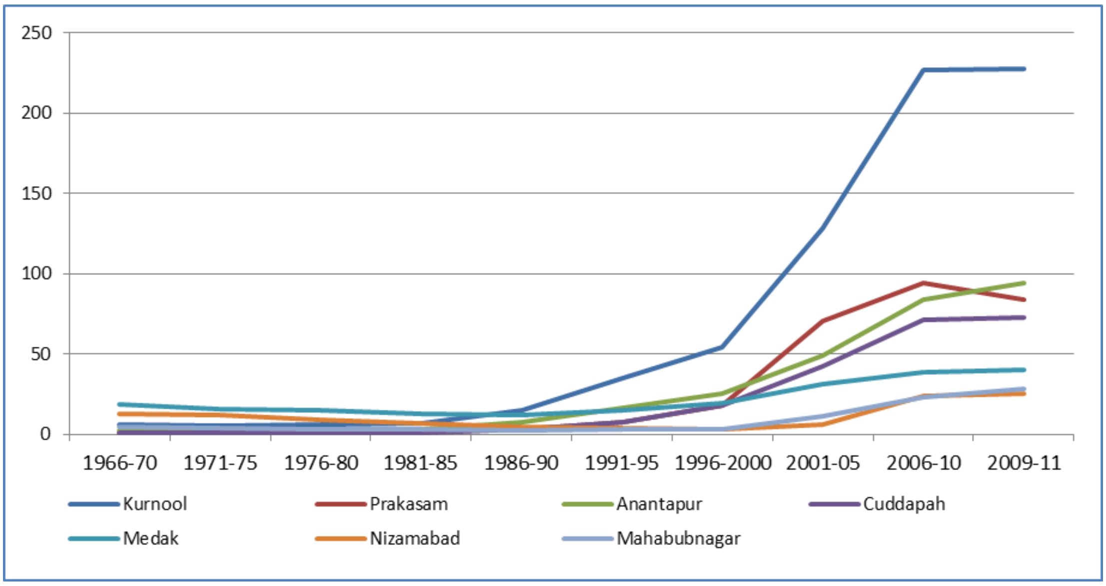


Table 2.7 Area grown to chickpea from 1966 to 2011in districts of Andhra Pradesh (‘000’ ha)

District	1966-70	1971-75	1976-80	1981-85	1986-90	1991-95	1996-2000	2001-05	2006-10	2009-11
Kurnool	6	5	6	6	15	35	54	128	227	228
Prakasam	1	1	1	1	3	8	18	70	94	84
Anantapur	2	2	2	3	7	16	26	49	84	94
Cuddapah	1	1	1	1	3	7	18	42	71	73
Medak	18	16	15	13	12	15	19	31	38	40
Nizamabad	13	12	9	6	4	4	3	6	24	25
Mahabubnagar	5	4	3	3	2	3	3	11	23	28
Adilabad	5	5	4	3	2	2	3	6	17	11
Guntur	8	5	5	5	3	2	1	8	12	9
Nellore	0	0	0	0	1	0	0	2	11	10
Karimnagar	5	5	3	2	1	1	1	4	3	3
Warangal	2	2	2	1	1	1	1	2	2	2
Krishna	1	1	1	0	0	0	0	0	1	1
Nalgonda	2	2	2	1	0	1	1	0	1	1
East Godavari	1	1	0	0	0	0	0	0	0	0
Visakhapatnam	0	0	0	0	0	0	0	0	0	0
Khammam	1	1	1	1	0	0	0	0	0	0
Srikakulam	0	0	0	0	0	0	0	0	0	0
Chittoor	0	0	0	0	0	0	0	0	0	0
Hyderabad	8	8	7	5	3	0	0	0	0	0
West Godavari	0	0	0	0	0	0	0	0	0	0
Total	80	71	62	52	59	95	147	361	607	609

3 Summary of Research

3.1 Research Context

Chickpea research domains and development of improved cultivars

This section describes the process of research and development for chickpea crop improvement in India with specific reference to the development of appropriate cultivars suitable for various agro-ecological zones. The global chickpea research domains are first presented with a description of the domain agro-ecology, the major constraints and countries covered. A more specific description for India is also provided which also identifies the major chickpea producing states within India under each research domain. The historical efforts towards the development of short-duration chickpea cultivars in India are discussed, and this includes a detailed documentation of the research cost. Finally, the complete list of releases of chickpea improved cultivars along with their pedigree information and time line are presented as final products of this research investment.

Broadly, five global chickpea research domains were identified by chickpea crop improvement scientists at ICRISAT. The delineation of chickpea research domains are based on the following critical parameters: latitude, length of growing period, temperature and soil type (ICRISAT MTP, 1994). As shown in Fig 3.1, these are (see also in Table 3.1):

- The low latitude (<20^0) regions with dry hot climate, vertisol soils and early maturing cultivars are grouped under Research domain-1. Deccan & Southern India states of Andhra Pradesh and Karnataka and Central Ethiopia are identified as homogenous regions in this domain.
- Latitude between 20-25^0 and medium maturing (110-120 days) and vertisols are delineated under Research domain-2. North Ethiopia, Sudan, Kenya, Myanmar and Central India (Maharashtra and part of Madhya Pradesh and Gujarat), fall into this category.
- High latitudes (25-30^0) with late maturing (> 120 days) and light soils are classified under Research domain-3. North-West India (Madhya Pradesh, Rajasthan, Uttar Pradesh, Bihar) and Pakistan exhibit these environmental characteristics.
- High latitudes (25-30^0), high humidity and medium to late maturing light soils are characterized under Research domain-4. Double cropping system is the specific characteristic of this research domain. Northern India, Nepal and Bangladesh are included in this domain.
- Very cool high latitude (>30^0) and late maturing climates are defined as Research domain-5. Turkey, Syria, Mexico and USA are the dominant countries identified under this climate.

Development of chickpea improved cultivars in these five research domains needs specific emphasis on crop improvement and breeding objectives.

Fig 3.1 Global Chickpea Research Domains

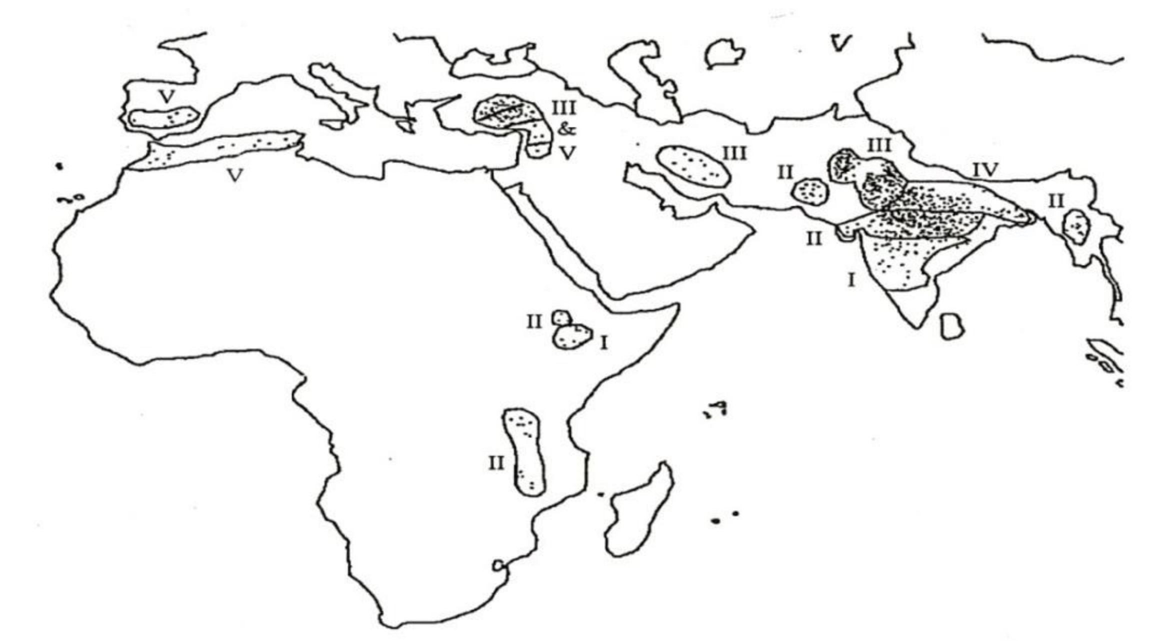


Table 3.1 Description of global chickpea research domains

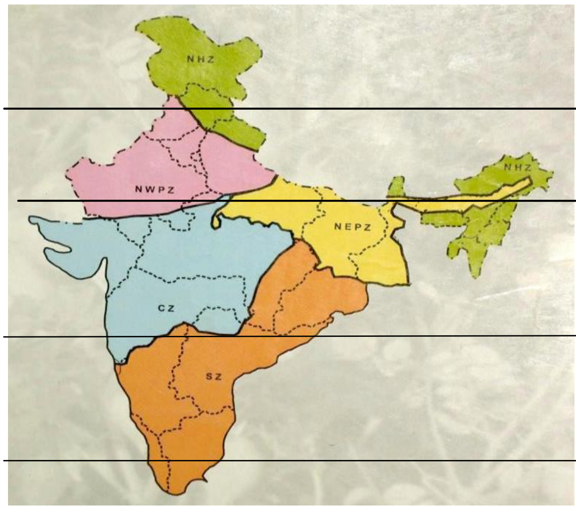
Research domain	Description	Major constraints	Locations
CP-I	Low latitude (below 20^0), dry hot, early maturing vertisols	Soilborne diseases, drought and heat	E Africa (C Ethiopia), India (Deccan and S India)
CP-II	$20\text{-}25^0$ latitude, early to medium maturing, single cropping system vertisols with LGP 110-120 days	Soilborne diseases, drought	E Africa (N Ethiopia, Kenya, Sudan), Central India, Myanmar, Mediterranean (Spring-sown)
CP-III	$25\text{-}30^0$ latitude, dry, cooler than II, late maturing than II, double cropping system light soils with LGP > 120 days	Foliar diseases (Aschochyta Blight), low temperature, drought	NW India, Pakistan, Mediterranean (spring-sown)
CP-IV	$25\text{-}30^0$ latitude, cooler than III. Medium-to late-maturing types. High humidity, Double cropping system (follows rainy season crop), light soils	Foliar diseases (Botrytis gray mold)	N India, Nepal and Bangladesh
CP-V	Above 30^0 latitude. Winter sowing, late-maturing, very cool	Cold, Aschochyta blight, Orobanche (parasitic weed)	Mediterranean (Turkey, Syria, Israel, Greece, N Africa, Spain, Portugal), Mexico and USA

Source: ICRISAT MTP, 1994. Refinement of these research domains for chickpea globally is reported in another paper using spatial analysis and GIS tools (Nedumaran and Bantilan, 2013 forthcoming).

The above domains align seamlessly with the research domains used by the ICAR research system for chickpea as shown in Figure 3.2 where they characterized three zones based primarily on the crop duration.

More specifically, the chickpea research domains in India are characterized in to three types based on the crop duration. Broadly, they are short (85-100), medium (100-120) and long (120-140) duration types (see Fig 3.2). States like Andhra Pradesh and Karnataka fall under short-duration with hot climate and early maturing types. Around 17-20 per cent of the India's chickpea area is situated in this climate. Maharashtra, parts of Madhya Pradesh and Gujarat states are grouped as medium maturing climates. Nearly 40-50 % of country's chickpea crop distribution is spread over in this environment. Certain parts of Madhya Pradesh, Uttar Pradesh, Rajasthan and Bihar states are having high latitude vertisols with double cropping systems and are categorized as long maturing types. About 25-30 per cent of the chickpea cropped area are grown in this climate.

Fig 3.2 Chickpea crop durations across India



CP-3: 120-140 days

CP-2: 100-120days

CP-1: 85-100 days

Spatial analysis using more detailed data identifying targeted research domains in the state of Andhra Pradesh

As shown above, the delineations of the targeted chickpea research domains are essentially determined by the latitude, length of growing period, temperature, irrigation and soil type of the above regions. For the state of Andhra Pradesh, spatial analysis using these parameters assists in identifying the specific homogeneous zones for chickpea adaptation and possible zones of diffusion. As it still remains an empirical question whether the area grown to chickpea has stabilized and already reached its ceiling level, a spatial analysis of the above parameters using data for Andhra Pradesh will guide us to answer this question. This may lead to confirmation of the following empirical questions: Has the ceiling level of chickpea area in Andhra Pradesh been reached? Or are there possible remaining new niche areas for further rapid diffusion of chickpea short-duration improved cultivars, e.g. Mahabubnagar, Medak and Nizamabad districts or possible potential in upper Adilabad district and rice fallows in Krishna and Godavari basins? Or have the irrigation investments in the neighboring districts expanded to present more remunerable crops or cropping systems which fetches more income to farmers other than chickpea?

Spatial distribution of rainfall in Andhra Pradesh

Chickpea is a post-rainy season crop and is highly influenced by rainfall. The distribution of rainfall during the cropping season also influences the productivity significantly. The annual average normal rainfall of the study districts ranges from 600 to 1000 mm. The highest normal rainfall was recorded in Nizamabad followed by Medak, Prakasam and Kadapa districts. The average normal rainfall for Kurnool and Mahabubnagar districts was around 600-650 mm. The lowest annual normal rainfall of 550 mm was observed in Anantapur district. It was observed that the risk of crop failure due to lack of sufficient moisture for the cultivation of chickpea was highest in Anantapur districts, followed by Kurnool and Mahabubnagar.

Fig 3.3 Chickpea area distribution under different rainfall regimes of AP

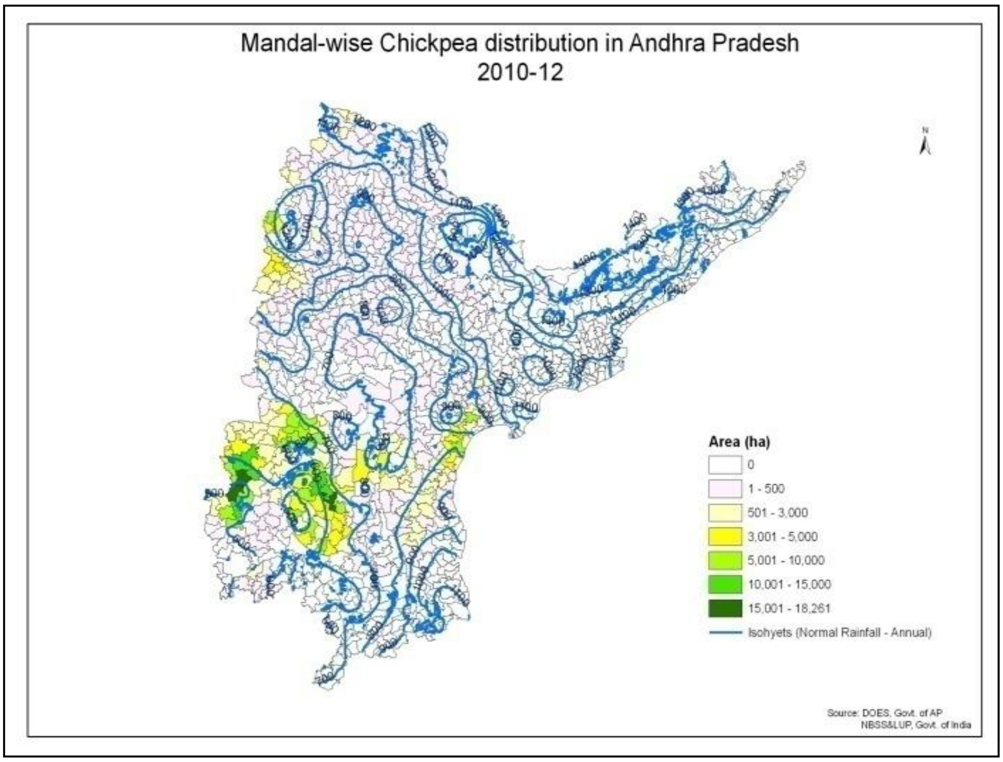


Fig 3.3 presents the distribution of chickpea area in Andhra Pradesh overlaid with different normal rainfall regimes (Isohyets) in a calendar year. The GIS image provides systematic information on diverse climatic situations existing for chickpea cultivation in Andhra Pradesh. The seven prominent chickpea cultivating districts in the state exhibited different ranges of rainfall patterns. This information may be used to measure the extent of risk in chickpea cultivation in that particular region/district. In general, the quantum and variability of rainfall will have a definite influence on chickpea yields in those mandals/districts. However, the high concentrated chickpea growing mandals fall in 500-700 mm rainfall range; these are Kurnool, Kadapa, Anantapur and Mahabubnagar districts. Prakasam has a slightly better rainfall regime of around 850 mm. Medak and Nizamabad districts receive the best rainfall pattern of around 1000 mm.

Table 3.2 District-wise rainfall deviations over normal, 2001-10 (mm)

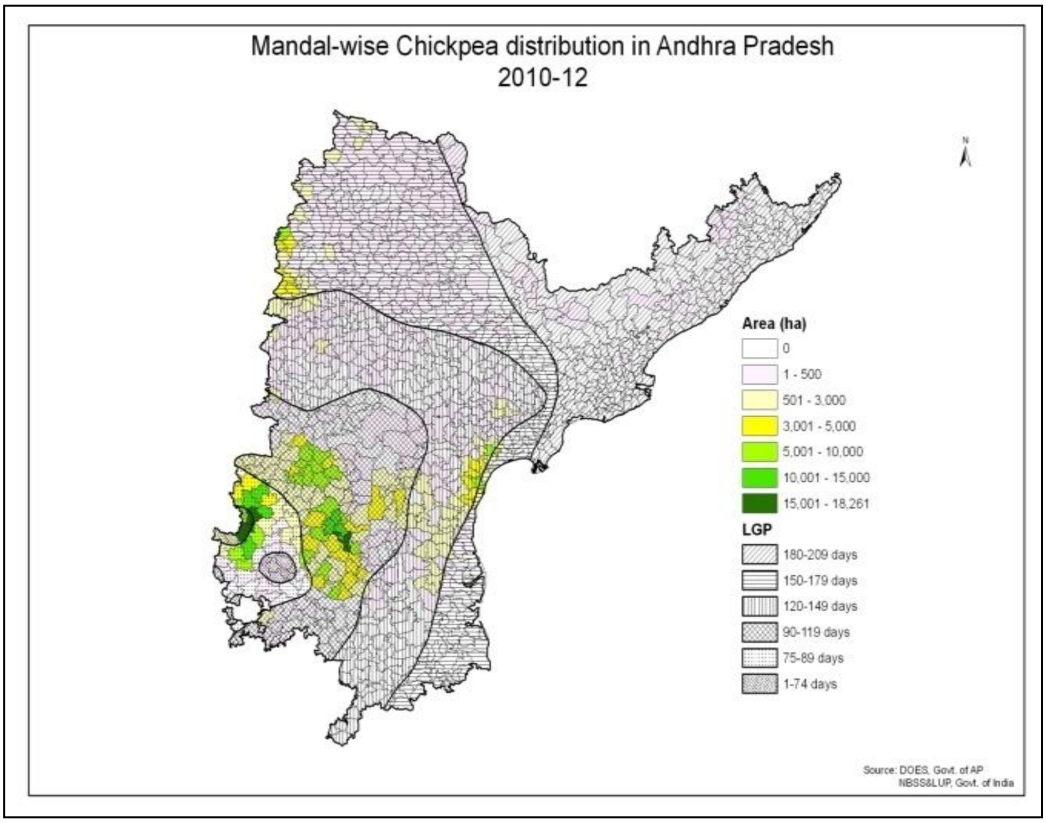
Year	ANT	KUR	PRM	KAD	MED	MAH	NIZ
Normal Rainfall	552	670	871	700	868	604	1035
2001	110	48	-135	181	-176	52	-165
2002	-165	-111	-295	-232	-309	-61	-351
2003	112	89	-230	-327	-109	-4	-203
2004	-38	-80	-233	-98	-332	-183	-320
2005	220	131	11	155	-31	283	149
2006	-118	-78	-47	-183	-25	-45	33
2007	184	339	12	306	-225	176	-177
2008	212	-10	48	0	6	-31	-102
2009	23	89	-260	-93	-276	119	-367
2010	204	154	438	207	56	151	45

The detailed secondary data analysis of rainfall (normal) across major chickpea growing districts of Andhra Pradesh is summarized in Table 3.2. The normal rainfall of Nizamabad stood on the top followed by Prakasam, Medak, Kadapa, Kunrool, Mahabubnagar and Anantapur districts. Out of the ten years, Medak exhibited the maximum number (8 times out of 10) of negative rainfall deviations years from the normal. Prakasam, Kadapa, Medak and Nizamabad districts also showed deficit rainfall from the normal rainfall in six out of 10 years. This pattern clearly indicates the extent of risk in rainfed agriculture. Especially crops like chickpea which germinate on residual soil moisture, but also needs enough moisture during the reproductive phase. Any moisture stress during the terminal stage reduces the crop yields drastically. So the quantum of rainfall in a particular district may be sometimes misleading, its distribution throughout the season is more crucial for chickpea performance. Relatively, the negative deviations in total rainfall from the normal were lower in Anantapur and Kurnool districts during the study period.

Length of growing periods (LGP) in chickpea cultivation

Length of growing period (LGP) is another crucial bio-physical parameter which determines the crop choices in a particular region/district. The choice between cropping systems depends on the available of LGP (days). Fig 3.4 presents the distribution of different LGPs in Andhra Pradesh overlaid with chickpea area distribution. The figure provides the clear evidence of the extent of chickpea distribution in two major LGP windows in Andhra Pradesh. They are Window-1: 75-89 days and Window-2: 90-119 days. However, traces of chickpea area are also present in the 1-74 days window and the 120-149 days window. More than 50 per cent of cropped area falls in the 90-119 days window. Majority of Anantapur and part of Kurnool districts have crop growth windows of 75-89 and 1-74 days. This clearly indicates the high risk to chickpea growth due to terminal moisture stress. A larger portion of Kurnool and entire Kadapa falls into the window of 90-119 days. This window is more suitable for chickpea cultivation as it matures in about 90-100 days. Prakasam district has a longer LGP period ranging from 120-149 days. Overall, the majority of the chickpea farmers in the state follow the 'fallow-chickpea' cropping system. However, the new up-coming districts (Medak and Nizamabad) have longer LGPs of 150-179 days. There is significant potential to diffuse chickpea into the rice fallows where the LGP is about 180-209 days.

Fig 3.4 Distribution of chickpea area under different LGPs (days)

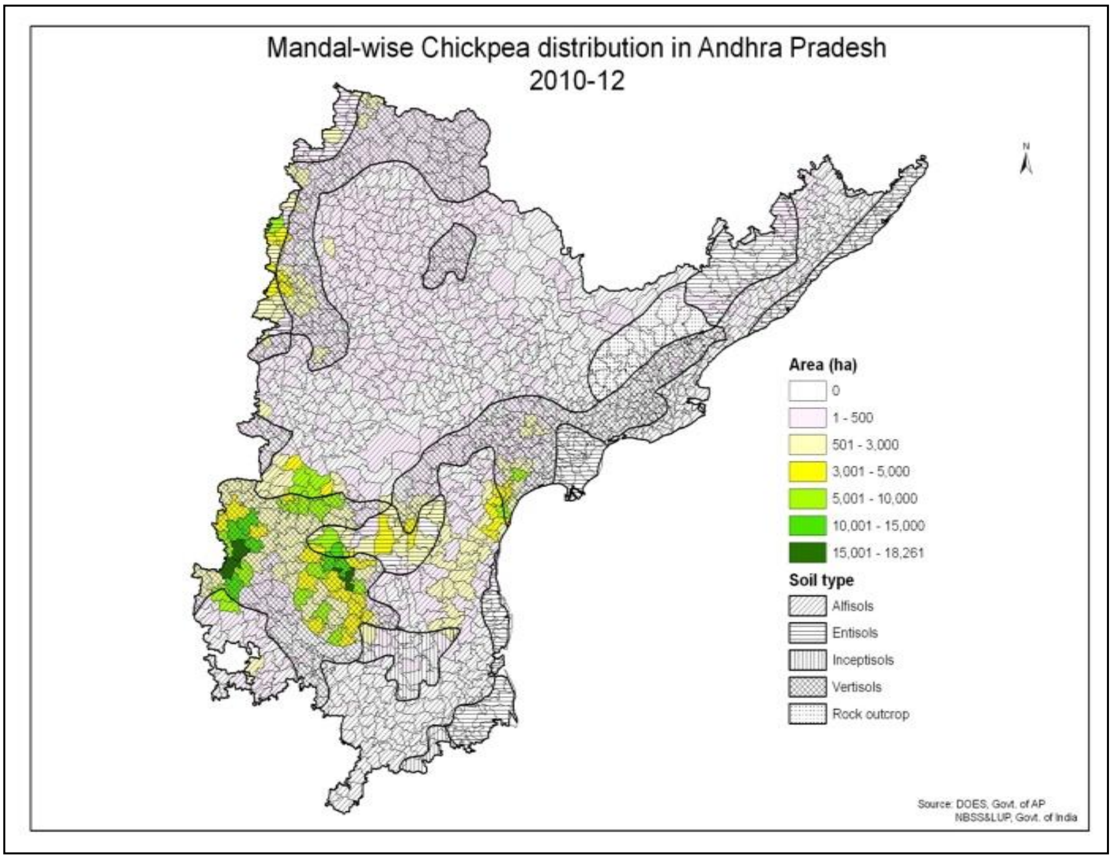


Spatial distribution of soil types in Andhra Pradesh

Chickpea requires cooler climates (< 35^{o} C) and can only be grown in post-rainy (rabi) conditions. Since crop thrives on retention/residual soil moisture, soil type is the important determinant for cultivating chickpea crop. In general, black soils have more soil moisture retention capacity than any other type. Deep to medium or light textured black cotton soils (also called vertisols) are most suitable for chickpea cultivation. Chickpea can also be grown on Alfisols with access to little irrigation facilities. However, red, sandy and chalky soils are not found to be suitable for chickpea cultivation.

Fig 3.5 presents the spatial distribution of soil types in Andhra Pradesh overlaid with chickpea area. It is observed that Alfisols, Inceptisols and Vertisols are more pre-dominant in this state. It seems that the spread of chickpea crop was limited to only Vertisols and Alfisols in Andhra Pradesh. The figure indicates the distribution of chickpea cropped area exactly falls under these two soil types which supports the hypothesis that for cultivation of chickpea soil type (vertisol or Alfisol) is a pre-condition.

Fig 3.5 Distribution of chickpea area in different soils of Andhra Pradesh



The above analysis was further pursued to inquire about chickpea short-duration improved cultivars' adoption and diffusion in Andhra Pradesh. There are bigger patches of vertisols on the upper part of the map (Adilabad and Nizamabad) and on the right hand side (Krishna and Godavari districts). This indicate a scope and potential for further spread of crop in the state.

Further details about extension of diffusion bounded by access to irrigation and beyond Andhra Pradesh has been furnished in Appendix 2.

3.2 Short Duration Chickpea Research Process

The section systematically traces the steps in the research process leading to the release of short duration (and fusarium wilt resistant) chickpea cultivars in Andhra Pradesh. The evolution of short-duration chickpea crop improvement research at ICRISAT in collaboration with NARS partners can be broadly discussed as below:

a. ***Establishment of germplasm repository***

The first systematic international effort to gather chickpea genetic resources of the world was made when ICRISAT was established in India in 1972. The regional and national programmes assembled a large number of chickpea lines afterwards. In 1978, the

International Bureau of Plant Genetic Resources (IBPGR) designated ICRISAT as the major repository for chickpea germplasm and subsequently a Genetic Resources Unit was established in 1979. Since then ICRISAT, in collaboration with national scientists not only in India but also in Afghanistan, Turkey, Greece, Burma, Ethiopia, Pakistan and Bangladesh, added several accessions to the gene bank. ICRISAT also established research collaboration with ICARDA in 1977 soon after its establishment.

b. Breeding for early sowings in Peninsular India

In general, plant growth and seed yield of chickpea in Peninsular India (Hyderabad, 17^0 N) is considerably lower than in northern India (Hissar, 29^0 N). On the other hand, in Peninsular India, the earlier onset of heat and moisture stresses reduces the crop yield to nearly half of the northern India. Chickpea is sown in Peninsular India late in October on land fallowed during the rainy season to conserve moisture. ICRISAT chickpea breeders visualize an opportunity for increasing seed yield by advancing the sowing date from late October to mid-September. Since 1978/79, several germplasm accessions and breeding lines have been evaluated and found superior than the cultivar check 'Annigeri' (ICRISAT, 1981). Early sown chickpea lines consistently produced higher yields under both irrigated and dryland conditions. Short-to-medium duration genotypes produced higher yields when sown early. The most promising cultivar identified for September sowing, 'P 1329', also produced a higher yield than the best adapted cultivar when sown at the normal time (ICRISAT 1983). Thus, it was realized that advancing the sowing date indeed increased yield.

c. Development of biotic (Fusarium) resistant cultivars

Fusarium wilt, caused by *Fusarium oxysporum f.sp. ciceri,* is the most important root disease of chickpea in the semi-arid tropics (SAT), where the growing season is dry and warm. Thus, chickpea cultivars targeted for SAT must have resistance to Fusarium wilt. Effective field, greenhouse and laboratory procedures for screening against Fusarium wilt have been developed at ICRISAT (Nene *et al.,* 1981) and more than 160 resistant accessions (150 desi and 10 kabuli) were identified and used in developing wilt resistant cultivars (Haware *et al*., 1992). Other major diseases in SAT are root rot and Ascochyta blight. Resistant lines are screened, identified and made available to NARS partners for their breeding program.

d. Breeding for early phenology

This shift in area from cooler- long season (160-170 days) environment to warmer short season (100-110 days) environment has further aggravated the importance and development of short duration cultivars in Peninsular India. The development of short-duration cultivars in the southern states of India had an advantage in these areas as they can escape end-of-season stresses by maturing early.

Breeding for early maturity has been directed towards the development of extra short duration varieties to the environments where the growing season is short and the characteristic of drought escape is essential for raising a successful crop. Phenology (time to flowering, podding and maturity) is an important component of crop adaptation in these environments. Crop maturity ranges from 80 to 180 days depending on genotype, soil moisture, time of sowing, latitude and altitude. However, in at least two-thirds of the chickpea growing area, the available crop-growing season is short (90-120 days) due to risk of drought or temperature extremities at the end of the season (pod filling stage of the crop). About 73 per cent of the global chickpea area is in South and Southeast Asia where chickpea is largely grown rainfed in the post-rainy season on receding soil moisture and often experiences terminal drought and heat stresses. Early phenology is also needed for promotion of chickpea to rice-fallows and other late sown conditions of South Asia. Hence, the development of early maturing cultivars is one of the major objectives in chickpea breeding programs of ICRISAT, Patancheru, India and in several countries, including India, Myanmar, Bangladesh, Ethiopia, Australia and Canada (Gaur *et al*., 2008).

Chickpea crop is known to be photo-thermo sensitive and matures in wide depends on climate. Lower temperatures, shorter photoperiods and optimal soil moisture, individually or in combination, help in extending growth period, while higher temperatures, longer photoperiods and moisture stress conditions are known to shorten all developmental phases thereby reducing the crop duration (Summerfield *et al*., 1990). In a study conducted by ICRISAT, the mean number of days to flowering in a set of 25 genotypes were 51 at Patancheru (18^0N), 76 at Gwalior (26^0N) and 96 at Hissar (29^0N) (Kumar and Abbo 2001).

Other research studies conducted by Berger *et al*., 2004, 2006; Subbarao *et al*., 1995 also revealed that phenology (flowering time, time of podding and maturity) was considered as one of the key traits for adaptation of chickpea to varied climatic conditions. Flowering time or days to flowering (number of days from sowing to appearance of first flower) can be recorded with high precision and provides fairly good indication of succeeding phonological traits (time of podding and maturity). Thus, most genetic studies in the past have concentrated on flowering time and suggest that it is under control of few genes. Kumar and van Rheenen (2000) reported a major gene (designated *efl-1*) for flowering time in ICCV2 from its cross with a medium duration cultivar JG 62. Thus, development of short crop duration types through the use of *efl-1* gene has helped reduce damage due to terminal drought. The genetic analysis of different components of crop duration in chickpea reveals earliness to be governed by recessive genes with predominance of additive gene action (Kumar *et al.,* 1999), recurrent selection would be effective in accumulating alleles for earliness. Development of super early lines ICCV 2 and ICCV 93929 (which flower in 30 to 32 days at Patancheru), further indicated involvement of more than one gene in controlling flowering time (Kumar and Rao, 1996; Kumar and Abbo, 2001). ICCV 96029 inherited *efl-1* from ICCV 2 and at least one additional gene affecting early flowering from ICCV 93929. Donors for earliness identified have been used for the development of varieties such as ICCV 2, BG 372, and KPG 59, which are gaining acceptance among the farmers of rainfed ecology because of their early maturity combined with other desirable traits. The availability of early varieties has been the main catalyst behind the expansion of chickpea area in South and Central zones. In spite of reduction in duration, the yield potential of these early varieties remains almost unaffected thus improving per day productivity of the crop.

However, the efficient and sustained research collaboration efforts commenced between ICRISAT and National Agricultural Research System (NARS) partners have led to development of several early maturing kabuli cultivars well adapted to the semi-arid environments, e.g., ICCV 2 (ICRISAT 1990), PKV Kabuli 2 or KAK 2 (Zope *et al*., 2002), JGK 1

(Gaur *et al*., 2004) and Chefe (Ketema *et al*., 2005). The development of extra short duration kabuli variety ICCV 2, which matures in 85-90 days and has resistance to Fusarium wilt, was instrumental in expanding the kabuli chickpea area in lower latitudes, with warmer temperature. Myanmar has also very short-growing season like Southern India, now has about 60 per cent of chickpea area under kabuli type. This change was brought by the extra-early cultivar ICCV 2 (released as Yezin 3 in Myanmar), which has witnessed very high rate of adoption and is now occupied nearly 55 per cent of cropped area (Than *et al*., 2007).

In desi chickpea also, several short duration cultivars are available which are ideally suited for the short winter season. Some of the most popular cultivars include ICCC 37 and JG 11 (ICCV 93954) in southern India. The variety ICCC 37 was released by the Government of Andhra Pradesh under the name of Kranthi. ICCV 2 and ICCV 10 are preferred in Gujarat because of higher grain price early in the season. ICCV 88202 (Yezin 4) in Myanmar and Mariye in Ethiopia are other popular desi types got well adopted in those locations.

The increase in area in southern states is attributed to growth in real prices of chickpea, high productivity levels and growth in limited available moisture conditions made chickpea competitive among other dry land crops (Gowda *et al.,* 2009).The silent chickpea revolution has taken place in Andhra Pradesh in last two decades period on rapid adoption of short duration chickpea cultivars due to its assured returns and highly suitable for mechanisation and transformed to higher productivity crop in Andhra Pradesh. It was also estimated that if moisture stress is alleviated, up to a 50 per cent increase in chickpea production could be achieved, with a present value (gross value of extra production) of about US $ 900 million (Ryan, 1997).

Apart from that, there is enormous potential (nearly 4 m ha rice fallow) for expanding chickpea area in India by making available cultivars and production technologies suitable to specific niche areas particularly in rice fallow and various late sowing conditions (Kumar *et al.*, 1994 and Subbarao *et al.,* 2001). According to Musa *et al*., 2001; Gaur and Gowda 2005, the development of short duration and super early chickpea lines have better chances of success in rice fallows and in several new farming systems.

Chickpea cultivar releases in Andhra Pradesh: 1978- present

Two types of chickpeas are grown in India based on market demand and farmers' resources availability (See Table 3.3). The *desi* type is more dominant in India (nearly 80 per cent) and *kabuli* type occupies the remaining share of the production. Relatively, *kabuli* types require better soils and supplemental irrigation facilities to attain better productivity. In general, most of the chickpea farmers grow *desi* types on marginal lands and rainfed conditions (under soil moisture retention). *Kabuli* types take little longer duration when compared with *desi* types. However, the average productivity levels were higher for *desi* types. Normally, farmers apply better management and inputs to *kabuli* types. Overall, the *kabuli* types fetch better prices in the market due to export demand in the international market, although this depends on the overall international market conditions.

Table 3.3 Features of *desi* vs *kabuli* chickpea types

Characters	Desi type	Kabuli type
Area under cultivation	More area	Less area
Color of seed	Yellow to dark brown	White or pale cream
Size of the seed	Small	Large, bold and attractive
Shape of the seed	Irregular and wrinkled	Smooth
Plant structure	Small and bushy	Taller and erect
Yield potential	Higher yielders (2.2 t/ha)	Low yielders (1.8 t/ha)
Adaptation	Mostly to winter climates	Mostly to spring
Varieties	Jyoti, Annegeri, JG-11, JAKI-9218	Swetha, Kranthi, KAK-2, Vihar
Unit costs of production	Lower	Higher
Unit price per kg	Lower	Higher

A summary list of chickpea varietal releases in Andhra Pradesh is given in Table 3.4. Annigeri was the first improved *desi* cultivar of chickpea developed through selection from a land race. It was developed by the Karnataka Agricultural University and released in 1978 and called it 'Annigeri-1'. It was adopted well in parts of Karnataka state initially and entered Andhra Pradesh slowly in early 1990s. Andhra Pradesh had almost negligible cropped area under chickpea cultivation during early 1990s. However, the extent of adoption of Annigeri became significant by late 1990s in Andhra Pradesh and cropped area also started expanding. Cultivars like Jyothi, D-8, ICCC-32, ICCV-10 (Bharathi) and ICCV-2 (Swetha) have been released in the 80s and early 90s but was not picked-up well by Andhra Pradesh farmers. Later, JAKI-9218 and JG11 improved cultivars were identified through multi-location trials and released in 1997 and 1999 respectively. The chickpea farmers in Andhra Pradesh accepted JG 11 very well because of its higher yield, bolder grain size and resistant to Fusarium wilt. It is clearly evident from the table that ICRISAT together NARS partners played significant role in the development of short-duration improved cultivars in India.

Tables 3.5 and 3.6 features the prominent characteristics of Annigeri and the other popular varieties, JG 11 (*desi*) *and* KAK 2 (*kabuli*)*,* that became popular and are liked very much by Andhra Pradesh farmers. JG11 is a slightly shorter duration cultivar (5-10 days) than Annigeri. The seeds of Annigeri are smaller in size, wrinkled and have low seed weight than the new improved cultivar JG 11. Table 3.5 clearly shows the yield advantage of JG 11 over Annigeri (nearly 40 per cent). Apart from this yield margin, JG 11 grain fetches higher price (nearly 10%) than Annigeri cultivar. Between the two improved desi cultivars released in late 90s, farmers preferred JG11 more than JAKI-9218 because of its high yielding and fusarium wilt resistant traits, as well as its attractive color, bold and uniform grain size and good market demand.

Table 3.4 Summary of all chickpea releases in Andhra Pradesh

Year of release	Cultivar	Desi/kabuli	Pedigree	Developed/ Released by
1978	Annigeri-1	Desi	Selection from local germplasm	Karnataka
1978	Jyothi	Desi	Pure line selection from local	Andhra Pradesh
1982	D-8	Kabuli	Selection from local material	Andhra Pradesh
1984	ICCC-32	Kabuli	L 550 X L 2	ICRISAT/NARS
1992	Bharathi (ICCV-10)	Desi	(P 1231 X P 1265)	ICRISAT/NARS
1993	Swetha (ICCV-2)	Kabuli	[(K850 X G45/7)X P458] XL550 Gaumirchil	ICRISAT/NARS
1994	Vijay** (Phule G-81-1-1)	Desi	P-127 X Annigeri-1	MPKV, Rahuri
1997	JAKI-9218	Desi	(ICCC37 X GW5/7) X ICCV 107	ICRISAT/NARS
1999	JG-11 (ICCV 93954)	Desi	(Phule G 5xNarsingpur bold) X (ICCC 37 x 860263-BP-BP-91-BP)	JNKVV Sehore; PKV, Akola and ICRISAT, Hyderabad
1998	KAK-2 (PKV-Kabuli-2)	Kabuli	ICCV-2 x Surutato-77 X ICC-7344, ICCX-870026-PB-PB-14P-BP-62AK-7AK-BAK	PDKV, Akola and ICRISAT
2002	Vihar/(Phule G-95311)	Kabuli	(ICCC32 X ICCL 8004)XICC7344)	MPKV, Rahuri and ICRISAT
2001	Kranthi (ICCC-37)	Desi	[(P 481 X JG 62) X P 1630]	ICRISAT/NARS
2005	Digvijay*	Desi	Phule G - 91028 x Bheema	MPKV, Rahuri
2006	L Be G-7	Kabuli	ICCV 96329	LAM, AP and ICRISAT
2012	N Be G-3	Desi	Annigeri XICC 4958	Nandyal, AP and ICRISAT

*** Central release across India*
** Released in Maharashtra State, but diffused to other places*
Source: Compilation from various CVRC Reports

Table 3.5 Typical characteristic features of Annigeri vs JG 11 (*desi* types)

Character	Annigeri	JG 11
Release year	1978	1999
Duration	95-100 days	90-95 days
Plant type	semi-spreading	semi-spreading
Seed size	round and medium	very bold
Testa texure	wrinkled	smooth
Seed color	yellowish brown	light brown
Seed weight	16-20gm/100 seeds	22.5 to 24gm/100seeds
Uniformity in crop	not similar	similar
Drought tolerance	low	high
Fusarium wilt resistance	low	high
Resistant to root rot	low	Moderate
Taste	very good	good
Seed shedding	higher	lower
Price premium	lower	higher
Ave grain yield (Kgs/ha)	988-1236	1483-1730

Source: CVRC reports, Seed Division, Govt. of India

Table 3.6 Typical characteristic features of KAK 2 vs Vihar (*kabuli* types)

Character	KAK 2	Vihar
Release year	1998	2002
Duration	105 days	90-95 days
Plant type	semi-spreading	semi-erect
Seed size	extra bold	extra bold
Seed color	white color	white color
Seed weight	35-40 gm/100 seeds	34-36 gm/100 seeds
Fusarium wilt resistance	resistant	resistant
Resistant to root rot	moderate	moderate
Price premium	high	high
Ave grain yield (Kgs/ha)	1977-2100	1853-1977
Source: CVRC reports, Seed Division, Govt. of India		

Among the *kabuli* varieties, KAK-2 and Vihar are the most popular short-duration *kabuli* introductions to Southern India. Development of these cultivars created the new opportunity for growing *kabuli* types in Central and Southern India. KAK-2 attracted the farmers' attention especially in the eastern part of the state. In assured rainfall regimes like in Prakasam district, and pockets of Kurnool and Kadapa districts, farmers have quickly shifted from *desi* to *kabuli* cultivation. Vihar, which was released from neighboring Maharashtra state, became popular in the western part of the state. As described in Table 3.6, Vihar matures in shorter period and having slightly lower productivity than KAK 2. Relatively, KAK 2 requires better soils and crop management practices for attaining optimum yields. The detailed information about all major cultivars in Andhra Pradesh (including cultivar name, release year, type, duration, characteristic features like flower color, seed color, seed size, seed weight, plant type, resistance and yield) is given in Appendix 3.

3.3 Research Timeline

Table 3.7 summarizes the chronological steps in the research process leading to the release of short duration and *Fusarium wilt* resistant cultivars in Andhra Pradesh from late 1980s to till now. The pictorial representation of the complete research process for development of short duration chickpea cultivars is shown in Fig 3.6.

The research and development effort (and therefore research cost) is reckoned in accordance with the R&D timeline for short duration chickpea research with identified research products as shown in Figure 3.6. As illustrated, ICRISAT initiated the research on development of short-duration cultivars in 1978. For reference, the full list of ICRISAT based global chickpea releases, in collaboration of respective NARS partners up to 2013, are given in Appendix 4. For Andhra Pradesh in south India, the relevant chickpea releases are summarized in Table 3.8.

Table 3.7 Research process in developing short duration and fusarium wilt research conducted by ICRISAT and the NARS

Year	Objectives/Activity
1978/79	Breeding lines and accessions evaluated and found superior than cultivar check 'Annigeri' (ICRISAT 1981)
1980/81	Effective field, greenhouse and laboratory procedures for screening against Fusarium wilt have been developed at ICRISAT (Nene et al. 1981) and original chickpea collection sown in a wilt-sick plot at ICRISAT in Patancheru
1981/82	Development continues; seed collected from resistant plants re-sown in wilt-sick plots for further purification
1983/85	Evaluation at ICRISAT
	Observed that early sown chickpea lines consistently produced higher yields under both irrigated and dryland conditions. Short-to-medium duration phenotypes produced higher yields when sown early. The most promising cultivar identified for September sowing, P 1329, also produced a higher yield than the best adapted cultivar when sown at the normal time (ICRISAT 1983).
1986/87	On-station trials at NARS location and on-farm adaptation trials
1988	Seed multiplication
1989-91	AICRP Trials - Multi-location screening under the collaborative ICAR/ICRISAT trials
1992	ICCV 10 (Bharati) released (desi type 110 days duration)
1993	ICCV 2 (Swetha) ICRISAT/NARS release; kabuli 85 days [(K850 X G45/7) X P458] XL550 Gaumirchil; two other varieties Vijay and JAKI-9218 were also released in 1994 and 1997, respectively.
Through 90s	More than 160 resistant accessions (150 desi and 10 kabuli) were identified and used in developing wilt resistant cultivars (Haware et al. 1992).
	Resistant lines are screened, identified and made available to NARS partners for their breeding program.
	Evaluation at ICRISAT station, JG 11, KAK 2 and cohort (1990-92)
	Multi-location screening for resistance
	Multi-location trials for short duration trait
	On-station and on-farm adaptation trials at NARS location (1993-1994)
	Seed multiplication (1995)
	AICRP trials related to JG 11 and KAK 2 (1996-98)
1999	JG11 and KAK 2 were released in Central Committee for southern India
	JG-11 is a desi type with 90-110 maturity and KAK-2 is a kabuli with 95-113 days maturity
1999-2001	Seed multiplication of JG-11 and KAK 2 for 2-3 years;
	Extension after release of JG 11 and KAK 2
2001	ICCV 37 release (desi 90-100 days)
2002	Vihar release (kabuli 105-110 days)
2006	LBeg-7 release (early kabuli)
2012	N Beg-3 release (desi)
2008/13	Further seed multiplication through TL II Project (2008-2013) further boost uptake in AP and Karnataka

Footnote: During the last 5 decades in India, chickpea was gradually displaced to marginal rainfed areas during the expansion of rice industry and development of wheat varieties (HYV) during green revolution period. Particularly during the 1975-1990, chickpea has seen tremendous change in terms of area shift of about 3 m ha from Northern India (cooler, long-season environments) to Southern India (warmer, short-seson environments).

Fig 3.6 Research Process: Chickpea Short duration varieties

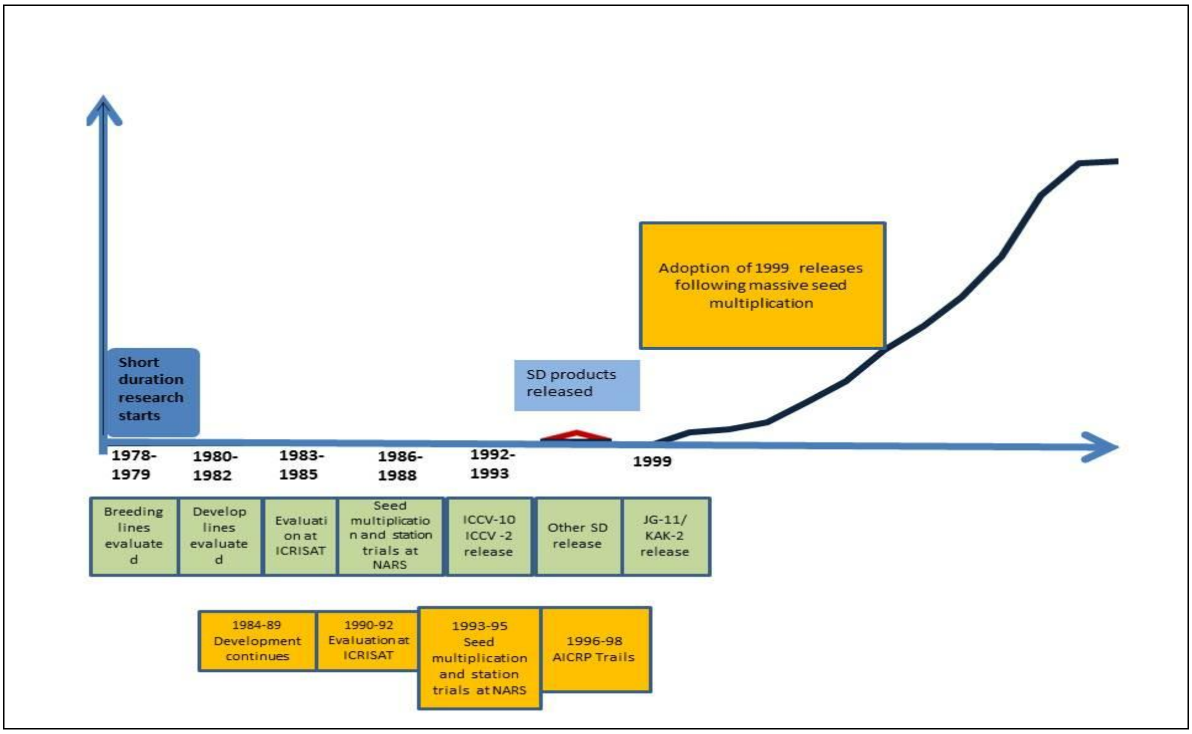


Table 3.8 Two waves of short duration chickpea releases in India (and other countries) in 1993, following the medium duration chickpea releases before 1993

Medium duration releases in India:

1978: Medium duration Annegiri released in Karnataka state in India
1978: Medium duration Jyothi (ICC 4923) released in India
1983: Medium duration ICCC 4 released in India
1986: Four improved cultivars released in Myanmar (Yezin 1 & 2, Keyhman and Schwe Keyhman)
1985: Medium duration variety called Mariye (K 850 x F 738 - segregating material supplied by ICRISAT from which selection was made by the national program) was released in Ethiopia
1992: Medium duration ICCV 10 (Bharati) released in 1992 in India. The variety also released as Barichhola-2 in Bangladesh in 1993

First wave of short duration releases:
1993: Short duration ICCV 2 (Swetha) released in India. The same variety also released in Sudan in 1998 as Wad Hamid. Later, it also spread to Myanmar and released as Yezin 3 (K) in 2000.
1993: Short duration Worku Golden (ICCL 82104) was released in Ethiopia
1995: Short duration Akaki (ICCL 82106) was released in Ethiopia
1998: Short duration GG 2 released in India in 1998
1998: Short duration ICCV 88202 (Sona) released in 1998 in Australia

Second wave of short duration releases:
1999: Short duration JG 11 (ICCV 93954) and KAK 2 (ICCV 92311) were released in India
2000: Short duration Sasho (ICCV 93512 – large seeded kabuli) released in Ethiopia
2000: Short duration ICCV 88202 was released in Myanmar as Yezin 4
2001: Short duration ICCC 37 released in India as Kranthi in 2001

2002: Short duration ICCV 92337 (JGK 1) released in India
2002: Short duration Vihar (kabuli ICCV 95311) released in India
2006: Short duration L BeG 7 (ICCV 96329) released for Southern India
2007: Short duration JAKI 9218 (desi ICCV 93952) released for Southern India
2012: Short duration N Be G-3 desi cultivar released for Andhra Pradesh
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The impact assessment analysis in Chapter 7 will refer to these two waves of short duration improved chickpea releases in India as research products or outputs when it demonstrates the impact pathway which tracks the outputs, outcomes and impacts of short duration chickpeas in Andhra Pradesh.

3.4 Research costs

The research cost of short duration chickpea research at ICRISAT and its partner institutions in NARS were estimated from annual budgets and scientists years (PY) allocated to chickpea short duration research. Historical budget records disaggregated by research program for research conducted at ICRISAT are not available and research investments particularly for chickpea are difficult to reconstruct during the earlier years. Personal communication with ICRISAT Finance Director indicated that as per standard accounting practices, detailed information on programmatic budgets is maintained only for 8 years. Thus, for the purpose of this study, expenditure for short duration chickpea research was estimated with guidance from scientists who were part of ICRISAT's chickpea crop improvement research team during those years, and administrative officers who had some historical recollection of annual budgets. The breakdown of research costs was made on the basis of person years of scientists and staff of the chickpea research team, standard annual salaries, and the proportion of each scientist's time on development of short duration chickpeas. Operating costs were estimated from estimated total operating costs for the Grain Legumes Program, which focused on three major research activities during that period. Similar imputations were also made for the NARS counterpart funds.

Two budget scenarios (low and high) are discussed. The range of budget allocations reflects the variation in estimates made by different staff members. The lower budget scenario is also a way to simulate the effect of marginal budget reductions on the net benefits flowing from the research. The steps described in the summary description of research process guided the elicitation of the research cost template.

It should be noted that even before the short duration chickpea research started, essential milestones have already been achieved at ICRISAT on which the above research built on. These include:

- First systematic international effort to gather chickpea genetic resources of the world was made when ICRISAT was established where the regional and national programmes assembled a large number of chickpea lines (1972);
- ICRISAT established research collaboration with ICARDA for chickpea crop improvement (1977);
- The International Bureau of Plant Genetic Resources (IBPGR) designated ICRISAT as the major repository for chickpea germplasm (1978)

- Genetic Resources Unit was established and ICRISAT is in collaboration with national scientists in India, Afghanistan, Turkey, Greece, Burma, Ethiopia, Pakistan and Bangladesh have added several accessions to gene bank (1979)

Past research investments involving the above establishments provided the foundation for chickpea crop improvement at ICRISAT. Nevertheless, these are considered as sunk cost with respect to the chickpea short duration chickpea research.

Research and development cost: research start to releases

Research and development costs in the development of short duration chickpeas were attributed to the investments by both ICRISAT and NARS partners involved in the developmental process since 1978. The careful calculations of staff-wise research costs including operating and overheads expenditure for ICRISAT was summarized in detailed in Table 3.9 from 1980-2013. Similarly, NARS partners from four research locations actively participated in the research process (Jabalpur, Nandhyal, Dharwad and Rahuri) towards the development of short-duration cultivars. The corresponding cost estimates across four locations were presented with detailed break-up in Table 3.10 between 1980 and 2013. The total costs involved for development of short-duration cultivars from all the stakeholders (ICRISAT and NARS) including research and dissemination costs are furnished in Table 3.11 over the years. The costs incurred at different time periods were adjusted using appropriate deflator and converted them in to real prices. Overall, the total estimated costs for developing this technology was 8.5 million US dollars. Around 6.8 m US $ (80 per cent) alone incurred by ICRISAT while the NARS partners shared the remaining 20% research costs.

Table 3.9 Basis for ICRISAT's annual research costs (US$)

Staff member	% time allocated for short-duration research	In 1980s		In 1990s		In 2000s		In 2010s	
		Cost per year (US $)	Total costs (US $)	Cost per year (US $)	Total costs (US $)	Cost per year (US $)	Total costs (US $)	Cost per year (US $)	Total costs (US $)
1 Principal scientist (Breeding)	0.15	80,000	12,000	95,000	14,250	1,20,000	18,000	1,50,000	22,500
4 National scientists (Breeding)	1.50	8,000	12,000	16,000	24,000	36,000	54,000	50,000	75,000
1 National scientist (Pathology)	0.25	8,000	2,000	16,000	4,000	36,000	9,000	50,000	12,500
6 Research Associates	1.50	2,500	3,750	6,667	10,000	9,333	14,000	13,043	19,565
30 Field Assistants	7.50	1,200	9,000	2,000	15,000	5,500	41,250	10,000	75,000
10 Field Laborers	0.25	750	187.5	1,600	400	4,000	1000	9,000	2,250
Operating expenses			10000		40000		60000		80000
Overheads			7341		19,377		35505		51627
Grand Total			56278		127027		232755		338442

Source: ICRISAT Chickpea crop improvement program scientists, personal communication

Table 3.10 Basis for NARS annual research costs (Rs.)

Staff member	% time allocated for short-duration research	In 1980s		In 1990s		In 2000s		In 2010s	
		Cost per year (in Rs)	Total costs (in Rs)	Cost per year (in Rs)	Total costs (in Rs)	Cost per year (in Rs)	Total costs (in Rs)	Cost per year (in Rs)	Total costs (in Rs)
1 Scientist (Breeding)	0.10	48,000	4,800	1,56,000	15,600	3,00,000	30,000	12,00,000	120,000
1 Scientist (Pathology)	0.10	48,000	4,800	1,56,000	15,600	3,00,000	30,000	12,00,000	120,000
1 Research Associate	0.10	12,000	1,200	48,000	4,800	1,20,000	12,000	3,60,000	36,000
5 Field Laborers	0.50	2,400	1,200	18,000	9,000	72,000	7,200	1,44,000	72,000
Operating expenses	20.0%	50,000	10,000	80,000	16,000	1,20,000	24,000	200,000	40,000
Total per NARS location			22,000		61,000		1,32,000		3,88,000
Grand Total*			88,000		2,44,000		5,28,000		15,52,000
** Mainly four NARS research locations were involved in the development process*									

Source: NARS scientists, personal communication

Table 3.11 Summary of total research expenditure for development of chickpea short-duration improved cultivars (US $)

Year	Research activity	Research costs				Extension costs	Total costs			
		ICRISAT	NARS				Nominal	Deflator	Deflator	Real
		US $	Rs	Exchange rate	US $	US $	US $	base=2005	base=2013	US $
1978	Development-Breeding and accessions evaluation for short-duration and Fusarium wilt resistance; sown at wilt sickplots at Patancheru; further purification	56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1979		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1980		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1981		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1982		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1983		56278	88000	12	7,395	-	63,673	70.48	0.59	108,411
1984	Development continues towards identificaiton of next batch of releases JG 11 and KAK 2	56278	88,000	12	7,395	-	63,673	70.48	0.59	108,411
1985		56278	88,000	12	7,195	-	63,474	69.74	0.58	109,210
1986		56278	88,000	13	6,886	-	63,164	80.22	0.67	94,488
1987		56278	88,000	13	6,785	-	63,063	87.91	0.73	86,087
1988		56278	88,000	15	6,069	-	62,347	93.61	0.78	79,922
1989		56278	88,000	17	5,285	-	61,563	93.05	0.78	79,393
1990	Evaluation of lines at ICRISAT Research station; ICCV-10 released in Andhra Pradesh	127027	244,000	18	13,601	-	140,628	96.60	0.81	174,689
1991		127027	244,000	24	9,971	-	136,998	96.30	0.80	170,722
1992		127027	244,000	31	7,961	-	134,988	97.80	0.81	165,637
1993	ICCV-2 released in Andhra Pradesh; Resistant lines identified and made avaiable to NARS partners for their breeding program	127027	244,000	31	7,781	5,000	139,808	98.34	0.82	170,597
1994	Station trials at NARS locations and seed multiplication	127027	244,000	31	7,771	5,000	139,798	98.58	0.82	170,181
1995		127027	244,000	33	7,294	5,000	139,321	107.75	0.90	155,167
1996	AICRP multi-locational trials conducted at All-India	127027	244,000	36	6,873	5,000	138,900	104.41	0.87	159,643
1997		127027	244,000	37	6,566	5,000	138,593	97.89	0.82	169,897
1998		127027	244,000	42	5,800	5,000	137,827	93.08	0.78	177,684
1999	JG11 and KAK2 released	127027	244,000	43	5,631	5,000	137,658	91.06	0.76	181,413
2000	Seed multiplication and extension	232755	528000	46	11,559	10,000	254,314	89.33	0.74	341,621
2001	ICCC-37 released	232755	528000	48	11,072	10,000	253,827	84.83	0.71	359,055
2002	Vihar released	232755	528000	48	10,911	10,000	253,666	84.31	0.70	361,051
2003		232755	528000	46	11,491	10,000	254,246	90.19	0.75	338,277
2004		232755	528000	45	11,752	10,000	254,507	97.13	0.81	314,441
2005	Dig Vijay released	232755	528000	44	11,927	10,000	254,682	100.00	0.83	305,618
2006	L Be G-7 released	232755	528000	45	11,661	10,000	254,416	102.17	0.85	298,805
2007	Seed multiplication and extension; Tropical Legumes-II project supported FPVS and seed multplication	232755	528000	40	13,121	150,000	395,876	108.58	0.90	437,501
2008	TL-II project seed multiplication and distribution in Andhra Pradesh	232755	528000	46	11,501	150,000	394,256	117.09	0.98	404,046
2009		232755	528000	47	11,128	150,000	393,883	109.35	0.91	432,249
2010		338442	1552000	46	34,057	150,000	522,499	112.95	0.94	555,123
2011		338442	1552000	55	28,019	150,000	516,461	122.52	1.02	505,827
2012	N Be G-3 released	338442	1552000	57	27,157	150,000	515,599	119.94	1.00	515,871
2013		338442	1552000	61	25,318	150,000	513,760	120.00	1.00	513,760
Grand total (US $)							**7175832**			**8586850**

4 Impact Assessment – Methodology and Data Requirements

This section describes the methodology used for welfare estimate calculations and its various sensitivity scenarios. The minimum data requirements for quantifying the impact of any technology also highlighted and discussed in detailed.

4.1 Methodology for estimation of welfare benefits

There has been a long history of using applied welfare economics to the measure the impact of and then returns to funds invested in agricultural research. A major review of this literature and excellent summary of the methodology is given in Alston *et al*., (1995). The majority of applications of this methodology have measured the impacts of research in a particular country where the research was focused and undertaken.

For internationally oriented research organizations, such as the CGIAR system and funding institutions, consideration of the impacts on many countries is important. Indeed it is the international public good nature of these institutions which often provides the basis for their operation. Alston *et al*., (1995) summarised the methods applicable to internationally focused research, however, there have been further developments since then. These developments have expanded the notion of research applicability between similar production environments or research domains and the associated spillover impacts between countries and regions.

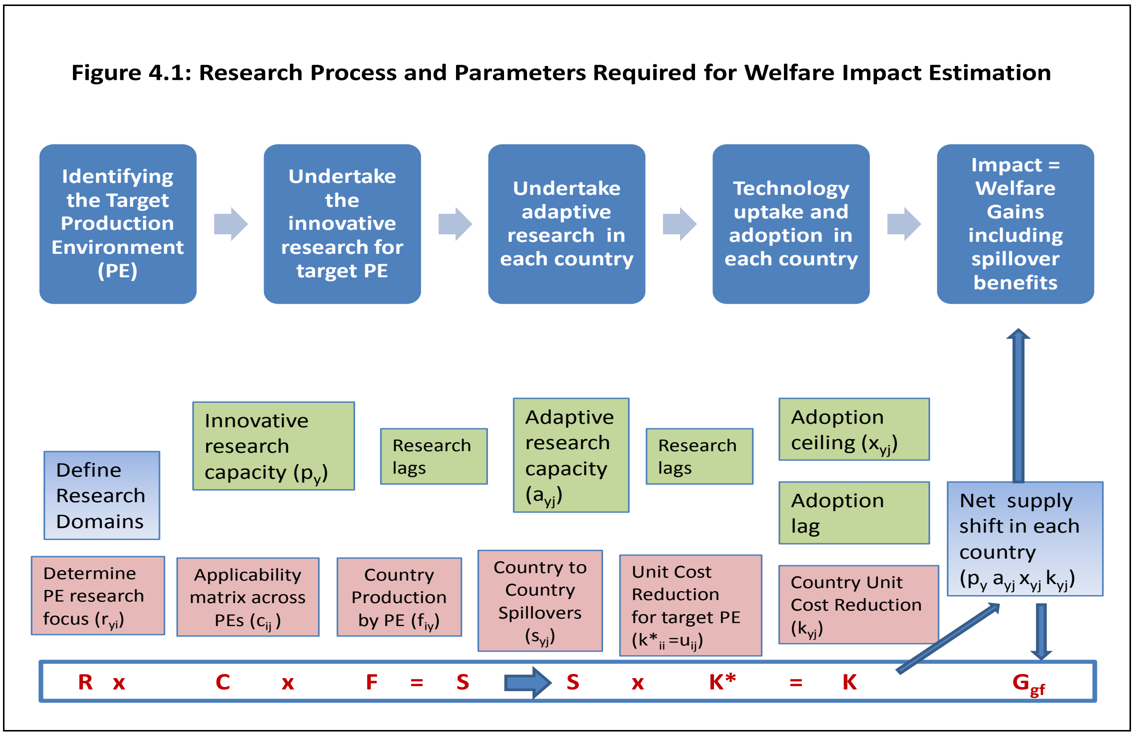
Early work by Edwards and Freebairn (1981, 1982 and 1984) first focused on this issue. They looked at the case of one country undertaking the research and the implications for that country of spillovers to the rest of the world when the product is traded. They also looked at the importance of spillovers between regions within a country. Extensions to this work to include many countries and regions and model in more detail the applicability and therefore spillovers between them, have been reported by Davis, Oram and Ryan (1987), Davis *et al*., (1989), Davis (1991), Bantilan and Davis (1991), Fearn and Davis (1991), and Deb and Bantilan (2001). More recently Bantilan *et al*., (2013) provided a synthesis of these past applications and highlighted how it is being developed and used at ICRISAT.

In the rest of this section we briefly highlight the important features of this framework as it will be applied in the analysis in this report.

Bantilan *et al*., (2013) emphasis that the international research process is a complex activity and it is important to make sure an impact assessment study considers all aspects to avoid a wide range of potential aggregation and empirical errors. Figure 4.1 is the simplified schematic representation of the research process they used. It illustrates the sub-components of the complex interactions which ultimately lead to impacts and then changed welfare for the community. It highlights the importance of understanding the range of production environments (research domains) that are applicable to chickpeas and especially the one(s) which generated the research focus on short duration varieties.

It notes the importance of understanding the strength of the adaptive research and adoption systems and their implications for quantifying final impacts. It also highlights the importance of understanding the effects of adoption of the new varieties on farmer's unit cost of production to understand the ultimate shift in the supply in each region/country. It is this shift in the supply that generates welfare changes for both chickpea producers and consumers and importantly many groups ultimately influenced by the initial chickpea market changes.

Fig 4.1: Research Process and Parameters Required for Welfare Impact Estimation



We will not discuss this is detail here, it is too complex. Instead below we briefly discuss three sub-components to highlight the important aspects for this chickpea application. Two are general features of the framework the flow chart summarises while the third is an adaptation we found necessary for this specific application. We finish with presentation of the formulae used to estimate the total welfare benefits and their distribution between producer and consumers. This includes a list and brief discussion of the data that is required to effectively quantify these welfare changes.

International trade has been an important aspect of the chickpea environment and has, as was briefly discussed in section 2, facilitated and driven much of the short duration germplasm technology adoption. Figure 4.2 illustrates how the framework incorporates multi-country traded good interactions. For simplicity only a two country model with research focused on an issue mostly applicable to country 1 but also applicable to the rest of the world is illustrated. In this study the application actually includes all regions/countries producing and/or consuming chickpeas – as is discussed later to best represent the impact of the short duration chickpea technology we found it was important to have over 60 supply/demand situations representing: types of groups of farmers, districts, states, countries and regions.

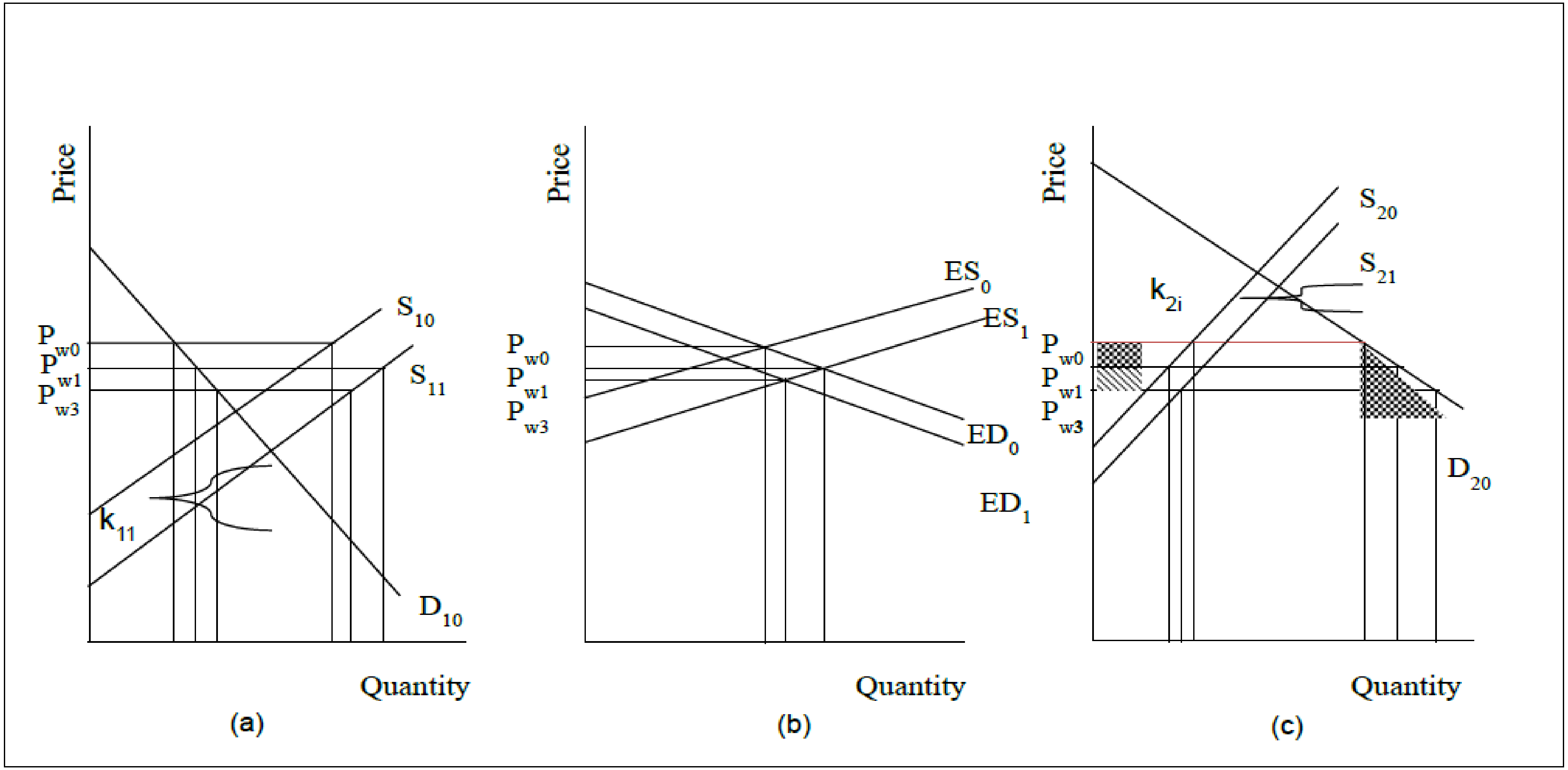


Fig 4.2 Two country / region traded good research impact framework

If research is undertaken on an issue specific to a particular production environment/research domain found mostly in country 1, then the impact of this can be represented as a shift in its chickpea supply. This is shown as a shift from S_{01} to S_{11} in Figure 4.2(a) and is measured as the vertical distance ‘k_{11}’ which is the unit cost reduction (UCR) due to adoption of the new technology. In country 2 (the rest of the world in this illustration, Figure 4.2(c)) the adoption of the short duration varieties shifts the aggregate supply from S_{02} to S_{12} measured as a unit cost reduction of ‘k_{21}’. In this representation $k_{21}<k_{11}$ or the technology is not as applicable.

The total welfare change due to this research is measure as the sum of the shaded areas in figure 4.2. There are four areas, one in each country for the change in producer’s welfare (called producer surplus) and the other in each country for the change in consumer welfare (consumer surplus). It can be seen that depending on the nature of the supply and demand in each country and the applicability, adaptation, adoption and other dimensions highlighted by Figure 4.1 there are many possible patterns of the distribution of the welfare changes. These shares of benefits are also determined by the world price impacts of the adoption of the research which shifts the supplies and associated excess demand and supply in the world market, illustrated in Figure 4.2(b).

In addition to taking account of spillovers between countries and the world price effects, it is important to ensure the level of disaggregation of the analysis is sufficient to accurately represent the impact of the new technology.

Figure 4.3 can be used to illustrate the importance of this issue. If we take country 1 in Figure 4.2(a) and disaggregate it into three separate groups of producers, figure 4.3 (d) then becomes the aggregated supply corresponding to Figure 4.2 (a), the demand is left out for simplicity. The three disaggregated supplies might represent a range of alternative production situations. Here though we use different types of adopters Figure 4.3 (c) might be the farmers who the short duration varieties are applicable to. Before the availability of the new short duration varieties they produced the old short duration variety (ies). Adopting the new varieties shifts their supply by reducing their unit cost of production. Figures 4.3 (a) and (b) might represent a range of other producer situations. One possibility is each represents the long and medium duration producers. For them the short duration varieties do not provide a yield and therefore cost advantage so they do not adopt them. Their supplies do not change - shift.

Alternatively one of these groups could be producers of the old varieties who do not adopt the new ones because they face several of the many factors which could constrain their adoption. For example, the seed production and distribution systems may not support them.

4.3 Disaggregation Based on Types of Adopters

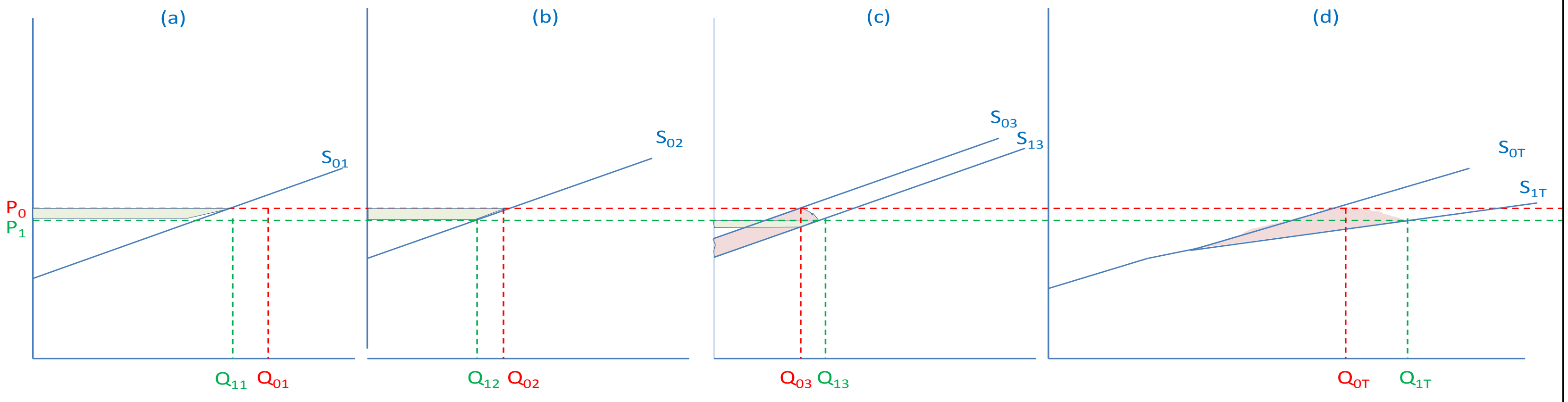


Fig 4.3.Disaggregation Based on Types of Adopters

Regardless of the reason for the non-adoption or applicability of the new technology the impact on welfare changes is demonstrated. The aggregated supply, Figure 4.3 (d), interfaces with the rest of the world supply and demand as in figure 4.2, there are potential other adopting producers in other regions or countries and disaggregated demands, to give price changes. At a disaggregated level we now see that producers in Figure 4.3 (a) and (b) experience a welfare loss due to the research, the pink shaded areas. Producers in Figure 4.3 (c) in Figure 4.3 (d) still have welfare improvements. This mixture of impacts is hidden by the aggregation in figure 4.2, there producers as an aggregated group have a net welfare gain – the welfare gains of adopters exceed the losses of the non-adopters.

In addition to masking the range of important implications of research impacts, if the aggregated representation of supply, Figure 4.2 (a), is used there is a significant chance that an empirical error will be made in estimating the welfare changes. The blue shaded area of welfare change in Figure 4.3 (d) is a much different shape to the equivalent parallelogram plus triangle in Figure 4.2 (a). While it is possible that with careful detailed understanding of the disaggregated environment and careful mathematical manipulation of the supply shift parameter the errors will not be made, the chance of successfully achieving this is low. If this detailed understanding is developed then a disaggregated model might as well be used since it facilitates incorporation of each component of the story in its appropriate form rather than developing an additional set of complex mathematical manipulations to achieve this. In the process many important aspects of the underlying impact story will be lost.[1]

During early discussions with research groups, focus group meetings and then when processing the survey results it became clear that the new short duration varieties were so profitable to farmers, especially combined with the changed market environment, that many farmers who had not previously produced chickpeas were substituting them for other crops, that is, switching to chickpeas. As discussed in section 2 the additional area planted to chickpea has been substantial. To facilitate better understanding of these changes and impacts farmers growing chickpeas were separated into five groups in the survey data analysis. These were:

- Non-adopters, NA – farmers who continue to grow the old varieties
- Adopters, A1 – farmers replacing existing varieties with the new short duration varieties
- Adopters, A2 – farmers (A1) substituting the new varieties for other crops grow on part of the farm
- Adopters, A3 – farmers (A1) acquiring, leasing or purchasing, additional land to grow the new varieties
- Switchers, SW - farmers who have not grown chickpeas before and replace other crops.

After analysing the survey information from this perspective it was decided that the impact assessment analysis should disaggregate the potential short duration chickpea producing

[1] Davis (1994) discusses this disaggregation issue in more detail.

areas, especially Andhra Pradesh into at least three groups of farmers: NA; A1; and A2+A3+SW.

It was therefore important to consider whether the underlying supply theory included in the methodological framework outlined above accommodates the third group of switchers - those expanding the area planted to chickpeas - and if so whether there are any guidelines to ensure effective empirical application. It is worth briefly discussing each of the three groups to keep them all in perspective.

Figure 4.4 considers the non-adopters, NA. Before research their supply of chickpeas is S_0 and at the market determined price P_0 they supply $Q_{0,NA}$. Notice we have drawn the supply with a kink at the point of minimum average total cost (ATC) (= marginal cost (MC)). For existing producers the kink point is usually not important so in many studies, for simplicity, the supply is drawn as a straight sloping line to the axis. Figures 4.2 and 4.3 used this convention. Note also for simplicity we have not drawn the rest of the disaggregated market and aggregated diagram which determines the equilibrium price, P_0.

After research these farmers do not adopt the new varieties so their supply remains the same, shown as S_0&S_1. However, since other farmers do adopt, after research the aggregate supply and demand situation results in a price fall to P_1, causing the non-adopters to reduce their output to $Q_{1,NA}$. As was discussed in relation to Figure 4.3, non-adopting farmers now loose due to the impact of research – their price is lower. In some cases eventually the kink point may be important if new improved varieties continue to be developed and released and the non-adopters continue not to adopt them, eventually the after research equilibrium price may fall below their kink price point. These non-adopter farmers will switch to other crops or move out of farming and sell/lease their land to, probably, adopters. However, the quantum of chickpea produced by non-adopters (NA group) is minimal. So, there are no changes anticipated in surplus for these non-adopters and therefore the current estimates are reasonable.

Fig 4.4 Representation of Non-Adopters: Before & After Research

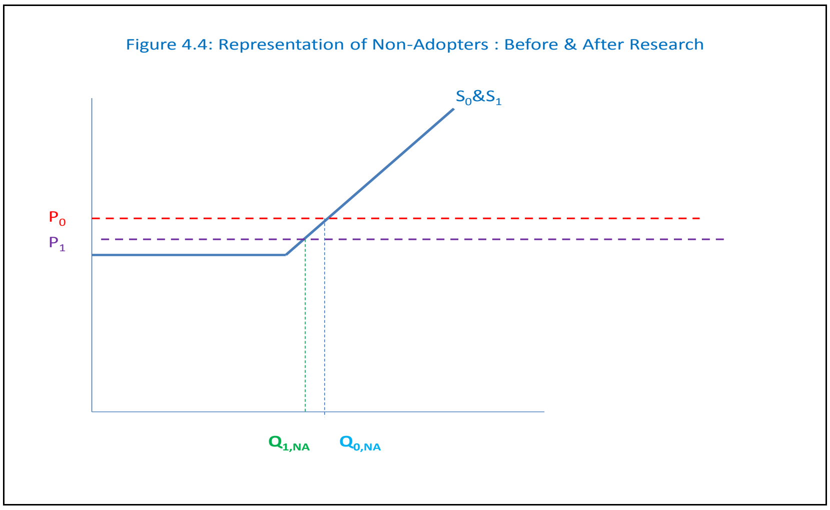
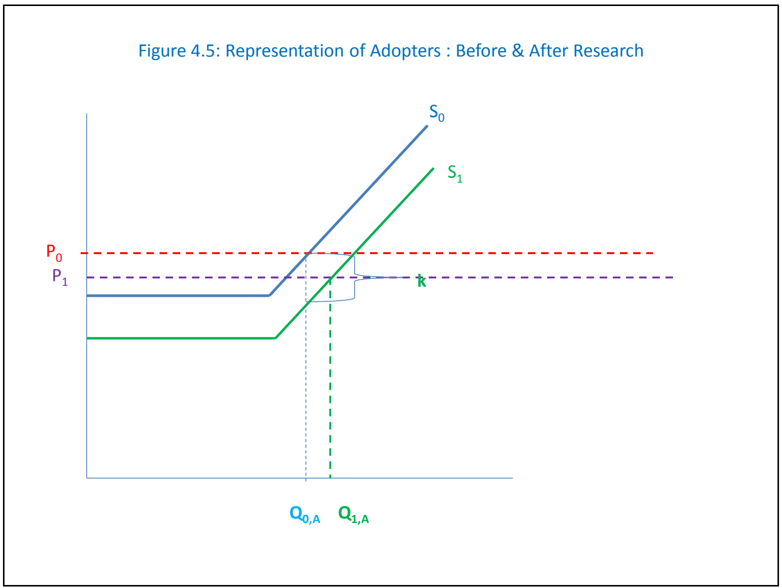


Figure 4.5 considers the adopters, A1. This is equivalent to the illustration in Figure 4.3 (c) but with a kinked supply. Adopting the new varieties reduces costs by 'k' and shifts their combined supplies from S_0 to S_1. In the aggregated market the price again falls from P_0 to P_1. The after research production level of adopters is increased to $Q_{1,A1}$. This is the usual situation when a new variety is just an improvement over an existing one but does not facilitate expansion to production environment(s) where the crop was previously not very suitable. There will be some increase in the area but these are the usual price responses not due to farmers operating at kink points. Having said this though unless the full cost situation is known for each case it is not possible to tell when kink points or switchers-substitution may be stirred into action. As a rule this should always be checked for, however, without detailed surveys (like the one undertaken for this study) it may not be easy to know when a new technology creates this situation.

Fig 4.5 Representation of Adopters: Before & After Research

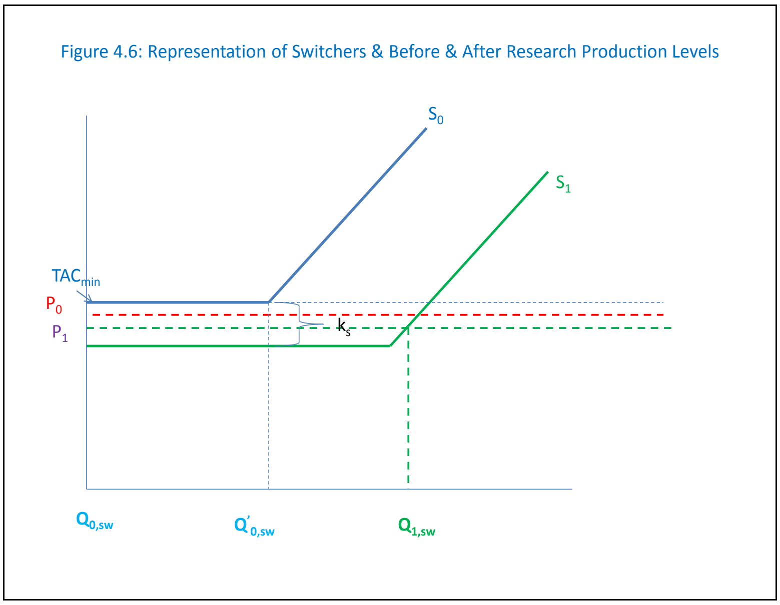


The important group for this study is the farmers who have expanded production onto additional land not previously used for chickpeas, that is, A2, A3 and SW farmers. Although it can be useful to consider each of these three groups separately the diagrammatical representation is basically the same. For all of them the new varieties mean that the farm gate market price is now higher than their 'with technology' kink point in their supply. Figure 4.6 depicts their 'with' and 'without' research supply situation.

Before the release of the new varieties it was not profitable to grow chickpeas on these areas of land – they had better, more profitable alternatives. The price for chickpeas, $P_{0,}$ was below their minimum average total cost of production, ATC_{min} (=MC), including the opportunity cost of producing the more profitable crops. Their before research production was $Q_{0,SW}$, that is, zero. After the release of the new varieties it is now profitable to grow chickpeas and many do so. The supply shifts by k_s (which is the reduction in the unit cost of production, UCR) and production increases to $Q_{1,SW}$ at the new after research equilibrium price, P_1.

The crucial issue for this group of farmers is what is the appropriate measure of welfare gains due to the farmers switching land to chickpea production and then how do we estimate this, given we are dealing with farmers and their production at the kink or switching point of their supply functions.

Fig 4.6: Representation of Switchers & before & after Research Production levels

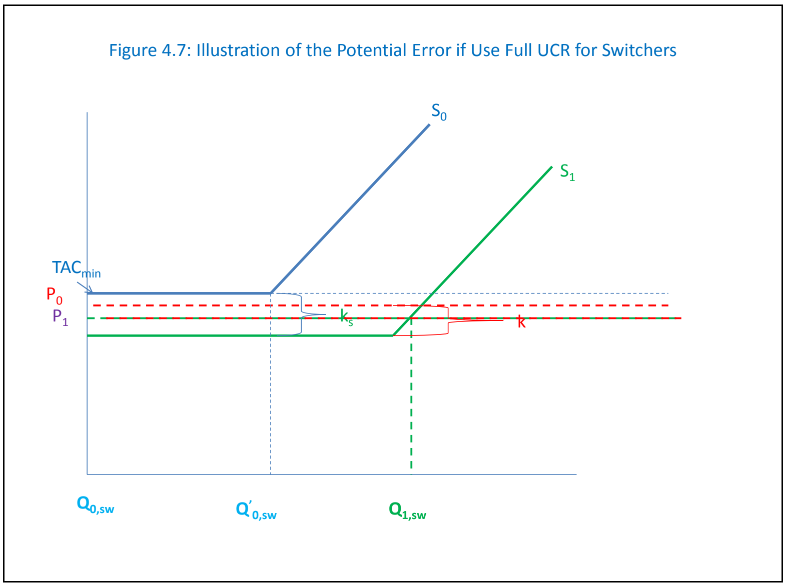


In the usual case of the adopter the welfare gains for the new technology is estimated as the area between the 'without research' supply and the 'with research' supply bounded by a line between the intersections with the price line before and after the research is adopted. The supply shift measured by the UCR of k_s and the before research production are usually important determinants of this area. The without research supply for the switchers is not observable because there is no production before adoption of the technology. While it would be possible to estimate the average total cost for the switchers for the old varieties and therefore k_s, the information would not come from actual production information – rather than hypothetical farm cost analyses.

However, the welfare change for adoption by switcher farmers can be shown to be the area under the original price line P_0 and above the with research switcher supply, S_1. This is found by estimating the area of a rectangle plus a small triangle. The rectangle area is found by finding the difference between the before research farm gate price and the after research ATC_{min} or unit cost (UC). The production is the level of output at the kink point of the supply. However, it is seem from figure 4.7 that the welfare change inducing 'supply shift' due to switchers is $k<k_s$. If the UCR k_s is used the welfare change will be overestimated by the area between the without research price line and the ATC_{min}. How large this error might be depends on how much higher than P_0 the without research cost is. The alternative though is to use the without research price and the unit cost after research to give k.

The other important issue is that the price response via standard supply elasticities does not handle the extreme switcher situation. The switcher response (and also the existing producers who expand their areas significantly) are not responding to a price change rather a substantial reduction in the unit cost of production and therefore increase in profitability (which in fact will be at a lower price).

Fig 4.7: Illustration of the Potential Error if use full UCR for Switchers



Some caution is required with this recommendation. True farm gate prices are often difficult to obtain. To be sure they are accurate farmer surveys are required. As a general rule using commodity prices to derive supply shifts (UCR's) should be avoided. Price series are difficult to find which do not have many off-farm service cost included. They can cause very large overestimates of welfare gains. If there is lack of confidence in the available farm gate prices then an alternative approximation for the switcher UCR is:

$$UCR_s = UCR_a - (UC'_a - UC'_s). \qquad (4.1)$$

Where:

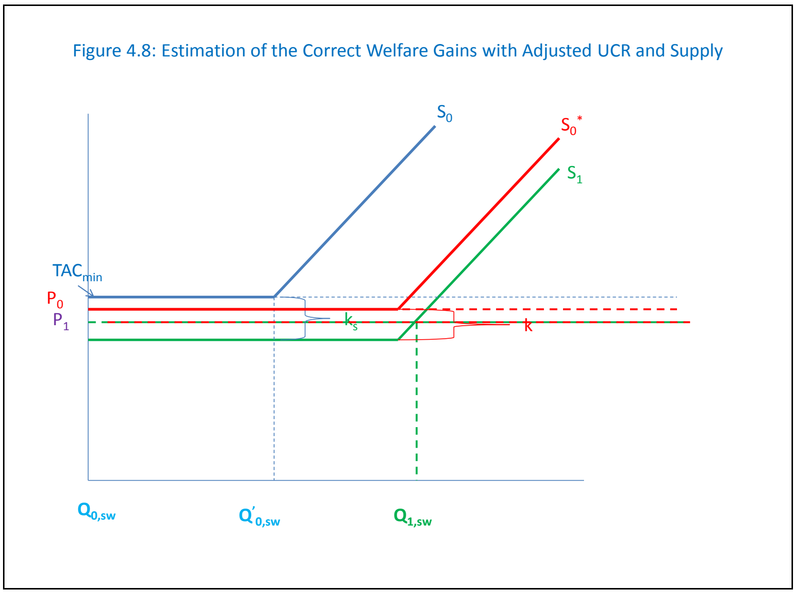
UCR_s	is the unit cost reduction (supply shift) of switchers
UCR_a	is the unit cost reduction (supply shift) of adopters in the same region
UC'_a	is the unit cost of production for the adopters with the new technology.
UC'_s	is the unit cost of production for the switchers with the new technology

This in effect means using the without research counterfactual adopter UC for the switcher counterfactual – equation 4.1 reduces to this if it is expanded out. In equilibrium this should equal P_0.

Since both measures can contain significant errors if the underlying information is not accurate, judgement is required by those collecting the data regarding which method has the most reliable underlying data.

Figure 4.8 is used to demonstrate diagrammatically what the above suggestion would involve. The constructed supply, S_0^*,is the without research or what is usually called the counterfactual supply. The vertical distance between this and the with research supply, S_1, is the counterfactual UCR, k. To use the usual formulae for estimation of the welfare changes due to research the additional information required is the 'without research' production. Since this was zero again we need to estimate this counterfactual production. It is the production consistent with the kink point in both supplies. The appropriate estimate of the counterfactual production is the area switcher's plant to the new variety multiplied by the new variety yield. This information should be available from detailed surveys, if this is not possible then a good approximation would be $Q_{1,sw}$ although this could involve some possible over estimation.

Fig 4.8: Estimation of the Correct Welfare Gains with Adjusted UCR and Supply



In summary, to accommodate disaggregation of a country, state or region to include switchers as a separate group of farmers requires:

i. Estimates of the shares of farmers and there production in the switcher group and therefore also in the other disaggregated groups, in this case non-adopters and existing producer adopters. This information is required each year from the start of adoption through to the full adoption year.

ii. Construction of a switcher counterfactual supply for each year to match the adoption levels. This is best estimated using the yield and estimates of area changed to chickpeas. If not readily available then an estimate of the actual production by switchers for each year would be an acceptable approximation, $Q_{1,sw}$.

iii. Estimation of the supply shift or unit cost reduction UCR) for switchers. This is best estimated as the without research equilibrium price less the unit cost of the new variety for the switchers, estimated from a switcher cost analysis. If the analyst does not have confidence that the farm gate price is an accurate estimate of the price for each farmer group then an alternative approximation for k is to use the adopter UCR and the adopter 'with research' unit cost compared to the switcher unit cost, see the discussion around equation 4.1 for this process.

Formulae for Estimation of Welfare Changes

The welfare impacts consistent with the above framework can be estimated using formulae adapted from Bantilan *et al.*, (2013; pp34-36). This set of formulae includes all of the parameters from figure 4.1. Some are only important for ex-ante impact assessment analysis. They have been left in the formulae for this ex-post analysis and are indeed included in the spread sheet model developed for the analysis. This is because it is important in the early stages of an impact assessment study to specifically consider all parameters and systematically give them a value after considering them carefully. In some case this may mean a value which means that parameter is redundant. For example in most ex-post studies the probability of innovative research success, p_{yt}, will be set at 1.[2]

The individual benefits for each farmer group, district, state or country 'f' from the research on short duration chickpea 'g' (f = 1 ... n) are given as:

$$E[PV(G_{gf})] = \sum_{t=1}^{T}\sum_{f=1}^{n} \frac{p_{gt} a_{gft} x_{gft} k_{gft}}{(1+d)^t} Q_{sft}$$
$$+ \sum_{t=1}^{T} \frac{p_{gt}(Q_{dft} - Q_{sft})\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{(1+d)^t \sum_{i=1}^{n}(\beta_i + b_i)}$$
$$+ \sum_{t=1}^{T} \frac{p_{gt} b_f (\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git})^2}{2(1+d)^t (\sum_{i=1}^{n}(\beta_i + b_i))^2}$$
$$+ \sum_{t=1}^{T} \frac{p_{gt} \beta_f}{2(1+d)^t} [a_{gft} x_{gft} k_{gft} - \frac{\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{\sum_{i=1}^{n}(\beta_i + b_i)}]^2 \quad \text{..... (4.3)}$$

Consumer benefits for each farmer group, district, state or country 'f' from the research on short duration chickpea 'g' (f = 1 ... n) are given as:

$$E[PV(G_{cgf})] = \sum_{t=1}^{T} \frac{p_{gt} Q_{dft} \sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{(1+d)^t \sum_{i=1}^{n}(\beta_i + b_i)}$$
$$+ \sum_{t=1}^{T} \frac{p_{gt} b_f (\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git})^2}{2(1+d)^t [\sum_{i=1}^{n}(\beta_i + b_i)]^2} \quad \text{(4.4)}$$

[2] *Bantilan et al., (forthcoming) provide more details on the importance of maintaining this linkage between ex-ante and ex- post impact assessments.*

Producer benefits for each farmer group, district, state or country 'f' from the research on short duration chickpea 'g' (f = 1 ... n) are given as:

$$E[PV(G_{pgf})] = \sum_{t=1}^{T} \frac{p_{gt} Q_{sft}}{(1+d)^t} [a_{gft} x_{gft} k_{gft} - \frac{\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{\sum_{i=1}^{n} (\beta_i + b_i)}]$$

$$+ \sum_{t=1}^{T} \frac{p_{gt} \beta_f}{2(1+d)^t} [a_{gft} x_{gft} k_{gft} - \frac{\sum_{i=1}^{n} \beta_i a_{git} x_{git} k_{git}}{\sum_{i=1}^{n} (\beta_i + b_i)}]^2 \qquad .... (4.5)$$

Where:

p_{yt} is the probability of success of the innovative short duration chickpea research undertaken by ICRISAT and its partners 'y' in year 't' ($0 \le p_{yt} \le 1$). As was noted above this value was set to 1 in the analysis since the original research was successful[3];

a_{yft} is the probability of success of adaptive research undertaken in each district, state, country or region 'f' for the short duration varieties developed by ICRISAT and its partners 'y' in year 't' ($0 \le a_{yft} \le 1$). Again for most groups of farmers, districts, states and countries this parameter was set to 1. However, there are several of these where this adaptive research did not occur so the parameter was set to zero[3].

x_{yft} is the expected level of adoption of the new short duration chickpea varieties developed by ICRISAT and its partners 'y' by producers in each district, state, country or region 'f' (f = 1 … N) in year 't' ($0 \le x_{yft} \le 1$). This parameter can change each year and will. Underlying specifying this parameter is the complex set of understanding of the various research and adoption lags plus an assessment of when adoption reaches its ceiling level.;

k_{yft} is the unit cost reduction (UCR) resulting from adoption of the short duration chickpea varieties developed by ICRISAT and its partners, 'y', in each district, state, country or region 'f' (f = 1 … N) in year 't'.

d is the social discount rate in real terms.

Q_{sft} is the quantity of chickpeas produced in each district, state, country or region 'f' in time period 't' without research, that is, the counterfactual production level.

Q_{dit} is the quantity of the chickpeas consumed in each district, state, country or region 'f' in time period 't' without research, that is, the counterfactual consumption level.

b_f and b_i are the slope parameters (dQ/dP) of the demand function in district, state, country or region 'f' or 'i'. Note that $b_i = e_{di}$ [Q_{dit}/P_{it}], where e_{di} is the elasticity of demand for the commodity in district, state, country or region 'i' evaluated at the original equilibrium prices and quantities, Q_{dit} and P_{dit}. Note because negative signs are included in the demand specification the absolute value for these parameters are entered in the formulae.

[3] *Bantilan et al. (forthcoming) provide complete set of equations and other details.*

$ß_f$ and $ß_i$ — are the slope parameters (dQ/dP) of the supply function in district, state, country or region 'f' or 'i'. Also note, $ß_i = e_{si}\ [Q_{sit}/P_{it}]$ where e_{si} is the elasticity of supply.

N — is the total number of district, state, country or region producing and consuming chickpeas in the world.

Figure 4.1 includes a complex schematic for identification and modelling requirement of research domains, research applicability and spillovers between all producers and consumers of chickpeas. This is achieved through adjusting the unit cost reduction, k, parameter. This was not formally used to calculate the UCR for each farmer grouping, district, state, country and region in the current study. However, the modelling process was used as a testing template for each UCR that was estimated for each unit.

A brief summary of the underlying relationship is:

$$K = K^{*}S \qquad \text{.........} \quad (4.6)$$

Where:

K — is a matrix of monetary direct and indirect spillover unit cost reductions. K is an N x N matrix where N is the number of countries/regions in the world. Each component of K , that is, k_{yjt}, is then the unit cost reduction in country/region 'j' resulting from research undertaken in country/region 'y'. This is what is used in equations 4.3 to 4.5.

K* — is a diagonal matrix of potential cost reductions for each country. k^{*}_{yy} is the potential cost reduction in country 'y' where the (innovative) research is undertaken, with all $k^{*}_{yj} = 0$.

S — is a matrix of research spillover indexes. In most cases it is expected that $0<s_{yj}<1$; although this is not a necessary condition of the framework.

$$S = R\ C\ F \qquad \text{.............} \quad (4.7)$$

Where:

S — is the same NxN spillover index matrix as in equation (4.6).

R — is an N x m matrix of potential research focus parameters; 'm' is the number of production environments (research domains) relevant to production of the commodity and for a particular type of research problem being considered. Research can be focused on one production environment or a mix of them in different proportions by assigning an index r_{yi} ($0 \le r_{yi} \le 1$) and $\sum_{i=1}^{m} r_{yi} = 1$ for country 'y'.

C — is an m x m matrix of the research applicability's between production environments for each commodity, c_{ij}.

F — is an m x N matrix of the shares of commodity production (production proportions) in each production environment for each country, f_{iy}. Again $\sum_{i=1}^{m} f_{iy} = 1$ for country 'y'.

4.2 Summary of Data Requirements

The minimum data requirements for the analysis using the framework outline in this section is embedded in the above discussion. It is worth briefly summarising these with some brief comments here. In the application section these will be revised in detail and the important sources and adjustments to this data to support the analysis will be discussed in detail.

The important sets of data are:

Level of Aggregation and Disaggregation

As the discussion earlier in this section highlights tailoring the level of disaggregation to ensure the important impacts are not aggregated into a general story is a very important consideration. As will be discussed in the analysis section the final choice required many iterations and considerable scrutiny of the survey results. The final disaggregation has enabled several important stories to be told and lessons learnt.

Production

A substantial set of historical production, area planted and yield information was assembled and used to guide the disaggregation strategy but was also crucial for understanding the complex story of this technology adoption and impact. As will be discussed in more detail based on the above considerations the choice of the counterfactual production data was a major activity with the final choice requiring many interactions. This is to be expected since these data are very crucial to the size of the final welfare benefits estimates.

Consumption

Data on consumption of agricultural commodities is difficult to assemble especially is a disaggregated level within a country is required. Once the base line for the production was chosen the consumption to match this was assembled.

Farm gate price

The detailed farm level survey and focus group discussions provided a good basis for developing a reliably set of farm gate prices. International prices were assembled from national sources. This data set is often difficult to obtain effectively. Although as long as the correct form of the framework is used and minimal use is made of prices for indirectly estimate some of the other critical parameters, this data is not as important as some of the others in terms of a source of large fluctuations in welfare estimates.

Research lag (years)

This very important parameter was estimated via detailed discussions with research groups and careful reviewing of many documents and varietal release information. Details are again provided in the later sections.

Adoption Parameters

Adoption lag; Years from research start to start of adoption; Years from release of the new technology to start of adoption; Years from research start to ceiling level of adoption; and Maximum adoption. This set of parameters is very important and have a major impact of the level of the benefits. They are also important in drawing implications about the impact of the technology. Information was enhanced by the extensive survey and the basis for estimation of the parameters is discussed in detail sections 5 and 6 but also 3.

Unit cost reduction

Estimation of the crucial parameter was a very elaborate activity. Full details are discussed in the survey and analytical sections.

Elasticity of supply and demand

These were taken from ICRISAT's extensive set of past studies.

Discount rate: The standard accepted discount rate of 5% was used.

Research Cost: These were discussed in detail in section 3.

Final Benefit Cost Analysis

The above set of 120 plus welfare change estimates and the stream of research and extension activity costs from section 3 are included in a financial analysis to give summary financial measures. These are:

Net Present Value (NPV)

Benefit/Cost Ratio B/C)

Internal Rate of Return (IRR)

Final words of caution

The extensive body of applied welfare analyse literature assures us that the estimates of total welfare changes provided by application of this framework are a very good approximations of what will occur. However, it cautions us about the final accuracy of the estimates for the distribution of these welfare changes. The economic framework is partial equilibrium so all the economic interactions are only the first round impacts on the world chickpea markets. General equilibrium considerations tell us that the second and subsequent round interactions will dissipate these first round welfare distributions much more widely throughout the local and then world economies. The efficiencies and even inefficiencies (through the many government interventions) of all other markets in agriculture and the rest of the world economy will influence the final distribution of these welfare changes. These are very complex so the ultimate distributional impacts will often surprise many! However, the important point is that applied welfare economics theory tells us that as long as those applying the framework have a good understanding of this theory when making judgements about data selection and interpretation then the total welfare changes are a very good approximation of what is achieved.

In addition to these two estimation issues, there is the further issue of which $Q_{0,t}$ should be used. That is, which years 'without research' production should be used? This is complex and needs to be considered with a clear picture of the way the adoption parameter is used in the estimation of the welfare gains.

This raises a crucial issue of making sure that the counterfactual situation is well defined. At the year of the ceiling adoption the Q_0 is the production without the research in year t-1. It is crucial therefore to use the estimate of this production as the level for all years before that.

Overall, many lessons learnt while undertaking this comprehensive impact study in Andhra Pradesh. They are as follows:

1. It emphasizes the real worry about using the percentage change in yield as the estimate of the horizontal supply shift. This misses the whole discussion of important aspects of production theory as well as the real risk that the implicit vertical shift can be unrealistically very large.
2. There were several arguments over parallel, pivotal, divergent etc. supply curve shifts in the IA literature. This study has provided a solution to this issue with incorporation of 'kinks in supply functions'. By going back to ATC and MC curves for different production systems/potential adopter groups, they provide a schema for capturing differential responses to new technology options that in principle provide a way of aggregating them into an implicit "after adoption" aggregate supply curve. This then avoids having to assume a certain type of aggregate supply shift as is the current practice. There are a number of other advantages in doing this, not the least is the added scope for linking ex-post and subsequent ex-ante impact assessment that is based in the first instance on production systems/research domains/recommendation domains and the exploitation of revealed spillover potentials among them."
3. This study also highlights the conclusion that each impact assessment study is very different. An assessment specific spread sheet analysis is nearly always required and therefore the real concern with software such as DREAM. These black boxes do not make the analyst keep asking the crucial questions. In fact they facilitate aggregating these questions away.
4. The study also highlight the importance of dis-aggregation of all key parameters so that the precision of estimation of welfare benefits will increase. Empirically, the study has proved that UCRs across different may not be same. The welfare benefits are underestimated when used the aggregated UCRs across PEs.
5. It highlights the concern about the trend to focus attention on environmental and social impacts – the fundamental production impacts are still rarely well understood let alone effectively estimated. It also highlights why we shudder when the 'evaluation society' impact studies start using qualitative subjective measure of impacts.

5 Survey Details

This section describes the data collection of primary data using a sample survey to enable an in-depth analysis of the adoption process. The survey was designed to ensure that it provided information for the welfare analysis.

5.1 Sampling framework and randomization procedure

Development of an appropriate robust sampling strategy is a critical important step in ensuring a truly representative sample for this study. There were several rounds of discussions with crop improvement scientists and SPIA team members (including Doug Gollin and Tim Kelley) and suggested experts on this issue. For example, Tavneet Suri, a sampling expert from the Massachusetts Institute of Technology (MIT) gave valuable advice during the development of the sampling frame. Guidelines developed by Tom Walker and Abdoulaye Adam (2012) for the DIIVA Project was also referred to during the sampling process. The methodology as described below ensured representative sample at each stage from primary level (mandal), secondary level (village) and tertiary level (household).

The critical issues carefully considered during the sampling process are as follows:

1. The primary sampling unit is determined at the mandal (sub-district) level, considering the results of the analysis of the available data on area, production and yield.
2. There are around 1120 mandals existing in Andhra Pradesh from 23 districts. There are 329 mandals growing chickpea, but only 61 with area larger than 3000 hectares[4] (based on 2009-11 secondary data – Table 5.1). The spatial distribution of area grown to chickpea is shown in Figure 5.1 below. Given limitation of budget and time, a sample of 30 mandals were randomly selected proportional to size (i.e. chickpea production area) was drawn out of the 61 mandals using a randomization procedure (see Appendix 9).
3. At the secondary sampling stage, i.e. the village, similar proportional to size sampling is applied. Three randomly selected villages from each mandal were drawn. Hence, a total of 90 villages across the chickpea growing areas were selected randomly in Andhra Pradesh.
4. A random sample of nine chickpea growing farm-households was identified irrespective of land holding size criterion[5]. A post-stratification sample scheme will be implemented during the analysis.

[4] In Andhra Pradesh, on an average, each mandal consists of 30-40 villages. Undertaking a primary survey was considered not cost effective if a particular village is not growing a minimum area of 100 ha under chickpea. Thus, the survey determine the cost effective cut-off point of 3000 ha (30 X 100 ha) per mandal.

[5] The land revenue records available with Village Development Officer (VDO) were used in the process of random selection of chickpea and non-chickpea growers. Based on VLS data in Andhra Pradesh, the proportion of landless lessees is very minimal (less than 2%). Thus, we considered the use of land revenue records as a good basis for objective sample selection with minimal sampling bias.

Table 5.1 List of mandals with chickpea area greater than 3000 ha

District	Chickpea growing mandals	No. of mandals with >3000 ha	Total chickpea cropped area	Area coverage of mandals with > 3000 ha	% covered
Anantapur	42	7	81362	64717	79.5
Kurnool	53	23	209255	172291	82.3
Kadapa	30	12	79942	68043	85.1
Nellore	18	0	10728	0	0.0
Prakasam	50	10	84004	45853	54.6
Guntur	30	0	10514	0	0.0
Mahabubnagar	31	3	27035	18438	68.2
Medak	45	3	31014	11721	37.8
Nizamabad	30	3	20705	13788	66.6
Total	**329**	**61**	**554559**	**394851**	**71.2**

Overall, three villages were randomly chosen from each selected mandal in the study. Thus, a total of 90 villages from 30 mandals were formally surveyed in seven districts (out of nine) of Andhra Pradesh (See Table 5.2 and Fig 5.1).

Fig 5.1 Spatial distribution of area grown to chickpea by mandal in A.P, 2010-12

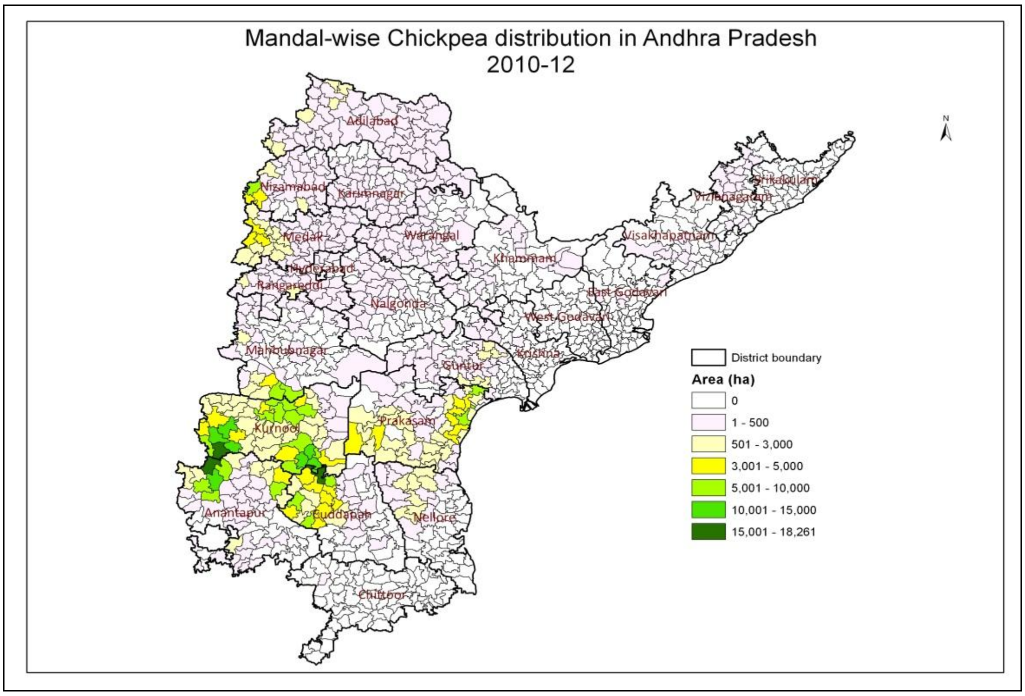


Table 5.2 Primary, secondary and tertiary samples based on the sampling frame constructed

District	No. of mandal growing chickpea	Mandals with chickpea area > 3000 ha	No. of mandals selected for the study	No. of villages covered in the study
Kurnool	53	23	13	39
Prakasam	50	10	4	12
Anantapur	42	7	5	15
Kadapa	30	12	5	15
Medak	45	3	1	3
Nizamabad	30	3	1	3
Mahabubnagar	31	3	1	3
Andhra Pradesh	281	61	30	90

Time series data on area, production and yield were obtained from FAOSTAT and relevant Government of India and State of Andhra Pradesh offices. State (sub-national) and district data were collected for examining the spatial distribution of crop production across all of India. More detailed sub-district (mandal) distribution available for the whole state of Andhra Pradesh was used as basis for constructing the primary level sampling frame for the study. The systematic collection of available census village/household data followed to construct the secondary and tertiary sampling frame for the study. For example, it was most useful to be guided by the spatial GIS map drawn using the mandal level data available.

Table 5.3 Final sample of mandals for the chickpea survey

Sl.no	District	Mandal	Sl.no	District	Mandal
1	Anantapur	Kanekal	16	Kurnool	Dornipadu
2	Anantapur	Vidapanakal	17	Kurnool	Sanjamala
3	Anantapur	Tadpatri	18	Kurnool	Uyyalawada
4	Anantapur	Uravakonda	19	Kadapa	Mylavaram
5	Anantapur	Beluguppa	20	Kadapa	Peddamudium
6	Kurnool	Gudur	21	Kadapa	Rajupalem
7	Kurnool	Kurnool	22	Kadapa	Simhadripuram
8	Kurnool	Midthur	23	Kadapa	Veerapunayunipalle
9	Kurnool	Adoni	24	Prakasam	Parchur
10	Kurnool	Alur	25	Prakasam	Janakavarampanguluru
11	Kurnool	Aspari	26	Prakasam	Naguluppalapadu
12	Kurnool	Banaganapalle	27	Prakasam	Ongole
13	Kurnool	Chippagiri	28	Mahabubnagar	Manopad
14	Kurnool	Maddikera (East)	29	Medak	Manoor
15	Kurnool	Koilkuntla	30	Nizamabad	Madnoor

Out of the 281 chickpea growing mandals in seven districts, mandals with chickpea area more than 3000 ha was initially considered for the study (i.e. nearly 61 mandals). The details on the sampling scheme (specifying the number of sample mandals, sample villages and sample households) are presented in Table 5.2. A sample of nine chickpea growers were randomly selected and interviewed with a structured questionnaire. The above formal surveys were complemented by a series of focus-group discussions (FGDs) which were conducted in each study village to capture both the quantitative and qualitative impacts of chickpea technology on farmers. The study collected information that pertained to the 2011-12 cropping season. Overall, a total of 810 households were covered from 90 villages and 30 mandals in seven districts of Andhra Pradesh representing more than 71% of the chickpea area in the state. The details of final sample mandals selected for study are summarized in Table 5.3.

5.2 Development of appropriate counter-factual scenarios

It is almost a decade after the introduction of the improved chickpea technology in Andhra Pradesh state and rapid diffusion of these cultivars has already taken place. Initial estimates obtained from crop improvement experts indicate that more than 90 per cent of cropped area is now under improved chickpea cultivars in AP; and identification of the remaining 10% area would be very challenging. It is also noted that there has been no socio-economic baseline survey conducted during last decade which may also serve as benchmark for establishing the counterfactual on a “before and after” impact analysis.

Given the current situation in chickpea production in Andhra Pradesh, two counter-factual scenarios are required for analysis. The first is comparison of farm-households growing old and new improved chickpea cultivars; and the second involves the comparison of farm-households growing chickpea and non-chickpea crops.

The above situations were considered while developing and finalizing the sampling strategy. An additional sub-sample of three non-chickpea growing farm households were included in the sample in addition to the 9 chickpea farm-households in each village. Thus, 33.3% representation of non-chickpea growers would be a good representation for establishing the second counter-factual in the study. Overall, the study is covering 1080 respondent farm-households from 90 villages (9 chickpea HH and 3 non-chickpea households).

5.3 Development of survey instruments and protocol

Adoption and impact survey instruments

The development of household and village questionnaires harnessed ICRISAT’s vast experience in conducting the ICRISAT ‘Village Level Studies (VLS)’ as well as its strong competence in implementing adoption and impact studies. The aim is to keep the household survey instrument simple and restricted to about 15 pages. The budget and time constraints were also binding and are seriously considered in the sample survey design and implementation. Refer to Appendix 7 and 8 which present the final household and village questionnaires used in the survey.

The survey instruments were developed, pretested, modified and refined through several iterations with group of chickpea experts from Andhra Pradesh and sample farmers. The household and village questionnaires were finalized after extensive on-site pre-testing in

Prakasam district which involved the scientists (economists and breeders together) and field investigators commencing the 2012 post-rainy cropping season. It was also pre-test in five villages of Kurnool district with the help of NARS partners from Nandyal station. Keeping in view some of the nagging issues involving the emerging chickpea crop intensification in southern India and in particular in the state of Andhra Pradesh and ICRISAT's interest in sustainable agricultural production in the semi-arid tropics (SAT) region where this crop is primarily grown, some additional variables were incorporated to enhance the questionnaire. The modules were refined after incorporating the feedback from farmers and considering the quality of information provided by them. The research/survey team spent more than one week on pre-testing and an additional week on finalization of survey instruments.

Varietal identification protocol

ICRISAT undertook the study with a component to develop and test a varietal identification protocol for chickpea. The protocol was designed and validated through field testing and in collaboration with breeders to increase the accuracy of varietal adoption estimates. This varietal identification protocol especially developed for the chickpea adoption and impact study in Andhra Pradesh evolved through close discussions with experts on chickpea crop improvement both from ICRISAT and the NARS partners including Acharya N G Ranga Agricultural University (ANGRAU) and other experts and stakeholders.

A simple 10-question survey (protocol) was used to administer to chickpea growing households in chickpea growing districts in Andhra Pradesh, India. The simple protocol relies on identifying chickpea improved varieties based on phenotypic characteristics, i.e. a combination of distinguishing characteristics of chickpea varieties – related to maturity, growth habit, flower color, pod shape, etc. – to identify traditional and specific improved varieties. The protocol survey was tested on a pilot scale among rural households with the aid of photographs to assist respondents in identifying the variety of chickpea.

The protocol was modified and refined through several iterations which considered as well the sample protocols developed for other crops shared by SPIA. Appendix 6 includes the details of this finalized protocol. Results show a high rate of correspondence between expert classifications and the protocol's classifications indicating the awareness of farmers on the improved varieties in contrast to the earlier dominating varieties which has been adopted for more than 30 years in AP.

The varietal identification protocol was piloted in Prakasam district. This pre-testing was conducted during the 2nd week of November 2012 and the feedback from farmers was useful in validating and finalizing the protocol developed. The chickpea farmers in Andhra Pradesh were observed to have very good awareness about improved cultivars and its plant types. Nearly 80-90 per cent of farmers were able to clearly indicate the cultivar name and its features to the survey team. At the same time, the research/survey team also confirmed that there were no traces of local races and inter species cultivars.

5.4 Focus group meetings (FGM) to enhance survey information

Discussions with chickpea field experts were undertaken during the survey design and testing. Reconnaissance surveys undertaken during the rabi chickpea growing season from

Nov 2012 to January 2013 brought out observations which provided a basis for systematic analysis of spatial data. Important observations were drawn from the consistent responses from FGM farmers and stakeholders which indicated that: "By and large, almost 85 per cent of the farmers in the 90 study villages are chickpea growers', with plot areas ranging from 1 to 100 acres. The remaining farmers who are not growing chickpea in these villages indicated that they are not growing chickpea because the soils were not suitable (e.g. red, sandy and chalky soils) or having access to irrigation facilities." This perspective from the FGMs presented as one empirical question which may be tested or verified from the surveys.

5.5 Disaggregation into 5 types of adoptors

Also based on focus group discussions with chickpea field experts (which were repeated even after the surveys were finished), the analysis of impact from the adoption of short duration chickpeas cultivars were realized to be even more involved. As well as farmers who previously did not grow chickpeas expanding their area, even those who previously grew chickpeas have not only adopted the new varieties but also expanded their area planted. From the survey information it seems that this expansion has been in two ways, (i) by substituting or switching from other crops and (ii) purchasing or leasing additional land which previously did not have chickpeas planted on it.

If this is the current situation in Andhra Pradesh then it was decided to classify (or disaggregate) farmers into well-defined categories of five groups, as discussed in the methodology sections in Chapter 4. This led to further disaggregation by types of adopters, and then to the need to better understand the production theory underlying costs and then supply shifts.

- Non-adopters, NA – farmers who continue to grow the old varieties
- Adopters, A1 - replacing existing varieties with the new short duration varieties
- Adopters, A2 - substituting the new varieties for other crops grow on part of the farm
- Adopters, A3 - acquiring additional land to grow the new varieties
- Switchers, SW - farmers who have not grown chickpeas before and replace other crops.

6 Key findings from primary household surveys

This chapter presents the results from primary household adoption surveys and data analysis. This includes the socio-economic profile of chickpea traditional and non-traditional growers in Andhra Pradesh, their land holding status, cropping pattern details and asset values, uptake and diffusion process of chickpea improved cultivars. It also reports on key variables that are essential in assessing the benefits accruing from the adoption of the improved short duration varieties. This includes costs and returns in crops cultivation, average household incomes and expenditures, unit-cost reductions due to adoption of new technology and ultimately the welfare benefits. This comprehensive analysis of the farm level survey data addresses farm level responses with respect to diffusion, adoption, dis-adoption, input use and crop management.

The details obtained through focus-group meetings are summarized in Appendix 5. These responses are primarily used to validate or cross-check the household level information collected in that particular village. The feedback helps in assessing the village information regarding extent of adoption of different cultivars, their average yields, price trends and various reasons for their preferences etc. Sometimes, they serve as a backup sources of information, particularly if the primary data has any descriptencies or outlayers.

6.1 Socio-economic profile: Occupational pattern, landholding status, cropping pattern and others

Chickpea is a relatively new post-rainy season crop sown by farmers in Andhra Pradesh. Consistent with the available district level data which indicated that chickpea was not even classified as a minor crop in Andhra Pradesh until 1985. The farm survey average figures in Table 6.1 shows that the representative sample of farmers growing chickpeas have been farming for more than two decades but most farmers (except in Medak district) have only started growing chickpeas during the last 10 years. While Medak farmers are seen on average to have been growing chickpea the longest (more than 16 years now), farmers from Kurnool, Anantapur and Prakasam were the first switchers from non-chickpea to chickpea crop about 10 years ago. The new comers to chickpea production come from Nizamabad, Kadapa and Mahabubnagar. This information re-confirms that Medak district farmers are the traditional grower of chickpea in Andhra Pradesh. Most of the sample farmers are male headed (99.2%) with an average age of 48 years. The education levels (schooling years completed) were observed to be higher in Kadapa district followed by Anantapur, Prakasam and Kurnool. The average size of the family including children is around 5.00. But, the sample households in Medak possess the highest size of 5.85 while the lowest was observed in Prakasam (3.97). Overall, the contribution of males is slightly higher (53%) than females in the family size. Three out of five members in an average family engaged with family agriculture work. The proportion of male contribution to family work is pre-dominant (54 %) in all the sample districts in the study. 1.36 members in an average family also participates in outside labor market.

Table 6.1 General characteristics of sample households

Item/ Districts	Unit	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Years of farming	Years	22.5	23.4	21.2	24.3	25.3	21.25	24.3	23.1
Years of CP farming	Years	9.5	10.9	8.9	11.1	16.9	7.4	9.2	10.4
Household head	Male	106	348	134	135	27	27	27	804
	Female	2	3	1	0	0	0	0	6
Average age	Years	50.3	47.4	47.3	48.8	50.2	49.6	50.3	48.3
Education (years completed)	Years	6	6	8	7	5	5	5	6
Average size of family*	No.	3.97	5.21	4.75	5.20	5.85	5.59	5.29	5.00
No.of male*	No.	2.12	2.77	2.54	2.74	3.26	2.89	2.63	2.65
No. of female*	No.	1.85	2.44	2.21	2.46	2.59	2.70	2.66	2.35
No.of family labour (no.)*	Male	1.42	1.66	1.46	1.66	2.18	1.88	1.70	1.62
	Female	1.24	1.43	1.40	1.38	1.41	1.55	1.37	1.39
	Total	2.66	3.09	2.86	3.04	3.59	3.43	3.07	3.01
Participation in labor market (no.)*	Male	0.45	0.93	0.43	0.70	0.96	0.70	1.22	0.75
	Female	0.38	0.75	0.37	0.54	0.77	0.66	1.00	0.61
	Total	0.84	1.68	0.80	1.24	1.73	1.36	2.22	1.36

* including children in the family

Occupational patterns of sample farmers

The details about occupational structure of the sample households are presented in Table 6.2. Overall, 97 per cent of the sample households are dependent on agriculture as a major occupation for their livelihood. Around 2 per cent of the total sample expressed non-farm labor participation as their primary source of income. Very few sample households are either regular salaried job-holders or dependent on livestock for their main source of income. This pattern is clearly evident across all the sample districts in the study. However, the entire sample farmers' are dependent on wide ranges of secondary sources of income. The prominent secondary occupation (nearly 42 per cent) observed in the entire sample was livestock rearing. It was followed-up by non-labor participation (21.5%), rental income (8%) and other skilled jobs (3.5%). A majority (17%) of the sample households also opined that they don't have any secondary sources of income in the family. More or less equal occupational structures have been observed across different sample farmers.

The details about caste category of the sample households are also discussed in Table 6.2. Nearly 51 per cent of the survey households belonged to advance castes (Open Category) while another 42 per cent sample from back-ward castes (BC). Scheduled Castes (SC) and Scheduled Tribes (ST) together accounted for 7 per cent in the whole sample. However, the share of scheduled castes is much higher than scheduled tribes. The distribution of sample to different caste category is varying from district to district.

Table 6.2 Occupational details of sample farmers

Item	Description	PRM n=108	KUR n=351	KAD n=135	ANA n=135	MED n=27	NIZ n=27	MAH n=27	Total n=810
Main Occupation	1.Agriculture	103	335	134	134	27	27	26	786
	2.Non-Farm Labour	2	11	1	0	0	0	1	15
	3.Employee	1	0	0	1	0	0	0	2
	4.Livestock	0	2	0	0	0	0	0	2
	5. Others	2	3	0	0	0	0	0	5
Secondary Occupation	1.Agriculture	5	16	1	1	0	0	0	23
	2. Agril. Labour	3	19	2	3	0	0	0	27
	3.Non-Farm Labour	18	85	18	26	9	6	12	174
	4.Livestock	47	132	62	67	7	15	9	339
	5. Skilled Labour	3	18	0	5	2	0	1	29
	6. Income from rentals	3	26	16	12	2	2	1	62
	7. Others	0	5	3	5	0	3	3	19
	8. None	29	50	33	16	7	1	1	137
Caste category	BC	23	174	34	61	11	23	17	343
	OC	72	151	101	71	9	3	6	413
	SC	12	25	0	3	7	1	4	52
	ST	1	1	0	0	0	0	0	2

Land holding particulars of sample households

The details of average landholding particulars of the sample farmers are summarized in Table 6.3. The average own-land holding of the pooled sample was 5.83 ha. However, the mean own-land holding are much larger in case of Anantapur followed by Kurnool and Kadapa districts. The smallest own-land holding size was observed in case of Prakasam district. Nearly 88 per cent of the whole sample own-land holdings are under rainfed cultivation while the remaining 12 per cent area has access to irrigation facilities. The share of irrigated area in the total own-land holdings of the respective districts was much higher in case of Medak (30%) and Nizamabad (21%) districts. Relatively, the own-land rainfed holdings also much higher in Anantapur followed by Kurnool and Kadapa districts.

Leasing-in land from outside land market is a peculiar characteristic in chickpea cultivation in Andhra Pradesh. The average leasing-in land for the pooled sample farmers was 1.86 ha which is almost 25 per cent of the total operated land-holding of the total sample. The average leasing-in land per household was the highest in Prakasam district (2.76 ha) followed by Kurnool (2.05 ha), Mahabubnagar (1.81 ha), Anantapur (1.62 ha) and Kadapa (1.35 ha) districts. Nearly 50 per cent of the total operated landholding in Prakasam district contributed by leasing-in. Similarly, these shares were almost 25 per cent in case of Kurnool and Mahabubnagar districts. More than 91 per cent of the leasing-in land is under rainfed cultivation while remaining area possessing some irrigation facilities in the total sample. Around 2 per cent of the pooled total operated land holding is either leased-out or kept as permanent fallow. Some of the reasons for permanent fallow may be high soil salinity, poor drainage facilities and poor fertility in nature. On the whole, the average operated land holding of the total sample was 7.57 ha which is quite high in rainfed cultivation. The average operated holdings were the highest for Kurnool (8.54 ha) followed by Anantapur (8.28 ha), Kadapa (7.39 ha) and Mahabubnagar (6.58 ha) districts. Due to more leasing-in land in Prakasam, the average operated landholding size became relatively higher (5.60 ha) than Medak (4.28 ha) and Nizamabad (4.18 ha). Quick adaptation to mechanized operations as well as leasing-in new land for scaling-up of chickpea cultivation are the peculiar features of chickpea salient revolution in Andhra Pradesh.

Table 6.3 Average landholding sizes of sample (ha per household)

Item	Type	PRM n=108	KUR n=351	KAD n=135	ANA n=135	MED n=27	NIZ n=27	MAH n=27	Total n=810
Total own land holding	Irrigated	0.22	0.93	0.72	0.46	1.20	0.67	0.72	0.72
	Rainfed	2.72	5.66	5.44	6.48	2.80	2.53	4.05	5.11
	Total	2.94	6.59	6.16	6.94	4.00	3.20	4.77	5.83
Leased-in land	Irrigated	0.04	0.32	0.04	0.02	0.13	0.00	0.12	0.16
	Rainfed	2.72	1.73	1.31	1.60	0.35	0.98	1.69	1.70
	Total	2.76	2.05	1.35	1.62	0.49	0.98	1.81	1.86
Leased-out and permanent fallow	Irrigated	0.01	0.02	0.06	0.02	0.21	0.00	0.00	0.03
	Rainfed	0.09	0.07	0.07	0.26	0.00	0.00	0.00	0.10
	Total	0.11	0.09	0.13	0.28	0.21	0.00	0.00	0.13
Operated landholding	Irrigated	0.26	1.23	0.71	0.46	1.13	0.67	0.84	0.85
	Rainfed	5.35	7.32	6.68	7.82	3.15	3.51	5.74	6.72
	Total	5.60	8.54	7.39	8.28	4.28	4.18	6.58	7.57

Cropping systems and cropping patterns of households

Understanding about existing cropping systems and various cropping patterns of the sample households is critical before assessing the adoption of chickpea improved cultivars in sample districts. The details about major chickpea cropping systems existed in the sample districts are presented in Table 6.4. Among all, the most adopted chickpea cropping system across all sample districts was 'Fallow-chickpea'. Farmers' keep their land fallow during the kharif (rainy season) and subsequently take-up chickpea cultivation during rabi (post-rainy) season. Chickpea farmers' open-up the land furrows with tractors/bullocks soon after receiving the rains during rainy season (i.e., in July onwards). This practice allows the black cotton soil (Vertisols) to retain the rainy water as much as they can. The retained/residual moisture will allow growing chickpea crop during late September or October in a normal year. This is the most pre-dominant practice in black soils for conserving the soil moisture. In few places like Medak and Nizamabad where the quantum of rainfall is much higher (around 900 mm), farmers' will grow for short-duration (65-70 days) pulse crops. They prefer to grow either greengram or blackgram crops. Some parts of Nizamabad district, where irrigation facilities are available, farmers are growing soybean in rainy season followed by chickpea in post-rainy season. In case of Anantapur, farmers having alternative irrigation sources preferring to grow groundnut during kharif followed by chickpea in rabi season. However, chickpea farmers' prefer to keep their land fallow during rainy season for obtaining more productivity per unit during post-rainy season and also to sustain the soil fertility for longer period.

Table 6.4 Major chickpea cropping systems in study districts (ha)

Cropping system	ANA	KAD	KUR	MAH	MED	NIZ	PRM
Black gram –Chickpea	-	-	-	-	4.25	13.56	-
Fallow -Chickpea	776.19	701.82	1865.43	107.09	39.27	3.64	398.89
Green gram –Chickpea	-	-	-	-	4.05	21.66	-
Groundnut –Chickpea	6.80	-	-	-	-	-	-
Jute -Chickpea	-	-	-	-	-	-	0.40
Onion -Chickpea	-	-	1.21	-	-	-	-
Paddy -Chickpea	-	-	1.62	-	-	-	-
Pigeonpea –Chickpea	-	-	-	-	1.82	-	-
Soybean -Chickpea	-	-	-	-	-	29.76	-

The average cropping pattern of sample households across study districts are detailed in Table 6.5. In case of Anantapur, only 22 per cent of the rainy season land holding were put under cultivation. Groundnut, paddy, pigeonpea and castor are the dominant crops during rainy season. In contrast to rainy seaon, nearly 71 per cent is area under crops cultivation in post-rainy season. Chickpea and sorghum are the dominant crops growing during post-rainy period. Around 15 per cent of cropped area is under cultivation during rainy season in Kadapa. Cotton and Paddy are the pre-dominant crops observed in Kadapa. Chickpea, sorghum and sunflower are some of the major post-rainy season crops in the cumulative 77 per cent of total landholding (7.45 ha). Cotton, paddy, azwan and pigeonpea are the dominant crops found in case of Kurnool district under rainy season. Chickpea, sorghum and sunflower rare major post-rainy season crops occupying nearly 69 per cent cropped area.

Maize, pigeonpea, chillies and cotton are the major crops grown in rainy season either under full or partial irrigated conditions in Mahabubnagar. Chickpea and tobacco are major pre-dominant post-rainy season crops having maximum share of cropped area. Pigeonpea, greengram, blackgram and cotton are some of major rainy season crops in Medak district. But, chickpea, sorghum and coriander are the principle post-rainy season crops having significant share of area allocations in Medak district. In case of Nizamabad, rainy season cropping pattern dominated by soybean, greengram, cotton, pigeonpea, blackgram and paddy crops. Chickpea and sorghum are major rabi crops grown significantly in the district. Nearly 90 per cent of the kharif cropped area in Prakasam district kept under fallow while it was dominated by chickpea and tobacco during post-rainy season.

All the seven districts cropping pattern are clearly dominated by post-rainy season crops. About 65-70 per cent rainy season cropped area are being put under fallow and subsequently grown with post-rainy season crops. Overall, chickpea is the most pre-dominant post-rainy season crop occupy alone around 60-70 per cent of the total cropped area.

Table 6.5 Average cropping pattern of sample farmers (ha per household)

Crops	ANA (N=135)	KAD (N=135)	KUR (N=351)	MAH (N=27)	MED (N=27)	NIZ (N=27)	PRM (N=108)
Rainy (kharif) season							
Groundnut	1.26	0.04	0.12	-	-	-	-
Paddy	0.16	0.24	0.45	-	-	0.16	0.04
Pigeonpea	0.12	0.04	0.20	0.89	0.73	0.65	0.00
Castor	0.12	-	0.12	0.04	-	-	-
Maize	0.04	-	0.12	1.26	0.04	-	-
Chillies	0.04	0.04	0.04	0.28	-	-	0.08
Cotton	0.04	0.53	0.57	0.24	0.28	0.69	0.24
Sorghum	0.04	0.04	0.08	0.04	0.04	0.04	-
Black gram	-	0.04	-	-	0.45	0.61	-
Onion	-	0.04	0.04	-	-	-	-
Azwan	-	-	0.24	-	-	-	-
Sunflower	-	-	0.08	-	-	-	-
Tobacco	-	-	0.08	0.08	-	-	-
Sugarcane	-	-	-	-	0.08	0.04	-
Greengram	-	-	-	-	0.65	0.93	-
Jute	-	-	-	0.04	-	-	0.20
Soybean	-	-	-	-	0.04	1.38	-
Fallow	6.68	6.36	6.36	4.25	1.66	0.28	4.90
Total	8.54	7.45	8.58	7.13	4.90	4.78	5.51
Post-rainy (rabi) season							
Chickpea	5.79	5.18	5.30	3.97	1.82	2.55	3.68
Sorghum	0.12	0.28	0.40	0.04	0.12	0.16	0.04
Sunflower	0.04	0.28	0.16	-	-	-	-
Maize	0.04	0.00	0.00	-	-	-	0.04
Blackgram	0.04	0.08	0.04	-	-	-	0.04
Paddy	-	0.04	0.04	-	-	0.04	0.20
Tobacco	-	-	-	0.20	-	-	0.45
Jute	-	-	-	-	-	-	0.12
Safflower	-	-	-	0.04	-	-	-
Coriander	-	-	0.01	-	0.08	-	-
Fallow	2.47	1.58	2.58	2.87	2.83	2.06	0.89
Total	**8.55**	**7.45**	**8.58**	**7.13**	**4.90**	**4.78**	**5.51**

The details of major chickpea competing crops during post-rainy season across different districts are summarized in Table 6.6. Overall, the major competing crops for chickpea in the study districts are sorghum, sunflower, blackgram, safflower and coriander. However, tobacco and maize are other important crops competing in selected districts. Chickpea has already replaced many of these competing crops significantly. However, chickpea has the following specific advantages over other competing crops:

1. The new chickpea cultivars provided a short-duration crop
2. Chickpea cultivation is less-labour intensive
3. Relatively low investment per ha is needed
4. Viewed as a less risky crop
5. Assured yields, market and good remunerative price of chickpea
6. Highly suitable for mechanical operations
7. Lower pest problem
8. Improves soil fertility
9. Can easily cultivate in large-scale

Due to the above valid reasons, chickpea competitiveness is much higher than any other rainfed crop during post-rainy season. The competitiveness of chickpea with other competing crops have been presented and discussed in the subsequent sections of this chapter.

Table 6.6 Chickpea competing crops (post-rainy) in the sample districts

PRM	KUR	KAD	ANA	MED	NIZ	MAH
Paddy	Sorghum	Sorghum	Sorghum	Sorghum	Sorghum	Tobacco
Jute	Sunflower	Sunflower	Sunflower	Coriander	Paddy	Sorghum
Maize	Blackgram	Blackgram	Maize		Safflower	Safflower
Blackgram			Blackgram			
Tobacco						

6.2 Household assets, income and expenditures

Average household assets across study districts

The average assets value of the sample households across study districts are presented in Table 6.7. The average total assets value was 111 thousand US $ per household for pooled sample. Nearly 85 per cent of the total asset value alone contributed by own land holdings. Total livestock value of pooled household is contributing hardly one per cent of the total. Around 14 per cent of the total assets per household are contributed by farm equipment, farm buildings and consumer durables. Among the various districts, the total asset value was the highest in case of Kurnool followed by Kadapa and Prakasam districts. The average total asset values per household in these three districts are much higher than pooled sample household. The higher total asset values in Kurnool and Kadapa districts was because of larger own-landholding sizes relative to other study districts. Even though Prakasam has smaller size of own-landholding, the per unit land values might be much higher contributed significantly.

Table 6.7 Average household assets ('000' $ per farmer)

Item	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Pooled (N=810)
Total land value	91 (80.5)	106 (87.0)	97 (82.9)	69 (83.1)	85 (88.5)	83 (85.5)	80 (86.0)	94 (84.7)
1.Irrigated	6	20	18	6	33	15	21	16
2. Dryland	85	86	79	62	52	68	58	78
3. Fallow land	0	0	0	0	0	0	0	0
Total livestock value	0.87 (0.88)	1.14 (0.82)	0.85 (0.85)	1.12 (1.20)	1.42 (1.04)	1.33 (1.03)	0.92 (1.07)	1.06 (0.90)
1. Draft	0	0	0	1	0	1	0	0
2. Buffaloes	1	0	1	0	1	0	0	1
3. Others	0	0	0	0	0	0	0	0
Total farm equipment	2.49	2.62	2.80	1.56	1.29	0.76	1.26	2.30
Total farm buildings	16.00	9.29	11.83	8.52	5.60	9.25	8.24	10.32
Total consumer durables	2.95	2.77	3.54	2.60	2.84	2.99	2.69	2.90
Total assets value	113 (100.0)	122 (100.0)	117 (100.0)	83 (100.0)	96 (100.0)	97 (100.0)	93 (100.0)	111 (100.0)

Note: Figures in the parenthesis indicates per cent to column totals

The share of irrigated land value in the total land value was only 17 per cent for the pooled sample households. Dryland values are significantly contributing (83 per cent) to the total land value of an average household. The value of total livestock was much higher in Medak followed Nizamabad, Kurnool and Anantapur districts. Farm equipment, farm buildings and consumer durables together added significant value (nearly 19 per cent) to the total assets value in Prakasam district. The average per household farm equipment value was higher in Kadapa district followed Kurnool and Prakasam districts. These values indicate the extent of investments on farm mechanization per household. Farm buildings also contributed significantly in the total asset values in Prakasam district followed by Kadapa and Kurnool. Consumer durables value per average household was higher in Kadapa district than the others. These higher total asset values per household indicates strong net worth of chickpea sample households and their potential for agricultural investments.

Average household incomes across sample districts

The average household incomes earned by the sample households during 2011-12 from various sources are summarized in Table 6.8. The average household income of the pooled sample household was 3.45 thousand US $ per annum. Around 60 per cent of the total household income was contributed by agriculture. It was followed-up by participation in farm work (8%) and livestock rearing incomes (8%). Non-farm labor participation and Government development programs were together accounting for 9.3 per cent share in the total household income.

Table 6.8 Average household income ('000' $ per household per annum)

Source of Income	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Agriculture	0.29	3.26	1.27	-0.23	2.73	2.68	4.18	2.03
Farm work	0.28	0.28	0.31	0.33	0.28	0.17	0.31	0.28
Non-farm work	0.16	0.09	0.26	0.28	0.22	0.18	0.11	0.18
Livestock	0.28	0.18	0.29	0.21	0.26	0.23	0.42	0.27
Caste occupations	0.02	0.01	0.01	0.00	0.00	0.00	0.01	0.01
Business	0.17	0.19	0.20	0.07	0.05	0.18	0.31	0.17
Migration	0.00	0.03	0.04	0.00	0.00	0.04	0.01	0.02
Remittances	0.09	0.13	0.04	0.07	0.11	0.00	0.09	0.07
Govt. programs	0.12	0.12	0.17	0.14	0.12	0.20	0.09	0.14
Others	0.22	0.54	0.37	0.13	0.18	0.06	0.51	0.29
Total	**1.63**	**4.83**	**2.96**	**0.99**	**3.96**	**3.74**	**6.05**	**3.45**

Among sample districts, the average incomes per household were the highest in case of Prakasam followed by Kadapa, Medaka and Nizamabad. The share of agriculture income in the total household income was much higher in case of Nizamabad (72%) followed by Prakasam (69.2%), Medak (69.1%) and Kadapa (67.6%). The mean agriculture income was negative in Mahabubnagar district due to severe drought in 2011-12. Districts like Anantapur, Mahabubnagar and Kurnool showed relatively lower incomes than the average pooled household income.

The contribution of livestock sector to the total household income was much significant in Prakasam district. Similarly, household earnings from business sector were also higher in Prakasam followed by Kurnool. The average non-farm labour earnings per household were relatively high in case of Mahabubnagar and Kurnool districts. The influence of drought on agriculture and average total household earnings was conspicuously high in Anantapur, Kurnool and Mahabubnagar districts.

Average household expenditures across sample districts

The detailed break-up of average household expenditures of the sample households across study districts are presented in Table 6.9. The average expenditure for pooled sample household was 2.4 thousand US $ per annum. Total food expenditure alone accounted for only 46 per cent of the total expenditure. Non-food expenditure contributed for the remaining share in the pooled sample.

The average total expenditure per household per annum was significantly higher in case of Prakasam district followed by Nizamabad and Kurnool districts. However, the lowest total expenditure was observed in case of Mahabubnagar district. The expenditure on total food was slightly lower in Mahabubnagar district. This pattern was more or less similar in other sample districts. Similarly, the expenditure on non-food items was much lower in case of Mahabubnagar than any other district. This pattern was significantly higher in case of Prakasam district followed by Nizamabad. The health expenditures per an average household were quite high in Nizamabad while investments on education were much larger in Prakasam district. The expenditure pattern on the other remaining items per household per annum was more or less same across sample households and districts. On an average, the pooled sample households spending nearly 69 per cent of their total earnings as household total expenditures. The remaining 31 per cent might be going for household savings and other investments in the households. This is a quite remarkable achievement in SAT environment.

Table 6.9 Average household consumption ('000'$ per household per annum)

Item	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Food Expenditure	**1.12**	**1.09**	**1.19**	**0.93**	**1.04**	**1.15**	**1.14**	**1.1**
Rice	0.31	0.29	0.30	0.26	0.31	0.29	0.31	0.30
Wheat	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Chickpea	0.03	0.02	0.01	0.01	0.02	0.01	0.02	0.02
Pigeon	0.05	0.05	0.06	0.04	0.05	0.05	0.04	0.05
Other Pulses	0.03	0.03	0.03	0.03	0.04	0.04	0.05	0.04
Milk	0.19	0.23	0.19	0.18	0.18	0.23	0.23	0.20
Other milk products	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.00
Non-vegetarian	0.09	0.10	0.12	0.09	0.06	0.10	0.08	0.09
Others-food expenditure	0.41	0.36	0.47	0.31	0.37	0.42	0.39	0.39
Non-food expenditure	**1.27**	**1.33**	**1.34**	**0.94**	**1.1**	**1.43**	**1.67**	**1.3**
Health	0.37	0.30	0.30	0.17	0.22	0.59	0.35	0.33
Education	0.42	0.57	0.46	0.33	0.37	0.33	0.59	0.44
Clothing	0.14	0.13	0.14	0.11	0.15	0.15	0.17	0.14
Entertainment	0.06	0.06	0.09	0.07	0.08	0.07	0.14	0.08
Ceremonies	0.03	0.02	0.09	0.02	0.03	0.04	0.16	0.06
Others	0.25	0.25	0.26	0.24	0.25	0.25	0.26	0.25
Total	**2.40**	**2.41**	**2.55**	**1.87**	**2.13**	**2.59**	**2.81**	**2.40**

Similarly, it would be interesting to understand the socio-economic characteristics of non-chickpea growers from the seven study districts of Andhra Pradesh. The average sizes of land holdings were smaller for non-chickpea growers than chickpea growers. The average annual earnings of household income and consumption expenditures were lower than chickpea sample households. The complete details of non-chickpea households are analyzed and furnished in Appendix 10.

6.3 Importance of chickpea, extent of adoption, yields and costs of production

Importance of chickpea in sample households

The relative importance of chickpea in the sample households are critically analysed and presented in the Table 6.10. Out of the total pooled area of the sample, only 24 per cent of land being utilized under rainy season crops cultivation. The remaining 76 per cent cropped are used for cultivating the post-rainy season crops. All the study districts and sample households have pre-dominant post-rainy season cropping pattern rather than rainy season crops. Wherever farmers' have some irrigation facilities or better rainfall regime, they are preferred to grow soybean, greengram, blackgram, maize, paddy and cotton crops.

Out of the total rabi season cropped area, nearly 88.2 per cent area have been allocated to chickpea crop alone. Tobacco, sorghum, sunflower and safflower occupied the remaining 11.8 per cent area under rabi season. This indicates the relative importance of chickpea in farmers' livelihood and household earnings. Chickpea as a single dominant crop has occupied nearly 67 per cent share of total cropped area in the entire sample households. The above statement itself lends clear support that 'Andhra Pradesh has achieved salient chickpea revolution' in the state during the last two decades.

Table 6.10 Importance of chickpea in sample households (ha)

Item	PRM	KUR	KAD	ANA	MED	NIZ	MAH	Total
Total cropped area	605.1	3018.9	1005.7	1083.5	176.2	200.4	192.1	6279.8
Area under kharif (rainy)	63.4	764.8	149.9	251.7	85.9	121.3	77.7	1512.1
Area under rabi (post-rainy)	541.7	2254.1	855.7	831.7	90.2	79.1	114.3	4767.6
Chickpea cropped area	444.5	1991.5	751.0	793.1	49.3	71.6	107.1	4208.4
	(100)	(100)	(100)	(100)	(100)	(100)	(100)	(100)
1.Ownland	223.4	1527.1	617.2	614.7	43.3	50.6	81.3	3157.9
	(50.3)	(76.7)	(82.8)	(77.5)	(87.7)	(70.6)	(75.9)	(75.0)
2. Leased-in land	221.1	464.3	133.8	178.3	6.0	21.0	25.7	1050.4
	(49.7)	(23.3)	(17.2)	(22.5)	(12.3)	(29.4)	(24.1)	(25.0)
% chickpea in post-rainy area	82.1	88.3	87.7	95.3	54.7	90.5	93.6	88.2
% chickpea in cropped area	73.4	66.0	74.7	73.2	28.0	35.7	55.7	67.0

Note: Figures in the parenthesis indicates percentage to total

Overall, about 75 per cent of the total chickpea cropped area came from farmers' own land holdings while the remaining 25 per cent came from land market i.e., leased-in land. Nearly one quarter of cropped area coming from other crops (non-chickpea) has been substituted by chickpea. These proportions were even much conspicuous that nearly half of the total cropped area in Prakasam district came from land market. In the remaining all districts, it is ranging from 15 to 25 per cent.

Among the study districts, chickpea has the highest dominance in the post-rainy season cropping pattern in Anantapur followed by Mahabubnagar, Nizamabad, Kurnool and Kadapa district. Relatively the lowest importance was observed in Medak district (around 55 per cent only).

First year of adoption and adoption lag

The sample farmers were asked to elucidate about the first adoption pattern of various chickpea short-duration cultivars during the household interviews. Based on their recall and feedback, the first adoption pattern of prominent short-duration chickpea cultivars were summarized in Tables from 6.11a to 6.11d respectively for Annigeri, JG 11, KAK 2 and Vihar.

These results really bring us to better understand of various patterns in adoption across cultivars and also identifying the differential adoption behaviour among the sample districts.

Table 6.11a First adoption pattern of Annigeri cultivar among sample districts (no.)

Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 1995	7	19	0	6	11	0	0	43
1996-2000	17	57	32	24	6	0	3	139
2001-2005	25	188	48	64	8	15	16	364
2006-2010	1	25	13	11	2	12	3	67
After 2010	0	0	0	0	0	0	0	0
Total*	50	289	93	105	27	27	22	613

** Differences in total and sample are non-adopters of Annigeri*

The details of first adoption pattern of Annigeri across sample households are presented in Table 6.11a. 'Annigeri' an improved landrace selection formally released during 1978 in Karnataka. Subsequently, the cultivar entered Andhra Pradesh during the early 1990s. Overall, nearly 76 per cent of the sample households first adopted Annigeri in differential periods of time. About 45 per cent of the total sample adopted between 2001 and 2005. 182 out of the 810 (nearly 23%) sample households adopted Annigeri before 2000 time period. The availability of medium duration varieties (Annigeri) initially paved the way for chickpea penetration in the study districts between early 1990s and 2000s. Kurnool, Prakasam and Medak district sample farmers are the early adopters of technology when compared to others.

Table 6.11b First adoption pattern of JG11 cultivar among sample districts (no.)

Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 2000	2	2	0	0	0	0	0	4
2001-2005	45	70	8	8	0	0	2	133
2006-2010	42	272	123	123	12	21	24	617
After 2010	2	3	4	2	1	0	0	12
Total*	91	347	135	133	13	21	26	766

** Differences in total and sample are non-adopters of JG 11*

The details of first adoption pattern of JG 11 across sample districts are summarized in Table 6.11b. The short-duration improved *desi* type cultivar JG 11 released during 1999. The initial adoption patterns have started since early 2000s. Nearly 95 per cent of total sample farmers first adopted JG 11 from late 1990s to till 2011. However, a huge chunk of sample (76 per cent) farmers got adopted between 2006 and 2010. Majority of the adopters between 2001 and 2005 belongs to either Prakasam or Kurnool districts. Development and availability of early maturing cultivars (JG 11 and KAK 2) further spur the chickpea expansion in the state. Major shares of Kurnool, Kadapa and Anantapur district sample farmers first adopted JG 11 during 2006-2010. Out of the total 810 farmers, very few (2 %) joined JG 11 adopters' group after 2010 time period.

Table 6.11c First adoption pattern of KAK 2 cultivar among sample districts (no.)

Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 2000	0	0	0	0	0	0	0	0
2001-2005	29	5	0	0	0	0	0	34
2006-2010	57	16	4	0	0	0	0	77
After 2010	1	2	0	0	0	0	0	3
Total	87	23	4	0	0	0	0	144
** Differences in total and sample are non-adopters of KAK 2*								

The details of first adoption pattern of KAK 2 across sample districts are presented in Table 6.11c. The short-duration improved *kabuli* type KAK 2 cultivar formally released during 1998. Only 18 per cent of the total sample farmers first adopted KAK 2 over the last one decade. Majority (60 per cent) of KAK 2 adopters belongs to Prakasam district followed by Kunrool (3%). Prakasam district sample farmers are the only first adopters of KAK 2 between 2001 and 2005. The peak adoption rate of KAK 2 was observed during 2006 and 2010.

The patterns of first adoption of Vihar across sample districts are summarized in Table 6.11d. 'Vihar' is an improved short-duration *kabuli* type cultivar formally released in 2002. Around 12 per cent of the total sample first adopted Vihar between 2001 and 2011. Most of the adopter farmers (57%) belong to Kurnool district followed by Kadapa and Prakasam. The peak rate of adoption was found during 2006 and 2011.

Table 6.11d First adoption pattern of Vihar cultivar among sample districts (no.)

Year	PRM (N=108)	KUR (N=351)	KAD (N=135)	ANA (N=135)	MED (N=27)	NIZ (N=27)	MAH (N=27)	Total (N=810)
Before 2000	0	0	0	0	0	0	0	0
2001-2005	4	6	3	0	0	0	0	13
2006-2010	4	34	14	0	0	0	1	53
After 2010	0	15	14	1	0	0	0	30
Total	8	55	31	1	0	0	1	96
** Differences in total and sample are non-adopters of Vihar*								

Fig 6.1 First adoption of chickpea improved cultivars in the sample (area in acres)

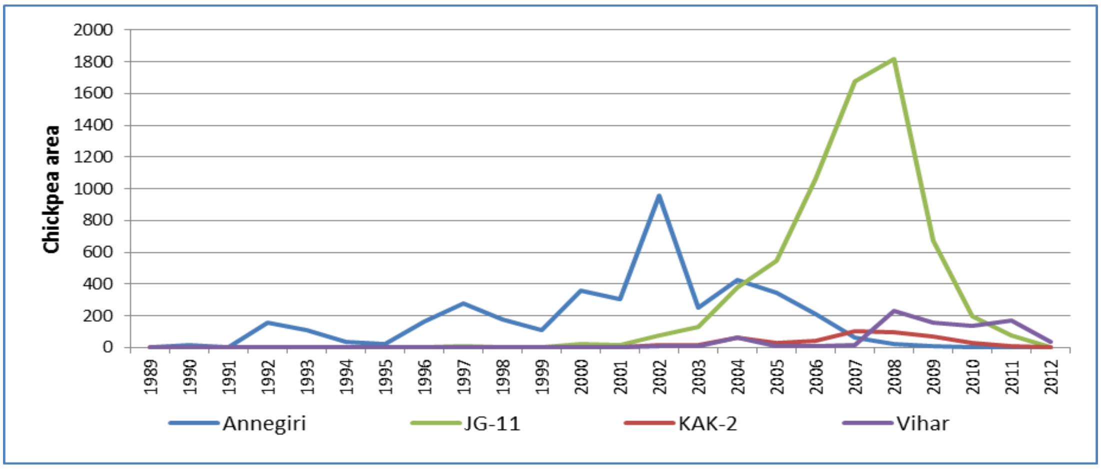
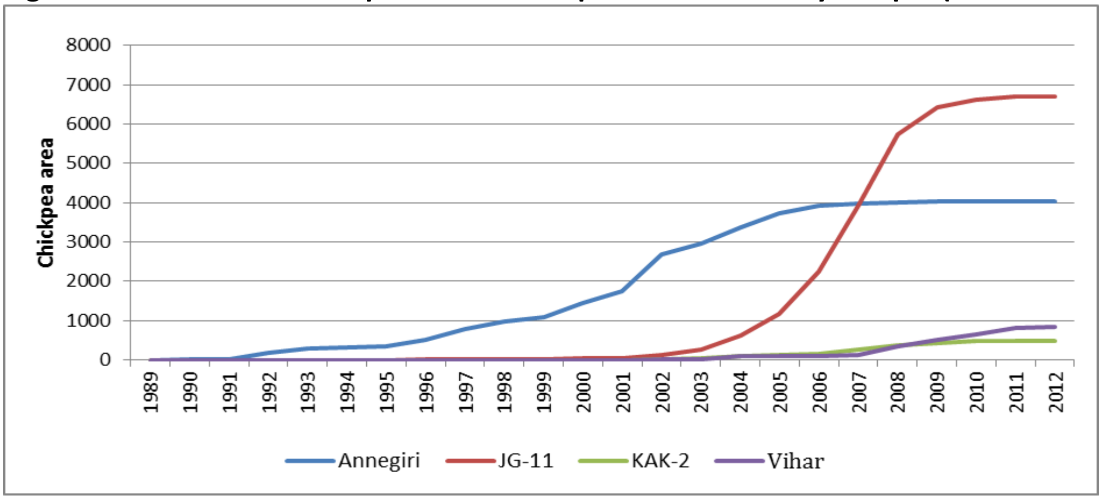


Fig 6.2 Cumulative first adoption area of improved cultivars by sample (area in acres)



The details of first adoption area of the sample farmers under each improved cultivars are illustrated in Fig 6.1. Similarly, the cumulative no. of farmers adopted over time in the sample is depicted in Fig 6.2. The adoption of Annigeri started in early 1990s and reached its peak in 2002 and after that gone down slowly. However, the adoption of JG 11 started in early 2000s and reached the peak around 2009. KAK 2 and Vihar started a little later but did not occupied much area in the sample. Fig 6.2 clearly confirms that from initial adoption to reaching its peak adoption took almost 17 years for Annigeri whereas JG 11 reached the same peak with a span of 9 years. It is remarkable achievement for JG 11 in Andhra Pradesh.

Fig 6.3 First adoption of chickpea improved cultivars in the sample (no. of farmers)

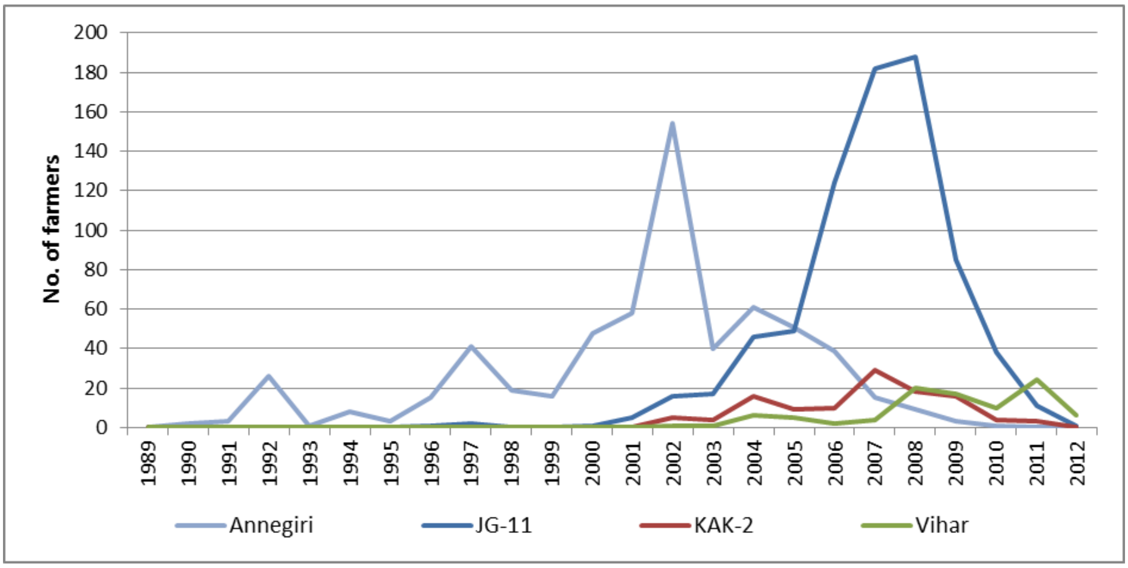
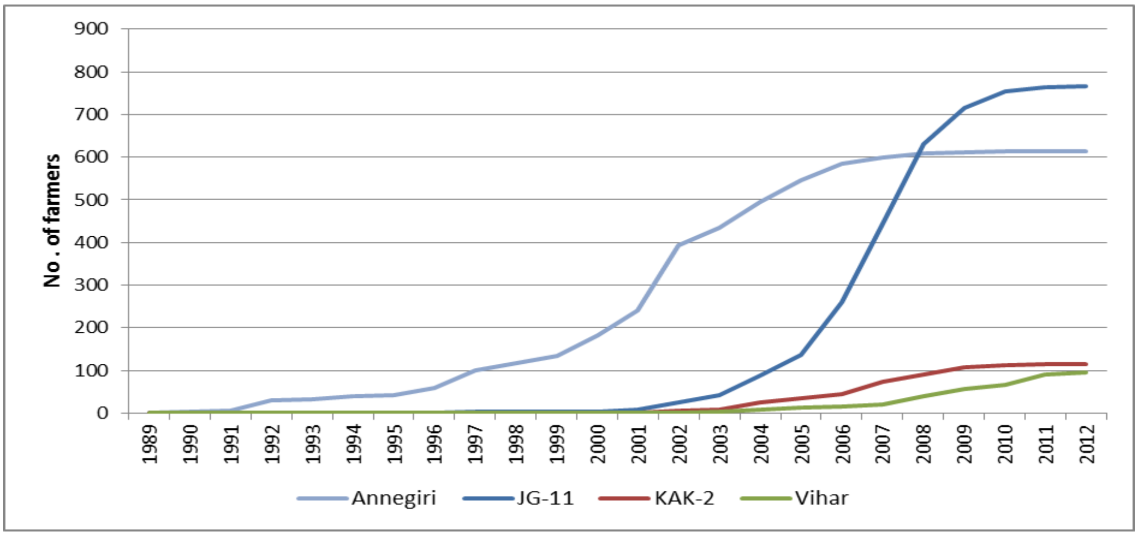


Fig 6.4 Cumulative first adoption of improved cultivars by sample farmers (no. of farmers)



Figs 6.3 & 6.4 illustrate the first adoption pattern based on no.of sample farmers adopted a particular cultivar at a specific point of time and cumulative of them over study period respectively. Over all, the trends of adoption of short-duration improved cultivars are exhibited the same as of Fig 6.1 and Fig 6.2.

Fig 6.5 presents the average time lag (from 1999 to first adoption) taken by each study district for the adoption of JG 11 improved cultivars. The average time tag was calculated based on cumulating each JG 11 adopter time lag in a district and divided by no.of JG 11 adopters in that particular district (detailed formulae furnished in Appendix 11). The lowest time lag was observed in case of Prakasam district while the longest time lag arrived for Medak district. All the other districts exhibited the ranges in between 6 to 10 years. These results clearly lend the support for differential uptake of JG 11 across districts in Andhra Pradesh.

Fig 6.5 Average time lag for adoption of JG11 in sample farmers

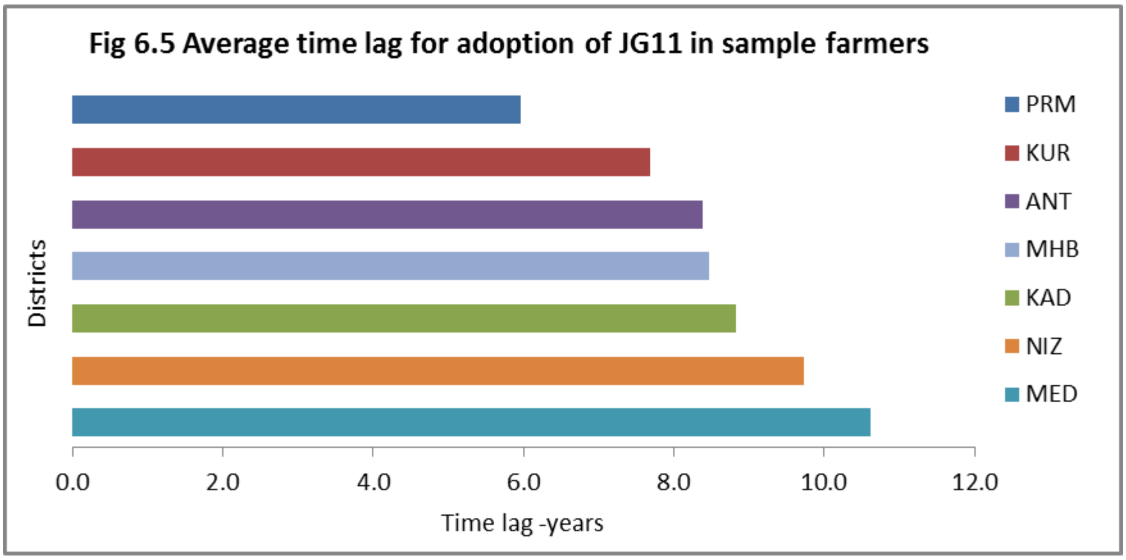


Table 6.12 First adoption sources of information and seeds (% farmers)

District	Variety – JG-11			
	Main source of information		Main source of first seed	
	FF*	GE*	VS*	LS*
PRM	72.2	17.5	49.5	27.8
KUR	82.0	12.0	66.6	17.1
KAD	94.1	3.0	94.8	0.0
ANA	81.5	14.1	81.5	1.5
MED	68.2	31.8	45.5	0.0
MAH	96.2	3.8	96.2	0.0
NIZ	91.7	4.2	70.8	0.0
Total	83.1	11.5	72.4	11.3

**FF: Fellow Farmer*
**GE: Government Extension Agency*
**VS: Villagers*
**LS: Local Seed Traders*

The details about major sources of information and major sources of first seed of JG 11 are summarized in Table 6.12. The results clearly conclude that main source of information for JG 11 was fellow farmers (83%) followed by Government extension agency (12%). Nearly 75 per cent of JG 11 first seed requirements met from villagers themselves. However, another 12 per cent of the first seed purchased from local seed traders. Nevertheless, farmers' were also dependent on some other sources of information and first seed but those were not summarized and reported in this table.

Area allocation under chickpea cultivation

Table 6.13 Allocation of chickpea area during the last three seasons (2009-12)

District	Area trend (no. of farmers)				Crops replaced by chickpea
	Increasing	Decreasing	Constant	Total	
Prakasam (N=108)	29 (26.9)	3 (2.8)	76 (70.4)	108 (100.0)	Cotton, Tobacco
Kurnool (N=351)	78 (22.2)	23 (6.6)	250 (71.2)	351 100.0)	Sunflower
Anantapur (N=135)	10 (7.4)	19 (14.1)	106 (78.5)	135 (100.0)	Groundnut
Kadapa (N=135)	28 (20.7)	3 (2.2)	104 (77.0)	135 (100.0)	Groundnut
Nizamabad (N=27)	7 (25.9)	0 (0.0)	20 (74.1)	27 (100.0)	Sorghum
Medak (N=27)	1 (3.7)	7 (25.9)	19 (70.4)	27 (100.0)	-
Mahabubnagar (N=27)	5 (18.5)	2 (7.4)	20 (74.1)	27 (100.0)	Sunflower
Total sample (N=810)	158 (19.5)	57 (7.0)	595 (73.5)	810 (100.0)	-

Note: Figures in the parenthesis are percentages to row totals

The details about area allocation to chickpea crop by sample farmers during the last three seasons are summarized in Table 6.13. During the household interview, farmers were asked to answer about area allocation pattern to chickpea during the last three consecutive years. On the whole, around 74 per cent of total farmers expressed that their area allocation to chickpea crop was constant. Another 20 per cent sample farmers indicated that they are increasing area allocation to chickpea over the time. Only negligible share of farmers (7 per cent) opined that decreasing area allocation to chickpea. These farmers' might get access to irrigation and moved away from chickpea to other commercial crops. However, more or less the same trends were observed across districts.

Diffusion and adoption of short duration improved chickpea cultivars

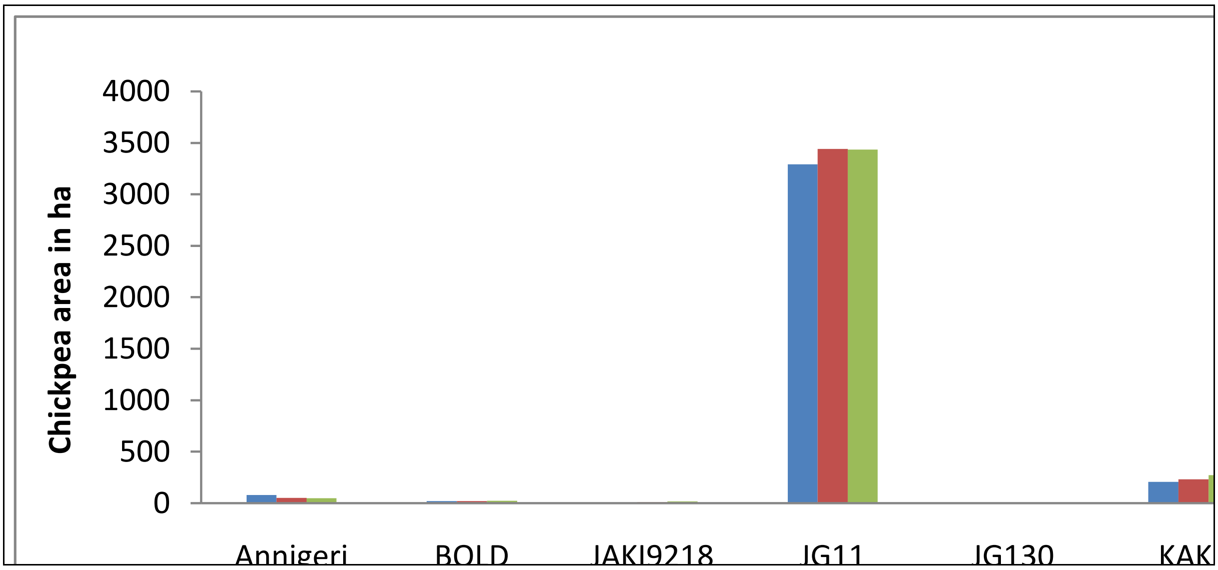
The information about cultivar specific adoption estimates for three consecutive years are summarized in Table 6.14. The area allocations by sample farmers across three cropping seasons to improved cultivars were much stable. Around 10 per cent increase in area expansion under chickpea was observed between 2009 and 2011. A huge chunk of area (85 per cent) has been allocated to only JG 11 cultivar (see also Fig 6.6). It is the single dominant improved cultivar in the state. It was followed-up by Vihar (7%) and KAK 2 (6%). The old improved cultivar 'Annigeri' has a little presence (2%) in Medak and Nizamabad districts. Other cultivars like JAKI 9218 and JG 130 has very negligible shares in the adoption. Dollar (BOLD) another informal *kabuli* type has some presence in Prakasam district. Overall, nearly 98 per cent of chickpea area in the state is under improved cultivars by 2011.

Table 6.14 Allocation of area under different chickpea cultivars, 2009-12 (ha)

Cultivar name	Area in 2009-10	Area in 2010-11	Area in 2011-12	Average (2009-12)
Annigeri	80.16 (2.0)	53.44 (1.3)	49.80 (1.2)	61.13 (1.52)
Dollar (BOLD)	21.46 (0.5)	21.86 (0.5)	25.91 (0.6)	23.08 (0.57)
JAKI 9218	7.69 (0.2)	11.74 (0.3)	18.62 (0.4)	12.67 (0.31)
JG 11	3294.33 (85.8)	3443.32 (84.9)	3436.84 (81.9)	3391.50 (84.19)
JG 130	0 (0.0)	4.86 (0.1)	4.86 (0.1)	3.24 (0.08)
KAK2	209.31 (5.4)	231.98 (5.7)	274.90 (6.6)	238.70 (5.92)
Vihar (Phule-G)	224.29 (5.8)	285.83 (7.0)	383.40 (9.1)	297.85 (7.39)
Grand Total	3837.25 (100.0)	4052.63 (100.0)	4194.74 (100.0)	4028.18 (100.0)

Note: Figures in the parenthesis are percentages to column total

Fig 6.6 Area allocation of chickpea area under different cultivars, 2009-12



Comparison of survey results and elicitation process

It is clear from Table 6.15 that desi JG11 has reached very high adoption rates in the south western districts of Kurnool, Anantapur, Kadapa and Mahabubnagar while kabuli KAK-2 is already covering 58% of Prakasam in the coastal belt of Andhra Pradesh. A wide variation in adoption pattern is revealed as diffusion to the northern districts is seen to be just starting. For example, the traditional Annigeri variety is still grown in about 40% of the chickpea cropped area in Nizamabad and Medak. Vihar is another dominant kabuli type grown mostly in Kadapa and Kurnool districts of Andhra Pradesh.

Table 6.15 District-wise chickpea area under different cultivars *(% area), 2011-2012*

District	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Desi types								
Annigeri	0	0	0.1	0	38.1	40.7	0	1.2
JAKI 9218	1.9	0.4	0	0	0	0	0	0.4
JG 11	97.5	79.4	87.7	100	61.9	59.3	33.9	81.9
JG 130	0.6	0	0	0	0	0	0	0.1
Kabuli types								
KAK 2	0	0.8	0.6	0	0	0	58	6.6
Vihar	0	19.4	11.6	0	0	0	2.2	9.1
Dollar (BOLD)	0	0	0	0	0	0	5.9	0.6
Total	100	100	100	100	100	100	100	100
Source: Primary household survey in Andhra Pradesh conducted in 2013, with reference to 2011-12 cropping season.								

Contrast the estimates (Table 6.16) drawn from the sample with the expert opinion elicited the year before through the TRIVSA Project (2011) covering all ICRISAT mandate crops for all relevant states in India. A comparative analysis can be drawn using the data in Table 6.15 as benchmark, i.e. comparing the implications of the elicited data from expert stakeholders to the findings from the primary farm survey data. Indirectly, this measures the additional value of the survey generating refined disaggregated data.

Table 6.16 Expert elicitations on adoption of improved cultivars in AP

Cultivar	Release year	% area in AP
JG-11	1999	70
KAK-2	1999	20
Annigeri	1978	3
Extra bold kabuli types (Dollar, Bhema etc.)	-	2
All MVs		**95**
Source: ICRISAT TRIVSA Project elicitations, 2011		

It seems that the panel of experts (comprising primarily of breeders and scientists) were relatively conservative in their estimates of the coverage of JG11 (see Table 6.16). The elicitation process revealed the experts rough estimate of 70% adoption specifically of JG 11 variety versus 82% JG 11 adoption level estimated from the survey data. On the other hand, the expert elicitation tended to overestimate the adoption level of KAK 2 (i.e. 20% adoption estimated during the expert elicitations versus only 7% estimated from the survey data).

The details about pattern of adoption by no. of sample farmers by district-wise are presented in Table 6.17. Nearly 78 per cent of the total sample farmers adopted JG 11 in their farms. It was followed by KAK 2 (9.4%) and Vihar (8%). Some of the sample farmers in Prakasam, Kurnool and Kadapa districts are growing more than one improved cultivars of chickpea on their farms. So it led to double counting the same farmers under those varieties (gone up to 908 from 810). Around 3 per cent of sample farmers still growing 'Annigeri' in the pockets of Medak and Nizamabad districts. Overall, 96 per cent of the total sample farmers allocated their chickpea area to improved cultivars.

Table 6.17 District-wise adoption pattern of improved cultivars *(no.of farmers)*

Variety	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Annigeri	0	0	2 (2)	0	15 (15)	12 (17)	0	27 (34)
JG11	131 (228)	123 (231)	331 (594)	27 (43)	14 (15)	18 (35)	60 (89)	704 (1235)
KAK2	0	1 (2)	5 (6)	0	0	0	79 (128)	85 (136)
Vihar	0	25 (47)	47 (81)	0	0	0	2 (2)	74 (130)
JAKI9218	3 (6)	1 (1)	0	0	0	0	0	4 (7)
JG130	2 (5)	0	0	0	0	0	0	2 (5)
Dollar	0	0	0	0	0	0	12 (14)	12 (14)
Total	136* (239)	150* (281)	385* (683)	27 (43)	29* (30)	30* (52)	153* (233)	908* (1561)

Note: Figures in the parenthesis indicates no. of plots
** Farmers growing more than one variety*

Table 6.18 Major sources of improved cultivars seeds during 2011-12

District	JG11	Major Source code	KAK2	Major Source code	Vihar	Major Source code
Prakasam	JG 11	5, 10	KAK 2	5	Vihar	5
Kurnool	JG 11	5, 10	KAK 2	5	Vihar	5
Anantapur	JG 11	5, 10	-	-	-	-
Kadapa	JG 11	5, 10	-	-		5
Nizamabad	JG 11	5, 10	-	-	-	-
Medak	JG 11	5, 10	-	-	-	-
Mahabubnagar	JG 11	5, 10	-	-	-	-
Code 5: Bought from villagers			*Code 10: Subsidized government seed scheme*			

Table 6.18 briefs about major sources of seeds for improved cultivars during 2011-12. Overall, two major forces are working for rapid spread of the improved seeds in Andhra Pradesh. They are a. Government seed subsidy program b. Buying seeds from villagers/neighbours. Government of Andhra Pradesh with the help of Andhra Pradesh State Seeds Development Corporation (APSSDC) multiplied huge quantities of JG 11 seed and providing on subsidy to encourage adoption in the state. Only public sector organizations like National Seeds Corporation (NSC), ANGRAU (Acharya N G Ranga Agricultural University) and SFCI (State Farm Corporation of India Ltd) are involved in multiplication, production and marketing in the state. None of the private seed companies are involved in seed production and multiplication. However, seed purchasing from villagers or neighbouring farmers is the most common practice (around 88 per cent) in case of chickpea. Few farmers (10%) are only using the subsidized seed for plantation purpose. Since chickpea is a self-pollinated crop, the seeds can be rotated safely up to three years. Strong policy encouragement coupled with highly innovative nature of the farmers has helped Andhra Pradesh in achieving this salient revolution in chickpea.

Adoption pathways of short-duration improved cultivars across districts

The adoption pathways of short-duration improved cultivars across sample districts are illustrated in Figs from 6.7 to 6.13. The cumulative number of adopters has been visualized by cultivar and time period across different study districts. Prakasam and Kurnool districts are the fore-runners for short-duration technology adoption in the state. Kadapa and Anantapur joined the adopters group a little later. Mahabubnagar closely followed Kurnool district along with Anantapur. Nizamabad and Medak districts are the laggards in adoption of these cultivars. The district-wise differential adoption patterns can be clearly envisaged by moving from Figs 6.7 to 6.13.

Fig 6.7 Adoption pathway in Prakasam district sample farmers (Cumulative no.)

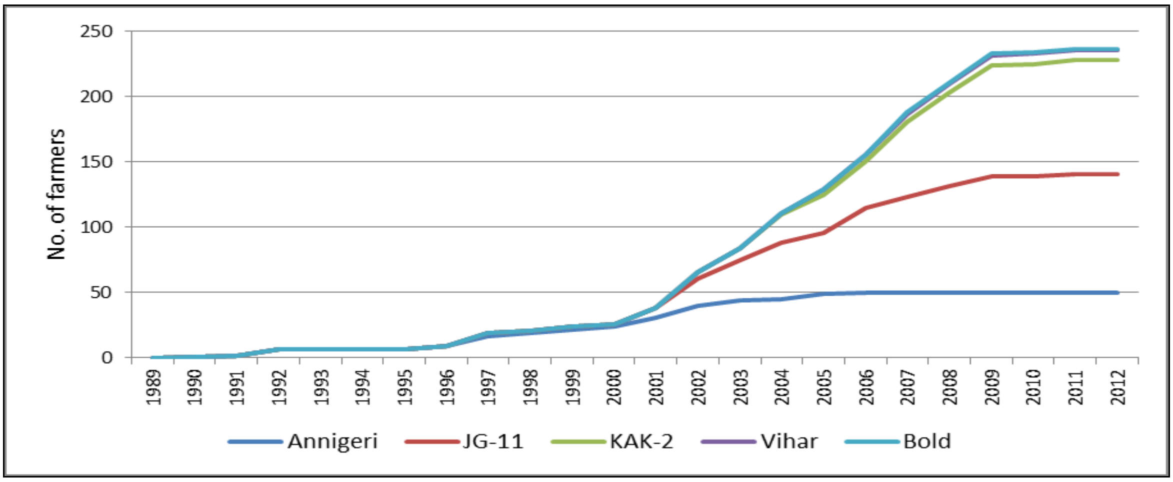


Fig 6.8 Diffusion pathway of Kurnool district sample farmers (Cumulative no.)

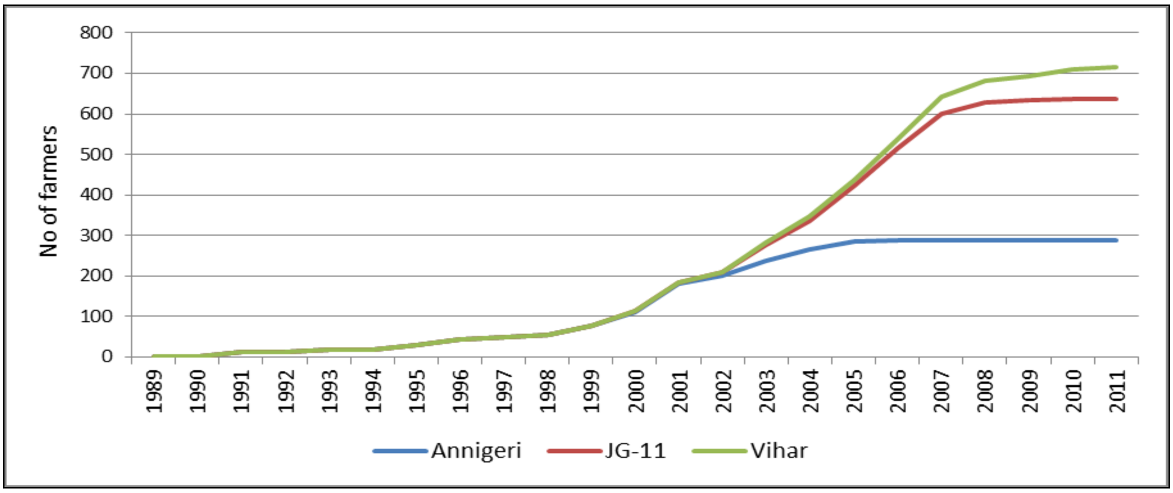


Fig 6.9 Adoption pathway of Anantapur district sample farmers (Cumulative no.)

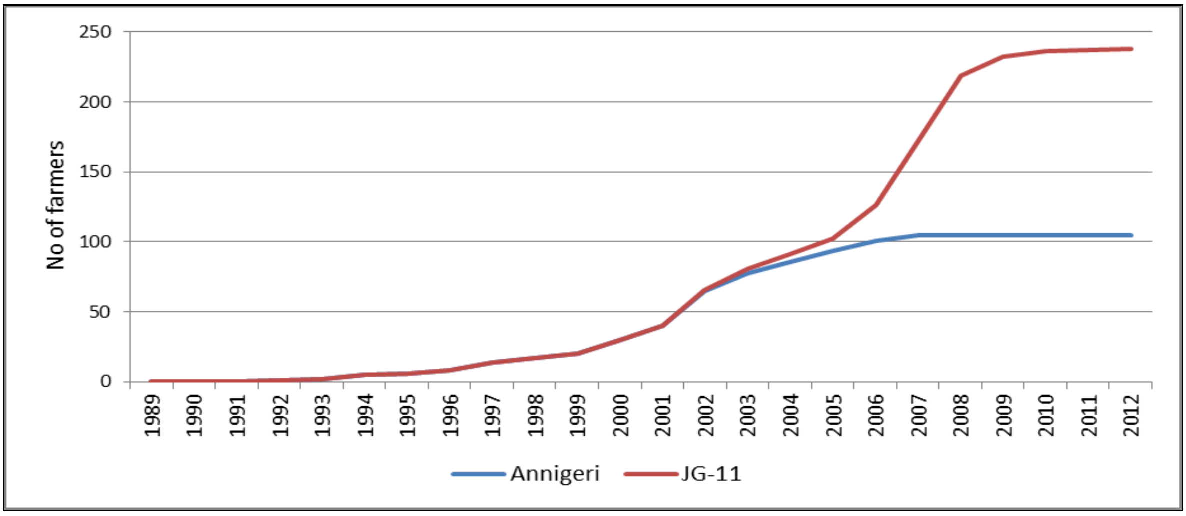


Fig 6.10 Adoption pathway of Kadapa district sample farmers (Cumulative no.)

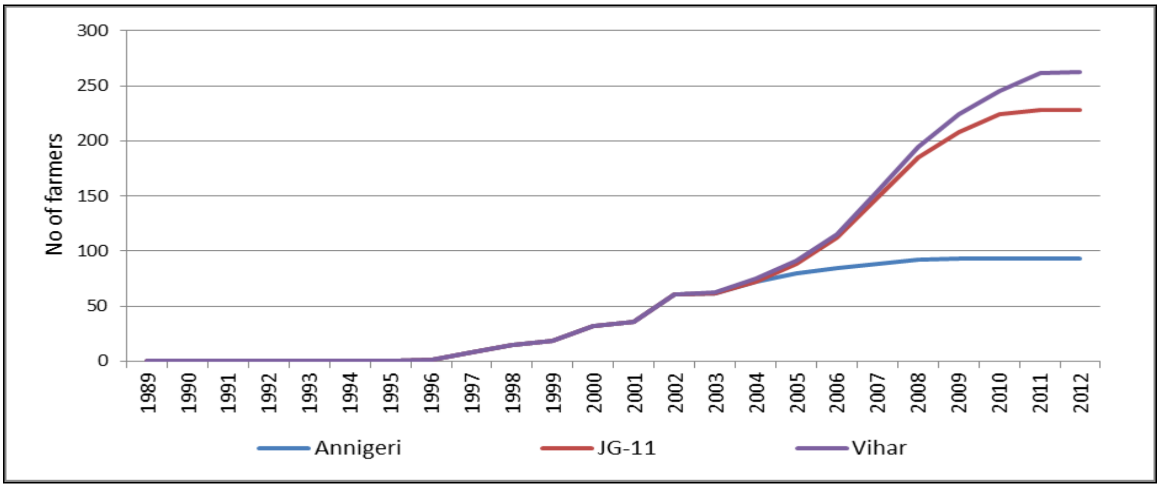


Fig 6.11 Adoption pathway of Medak district sample farmers (Cumulative no.)

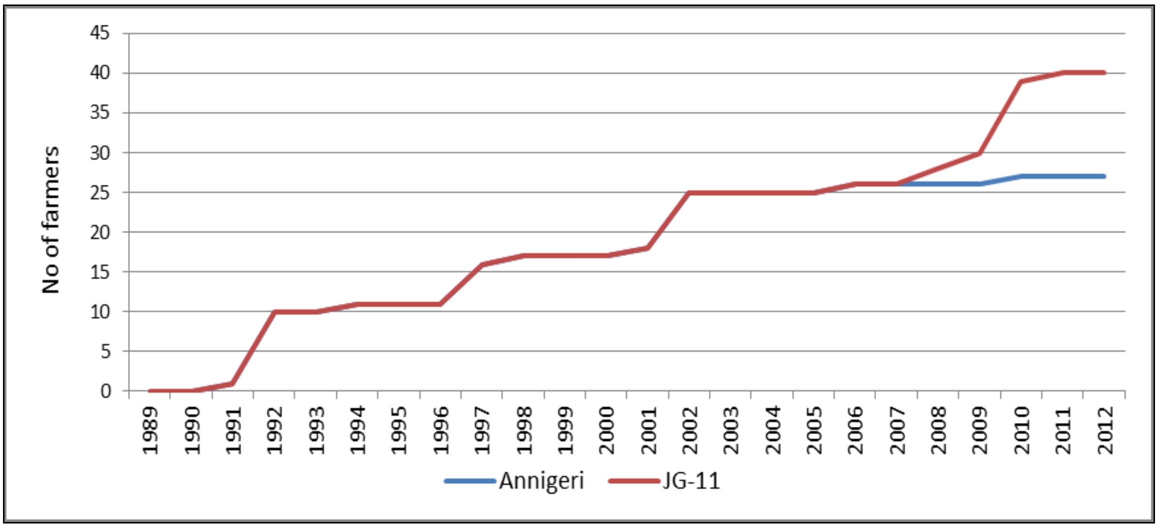


Fig 6.12 Adoption pathway of Mahabubnagar district sample farmers (Cumulative no.)

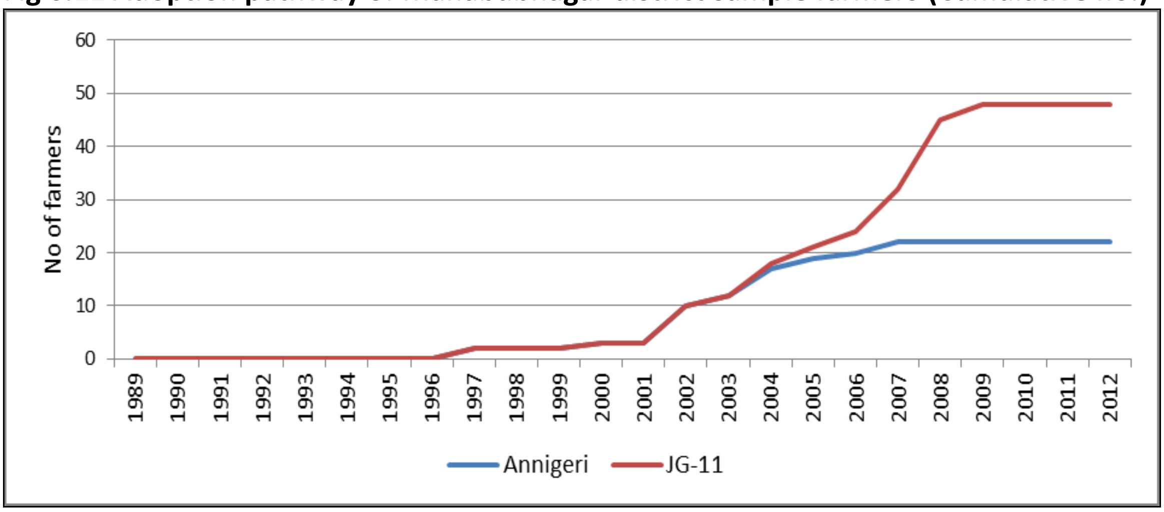
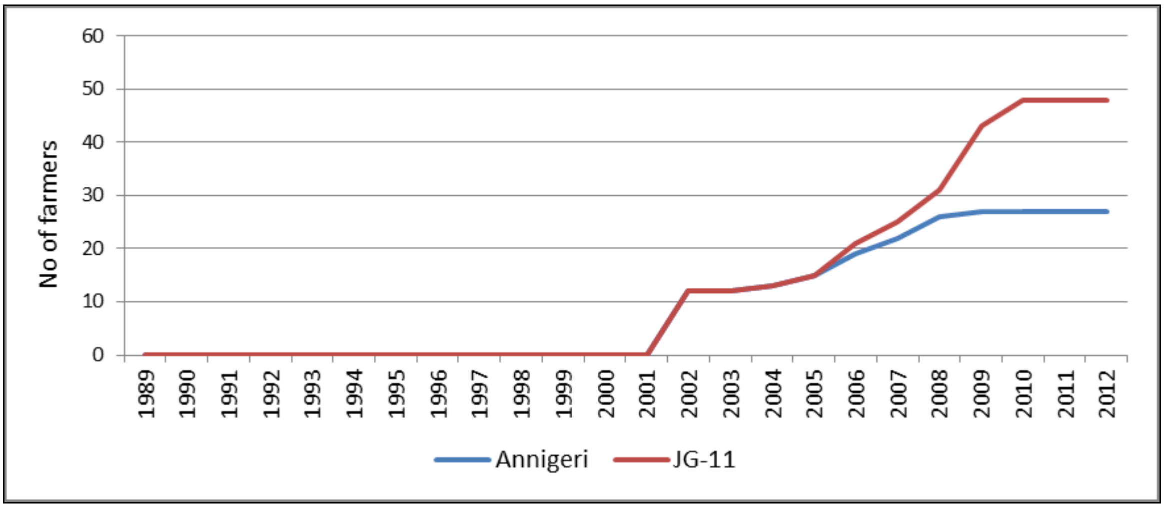


Fig 6.13 Adoption pathway of Nizamabad district sample farmers (Cumulative no.)



Further, the variety-wise initial adoption of sample farmers over the period and their respective area allocation by district-wise are furnished in Appendix 12.

Average productivity levels of chickpea in study districts

The average productivity levels of chickpea in study districts elicited from primary household surveys are presented in Table 6.19. The data clearly visualizes the geographical differences in chickpea yields based on cultivar type and perceptions of sample farmers. Under normal conditions, Annigeri used to produce an average yield of 1062 kg per ha. But, the new improved chickpea cultivar generates a mean yield of 1583 kg per ha. Nearly 40-50 per cent yield advantage have been noticed when switch over from Annigeri to JG 11. However, the highest yield increase was observed in case of Kadapa district followed by Anantapur and Kurnool. The lowest yield benefit was noticed in case of Nizamabad followed by Medak districts. Low yield differences may be the reason for low adoption of JG 11 in these two districts. The extent of yield deviations due to climatic aberrations was much similar in case of both Annigeri and JG 11. The *kabuli* type KAK 2 was most preferred only in Prakasam while another *kabuli* type Vihar was much adopted in Kurnool and Kadapa districts. Overall, the performance of KAK 2 was better than Vihar in Andhra Pradesh. In general, the highest productivity levels across cultivars were observed in case of Prakasam district.

Table 6.19 Average chickpea yields under different climatic situations (kg per ha)

District	Annigeri			JG11			KAK2			Vihar		
	Normal	Bad	Best	Normal	Bad	Best	Normal	Bad	Best	Normal	Bad	Best
PRM	1480	1097	1855	2114	1556	2623	1919	1408	2369	-	-	-
KUR	1074	593	1492	1606	632	2127	-	-	-	1591	1032	2045
ANA	798	324	1099	1203	368	1692	-	-	-	-	-	-
KAD	837	371	1198	1450	776	1907	-	-	-	1554	687	1988
NIZ	1680	1013	2060	1865	1233	2048	-	-	-	-	-	-
MED	1324	776	1739	1598	1107	2100	-	-	-	-	-	-
MAH	1099	454	2211	1568	393	2082	-	-	-	-	-	-
Overall	1062	566	1435	1583	729	2139	1773	1284	2428	1541	941	1969

6.4 Comparison of improved cultivar yields from on-station trial data

Table 6.20 Performance of improved cultivars in Initial Varietal Trial (desi, Rabi: 2008-09)

Entry	Days to 50% Flowering	Days to Maturity	Initial Plant Population/ Plot	Final Plant Population/Plot	Plant Height	Number of Pods per plant	Pod borer	Yield/ Plot	100 Seed Weight (g)	Seed yield (kg/ ha)
NBEG-84	50	102	18	15	45.1	47.8	0.30	319.7	25.5	2880
NBEG-89	48	97	26	23	40.1	44.7	1.20	241.3	24.3	2174
NBEG-90	48	92	26	23	39.7	35.1	1.00	224.0	25.3	2018
JG-11 (C)	47	97	30	28	37.8	48.7	0.40	220.3	24.3	1985
NBEG-86	49	102	22	19	42.4	38.6	0.20	201.7	24.8	1817
NBEG-85	47	92	21	19	33.9	38.5	1.20	199.3	25.3	1796
NBEG-82	48	100	17	15	39.5	50.8	0.20	193.0	25.5	1739
NBEG-81	47	99	18	16	38.0	37.3	0.90	178.3	25.2	1606
NBEG-87	48	95	22	20	37.6	40.8	0.40	166.3	24.2	1498
Annigeri ©	50	103	16	13	44.9	45.0	1.40	162.2	21.5	1461
NBEG-91	43	91	18	15	39.7	28.5	0.10	144.5	26.5	1302
NBEG-94	41	92	20	19	39.1	32.6	0.30	126.7	26.2	1141
NBEG-95	43	98	16	14	42.4	38.3	0.80	113.6	25.5	1023
Grand Mean	46	97	20	18	40.0	40.5	0.64	191.62	24.9	1862
SEm±	0.138	1.214	3.328	3.50	2.544	5.714		36.78	0.417	165.5
CD at P≤ 0.05	0.300	2.65	NS	NS	NS	NS		80.14	0.908	360.6
CV %	0.42	1.77	22.50	26.58	8.99	19.95		27.15	2.37	27.15
Date of sowing: 27-10-2008 at Nandyal Research Station, ANGARU Source: Personal communication from Dr V Jayalakshmi										

The performance of chickpea improved cultivars under various on-station trials are summarized in Tables from 6.20 and 6.24. The data clearly visualize the yield potential of JG 11 when compared the old variety 'Annigeri' at Nandyal Research Station located in Kurnool district of Andhra Pradesh. In case of Initial Varietal Trial (IVT) conducted during 2008-09 among desi type exhibits nearly 36 per cent increase in yield per ha between JG 11 and Annigeri cultivars. These findings were confirmed in the subsequent International Chickpea Screening Nurseries (ICSN) conducted at Nandyal (see Tables 6.21, 6.23 and 6.24).

Table 6.21 Performance of improved cultivars in International Chickpea Screening Nurseries (*desi, Rabi: 2008-09*)

S.No.	Entry	Days to 50% Flowering	Days to Maturity	Initial Plant Population/Plot	Final Plant Population/ Plot	Number of Pods per plant	Pod borer	Yield/ Plot	100 Seed Weight (g)	Seed yield (kg/ ha)	Seed yield (kg/ ha) Adjusted
1.	ICCV-07117	44	89	48	39	40.2	0.0	561.5	28.0	2529	2509
2.	ICCV-08101	46	92	43	41	52.3	0.0	535.3	23.1	2411	2362
3.	ICCV-08108	50	93	42	36	57.4	0.1	477.2	22.1	2149	2187
4.	JG-11 ©	45	91	42	39	53.5	0.0	490.0	25.5	2207	2187
5.	ICCV-08104	44	91	44	41	56.0	0.3	492.5	32.0	2218	2159
6.	ICCV-07103	47	93	51	47	47.0	0.8	510.0	21.3	2297	2121
7.	ICCV-08102	48	95	42	38	68.3	0.0	468.0	24.6	2108	2107
8.	ICCV-07104	45	89	50	48	56.5	0.2	497.5	21.7	2240	2055
9.	ICCV-07116	46	92	43	37	44.2	0.0	435.5	25.5	1961	1980
10.	ICCV-07112	48	94	35	33	56.5	1.4	414.8	20.5	1808	1965
11.	ICCV-08103	48	90	34	30	58.2	0.6	397.5	36.0	1790	1943
12.	ICCV-08105	46	91	40	38	34.2	0.7	426.0	33.3	1918	1917
13.	ICCV-08111	47	90	41	38	34.6	0.0	423.0	35.0	1905	1914
14.	ICCV-08106	46	90	40	33	37.0	0.0	401.0	36.0	1806	1903
15.	ICCV-07113	47	91	44	41	37.3	0.3	425.5	23.3	1916	1867
16.	ICCV-08110	46	91	35	33	27.0	0.6	389.5	32.2	1754	1860
17.	ICCV-08107	46	93	46	44	37.7	0.0	433.6	27.3	1953	1845
18.	ICCV-07111	47	93	36	32	42.1	1.0	371.0	22.5	1671	1787
19.	ICCV-07116	48	90	43	39	37.5	0.0	366.5	28.3	1650	1630
20.	Annigeri ©	50	91	38	35	59.1	1.1	316.2	35.0	1424	1482
	Grand Mean	46	91	42	38	46.8	0.35	441.6	27.6	1987	1987
	SEm±	0.802	0.977	4.62	4.748	2.310		27.95	0.698	125.8	101.2
	CD at P≤ 0.05	1.67	2.04	**NS**	9.93	**NS**		58.49	1.46	263.2	211.81
	CV %	2.42	1.51	15.54	17.47	6.98		8.95	3.57	8.95	6.25

Date of sowing: 27-10-2008 at Nandyal Research Station, ANGARU
Source: Personal communication from Dr V Jayalakshmi

Table 6.22 Advanced chickpea yield Trial- II (*Desi*, Rabi 2009-10)

S.No.	Entry	Days to 50% Flowering	Days to Maturity	Initial Plant Population/Plot	Final Plant Population/Plot	Number of Pods per plant	Pod borer (Incidence %)	100 Seed Weight (g)	Seed yield (kg/ ha)
1	NBeG-49	49	82	56	55	30.6	10.22	30.5	2033
2	NBeG-165	45	84	67	63	26.6	8.49	30.0	1975
3	NBeG-43	48	84	64	60	27.0	2.96	24.8	1918
4	JG-11©	46	84	55	51	34.1	2.34	24.6	1874
5	NBeG-63	45	89	44	49	23.2	8.62	37.4	1760
6	NBeG-50	50	83	63	51	28.2	5.88	30.4	1740
7	NBeG-47	45	82	58	60	22.2	2.38	36.6	1639
8	Annigeri	44	84	52	53	36.9	2.33	14.2	1621
9	NBeG-52	53	90	62	58	22.8	4.64	33.4	1601
10	NBeG-60	50	85	64	61	17.8	11.90	31.1	1593
11	NBeG-62	49	84	57	52	25.8	8.75	35.8	1586
12	NBeG-57	51	89	45	43	25.7	13.70	33.4	1582
13	NBeG-51	52	83	59	52	30.0	4.86	32.5	1562
14	NBeG-53	52	83	63	59	24.2	4.66	30.1	1312
Grand Mean		48	85	58	55	26.8	6.45	30.3	1700
SEm±		0.882	1.265	4.920	4.724	3.488		0.904	108.2
CD at P≤ 0.05		2.56	3.70	NS	NS	NS		2.04	316
CV %		3.14	2.58	14.66	14.85	22.51		5.16	11.08

Date of sowing: 10-10-2009 at Nandyal Research Station, Kurnool.
Source: Personal communication from Dr V Jayalakshmi

Table 6.23 Advanced chickpea yield Trial- I (*Desi*, Rabi 2010-11)

S.No	Entry	DF	DM	I PP/ Plot	F PP/ Plot	PH	NP	PB (Incidence)	100SW	NPY	Seed Yield (kg/ha)
1	JG-11	52	90	65	62	30.5	27.7	1.7	24.5	311.4	1366.0
2	NBeG-389	51	91	62	62	30.0	30.6	3.3	22.7	306.8	1345.6
3	NBeG-390	59	103	69	66	33.1	20.4	3.7	27.4	305.1	1338.3
4	NBeG-146	53	96	68	66	30.4	25.3	4.0	27.7	298.4	1308.6
5	NBeG-147	54	97	67	65	31.1	23.3	2.5	26.4	294.5	1291.7
6	NBeG-394	54	96	70	66	31.9	29.3	3.7	30.9	293.2	1286.0
7	NBeG-393	53	95	64	60	39.3	21.3	3.2	27.0	287.6	1261.3
8	NBeG-155	52	91	68	62	32.4	24.7	1.9	29.4	284.8	1249.0
9	NBeG-156	53	95	61	54	31.9	23.9	1.3	28.7	275.2	1207.2
10	NBeG-396	54	94	62	56	29.6	22.3	2.3	29.7	272.5	1195.3
11	NBeG-397	52	91	74	69	27.3	23.5	1.3	22.4	272.3	1194.2
12	NBeG-395	53	95	73	71	31.5	24.3	2.8	27.4	269.0	1179.9
13	NBeG-388	53	96	66	63	30.0	21.4	2.5	24.5	261.1	1145.0
14	NBeG-391	60	103	71	62	32.3	20.1	3.5	26.7	245.7	1077.8
15	Annigeri	54	93	53	50	34.3	33.8	2.8	16.0	233.6	1024.4
16	NBeG-392	50	93	54	50	42.3	32.4	1.7	20.2	226.5	993.6
Grand Mean		53.6	94.92	65	61	32.4	25.28		26	277.4	1216.5
CV %		2.94	2.37	11.10	11.53	6.45	22.24		6.81	18.71	82.1
SEm±		0.91	1.30	4.20	4.09	1.21	3.25		1.01	29.96	131.4
CD at P≤ 0.05		2.63	3.75	12.12	11.81	3.48	NS		2.92	NS	0.0

Date of sowing: 27-10-2010 at Nandyal Research Station, Kurnool.
Source: Personal communication from Dr V Jayalakshmi

Table 6.24 Advanced chickpea yield Trial-II (Desi, Rabi-2011-12)

S. No	Entry	DF	DM	I PP/ Plot	F PP/ Plot	PH/ Plant (cm)	NP/ Plant	100 SW (g)	NPY/ Plot (g)	Seed Yield (kg/ha)
1	JG-11	44	96	72	74	31.6	32.6	23.0	425.3	1865
2	NBeG-389	42	91	78	72	33.5	32.8	24.4	414.0	1816
3	NBeG-396	43	93	73	65	36.9	31.1	32.0	397.0	1741
4	NBeG-147	52	92	72	70	34.9	29.9	29.5	387.0	1697
5	NBeG-394	53	92	67	66	37.4	27.1	30.4	387.0	1697
6	NBeG-146	53	94	72	72	35.2	31.3	30.1	382.3	1677
7	NBeG-393	49	94	75	69	40.0	19.1	24.9	350.6	1538
8	NBeG-155	45	94	72	65	34.2	25.0	29.6	346.3	1519
9	NBeG-388	42	94	77	68	37.0	36.3	26.6	342.0	1500
10	NBeG-397	42	92	71	67	30.4	26.4	24.7	342.1	1500
11	Annigeri	42	92	77	73	37.7	50.4	15.3	339.0	1487
12	NBeG-395	50	92	75	66	34.9	28.4	28.0	326.0	1430
13	NBeG-156	45	94	78	71	36.0	26.5	29.5	325.3	1427
14	NBeG-392	40	87	78	77	43.8	26.2	20.5	308.4	1353
15	NBeG-390	62	98	74	72	37.2	26.3	29.3	263.6	1156
16	NBeG-391	62	98	75	69	37.3	22.9	29.5	208.5	914
Grand Mean		48	94	75	70	36.1	29.5	26.7	346.5	1520
SEm±		1.04	0.814	2.27	3.31	1.72	4.28	0.578	16.90	74
CD at P≤ 0.05		2.12	1.66	NS	NS	3.51	8.73	1.18	34.5	151.1
CV %		3.75	1.51	5.28	8.20	8.27	25.14	3.75	8.45	8.45

Note: Trial conducted at Nandyal Research Station, Kurnool.
Source: Personal communication from Dr V Jayalakshmi

Table 6.25 Impact of drought on chickpea yields during post-rainy season, 2011-12 (kg/ha)

District	JG11			KAK2			Vihar		
	NY	AY	% C	NY	AY	% C	NY	AY	% C
Prakasam	2114	2339	11	1919	2038	6	-	-	-
Kurnool	1606	842*	-48	-	-	-	1591	1391	-13
Anantapur	1203	610*	-49	-	-	-	-	-	-
Kadapa	1450	1381	-5	-	-	-	1554	1969	27
Nizamabad	1865	1645	-12	-	-	-	-	-	-
Medak	1598	1746	9	-	-	-	-	-	-
Mahabubnagar	1568	165*	-89	-	-	-	-	-	-
Mean	1630	1778	9	1919	2038	6	1573	1680	7

NY: Mean normal yield based on farmer perception (kgs per ha)
AY: Mean actual yields realized during survey period, 2011-12 (kgs per ha)
*% Change : Percentage change over normal yield; * severely drought affected*

Table 6.25 clearly envisage the extent of damage of drought on chickpea yields during the survey period 2011-12. Even though chickpea is a short-duration crop (90 days), the terminal moisture (reproductive stage) stress could impact 40-50 per cent yield reductions than the normal average yields. Districts like Prakasam and Medak did not experience any drought effect during the post-rainy cropping season. Kurnool, Anantapur and Mahabubnagar severely damaged due to the drought and the extent of yield losses more significant. More pronounced yield losses (90%) were noticed in case of Mahabubnagar followed by Anantapur (49%) and Kurnool (48%) districts. A little influence of climate aberrations was observed in case of Kadapa and Nizamabad where the losses were ranging from 5-10 per cent. The extent of damage on Vihar cultivar in Kurnool district was low because of allocation of better soils and supplemental irrigation facilities. In general, farmers' do better resource allocation (better land, more fertilizer and supplemental irrigation etc.) to *kabuli* types than the *desi* types. The detailed yield variability analysis across study districts are also summarized in Appendix 13.

Cultivar-wise costs and returns of chickpea

Similarly, the detailed break-up of costs of cultivation of chickpea by variety wise is presented in Appendix 14. The district-wise and cultivar-wise costs and returns per ha were analyzed and compared. However, the summary of that information is presented in Table 6.26. Districts like Mahabubnagar, Anantapur and Kurnool severely drought effected during 2011-12 cropping year. Among the other districts, the net margins per ha was much in Prakasam district. The performance Vihar was good in case of Kadapa than Kurnool district. KAK 2 was only grown in Prakasam and derived good net benefits. As discussed earlier, the category-wise costs and returns from chickpea cultivation are analysed and presented in Appendix 15.

Table 6.26 Cultivar-wise costs and returns across sample districts# (US $ per ha)

District name	**JG 11**		**KAK 2**		**Vihar**	
	COC/ha	GR/ha	COC/ha	GR/ha	COC/ha	GR/ha
Prakasam	1206.2	1713.5	1306.9	1733.5	-	-
Kurnool*	798.1	634.3	-	-	1052	1118.1
Anantapur*	639.0	430.6	-	-	-	-
Kadapa	795.7	1026.4	-	-	865.6	1668
Mahabubnagar*	785.1	102.4	-	-	-	-
Nizamabad	919.9	911.5	-	-	-	-
Medak	814.3	988.6	-	-	-	-

** drought affected during 2011-12; COC: Costs of cultivation; GR: Gross Returns; # Based on primary household survey analysis*

Competitiveness of chickpea with other crops

Table 6.27 Competitiveness of chickpea across crops and districts# ($ per ha)

District	Crop	Net returns over TC	Net returns over VC
Prakasam	Chickpea	458.7	1014.4
	Maize	-427.2	111.7
	Tobacco	397.5	919.6
Kurnool	Chickpea (N)	345.3	693.2
	Sorghum (N)	326.3	693.6
	Sunflower (N)	-21.6	286.0
	Coriander (N)	71.8	171.8
Anantapur	Chickpea (N)	235.8	462.3
	Sorghum (N)	-13.0	180.7
	Sunflower (N)	-291.9	-202.1
Kadapa	Chickpea	331.9	616.9
	Blackgram	105.3	369.1
	Sorghum	-69.8	262.5
	Sunflower	-198.5	35.0
Mahabubnagar	Chickpea (N)	272.8	605.1
	Maize (N)	48.0	317.5
Medak	Chickpea	106.0	525.1
	Cotton	143.0	547.2
Nizamabad	Chickpea	80.3	471.6
	Sorghum	-102.0	223.6

'N' indicates returns at normal year # Based on primary household survey analysis

The competitiveness/substitutability of chickpea is also assessed in the sample districts and summarized in Appendix 16. However, the summary of the information is presented in Table 6.27. Due to impact of drought in few sample districts in 2011-12 cropping year, the chickpea net returns were calculated using 'normalized yield levels' in those districts for comparison with other competing crops. The data clearly demonstrate competitive edge of chickpea in study district over other post-rainy season crops. Farmers' in the sample districts preferred chickpea because of higher returns per ha, less risk and highly suitable mechanization etc.

6.5 Estimation of unit cost reduction from focus-group meetings

Due to peak adoption (nearly 98%) of chickpea short-duration improved cultivars in Andhra Pradesh, the primary survey could not able to capture enough 'Annigeri' growers in the study sample. The presence of 'Annigeri' was observed in selected traces of Medak and Nizamabad districts. Some of the chickpea growers in Medak combine their chickpea crop with Safflower at 9:1 ratio. Some of the chickpea households' costs and returns were not collected in the survey because of randomization of processes. Only one-third of the total samples were subjected to costs and returns information collection by plot-wise. Finally with a given probability, few plots information was only available on 'Annigeri'. This situation made us the research team to re-visit some of these sample villages and generates the estimates through focus-group meetings. For generating appropriate counter-factual at the same site and time, second round of field visits were conducted. Due to ceiling level adoption of technology, most of the sample farmers left 'Annigeri' cultivation few years back. The focus-groups were specifically designed and concentrated mostly in eliciting the expenditure pattern on JG 11 vs 'Annigeri'. The costs and returns for 'Annigeri' were collected based on their judgements 'as if they are growing Annigeri today, what kind of investments they do' and 'the corresponding plot yields based on their experience'. Thus, the focus-group results have helped the team to complement the primary household analysis as well as in estimating the UCR.

In general, most of the sample farmers agreed that they do and follow similar crop management practices between JG 11 and Annigeri cultivars. In case of Annigeri, the costs of seeds per ha would be relatively lower than JG 11. The average seed rate and corresponding price will be much lower in case of Annigeri than JG 11. The quantum of fertilizer application per ha of JG 11 will be a little higher (around 20-30 kg) than Annigeri. However, the margin of yield advantage per ha between these two cultivars was thoroughly discussed in the earlier sections (refer Table 6.19). Nearly 30-40 per cent yield benefits were perceived while discussing in the FGMs and based on research station data (see Tables 6.28, 6.20 and 6.21). The item-wise costs on different operations were elicited and analysed for obtaining the unit cost of reduction (UCR) per ton when switching from Annigeri to JG 11 (see Table 6.28). The above analysis clearly revealed that the crop yields have increased from 1475 to 2017 kg per ha. The corresponding total costs[6] associated for producing them was $ 983 and $ 1054 per ha. The average cost of production per ton has come down from $ 666 to $ 522 due to increased yields of short-duration cultivars. Finally the translated unit cost reduction per ton was $ 144. In terms of rupees, UCR was estimated at Rs.7930 per ton.

[6] *Total costs includes variable (seed, fertilizer, labor etc.) and fixed (rental value of land) costs per ha*

Table 6.28 Summary of unit cost reductions due to adoption of short-duration improved cultivars ($ per ton)

Item	Prakasam (J Panguluru)				Prakasam (Parchuru)				Mahabubnagar (Manopad)				Kurnool (Koilkuntla)		Kurnool (Uyyalawada)		Guntur (Tadikonda)		Pooled	
	FGM-1		FGM-2		FGM-1		FGM-2		FGM-1		FGM-2		FGM-1		FGM-2		FGM-1			
	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11	A-1	JG-11
Land preparation	99	102	94	94	103	107	117	117	67	70	90	90	72	74	67	67	79	79	88	89
Seed bed preparation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Compost/AP	0	0	0	0	0	0	0	0	0	0	0	0	22	43	0	0	0	0	2	5
Planting	46	47	45	45	38	38	43	43	27	27	27	27	27	30	27	27	40	45	36	36
Seed cost	90	138	81	121	72	105	72	112	54	111	54	92	72	97	54	90	54	90	67	106
Seed treatment	0	0	0	0	0	0	0	0	0	3	0	0	0	6	7	7	0	0	1	2
Fertilizer cost	88	98	81	90	81	82	94	94	90	97	99	108	81	87	81	85	112	126	90	96
Micro-nutrient	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Interculture	0	0	0	0	0	0	0	0	0	10	0	0	0	8	0	0	0	0	0	2
Weeding	63	63	54	54	31	30	40	40	40	32	36	36	36	39	40	40	22	22	40	40
Plant protection	67	65	67	67	108	110	76	79	76	78	99	112	54	54	54	54	90	90	77	79
Irrigation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Watching	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Harvesting	67	77	63	67	72	81	72	81	54	58	45	54	49	56	49	54	63	67	59	66
Threshing	67	72	63	67	81	100	67	72	54	54	45	49	45	48	45	45	81	99	61	67
Marketing	11	14	9	9	7	8	9	11	4	9	9	9	9	18	9	13	9	13	8	12
Total-VC	598	676	557	615	593	662	591	649	467	549	503	577	467	559	433	483	550	631	529	600
Fixed cost/ha	539	539	404	404	584	584	584	584	269	269	269	269	539	539	449	449	449	449	454	454
Total cost (TC)	1137	1215	961	1019	1177	1245	1174	1233	737	818	772	847	1006	1098	882	932	999	1080	983	1054
Yield /ha (kg)	1606	2223	1482	1976	1729	2347	1853	2347	1112	1606	1173	1606	1359	1853	1235	1729	1729	2470	1475	2017
Price ($/ton)	545	600	545	600	545	600	545	600	545	600	545	600	545	600	545	600	545	600	545	600
Gross Returns	876	1334	808	1186	943	1408	1010	1408	606	963	640	963	741	1112	674	1037	943	1482	805	1210
Net returns over TC	-261	119	-153	166	-234	163	-164	175	-130	145	-132	117	-265	13	-209	106	-56	402	-178	156
Net returns over VC	278	658	251	570	350	746	420	759	139	414	137	386	274	552	240	555	393	851	276	610
COP ($)	708	546	648	516	681	531	634	525	663	510	658	527	740	593	715	539	578	437	666	522
UCR per ton ($)		162		133		150		109		153		131		148		176		141		144

Note: $ US = Rs.55.

6.6 Major drivers of short-duration chickpea technology adoption

The comprehensive study has facilitated the research team to identify various drivers for quick adoption of chickpea short-duration improved cultivars in Andhra Pradesh. It is worthwhile to identify and discuss those drivers upfront in the report. They are as follows:

1. ***Early maturing technology:*** Availability of early maturing technology itself is the major driver for rapid penetration of chickpea in Andhra Pradesh. Initially, the medium duration varieties has created some scope for entry of new chickpea crop in the late 1990s in the state. After the release (in 1999) of new improved cultivar 'JG 11', there was a boom in chickpea spread in the state. The new improved cultivars has numerous advantages like high yielding, Fusarium wilt resistance, bold seeded, attractive brownish color, round and uniform size seeds etc. than earlier cultivars. This has helped the farmers to fetch higher yields (30-40%) than previous.

2. ***Remunerative market prices:*** India is the largest producer and consumer of chickpea in the world. In general, they consume chickpea either in whole grain, roasted split dhal, flour etc. With burgeoning population in the country, the demand for chickpea consumption increased significantly over period. During the recent time, Government of India has also increased the Minimum Support Price (MSP) for major pulses in the country to enabling pulse revolution in the country. Because of huge demand, the market prices of chickpea per unit was much higher than MSP announced by Government of India (Fig 6.14). This has motivated the farmers to quickly shift towards to chickpea from other crops. Relatively, the extent of increase in prices of chickpea competing crops was lower (Fig 6.15).

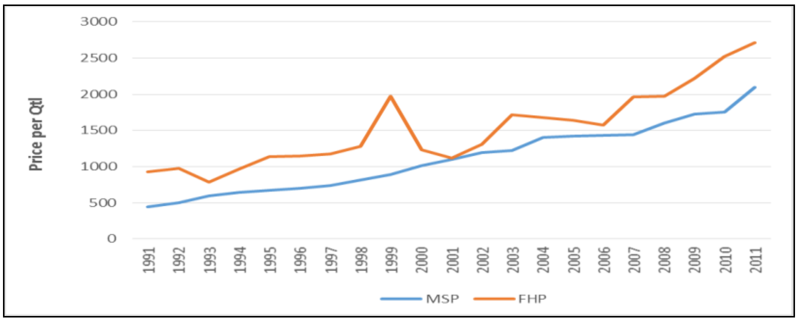


Fig 6.14: Comparative price levels of chickpea (Rs/qtl)

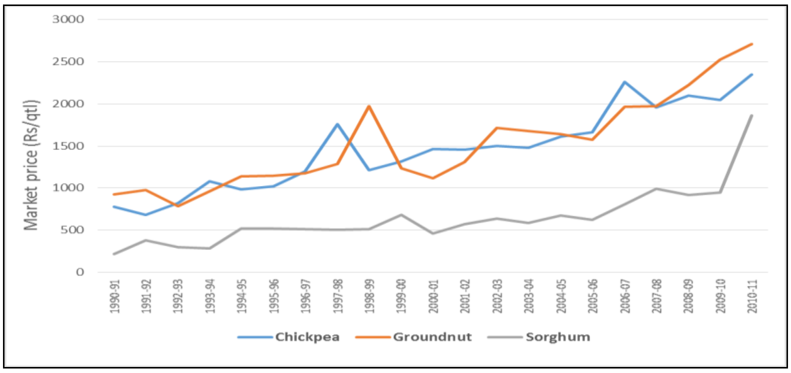


Fig 6.15: Farm harvest prices in Kurnool district, 1990-2010

3. ***Less labor intensive:*** Basically, chickpea is a less labor intensive crop when compared with other competing crops in the study districts. Because of its short-duration (90 days) and suitability to mechanical cultivation led to less dependency on either family labor or hired labor for cultivation. Fig 6.16 clearly visualizes the extent of labor utilization among chickpea and its competing crops per ha.

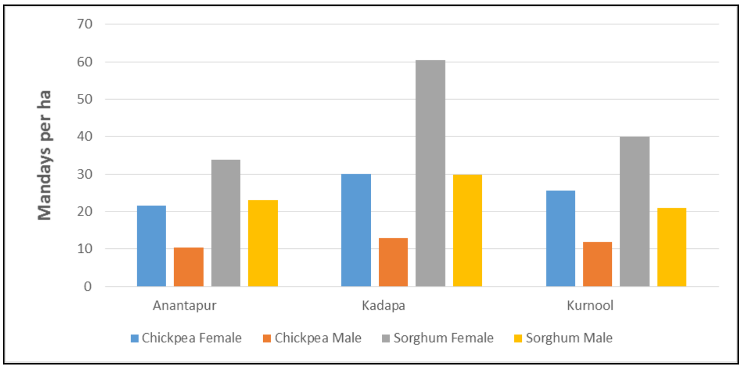


Fig 6.16: Labor utilization in chickpea vs sorghum per ha

4. ***Highly suitable for mechanization:*** Unlike other crops, chickpea suits well with mechanical cultivation in rainfed areas. This is clearly evident from the household data analysed for chickpea and other competing crops (Fig 6.17). Except harvesting, all other operations can be performed with machinery. Based on chickpea farmers' feedback in the survey, a farmer can cultivate up to 8 ha of chickpea with one tractor and with own family labor. With increased agricultural wage rates, farmers are preferring towards mechanization to perform timely operations in the crop.

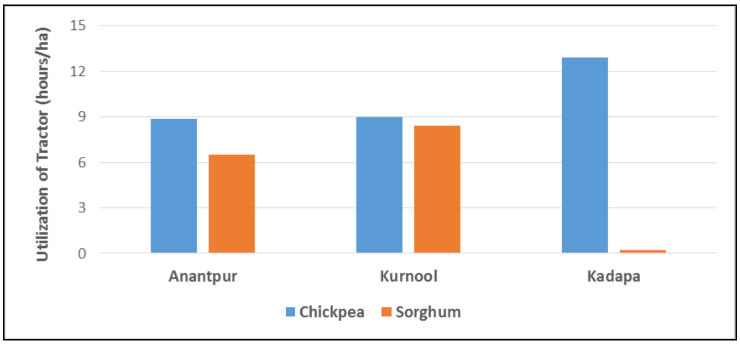


Fig 6.17: Extent of utilization of tractor (hours/ha)

5. ***Requires low investment and less risky:*** The average capital investment per ha of chickpea cultivation was relatively lower than other competing crops. Additionally, the return on investment in chickpea is more assured because of higher yields and remunerative market prices. Whereas, the capital investments in chickpea competing crops was higher (10-20%) and risky. If we compare with other commercial crops like cotton and tobacco, the average investment per ha will be nearly 30 per cent higher than chickpea. It is clearly evident from primary survey data collected from chickpea growers (refer Appendix 16 for more details).

7 Impact Assessment – Results and Discussion

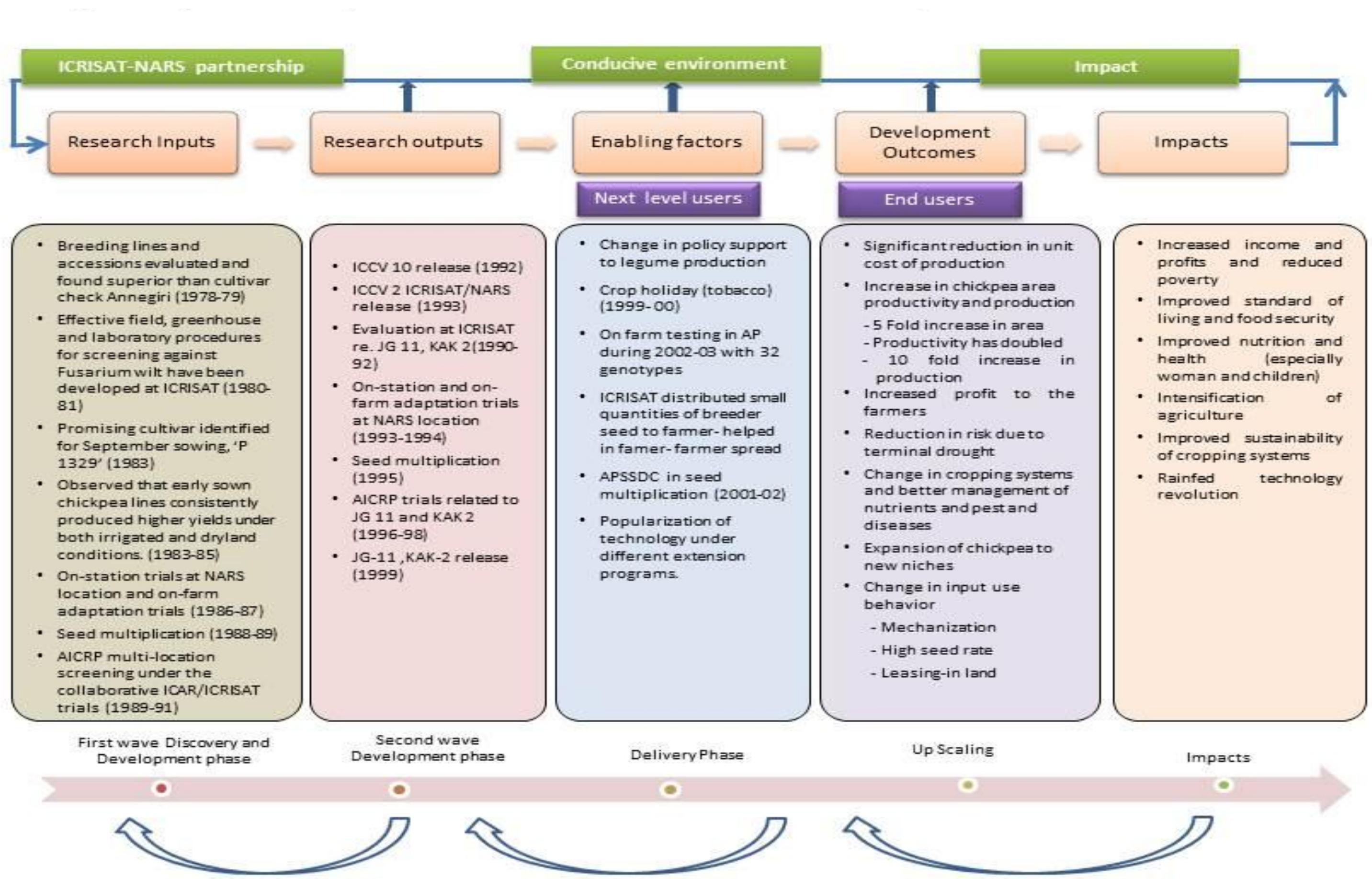
The quantification of the welfare gains or research benefits from adoption of short-duration chickpea improved cultivars in Andhra Pradesh are estimated and presented in this section. The impact assessment analysis starts with a schematic illustration of the impact pathway for the short duration chickpea technology (Fig 7.1). This pathway appeals to the framework illustrated (Fig 4.1) in the methodology chapter 4. The impact pathway uses the data and information collated from Chapters 3, 5 and 6 and demonstrates the role of critical variables in quantifying final impacts. It illustrates the components of the complex interactions which ultimately lead to impacts. The adaptive research infrastructure, and seeds and adoption systems are highlighted, along with the effects of new short duration varieties on farmer's unit cost of production which enhances the chickpea market supply. It is this shift in the supply that generates welfare changes for the community, particularly the chickpea producers and consumers and the many groups ultimately influenced by the initial chickpea market changes. As explained in Chapter 4, all the minimum dataset parameters used in welfare calculations are analysed from either primary household survey data or secondary sources of information. The summary of break-up of welfare estimates are summarized and discussed in this chapter. Similarly, sensitivity analysis has also been performed to understand the extent of sensitivity of each parameter in welfare quantification process.

7.1 The Impact Pathway: ICRISAT/NARS short duration improved chickpea varieties

The impact pathway for chickpea short duration R4D is illustrated in Figure 7.1. The impact pathway tracks the technology development, introduction and expansion of short duration chickpeas through ICRISAT-NARS partnerships which produced the successful varieties in 1999 and hastened adoption which ultimately resulted to replacement of the long-dominating old variety (Annigeri). It demonstrates the critical engagement of stakeholders (which enabled the release, uptake and impact in Andhra Pradesh) along the R4D, extension and dissemination horizon.

It is notable that chickpea was not even a minor crop in Andhra Pradesh until 1985. While short winters, terminal moisture stress, wilt disease and pod borer were the major constraints for growing chickpea in this southern states of India, there were at least four recognised advantages in chickpea crop cultivation - easy to grow, free from foliar and fungal diseases, and less vegetative growth. Farmers also perceived chickpea production to have less risk in production. Late maturing varieties namely Gulabi and Jyoti (selections from land races) were under cultivation in Andhra Pradesh, alongside Annegiri which was released in 1978 from the state of Karnataka. While four more releases of medium duration cultivars were noted including ICCC 4 and ICCV 10 in subsequent years, it was the medium duration variety Annegiri which continued to dominate chickpea cultivation in Andhra Pradesh and the rest of southern India for more than three decades.

Fig 7.1 Impact pathway for short duration chickpea research



The schematic diagram indicates that research on short duration started in 1978 when the initial investment of ICRISAT/NARS research inputs towards this research focus was recorded. As detailed in Chapter 3, the close and sustained collaborative efforts led to the development of the first short duration improved chickpea cultivar Swetha (ICCV 2) which was released in India in 1993. But the farmers of southern India, particularly Andhra Pradesh farmers, were seemingly not ready for uptake of this new release at that time. It seems that (based on focus group meeting with farmers and personal communication with concerned breeders) this first short duration release was considered to be too extra early maturing. Also relevant was the constrained seed multiplication encountered and therefore limitations in seed availability. In other words, this release in 1993 did not have a successful uptake. While other short duration varieties were also released during the mid-90s, all faced similar constraints as well.

The continuing research collaboration between ICRISAT with JNKVV Jabalpur and Acharya N G Ranga Agricultural University (ANGRAU), Rajendranagar, Hyderabad on crop improvement and management addressed more aggressively the above constraints and harnessed opportunities to develop new cultivars which could make chickpea a most suitable crop for the region. A network programme from ICRISAT with South and Central zone research stations was initiated through exchange of breeding material with an aim of identifying short duration, high yielding and disease resistant varieties. This led to the development of a second wave of releases starting 1999 including *desi* type cultivars (JG11, JAKI 9218, SAKI Nandyal-1) as well as *kabuli* types (KAK 2, VIHAR, JKG 1). To follow this up, on-farm trials which were conducted in early 2000 strongly recommended the adoption of short-duration and high yielding varieties, specifically JG 11 and KAK 2. Since then Andhra Pradesh witnessed a notable uptake of improved chickpea cultivars and corresponding increase in cropped area.

The joint partnerships that successfully released and promoted the second wave of short duration chickpea releases, particularly JG 11 and KAK 2 among others, seemed to have come at exactly the right time given the context of the crop production and economic environment surrounding chickpea around 1999. Interviews with farmers and focus group meetings revealed that Andhra Pradesh farmers in the late 90s to early 2000s were particularly looking for alternative more remunerable crop options to substitute for the traditional crops like tobacco, sunflower and sorghum; and they especially recognised that chickpea fetched good market prices. It was also noted that it was also in the late 90s when the Government of Andhra Pradesh declared a "tobacco holiday" which banned or discouraged tobacco production due to unfavourable global export markets. But most critically, the driving factor that enabled the fast uptake process was the research, extension and seed multiplication agencies in Andhra Pradesh actively joining with ICRISAT and the JNKVV Central Chickpea Research Institute based in Jabalpur to address the binding seed constraint experienced during earlier years. Specifically, the bulk introduction and multiplication of seed by Andhra Pradesh State Seed Development Corporation (APSSDC) were complemented by the Department of Agriculture subsidy which enabled distribution of huge quantities of improved seeds to farmers. This joint massive collective effort not only made farmers aware of the new releases but enabled them to have access to improved seeds as farmers increasingly found chickpea to be more remunerative compared to the old chickpea variety Annigeri and even more competitive than other traditional crops grown in the rainfed regions of the state.

By and large, the impact pathway highlights the Andhra Pradesh farmers' hastened uptake of JG 11 and KAK 2 (among the second wave releases of short duration chickpea varieties technology) as the R4D effort of ICRISAT and national program partners were significantly complemented with enabling seed systems infrastructure and conducive economic and policy environment, all of which are instrumental in up-scaling the chickpea technology towards creating a real legumes revolution in Andhra Pradesh. Approaching the year 2010, the earlier dominating chickpea variety Annigeri (and other traditional crops including tobacco, sorghum, sunflower etc.) has been replaced by improved short duration cultivars. This resulted in what is now referred to as the "AP chickpea silent revolution" with five-fold increase in area, with doubling productivity and ten-fold increase in production in the state. Currently, more than 90 per cent of chickpea area in the state is covered with short-duration chickpea cultivars (especially JG 11 and KAK 2) and most of farmers have moved from subsistence to commercial chickpea farming by mechanizing their operations except harvesting.

The impact analysis and measurement in subsequent sections will show how JG 11 and KAK 2 (among the second wave release of short duration cultivars) which produced significant higher yields and lower unit cost of production (and therefore higher profits) have ultimately achieved measurable impacts with widespread welfare gains to both chickpea producers and consumers of Andhra Pradesh in India.

7.2 Key parameters used in welfare estimation calculations

The robustness of welfare estimates for any technology lies in usage of proper or most reliable key parameters. The minimum dataset parameters should be properly assessed and validated through rigor process. Any error in the estimation or usage of improper parameters leads to un-realistic estimation of welfare benefits. So enough care has been taken in assessing the following key parameters:

1. ***Base level of annual production:*** The base level of annual production of chickpea used for chickpea short-duration improved cultivars are 2011-12 data generated by both Directorate of Economics and Statistics, Andhra Pradesh (at sub-national level) and Department of Agriculture and Cooperation, New Delhi (at national level). Since the technology adoption is in its peak stage in Andhra Pradesh (around 98 per cent) during the survey reference year, we have used this base level production data for welfare estimate calculations. However, the analysis of this time series data have extensively discussed in Chapter 3.

2. ***Elasticity's:*** The demand and supply elasticity values used for the chickpea welfare estimations were adopted from earlier ICRISAT research studies. The important result of disaggregation which started with just having multiple countries in the early ACIAR analysis is that the welfare estimates and even their distribution between different groups become much less sensitive to supply and demand elasticities than with an aggregate analysis. This surprises many but when the analysis is dissected in more detail

what becomes clear is that it is the share of total production by each group and associated spillovers/applicability which become the overriding parameters which drive the distributive effects not the elasticities. This means that using different elasticity estimates for each disaggregated group does not make very much difference to the total but even distribution of the benefits.

3. ***Unit cost reduction (UCR):*** The details of adoption of short-duration improved cultivars and the corresponding unit cost reduction was estimated and presented in Table 6.28.

4. ***Adoption:*** The research and adoption lags were estimated with through discussions with ICRISAT chickpea breeders and other experts from Andhra Pradesh. ICRISAT has started the research for development of short-duration cultivars in early 1980s. The first batch of cultivars has been released in early 1990s but did not accept by farmers due to various reasons. The second batch of releases happened during 1999 which liked by farmers very much. Nearly, 22 years (from 1978 to 1999) of research lag was estimated for this study. After formal release of these cultivars, the seed multiplication and subsequent adoption taken little more time to reach the ceiling level of adoption in the state. Different sample districts taken diverse adoption pathways to reach the peak level adoption by 2012. The initial adoption lag ranged from 3 to 8 year across sample districts of AP. However, the total time taken from start of the project to reach the ceiling level of adoption was ranged between 35 to 41 years in case of Andhra Pradesh (also see Table 7.1 and 7.2). For estimating the welfare benefits beyond AP, the key parameter assumed beyond AP are summarized in Table 7.3.

5. ***Discount rates:*** 5 per cent discount rate was used in the welfare estimates calculation.

6. ***Exchange rates:*** Rs.55 per US dollar exchange rate was used for all necessary conversions in the report.

7. ***Research costs:*** The costs incurred by both ICRISAT and NARS for short-duration cultivar development and extension costs were estimated and used in the welfare calculations. The detailed break-up of the same is summarized in Chapter 3 from 1978 to 2013 (also see Table 3.9).

8. ***Estimation of BCR and IRR:*** The research benefits accruing over a period (1978-2037) and costs incurred in the developing the technology and extension (1978-2013) were discounted and calculated the Net Present Value (NPV) from those differences between them. Similarly, the Benefits-Cost Ratio (BCR) and Internal Rate of Return (IRR) were estimated and summarized in this section.

Table 7.1 Summary of adoption parameters

Parameter	PRM	KUR	ANA	KAD	MED	NIZ	MAH	Rest of AP	Rest of India
Start of project: 1978 Completion date: 1999									
Year of start of adoption (addl years seed multiplication)	2002	2001	2002	2003	2007	2007	2003	2003	2003
Year ceiling level of adoption reached	2012	2012	2012	2012	2012	2012	2012	2018	2018
Unit cost reduction ($/ton)	144	144	144	144	144	144	144	144	-

Table 7.2 Summary of key parameter estimates for assessing welfare gains (for AP)

Parameter	PRM	KUR	ANA	KAD	MED	NIZ	MAH	Rest of AP	Rest of India
Chickpea Production ('000' tons)	150.0	310.0	83.0	61.0	44.0	52.0	38.7	71.3	5727
Chickpea consumption ('000' tons)	20.7	42.8	11.5	8.4	6.1	7.2	5.3	9.8	8239
Farm gate price ($/ton)#	651	651	651	651	651	651	651	651	651
Elasticity of supply	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9	0.9
Elasticity of demand	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
Research lag (years)	22	22	22	22	22	22	22	22	22
Years from start of the project to start of the adoption (years)*	25	24	25	26	30	30	26	26	26
Initial adoption lag (years)**	3	2	3	4	8	8	4	4	4
Years from start of the project to maximum adoption (years)	35	35	35	35	35	35	35	41	41
Maximum adoption (Proportion)	1	1	1	1	1	1	1	1	-
Unit cost reduction ($/ton)[+]	144	144	144	144	144	144	144	144	-

Estimates based on survey results, FGDs and secondary data.
** ICRISAT started research on short duration cultivars in 1978 (Improved cultivars were released in 1999).*
** * From release of cultivars to initial adoption*
 # Based on Andhra Pradesh Agricultural Statistics, 2012
[+] Aggregated UCR

Table 7.3 Summary of key parameter estimates for assessing welfare gains (Beyond AP)

Parameter	Karnataka	Maharashtra
Chickpea Production ('000' tons)	573	1100
Chickpea consumption ('000' tons)	429	784
Farm gate price ($/ton)#	651	651
Elasticity of supply	0.9	0.9
Elasticity of demand	0.6	0.6
Research lag (years)	22	22
Years from start of the project to start of the adoption (years)*	26	26
Initial adoption lag (years)**	4	4
Years from start of the project to maximum adoption (years)	41	41
Maximum adoption (Proportion)	1	1
Unit cost reduction ($/ton)[+]	80	80

Estimates based on survey results, FGDs and secondary data.
** ICRISAT started research on short duration cultivars since 1978 (Improved cultivars released in 1999 & 2000)*
** * From release of cultivars to initial adoption*
 # Based on Andhra Pradesh Agricultural Statistics, 2012
[+] Estimated based on Tropical Legumes II (TL II) and VLS project studies

7.3 Estimation of direct welfare benefits to Andhra Pradesh

Based on the principle of economic-surplus, the direct welfare benefits to Andhra Pradesh are estimated and presented in Table 7.4. The minimum dataset parameters used for generation of these benefits were summarized in Tables from 7.1 to 7.2. Based on the estimated average UCR of 144 $ per ton, the direct welfare benefits to Andhra Pradesh due to adoption of short-duration cultivars was 358.9 million dollars. Producers received more benefits than the consumers because Andhra Pradesh is exporting chickpea to the rest of India, especially northern India. In a most conservative scenario, the accrued benefits may go down to 284.2 million dollars due to variation in yields across different eco-systems. But, under the most optimistic conditions, the total benefits may go up to 429.8 million dollars over the estimated period i.e., 1978 to 2037. Farmers who adopted the short-duration improved cultivars received the principal share of benefits. This was made possible because of strong partnerships between ICRISAT and NARS coupled with policy support from Government of Andhra Pradesh.

Table 7.4 Direct welfare gains due to adoption of short-duration improved cultivars in Andhra Pradesh (US $ millions)

Type	S1: Conservative scenario (UCR=117 $/ton)	S2: Business as usual scenario (UCR=144 $/ton)	S3: Optimistic scenario (UCR=169 $/ton)
Total chickpea production ('000' m tons)	810.0	810.0	810.0
Total chickpea consumption ('000' m tons)	111.8	111.8	111.8
Total welfare change #	**284.2**	**358.9**	**429.8**
Producer surplus #	279.3	353.3	423.7
Consumer surplus#	5.0	5.6	6.1
Adopters benefits #	284.1	358.7	429.7
Non-adopters #	-4.9	-5.4	-5.9
UCR: Unit Cost Reduction # Million dollars			

Dis-aggregated UCR and welfare benefits

The welfare benefits accrued to Andhra Pradesh using the dis-aggregated UCRs across production environments (PEs) are summarized in Table 7.5. In general, the normal aggregate estimates masks the range of important implications of research impacts by hiding the exceeded welfare gains of favourable environments with that of lower benefits to the non-favourable environments. There is an equal chance of committing significant empirical error in over or under measuring the welfare changes by ignoring the different production environments. The detailed understanding of different production environments and technology adoption process facilitates incorporation of each component of the story/activity in its appropriate form rather than developing an additional set of hypothetical assumptions. The total welfare benefits for Andhra Pradesh have increased marginally (8%) when we used dis-aggregated UCRs than the aggregated UCR (144 $/ton). This clearly reflects the underestimation of total welfare benefits due to short-duration improved cultivars in Andhra Pradesh. This empirical exercise clearly reveals that the UCR estimations will not be same across different production environments (PEs) as we perceive normally[7]. For increasing the precision in estimates of welfare benefits, it would always be better if we use the dis-aggregated UCR across PEs.

Table 7.5 Welfare benefit estimates for Andhra Pradesh using dis-aggregated UCR (US $ millions)

Type	S1: Dis-aggregated UCR*	S2: Aggregated UCR
Total chickpea production ('000' m tons)	810.0	810.0
Total chickpea consumption ('000' m tons)	111.8	111.8
Total welfare change #	**388.4**	**358.9**
Producer surplus #	382.6	353.3
Consumer surplus#	5.8	5.6
Adopters benefits #	388.2	358.7
Non-adopters #	-5.6	-5.4
UCR: Unit Cost Reduction *# Million dollars* * Actual UCRs estimated across study districts used.		

Welfare benefits across major districts of AP

The aggregate welfare benefits for Andhra Pradesh will not provide the clear idea on the extent of benefits accruing to various study districts in the state. For deeper understanding, the detailed break-up of welfare benefits across the sample districts are summarized in Table 7.6 using the business as usual scenario. Nearly 47 per cent of the total Andhra Pradesh benefits accrue to Kurnool district followed by Prakasam, Anantapur and Kadapa districts. The rest of Andhra Pradesh does not benefit because of very low levels of adoption beyond the seven districts included in the study. It is noted that the non-adoptors of short duration chickpea technology in Medak and Nizamabad have measurable welfare losses.

Table 7.6 Break-up of welfare benefits across major districts of AP

Type	AP Total	KUR	PRM	ANA	KAD	MAHA	NIZ	MED	Rest of AP
Total research benefits	358.9	167.5	77.8	43.5	30.7	19.5	11.8	8.5	-0.4
Producer gain	353.3	165.3	76.8	42.9	30.3	19.2	11.5	8.2	-0.9
Consumers gain	5.6	2.1	1.0	0.6	0.4	0.3	0.4	0.3	0.5
Adopters benefits	358.7	165.4	76.8	42.9	30.3	19.2	12.6	9.3	2.2
Non-adopters losses	-5.4	-0.1	0.0	0.0	0.0	0.0	-1.1	-1.1	-3.1
# Million dollars									

[7] Check http://ageconsearch.umn.edu/bitstream/165847/2/KumaraCharyulu%20CP.pdf for more details.

Welfare benefits by category of farmers in AP

As we have explained in Chapter 4 and 5 (see Appendix 15) of this report, the silent rainfed chickpea revolution in Andhra Pradesh happened because of rapid uptake of short-duration improved cultivars by farmers in a short span of time. The deeper secondary analysis of chickpea data and research process clearly convince us that the steep rise in chickpea production in Andhra Pradesh was achieved due to the adoption and changed behaviour of two types of farmers: 1. Traditional chickpea growers who replaced Annegiri by JG 11 and other improved cultivars; and 2. Non-chickpea growers who shifted from other non-chickpea traditional crops grown in rainfed regions to chickpea cultivation (switchers). The aggregate total welfare estimate for Andhra Pradesh given in Scenario 1 masks or hides the significance of this story. The disaggregation or relative break-up of these benefits under the business as usual scenario is presented in Table 7.7. Nearly 68 per cent of total welfare benefits were derived in AP due to switcher farmers who moved from non-chickpea to chickpea cultivation. A significant share of almost $US 120 m total benefits accrued to traditional chickpea growers who replaced Annigeri with the improved short duration cultivars.

Table 7.7 Welfare benefits by category of farmers

Type	Total AP benefits	Benefits due to non-adoptors	Adopters	
			Benefits due to traditional growers	Benefits due to switcher farmers
Total welfare change #	**358.9**	**-4.6**	**119.5**	**244.0**
Producer surplus #	353.3	-5.4	118.0	240.8
Consumer surplus#	5.6	0.8	1.6	3.2

 # Million dollars

7.4 Estimation of total welfare gains to India

The diffusion of short duration chickpea cultivars are slowly spreading beyond Andhra Pradesh borders to the neighbouring vertisol areas of Karnataka and southern Maharashtra. As we pointed out in Appendix 2 and Fig 3.2, the short duration cultivars have strong research applicability in these neighbouring states. However, the institutional constraints and lack of conducive policy support plays a significant role in determining the extent of research benefits in those respective states. ICRISAT, in collaboration with NARS partners from fours states of India were involved in the development of these short duration cultivars, the present study also made an attempt to quantify those research benefits beyond Andhra Pradesh. The total accrued benefits for total India (including Andhra Pradesh) is summarized in Table 7.8. Note that in calculating the research benefits to India, only the short duration research domains were considered. Consumers are noted to be deriving larger benefits than producers due to the benefits derived from lower prices of chickpea. Non-adopters are shown to be losing a huge share of research benefits.

Table 7.8 Direct welfare benefits to India due to short duration cultivars (US $ millions)

Type	Total benefits to India*
Total chickpea produced ('000' m tons)	8210.0
Total chickpea consumed ('000' m tons)	9563.8
Total welfare change #	**543.9**
Producer surplus #	83.7
Consumer surplus#	460.2
Adopters benefits #	425.3
Non-adopters #	-341.6
# Million dollars only	** only for short-duration environment*

7.5 Flow of research benefits due to adoption of short duration cultivars

It may be of interest to see the flow of research costs and research benefits over the period for deeper understanding about welfare gains due to short duration chickpea improved cultivars in India. The research and development costs including the extension costs of ICRISAT and NARS were considered from 1978 to 2013 for calculation of project costs (see Table 3.9). The research benefits gained each year from 1978 to 2037 (60 years) were taken into consideration for calculation of project net benefits and internal rate of returns on research investments. The summary of the flow of project research costs and benefits are summarized in Table 7.9. The flow of costs and benefits were discounted with five per cent discount rate for the project period. The resulting net present value (NPV) was calculated by taking the differences between total discounted costs and discounted research benefits. Similarly, the project benefit-cost-ratio (BCR) and internal rate of returns were also estimated and presented in Table 7.10.

The total discounted project cost estimated at $US 2.96 million while the discounted welfare benefits estimated at $US 543.85 million. Therefore, the net present value of 540.89 million US $ was achieved. The investment of each dollar in the project earned 183.5 $ over the period of time. This is translated to an internal rate of research investments of 28 per cent. Figure 7.2 presents the flow of net benefits derived over the horizon of 60 years.

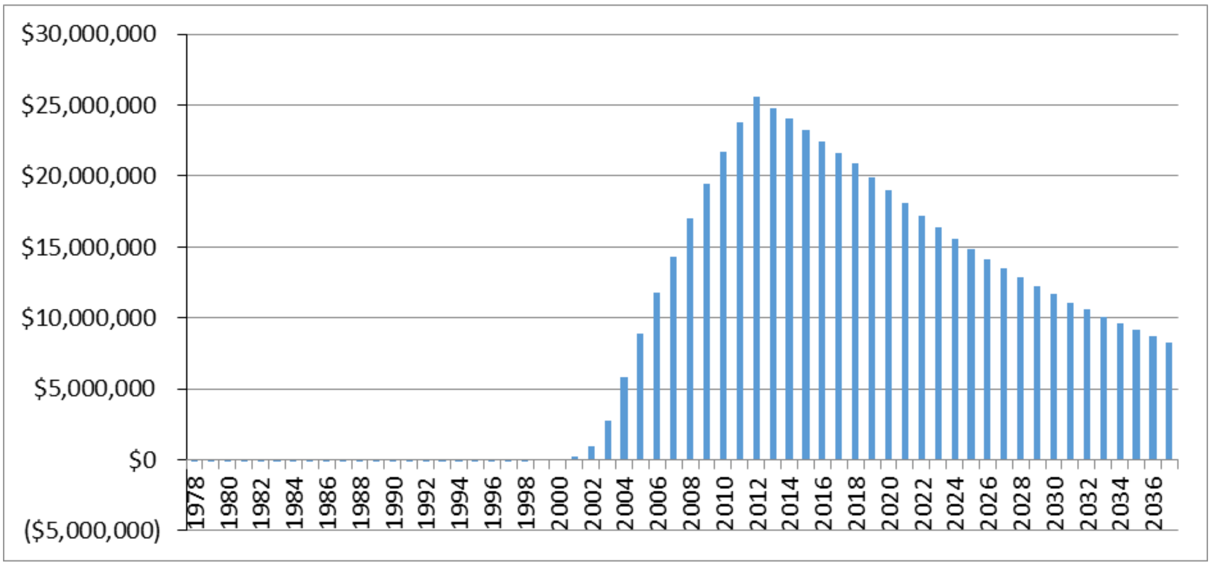
Table 7.9 Flow of research costs and benefits (US $)

Year	Costs	Research benefits to India (including AP)	Net benefits	Discounted net benefits
1978	108,411	-	-108,411	($103,248)
1979	108,411	-	-108,411	($98,332)
1980	108,411	-	-108,411	($93,649)
1981	108,411	-	-108,411	($89,190)
1982	108,411	-	-108,411	($84,943)
1983	108,411	-	-108,411	($80,898)
1984	108,411	-	-108,411	($77,046)
1985	109,210	-	-109,210	($73,918)
1986	94,488	-	-94,488	($60,908)
1987	86,087	-	-86,087	($52,850)
1988	79,922	-	-79,922	($46,729)
1989	79,393	-	-79,393	($44,209)
1990	174,689	-	-174,689	($92,641)
1991	170,722	-	-170,722	($86,226)
1992	165,637	-	-165,637	($79,674)
1993	170,597	-	-170,597	($78,152)
1994	170,181	-	-170,181	($74,249)
1995	155,167	-	-155,167	($64,475)
1996	159,643	-	-159,643	($63,176)
1997	169,897	9,986	-159,910	($60,269)
1998	177,684	174,873	-2,811	($1,009)
1999	181,413	339,973	158,560	$54,204
2000	341,621	535,030	193,408	$62,968
2001	359,055	1155,827	796,772	$247,053
2002	361,051	3,650,307	3,289,256	$971,327
2003	338,277	10,175,651	9,837,374	$2,766,670
2004	314,441	21,931,921	21,617,479	$5,790,206
2005	305,618	35,191,342	34,885,724	$8,899,126
2006	298,805	48,648,052	48,349,247	$11,746,272
2007	437,501	62,368,720	61,931,219	$14,329,487
2008	404,046	77,575,183	77,171,137	$17,005,391
2009	432,249	93,317,794	92,885,545	$19,493,533
2010	555,123	10,9293,141	108,738,018	$21,733,744
2011	505,827	125,054,288	125,018,460	$23,797,864
2012	515,871	141,758,895	141,243,024	$25,605,988
2013	513,760	143,914,536	143,400,776	$24,759,207
2014		146,083,109	146,083,109	$24,021,268
2015	-	148,204,080	148,204,080	$23,209,554
2016	-	150,337,975	150,337,975	$22,422,603
2017	-	152,484,793	152,484,793	$21,659,806
2018	-	154,644,534	154,644,534	$20,920,560
2019	-	154,666,150	154,666,150	$19,927,128
2020	-	154,687,768	154,687,768	$18,980,870
2021	-	154,687,768	154,687,768	$18,077,019
2022	-	154,687,768	154,687,768	$17,216,209
2023	-	154,687,768	154,687,768	$16,396,389
2024	-	154,687,768	154,687,768	$15,615,609
2025	-	154,687,768	154,687,768	$14,872,008
2026	-	154,687,768	154,687,768	$14,163,817
2027	-	154,687,768	154,687,768	$13,489,350
2028	-	154,687,768	154,687,768	$12,847,000
2029	-	154,687,768	154,687,768	$12,235,238
2030	-	154,687,768	154,687,768	$11,652,608
2031	-	154,687,768	154,687,768	$11,097,722
2032	-	154,687,768	154,687,768	$10,569,259
2033	-	154,687,768	154,687,768	$10,065,961
2034	-	154,687,768	154,687,768	$9,586,629
2035	-	154,687,768	154,687,768	$9,130,123
2036	-	154,687,768	154,687,768	$8,695,355
2037	-	154,687,768	154,687,768	$8,281,291
Total	**8,586,850**	**4,566,365,991**	**4,557,779,141**	**540,890,627**
Discounted*	**2,963,872**	**543,854,499**	**540,890,627**	
**** at 5 per cent discount rate***				

Table 7.10 Short-duration chickpea cultivars impact evaluation indicators for India

Item	Indicator value
Discounted total flow of costs#	2.96
Discounted total flow of benefits#	543.85
Net present value (NPV)#	540.89
Benefit-cost-ratio (BCR)	183.5
Internal rate of returns (IRR)	28%
Modified Internal rate of returns (MIRR) @ 30 per cent	27%
# US million dollars	

Fig 7.2 Flow of discounted net benefits over the project period (US $)



7.6 Sensitivity analysis of welfare benefits *(Reference to Andhra Pradesh only)*

The exercise on sensitivity of welfare benefits in Andhra Pradesh was done and presented in Tables 7.11a to 7.11e. This exercise clarified that the results are more sensitive to yield variations due to drought/climate aberrations. Changes in farm gate prices per ton did not have significant implications of the extent of derived welfare benefits. However, the change in research lags, adoption lags and unit cost reductions (UCR) show significant implications on the magnitude of the research benefits accruing over a period of time. The following five scenarios specifically for Andhra Pradesh were undertaken and their corresponding research results are summarized below:

1. *Impact of drought on productivity*

The impact of drought has significant influence on the welfare gains from short-duration chickpea in Andhra Pradesh. The deviation in crop yields per ha have direct influence on unit cost reduction (see Table 7.11a). A 10 percent deviation in normal yield per ha has considerably reduced welfare gains for AP (by around 150 million) as this translated to almost 40 percent unit cost reduction (UCR). Similarly, a 20 per cent reduction in normal yield per ha brought almost negligible research benefits (with 90% reduction in UCR). Any further reduction in crop yields (> 25 per cent than normal) generates welfare losses to the state. These results give an imperative high importance in the crop improvement for generating drought tolerant cultivars for reaping higher research benefits or minimizing welfare loss.

Table 7.11a Influence of drought on chickpea crop yields

S1: UCR $ 144/ton @ chickpea productivity at 1975 kg per ha
S2: UCR $ 117/ton @ chickpea productivity at 1777 kg per ha (10% reduction)
S3: UCR $ 86/ton @ chickpea productivity at 1580 kg per ha (20% reduction)

Type	S1: Business as usual scenario (UCR=144 $/ton)	S2: 10% reduction in yield (UCR=86 $/ton)	S3: 20% reduction in yield (UCR=14 $/ton)
Total chickpea produced ('000' m tons)	810	810	810
Total chickpea consumed ('000' m tons)	111.8	111.8	111.8
Total welfare change #	**358.9**	**201.1**	**18.7**
Producer surplus #	353.3	196.8	15.9
Consumer surplus#	5.6	4.3	2.8
Adopters benefits #	358.7	201.1	18.7
Non-adopters #	-5.4	-4.2	-2.8
UCR: Unit Cost Reduction # Million dollars			

2. *Changes in farm gate prices due to increase in imports (as experienced by Andhra Pradesh in Sept 2013)*

The influence of farm gate prices on the chickpea welfare estimates are summarized in Table 7.11b. The deviations in farm gate prices per ton did not have significant influences on the derived welfare gains in Andhra Pradesh. Due to changes in the international market, countries like Canada, Australia and Iran are already importing huge quantities of *kabuli types of chickpeas* into India. This importation definitely reduces the farm gate prices per ton and also weakens the market demand of local chickpeas grown within the country. However, India being is the largest producer and consumer of chickpea in the world, the total welfare is not changing much.

Table 7.11b Change in farm gate price ($/ton) due to measurable increase in imports

S1: Business as usual (Farm gate price @ $ 651 per ton)
S2: 5% decrease in farm gate price @ $618 per ton
S3: 10% decrease in farm gate price @ $ 586 per ton
S4: 15% decrease in farm gate price @ $ 553 per ton

Type	S1: Farm gate price @ $ 651/ton	S2: Farm gate price @ $ 618/ton	S3: Farm gate price @ $586/ton	S4: Farm gate price @ $ 553/ton
Total chickpea produced ('000' m tons)	810	810	810	810
Total chickpea consumed ('000' m tons)	111.8	111.8	111.8	111.8
Total welfare change #	**358.9**	**359.4**	**360.0**	**360.6**
Producer surplus #	353.3	353.7	354.1	354.6
Consumer surplus#	5.6	5.7	5.9	6.0
Adopters benefits #	358.7	359.2	359.8	360.4
Non-adopters #	-5.4	-5.5	-5.7	-5.8
UCR: Unit Cost Reduction # Million dollars				

3. *Change in ceiling level of adoption lag*

Research and adoption lags are sensitive parameters in the welfare benefits calculations for any technology. In case of chickpea in Andhra Pradesh, the short-duration cultivar development research initiated at ICRISAT in early 1978 and successful cultivars have been released in 1999.

Table 7.11c Change in ceiling level of adoption lag (years)

S1: Business as usual (ceiling level of adoption lag is 35 years i.e., 2012)
S2: Advancing the ceiling level of adoption lag to 30 years i.e., 2007)
S3: Absence of TL-II project interventions (adoption lag might be extended up to 40 years)

Type	S1: Ceiling adoption @ 35 years	S2: Ceiling adoption @ 30 years	S3: Ceiling adoption @ 40 years
Total chickpea produced ('000' m tons)	810	810	810
Total chickpea consumed ('000' m tons)	111.8	111.8	111.8
Total welfare change #	**358.9**	**419.0**	**307.7**
Producer surplus #	353.3	413.0	302.5
Consumer surplus#	5.6	6.0	5.1
Adopters benefits #	358.7	418.9	307.5
Non-adopters #	-5.4	-5.9	-5.0
UCR: Unit Cost Reduction # Million dollars			

This reckons 22 years of research lag, and an additional 13 years were needed from formal release of the cultivars to reach ceiling level of adoption. Any advance of adoption lag (say five years) would enhance the research benefits (nearly 60 million) in shorter period of time (see Table 7.11c). However, Tropical Legumes Project-II supported by BMGF has targeted for hastening-up the adoption process in AP since 2008 through conduct of FPVS trials, seed samples distribution and other mass media communications. The adoption has reached its peak in 2012 due to project intervention activities in Andhra Pradesh. In the absence of this project, it would have been taken another 3-5 years to reach the ceiling level of adoption in the state. By advancing the ceiling level of adoption from 40 to 35 years, Andhra Pradesh chickpea farmers have accrued almost 50 million US dollars (307.7 m $ to 358.9 m $).

4. *Unit cost reduction across study districts*

Table 7.11d Ranges in UCR across favourable and un-favourable environment districts

S1: Business as usual (Mean UCR @ 144 $ per ton)
S2: Un-favourable environment district UCR @ 131 $ per ton
S3: Favourable environment district UCR @ 176 $ per ton

Type	S1: Mean UCR @ 144 $/ton	S2: Un-favourable district UCR @ 131 $/ton	S3: Favourable district UCR @176 $/ton
Total chickpea produced (‘000’ m tons)	810	810	810
Total chickpea consumed (‘000’ m tons)	111.8	111.8	111.8
Total welfare change #	**358.9**	**322.7**	**450.0**
Producer surplus #	353.3	317.4	443.8
Consumer surplus#	5.6	5.3	6.3
Adopters benefits #	358.7	322.6	449.8
Non-adopters #	-5.4	-5.1	-6.1
UCR: Unit Cost Reduction # Million dollars			

Other most important parameter in technology assessment and research welfare estimates is unit cost reduction (UCR). Due to enhancement of yield with new technology or saving the losses due to resistant cultivars reduces per unit cost of production and ultimately brings welfare benefits to the farmer. Similarly, any changes in crop management and its associated environmental conditions exhibit in terms of variability in productivity. Among the seven sample districts; Prakasam, Kadapa, Nizamabad and Medak districts have better rainfall regimes and soils. But, districts like Anantapur, Mahabubnagar and Kurnool receives low rainfall and having poor soils. The UCR calculations across seven districts showed a range from 131 to 176 $ per ton. These differences in UCR among study districts bring huge variability in welfare calculations (see Table 7.11d).

5. Further diffusion of chickpea in Andhra Pradesh

The spatial analysis undertaken in chapter 2 demonstrated that the scope for further expansion of chickpea production in Andhra Pradesh is rather quite limited to the remaining rainfed niches in the vertisol regions of Adilabad in northwestern AP. Determination of the possible extent of area expansion is achieved by re-examining some more details of the chickpea research domains defined in chapter 2. For example, the research domain for chickpea production has been delineated by five variables: rainfall, temperature, soil type, latitude, and length of growing period. Consideration of one additional variable, i.e. irrigation, has been shown to be critical delineating likely areas of expansion as well as the likely influences on crop suitability and competitiveness of chickpea production vis-a-vis other cropping system options. While irrigation has not been taken into account in the initial spatial analysis of the research domain, the analysis of chickpea illustrated that it may indeed be an important factor influencing the suitability of chickpea and therefore the expansion of chickpea area and production. The conclusions drawn from the spatial analysis in Chapter 2 indicates a high probability scenario representing a specific situation where the district of Adilabad (which is currently classified under "rest of AP" may doubles its chickpea production from the current production of 71,300 tons of chickpea. This scenario considers that the increase in production is due to farmers adopting new improved varieties (JG 11, Vihar and/or KAK 2) or farmers switching from non-chickpea crops. Thus, this scenario presents the likely additional benefits if indeed this expansion occurs in the remaining rainfed vertisols of Andhra Pradesh including the district of Adilabad. This will add an estimated research benefits of 11 million US $ to the existing baseline scenario (see Table 7.11e).

Table 7.11e Ceiling level of adoption has not been reached and continues to expand chickpea area further to other districts

S1: Business as usual UCR $ 144/ton and ceiling adoption of 7.5% by 2018
S2: Expansion of area, particularly in Adilabad ceiling adoption of 37 % by 2015

Type	S1: Business as usual (UCR=144 $/ton)	S2: Expansion to Adilabad with 37% adoption by 2015
Total chickpea produced ('000' m tons)	810	810
Total chickpea consumed ('000' m tons)	111.8	111.8
Total welfare change #	**358.9**	**369.6**
Producer surplus #	353.3	364.0
Consumer surplus#	5.6	5.6
Adopters benefits #	358.7	368.5
Non-adopters #	-5.4	-4.5
UCR: Unit Cost Reduction # Million dollars		

8 Summary and Conclusions

The whole series of short duration wilt resistant chickpea varietal releases in India starting the early 90s was a product of strategic research for development partnership by ICRISAT and the Indian NARS. Initially targeting the research domains in the southern regions of India, breeding has been directed towards the development of early maturing varieties suitable for environments where the growing season is short and the characteristic of drought escape is essential for raising a successful crop. The broader international mandate of the crop improvement scientists at ICRISAT, however, expanded the ultimate target on the applicability of short duration varieties for the global research domains delineated by specifically defined parameters - latitude, length of growing period, temperature and soil type. The low latitude (<20^0) regions of the world with dry hot climate and vertisol soils were grouped in this homogenous Research Domain 1 covering not only the Deccan & Southern India states of Andhra Pradesh, Karnataka and Southern Maharashtra but also similar agro-ecological zones in Myanmar, Bangladesh, Central Ethiopia, Tanzania and other countries around the world.

The successful release of early maturing short duration chickpeas benefited from the systematic evaluation of breeding lines and accessions from the ICRISAT germplasm collection and harnessed the effective field, greenhouse and laboratory procedures for screening against Fusarium wilt which were developed at ICRISAT. Through the 80s, early maturing resistant lines are screened, identified and made available to NARS partners for their breeding program. The continuous development of the original chickpea collection sown in a wilt-sick plot at ICRISAT in Patancheru which were re-sown for further purification found its way to on-station trials through the AICRP trials in India. Multi-location screening for resistance and short duration, and on-farm adaptation trials globally were simultaneously undertaken through cooperative trials involving ICRISAT and several NARS research institutions globally. The joint efforts produced the first batch of releases in the early 90s (e.g. ICCV 2, ICCV 37, Akaki, Barichhola, Schwe Kyehman among others). A second batch of releases followed in the late 90s to early 2000s (JG 11, KAK 2, Sacho, Chefe, Yezin series and Sona). While the critical binding constraint of seed multiplication limited the uptake of the first cohort of releases particularly in India, the second series of releases particularly JG 11 and KAK 2 was adequately supported with a strong partnership of research, dissemination and extension with a massive seed multiplication program involving ICRISAT, the national programs and the extension and seed multiplication sector. During the period 2000-2003, scientists from ANGRAU, JNKVV Jabalpur and ICRISAT pushed aggressively for meeting the high demand for improved chickpea short duration cultivars soon after their release in 1999. Continuing seed multiplication and extension was sustained through the Andhra Pradesh State Seeds and Development Corporation (APSSDC). Further seed multiplication through the Tropical Legumes II Project PVS trials (TL II 2008-2013 supported by BMGF) in southern India further boosts the uptake in AP and Karnataka states.

The entire process, from selection to the release of the first set of early duration varieties in 1993, involved an average total of 4 years of strategic research and 12 years of applied and adaptive research conducted jointly by ICRISAT and the NARS. The second set of releases which became very popular and quickly replaced the earlier dominating variety Annigeri was finally produced in 1999, accounting for 6 additional years of research and development. The Andhra Pradesh and Madhya Pradesh national programs together with ICRISAT invested another 3 years on continuous massive seed multiplication together with APSSDC; and subsequently the additional support from the TL II Project commencing 2008.

A systematic tracking approach was developed using a representative sample survey conducted in the state of Andhra Pradesh. This was complemented by an analysis of available secondary district and sub-district level data on area, production and yield, and seed sector information for assuring a robust sampling frame. The adoption and impact surveys as well as an in-depth understanding from the temporal changes in area, production and yield revealed the fast changing cropping patterns as a result of key drivers of technology adoption and other sources of growth. The analysis harnessed both the time series data from 1966-2012 and spatial analysis using GIS tools of geo-referenced parameters which related to the chickpea homogeneous research domains. Farm level reconnaissance was extensively used in gaining an understanding of the underlying qualitative factors not covered in the formal representative survey.

The results of the study clearly demonstrates the significant impact primarily of JG 11, KAK 2 and other improved cultivars released in the state of Andhra Pradesh during the period of 1999 to early 2000s. JG 11 (a desi short duration) and KAK 2 (a kabuli short duration) principally have been taken up in farmers' fields across the chickpea growing areas primarily in the rainfed regions of the state. Diffusion to the districts beyond initially targeted regions and countries outside India also occurred. This report covers the measured impacts in the state of Andhra Pradesh and a subsequent sequel series of studies are also looking at the impact in other countries. The above cultivar occupies almost 90% of the area in the chickpea growing districts of Andhra Pradesh. While non-availability of the seeds constrained the adoption of the first cohort of short duration varietal releases in the early 90s, the subsequent massive R4D effort by ICRISAT and the NARS which also involved a massive investment in making the improved short duration and disease resistant seeds available to farmers through partnerships of the research, extension, seed multiplication and philantrophic agencies in fact created an wave of grey-to-green revolution in 7 districts comprising the rainfed regions of the state.

The new short duration cultivars gave yields about 37% higher than the best cultivar previously available. It reduced unit cost by 22 % or by an average of $144 per ton. The net present value of benefits from short duration fusarium wilt resistant research was estimated to be approximately US$ 359 million (baseline scenario) based on the most reasonable conditions describing the present socio-economic situation of the state and the global economy. However, the total welfare benefits have increased marginally to US $ 388.4 million when we used the dis-aggregated UCRs across production environments (PEs). This represents an internal rate of return (IRR) of 28 per cent.

During the field reconnaissance visits and other interactions, farmers confirmed that they are better-off after their adoption of short-duration chickpea cultivars in Andhra Pradesh, especially cultivars like JG 11 and KAK 2. Other impact dimensions including qualitative indicators are planned as a follow-up to this quantitative assessment to cover sustainable intensification, nutrition and gender. Focus group meetings informed that as adopters' average household incomes have gone up, the food intake and consumption have improved when compared a decade ago and that they are doing better investments in children's education and health. Additional metrics development will be investigated, e.g. agricultural intensification by leasing in-land, change in tenancy and land allocation, or legumes having a range of important nutritional properties or possible qualitative indicators showing that increases in legume productivity favor women.

The comprehensive analysis of adoption and impact in this study used farm level survey data to address farm level responses with respect to diffusion, adoption, dis-adoption, input use, crop management and unit cost reduction in chickpea production. It aimed to answer many inter-linked issues in technology adoption, emerging collective or group action to capture economies of scale, agricultural intensification and commercialization. The quantitative analysis showcases the impact of chickpea improved technology in Andhra Pradesh with understanding of the underlying socio-economic, institutional and policy drivers for technology adoption and enhanced household welfare.

The main message from the comprehensive analysis is that significant research benefits have been achieved from the wide adoption of short duration improved chickpea varieties in the rainfed regions of Andhra Pradesh in India. This technology is applicable beyond Andhra Pradesh borders and is likely to be diffused further and raise the production potentials thereby significantly increasing the welfare benefits from the research investments made by ICRISAT and NARS partners. This research findings show that significant gains can be achieved towards enabling a 'Legume Revolution' harnessing the rainfed regions in South Asia and sub-Saharan Africa.

Ultimately, better focused research directly addressing the farmers' needs for short duration chickpeas in southern India generated a technology revolution in the rainfed areas of Andhra Pradesh. The benefits from the first wave of research products released in the early 90s were curtailed by lack of adoption. The continuing strategic partnerships between ICRISAT and NARS in technology development generated a second wave of research products of short duration wilt resistant cultivars that expanded production levels as a result of yield gains that translated to lower unit costs for farmers. It converted even non chickpea growers to realize significant increase in incomes in chickpea production. The significant diffusion coupled with conducive policy and institutional support from relevant public or private sector seed multiplication and extension systems and seed organizations generated a technology revolution in rainfed areas which may be unsurpassed for many years.

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11 Appendices

Appendix 1: Broad shifts in cropping patterns

Appendix 2: Extent of diffusion bounded by access to irrigation and beyond Andhra Pradesh

Appendix 3: Characteristic features of major chickpea improved cultivars in Andhra Pradesh

Appendix 4: ICRISAT Global chickpea releases across different countries

Appendix 5: Insights from Focus-Group Meetings (FGMs) and field observations

Appendix 6: Decision tree protocol for identification of chickpea cultivars

Appendix 7: Household survey questionnaire, 2011-12

Appendix 8: Village survey questionnaire, 2011-12

Appendix 9: Randomization procedure for selection of mandals

Appendix 10: Socio-economic characteristics of non-chickpea sample farmers

Appendix 11: Derivation of average time lag based on data on first year of adoption

Appendix 12: Variety and district-wise first adoption details

Appendix 13: Chickpea yield variability across different locations

Appendix 14: Costs and returns from chickpea cultivation

Appendix 15: Costs and returns from chickpea by category of farmers

Appendix 16: Competitiveness of chickpea with other crops in sample districts

Appendix 1: Broad shifts in cropping patterns

The country's gross cropped area has increased significantly from 162.5 m ha in triennium ending 1968-1970 to 193.78 m ha by the triennium period 2008-2010 to meet the rising demand for food from the rapidly growing population. Among different crops, the major share is occupied by rice (22.42%) followed by wheat (14.67%), fruits and vegetables (7.44%), cotton (5.29%), soybean (4.96%), bajra (4.69%), maize (4.3%) and bengal gram (4.34%) during the triennium period of 2008-10. For deeper understanding about the crop-wise shifts, the analysis on the last four decades cropped area data is summarized in Table 11.1.1.

The performance of rice was pretty stable from early 1960's to till 2010. Area under wheat has tremendously increased from 10.43% in 1968-1970 to 14.67 per cent by 2010 in the country's gross cropped area. This major shift in favour of wheat area might be because of impact of Green Revolution and quicker adoption of improved cultivars. Under cereals category, maize area also showed impressive growth because of increased demand for food, feed and industrial segments. Crops like jowar had lost its significance drastically during the four decades period and the corresponding reduction in area has taken away by soybean and cotton. Bajra also lost some proportion of area but it is still concentrated in specific niches. Major factors attributed for these shifts are increased household income, changing food habits and subsidized PDS system (especially on rice and wheat).

The cropped area under pulses has resumed conspicuously because of significant progress in development and adoption of short duration, disease resistant cultivars. Chickpea is major crop which occupied significant area followed by pigeonpea, lentils, moong and uradbean. During late 1970 and 1980's chickpea cropped area significantly declined due to high incidence of pests and diseases and improved access to irrigation facilities (shifted to wheat). However, the area picked-up significantly by late 1990s after introduction of short-duration cultivars in Southern and Central India. Overall, the absolute cropped area of chickpea increased marginally. Pigeonpea has increased its share slightly from 1.59 to 1.93 per cent during the four decades period.

Among oilseeds, soybean and rape & mustard seeds have diffused much faster than other crops. Groundnut significantly declined its share from 4.42 to 3.01 in the same period. Commercial crops like cotton, fruits and vegetables have penetrated well in to the different cropping systems in India.

Table 11.1.1 Broad shifts in cropping pattern at all India level (% shares in area)

Crop	1968-1970	1978-1980	1988-1990	1998-2000	2008-2010
Rice	23.02	23.22	23.00	23.82	22.42
Wheat	10.43	12.98	13.04	14.28	14.67
Jowar	11.22	9.41	7.95	5.29	3.90
Maize	3.57	3.38	3.22	3.40	4.30
Pearl millet	7.68	6.50	6.07	4.96	4.69
Pigeon pea	1.59	1.59	1.94	1.86	1.93
Chickpea	4.66	4.12	3.78	3.50	4.34
Lentil	NA	0.54	0.61	0.77	0.74
Groundnut	4.42	4.14	4.64	3.68	3.01
Rape and mustard seed	1.92	2.15	2.83	3.01	3.23
Sesamum	1.47	1.40	1.33	0.86	1.00
Linseed	1.10	1.04	0.62	0.77	0.77
Castor	0.25	0.26	0.39	0.45	0.43
Niger	0.29	0.34	0.33	0.31	0.20
Safflower	0.36	0.42	0.45	0.23	0.14
Sunflower	0.07	0.07	0.71	0.74	0.73
Soybean	0.02	0.27	1.19	3.38	4.96
Cotton	4.70	4.66	4.08	4.70	5.29
Sugar cane	1.62	1.62	1.90	2.23	2.32
Jute and Mesta	0.61	0.73	0.52	0.55	0.46
Tobacco	0.27	0.25	0.22	0.21	0.21
Guar seed	0.73	1.32	1.32	NA	NA
Fruits and vegetables	2.23	2.77	3.56	4.35	7.44
Condiments and Spices	1.04	1.22	1.32	1.52	1.30
Others	16.52	15.36	14.75	14.93	12.37
Total cropped area	100.00	100.00	100.00	100.00	100.00

Table 11.1.2 Shifts in chickpea cropped area across major states (% share)

Crops	Madhya Pradesh			Andhra Pradesh			Maharashtra			Karnataka			Uttar Pradesh			Rajasthan		
	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10	1991-93	2001-03	2008-10
Rice	21.20	9.10	7.50	28.44	26.23	31.78	7.42	6.97	6.67	8.78	10.52	11.99	21.25	22.93	22.40	0.73	0.59	0.62
Wheat	14.86	19.64	19.65	0.07	0.10	0.09	3.27	3.36	5.04	1.79	2.13	2.13	34.74	36.58	38.24	10.50	11.12	10.74
Jowar	5.64	3.66	2.15	8.24	5.21	2.32	27.93	21.93	18.21	17.44	15.22	10.55	1.83	1.20	0.78	3.73	3.39	3.03
Maize	3.77	4.61	3.97	1.31	0.86	6.01	0.82	1.63	2.89	2.37	5.33	9.50	4.22	3.50	3.00	4.96	5.59	4.93
Pearlmillet	0.64	0.94	0.80	2.42	4.57	0.43	8.91	6.51	4.34	2.93	2.40	2.32	3.06	3.40	3.44	24.23	25.51	23.71
Pigeonpea	1.88	1.62	1.86	2.49	3.74	3.90	4.87	4.79	5.04	3.61	4.41	5.53	2.07	1.49	1.28	0.11	0.11	0.09
Chickpea	9.60	12.89	14.32	0.55	2.99	4.64	2.71	3.66	5.73	1.91	4.18	7.02	4.16	3.29	2.31	6.43	4.56	5.88
Other pulses	8.21	8.14	7.06	9.38	10.18	6.19	7.98	7.42	4.76	7.77	8.23	6.89	5.12	5.94	5.98	6.54	4.66	11.90
Groundnut	1.16	1.13	0.93	18.65	12.69	11.85	3.26	1.87	1.47	10.39	7.26	6.65	0.53	0.38	0.36	16.69	16.20	1.49
Rape and mustard seed	2.68	2.48	3.56	0.04	0.02	0.04	0.04	0.05	0.03	0.04	0.05	0.04	4.88	3.29	2.79	13.41	9.88	13.22
Sesamum	0.95	0.71	1.11	1.34	1.11	0.75	1.32	0.54	0.25	1.06	0.59	0.58	0.60	0.59	1.24	2.78	1.47	2.50
Linseed	1.70	0.79	0.58	0.05	0.04	0.01	0.65	0.28	0.17	0.21	0.14	0.10	0.68	0.34	0.24	0.19	0.01	0.01
Castor	0.01	0.01	0.00	2.17	2.20	1.25	0.03	0.10	0.04	0.19	0.16	0.15	0.00	0.00	0.00	0.07	0.24	0.60
Safflower	0.02	0.00	0.00	0.16	0.15	0.10	2.29	1.21	0.81	1.29	0.80	0.52	0.00	0.00	0.00	0.00	0.00	0.00
Sunflower	0.10	0.01	0.00	2.53	3.20	2.51	2.25	1.28	1.02	10.08	7.49	5.82	0.13	0.02	0.03	0.03	0.00	0.00
Soybean	12.32	22.58	25.41	0.02	0.35	1.08	1.81	6.02	13.03	0.31	0.58	1.28	0.11	0.12	0.04	1.37	2.91	3.55
Cotton	2.12	2.93	2.99	5.80	7.49	11.99	12.21	13.22	15.66	4.78	3.80	3.73	0.05	0.02	0.02	2.56	2.23	1.62
Sugarcane	0.21	0.22	0.31	1.42	1.80	1.38	1.91	2.43	3.68	2.26	2.98	2.75	7.25	8.27	8.21	0.13	0.04	0.03
Other crops	12.95	8.54	7.78	14.92	17.05	13.69	10.30	16.73	11.16	22.78	23.71	22.46	9.32	8.64	9.65	5.54	11.49	16.08
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Per cent shares in those respective states during that period.

Fig 11.1.1 District-wise pattern of chickpea expansion in Andhra Pradesh, 2001-11 (Area in '000 ha)

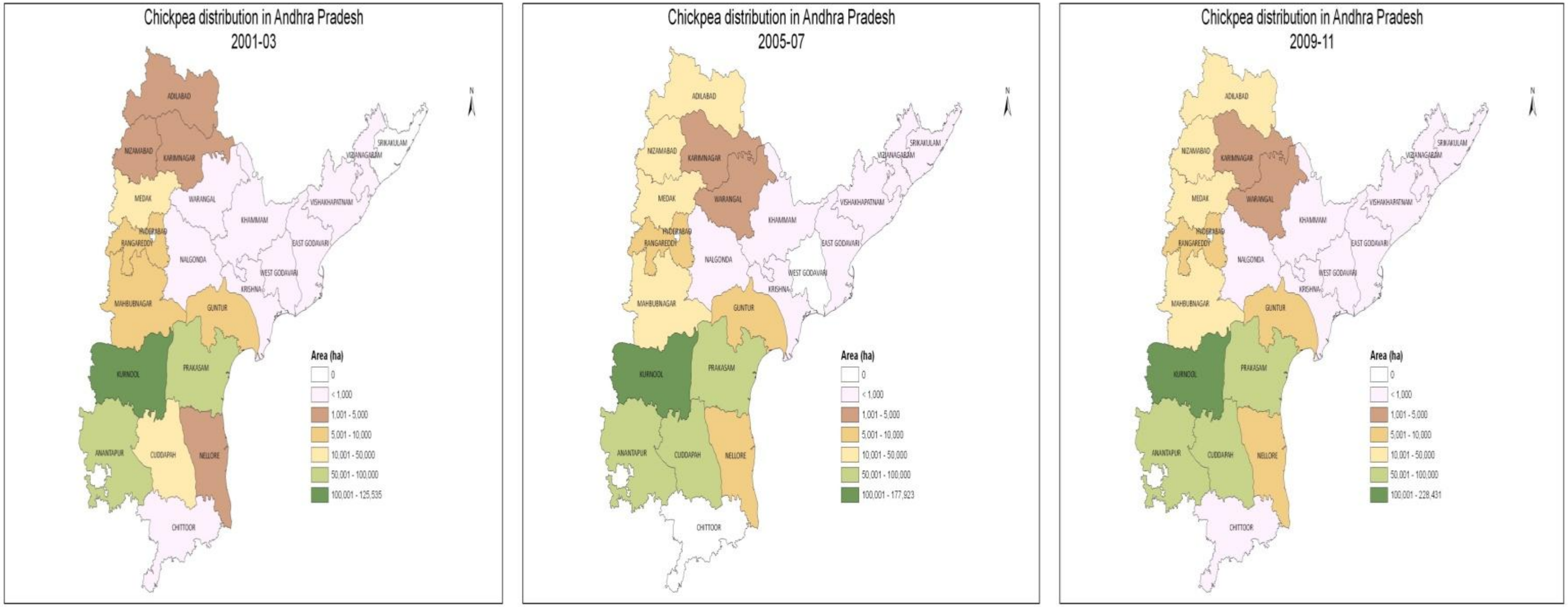


Table 11.1.3 Shifts in cropping pattern among major chickpea growing districts of Andhra Pradesh, 1991-93 to 2001-03 (% area)

Crop	Prakasam		Kadapa		Anantapur		Kurnool		Nizamabad		Mahabubnagar		Medak		Andhra Pradesh	
	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03	1991-93	2001-03
Rice	21.15	15.07	14.06	11.30	5.14	4.45	7.46	6.47	36.73	37.58	12.76	12.22	21.76	16.77	28.44	26.23
Wheat	0.00	0.00	0.02	0.01	0.03	0.02	0.06	0.10	0.45	0.53	0.02	0.02	0.54	0.64	0.07	0.10
Jowar	4.97	1.57	3.91	2.16	4.35	2.20	14.66	11.26	9.60	9.35	27.84	25.01	24.50	14.65	8.24	5.21
Bajra	4.19	2.64	1.01	0.95	0.50	0.19	1.79	1.40	1.11	1.40	1.78	1.91	0.52	0.16	1.31	0.86
Maize	1.58	1.65	0.02	0.01	0.10	0.53	0.07	0.32	18.28	16.57	0.32	2.00	15.14	18.07	2.42	4.57
Ragi	1.56	0.69	0.42	0.18	1.15	0.47	0.00	0.00	0.03	0.01	2.58	1.92	0.18	0.00	1.09	0.63
Other minor millets	2.62	0.37	0.22	0.05	0.76	0.10	4.11	1.82	0.00	0.00	0.63	0.43	0.09	0.03	1.16	0.42
Cereals sub total	36.06	22.00	19.67	14.66	12.04	7.97	28.16	21.39	66.21	65.46	45.93	43.51	62.73	50.32	42.74	38.02
Pigeon pea	5.01	11.43	1.84	4.48	2.48	3.26	2.11	3.34	0.91	0.84	4.80	5.22	2.68	3.89	2.49	3.74
Chickpea	0.76	11.02	1.15	10.96	0.84	4.90	2.45	14.02	1.06	1.05	0.22	0.45	2.81	5.47	0.55	2.99
Other pulse crops	5.07	11.03	0.14	1.26	1.24	0.58	0.44	1.88	7.20	7.83	4.73	5.84	10.54	19.19	9.38	10.18
Pulses sub total	10.84	33.47	3.13	16.70	4.56	8.73	5.00	19.25	9.17	9.73	9.75	11.51	16.04	28.55	12.42	16.92
Groundnut	10.63	1.20	57.94	29.08	72.71	70.67	33.51	21.02	2.40	2.36	20.56	17.18	1.76	0.82	18.65	12.69
Sesamum	2.49	1.96	0.84	0.88	0.02	0.00	0.08	0.02	0.38	0.36	0.15	0.14	0.54	0.41	1.34	1.11
Castor	4.13	2.40	0.25	0.61	0.23	0.23	0.08	0.84	0.04	0.03	11.72	14.12	0.42	0.63	2.17	2.20
Sunflower	0.89	2.41	5.67	18.73	2.84	5.94	15.31	19.45	2.36	2.12	4.60	4.22	2.68	0.91	2.53	3.20
Soybean	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.35
Other oilseed crops	0.63	0.28	0.07	0.03	0.48	0.31	0.43	0.31	0.66	0.71	0.49	0.51	1.59	1.45	0.45	0.35
Oilseeds sub total	18.78	8.27	64.77	49.34	76.28	77.15	49.40	41.66	5.85	5.59	37.52	36.17	6.98	4.22	25.17	19.91
Sugar cane	0.06	0.05	0.21	0.17	0.15	0.04	0.04	0.02	4.98	6.62	0.01	0.01	4.02	6.71	1.42	1.80
Cotton	8.39	5.68	1.40	3.82	1.28	0.66	8.16	6.34	4.38	4.10	3.88	5.53	2.15	1.80	5.80	7.49
Other crops	25.87	30.54	10.83	15.31	5.70	5.45	9.24	11.32	9.41	8.51	2.91	3.28	8.07	8.40	12.46	15.86
Other crops Sub total	34.32	36.26	12.43	19.30	7.13	6.15	17.44	17.69	18.77	19.23	6.79	8.81	14.24	16.91	19.68	25.15
Total cropped area	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Per cent shares in those respective states during that period.

Table 11.1.4 Shifts in cropping pattern among major chickpea growing districts of Andhra Pradesh, 2001-03 to 2008-10 (% area)

Crops	Prakasam		Kadapa		Anantapur		Kurnool		Nizamabad		Mahabubnagar		Medak		Andhra Pradesh	
	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10	2001-03	2008-10
Rice	15.07	20.47	11.30	13.27	4.45	4.95	6.47	12.67	37.58	37.72	12.22	13.18	16.77	20.58	26.23	30.75
Wheat	0.00	0.00	0.01	0.01	0.02	0.01	0.11	0.06	0.53	0.60	0.02	0.01	0.64	0.51	0.10	0.08
Jowar	1.57	0.82	2.16	1.59	2.20	2.76	11.26	6.54	9.35	8.61	25.00	21.36	14.65	6.59	5.21	2.24
Bajra	2.64	1.83	0.95	0.73	0.19	0.14	1.40	0.76	1.40	1.46	1.91	1.80	0.16	0.08	0.86	0.42
Maize	1.65	1.08	0.01	0.32	0.53	1.20	0.32	1.91	16.57	15.56	1.99	4.78	18.07	17.45	4.57	5.81
Ragi	0.69	0.21	0.18	0.03	0.47	0.24	0.00	0.00	0.01	0.00	1.92	1.44	0.00	0.00	0.63	0.34
Other minor millets	0.37	0.11	0.05	0.03	0.10	0.05	1.82	0.78	0.00	0.00	0.43	0.39	0.03	0.00	0.42	0.21
Cereals sub total	22.00	24.51	14.66	15.99	7.97	9.35	21.39	22.73	65.46	63.95	43.50	42.96	50.32	45.21	38.02	39.86
Pigeonpea	11.43	10.11	4.48	2.83	3.26	3.73	3.35	4.54	0.84	0.77	5.22	5.92	3.89	4.70	3.74	3.78
Chickpea	11.02	12.82	10.96	14.43	4.90	8.05	14.02	23.00	1.05	1.18	0.45	0.86	5.47	6.77	2.99	4.49
Other pulse crops	11.03	4.06	1.26	1.06	0.58	0.57	1.88	1.54	7.83	9.06	5.84	6.94	19.19	13.33	10.18	6.00
Pulses sub total	33.47	26.99	16.70	18.32	8.73	12.35	19.25	29.08	9.73	11.00	11.51	13.72	28.55	24.79	16.92	14.27
Groundnut	1.20	1.24	29.08	28.54	70.67	69.13	21.02	20.82	2.36	1.94	17.17	14.06	0.82	0.31	12.69	11.47
Sesamum	1.96	2.75	0.88	1.28	0.00	0.00	0.02	0.06	0.36	0.35	0.14	0.13	0.41	0.15	1.11	0.72
Castor	2.40	1.12	0.61	0.22	0.23	0.20	0.85	4.14	0.03	0.02	14.12	15.80	0.63	0.16	2.20	1.21
Sunflower	2.41	4.03	18.73	14.62	5.94	3.56	19.45	12.27	2.12	2.01	4.22	3.76	0.91	2.27	3.20	2.43
Soybean	0.00	0.00	0.00	0.01	0.00	0.06	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.55	0.35	1.04
Other oilseed crops	0.28	0.03	0.03	0.14	0.31	0.08	0.32	0.49	0.71	0.71	0.51	0.19	1.45	1.25	0.35	1.28
Oilseeds sub total	8.27	9.18	49.34	44.82	77.15	73.03	41.66	37.79	5.59	5.01	36.17	33.95	4.22	4.70	19.91	18.15
Sugar cane	0.05	0.04	0.17	0.08	0.04	0.02	0.02	0.15	6.62	7.19	0.01	0.00	6.71	5.04	1.80	1.33
Cotton	5.68	5.97	3.82	2.59	0.66	0.25	6.35	3.83	4.10	3.49	5.53	5.58	1.80	11.33	7.49	11.35
Other crops	30.54	33.31	15.31	18.21	5.45	5.00	11.32	6.43	8.51	9.35	3.28	3.79	8.40	8.92	15.86	15.04
Other crops sub total	36.26	39.31	19.30	20.87	6.15	5.26	17.69	10.40	19.23	20.03	8.81	9.37	16.91	25.29	25.15	27.73
Total cropped area	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: Per cent shares in those respective states during that period.

Crop shifts across major chickpea growing states

The summary details about major shifts in cropping pattern of main chickpea growing states are tabulated in Table 11.1.2. States like Madhya Pradesh, Karnataka, Maharashtra, Uttar Pradesh and Rajasthan represent more than 90 per cent cropped area of chickpea in India. In Madhya Pradesh, chickpea got adopted well and increased its share from 9.6 in early 1990s to 14.32 (1.5 times) per cent by the end of 2008-10. Rice, jowar and linseed lost their shares respectively and this area has been diverted to crops like soybean and chickpea. In case of Andhra Pradesh, the performance of chickpea increased significantly from 0.55 in early 1990s to 4.64 % (8.5 times) by the end of triennium 2008-10. It was a salient revolution in chickpea area in the state during short span of time. Jowar, pearl millet, groundnut, castor and other pulses (moong and urad beans) have replaced significantly with chickpea, rice, cotton and maize. The chickpea area share in Maharashtra has doubled during the last two decades (1990-2010). Cropped area under jowar, pearl millet, safflower, sunflower, groundnut and other pulses have given away to cotton, soybean and chickpea. The chickpea area share in the total cropped area in Karnataka has increased significantly from 1.91 to 7.02 per cent (3.5 times). Due to high risk and un-remunerative incomes in jowar, groundnut and sunflower cultivation, the dryland farmers switched over to chickpea, maize and pigeonpea. Typically, Uttar Pradesh has lost remarkable area under chickpea cultivation since early 1990s. Due to improved access to irrigation facilities and availability of Green Revolution technologies, farmers have intensified their cereal based cropping systems (rice and wheat) further. However, the area under other pulses (moong, urad, lentils and cowpeas) was much stable during the same period. Relatively, the chickpea area under Rajasthan was dwindling, gone down in early 2000 and increased by end of 2008-2010. This shifting may be due to climatic conditions/variations in Rajasthan. Except groundnut, all other crops was exhibited much stable pattern in Rajasthan between 1990 and 2010.

Crop shifts across major chickpea growing districts in Andhra Pradesh

The major shifts in cropping pattern across chickpea growing districts in Andhra Pradesh are summarized in Tables 11.1.3 (P1: 1991-93 to 2001-03) and 11.1.4 (P2: 2001-03 to 2008-10). To critically examine the shifts in cropping pattern, the study period has been divided in to two i.e., period1: 1991-93 to 2001-03 and period2: 2001-03 to 2008-10.

During the first period, the area under chickpea in Kurnool district has expanded from 2.45 to 14.02 (5.7 times) per cent in total cropped area (see Table 2.9). Sorghum, other minor millets, groundnut and cotton have lost their cropped areas and given way to chickpea cultivation. Chickpea area under Prakasam district has increased quite remarkably from 0.76 to 11.02 per cent (14.5 times) of the total cropped area. Chickpea has replaced sorghum, millets, groundnut and sesamum crops due to its high productivity, good remunerative prices and less risk in its cultivation. In the case of Kadapa, area under chickpea has increased nearly 9.5 times (from 1.15 to 10.96 %) during first period. Rice, sorghum and groundnut have been replaced by chickpea and sunflower significantly. Kurnool, Prakasam and Kadapa were ahead of all other districts in the adoption of the newly developed short-duration chickpea cultivars.

Anantapur is another major district which increased the chickpea cultivation significantly (from 0.84 to 4.90%) by sacrificing the areas from jowar and ragi crops. Nizamabad and Mahabubnagar districts did not respond well for short-duration chickpea cultivars between 1990 and 2000. The area coverage under chickpea in these districts was minimal. However, Medak district was a traditional chickpea grower and increased its area twice during the same period. Sorghum and rice allocated its area for expansion of chickpea in this district.

During the second period, the expansion pattern of chickpea area across seven districts is presented in Fig 11.1.1. Kurnool expanded its chickpea area to almost double by sacrificing the cropped areas from jowar and sunflower crops (see Table 2.10). But, the expansion was rather low in Prakasam district. However, chickpea replaced other pulse crops (moong and urad) significantly in the district due to its higher net incomes. The chickpea area growth in Kadapa was marginal (from 10.96 to 14.43 per cent) and it substituted sunflower crop significantly in the district. Expansion of chickpea in Anantapur district was slightly lower (from 4.90 to 8.05 %) during the last decade. Sunflower cropped area lost marginally and gave way to chickpea cultivation in the district. Nizamabad, Mahabubnagar and Medak districts have expanded their areas under chickpea by substituting mainly sorghum, groundnut and other pulses and sunflower.

Appendix 2: Extent of diffusion bounded by access to irrigation and beyond Andhra Pradesh

The penetration of crop started in two districts of Nizamabad and Adilabad were observed early 2000s but reached its peak are in 2008. It is noted that expansion may have been limited by the increased irrigation investments in these regions. Further diffusion of improved cultivars may also be anticipated even in the irrigated Krishna and Godavari rice dominated districts, where chickpea has a potential to grow immediately after rice cultivation (rice–chickpea cropping system). Nevertheless, the competitive advantage of chickpea over other crops or cropping systems significantly depends on the profitability of the chickpea *vis-a-vis* existing crops grown in the system.

Determination of the possible extent of area expansion is determined by re-examining some more details of the chickpea research domains. As discussed above, the research domain for chickpea production has been delineated by five variables: rainfall, temperature, soil type, latitude, and length of growing period. One variable that has not been considered, and may be an important factor, is the extent of irrigation as this variable likely influences the suitability and competitiveness of chickpea production in the region. Thus, available spatial maps and district level data were further analysed to explore the possible areas of expansion. In fact, further analysis of sub-district data (see Tables 11.2.1 and 11.2.2) may identify possible niches of non-irrigated vertisols where chickpea production may expand (also see Figs 11.2.3 and 11.2.4).

Traditional access to water in Andhra Pradesh is illustrated through the three river system – Godavari, Krishna and Penna - that flows through the state of Andhra Pradesh as shown in Figure 11.2.1. Investments in irrigation started in the 60s and continued to expand especially around these river systems as shown in the spatial distribution of the extent of irrigation, Figure 11.2.2. Complementary time series data on percent net cropped area indicates aggregated district level irrigation identifying that the specific districts where short duration chickpea has expanded are in the remaining rainfed regions of Andhra Pradesh which exactly corresponds to the 7 districts included in the sampling frame of this study. The expansion of chickpea production is shown to be possible but limited in the vertisol regions of Adilabad in the northwest Andhra Pradesh. Further expansion to Nizamabad (NW region of AP) is seemingly very limited due to the massive investments in the districts. Furthermore, the increasing urbanization of the districts of Medak, Rangareddy and Mahabubnagar (due to its nearness to the urban center of Hyderabad) presents alternative diverse options to agriculture and chickpea production. Nevertheless, this one large district of Adilabad, which is primarily vertisols remains to be primarily rainfed (only about 12-13 % net irrigated area which is almost similar to the % irrigation in chickpea growing district of Anantapur) presents viable opportunities for further expansion of chickpea production in Andhra Pradesh.

Fig.11.2.1 Three river systems flowing through the state of Andhra Pradesh

Fig. 11.2.2 Spatial distribution of surface water irrigation area in AP, 2010-12

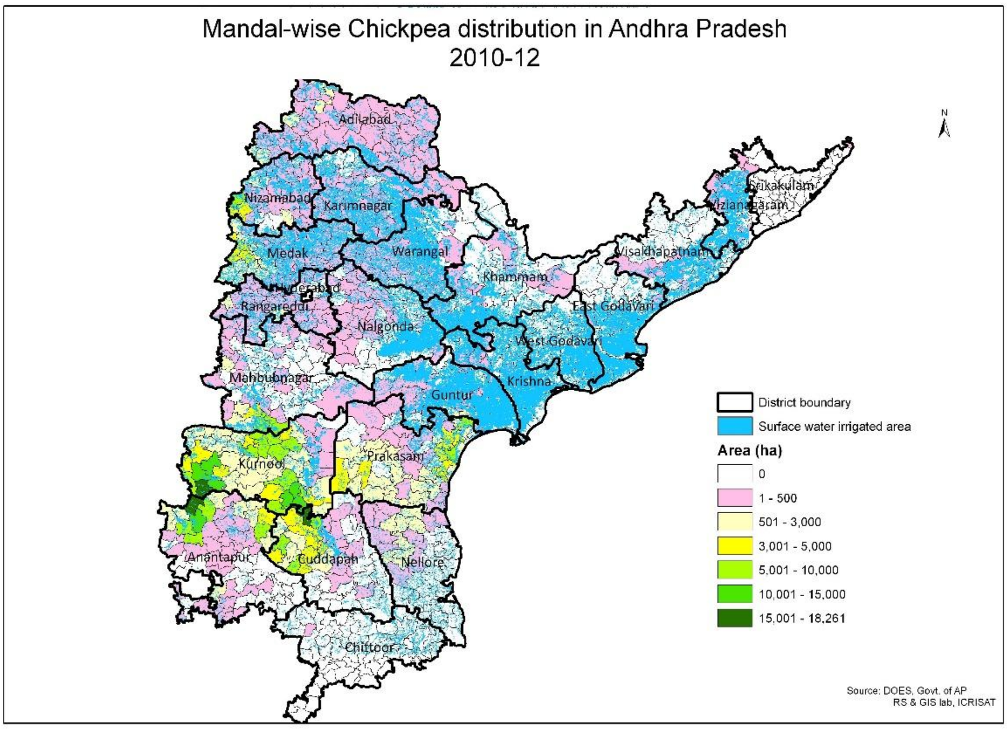


Table 11.2.1 Average % net irrigated area in Andhra Pradesh, 1966-2010

Region/District	1966-75	1976-85	1986-95	1996-05	2006-10
Irrig NE Andhra Pradesh	56.9	59.9	58.8	56.6	59.7
Irrig NW Andhra Pradesh	25.3	33.9	50.5	57.1	61.1
Irrig SE Andhra Pradesh	29.1	35.5	44.4	47.5	51.3
Rainfed Andhra Pradesh	13.8	16.3	19.8	23.2	26.5

Fig 11.2.3 Percent net irrigated area in four regions of AP, 1966-2010

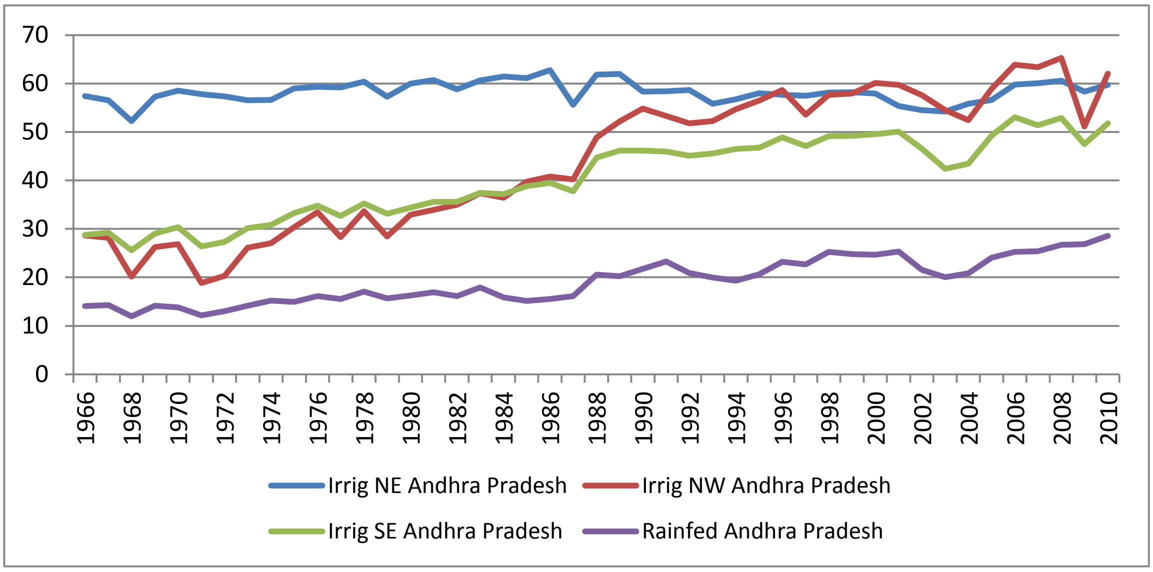
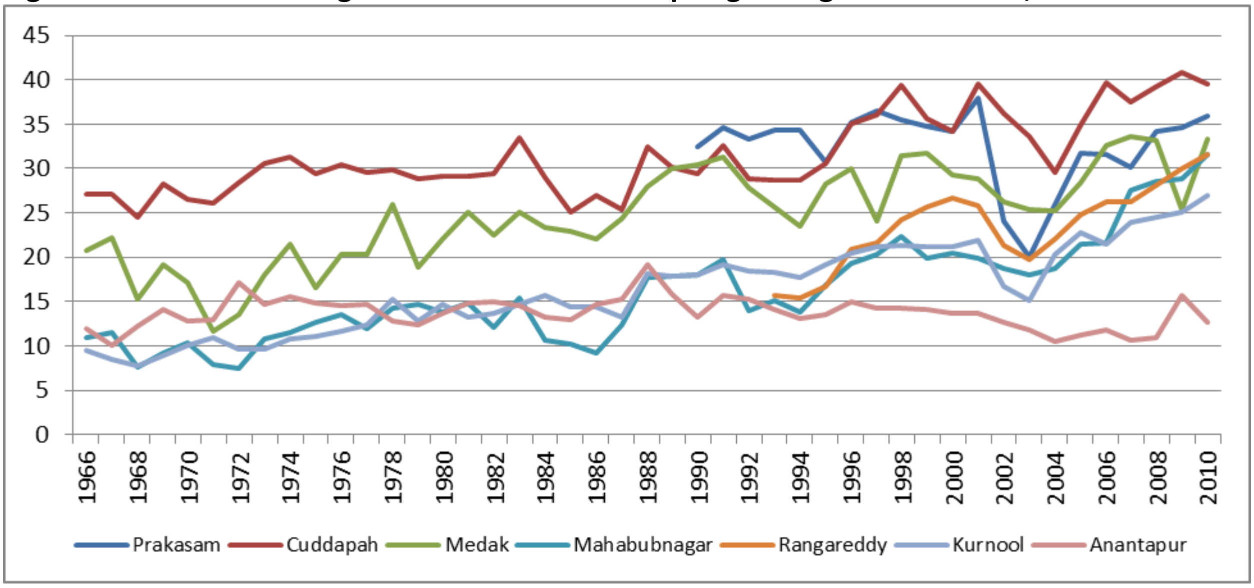


Fig 11.2.4 Percent net irrigated area in seven chickpea growing districts of AP, 1966-2010



The above scenario represents the specific situation for possible simulation in Chapter 7. In this case, it may be illustrated that the remaining rainfed vertisols of the state including the districts of Adilabad (which is currently classified under "rest of AP" may still expand its chickpea production from the current production of 71,300 tons of chickpea). This scenario considers that the increase in production is due to farmers increasing adoption of new improved varieties (JG 11, Vihar and/or

KAK 2) or farmers switching from non-chickpea crops. However, this situation may be limited to districts like Adilabad, Guntur, Nellore and Karimnagar where the area of chickpea production has increased in the mid-2000s but has already gradually declined henceforth.

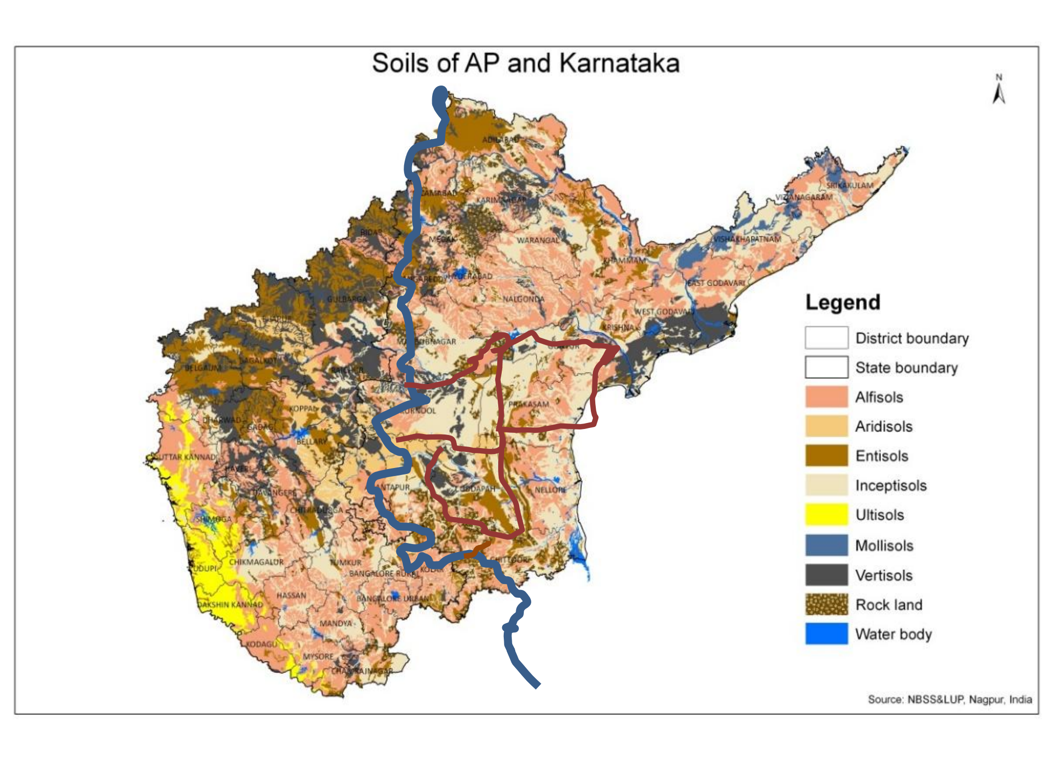
Table 11.2.2 District level percent net irrigated area in Andhra Pradesh, 1966-2010

District	1966-75	1976-85	1986-95	1996-05	2006-10
West Godavari	74.4	78.6	81.5	80.9	84.7
Krishna	63.2	68.2	70.1	65.7	65.4
East Godavari	61.7	64.3	62.8	64.3	67.1
Srikakulam	48.6	50.7	50.4	51.8	55.6
Visakhapatnam	36.7	37.7	38.5	35.6	38.4
Vizianagaram	24.1	-	42.3	41.2	46.9
Karimnagar	24.1	33.9	58.3	65.2	74.7
Nizamabad	37.7	47.8	55.1	62.4	61.7
Warangal	22.4	29.9	51.4	60.5	64.4
Khammam	16.9	24.1	37.2	40.4	43.8
Adilabad	5.5	7.2	10.2	14.1	13.3
Nellore	42.9	50.9	60.8	58.9	56.4
Nalgonda	19.2	27.5	33.6	37.9	52.0
Guntur	37.1	44.6	48.4	47.6	53.2
Chittoor	32.0	30.6	31.6	38.3	42.1
Prakasam	-	-	33.3	31.6	33.3
Cuddapah	27.9	29.4	29.4	35.4	39.3
Medak	17.6	22.7	27.1	28.1	31.6
Hyderabad	12.1	13.8	17.8	23.3	28.4
Mahabubnagar	10.0	13.1	15.5	19.9	27.6
Rangareddy	-	-	15.9	23.3	28.4
Kurnool	9.7	13.9	17.5	20.2	24.4
Anantapur	13.6	13.9	15.0	13.1	12.4

Diffusion across the borders of Karnataka and Maharashtra

Going beyond the boundaries of the state of Andhra Pradesh, Fig 11.2.5 presents the distribution of various soil types in the states of Andhra Pradesh and adjoining Karnataka. It is evident that while entisols and ultisols dominate, figure indicates that the extent of presence of vertisols is much higher in Karnataka state than the Andhra Pradesh.

Fig 11.2.5 Major soil types in Andhra Pradesh and Karnataka states



Spatial distribution of chickpea cropped area

The spatial distribution of chickpea area among the top three Southern states are depicted Fig 11.2.6 based on 2008-10 data. We can clearly conclude from the figure that chickpea has now become one of the pre-dominant post-rainy season crop in these states. Apart from Andhra Pradesh, the crop is well distributed in districts of Karnataka (Gulbarga, Bijapur, Dharwad, Raichur and Bagalkot) and Maharashtra (Ahmednagar, Beed, Latur, Osmanabad, Buldana, Akola, Washim and Aurangabad etc.). The crop spread is much more conspicuous in Maharashtra than Karnataka and Andhra Pradesh. However, Andhra Pradesh and Karnataka states completely fall under short-duration group (90-110 days) while part of Maharashtra belongs to medium maturing environment.

Fig 11.2.6 Chickpea area distribution in AP and neighbouring KN and MH

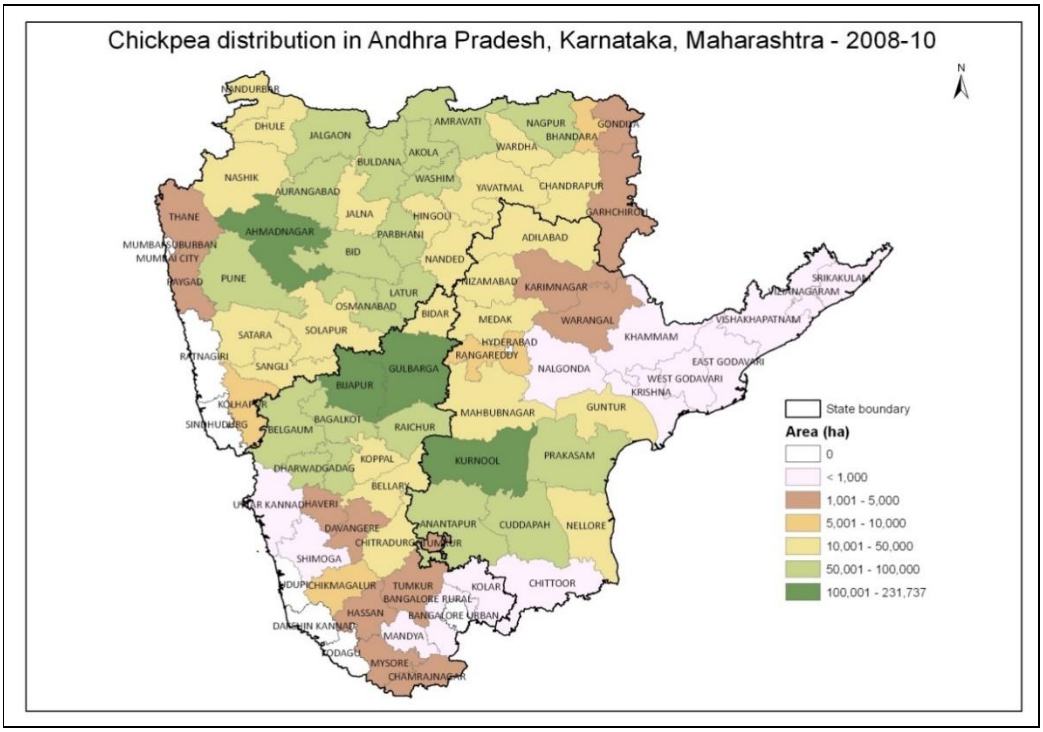
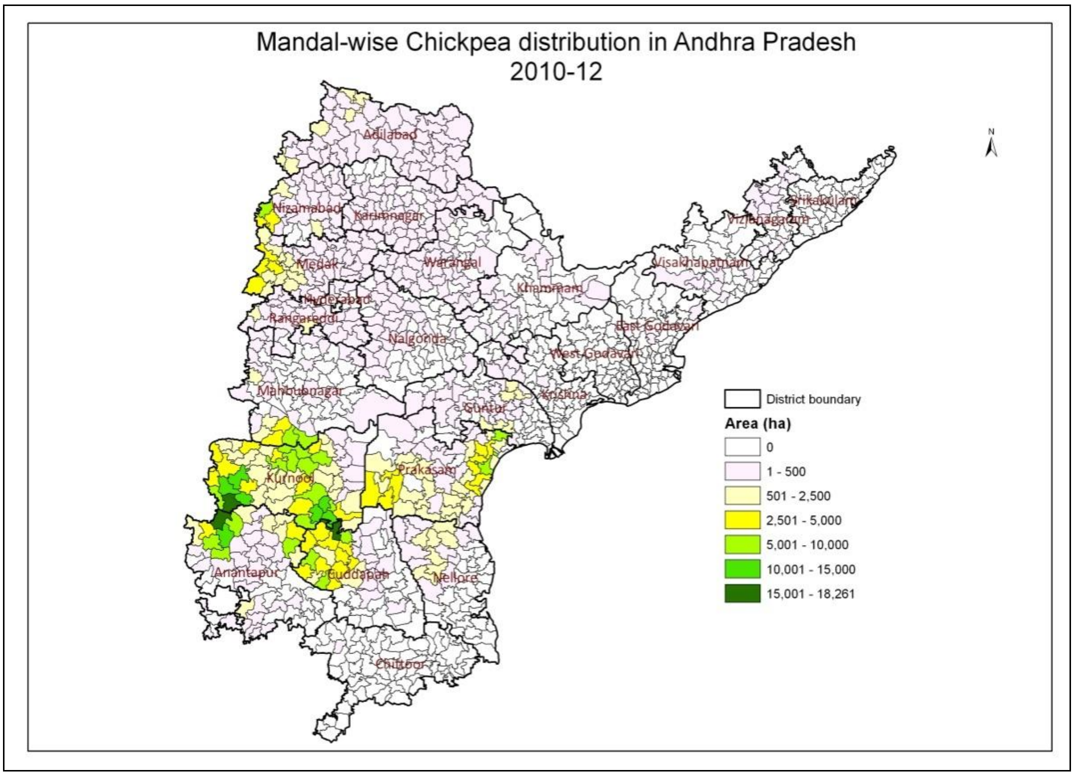


Fig 11.2.7 presents the mandal-wise distribution of chickpea crop in Andhra Pradesh for period 2010-12. Out of the total 1120 mandals from 23 districts of Andhra Pradesh, there are only 329 mandals having chickpea grown even in one ha. They are much concentrated (at least > 3000 ha) in Kurnool districts followed by Kadapa, Prakasam and Anantapur districts.

Fig 11.2.7 Chickpea area distribution by mandal-wise in AP: 2010-12



Appendix 3 : Characteristic features of major chickpea improved cultivars in Andhra Pradesh

Cultivar	Release year	Type	Duration	Flower color	Seed color	Seed size	Plant type	Resistance	100 seed weight (g)	Yield (Kg/ha)
Annigeri	1978	Desi	100	Pink	Yellowish brown	Round & medium size	Semi spreading	Resistant to wilt disease	16-20	988-1236
Jyoti	1978	Desi	110-120	Flower pink in color	Yellowish brown	Round, smooth and small in size (15-18g/100seeds)	Semi spreading, Plant height 40 cm	Resistant to drought	15-18	1000-1200
D-8	1982	Kabuli	145	White flower	Brown yellow	Medium , smooth seed surface, round in shape	-	Suitable for perching purpose	15	1200-1400
ICCV-32	1984	Kabuli	135	-	-	Seed medium bold	-	Resistant to wilt, tolerant to root rot and pod borer	-	2600
ICCV-10 (Bharati)	1992	Desi	110	-	-	-	Semi erect ,long fruiting branches, 32-68 cm plant height	Resistant to fusarium wilt and tolerant dry root rot & less susceptible to pod borer	-	1800-2000
Swetha (ICCV-2)	1993	Kabuli	85	White flower	Creamy white	Medium bold seed	50-60 cm	Resistant to fusarium wilt	24-26	1200-1300
JAKI 9218	1997	Desi	120	-	-	-	-	Resistant to wilt and root rot	-	1800
JG-11	1999	Desi	97	Dark pink	light brown	Very bold and smooth	Semi spreading	resistant to wilt, moderately resistant to root rot and stunt, tolerant to Helicoverpa pod borer	22.5-24	1483-1730
KAK2	1999	Kabuli	90-110	white flower	-	bold seeded	Plant medium tall and bushy, semi spreading	Resistant to wilt	34-38	1977-2100
Kranthi (ICCV-37)	2001	Desi	90-100	Pink (red-purple)	Light brown	Angular, ream's head, smooth	Plants dwarf , semi- erect	Resistant to wilt and root rot	18.6	1600-2000
Vihar	2002	Kabuli	105-110			Large seeded		resistant to wilt	32-34	1853-1977
Digvijay	2005	-	105-110	-	Yellowish brown	Large seeded	-	Wilt resistant variety	-	1800-1900
LBeg-7	2006	Kabuli	early	-	Pearly white	bold seeds	Plant 40-60 cm height	-	32-34	-
N Beg -3	2012	Desi		-	-	-	-	Tolerant to drought and heat	-	-

Source: Various CVRC Reports, Government of India

Appendix 4: ICRISAT Chickpea global releases across different countries

ICRISAT Code	Pedigree	Developed at	Year	Country of release	Release name
ICC 4923	Jyothi		1978	India	Jyothi
ICC 8521			1980	USA	Aztee
ICCV 1	II 208X T3	Patancheru	1983	India	ICCC 4
ICC 13816			1984	Algeria	Yialousa
ILC 3279 (ICARDA)	ICC19418		1984	Cyprus	Yialousa
ICC 13816			1984	Cyprus	Yialousa
F-378 x F-496	F-378 X F-496	Patancheru	1984	India	Anupam
Selection from ICCX-730089	K 850 x F 378	Patancheru	1985	Ethiopia	Mariye
Selection from ICCX-730085	L 550 x L 2	Patancheru	1985	India	GNG 149
ILC 72 (ICARDA)	ICC12961		1985	Spain	Fardan
ILC 200 (ICARDA)	ICC12965		1985	Spain	Zegri
ILC 200 (ICARDA)	ICC12965		1985	Spain	Atalaya
ILC 2548 (ICARDA)			1985	Spain	Almena
ILC 2555 (ICARDA)			1985	Spain	Alcazaba
ICCL 83110	(K 850x T3)x(JG 62 x BEG 482)	Patancheru	1986	Kenya	ICCL 83110
ICC 552			1986	Myanmar	Yezin 1
ICC 4994			1986	Myanmar	Keyhman
ICC 4951			1986	Myanmar	Yezin 2
Selection from ICCX 730089	K 850 x F 378	Patancheru	1986	Myanmar	Schwe Kyehmon
ILC 482 (ICARDA)	ICC11879		1986	Syria	Ghab 1
ILC 3279 (ICARDA)	ICC19418		1986	Syria	Ghab 2
FLIP 83-46C (ICARDA)			1986	Tunisia	Kassab
Be-Sel-81-48 (ICARDA)			1986	Tunisia	Amdoun 1
ILC 3279 (ICARDA)	ICC19418		1986	Tunisia	Chetoui
ICC 11879			1986	Turkey	
ICC 14911			1986	Turkey	
ILC 195 (ICARDA)	ICC14911		1986	Turkey	ILC 195
ILC 482 (ICARDA)	ICC11879		1986	Turkey	Guney Sarisi 482
ICCL 81248	P 481 x (JG 62 x P1630)	Patancheru	1987	Bangladesh	Nabin
ILC 464 (ICARDA)	ICC17410		1987	Cyprus	Kyrenia
ILC 72 (ICARDA)	ICC12961		1987	Italy	Califfo
ILC 3279 (ICARDA) - ICC 13816	ICC19418		1987	Italy	Sultano
ICC 11879	ICC11879		1987	Morocco	
ICC 14911			1987	Morocco	
ILC 195 (ICARDA)			1987	Morocco	ILC 195
ILC 482 (ICARDA)	ICC11879		1987	Morocco	ILC 482
ICC 6098			1987	Nepal	Radha
ICCV 1	II 208X T3		1987	Nepal	Sita
ILC 1335 (ICARDA) - ICC 8649			1987	Sudan	Shendi
ICC 11879			1988	Algeria	
ILC 482 (ICARDA)	ICC 11879		1988	Algeria	ILC 482
ILC 3279 (ICARDA)	ICC19418		1988	Algeria	ILC 3279
ILC 202 (ICARDA)	ICC11874		1988	China	ILC 202
ILC 411 (ICARDA)	ICC18040		1988	China	ILC 411
ILC 482 (ICARDA)	ICC11879		1988	France	TS 1009
FLIP 81-293C (ICARDA)			1988	France	TS 1502
ILC 237 (ICARDA)			1988	Oman	ILC 237
ILC 482 (ICARDA)	ICC11879		1989	Lebanon	Janta 2
ILC 5566 (ICARDA)			1989	Portugal	Elmo
FLIP 85-17C (ICARDA)			1989	Portugal	Elvar
ILC 482 (ICARDA)	ICC11879		1990	Jordan	Jubeiha 2
ILC 3279 (ICARDA)	ICC19418		1990	Jordan	Jubeiha 3
ICCL 82108	(JG62 x WR 315)x (p 1363-1 xPRR 1)	patancheru	1990	Nepal	Kalika
ICCC 32/ ICCV 6	L550x L2	Patanchru	1990	Nepal	Koselee **(K)**
FLIP 85-7C (ICARDA)			1990	Turkey	Damla 89
FLIP 85-135C (ICARDA)			1990	Turkey	Tasova 89
FLIP 84-79 C (ICARDA)			1991	Algeria	FLIP 84-79 C
FLIP 84-92C (ICARDA)			1991	Algeria	FLIP 84-92C
Selection from ICCX-730167	JG 62 X F 496	Patancheru	1991	India	RSG 44
ILC 482 (ICARDA)	ICC11879		1991	Iraq	ILC 482
ILC 3279 (ICARDA)	ICC19418		1991	Iraq	ILC 3279
FLIP 84-92C (ICARDA)			1991	Morocco	FLIP 84-92C
FLIP 82-150 C (ICARDA)			1991	Syria	Ghab 3
FLIP 84-92C (ICARDA)			1991	Tunisia	FLIP 84-92 C
FLIP 84-79C (ICARDA)			1991	Tunisia	FLIP 84-79C
87AK 71115			1991	Turkey	Akcin

ICCV 10	P1231 x P1265	Patancheru/ india	1992	India	Bharati (ICCV 10)
ICC 6304			1992	Portugal	ICC 6304
ICCV 10	P1231 x P1265	Patancheru	1993	Bangladesh	Barichhola - 2
ICCL 83105	(K 850x T3)x(JG 62 x BEG 482)	Patancheru	1993	Bangladesh	Barichhola - 3
ICCL 82104	(Annegeri x Chaffa) x (Rabat x F 378)	Patancheru	1993	Ethiopia	Worku Golden
ICCV 2	[(K 850 x GW 5/7)x P458]x (L550x Guamuchal]	Patancheru	1993	India	Swetha (ICCV 2)
ICCL 79096	(JG62 x F 496)	patancheru	1993	Pakistan	DG 92
ICC 4998			1994	Bangladesh	Bina-Sola 2
ICCV 92809	(BDN 9-3 x K 1184)x ICP 87440)	Patancheru	1994	USA	Myles
ICCL 82106	(P 99x NEC 108) X Radhey	Patancheru	1995	Ethiopia	Akaki
ICCL 87207	K850 x ICCL 80074	Patancheru	1995	India	Vishal
ICCL 85222	HMS 10 x (P 436 x H 223)	Patancheru	1996	Bangladesh	Barichhola - 4
ICCL 83149	(G 130 x B 108) x NP 34 x GW 5/7)	Patancheru	1996	Bangladesh	Barichhola- 6
ICC 14880			1997	Australia	Heera
ICCV 88202	PRR1 x ICCC1	Patancheru	1998	Australia	Sona
ICC 5035			1998	Portugal	Elite
ICCV 2	[(K 850 x GW 5/7)x P458]x (L550x Guamuchal]	Patancheru	1998	Sudan	Wad Hamid **(K)**
ICCV 89509	(L550 x Radhey)x (K 850 x H 208)	Patancheru	1998	Sudan	Atmor **(K)**
ICCV 91302	ICCC32 x (K 4 x Chaffa)	Patancheru	1998	Sudan	Burgeig **(K)**
ICCV 92318	ICCC2 x Surutato 77)X ICC 7344)	Patancheru	1998	Sudan	Hawata **(K)**
ICC 3274			1999	Bangladesh	Barichhola - 7
ICCV 88003	(K 4 x chaffa)x ICCL 81001)	Patancheru	1999	Bangladesh	Barichhola - 8(k)
Selection from ICCX-820065	JG 1258 x BDN 9 - 3	Patancheru	1999	India	GG 2 (GCP 107)
ICCV 93958	ICCC 42 X ICC 12237	Patancheru	1999	India	CO 4
ICCV 93954	[(Phule G 5 X Narsinghpur bold) X ICCC 370) ICCX-860263-BF-BP-91-BP	Patancheru	1999	India	JG 11
ICCX-810800-3H-BW-1H-1H-BW	(GL829 xILC202) selection from ICCX-810800-	Patancheru	1999	India	Himachal Chana 1
Selection from ICCX-840429	ICC C 32 x (Pant G-114 x GL 629)	Patancheru	1999	India	L 551
		Patancheru	1999	India	HPG 17
ICCV 92311	(ICCV 2 x Surutato 77)X ICC 7344	Patancheru	1999	India	PKV Kabuli 2 (KAK 2)
ICCV 93512	ICCC33 x [L144 x E 100 Y (M)	Patancheru	2000	Ethiopia	Sasho (K)
Selection from ICCV 91106	SELECTION FROM G . P ICCV - 91106 .	Patancheru	2000	India	Vaibhav
ICCV 89314	ICCL80074 X ICCC30	Patancheru	2000	India	Dilaji
Selection from ICCX-870105	ICCL 84224 X Annegeri	Patancheru	2000	India	GG4 (GCP 105)
ICCV 2	[(K 850 x GW 5/7)x P458]x (L550x Guamuchal]	Patancheru	2000	Myanmar	Yezin 3 **(K)**
ICCV 88202	PRR1 x ICCC1	Patancheru	2000	Myanmar	Yezin 4
ICCC 37	P481x(JG62 x P1630)	Patancheru	2001	India	Kranthi (ICCC 37)
ICCV 95418	ICC - 7676 X ICCC - 32) X (ICCC - 49 X FLIP 82 - IC) X ICCV - 3)	Patancheru	2001	India	Virat
ICCV 96970	(ICCC42 X ICCCV88506)X (KPG 59 X JG74)	Patancheru	2001	India	JG 16
ICCV 94954	ICCC 42 x BG 256	Patancheru	2002	India	JG 130
ICCV 95311	(ICCC32 X ICCL 8004)XICCC-49 XFLIP-82-8C)XICCV3	Patancheru	2002	India	Vihar (Phule G 95311)
ICCV 92337	(ICCV2 X Surutato 77)X ICCV7344)	Patancheru	2002	India	JGK 1
ICCV 90201	GL769 X P919	Patancheru	2003	India	Himachal Chana 2
	ICCV 2 x Surutato 77	Patancheru	2003	India	HK 98-155
ICCV 92318	(ICCV 2 x Surutato 77) x ICC 7344		2004	Ethiopia	Chefe
Selection from ICCX-860263	(Phule G-5 x Narsingpur Bold) x ICCC 37	Patancheru	2004	India	JG 412
ICCV 3	[(K 850 x GW 5/7) x P 458] x (L 550 x Guamuchil)		2004	Myanmar	Yezin 5
ICCV 92944	(GW 5/7 x P 326) x ICCL 83149	patancheru	2004	Myanmar	Yezin 6
ICCV 96836	(BDN 9-3 x K 1184) x ICP 87440		2005	Australia	Genesis 836
ICCV 92033	Annigeri x((Annigeri x ICC 506-EB) x (Annigeri x ICC 12237))	patancheru	2005	Ethiopia	Kutaye
ICCV 88202	PAR1 XICCC1	Patancheru	2005	India	Pratap Chana 1
Selection from (Annigeri x ICCV 6)	Derivative from cross of Annegiri x ICCV 6	Patancheru	2005	India	BDNG 797
ICCV 92006	(GW 5/7 x ICCC 37) x ICC 12271		2006	Ethiopia	Mastewal
ICCV 92069	(K 850 x JG 62) x [((Annigeri x (JG 62 x F 496)) x WR 315]		2006	Ethiopia	Fetenech
ICCV 14808		Patancheru	2006	Ethiopia	Yelbey (K)
ICCV 96329	(ICCL 81001 x ICCC 32) x [(ICCC 49 x FLIP 82-1C) x ICCV 3]	Patancheru	2006	India	L BeG 7

ICCV 95332	(ICC32 X L144)X ICCC49X FLIP 82-16C)X ICCVX3)	Patancheru	2006	India	JGK 2
ICCV 95334	[(ICCV 2 x Surutato 77) x ICC 7344] x Blanco Lechozo	Patancheru	2006	India	JGK 3 (JSC 19)
ICCV2 x ICCV5	ICCV 2 x ICCV 5	Patancheru	2006	India	BGD 128
selection from ICC X-910112-6	(ICCV 88102 x ICCV 10) x ICC 4958		2007	Ethiopia	Natoli
ICCV 93952	(ICCC37 XGW5/7)XICCV107	Patancheru	2007	India	JAKI 9218
ICCX-880203	(ICCV 10 x K 850) x (H 208 x RS 11)	Patancheru	2008	India	JG 6 (JSC 6)
ICCV 92944	[(GW5/7XP327)XICCL83149}	Patancheru	2008	India	JG 14
		Patancheru	2008	India	BGD103**
ICCX-840508-36	Dhanush x K 850		2008	Nepal	Tara
ICCV 96325	[(ICCV2XICCV88507)XICCV42}XICC7344	Patancheru	2009	India	IPCK 2004-29 (K)
		Patancheru	2009	India	KRIPA (K)
Chania Desi 1	ICCV 10 x GL 769	patancheru	2009	Kenya	ICCV 97105
Saina K1	(ICC 7676 x ICCC 32) x [(ICCC 49 x FLIP 82-1C) x ICCV 3]	patancheru	2009	Kenya	ICCV 95423
LDT 068	IG 9216 x ICCV 10	patancheru	2009	Kenya	ICCV 00108 **
LDT 065	ICCV 5 x ICCL 83007	patancheru	2009	Kenya	ICCV 00305**
ICCV 00108			2009	Kenya	
ICCV 00305			2009	Kenya	
			2009	Myanmar	Yezin 7
ICCV 97314	(ICCL 81001 x ICCC 32) x [(ICCC 49 x FLIP 82-1C) x ICCV 3]	patancheru	2009	Myanmar	Yezin 8 **(K)**
ICCV 03107 (desi)	(ICCV 92065 x ICCV 88202) x KW 118		2010	Ethiopia	Minjar**
	selection from local germplasm	Patancheru	2010	India	IPCK 02 (K)
	selection from local germplasm	Patancheru	2010	India	MNK-1**
ICCV 95318 (Kabuli)	ICCV 2 x ICC 7344	patancheru	2011	Bangladesh	Barichhola - 9 (K)
ICCV03402	GNG 1044 x [(L 550 x L 2) x Surutato 77]		2011	Ethiopia	Akuri
Sel. From ICCX-920215 (desi)	(ICCV 91902 x ICCV 10) x ICCV 89230	Patancheru	2011	India	RVG 101
		Patancheru	2011	India	RVG 201
ICCV 92944	(GW 5/7 x P 326) x ICCL 83149	patancheru	2011	Kenya	ICCV 92944
ICCV 97126	ICCC 42 x ICCV 10		2011	Kenya	ICCV 97126
ICCV 00302			2011	Kenya	NPT
ICCV 00108 (desi)	IG 9216 x ICCV 10		2011	Tanzania	Mwanza 1**
ICCV 00305 (kabuli)	ICCV 5 x ICCL 83007		2011	Tanzania	Mwanza 2**
ICCV 92318 (Kabuli)	(ICCV 2 x Surutato 77) x ICC 7344		2011	Tanzania	Mwangaza**
ICCV 97105 (desi)	ICCV 10 x GL 769		2011	Tanzania	Ukiriguru 1**
		Patancheru	2012	India	RVG 203
Selection from Annigeri X ICC 4958	Annigeri XICC 4958	Patancheru	2012	India	Nanghyala sanaga 1(N BeG 3)
ICCX-000006	ICCV 2 x Bhawanipatna Local	Patancheru	2013	India	Birsa Chana-3
*** Tropical Legumes-II project releases*					

Source: ICRISAT Germplasm Unit and personal communication from BV Rao and Thimma Reddy

Appendix 5: Insights from focus group meetings (FGMs) and field observations

Insights on the chickpea research domain

1. Chickpea requires cooler climates (< 35^{o} C) and can only be grown in post-rainy (rabi) conditions. Deep to medium or light textured black cotton soils are most suitable for cultivating chickpea as this crop grown in the post-rainy season depends on the moisture remaining in the soil. Red, sandy and chalky soils are not found to be suitable for chickpea cultivation.

2. Since it is a post-rainy season crop, the performance of chickpea is highly influenced by rainfall of that region. The distribution of rainfall also influences the productivity significantly. The annual average normal rainfall of the study districts ranges from 600 to 1000 mm. The highest normal rainfall was recorded in Nizamabad followed by Medak, Prakasam and Kadapa districts. The average normal rainfall for Kurnool and Mahabubnagar districts was around 600-650 mm. The lowest annual normal rainfall of 550 mm was observed in Anantapur district. It was observed that the risk of crop failure due to lack of moisture for the cultivation of chickpea was highest in Anantapur districts, followed by Kurnool and Mahabubnagar.

Cropping system in AP

3. Chickpea is mostly grown as a sole crop in Andhra Pradesh. It was observed to be used as inter-crop only in Medak district (with safflower in 9:1 ratio).

4. Crops like sorghum, tobacco, groundnut, redgram, cotton, coriander and sunflower were dominant crops during 1990s in most of the mandals and study districts. Through the years, chickpea has replaced these crops because of the following reasons:
    1. The new chickpea cultivars provided a short-duration crop
    2. Chickpea cultivation is less-labour intensive
    3. Relatively low investment per acre is needed
    4. Viewed as a less risky crop
    5. Assured yields, market and good remunerative price of chickpea crop
    6. Highly suitable for mechanical operations
    7. Lower pest problem
    8. Improves soil fertility
    9. Can easily cultivate in large-scale

Farm size and land utilization

5. By and large, a large proportion of the farmers in the 90 study villages are chickpea growers, with plot areas ranging from very small (about 1 acre) to very large (about 100 acres). The remaining farmers who are not growing chickpea in these villages indicated that they are not growing chickpea because the soils were not suitable (e.g. red, sandy and chalky soils) or lack of access to irrigation facilities.

    So, based on a random sample of 90 villages representing current chickpea farmers, the following questions may be resolved: Has the ceiling level of adoption been reached? How much of the vertisols is currently covered? Are there other factors that must be considered which determine the limits of the chickpea crop production in Andhra Pradesh (for example, irrigation)? Or other factors explain other crop diversification options? GIS may estimate % of cropped area is vertisols; vertisols/unirrigated – which may be the potential boundary of applicability. Or other variables may be realized to explain why the maximum possible adoption level has actually been reached.

6. Initial results show that while nearly 55 per cent of the total cultivable area in these villages is under chickpea cultivation (and the rest of the area remains under traditional crops - cotton, sorghum, groundnut, tobacco, soybean, paddy, etc), it is notable that about 72 per cent of total black soil (vertisols) area in the study villages covered is now grown to chickpea.

7. The chickpea cropped area in the sample villages were found to increase nearly seven times between 1997 and 2002. This expanded nearly four times during the period 2003 and 2007. After this period of rapid expansion, chickpea area further doubled in later years (from 2008 to 2011).

8. The average land holding sizes of chickpea growers were found to be much higher in Prakasam and Kurnool districts (15-20 acres); and this is followed by Kadapa (10-12 acres) and Anantapur (5-8 acres) districts.

9. In most of the mandals, the area under chickpea was very low even up to the late 1990s. Adoption of chickpea as a crop through the introduction of short duration improved varieties picked-up significantly since early 2000s. Phenomenal increase in area was observed after getting access to JG-11 variety seeds and facilitated distribution by the Agricultural Department. Much of the awareness about this variety started in 2004 onwards.

10. In general, farmers in most of the study districts have very good awareness about chickpea improved cultivars and their features. Nearly 80 percent of the farmers knew about the cultivar they were growing. There were two districts, however, where the awareness of improved cultivars was still very low, i.e. Medak and Nizamabad districts.

11. During the survey implementation, the experimentation of the 'Varietal Identification Protocol' actually facilitated the process of obtaining more accurately the information about specific varietal adoption and other related information.

12. Up to the late 90s, most of the farmers used to grow a chickpea variety called Annigeri (released in 1978). Farmers report that they used to get an average yield of 725 to 967 kg per ha. But after shifting to JG-11 and other improved cultivars, the average yields were reported to increase to 1450 to 1934 kg per ha. In some mandals, the best yields were recorded as high as 2417 to 2900 kg per ha under favourable climatic conditions.

13. The two major desirable traits of JG 11 reported by farmers when they compared this to Annigeri are: higher productivity and wilt resistance.

14. Based on the focus group meetings, it seems that a very large proportion of the chickpea area is under improved cultivars. The most progressive Prakasam district is dominated by *kabuli* varieties (around 60%) while the rest of the district's chickpea growing area is planted to JG-11 (*desi* type). The older variety Annigeri was found in the villages of Nizamabad and Medak districts.

15. By and large, the survey team reckon that nearly 85 per cent of chickpea area in the whole state is under JG-11. It is the single largest variety occupying major proportion of chickpea area across different districts. JG-11 is followed by KAK-2, Vihar, Dollar or Bolt, JAKI-9218, and N Beg-3, in that order.

16. It is observed that about 50-60 per cent of seed requirement of the farmers in the villages is met by their own sources and the remaining 30-40 percent is procured from market sources. Most farmers procure seeds from the Department of Agriculture or from farmers and traders from other locations.

17. Most of the farmers buy new seed only once in three years.

18. Chickpea productivity per ha has nearly doubled after the introduction of short-duration improved cultivars.

19. The average chickpea yields in the state are 1450 to 1934 kg per ha and it varies across districts. The highest yields were observed in Prakasam district – ranging from 2175 to 2900 kg per ha. The average yield levels were only 967 to 1209 kg per ha in Kurnool and Anantapur districts because of the drought during 2011-12 season. Between these two extremes, the yields in the Nandyal region of Kurnool and Kadapa districts were between 1692 and 2175 kg per ha. The impact of drought was obvious as reflected in the chickpea yields during the 2011-12 drought striken rabi season.

20. The farmers' average expectation of yield was 2417 kg per ha. They also anticipate a market price of Rs.50 per kg. As long as these conditions on yield and price are met, farmers indicate that they will continue to grow the chickpea crop. Otherwise, they will look for alternative crops like maize, foxtail millet, Azwan, among alternative options.

Summary on demographics

21. The average farm family size in the study districts is between 4 and 6. More joint families were observed in Kurnool district when compared to other study districts. A maximum of two family members per household are participating in agriculture.

22. Usage of bullocks in crop cultivation has reduced significantly. Mechanization (usage of tractors) has increased in agriculture right from land preparation to threshing and transportation. With increasing labour scarcity, wage rates have gone up enormously during the last five years.

23. Most of farmers depended on formal sources of credit for cultivation in sample districts. A decade ago, they tended to rely more on the informal sector.

Insights on some dimensions of outcomes and impacts

24. The impact on farmers' welfare of short-duration chickpea technology especially after introduction of JG-11 is initially assessed qualitatively. Most of the farmers expressed that they are better-off now when compared to ten years back. Renovating the houses, education of children, marriages of children, purchase of lands, purchase of gold, among others were

reported to be some of the investments made by farmers as a result of increased income from growing chickpea during the last ten years.

25. There exists no regulated market for chickpea in Andhra Pradesh. As a consequence, the sample farmers reported that most of them sell their output to middlemen or traders within the villages. But in more progressive districts of Prakasam and part of Kurnool districts where farmers have good access to cold storage facilities, they are able to avoid the distress sales and are able to benefit from more remunerative prices.

26. With the chickpea revolution brewing in the chickpea growing districts of AP, the leased-in land values have gone-up very significantly. These values were highest in Prakasam district followed by Kurnool district.

27. Role of women in chickpea cultivation is critical especially for sowing, weeding and harvesting operations. But, because of increased mechanization opportunities, their role has been slowly going down.

28. When asked what traits of chickpea improved cultivars they wish to be available in the future, respondent farmers clearly mention the following:
    - high yielding with drought and mid-season fog resistant types
    - tall & erect plant types with mechanical harvestable cultivars
    - disease resistant particularly for dry root rot and wilt
    - high fodder quality types which are more suitable to animal feeding

29. To sustain the chickpea area in the state and study regions, farmers gave the following additional requirements:
    - More drought resistant cultivars yielding around 2417 kg per ha
    - Stable market price is important, noting the price decline during 2012-13
    - Coverage of crop insurance for chickpea
    - Control of wild pigs and deers
    - Better storage and value addition facilities for chickpea

30. The farmers in the study districts showed their willingness to pay more for seeds over the base price if the new cultivars have the desired traits. This premium price ranges from 25-50 per cent more per kg of seeds based on specific desired traits.

Appendix 6: Decision tree protocol for identification of chickpea cultivars

Farmer name: ....Village:.................................... I.D.no...........................

(Note: If farmer is growing both desi and kabuli types, fill two forms separately for desi and kabuli types. After identification of variety, pl. Round-off the name of variety)

1. Type of chickpea variety: Local, desi and kabuli?

No	Question
1	Which chickpea variety did you grow last year? ....
2	2.1 Which type of chickpea variety it was (desi/kabuli)? .... 2.2 What was the flower colour of the variety (white/purple)? .... 2.3 What was the seed coat colour (yellowish brown/ white seeded)? .... 2.4 What was the foliage colour (dark green/light green)? .... 2.5 What was the plant type (erect/bushy)? ....
3	3.1 IF answers are **white** seeded, **erect** plant type with **light green** foliage and **white** flowers→CLASSIFY as**KABULI**varietyandgo to**QUESTION 4** 3.2 IF answers are **yellowishbrown** seeded**,**bushy plant type with dark green foliage and purple flowers → CLASSIFY as **DESI**varietyandgo to **QUESTION 5**
4	Does the cultivar feature:short duration (95-110 days), spreading, large size &owl headed seeds? IF **YES**, → CLASSIFY as **KAK-2 Variety**(no more questions) IF **NO**, → CLASSIFY as **VIHAR** (if it has medium maturity (105 to 110 days), little upright, medium size seeds) **Otherwise**→ CLASSIFY as **Dollar (Bold non descriptive)** (if it has **extra large** size seeds)
5	How long you have been growing this **desi same chickpea variety**? (> 10 years / < 10 years) IF ANSWER is> 10 years→CLASSIFY as**ANNEGIRI**variety(no more questions) IF ANSWER is< 10 years, go to QUESTION 6

2. Which improved desi variety of chickpea?

No	Question	
6	Does the crop mature in <**100 days**, pink flowers and less angular seeds? (Yes/No). **If yes → variety may be JG-11 or Kranthi** go to question no.7 **If No, SKIP to** question no. 8	
7	Does the plant have more **basal branches**, **erect** and **weak purple** pigmentation? (Yes/No) IF Yes, the variety is **JG-11** (ICCV 93954) IF No, the variety is **Kranthi** (ICCC-37)	
		
	JG-11	**Kranthi (ICCC-37)**
8	Does this variety take >**110 days** to mature, **semi-spreading** and seeds are **more angular**? (Yes/No) If answer is YES, the variety is **JAKI 9218** If answer is No, go to question no.9	
9	If this sequence doesn't follow, i.e., they are non-descriptive type→ **(VISHAL or CHAFFA)**	

Appendix 7: Household survey questionnaire, 2011-12

CPF

Particulars	ANSWERS			CODE/ID
Name				
S/o or D/o or W/o				
Village				
Mandal				
District				
State				
Mobile				
GPS reading of HH	**LAT (N):**		**LONG (E):**	
Is this HH (tick)	**TCF**	**MCF**	**SCF**	

TCF: Traditional chickpea grower MCF: Modern chickpea grower SCF: Switcher chickpea grower

1.1 Household Information

Main occupation: ----------------------------------- Subsidiary occupation: -------------------------------------

Caste category: ----------------------------- (SC/ST/BC/OC)

No.of years of farming: ------------------------ No. of years of chickpea growing: ------------------------- (Yrs)

1.2 Family composition

Name	Relation with Head	Sex (M/F)	Age (Yr)	Education (Yr)	Working in (Y/N)	
					Own-farm	Labor market

1.3 Landholding details in 2011-12 cropping year (acres)

Type	Owned	Leased/shared-in	Leased/shared-out	Permanent Fallow/grazing land	Operated
Wetland					
Dryland					
Total					
Operational land: (Owned + leased/shared-in) –(leased-out/shared-out +permanent fallow/grazing land)					

_1.4_ Cropping pattern _(details of CY 2011-12Kharif crops in acres)_

Plot name	Owner ship*	Plot area (acres)	Name of the crop	Prop-ortion	Variety**	Specify name	Cropped area	Irrigated area	Main Production (Kg)	Price /kg	By-product (Qt)	Price/ Qt

1.5 Cropping pattern _(details of CY 2011-12Rabi crops in acres)_

Plot name	Owner ship*	Plot area (acres)	Name of the crop	Prop-ortion	Variety**	Specify name	Cropped area	Irrigated area	Main Production (Kg)	Price /kg	By-product (Qt)	Price/ Qt

* Use the codes. Own land (OW), Leased-in (LI), leased-out (LO), Shared-in (SI), and Shared-out (SO)

** 1. Local 2. Improved 3. Hybrid

1.6* Details of household assets *(As on July 2012)

Resources	Quantity	Unit price	Total value
1.1. LAND (Acres)			
1. Dry land			
2. Irrigated land			
3. Grazing/ Fallow land			
1.2 LIVESTOCK (Number)			
1. Draft animals			
2. She buffaloes			
3. Cows			
4. Young cattle			
5. Goats/sheep			
6. Others (Specify)			
1.3. FARM EQUIPMENT (Number)			
1. Tractor with attachments			
2. Threshers/Power tillers			
3. Electric motors/oil engines			
4. Sprinkler sets/Drip irrigation			
5. Submersible pump sets			
6. Power or manual sprayer/duster			
7. Modern plough/seed drill/disc harrow etc.			
8. Other tools and implements			
9. Others if any			
1.4. FARM BUILDING (Sq. yard)			
1. Residential house including courtyard			
2. Farm house including cattle shed			
3. Residential plots (if any)			
4. Others (Specify--------------------------)			
1.6 Consumer Durables			
1. Gold and Silver			
2. Auto/Two wheelers			
3. Fridge/television/washing machine			
4. Mobile/Fan/Radio/Tape recorder etc.			
5. Cooking gas (LPG)			
6. Mobile phones			
7. Others (specify ------------------------)			

II Adoption of Chickpea improved cultivars

2.1 In general, what is your choice of cultivar preferences in chickpea cultivation ---------------(local/improved)

2.2 Reasons: --

2.3 First adoption of improved chickpea cultivars and sources of seed

Crop (**Codes A**)	Improved varieties Known **Use Annex**	Year variety was known First	**Main** source of variety information (**Codes B)**	Ever planted? **(Codes C)**	If **NO,** Why? **(Codes D)**	If **YES,** year first planted	**Area first planted (acres)**	**First seed details**			**Adoption in 2011-12**		**Future Adoption**	
								Main source of first seed (**Codes F)**	Quantity of first seed **kg**	Means of acquiring first seed **(Codes E)**	Planted variety in 2011/12 season? **(Codes c)**	If NO in 2011/12 why? **(Codes D)**	Will you plant the variety in 2012-13? **(Codes c)**	If No, why? **(Codes D)**
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**

Codes A	**Codes B**	**Codes C**	**Codes D**	**Codes F**	**Codes E**
1. Chickpea	1. Govt.Extension 2. Farmer Association 3. NGO 4. Research centre 5. On farm trials/demos 6. Fellow farmer 7. Private shop 8. Newspaper/radio/TV 9. Others --------	1. Yes 2. No	1. Didn't get seed 2. Lack of cash to buy 3. Diseases and pests 4. Poor taste 5. Low yielding 6. Require more rainfall 7. Expensive seed cost 8. No market 9. Poor price 10.Others -----------	1. Research PVS 2. Extension demo plots 3. Farmer club 4. Local seed producers 5. Local trader or agro-dealers 6. Farmer to farmer seed exchange (relative, friend, etc) 7. NGOs 8. Govt agency 9. Inherited from family 10. Villagers 11. Other (specify)……	1. Gift/Free 2. Borrowed seed 3.Bought with cash 4. Payment in kind 5. Exchange with other seeds 6. Others -------------

2.4 How often do you grow chickpea on same land (crop rotation)? (……………….)

(a) Every year (b) Once in two years (c) Once in three years (d) Others specify ....

2.5 Area allocation under chickpea during the last three years? -------------------------- **(I/D/C)**

2.6 What are the crops replaced by chickpea crop, if the area is increasing?

(a) -------------------- (b) --------------------- (c) --------------------------

2.7 Which year did you switch from other crops to Chickpea crop? ------------------------ (Year)

2.8 What are the crops replacing chickpea crop, if the area is decreasing?

(a) -------------------- (b) --------------------- (c) --------------------------

2.9 Which year did you re-switch from chickpea to other crops? ---------------------------- (Year)

2.10 Is Chickpea crop grown as sole/inter crop? ------------------- (if inter crop, specify: ---------------)

2.11Sources of seedsin 2011-12 planting ***(major three crops including chickpea)***

Crop	Variety	Source-1	Source-2	Source-3
Chickpea				
Crop-2.....................				
Crop-3.....................				

1. Research PVS 2. Extension demo plots 3. Farmer club 4. Own seed	5. Bought from villagers 6. Farmer to farmer seed exchange (relative, friend, etc) 7.Provided free by NGOs 8. Provided free by govt agency	9. Seed dealer 10. Subsidized government seed scheme 11. Other, specify..............................

2.12 Allocation of chickpea area under different cultivars/varieties in the last three years?

Cultivars	Area chickpea sown in acres		
	Area in 2011-12	Area in 2010-11	Area in 2009-10
1.			
2.			
3.			
4.			
5.			

2.13 Varietal replacement during last five years (2007-2011)

1. How many new cultivars did you introduced/tested?	
2. What is the main source for those new cultivars (codes refer above)	
3. How many times did you buy seed from market (out of five years)	
4. What is your preferred source of borrowing seed (codes refer above)	

2.14 Average Chickpea yield harvest by this household (kgs/acre)

Year	Variety-1:…………….	Variety-2:……………….	Variety-3:………………….
Normal year			
Bad year			
Best yield recorded so far			

3.1 Awareness and adoption of NRM technologies in chickpea cultivation

Can you provide the details of plot-level soil characteristics?

(plot details should match with cropping pattern module)

Plot name	Crop name	Soil type	Soil depth	Soil slope	Soil fertility	Risk of soil erosion	Soil degradation problems

Soil type	**Soil depth**	**Soil slope**	**Soil fertility**	**Risk of soil erosion**	**Soil degradation**
Black-1 Alluvial-2 Sandy-3 Red soil-4	Shallow-1 Medium-2 Deep-3 Very deep-4	Levelled-1 Gentle slope-2 Medium slope-3 High slope-4	Very poor (not used)-1 Poor-2 Good-3 Very good-4	No risk-1 Low risk-2 Medium-3 High risk-4	No problem-1 Soil erosion-2 Nutrient deplection-3 Water logging-4 Salinity/alkalinity-5 Acidity-6

3.2 Does the household practice the following NRM technologies since 2000?

Method	Practice (Y-1/N-2)	When started (Year)	Total costs incurred so far (Rs.)	Specify your share (Rs.)	Investment during the 3 years (Rs.)	Specify the crop grown in that plot
Soil or stone bunds						
Field/boundary bunds						
Biological barriers						
Broad bed and furrow						
Land levelling						
Check dams						
Farm ponds						
Contour bunding						
Others						

3.3 What is specific contribution of this technology in chickpea cultivation?

a. ---
b. ---
c. ---

4.1 Role of networks in technology adoption

Does this household is member in any social network? -------------------------- (Y/N)

If yes, Network type	Member in (tick)	Which network does this hh use to share/acquire information about new seeds/NRM technologies (tick)	How frequently this group meets in three months (no.)	Sources of information for network (code)	Which network you have more faith (tick)
SHGs					
Rythu-mitra					
Cooperative					
Farmer club					
Caste group					
Relative					
Friends/villagers					
Panchayat					

If HH is not a member in any social networks, reasons?

--- ---

4.2 Crop utilization ***(Major three crops including chickpea)***

Crop (codes)	Variety	Total Production (kg)	Utilisation of product					
			Saved as seed (kg)	Gift/kind payments (kg)	Consumed as food/feed (kg)	Paid as land rent (Kg)	Sold in market (kg)	In store (kg)
1								

Code A:1. Chickpea 2........................ 3. ....

4.3 Marketing of crop production ***(refer three major crops including chickpea)***

Total chickpea production during the year: ------------------------ Qtls

Crop code	Market type **(codes A)**	Marketing cost **(Rs/qtl)**					Cold storage cost (Rs/qtl)	Sold as (Qtl)		Price (Rs/Qtls)	
		Bagging	Trans-port	Commi-ssion agent	Market fee	Hamali (labor)		grain	seed	grain	seed
1											

Codes A: village market-1, Weekly market-2, Regulated market-3, Others -4

V Sources of information ***(Rank three major sources)***

	Chickpea			Crop-2........................			Crop-3.................		
Issue	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3	Rank 1	Rank 2	Rank 3
1. New varieties of crops									
2.Crop pest and disease control									
3. Output markets and prices									
4. Input markets and prices									
5. Weather forecasting									
6. Soil and water conservation									

1. Government extension agent 2. Research centre 3. Newspaper 4. Seed traders/Agro-dealer	5. Other private shops 6. Radio/TV 7. Mobile phone 8. Neighbour/other farmers	9. NGOs 10. Farmer clubs/associations 11.Market 12. Other, specify………………..

VI. Source of credit for chickpea cultivation during 2011-12 ***(Need and access)***

Purposes for borrowing	Needed credit? **(Codes A)**	If YES, did you get it **(codes A)**	If you **did not get** credit, why? **Rank-2(codes B)**		If **you got credit**				
					Did you get the required amount (Codes A)	Source of credit **(Codes C)**	Amount Received (Rs)	Interest rate (%)	Month borrowed ***(1-12)***
1	2	3	4		5	6	7	8	9
1. Buying seeds									
2. Buying fertilizer									
3. Buy pesticides									
4. Hiring farm equipment/labour									
5. Buying livestock									
6. Adopting soil and water conservation									
Others									

Codes A
1. Yes
0. No

Codes B
1. Borrowing is risky
2. Interest rate is too high
3.Too much paperwork
4. Does not know application procedures
5. No lenders in this area for this purpose
6. Lenders do not provide the amount needed
7. Other, specify…………………………….

Codes C
1. Commercial banks
2. Cooperatives (PACs)
3. Micro-finance
4. Money lender
5. Relatives/friends
7. Farmer club/SHGs
8. Input-dealer
9. Other, specify………

VII. Major sources of household (Rs) ***(net income from July 2011 to June 2012 only)***

Sources of income	Net income (Rs)
1. Income from crops including orchards	
2. Farm work (labor earnings)	
3. Non-farm work (labor earnings)	
4. Regular Farm Servant (RFS)	
5. Livestock (milk and milk products selling)	
6. Income from hiring out bullocks	
7. Income from selling sheep, goat, chicken, meat, eggs etc.	
8. Selling of water for agriculture purpose	
9. Selling CPR (firewood, fruits, stones, and mats etc)	
10. Selling handicrafts (specify)	
11. Rental income (tractor, auto, sprayer, & truck etc.)	
12. Rent from land, building and machinery etc.	
13. Caste occupations (specify)	
14. Business (specify)	
15. Regular salaried jobs (Govt./private)	
16. Out migration	
17. Remittances	
18. Interest on savings and from money lending	
19. Cash and kind gifts including dowry received	
20. Pension from employer	
21. Government welfare/development Programs	
22. Others 1	
23. Others 2	

VIII. Household consumption expenditure ***(from July 2011 to June 2012)***

Total members of the household consumed the food (adults) ----------- (children >12 years) --------

Item	Code ** D/W/M/Y	Average quantity consumed Kg/litre	Average unit price (Rs)	Total value (Rs)
1. Food expenditure:				
Rice				
Wheat				
Other cereals				
Pigeon pea				
Chick pea				
Green gram				
Black gram				
Others pulses				
Milk				
Other milk products				
Cooking oil				
Groundnut kernels				
Non-veg (chicken, mutton, beef, fish, eggs etc.)				
Fruits				
Vegetables				
Tea, coffee, sugar &gur				
All spices				
Processed food items & hotel expenses				
Other food items				
2. Non-food expenditure:				
Health expenditure				
Education/stationery				
Clothing/shoes				
Entertainment/travel/vehicle				
Ceremonies				
Toddy & alcohol				
Cosmetics (hair oil, soaps etc)				
Taxes/maintenance				
Pan, beedi, cigarettes etc.				
Cooking fuel/ LPG				
Phone/mobile bill				
Others				

** D-day, W- week, M- month, and Y- year

IX. Perceptions about farm-level Chickpea and NRM technology benefits

9.1 Does the improved technologies benefitted in any way? .... (Y/N)
If no, go to section 9.3

If yes, please provide the following information:

Type of benefit	Chickpea technologies		NRM technologies	
	Benefitted (Yes/No)	Extent of benefit (%)	Benefitted (Yes/No)	Extent of benefit (%)
Increase grain yield				
Increased fodder yield				
Reduced cost of cultivation/Qtl				
Increased net returns per acre				
Better grain quality				
Better fodder quality				
Reduced the duration				
Resistant to pests and diseases*				
Resistant to drought*				
Improved soil condition*				
Reduced the crop risk				
Increased mechanization (cost/acre)				
Increased gender participation/acre				
Others				

** Pl. refer them in terms of yield per acre*

9.2 After benefitted by using these technologies, would you like to continue these technologies in future? ----- ------------ (Y/N)

If No, what are the reasons: ----------------------------- ---------------------------- ---------------------

If yes, does the adoption of these technologies changed input-use behaviour ---------- (Y/N)

If yes (already changed behaviour) go to a. Otherwise go to b (planning to change).

a. **If yes, how you used the allocation of various inputs in chickpea cultivation?**

Input allocation	When you changed (year)	Old allocation	Revised allocation
Own land allocation (acres)			
Leased-in land allocation (acres)			
Mechanization (Rs per acre)			
Fertilizer application cost (Rs/acre)			
Pesticide application cost (Rs/acre)			
Irrigation expenditure (Rs/acre)			
Soil & water conservation expenditure (Rs/acre)			
Others			

b. If No, how are you planning to change the allocation in chickpea cultivation?

Input allocation	When you start (year)	Present allocation	Future allocation
Own land allocation (acres)			
Leased-in land allocation (acres)			
Mechanization (Rs per acre)			
Fertilizer application cost (Rs/acre)			
Pesticide application cost (Rs/acre)			
Irrigation expenditure (Rs/acre)			
Soil & water conservation expenditure (Rs/acre)			
Others			

9.3 If the **household not benefitted** by any technology, specify the problems/constraints encountered in implementing them? ***(major three only)***

a. --
b. --
c. --

9.4 List out the **limitations in expanding** the adoption under these technologies? ***(major three)***

a. --
b. --
c. --

9.5 What are the important **traits looking for in new chickpea cultivars *(major three)***

a. --
b. --
c. --

9.6 Any other **feedback or suggestions** for promotion of these technologies ***(major three)***

a. --
b. --
c. --

Investigator name: ----------------------------------- Remarks if any ---*(Input-output module will be added for collecting the COC data for one-third sample covering all crops)*

Cost of cultivation module **ID no. ---**

Study crop name: --------------------- Variety: ------------------- Plot size: ------------------ Season: ------------

Sole/inter-crop: ---------------------------------- (if it is intercrop: ratio ------------------)

Operations			Labor use[1]		Input/Output		
		Unit	Quantity	Wage rate	Quantity	Unit price	Remarks
1A. Land preparation (Ploughing primary and secondary tillage)	M	D					
	F	D					
	B	D					
	T	HR					
1B. Seedbed preparation (BBF/NBF/FLAT)	M	D					
	F	D					
	B	D					
	T	HR					
Compost/Sheep penning/Tank silt application	M	D					
	F	D					
	B	D					
	T	HR					
FYM/Compost/poultry		QT					
Animal penning		NO					
Date of sowing							
3. Planting/Sowing	M	D					
	F	D					
	B	D					
	T	HR					
4A. Seed: Crop code		KG					
Crop code		KG					
Crop code		KG					
4B. Seed treatment	M	D					
	F	D					
------------------		KG					
------------------		L					
5A. Fertilizer application	M	D					
	F	D					
---------------------------		KG					
--------------------------		KG					
---------------------------		KG					
---------------------------		KG					

Operations		Unit	Labor use[1] Quantity	Wage rate	Input/Output Quantity	Unit price	Remarks
5B. Micronutrient application	M	D					
	F	D					
-----------------------		KG					
-----------------------		KG					
6. Interculture	M	D					
	F	D					
	B	D					
	T	HR					
7. Weeding/Weedicide application	M	D					
	F	D					
	SP	HR					
Type (sprayer/duster/other)	T	HR					
-------------------------		LT					
-------------------------		LT					
8.PlantprotectionSpraying/Dusting/Shaking /Hand picking pest)	M	D					
	F	D					
	B	D					
	T	HR					
Type (sprayer/duster/other)	SP	HR					
	DU	KG					

----------------------							
9. Irrigation	M	D					
	F	D					
	ME	HR					
Source of Irrigation							
10. Watching (Birds, Pigs etc.,)	M	D					
	F	D					
Date of harvesting main crop							
11. Harvesting[2] : Crop code.......	M	D					
	F	D					
Crop code.....................	M	D					
	F	D					
Crop code....................	M	D					
	F	D					
12. Threshing and cleaning Crop code......	M	D					
	F	D					
	B	D					
	TH	HR					

Operations			Labor use[1]		Input/Output		
		Unit	Quantity	Wage rate	Quantity	Unit price	Remarks
Crop code..........	M	D					
	F	D					
	B	D					
	TH	HR					
Crop code.............	M	D					
	F	D					
	B	D					
	TH	HR					
13. Marketing (including transport, and storage)	M	D					
	F	D					
	B	D					
	T	HR					
14. Fixed Cost: Land Rent (Ac) Cash		RS					
Kind		KG					
Land tax (Acre)		RS					
15. Grain Yield: Crop code.........		KG					
Crop code.........		KG					
Crop code.........		KG					
		KG					
		KG					
16. Fodder yield: Crop code.........		QT					
Crop code.........		QT					
Crop code.........		QT					
		QT					
		QT					
17. Stalk:-------- Crop code..........		QT					
---------------- Crop code..........		QT					

1 Labor input includes total labor days of family and hired labor for each operation. Specify male and female labor as well as bullock labor separately wherever necessary.

2 Estimate the labor requirement if you had given to contractor for harvesting.

3 Specify clearly the units (eg. 5 kgs, FYM - 2 qtsetc).

M = Male labor, F = Female labor, B = Bullock pair labor,

T = Tractor/Truck, TH = Thresher, SP = Sprayer, DU = Duster.

Note : Irrigation (Open dugwell, borewell, Submersible pump, tank, canal, and others(specify)---------

Note : Cost of hiring tractors\bullocks pair includes cost of operator.

Note : Ask\calculate land rent (Rs/acre) for that particular crop.

Appendix 8: Village survey questionnaire, 2011-12

1. Village particulars

Village name		**Code:**
Mandal name		
District name		
State name		
Avg. Rainfall (mm)		
GPS readings	**Lat (N):**	**Long (E):**

2. Main respondent details

Main respondent name	
S/o or D/o or W/o	
Position in the village	
Major occupation	
Mobile no:	

3. General particulars of village

Total population of the village	
No. of Households	
Total no. of cultivators/farmers	
No. of chickpea cultivators/farmers	
Average land holding size (acres)	
Total geographical area of village (acres)	
Area under cultivation (acres)	
Area under irrigation (acres)	
Distance to regulated market (Kms)	
Distance to storage facility (Kms)	
Distance to Agricultural Research station (Kms)	
Distance to Agriculture Office (Kms)	
Distance to Input-shop (Kms)	

4. Cropping pattern details (2011-12 acres)

Kharif major crops	Area	Rabi major crops	Area	Summer major crops	Area

5. Major sources of Irrigation and soil types

Source	Area (acres)	% cropped area	Soil type	Area (acres)	% cropped area
Tanks					
Canals					
Open dug wells					
Borewells					
Others					

6. Area under Chickpea over the last one and half decade (1997-2012)

Year	1997	2002	2007	2011
Area in acres				

7. Major cultivars in chickpea cultivation

Year 2011		Year 2007		Year 2002		Year 1997	
Cultivar name	% area	Cultivar name	% area	Cultivar name	% area	Cultivar name	% area

8. Reasons for preference of major cultivars in Chickpea during 2011-12

Cultivar name	Reason for preferences-1	Reason for preferences-2

9. Pattern of varietal replacement in Chickpea during last one decade (2001-11) (write in box)

10. Major sources of seed supply for Chickpea in the village

Major cultivar name	Major supplier of seed-1	Major supplier of seed-2

11. Performance of chickpea yields (Kgs per acre) during 2010-11 and 2011-12

Year	Variety-1:		Variety-2:		Variety-3:	
	2010-11	2011-12	2010-11	2011-12	2010-11	2011-12
Normal yield						
Bad yield						
Best yield so far						

12. Major constraints for Chickpea in the village

a. Biotic constrains	b. Abiotic constraints
1.	1.
2.	2.
3.	3.
4.	4.

13. What are the major competing crops for chickpea in the village?

Competing crop	What is the advantage of competing crop over chickpea
	1. 2.
	1. 2.

14. Market price for chickpea over the last one and half decade (1997-2011)

Year	1997	2002	2007	2011
Desi Price/ Qtl				
Kabuli Price/ Qtl				

15. Any value addition practices followed for chickpea in the village ---------------------- (Y/N)

If yes, what are they: 1.---

2.---

3.---

16. How did you perceive the difference between the new and old chickpea cultivars?

Characteristics	Ranking of variety			
	Chickpea desi*		***Chickpea kabuli****	
Variety name				
1. Production traits				
High yield				
Short duration				
Drought tolerance				
Heat tolerance				
Pod bore resistance				
Disease resistance				
Fit into existing cropping system				
2.Consumption traits				
Better taste				
Less cooking time				
Others				
3.Marketing traits				
High demand				
Fetches higher price				
Low price fluctuations				
Others				
Overall variety score				

* Codes: 1. Poor, 2. Average, 3 Good, 4 Same, 5 Low, 6 High, 7 Short, 8 Long

17 Cultivar-wise constraints *(Please tick across specific constraints)*

CONSTRAINTS	*Chickpea desi*		*Chickpea kabuli*	
	Variety name		Variety name	
Low yield				
High pod borer incidence				
High disease incidence				
Long duration				
Small grain size				
Not attractive color				
Poor taste				
Low recovery of dal (%)				
Low market price				
Not fit into cropping system				
Poor fodder quality				
Susceptible to storage pest				

18. Subsidies benefitted from government for growing Chickpea crop (2011-12)?

Inputs/outputs	Name of program	Extent of benefits (in Rs per acre)	Extent of benefits (in kind if any/acre)
Seeds			
Credit			
Fertilizers			
Pesticides			
NRM activities			
Water exploration			
Output prices			
Others			

19. How the Chickpea modern cultivars benefitted the farmers? (Perceptions)

Quantitative parameter	Before adoption of new cultivars (Year.............)	After adoption of new cultivars in 2011-12
1. Yield (kgs/acre)		
2. Net income per acre of chickpea (Rs.)		
3. Cost per acre (Rs.)		
4. Pesticide application per acre (Rs.)		
5. Fertilizer application per acre (Rs.)		
6. Labor cost per acre (Rs.)		
7. Unit price of output (Rs.)		
8. Mechanization cost per acre (Rs.)		
9. Rental value of land per acre (Rs.)		

Qualitative parameter	Before adoption of new cultivars (Year ....)	After adoption of new cultivars in 2011-12
1.Risk in agriculture (H/S/L)		
2.Better fit to cropping system (Y/N)		
3.Improved soil fertility (H/S/L)		
4.Loan repaying capacity (H/S/L)		
5.Savings per average farm (H/S/L)		
6.Improved nutrition of HH (H/S/L)		
7.Gender empowerment (H/S/L)		

H: High S: Same L: Low

20. Village infrastructure details

Item	(Yes / No)	Distance
1.Well connected road to nearest town (kms)		
2.Storage facility (M tons)		
3.Cold storage facility (M tons)		
4.Good communication system (no. of mobiles)		
5. Inter-net connections (no.s)		

21. Village lending system

Major source	% farmers benefitted	% share in total lending requirement
1. Govt. banks		
2. PACs/cooperatives		
3. Private banks		
4. Money lenders		
5. Input-dealers/Shop		
6. Friends/relatives		
7. Others		

22. Types of traits looking for in new chickpea cultivars?

a. --

b.--

c.--

23. Willingness to pay more for improved seeds (over existing base price of seed)

Cultivar type	% over base price
Cultivar suitable for mechanical harvesting	
Cultivar having herbicide resistance	
Cultivar having root rot disease resistance	
Cultivar with heat tolerance	
Others if any	

24. Suggestions for promoting the chickpea in the village?

a.---

b.---

c.--

Appendix 9: Randomization procedure for selection of mandals for primary survey

Mandal	District	Chickpea area ('000 ha)	Cumulative total	Scale to Cum.total	Add random no. (0.8218)	Int. differences
KANEKAL	Anantapur	9888	9888	0.75	1.57	1.00
VIDAPANAKAL	Anantapur	15777	25665	1.95	2.77	1.00
TADPATRI	Anantapur	3218	28883	2.19	3.02	1.00
URAVAKONDA	Anantapur	11699	50320	3.82	4.64	1.00
BELUGUPPA	Anantapur	8114	58434	4.44	5.26	1.00
GUDUR	Kurnool	4482	69199	5.26	6.08	1.00
KURNOOL	Kurnool	7130	84399	6.41	7.23	1.00
MIDTHUR	Kurnool	7016	94608	7.19	8.01	1.00
ADONI	Kurnool	3120	109750	8.34	9.16	1.00
ALUR	Kurnool	11053	131770	10.01	10.83	1.00
ASPARI	Kurnool	10900	142670	10.84	11.66	1.00
BANAGANAPALLE	Kurnool	5654	148324	11.27	12.09	1.00
CHIPPAGIRI	Kurnool	16453	169650	12.89	13.71	1.00
MADDIKERA (EAST)	Kurnool	10167	179817	13.66	14.48	1.00
KOILKUNTLA	Kurnool	11955	194968	14.81	15.64	1.00
DORNIPADU	Kurnool	5084	203679	15.48	16.30	1.00
SANJAMALA	Kurnool	13282	216961	16.48	17.31	1.00
UYYALAWADA	Kurnool	14240	237008	18.01	18.83	1.00
MYLAVARAM	Kadapa	4554	241561	18.35	19.18	1.00
PEDDAMUDIUM	Kadapa	18261	259822	19.74	20.56	1.00
RAJUPALEM	Kadapa	8402	268224	20.38	21.20	1.00
SIMHADRIPURAM	Kadapa	5773	281961	21.42	22.24	1.00
VEERAPUNAYUNIPALLE	Kadapa	3232	294084	22.34	23.17	1.00
PARCHUR	Prakasam	6347	311397	23.66	24.48	1.00
JANAKAVARAMPANGULURU	Prakasam	3400	319227	24.25	25.08	1.00
NAGULUPPALAPADU	Prakasam	9151	332981	25.30	26.12	1.00
ONGOLE	Prakasam	3856	347551	26.41	27.23	1.00
MANOPAD	Mahabubnagar	7327	362665	27.55	28.38	1.00
MANOOR	Medak	3646	372987	28.34	29.16	1.00
MADNOOR	Nizamabad	6432	387493	29.44	30.26	1.00

Appendix 10: Socio-economic characteristics of non-chickpea sample farmers

Table 11.10.1 Characteristics of non-chickpea sample households. (N=270)

Item	Unit	PRM (N=36)	KUR (N=117)	KAD (N=45)	ANA (N=45)	MED (N=9)	NIZ (N=9)	MAH (N=9)	Pooled (N=270)
Years of farming	Years	21.9	19.9	23.0	28.1	20.0	22.4	22.2	22.2
Household head (no.)	Male	36.0	117.0	45.0	45.0	9.0	9.0	9.0	270.0
Average age	Years	52.3	44.9	48.3	52.2	43.6	48.4	50.8	47.9
Education (years completed)	Years	5.0	5.0	7.0	6.0	4.0	3.0	5.0	5.0
Average size of family*	No.	3.9	5.2	5.1	5.1	5.0	5.8	4.2	5.0
No. of male*	No.	2.1	2.8	2.6	2.4	3.1	3.4	2.3	2.6
No. of female*	No.	1.8	2.4	2.5	2.7	1.9	2.4	1.9	2.4
No. of family labor (no.)*	Male	1.4	1.8	1.6	1.6	1.2	2.3	1.3	1.6
	Female	1.3	1.5	1.3	1.4	1.0	1.3	1.1	1.4
	Total	2.7	3.3	2.9	3.0	2.2	3.6	2.4	3.0
Participation in labor market (no.)*	Male	0.8	1.3	0.5	0.8	0.6	1.9	0.9	1.0
	Female	0.6	1.2	0.4	0.6	0.6	1.1	0.9	0.8
	Total	1.3	2.5	0.9	1.4	1.2	3.0	1.8	1.8

** including children in the family*

The average years of farming experience of non-chickpea growers were 22 years. All the sample farmers were male headed households. The average age of the pooled sample was around 48 years. Most of non-chickpea growers having five years of completed education. The pooled average size of the family was 5.0. The family size was the highest in Nizamabad while the lowest was observed in Prakasam district. Three out of five members in the family are working as family labor. Around 60 per cent of them even participate in the village labor market.

Table 11.10.2 Land holding particulars of non-chickpea sample households (ha/HH).

Item	Type	PRM	KUR	KAD	ANA	MED	NIZ	MAH	Pooled
Total own land holding	Irrigated	0.2	0.6	0.8	0.6	1.5	0.6	0.9	0.6
	Rain fed	1.2	1.7	2.2	3.3	0.6	2.0	1.3	1.9
	Total	1.4	2.3	3.0	3.9	2.1	2.6	2.1	2.5
Leased-in land	Irrigated	0.2	0.2	0.2	0.1	0.0	0.0	0.7	0.2
	Rain fed	1.1	0.3	0.1	0.1	0.0	0.0	0.1	0.3
	Total	1.3	0.6	0.2	0.2	0.0	0.0	0.8	0.5
Leased-out and permanent fallow	Irrigated	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
	Rain fed	0.2	0.0	0.1	0.0	0.0	0.0	0.4	0.0
	Total	0.2	0.0	0.1	0.0	0.0	0.0	0.4	0.0
Operated landholding	Irrigated	0.4	0.9	1.0	0.7	1.5	0.6	1.6	0.8
	Rain fed	2.2	2.0	2.1	3.4	0.6	2.0	0.9	2.2
	Total	2.6	2.9	3.1	4.1	2.1	2.6	2.5	3.0

The average operational landholding of pooled non-chickpea farmers was 3.0 ha. The landholding across the districts are dominated by rainfed farming. Nearly 15 per cent of operational landholding are leased-in from land market. The average holdings were the highest in Anantapur followed by Kadapa, Kurnool, Nizamabad and Prakasam districts. The average relative landholding sizes of non-chickpea growers were smaller than the chickpea sample farmers in the respective study districts.

Table 11.10.3 Asset particulars of non-chickpea sample households ('000 $/HH).

Item	PRM	KUR	KAD	ANA	MED	NIZ	MAH	Pooled
Total land value	44.8	35.6	46.4	37.3	60.0	73.3	42.0	41.2
1.Irrigated	5.5	14.1	15.0	7.6	43.0	19.5	21.1	13.4
2. Dryland	39.2	21.5	31.5	29.7	16.9	53.8	20.9	27.8
3. Fallow land	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Total livestock value	1.0	0.8	1.0	1.2	0.1	0.9	0.2	0.9
1. Draft Animals	0.1	0.2	0.1	0.3	0.0	0.3	0.0	0.2
2. She Buffaloes	0.9	0.4	0.7	0.5	0.1	0.2	0.2	0.5
3. Others	0.0	0.2	0.2	0.4	0.0	0.4	0.0	0.2
Total farm equipment	1.5	1.2	2.1	1.4	0.4	1.4	1.3	1.4
Total farm buildings	10.1	6.9	9.9	7.8	5.5	5.6	6.5	7.9
Total consumer durables	1.9	2.2	2.7	2.3	2.0	2.0	1.9	2.2
Total assets	59.3	46.7	62.2	49.9	67.9	83.2	51.9	53.6
USD $ = Rs.55								

The average total asset value of non-chickpea sample farmers was 53,600 $ per household. Own land value contributes (77%) major share of the total asset value across study districts. It was followed by farm buildings, consumer durables and farm equipment. Nizamabad farmers possess the highest value of total assets followed by Medak, Kadapa, Prakasam and Mahabubnagar districts. The average asset value of non-chickpea farmers were relatively much lower (50%) than that of chickpea sample farmers in the study districts.

Table 11.10.4 Annual household incomes of non-chickpea households ('000 $/HH).

Item	ANA	KAD	KUR	MAH	MED	NIZ	PRM	Pooled
Agriculture	0.67	1.65	1.08	1.31	2.11	1.69	2.39	1.35
Farm work	0.20	0.11	0.32	0.26	0.15	0.42	0.28	0.26
Non-farm work	0.23	0.09	0.36	0.27	0.38	0.49	0.22	0.28
Livestock	0.23	0.22	0.30	0.05	0.01	0.28	0.28	0.26
Caste occupations	0.00	0.00	0.02	0.00	0.10	0.00	0.00	0.01
Business	0.00	0.00	0.03	0.00	0.00	0.00	0.05	0.02
Migration	0.00	0.04	0.03	0.00	0.00	0.00	0.05	0.03
Remittances	0.04	0.24	0.06	0.12	0.06	0.00	0.02	0.08
Govt. Programs	0.11	0.14	0.20	0.14	0.10	0.14	0.12	0.15
Others	0.80	0.48	0.33	0.24	0.24	0.18	0.44	0.44
Total	2.27	2.97	2.73	2.40	3.16	3.20	3.86	2.86

The average annual household income of the pooled non-chickpea farmers was 2860 USD $ per household. Agriculture is contributing the major source (47%) of the total income across study districts. Participation in farm and non-farm work together contributing nearly 19 per cent of total income for the pooled sample households. But, the net income generated from livestock contributed another 9 per cent in total income. The share of contribution of agriculture in total household income was the highest in case of Prakasam followed by Medak and Nizamabad. The pooled average earnings per household of non-chickpea per annum was relatively lower (17%) when compared with chickpea farmers in the study.

Table 11.10.5 Household consumption of non-chickpea households ('000 $/HH/annum).

	PRM	KUR	KAD	ANA	MAH	MED	NIZ	Pooled
Food expenditure	**0.09**	**0.18**	**0.24**	**0.28**	**0.12**	**0.23**	**0.17**	**0.19**
Rice	0.02	0.07	0.11	0.13	0.04	0.09	0.05	0.08
Wheat	0.00	0.00	0.00	0.01	0.00	0.01	0.01	0.00
Chickpea	0.00	0.01	0.01	0.01	0.00	0.01	0.00	0.01
Pigeonpea	0.00	0.01	0.03	0.03	0.01	0.02	0.01	0.02
Other pulses	0.01	0.01	0.02	0.02	0.00	0.02	0.01	0.01
Milk	0.01	0.01	0.01	0.01	0.01	0.00	0.01	0.01
Other milk products	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Non-vegetarian	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Other food-expenditure	0.04	0.06	0.06	0.07	0.05	0.07	0.07	0.06
Non-food expenditure	**0.68**	**0.91**	**1.19**	**0.93**	**0.89**	**1.16**	**0.65**	**0.93**
Health	0.22	0.25	0.39	0.36	0.27	0.60	0.34	0.30
Education	0.20	0.39	0.59	0.31	0.33	0.33	0.08	0.37
Clothing	0.11	0.12	0.11	0.12	0.10	0.11	0.13	0.12
Entertainment	0.04	0.03	0.02	0.03	0.01	0.02	0.04	0.03
Ceremonies	0.04	0.03	0.01	0.03	0.01	0.02	0.01	0.03
Others	0.06	0.08	0.07	0.09	0.16	0.07	0.06	0.08
Grand Total	**0.77**	**1.09**	**1.43**	**1.21**	**1.01**	**1.39**	**0.82**	**1.12**

The average total expenditure of pooled sample households of non-chickpea was 1120 USD $ per household per year. Constrastingly, the share of non-food expenditure was much higher than the food expenditure per annum. The average expenditure levels were much higher in case of Kadapa followed by Medak, Anantapur, Kurnool and Nizamabad. Nevertheless, the average consumption standards of non-chickpea farmers were significantly lower (50%) than chickpea growers respectively across study districts.

Appendix 11: Derivation of average time lag based on data on first year of adoption

$$Adoption\ lag = A_{it} = \frac{\sum_{n}^{i=1}(t_{it} * n_{it})}{N_i}$$ Where,

$$t_{it} = t_a - t_r$$

t_a = year of first adoption

t_r = year of release of i^{th} variety

n_{it} = number of famers first adopted at t_{it} time period for i^{th} variety

N_i = total number of farmers first adopted by the i^{th} variety

Appendix 12: Variety and district-wise first adoption details

Table 11.12.1 First adoption of chickpea improved cultivars in the sample (N=810)

Year	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	16	16	16	16	16	16	16	2	2	2	2	2	2	2
1991	21	21	21	21	21	21	21	5	5	5	5	5	5	5
1992	178	178	178	178	178	178	178	31	31	31	31	31	31	31
1993	288	288	288	288	288	288	288	32	32	32	32	32	32	32
1994	327	327	327	327	327	327	327	40	40	40	40	40	40	40
1995	349	349	349	349	349	349	349	43	43	43	43	43	43	43
1996	515	518	518	518	518	518	518	58	59	59	59	59	59	59
1997	796	809	809	809	809	809	809	99	102	102	102	102	102	102
1998	971	984	984	984	984	984	984	118	121	121	121	121	121	121
1999	1079	1092	1092	1092	1092	1092	1092	134	137	137	137	137	137	137
2000	1437	1470	1470	1470	1470	1470	1470	182	186	186	186	186	186	186
2001	1740	1787	1787	1787	1787	1787	1787	240	249	249	249	249	249	249
2002	2696	2818	2833	2843	2843	2843	2843	394	419	424	425	425	425	425
2003	2948	3200	3233	3253	3253	3253	3253	434	476	485	487	487	487	487
2004	3377	4010	4104	4188	4215	4215	4215	495	583	608	616	618	618	618
2005	3720	4899	5022	5117	5144	5144	5144	546	683	717	730	732	732	732
2006	3930	6172	6337	6439	6466	6466	6466	585	846	890	905	907	907	907
2007	3992	7911	8181	8298	8327	8349	8349	600	1043	1116	1135	1138	1140	1140
2008	4017	9758	10127	10472	10501	10523	10523	609	1240	1331	1370	1373	1375	1375
2009	4029	10447	10887	11389	11418	11448	11448	612	1328	1435	1491	1494	1498	1498
2010	4031	10649	11119	11758	11787	11825	11837	613	1367	1478	1544	1547	1552	1554
2011	4031	10728	11209	12023	12052	12090	12102	613	1378	1492	1582	1585	1590	1592
2012	4031	10730	11211	12060	12089	12141	12153	613	1379	1493	1589	1593	1600	1602

Table 11.12.2 First adoption of chickpea improved cultivars in Prakasam district (N=108)

Year	Variety wise cumulative area (acres)								Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130		Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1990	1	1	1	1	1	1	1		1	1	1	1	1	1	1
1991	3	3	3	3	3	3	3		2	2	2	2	2	2	2
1992	17	17	17	17	17	17	17		7	7	7	7	7	7	7
1993	17	17	17	17	17	17	17		7	7	7	7	7	7	7
1994	17	17	17	17	17	17	17		7	7	7	7	7	7	7
1995	17	17	17	17	17	17	17		7	7	7	7	7	7	7
1996	20	20	20	20	20	20	20		9	9	9	9	9	9	9
1997	30	40	40	40	40	40	40		17	19	19	19	19	19	19
1998	32	42	42	42	42	42	42		19	21	21	21	21	21	21
1999	48	58	58	58	58	58	58		22	24	24	24	24	24	24
2000	56	66	66	66	66	66	66		24	26	26	26	26	26	26
2001	69	93	93	93	93	93	93		31	38	38	38	38	38	38
2002	89	150	166	166	166	166	166		40	61	66	66	66	66	66
2003	103	204	238	238	238	238	238		44	75	84	84	84	84	84
2004	106	247	310	320	320	320	320		45	88	110	111	111	111	111
2005	130	288	368	384	384	384	384		49	96	125	129	129	129	129
2006	135	346	445	465	465	465	465		50	115	151	156	156	156	156
2007	135	373	541	565	567	567	567		50	123	181	187	188	188	188
2008	135	434	679	704	706	706	706		50	132	203	210	211	211	211
2009	135	458	756	782	784	784	784		50	139	224	232	233	233	233
2010	135	458	759	785	787	787	787		50	139	225	233	234	234	234
2011	135	462	767	793	795	795	795		50	141	228	236	237	237	237
2012	135	462	767	793	795	795	795		50	141	228	236	237	237	237

Table 11.12.3 First adoption of chickpea improved cultivars in Kurnool district (N=351)

Year	Variety wise cumulative area (acres)								Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130		Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1990	15	15	15	15	15	15	15		1	1	1	1	1	1	1
1991	16	16	16	16	16	16	16		2	2	2	2	2	2	2
1992	91	91	91	91	91	91	91		13	13	13	13	13	13	13
1993	91	91	91	91	91	91	91		13	13	13	13	13	13	13
1994	103	103	103	103	103	103	103		17	17	17	17	17	17	17
1995	121	124	124	124	124	124	124		19	19	19	19	19	19	19
1996	243	246	246	246	246	246	246		29	30	30	30	30	30	30
1997	374	377	377	377	377	377	377		42	43	43	43	43	43	43
1998	442	445	445	445	445	445	445		48	49	49	49	49	49	49
1999	479	502	502	502	502	502	502		54	55	55	55	55	55	55
2000	632	655	655	655	655	655	655		76	78	78	78	78	78	78
2001	816	859	859	859	859	859	859		112	114	114	114	114	114	114
2002	1337	1455	1455	1465	1465	1465	1465		181	184	184	185	185	185	185
2003	1423	1857	1857	1867	1867	1867	1867		201	209	209	210	210	210	210
2004	1688	2485	2517	2560	2587	2587	2587		237	276	279	283	285	285	285
2005	1871	3376	3420	3468	3495	3495	3495		264	336	341	347	349	349	349
2006	1978	4285	4352	4400	4427	4427	4427		284	422	430	436	438	438	438
2007	1985	4874	4976	5029	5056	5056	5056		287	516	530	538	540	540	540
2008	1989	5096	5206	5469	5496	5496	5496		288	600	617	641	643	643	643
2009	1993	5125	5238	5588	5615	5615	5615		289	628	646	681	683	683	683
2010	1993	5151	5291	5704	5731	5731	5731		289	633	654	694	696	696	696
2011	1993	5151	5299	5795	5822	5822	5822		289	636	659	710	712	712	712
2012	1993	5151	5299	5828	5855	5855	5855		289	636	659	714	716	716	716

Table 11.12.4 First adoption of chickpea improved cultivars in Kadapa district (N=135)

Year	Variety wise cumulative area (acres)							Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	8	8	8	8	8	8	8	1	1	1	1	1	1	1
1997	80	80	80	80	80	80	80	8	8	8	8	8	8	8
1998	147	147	147	147	147	147	147	15	15	15	15	15	15	15
1999	182	182	182	182	182	182	182	19	19	19	19	19	19	19
2000	267	267	267	267	267	267	267	32	32	32	32	32	32	32
2001	287	287	287	287	287	287	287	36	36	36	36	36	36	36
2002	423	423	423	423	423	423	423	61	61	61	61	61	61	61
2003	438	438	438	448	448	448	448	62	62	62	63	63	63	63
2004	504	504	504	535	535	535	535	72	72	72	75	75	75	75
2005	542	623	623	654	654	654	654	80	88	88	91	91	91	91
2006	574	827	827	858	858	858	858	85	112	112	115	115	115	115
2007	583	1239	1241	1277	1277	1279	1279	88	149	150	154	154	155	155
2008	593	1597	1613	1668	1668	1670	1670	92	185	188	195	195	196	196
2009	598	1802	1833	1957	1957	1967	1967	93	208	212	224	224	226	226
2010	598	1903	1934	2133	2133	2143	2143	93	224	228	245	245	247	247
2011	598	1934	1965	2255	2255	2277	2277	93	228	232	262	262	265	265
2012	598	1934	1965	2257	2257	2279	2279	93	228	232	263	263	266	266

Table 11.12.5 First adoption of chickpea improved cultivars in Anantapur district (N=135)

Year	Variety wise cumulative area (acres)								Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130		Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1992	8	8	8	8	8	8	8		1	1	1	1	1	1	1
1993	118	118	118	118	118	118	118		2	2	2	2	2	2	2
1994	143	143	143	143	143	143	143		5	5	5	5	5	5	5
1995	148	148	148	148	148	148	148		6	6	6	6	6	6	6
1996	181	181	181	181	181	181	181		8	8	8	8	8	8	8
1997	221	221	221	221	221	221	221		14	14	14	14	14	14	14
1998	255	255	255	255	255	255	255		17	17	17	17	17	17	17
1999	275	275	275	275	275	275	275		20	20	20	20	20	20	20
2000	384	384	384	384	384	384	384		30	30	30	30	30	30	30
2001	465	465	465	465	465	465	465		40	40	40	40	40	40	40
2002	667	685	685	685	685	685	685		65	66	66	66	66	66	66
2003	784	817	817	817	817	817	817		78	81	81	81	81	81	81
2004	862	910	910	910	910	910	910		86	91	91	91	91	91	91
2005	946	1076	1076	1076	1076	1076	1076		94	102	102	102	102	102	102
2006	997	1244	1244	1244	1244	1244	1244		101	126	126	126	126	126	126
2007	1029	1679	1679	1679	1679	1699	1699		105	172	172	172	172	173	173
2008	1029	2439	2439	2439	2439	2467	2467		105	219	219	219	219	222	222
2009	1029	2589	2589	2589	2589	2617	2617		105	232	232	232	232	235	235
2010	1029	2619	2619	2619	2619	2647	2659		105	236	236	236	236	239	241
2011	1029	2634	2634	2634	2634	2662	2674		105	237	237	237	237	240	242
2012	1029	2636	2636	2637	2637	2667	2679		105	238	238	239	239	243	245

Table 11.12.6 First adoption of chickpea improved cultivars in Medak district (N=27)

Year	Variety wise cumulative area (acres)								Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130		Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1991	2	2	2	2	2	2	2		1	1	1	1	1	1	1
1992	63	63	63	63	63	63	63		10	10	10	10	10	10	10
1993	63	63	63	63	63	63	63		10	10	10	10	10	10	10
1994	65	65	65	65	65	65	65		11	11	11	11	11	11	11
1995	65	65	65	65	65	65	65		11	11	11	11	11	11	11
1996	65	65	65	65	65	65	65		11	11	11	11	11	11	11
1997	81	81	81	81	81	81	81		16	16	16	16	16	16	16
1998	85	85	85	85	85	85	85		17	17	17	17	17	17	17
1999	85	85	85	85	85	85	85		17	17	17	17	17	17	17
2000	85	85	85	85	85	85	85		17	17	17	17	17	17	17
2001	90	90	90	90	90	90	90		18	18	18	18	18	18	18
2002	110	110	110	110	110	110	110		25	25	25	25	25	25	25
2003	110	110	110	110	110	110	110		25	25	25	25	25	25	25
2004	110	110	110	110	110	110	110		25	25	25	25	25	25	25
2005	110	110	110	110	110	110	110		25	25	25	25	25	25	25
2006	113	113	113	113	113	113	113		26	26	26	26	26	26	26
2007	113	113	113	113	113	113	113		26	26	26	26	26	26	26
2008	113	119	119	119	119	119	119		26	28	28	28	28	28	28
2009	113	151	151	151	151	151	151		26	30	30	30	30	30	30
2010	115	182	182	182	182	182	182		27	39	39	39	39	39	39
2011	115	185	185	185	185	185	185		27	40	40	40	40	40	40
2012	115	185	185	185	186	186	186		27	40	40	40	41	41	41

Table 11.12.7 First adoption of chickpea improved cultivars in Mahabubnagar district (N=27)

Year	Variety wise cumulative area (acres)								Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130		Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1997	12	12	12	12	12	12	12		2	2	2	2	2	2	2
1998	12	12	12	12	12	12	12		2	2	2	2	2	2	2
1999	12	12	12	12	12	12	12		2	2	2	2	2	2	2
2000	16	16	16	16	16	16	16		3	3	3	3	3	3	3
2001	16	16	16	16	16	16	16		3	3	3	3	3	3	3
2002	37	37	37	37	37	37	37		10	10	10	10	10	10	10
2003	57	57	57	57	57	57	57		12	12	12	12	12	12	12
2004	74	83	83	83	83	83	83		17	18	18	18	18	18	18
2005	83	96	96	96	96	96	96		19	21	21	21	21	21	21
2006	87	105	105	109	109	109	109		20	24	24	25	25	25	25
2007	92	152	152	156	156	156	156		22	32	32	33	33	33	33
2008	92	211	211	215	215	215	215		22	45	45	46	46	46	46
2009	92	222	222	226	226	226	226		22	48	48	49	49	49	49
2010	92	222	222	226	226	226	226		22	48	48	49	49	49	49
2011	92	222	222	226	226	226	226		22	48	48	49	49	49	49
2012	92	222	222	226	226	226	226		22	48	48	49	49	49	49

Table 11.12.8 First adoption of chickpea improved cultivars in Nizamabad district (N=27)

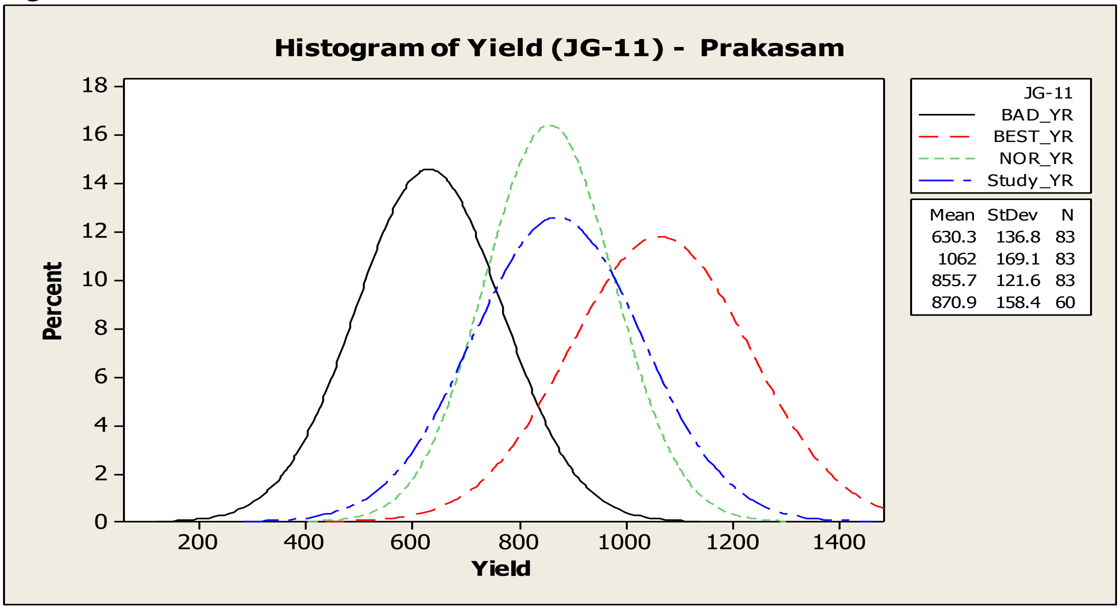
Year	Variety wise cumulative area (acres)								Variety wise cumulative no. of sample farmers						
	Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130		Annigeri	JG-11	KAK-2	Vihar	Bold	JAKI-9218	JG-130
1989	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1992	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1993	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1996	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1998	0	0	0	0	0	0	0		0	0	0	0	0	0	0
1999	0	0	0	0	0	0	0		0	0	0	0	0	0	0
2000	0	0	0	0	0	0	0		0	0	0	0	0	0	0
2001	0	0	0	0	0	0	0		0	0	0	0	0	0	0
2002	37	37	37	37	37	37	37		12	12	12	12	12	12	12
2003	37	37	37	37	37	37	37		12	12	12	12	12	12	12
2004	38	38	38	38	38	38	38		13	13	13	13	13	13	13
2005	43	43	43	43	43	43	43		15	15	15	15	15	15	15
2006	51	59	59	59	59	59	59		19	21	21	21	21	21	21
2007	60	70	70	70	70	70	70		22	25	25	25	25	25	25
2008	72	87	87	87	87	87	87		26	31	31	31	31	31	31
2009	75	133	133	133	133	133	133		27	43	43	43	43	43	43
2010	75	150	150	150	150	150	150		27	48	48	48	48	48	48
2011	75	150	150	150	150	150	150		27	48	48	48	48	48	48
2012	75	150	150	150	150	150	150		27	48	48	48	48	48	48

Appendix 13: Yield variability in chickpea cultivation

This appendix section uses survey results to estimate the yield distributions for three possible scenarios: normal year, bad and best seasons. It presents the extent of yield variability in chickpea based on statistical measures of mean and standard deviation during normal years and deviations from normal years, i.e., bad and best seasons. This is used in examining the alternative yield scenarios which differs across the seven major chickpea growing districts representing different agro-ecologies where chickpea is grown. Key observations from the yield analysis are associated with variations in rainfall regimes, soil type and length of growing period.

The influence of drought was much conspicuous on chickpea in parts of Andhra Pradesh (especially in Kurnool, Anantapur and Mahabubnagar districts) during survey year i.e., 2011-12. Subsequently, the drought impact was also observed in certain parts of Kurnool, Anantapur and Mahabubnagar districts during cropping year 2012-13. During the household data collection and village Focus Group Meetings (FGMs), the sample farmers were asked to provide their perceptions about the normal, bad and best yields obtained in chickpea cultivation so far in the respective households and villages. Based on their perceptions in chickpea cultivation during almost 5-10 years, the histograms were fitted using Normal distribution.

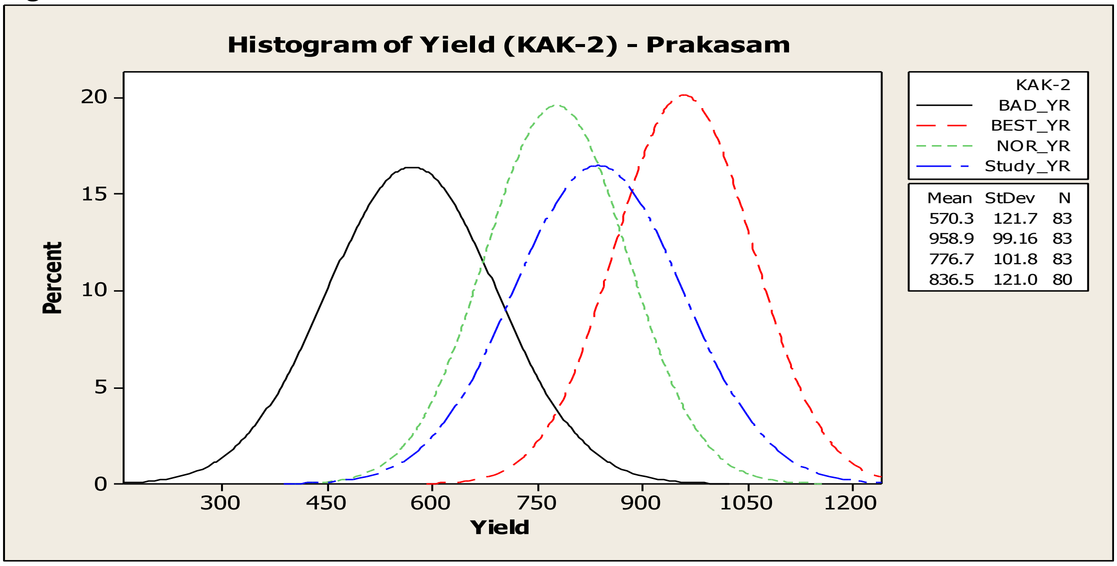
Fig 11.13.1 Yield distribution of JG 11 in Prakasam district



Figs 11.13.1 & 11.13.2 respectively present the histograms for JG11 and KAK2 (most popular cultivars occupy nearly 90 per cent area) in Prakasam district. The average normal yield for JG11 in the district was around 856 kg per acre. The bad yield based on perceptions was nearly 630 kg per acre while the best yields obtained by sample farmers were 1062 kg per acre. On an average, nearly 30-40 per cent yield deviations per acre were observed due to climatic aberrations. The mean survey year yield per acre was 871 which were close to normal yield of that district. Similarly in case of KAK 2, the normal yield was 777 kg per acre, whereas the bad and best yields were 570 and 959 kg per acre respectively. Approximately

20-30 per cent yield deviations were found in the analysis. The average yield during the survey period observed was 836 kg per acre which is slightly higher than the normal yield. It confirms that Prakasam did not experience any drought during 2011-12 survey/cropping year.

Fig 11.13.2 Yield distribution of KAK 2 in Prakasam district



Figs 11.13.3 & 11.13.4 depict the histograms of JG 11 and Vihar (most popular in the district) cultivar yield distributions respectively in Kurnool district. The normal yield for JG 11 cultivar was around 650 kg per acre. The bad and best yields per acre were ranging from 256 to 861 kg per acre. A huge variation in yield perceptions was observed because of Kurnool district is sensitive to rainfall deviations. The actual average yield obtained during the survey year was 322 kg/acre. It was almost half of the normal yield in the district. Similarly in case of Vihar, the normal yield is at 646 kg per acre while the actual mean yield reported in the household survey was only at 577 kg per acre. A marginal decrease (10 per cent) in yield was observed in the analysis. The performance of Vihar was slightly better than JG 11 under drought conditions. This clearly lends support that Kurnool district is highly sensitive to terminal drought than Prakasam district.

Fig 11.13.3 Yield distribution of JG 11 in Kurnool district

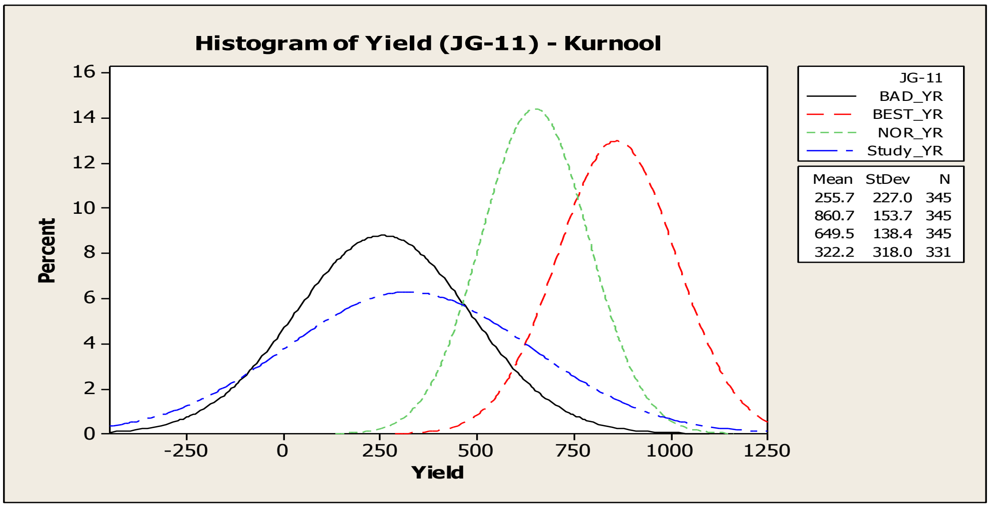
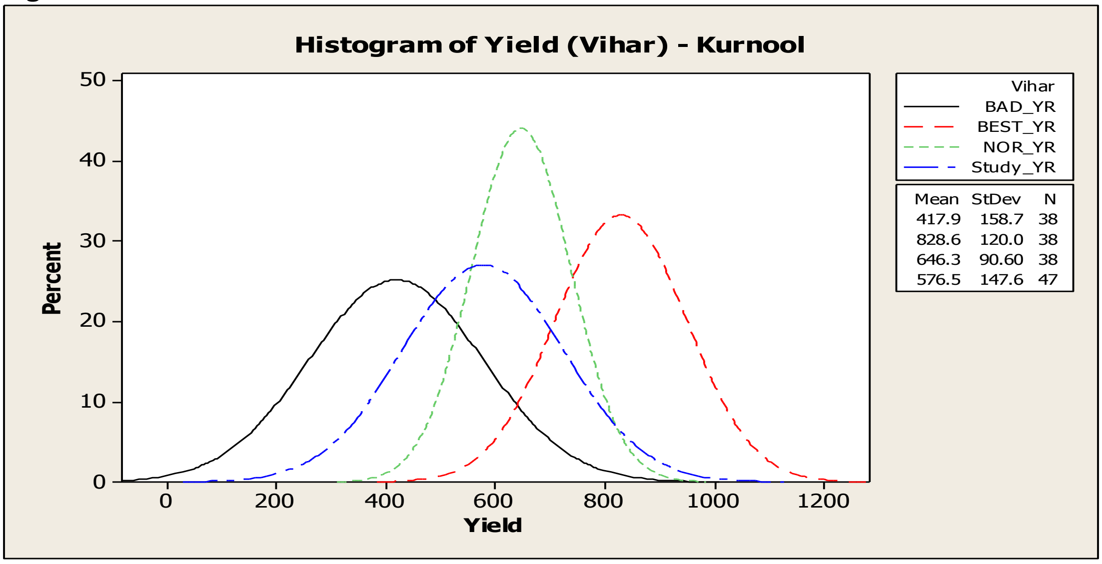


Fig 11.13.4 Yield distribution of Vihar in Kurnool district



Figs 11.13.5 & 11.13.6 reported the Normal distribution of chickpea yields respectively for JG 11 and Vihar cultivars in Kadapa district. JG 11 is the pre-dominant cultivar (85-90%) in the district while few farmers started growing *kabuli* type i.e., Vihar. The mean normal yield of the district is around 587 kg per acre based sample farmers' perception. Nearly 25-40 per cent deviations were observed between best and bad yields relative to normal yields. However, the actual yield reported by chickpea households was 597 kg/acre. This is pretty close to the normal yield indicates less influence of climate on the district. In case of Vihar, the perceived normal yield expressed by sample farmers was 629 kg per acre. During the survey year, Vihar performed better (749 kg/acre) than normal situation. The analysis provides clearly indications that Kadapa district did not expose to any drought situation during the cropping year 2011-12.

Fig 11.13.5 Yield distribution of JG 11 in Kadapa district

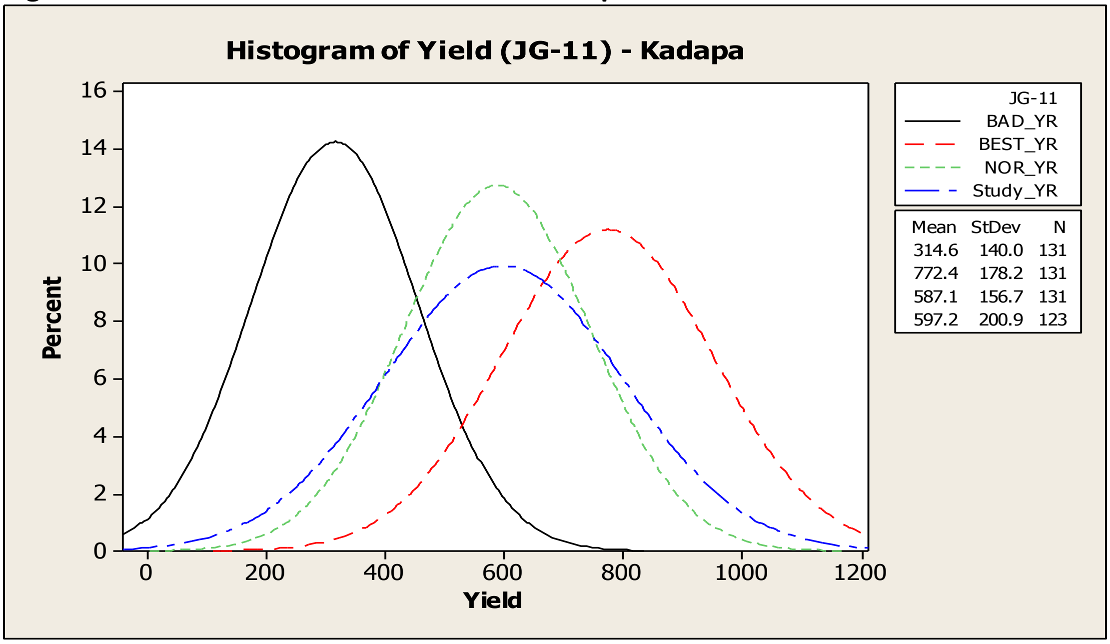
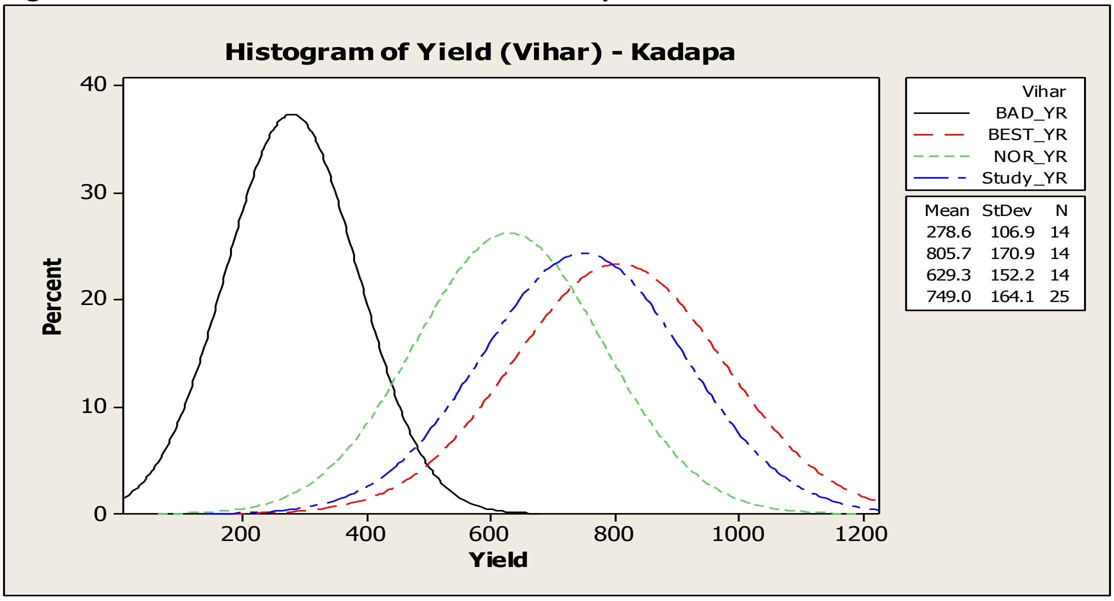
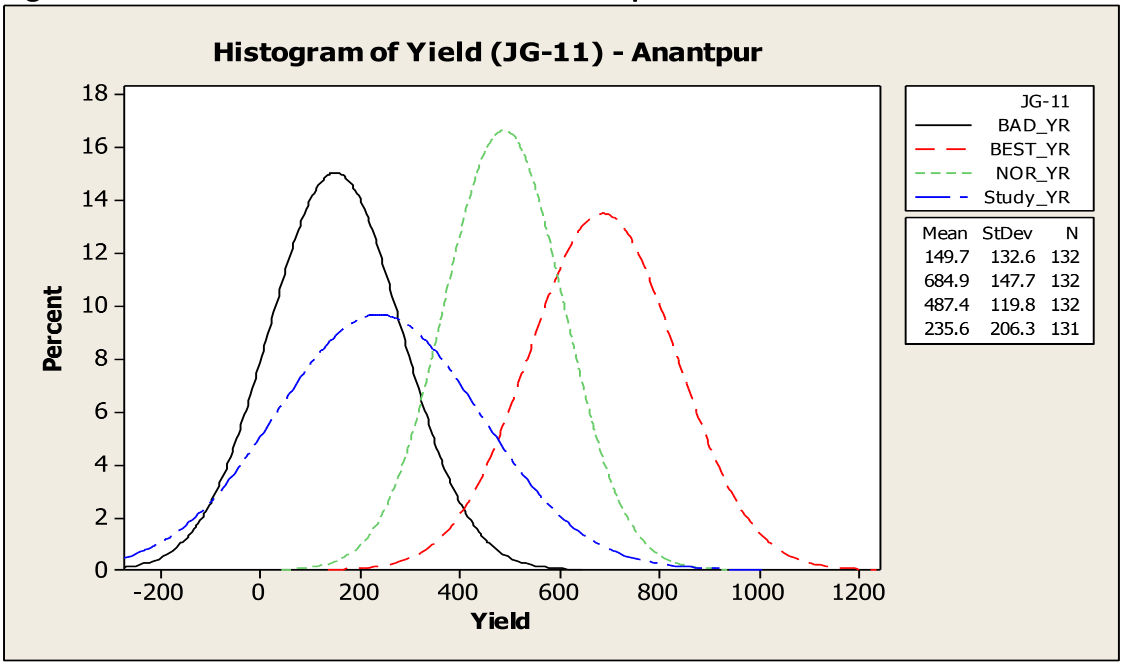


Fig 11.13.6 Yield distribution of Vihar in Kadapa district



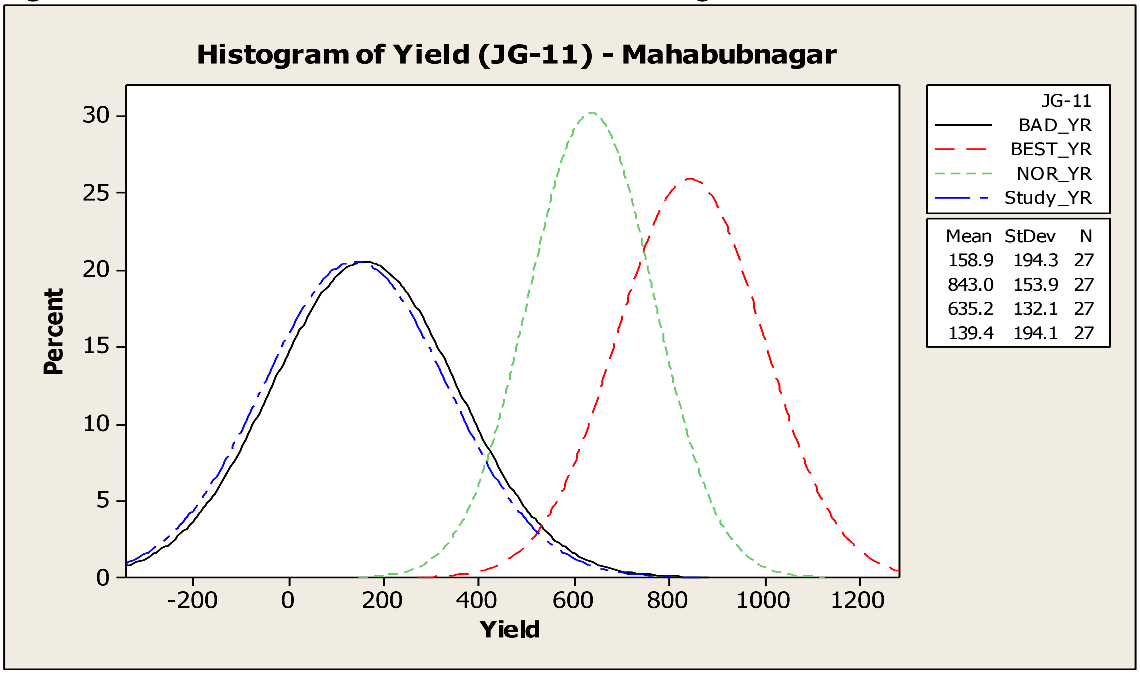
The details of performance of chickpea yields in Anantapur district is illustrated in Fig 11.13.7. JG 11 is the most dominant (around 95%) *desi* cultivar in the district. The normal yield of JG 11 was reported at 487 kg per acre which is far lower than Prakasam, Kurnool and Kadapa districts. Anantapur is one of most drought prone district of Andhra Pradesh and having an average rainfall of around 500 mm. To support the same, huge deviations in bad and best yields were observed relative to normal yield. However, the actual mean yield during survey year was at 236 kg per acre which is almost half of the normal yield. Over all, the entire exercise concludes that Anantapur has experienced severe drought during 2011-12.

Fig 11.13.7 Yield distribution of JG 11 in Anantapur district



Another most drought prone district in the state of Andhra Pradesh was Mahabubnagar. Even though the average normal rainfall in the district shows a little higher but it experiences maximum deviations in its distributions. Due to the negative deviations during terminal crop period, the extent of yield reductions will be higher. Fig 11.13.8 elucidates the extent of variations in yield perceptions across different climatic situations in Mahabubnagar. The normal yield informed by sample farmers was 635 kg/acre. The yield data collected through primary survey exactly matched with the bad yield situation in the histogram. This clearly concludes that Mahabubnagar district severely damaged with drought effect during 2011-12.

Fig 11.13.8 Yield distribution of JG 11 in Mahabubnagar district



Figs 11.13.9 and 11.13.10 elucidate the performance of chickpea in Medak and Nizamabad districts of Andhra Pradesh. JG 11 is the dominant *desi*cultivar in these districts. However, the old Annigeri cultivar was observed in traces in these districts. Chickpea is mostly grown as a sole crop except in Medak district. Farmers' prefer to grow chickpea as an inter-crop with safflower (9:1 ratio) in Medak. Nizamabad is a new niche area for spreading of chickpea in the state. But, Medak district is a traditional chickpea grower since 1990s at low key. The average normal yield revolves around 647 kg per acre. The mean actual survey data reported at 677 kg per acre. This clearly reveals that Medak did not affect with drought situation.

Similarly, the farmers' in Nizamabad perceived the average normal yield of 755 kg per acre. The best yields reported by farmers were higher in Nizamabad than Kurnool, Anantapur, Kadapa, Mahabubnagar and Medak. This indicates the huge potential of the crop in the district coupled with availability of better soils and rainfall patterns. The actual mean yields stated by sample farmers were 738 kg per acre. This is much closer to normal yields in the district indicates no terminal drought effect and yield losses.

Fig 11.13.9 Yield distribution of JG 11 in Medak district

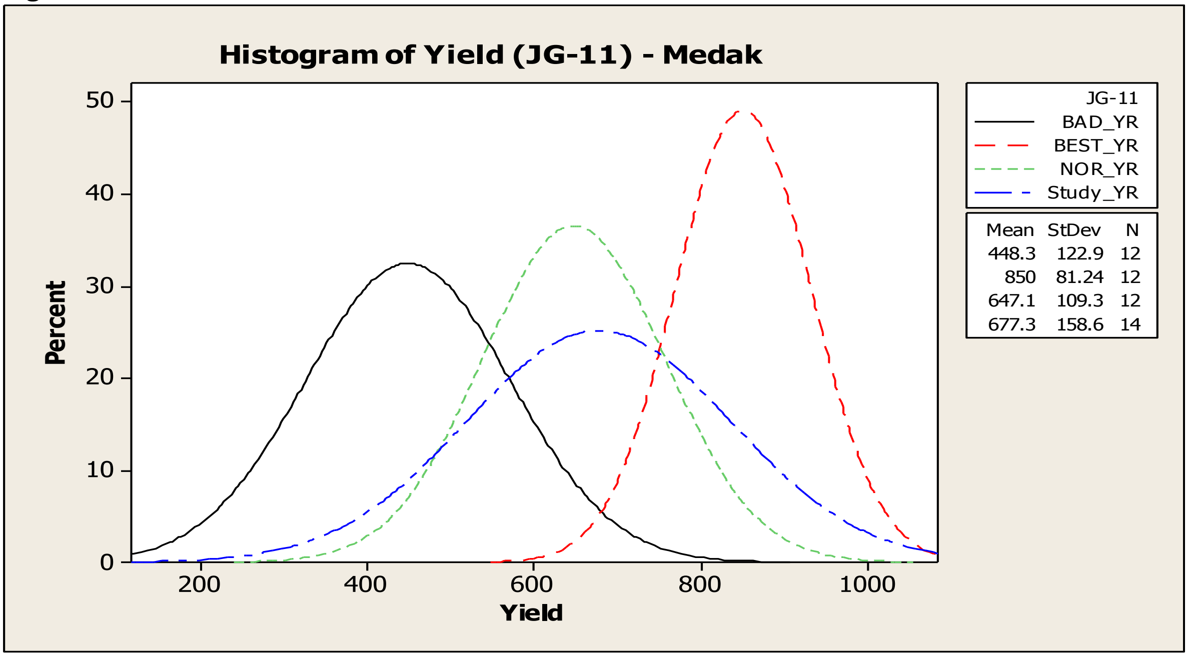
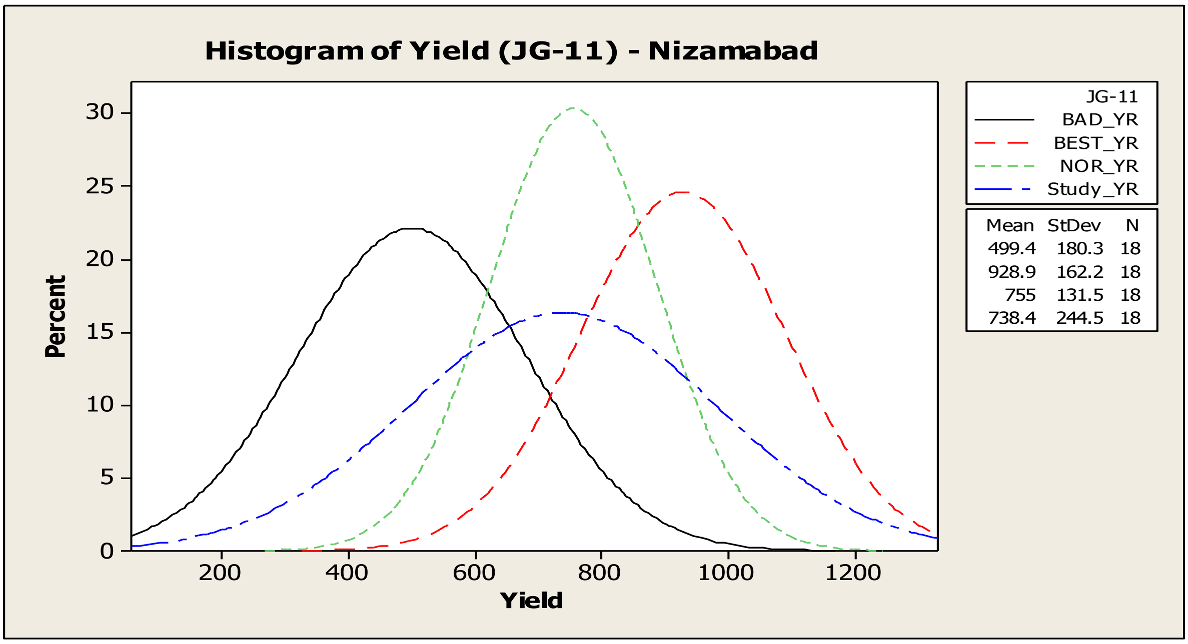


Fig 11.13.10 Yield distribution of JG 11 in Nizamabad district



Appendix 14: Cultivar-wise costs and returns in chickpea cultivation

Table 11.14.1 Costs and returns of JG11 ($ per ha) cultivation across study districts

Item	PRM	KUR	ANA	KAD	MED	MAH	NIZ
	23 plots	183 plots	70 plots	65 plots	2 plots	10 plots	10 plots
Land preparation	105.8	55.9	55.5	68.4	64.4	76.8	88.0
Seed bed preparation	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Compost/Animal penning	18.0	45.2	37.3	21.1	0.0	0.0	0.0
Planting	42.2	20.3	23.0	21.2	32.6	30.5	29.6
Seed cost	116.8	98.2	104.7	107.5	63.6	115.1	79.1
Seed treatment	0.2	2.0	2.5	2.6	0.0	5.0	0.0
Fertilizer cost	83.8	85.1	52.5	87.3	57.3	92.3	59.8
Micro-nutrient	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Interculture	0.0	10.8	15.6	15.2	0.0	14.0	6.4
Weeding	49.4	28.1	22.6	32.2	39.3	40.2	50.9
Plant protection	64.6	42.8	37.7	58.6	31.8	46.9	78.6
Irrigation	0.0	1.3	0.9	0.0	0.0	0.0	3.1
Watching	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Harvesting	79.3	34.7	30.2	49.7	51.6	18.9	62.2
Threshing	86.9	30.4	24.7	43.2	57.8	10.7	55.1
Marketing	12.4	6.5	5.4	8.2	11.8	2.2	16.3
Total-Variable cost (TVC)	659.4	461.4	412.5	515.2	410.2	452.8	529.2
Fixed cost/acre	546.7	336.7	226.5	280.5	404.2	332.3	390.7
Total cost (TC)	1206.2	798.1	639.0	795.7	814.3	785.1	919.9
Grain yield (kg/ha actual)	2339.1	842.3	610.1	1380.7	1746.3	165.5	1645.0
Gross Returns	1713.5	634.3	430.6	1026.4	988.6	102.4	911.5
COP/ton over VC	281.9	547.8	676.2	373.2	234.9	2736.2	321.7
COP/ton over TC	515.7	947.5	1047.4	576.3	466.3	4744.4	559.2
Grain yield (kg/ha Normal)	2114.3	1605.5	1202.9	1449.9	1598.1	1568.5	1864.9
COP/ton over VC – N	311.9	287.4	342.9	355.4	256.7	288.7	283.8
COP/ton over TC – N	570.5	497.1	531.2	548.8	509.6	500.6	493.3
N – Normal yield							

The details of costs and returns in JG 11 cultivation per ha across study districts are presented in the Table 11.14.1. The average gross returns per ha were highly significant in Prakasam district followed by Kadapa, Medak and Nizamabad. However, the total costs per ha were the lowest in case of Anantapur followed by Mahabubnagar, Kadapa and Kurnool districts. The net returns were marginally higher in Prakasam followed by Kadapa and Medak districts. The values were significantly negative in Mahabubnagar district due to drought effect. Similarly, Anantapur and Kurnool districts also could not able to recover the full costs invested in chickpea cultivation. In case of Nizamabad, the total costs were just covered with gross returns per ha. However, the costs of production per ton under actual yields were lower in Medak followed by Prakasam districts. The average cost of production per ton across seven districts with normal yields was $ 521.6.

Table 11.14.2 Costs and returns of KAK 2 ($ per ha) cultivation across study districts

Item	PRM
	36 plots
Land preparation	107.1
Seed bed preparation	0.0
Compost/Animal penning	10.0
Planting	40.5
Seed cost	173.3
Seed treatment	0.4
Fertilizer cost	109.1
Micro-nutrient	2.1
Interculture	0.0
Weeding	46.0
Plant protection	67.1
Irrigation	0.0
Watching	0.0
Harvesting	86.9
Threshing	91.1
Marketing	13.8
Total-Variable cost (VC)	747.4
Fixed cost/acre	559.5
Total cost (TC)	1306.9
Grain yield (kg/ha actual)	2037.8
Price ($/ton)	854.5
Gross Returns	1733.5
COP/ton over VC	366.8
COP/ton over TC	641.3
Grain yield (kg/ha Normal)	1919.2
COP/ton over VC – N	389.4
COP/ton over TC - N	680.9
N – Normal yield	

The average costs and returns of KAK 2 cultivar in Prakasam district is summarized in Table 11.14.2. The gross returns earned per ha of KAK 2 were $ 1733.5. While the total costs associated with its production was $ 1307. An average net profit of $ 426.6 per ha was benefited by a chickpea farmer. The costs of production per ton were slightly higher in case of KAK 2 when compared with JG 11. The seed costs of *kabuli* cultivars per ha are significantly higher than *desi* types.

Table 11.14.3 Costs and returns of Vihar ($ per ha) cultivation across study districts

Item	KUR	KAD
	17 plots	11 plots
Land preparation	62.3	76.3
Seed bed preparation	0.0	0.0
Compost/Animal penning	41.9	12.6
Planting	22.5	21.4
Seed cost	127.9	143.3
Seed treatment	3.3	2.6
Fertilizer cost	104.2	94.3
Micro-nutrient	0.0	0.0
Interculture	20.5	13.5
Weeding	39.4	35.4
Plant protection	46.4	54.3
Irrigation	3.8	0.0
Watching	0.0	0.0
Harvesting	57.2	48.6
Threshing	48.2	48.7
Marketing	12.0	8.5
Total-Variable cost (VC)	589.7	559.4
Fixed cost/acre	462.3	306.2
Total cost (TC)	1052.0	865.6
Grain yield (kg/ha actual)	1390.6	1968.6
Price ($/ton)	800.0	854.5
Gross Returns	1118.1	1667.9
COP/ton over VC	424.0	284.2
COP/ton over TC	756.5	439.7
Grain yield (kg/ha Normal)	1590.7	1553.6
COP/ton over VC - N	370.7	360.1
COP/ton over TC – N	661.3	557.1
N – Normal yield		

The detailed break-up of costs and returns of ‘Vihar’ cultivar are presented in Table 11.14.3. The average gross returns per ha were higher in case of Kadapa than Kurnool district. The total costs incurring per ha was higher for Kurnool district. The mean net returns per ha were significantly larger in case of Kadapa. These differences may be due to the differential productivity in the study districts. The costs of production per ton were slightly lower than KAK 2 but higher than JG 11.

Appendix 15: Costs and returns from chickpea by category of farmers

With the observed adoption patterns of different groups of farmers in Andhra Pradesh, the estimation of cost and returns were undertaken for each category of farmers in the sample:

- Non-adopters, NA – farmers who continue to grow the old varieties
- Adopters, A1 - replacing existing varieties with the new short duration varieties
- Adopters, A2 - substituting the new varieties for other crops grow on part of the farm
- Adopters, A3 - acquiring additional land to grow the new varieties
- Switchers, SW - farmers who have not grown chickpeas before and replace other crops

Table 11.15.1 summarizes the categorization of sample farmers based on extent of chickpea improved cultivars in their farms across study districts. The detailed break-up visualizes that the no. of non-adoptors in the total sample was only 28 (3.45%) out of 810. Among the four categories of adoptors, the highest no.of sample farmers fell under A1 (30.8%) followed by switchers (24.3%), A3 (21.8%) and A2 (19.4%). Overall, the plot-wise costs and returns data at household level were collected from only 1/3rd of the total sample i.e., 270 HH covered out of 810 HH. By using randomization procedure, crop economics data were only collected from 3 out of 9 HH from each selected village. Due to the smaller size of the non-adopters (28), the probability of non-adoptor household being selected under costs and returns data collection was very low (33.3 per cent). Around 10 HH plot-level costs and returns data were collected across three study districts. In case of Medak, chickpea was cultivated along with Safflower at 9:1 proportion. Such inter-crop based plot-level costs information was not used for costs and returns analysis. With these limitations, the non-adoptors costs and returns analysis was not compared with adoptors information. However, the computation of cost and returns by other category of farmers is presented in following tables.

Table 11.15.1 Categorization of sample households (N=810)

District	Mandal	Sample size for each category of farmers by district/mandal					Total
		NA	**A1**	**A2**	**A3**	**SW**	
Anantapur			**46**	**43**	**16**	**30**	**135**
	Beluguppa		13	11	3	0	27
	Kanekal		4	17	4	2	27
	Tadiparthi		3	4	2	18	27
	Uravakonda		11	7	5	4	27
	Vidapanakal		15	4	2	6	27
Kadapa			**36**	**33**	**24**	**42**	**135**
	Mylavaram		11	8	6	2	27
	Peddamudium		11	9	6	1	27
	Rajupalem		5	8	9	5	27
	Simhadripuram		4	4	3	16	27
	Veerapunayunipalle		5	4	0	18	27
Kurnool		**2**	**128**	**64**	**95**	**62**	**351**
	Adoni		14	2	3	8	27
	Alur		6	6	8	7	27
	Aspari		10	6	5	6	27
	Banaganapalle		16	2	4	5	27
	Chippargiri		5	5	10	7	27
	Dorinipadu		12	8	4	3	27
	Gudur	2	6	4	9	6	27
	Koilkuntla		7	4	12	4	27
	Kurnool		8	2	14	3	27
	Maddikera (East)		10	8	7	2	27
	Midthur		12	6	6	3	27
	Sanjamala		12	4	9	2	27
	Uyyalawada		10	7	4	6	27
Mahabubnagar			**7**	**8**	**8**	**4**	**27**
	Manopad		7	8	8	4	27
Medak		**14**	**13**				**27**
	Manoor	14	13				27
Nizamabad		**12**	**11**		**3**	**1**	**27**
	Madnoor	12	11		3	1	27
Prakasam			**9**	**10**	**31**	**58**	**108**
	Janakavarampanguluru		1	2	10	14	27
	Naguluppalapadu		2	3	5	17	27
	Ongole		4	2	10	11	27
	Parchuru		2	3	6	16	27
	Grand total	**28**	**250**	**157**	**177**	**197**	**810**

Table 11.15.2 COC across category of farmers (JG 11 $ per ha)

Item	A1	A2	A3	SW
	92 plots	99 plots	96 plots	76 plots
Land preparation	61.3	58.0	57.5	67.0
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/Animal penning	33.1	39.5	27.4	19.4
Planting	22.5	21.5	20.4	28.0
Seed cost	98.5	101.0	103.7	105.6
Seed treatment	2.2	2.2	2.1	2.1
Fertilizer cost	80.5	65.9	76.8	84.6
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	11.5	12.1	11.2	11.9
Weeding	29.9	28.2	28.0	33.6
Plant protection	48.4	46.7	46.8	46.1
Irrigation	2.2	1.3	0.2	0.0
Watching	0.0	0.0	0.0	0.0
Harvesting	38.9	35.7	37.5	46.7
Threshing	35.2	29.5	33.2	45.2
Marketing	7.5	6.1	6.8	8.0
Total-Variable Cost (TVC)	471.6	447.8	451.7	498.3
Fixed cost/acre (FC)	319.0	282.8	345.3	339.8
Total cost (TC)	790.6	730.6	797.0	838.0
Grain yield (kg/ha actual)	1079.4	839.8	946.0	1165.8
Price ($/ton)	654.5	618.2	690.9	672.7
Gross Returns	757.0	631.5	738.4	808.1
COP/ton over VC	436.9	533.2	477.5	427.4
COP/ton over TC	732.4	870.0	842.4	718.8
Grain yield (kg/ha Normal)	1620.3	1632.7	1667.3	1568.5
COP/ton over VC - N	291.1	274.3	270.9	317.7
COP/ton over TC – N	487.9	447.5	478.0	534.3
N : Normal yield				

Table 11.15.3 COC across category of farmers (KAK 2 $ per ha)

Item	A1	A2	A3	SW
	2 plots	2 plots	15 plots	20 plots
Land preparation	102.2	110.2	97.1	99.3
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/Animal penning	0.0	0.0	5.5	13.8
Planting	41.5	43.2	30.1	43.5
Seed cost	148.2	181.9	174.2	171.9
Seed treatment	0.0	0.0	1.1	0.3
Fertilizer cost	93.2	89.7	119.5	100.7
Micro-nutrient	0.0	0.0	0.0	3.8
Interculture	0.0	0.0	1.6	0.0
Weeding	46.9	44.0	37.8	48.8
Plant protection	50.3	46.7	67.6	68.3
Irrigation	0.0	0.0	0.0	0.0
Watching	0.0	0.0	0.0	0.0
Harvesting	94.3	94.8	78.0	85.5
Threshing	105.8	87.9	81.6	88.3
Marketing	18.0	20.8	11.7	13.7
Total-Variable Cost (TVC)	700.4	719.1	705.9	737.8
Fixed cost/acre (FC)	538.9	494.0	509.0	576.0
Total cost (TC)	1239.3	1213.1	1214.9	1313.8
Grain yield (kg/ha actual)	2178.5	1901.9	2015.5	2040.2
Price ($/ton)	890.9	854.5	854.5	854.5
Gross Returns	1983.4	1622.1	1723.4	1723.4
COP/ton over VC	321.5	378.1	350.2	361.6
COP/ton over TC	568.9	637.8	602.8	643.9
Grain yield (kg/ha Normal)	2003.2	1993.3	1906.8	1897.0
COP/ton over VC – N	349.6	360.7	370.2	388.9
COP/ton over TC – N	618.7	608.6	637.1	692.6
N: Normal yield				

Table 11.15.4 COC across category of farmers (Vihar $ per ha)

Item	A1	A2	A3	SW
	5 plots	7 plots	9 plots	7 plots
Land preparation	64.0	80.8	62.2	64.7
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/Animal penning	54.7	44.3	16.0	17.8
Planting	25.3	21.2	23.2	22.6
Seed cost	119.2	151.1	135.9	124.8
Seed treatment	1.3	2.0	4.3	3.6
Fertilizer cost	115.1	85.1	103.2	95.2
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	22.4	13.9	17.2	18.9
Weeding	34.2	42.9	30.2	36.2
Plant protection	55.7	42.4	54.8	45.3
Irrigation	0.0	2.6	5.2	0.0
Watching	0.0	0.0	0.0	0.0
Harvesting	61.0	50.7	48.9	58.2
Threshing	43.1	49.7	46.3	48.5
Marketing	15.1	9.2	10.7	6.1
Total-Variable Cost (TVC)	611.2	595.9	558.0	541.9
Fixed cost/acre (FC)	368.3	295.1	424.1	500.4
Total cost (TC)	979.4	891.0	982.2	1042.3
Grain yield (kg/ha actual)	1264.6	1817.9	1785.8	1452.4
Price ($/ton)	690.9	872.7	800.0	872.7
Gross Returns	865.1	1610.4	1434.3	1263.8
COP/ton over VC	483.3	327.8	312.5	373.1
COP/ton over TC	774.5	490.1	550.0	717.7
Grain yield (kg/ha Normal)	1524.0	1647.5	1449.9	1642.6
COP/ton over VC - N	401.0	361.7	384.9	329.9
COP/ton over TC – N	642.7	540.9	677.4	634.6
N: Normal yield				

Appendix 16. Competitiveness of chickpea with other crops in sample districts.

Understanding the substitutability/competitiveness of chickpea across study districts is important for better assessment of chickpea adoption in Andhra Pradesh. This exercise lends clear support to chickpea where it stands with other competing crops during post-rainy season. Tables from 11.16.1 to 11.16.7 discuss the competitiveness of chickpea with other crops in the respective seven study districts in the state.

Table 11.16.1 Competitiveness of chickpea in Prakasam district ($ per ha)

Item	Chickpea	Maize	Tobacco
	60 plots*	3 plots	8 plots
Land preparation	107.3	88.8	113.4
Seed bed preparation	0.0	5.3	21.1
Compost/Animal penning	12.9	0.0	60.4
Planting	41.1	39.3	76.6
Seed cost	152.1	113.8	131.8
Seed treatment	0.3	4.2	0.0
Fertilizer cost	99.4	119.5	141.9
Micro-nutrient	1.3	0.0	0.0
Interculture	0.0	14.7	62.1
Weeding	47.2	56.2	64.5
Plant protection	65.8	35.0	136.1
Irrigation	0.0	50.7	18.8
Watching	0.0	0.0	0.0
Harvesting	84.0	66.9	222.7
Threshing	89.5	103.6	781.6
Marketing	13.1	17.7	13.4
Total-Variable cost (TVC)	714.0	715.6	1844.3
Fixed cost	555.8	538.9	522.1
Total cost (TC)	1269.7	1254.5	2366.4
Grain yield (kg/ha actual)	2148.9	4117.5	2230.4
Price ($/ton)	818.2	200.0	1327.3
Gross Returns	1728.4	827.3	2763.9
Net returns over TC	458.7	-427.2	397.5
Net returns over VC	1014.4	111.7	919.6
BCR	1.36	0.66	1.16
Grain yield (kg/ha Normal)	1983.4	7323.6	2423.1
Net returns over TC	353.1	210.2	849.7
Net returns over VC	908.8	749.1	1371.7

** All the chickpea plots adopted improved cultivars*

The benefit-cost ratio of chickpea is higher in case of chickpea when compared with competing crops like tobacco and maize in Prakasam district (Table 11.16.1). Among the seven study districts, farmers' in Prakasam are more progressive and innovative in chickpea cultivation. Due to that chickpea realizes the highest productivity in the country. Most of them prefer to grow *kabuli* types which increase their gross revenue further. With all these factors in the background, chickpea could able to compete with tobacco and maize in the district. Relatively, chickpea needs less investment per ha as well as highly mechanical suitable crop. Even though tobacco competing very closely with chickpea, it requires more labour units per ha.

Table 11.16.2 Competitiveness of chickpea in Kurnool district ($ per ha)

Item	Chickpea	Sorghum	Sunflower	Coriander
	201 plots*	50 plots	10 plots	2 plots
Land preparation	56.5	64.5	53.8	20.9
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/Animal penning	44.7	35.7	12.8	0.0
Planting	20.4	26.8	23.8	2.1
Seed cost	101.0	11.5	31.2	10.3
Seed treatment	2.2	0.4	0.0	0.0
Fertilizer cost	86.7	91.3	74.3	27.1
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	11.5	18.6	17.4	5.5
Weeding	29.1	34.3	31.7	6.2
Plant protection	43.3	39.3	24.3	12.0
Irrigation	1.6	18.3	13.1	0.0
Watching	0.0	4.7	8.8	0.0
Harvesting	36.6	74.5	23.4	4.7
Threshing	32.0	49.7	27.8	0.9
Marketing	6.9	11.5	7.8	0.2
Total-Variable cost (TVC)	472.7	481.2	349.9	90.0
Fixed cost	347.9	367.4	307.6	100.0
Total cost (TC)	820.5	848.6	657.6	190.0
Grain yield (kg/ha actual)	894.1	2665.1	876.9	0.2
Price ($/ton)	727.3	290.9	545.5	0.9
Gross Returns	680.0	744.2	480.4	11.6
Net returns over TC	-140.6	-104.3	-177.1	-178.4
Net returns over VC	207.3	263.0	130.5	-78.4
BCR	0.83	0.88	0.73	0.06
Grain yield (kg/ha Normal)	1603.0	4038.5	1165.8	5.5
Net returns over TC	345.3	326.3	-21.6	71.8
Net returns over VC	693.2	693.6	286.0	171.8

** All the chickpea plots adopted improved cultivars*

The competitiveness of chickpea in Kurnool district is analysed and presented in Table 11.16.2. Chickpea is closely competing with sorghum crop in the district. However, the gross revenues per ha were much higher in chickpea when compared with sunflower and coriander crops. The impact of drought was much conspicuous across all crops in the district during 2011-12. As per the secondary statistics, chickpea has significantly replaced sorghum and sunflower crops in the district during the last two decades. Many of the sample farmers expressed that relatively chickpea is a less risk crop and highly mechanical suitable. Due to the recent increase in agricultural wages, farmers' prefer less intensive crops than the others.

Table 11.16.3 Competitiveness of chickpea in Anantapur district ($ per ha)

Item	Chickpea	Sorghum	Sunflower
	70 plots*	8 plots	1 plots
Land preparation	55.5	54.0	125.7
Seed bed preparation	0.0	0.0	0.0
Compost/Animal penning	37.3	66.9	101.0
Planting	23.0	23.6	20.2
Seed cost	104.7	9.4	29.2
Seed treatment	2.5	0.0	0.0
Fertilizer cost	52.5	65.0	83.1
Micro-nutrient	0.0	0.0	0.0
Interculture	15.6	24.4	35.9
Weeding	22.6	27.9	52.1
Plant protection	37.7	11.4	60.2
Irrigation	0.9	0.0	0.0
Watching	0.0	23.0	0.0
Harvesting	30.2	65.3	0.0
Threshing	24.7	43.6	26.9
Marketing	5.4	11.1	4.5
Total-Variable cost (TVC)	412.5	425.6	538.9
Fixed cost	226.5	193.7	89.8
Total cost (TC)	639.0	619.3	628.7
Grain yield (kg/ha actual)	610.1	2126.7	370.5
Price ($/ton)	709.1	272.7	545.5
Gross Returns	430.6	616.8	202.1
Net returns over TC	-208.4	-2.5	-426.6
Net returns over VC	18.1	191.2	-336.8
BCR	0.67	1.00	0.32
Grain yield (kg/ha Normal)	1202.9	2223.0	617.5
Net returns over TC	235.8	-13.0	-291.9
Net returns over VC	462.3	180.7	-202.1
Almost all chickpea plots adopted improved cultivars			

The extent of substitutability/competitiveness of chickpea with other major post-rainy crops in Anantapur district is presented in Table 11.16.3. Just as like in Kurnool, chickpea is narrowly competing with sorghum crop. However, the gross revenues were higher in sorghum when compared to chickpea. Due to the influence of drought during 2011-12, chickpea in Anantapur experienced severe yield losses. However, when we examine both the crops with average normal yields, chickpea is significantly competing with sorghum and sunflower in the district. It has substantially replaced sorghum and sunflower crops in the district during the last two decades period.

Table 11.16.4 Competitiveness of chickpea in Kadapa district ($ per ha)

Item	Chickpea	Blackgram	Sorghum	Sunflower
	78 plots*	4 plots	5 plots	5 plots
Land preparation	69.4	57.8	69.6	58.7
Seed bed preparation	0.0	0.0	0.0	0.0
Compost/Animal penning	19.3	0.0	0.0	21.6
Planting	21.2	24.3	28.3	25.5
Seed cost	113.8	23.1	18.1	35.0
Seed treatment	2.6	2.3	0.0	0.0
Fertilizer cost	88.1	82.0	117.4	97.4
Micro-nutrient	0.0	0.0	0.0	0.0
Interculture	14.9	14.8	24.8	6.3
Weeding	32.5	38.0	55.0	31.9
Plant protection	57.5	101.9	68.1	16.1
Irrigation	0.0	0.0	28.3	0.0
Watching	0.0	0.0	0.0	7.0
Harvesting	49.4	59.3	111.2	33.6
Threshing	44.2	42.2	91.0	20.8
Marketing	8.3	7.5	24.0	4.8
Total-Variable cost (TVC)	521.2	453.1	635.8	358.6
Fixed cost	285.0	263.8	332.3	233.5
Total cost (TC)	806.2	717.0	968.2	592.1
Grain yield (kg/ha actual)	1482.0	1128.8	3369.1	622.4
Price ($/ton)	727.3	709.1	236.4	618.2
Gross Returns	1138.1	822.2	898.4	393.6
Net returns over TC	331.9	105.3	-69.8	-198.5
Net returns over VC	616.9	369.1	262.5	35.0
BCR	1.41	1.15	0.93	0.66
Grain yield (kg/ha Normal)	1449.9	1111.5	3598.8	1017.6
Net returns over TC	248.3	71.2	-117.5	37.0
Net returns over VC	533.3	335.0	214.8	270.5
**Almost all chickpea plots adopted improved cultivars*				

The performance of chickpea in Kadapa district is presented in Table 11.16.4. Chickpea is strongly competing with other crops which are evident of high benefit-cost ratio values. The gross revenues per ha are significantly higher in chickpea than blackgram, sorghum and sunflower crops. However, blackgram crop is closely following chickpea in the district in the benefit-cost ratio. The actual yields in the district are much closer to normal yields due to low influences of climatic aberrations.

Table 11.16.5 Competitiveness of chickpea in Mahabubnagar district ($ per ha)

Item	Chickpea	Maize
	10 plots*	5 plots
Land preparation	76.8	68.2
Seed bed preparation	0.0	0.0
Compost/Animal penning	0.0	0.0
Planting	30.5	35.7
Seed cost	115.1	38.6
Seed treatment	5.0	0.0
Fertilizer cost	89.5	145.7
Micro-nutrient	0.0	0.0
Interculture	14.0	28.9
Weeding	40.2	45.8
Plant protection	46.9	28.1
Irrigation	0.0	28.8
Watching	0.0	0.0
Harvesting	18.9	55.6
Threshing	10.7	27.8
Marketing	2.2	10.9
Total-Variable cost (TVC)	450.0	514.1
Fixed cost	332.3	269.5
Total cost (TC)	782.4	783.5
Grain yield (kg/ha actual)	165.5	1980.9
Price ($/ton)	672.7	218.2
Gross Returns	102.4	479.0
Net returns over TC	-679.9	-304.5
Net returns over VC	-347.6	-35.1
BCR	0.13	0.61
Grain yield (kg/ha Normal)	1568.5	3811.2
Net returns over TC	272.8	48.0
Net returns over VC	605.1	317.5
**Almost all chickpea plots adopted improved cultivars*		

Table 11.16.5 analyse the chickpea performance in Mahabubnagar in relation to other crops in the district. As discussed and highlighted in the earlier sections, chickpea is severely damaged in the district due to the drought. The effect of drought was much conspicuous in both chickpea and maize crops in the district. Under the normal yields, chickpea strongly competing with maize crop with sizable amount of net returns per ha.

Table 11.16.6 Competitiveness of chickpea in Medak district ($ per ha)

Item	Chickpea	Cotton
	3 plots*	3 plots
Land preparation	84.8	88.8
Seed bed preparation	0.0	0.0
Compost/Animal penning	0.0	44.1
Planting	46.7	54.2
Seed cost	72.3	160.8
Seed treatment	0.0	0.0
Fertilizer cost	61.7	162.4
Micro-nutrient	0.0	0.0
Interculture	0.0	57.9
Weeding	43.2	55.4
Plant protection	41.3	127.9
Irrigation	0.0	0.0
Watching	0.0	0.0
Harvesting	62.8	187.8
Threshing	65.0	0.0
Marketing	15.9	19.2
Total-Variable cost (TVC)	493.7	958.6
Fixed cost	419.1	404.2
Total cost (TC)	912.9	1362.8
Grain yield (kg/ha actual)	1729.0	2200.8
Price ($/ton)	581.8	690.9
Gross Returns	1018.9	1505.8
Net returns over TC	106.0	143.0
Net returns over VC	525.1	547.2
BCR	1.12	1.1
Grain yield (kg/ha Normal)	1598.1	1939.0
Net returns over TC	16.9	-23.1
Net returns over VC	436.1	381.1
** Only sole plots considered for analysis*		

The detailed break-up of costs and returns per ha of chickpea cultivation in Medak district are presented in Table 11.16.6. Chickpea is closely competing with commercial crops like cotton in Medak district. Even though the gross returns per ha are much higher in cotton, the costs/investments per ha associated with it also larger. In general, farmer prefers chickpea because of high net returns as well as lower investments per ha.

Table 11.16.7 Competitiveness of chickpea in Nizamabad district ($ per ha)

Item	Chickpea	Sorghum
	14 plots*	4 plots
Land preparation	82.5	78.3
Seed bed preparation	0.0	0.0
Compost/Animal penning	0.0	0.0
Planting	29.4	45.3
Seed cost	75.6	7.8
Seed treatment	0.0	0.0
Fertilizer cost	59.4	43.1
Micro-nutrient	0.0	0.0
Interculture	6.1	0.0
Weeding	46.8	36.6
Plant protection	72.8	7.7
Irrigation	2.2	0.0
Watching	0.0	0.0
Harvesting	58.9	106.9
Threshing	54.6	56.0
Marketing	16.6	12.0
Total-Variable cost (TVC)	504.9	393.7
Fixed cost	391.3	325.6
Total cost (TC)	896.2	719.3
Grain yield (kg/ha actual)	1751.2	1538.8
Price ($/ton)	563.6	400.0
Gross Returns	976.5	617.3
Net returns over TC	80.3	-102.0
Net returns over VC	471.6	223.6
BCR	1.09	0.86
Grain yield (kg/ha Normal)	1864.9	2776.3
Net returns over TC	154.9	391.2
Net returns over VC	546.2	716.8
**More than half plots under improved cultivars*		

The competitiveness of chickpea in Nizamabad district is summarized in Table 11.16.7. The gross returns per ha were significantly higher in case of chickpea than the sorghum crop. However, sorghum is highly competing with chickpea under normal yields in the district.

Appendix 17: Summary of welfare benefits across different category of farmers

Table 11.17.1 Break-up of total welfare benefits ($ million)

Item	Total All	Total AP	PRM-NA	PRM-A	PRM-SW	KUR-NA	KUR-A	KUR-SW	ANA-NA	ANA-A	ANA-SW	KAD-NA	KAD-A	KAD-SW
Total Welfare Change	711.7	358.9	0.0	6.7	71.1	-0.1	62.9	104.7	0.0	15.2	28.3	0.0	8.4	22.3
Producer Surplus	228.8	353.3	0.0	6.6	70.2	-0.1	62.1	103.3	0.0	15.0	27.9	0.0	8.3	22.0
Consumer Surplus	482.9	5.6	0.0	0.1	0.9	0.0	0.8	1.3	0.0	0.2	0.4	0.0	0.1	0.3
Adopters	606.0	358.7												
Non-adopters	-377.2	-5.4												

NA: Non-adopters; A: Adopters; SW: Switchers

Contd.,

Item	Total All	Total AP	MED-NA	MED-A	MED-SW	NIZ-NA	NIZ-A	NIZ-SW	MAH-NA	MAH-A	MAH-SW	RAP-NA	RAP-A	RAP-SW
Total Welfare Change	711.7	358.9	-0.9	9.5	0.0	-0.9	9.5	3.3	0.0	5.2	14.3	-2.7	2.3	0.0
Producer Surplus	228.8	353.3	-1.1	9.3	0.0	-1.1	9.3	3.3	0.0	5.1	14.1	-3.1	2.2	0.0
Consumer Surplus	482.9	5.6	0.2	0.1	0.0	0.2	0.1	0.1	0.0	0.1	0.2	0.5	0.0	0.0
Adopters	606.0	358.7												
Non-adopters	-377.2	-5.4												

NA: Non-adopters; A: Adopters; SW: Switchers; RAP: Rest of AP

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ICRISAT is headquartered in Patancheru near Hyderabad, Andhra Pradesh, India, with two regional hubs and five country offices in sub-Saharan Africa. It is a member of the CGIAR Consortium. CGIAR is a global research partnership for a food secure future.

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