an AICRPDA compendium

Research Publications and Recommendations in Dryland Agriculture

Annotated Bibliography 1971-2002

Central Research Institute for Dryland Agriculture
Hyderabad
About this compendium . . .

The All India Co-ordinated Research Project for Dryland Agriculture network started functioning from 1971 with head quarters at Hyderabad, Andhra Pradesh. There were twenty-three centers to start with, but consolidated to twenty-two centers at present. There are more than one hundred scientists from different disciplines, which distinguish this project from others. The centers cover eight crop(s) based production systems, almost all soil orders and climatic regions from arid through semi arid to sub-humid. The scientific publications and recommendations are the primary indicators of success of any mission-oriented project in meeting the clientele needs.

At present a compilation of annotated bibliography showed more than a thousand publications in scientific journals. Other popular articles, book contributions, presentations etc. were not considered. The general trend of publications was increase to a plateau at present. Among the centers Indore, Rajkot, Bangalore, Solapur, Bijapur, Ranchi, Phulbani, Kovilpatti cover seventy per cent of the publications with Indore as the topnotch publisher covering thirteen per cent of the total. An index is made on programs and issues in which publications are made. The work on cropping system increased with time. Research on rainwater management has decreased as expected. Little change in integrated nutrient management was noticed.

Cover: Greening the grey areas

Cover design: KVGK Murthy and I Ram Mohan
an AICRPDA compendium

Research Publications and Recommendations in Dryland Agriculture

Annotated Bibliography 1971-2002

KPR Vittal
HP Singh
GR Maruthi Sankar
G Ravindra Chary
T Sri Jaya
Vibha Srivastava

All India Coordinated Research Project for Dryland Agriculture
Central Research Institute for Dryland Agriculture
Hyderabad 500 059

2003
Contents

1. Introduction 1

2. Research Publications 4

3. Important Recommendations 55

4. Subject Index 74
1. Introduction

An annotated bibliography of the research publications, is prepared for the period ending 2002 since inception of the All India Co-ordinated Project for Dryland Agriculture in 1971. There are a total of 1002 publications from various centers during this period. We believe that there can be other publications unquoted, the limitations being non-availability of information. The centers also include those in the network but later on either discontinued or shifted location to other places. From 23 centers at start, now the network has only 22 centers. These include the centers from State Agricultural Universities, Technical Universities and ICAR institutes. During this period, there were two peaks in number of publications: one during 1980-81 and other in 1995-96. However the general trend was quadratic with plateau at present.

Among the various centers the topnotch publishers are Indore, Rajkot, Bangalore, Solapur, Bijapur, Ranchi, Phulbani, Kovilapatti, Varanasi. These almost cover 70% of the publications.
The publications are divided into nine programmes - resource characterization, rainwater management, crops and cropping system, soil fertility and nutrient management, alternate land use systems, energy management, post-harvest technology, socio economics and on-farm work. Among the various programs, the top four from which the publications take a lion’s share are crops and cropping systems, soil fertility and nutrient management, resource characterization, Rainwater management. It is seen that crops and cropping system increased slightly with time and the work on rainwater management is as expected decreased with time. Integrated nutrient management almost remained constant and resource characterization work marginally increased.

To the top four programmes major contributor was Indore. Thus cropping system programme, the resource management and utilization programmes almost shared equally in the publications.
The details on publications, recommendations and subject index follows.
2. Research Publications

A list of research articles published in various journals from the work carried out at the centers in the All India Co-ordinated Research Project is compiled. A few of the centers could not supply the full list of publications from the early period of the project formulation. The present listing has about 1002 numbers of annotated bibliographies published by various scientists from different disciplines from inception of the project - 1971 to 2002. The list includes some popular journals in case of socio-economics; otherwise the compilation is limited to refereed and reviewed articles published in professional journals. The center-wise information in chronological order follows:

Agra


Research Publications and Recommendations in Dryland Agriculture


Akola


Anantapur


Bangalore


Research Publications and Recommendations in Dryland Agriculture


Bellary


**Bhilwara**


18 Maliwal, P.L., Gupta, I.N. and Rathore, S.S. (1993). Response of barley (Hordeum vulgare) to different fertility levels and PMA. under tank - bed conditions. Indian Journal of Agricultural Sciences 63(12). (Other details not available)


**Bijapur**

1 Badanur, V. P. (1976). Greengram followed by rabi jowar double cropping system is most remunerative under dryland conditions of Bagalkot. Current Research. 5:149-155.


8 Satyanarayana T. (1979). A study on water availability to the crops grown under rainfed conditions in different soils at Bijapur. Indian Journal of Meteorology, Geophysics and Hydrology. 27 (4): *(Other details not available)*


Dantiwada


Dehradun


Faizabad


Research Publications and Recommendations in Dryland Agriculture


Hisar


Hoshiarpur


**Hyderabad**


**Indore**


Research Publications and Recommendations in Dryland Agriculture


29 Sharma, R.A. and Dixit, B.K. (1987). Effect of varying soil water potentials on seeding emergence,

on yield and protein content of different varieties of ragi (Eucleusine coracana Gaertn) grown under
rainfed conditions. Agriculture Science Digest, 8(3): 161-164.


phase of rainfed wheat and safflower. Progress in ecology 10: 317-328.


Soil Science. 15:111-112.


Merril) varieties grown on black clay soils under rainfed conditions. Legume Research, 12(3): 143-147.


water use efficiency of some soybean (Glycine max (L.) Merril) cultivars grown on vertisols under rainfed


yield, dry matter and water-use efficiency of soybean (Glycine max) under rainfed condition. Indian
Journal of Agricultural Sciences. 60(3): 185


intercropping system to phosphorus fertilization in vertisols under rainfed conditions. Journal of
NATCON. 3(2): 197-203.

conditions. Agriculture Reviews 12(3): 121-130.


and pigeonpea (Cajanues cajon) genotypes grown in intercropping system. Indian Journal of Agricultural
Sciences 61 (2): 93-6.


105 Sharma, R.A. Weekly initial and conditional probabilities of rainfall during rainy season in western Madhya Pradesh. Crop Research. 5: 193-198. (Other details not available)


Research Publications and Recommendations in Dryland Agriculture


Jhansi


Jodhpur


Kovilpatti


<table>
<thead>
<tr>
<th>No.</th>
<th>Author(s)</th>
<th>Title</th>
<th>Journal and Volume</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td>Muthvel, P., Rajkannu, K., Manickam, T.S. and Balasubramanian, T.L.</td>
<td>Effect of P and Zn on the yield of sunflower</td>
<td>Oil Seeds Journal 54:</td>
<td>1986</td>
</tr>
<tr>
<td>32</td>
<td>Balasubramanian, T.N., Subramanian, S.</td>
<td>Agronomic options for stabilized crop productivity in vertisols under rainfed conditions</td>
<td>Indian Journal of Dryland Agriculture Research and Development 5 (1 and 2):</td>
<td>1990</td>
</tr>
<tr>
<td>33</td>
<td>Balasubramanian, T.N., Sree Ramulu, U.S. and Nalliah Devraj, S.</td>
<td>Canopy management of Karunganni cotton under rainfed conditions</td>
<td>Madras Agriculture Journal 79(9):</td>
<td>1992</td>
</tr>
<tr>
<td>35</td>
<td>Balasubramanian, T.N. and Subramanian, S.</td>
<td>Correlation and multiple regression inter cropping system</td>
<td>Madras Agriculture Journal 81(3):</td>
<td>1994</td>
</tr>
<tr>
<td>38</td>
<td>Chidambaram, S. Ramanatha Pillai, O., Muthuawamy, P., Dhannakodi, C.V. and Sankarapandian, P.</td>
<td>A high yielding drought tolerant blackgram for rainfed vertisols</td>
<td>Madras Agriculture Journal 82(9,10):</td>
<td>1995</td>
</tr>
</tbody>
</table>


Phulbani


Research Publications and Recommendations in Dryland Agriculture


Rajkot


Research Publications and Recommendations in Dryland Agriculture


Ranchi


Rewa


Solapur


Research Publications and Recommendations in Dryland Agriculture


Research Publications and Recommendations in Dryland Agriculture


Varanasi


3. Important Recommendations

Important recommendations given to the state departments of agriculture and have become popular with the farmers from various centers are given production system-wise since inception till date. These recommendations are linked to the list of publications to the possible extent. The centers name is identified after the recommendations within paranthesis by first four letters of the center’s name followed by the publication serial number.

Rainfed Rice based Production System (Ranchi)

**Rainwater Management**

The fields must be bunded to conserve soil moisture in uplands.

**Crops and Cropping Systems**

**Rice**

Sowing of upland rice should be completed by last week of June by line sowing behind the plough 35 cm apart with a seed rate of 6 to 8 kg/ha of Birsa Gora 102, Birsa Dhan 101 (Ranc 5,15)

In medium and low lands where water will stagnate up to 15th November, transplant (rice IR 36, Kanak, or Pankaj) before third week of July, one month old seedlings with a spacing of 20 x 15 cm. For late transplanting 15 x 10 cm to compensate the yield reduction.

**Crop substitution**

In case of upland, groundnut, maize and soybean must be substituted in place of rice and finger millet. Comparatively deeper and light textured uplands can support a good crop of groundnut, soybean, finger millet, maize, sorghum, minor millet, pigeonoea, blackgram, greengram, sweet potato, sesame, niger, horsegram etc... Intercropping are benefical for these lands and recommended intercrops are:

- Pigeonpea + Maize (Alternate rows 75 cm apart full population of both) (Ranc 21,27, 48, 49, 50, 68)
- Pigeonpea + Rice (Two rows of rice in between 2 rows of pigeonpea spaced 75 cm) (Ranc 36, 65, 68, 70)
- Pigeonpea + Groundnut (Three rows of groundnut in between 2 rows of pigeonpea spaced at 90 cm) (Ranc 63)
- Pigeonpea + Blackgram/ Greengram (Two rows of black gram/Green gram in between 2 rows of pigeonpea at 75 cm) (Ranc 32)

**Weeding**

2-3 days after transplanting Butachlor @ 1.5 kg ai/ha must be sprayed to control the weeds. Weeding is critical within 3 to 4 weeks. After one month one hand weeding is essential.

**Soil and Nutrient Management**

In uplands FYM, compost as per availability and 40 N, 30 P₂O₅ and 20 K₂O kg/ha. (Ranc 22, 54)

In lowlands 2.5 t/ha FYM/compost, 50 P₂O₅ and 40 K₂O kg/ha basal. Equal splits of total 80 N kg/ha at the time of transplanting and after one month after weeding. After application of N water should not flow in to another field up to 3 to 4 days.

**Alternate Land Use System**

Social forestry, farm forestry and establishment of pasture crops in denuded, eroded, highly sloppy and shallow lands.

Rainfed Rice based Production System (Varanasi)

**Rainwater Management**

**Land treatment**

Tillage during summer

Open end contour or graded bunds (0.3 to 4%)
Drop structure at intervals across seasonal rivulets in Vindhyan tract with rolling abrupt/dissected topography

**Supplemental irrigation**
Farm ponds/storage bundhies in mild to flat toposequence of Gangetic plains and foot hills of Vindhyan range.

Wide diameter wells as additional minor irrigation source.

Supplementing irrigation utilizing harvested water

Rajmash + barley with 3 cm irrigation 30 days after sowing (Vara 60)

<table>
<thead>
<tr>
<th>Crops</th>
<th>Crops</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chickpea replacing traditional wheat</td>
<td>Lentil mutant HUL 11 has been ranked first in multilocation trial conducted in North-East palin zone over recommended Pant L639 and Pant L 406</td>
</tr>
</tbody>
</table>

**Cropping systems**
Upland rice-chickpea/lentil for flat low lands (Vara 60,56,57)
Sesame-chickpea/lentil in well drained medium/uplands (Vara 48, 56, 57)
Intercropping blackgram (50% population) or sesame (75% population) with pigeonpea (100%population),
Barley + mustard (8:1) (Vara 39)
Lentil + mustard (4:1).
Okra + Pigeonpea
Tomato + lentil or linseed

**Plant protection**
Sowing in time
First 30 days (after sowing) is most crucial for weed control in Kharif crops of dryland.
Pre-emergence application of Alachlor and post emergence application of proponil @ 2 kg/ha in upland rice (Vara 1,14, 34, 41)
Pre emergence application of atrazine @ 1-2 kg ai/ha in maize, pearlmillet and sorghum
Alternatively two inter culture operations 30-35 and 45-50 DAS

<table>
<thead>
<tr>
<th>Soil and Nutrient Management</th>
<th>Inorganics</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>80:40:30 N - P₂O₅ - K₂O to cereals</td>
</tr>
<tr>
<td></td>
<td>20:40:20 N - P₂O₅ - K₂O to pulses</td>
</tr>
<tr>
<td></td>
<td>40:20:20 N - P₂O₅ - K₂O to oilseeds</td>
</tr>
</tbody>
</table>

**Integration**
Pulse component in the system
Conjunctive use of nutrients through organic (40 kg N/ha) and inorganic (40 kg N/ha) fertilizers in rice – lentil (sustainability index 0:70) (Vara 44)

**Alternate Land Use System**
Agro-horti system
Pigeonpea + field pea in guava
Ber+ wheat

**Implements**
Seed drills
Bullock drawn multi crop seeder
Malviya machine

**Others**
Multi farming unit for operations like seed bed preparation, seeding and weeding
Dryland weeders
Rainfed Rice based Production System (Faizabad)

Rainwater Management
- Summer tillage
  - Deep ploughing during summer followed by two cultivators
  - Seeding time
  - Preparation of seedbed by two ploughings
  - Two planking at the time of sowing of sorghum was proved more remunerative.

Crops and Cropping Systems
- Cultivars
  - Rice (variety NDR-312)
  - Groundnut (variety Chandra)
  - Pigeonpea (variety Bahar)
  - Groundnut and pigeonpea proved more remunerative than paddy, blackgram, sunflower, greengram, sorghum, maize, pearl millet and sesame crops.
  - Mustard (RSM-106, Varuna and NDR-8501) 9Faiz 21)
  - Chickpea (Type-3)
  - Lentil (HUL-11)

Intercropping
- Mustard + chickpea (1:4)
- Gram and mustard crops gave higher yields when sown after the early sown blackgram. (Faiz 8,6)
- Barley produced more yield when sown after the early sown fodder crops of maize + cowpea.
- Pigeonpea + groundnut or blackgram (Faiz 8,6)

Sequence cropping
- Rice – chickpea (NDG-8605)

Soil and Nutrient Management
- Inorganics
  - Mustard + Chickpea (1:4 and 1:3) with recommended dose of fertilizer i.e., 60kg N+ 30Kg P₂O₅/ha to mustard and 18kg N+46 P₂O₅/ha to chickpea (Faiz 8,11)
  - Maize varieties like Sartaj and Naveen grown on grade bund or ridge furrow with 100:50:50 N P₂O₅ K₂O kg/ha
  - Rice 80 kg N/ha
  - Linseed (Garima and Mukta) with 30kg N/ha (Faiz 1)
  - Lentil 30kg P₂O₅ and 15kg S/ha. (Faiz 2)
  - Mustard 60kg N and 40kg S/ha (Faiz 3, 16)
  - Sorghum 30 N 40 P₂O₅ 30 K₂O kg/ha 50% at sowing and 30 N kg/ha at 40 days
  - Chickpea 60 P₂O₅ and 25 Zn kg/ha

Alternate Land Use System
- Implements
  - Land preparation and sowing of seed and application of fertilizer by power tiller operated till plant machine.

Rainfed Rice based Production System (Phulbani)

Rainwater Management
- Intercropping system of pigeonpea + groundnut, pigeonpea + rice, pigeonpea+ greengram, maize + cowpea and pigeonpea + ragi. (Phul 4, 6, 7 10,11,12,14,15,16,18, 28, 29,43,47,55, 70)
- Replacement of long duration local rice varieties by short duration high yielding varieties like Subhadra, ZHO-11-26 and BAU 146-16-3 for rainfed uplands.
- Practice of short duration high yielding rice variety/ maize in Kharif followed by short duration high yielding variety of mustard/ Horsegram as sequence crop to enable the farmers to take two crops under rainfed situation. (Phul 22,71)
- Recommendations of management practices like early sowing before the onset of monsoon or just after, line sowing by suitable implements, timely weeding, seed treatment and maintenance of optimum plant population.
All India Coordinated Research Project for Dryland Agriculture (AICRPDA)

**Soil and Nutrient Management**
Application of lime in acid soil to improve the productivity of pulse and oilseed crops as well as maize crop. Split application of Nitrogenous fertilizers to Kharif crops to improve the fertilizer use efficiency.

**Alternate Land Use System**

**Groundnut based Production System (Anantapur)**

**Rainwater Management**
- Contour bunding of 0.63 m² cross section at 50 m interval
- Deep ploughing once in three years (Anan 14)
- Dead furrow at 3 to 6 mm interval (Anan 5, 10)

**Crops and Cropping Systems**
- **Varieties**
  - Groundnut - Verma, K-4 JL-24
  - Pigeonpea - LRG 30
  - Pearl millet – Ananta (APS 1)
  - Sorghum - Taapijonna (AJ-140)
  - Foxtail millet - Lepakshi

- **Intercropping**
  - Groundnut + pigeonpea (7:1) (Anan 7)

**Plant protection**
Control late leat spot in groundnut by spraying Carbendazim (0.1%) + Mancozeb (0.2%) (Anan 18)
Need based plant protection for the control of leat webber

**Management**
Contour cultivation

**Soil and Nutrient Management**
- Sand @ 40t/ha application at the time of sowing (Anan 5, 12, 17)
- Fertilizer dose of 20 N - 40 P₂O₅ - 20K₂O kg/ha for groundnut and groundnut + pigeonpea intercropping system.
- Fertilizer placement
  - Zinc sulphate @ 50 kg/ha application for groundnut once in 3 years.
  - Application of groundnut shells as mulch @ 5 t/ha 10 days after sowing of groundnut. (Anan 10,12)
  - Fertilizer of 40 N –80 P₂O₅ kg/ha for pearl millet.

**Alternate Land Use System**
Stylo for degraded lands and seed production

**Implements**
Enanti gorru for simultaneous drilling of seed and fertilizers.

**Groundnut based Production System (Rajkot)**

**Rainwater Management**
- Two to four interculturings along with deep ploughing in groundnut.
- Spreading groundnut on sloppy lands. Adopt shallow ploughing before sowing and make ridge and furrow after 25 days after sowing. At the stage of pegging, earthing up

**Supplemental irrigation**
Irrigate groundnut (GAUG-10) of 5 cm depth by flooding whenever there is a stress period (Rajk 26, 33)

**Crops and Cropping Systems**
- In North Saurashtra Agroclimatic Zone to sow improved variety of pearl millet (GHB-32) within 15 days of onset of monsoon for harvesting maximum fodder yield.
- Next priority should be given to fodder maize (Ganga safed-2) or sorghum (CSH-5) for better economic return
**Groundnut**
Grow in kharif erect groundnut by adopting ridge and furrow method of sowing.
The practice of discarding light pods and small seeds by the farmers for sowing groundnut is discouraged. The small seeds (test weight not less than 20 g) can be used effectively for sowing. With the use of small size seeds, the farmers can save seed rate to the extent of 25% i.e. >30 kg/ha
In Chotila taluk to grow either Junagadh-11 or Punjab-1 variety of groundnut keeping row spacing of 45 or 60 cm. In Dhari region, higher yields obtained with keeping row spacing of 30, 45 or 60 cm.
The farmers of Dhari and Jamkhambhalia regions of North Saurashtra Zone are advised to grow groundnut (GAUG-1 or 10) at 45 cm row spacing over 75 to 90 cm spacing. (Rajk 31,70)

**Pearlmillet**
For pearlmillet HB-3, row spacing of 60cm is profitable.
In North Saurashtra Agroclimatic Zone to sow late type pigeonpea BDN-2 at a distance of 75 cm between rows (Rajk 17)

**Castor**
In North Saurashtra Agroclimatic Zone to sow the castor GAUCH-1 at a distance of 90x45 cm
The farmers of North-west Agroclimatic zone of Gujarat should follow a crop geometry of 120x60 cm rainfed castor.

**Intercropping system**
Groundnut (J-11) + castor (GAUCH-1) as intercropping in the row ratio of 3:1
In North Saurashtra Agroclimatic Zone to follow intercropping system of bunch groundnut (J-11) + castor (GAUCH-1) in either 3:1 or 6:1 crop rows ratio.
The inter-row spacing of groundnut and Castor should be maintained at 45 and 180 cm respectively of 3:1 crop row ratio.
For 6:1 crop row ratio the inter – row spacing for groundnut and Castor should be kept at 45 and 35 cm respectively.
In North Saurashtra region to follow intercropping of groundnut with castor (GAUCH-1) in 3:1 ratio
Intercropping of pearlmillet + pigeonpea (2:1 and 4:1). (Rajk 29, 71)
Pearlmillet (BJ-104) should be grown in paired rows (40cm apart with a spacing of 40x 15 cm) in between two rows of pigeonpea (UPAS-120) at a spacing of 120 x 45 cm. Sorghum + pigeonpea (1:1) with recommended fertilizer (90-30 N-P2O5 kg/ha) to base crop Cotton (V-797) + greengram (Gujarat-1)
Cotton G.cot-10 + groundnut (J-11)
Cotton (CJ-73) with greengram or blackgram or groundnut (Rajk 64)
In Bhal region intercropping of greengram or blackgram in a paired row system of planting cotton

**Mixed cropping**
In North Saurashtra zone to grow pearlmillet (100% recommended seed rate) as mixed cropping with greengram (20% recommended seed rate). The mixed crop of greengram and pigeonpea with pearlmillet

**Plant protection**
In Ghed area of South Saurashtra zone only one interculturing 30 days after sowing in cotton V-797.
Nil to very low rainfall in early stage of plant growth, particularly in the third week of July i.e. 29th standard week was found favourable for the appearance and high build up to aphid population. Whereas continued rainfall about 20mm with 2 to 4 rainy days during this period was unfavourable. (Rajk 39)
Controlling major sucking pests (aphids, jassids and trips) in groundnut (GAUG – 10) by applying following insecticidal schedule for the farmers of dry farming areas of Saurashtra. The net ICBR obtained was 1:7.11 with two sprays and 1:4.09 with three sprays. (Rajk 48)
Spray schedule:

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Concentration</th>
<th>Time of spray</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phosphamidon 0.03%</td>
<td>@ 180 ml a.i./ha</td>
<td>Two weeks after notice of aphid on stickytrap</td>
</tr>
<tr>
<td>Dimethoate 0.03%</td>
<td>@ 180 ml a.i./ha</td>
<td>One spray after first spray</td>
</tr>
</tbody>
</table>

In addition to two sprays as cited above the farmers can also go for one more additional spray with endosulfan (0.07%) @ 420 lit/ha after 15 days of second spray.

For the control of army worm and stem borer pests of hybrid sorghum CSH-6, following insecticidal schedule is recommended.

<table>
<thead>
<tr>
<th>Insecticide</th>
<th>Concentration</th>
<th>Time of application</th>
</tr>
</thead>
<tbody>
<tr>
<td>Endosulfan 4G 0.8 kg</td>
<td>Apply in whorl 30 DAS</td>
<td></td>
</tr>
<tr>
<td>Endosulfan 4G 0.8 kg</td>
<td>Apply in whorl 60 DAS</td>
<td></td>
</tr>
<tr>
<td>Endosulfan 35 EC 0.07%</td>
<td>Apply in spray 60 DAS</td>
<td></td>
</tr>
</tbody>
</table>

In case of non-availability of endosulfan 4G, the application of three sprays of endosulfan 35 EC 0.07 % at 30, 60 and 60 DAS may be recommended as it has net ICBR of 1:1.26.

It is most profitable for the farmers to follow the spray schedule for controlling both tikka and rust diseases of erect groundnut (GAUG-1)

Fungicide          | Concentration | Time of spray                        |
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Mancozeb 0.2 %</td>
<td>35 days after germination</td>
<td></td>
</tr>
<tr>
<td>Carbendazim 0.025%</td>
<td>50 days after germination</td>
<td></td>
</tr>
<tr>
<td>Mancozeb 0.2 %</td>
<td>70 days germination</td>
<td></td>
</tr>
</tbody>
</table>

Contingency plans

The cultivators of Bhal Agroclimatic Zone to grow safflower or chickpea instead of dry wheat

Soil and Nutrient Management

It is recommended to apply nitrogen to pearlmillet, sorghum, and cotton crops in two splits i.e. 1/2 dose at sowing and the remaining 1/2 to be top dressed after 25-35 days from sowing date for pearlmillet and sorghum and after 45-50 days after sowing for cotton when the soil moisture conditions are favourable. (Rajk 74,79,88). The top dressed dose of N should be well mixed during the suggested period and if there is a prolonged drought, the second split may be omitted this will resulted in saving of fertilizers.

Pearlmillet

The farmers of North Saurashtra Agroclimatic Zone adopting groundnut-pearlmillet crop rotation need to apply 100% of recommended dose of fertilizer only to the pearlmillet crop.

Pigeonpea (UPAS-120 or Hy –2) raised as mixed crop with pearlmillet (BJ 104) @38 N and 19 P₂O₅ kg/ha. The rate of fertilizer application should be doubled for obtaining higher production. The seed rates were 20 and 3.75 kg/ha for pigeonpea and pearlmillet respectively.

Pearlmillet HB-3 can be given 80N kg /ha.

Maximum pearlmillet grain yield can be obtained by adopting the recommended package of practices in terms of variety (BJ-104), fertilizer (75 N and 37.5 P₂O₅ kg/ha) and crop management (seed treated with fungicides), seed rate of 3.75 kg/ha and spacing of 60X 15 cm. (Rajk17)

To minimize the risk factors, the farmers growing pearlmillet as rainfed crop are advised to apply the recommended dose of nitrogen fertilizer either in two splits (25% as basal + 75% at tillering) or in three splits (25% as basal + 50% at tillering+ 25% at flag leaf stage) instead of the existing recommendation of 50% as basal and 50% at tillering. (Rajk 18)

The farmers are recommended to apply recommended dose of base crop of pearlmillet (80 N and 40 P₂O₅ kg/ha) to the intercropping of pearlmillet + pigeonpea for maximum monetary returns. The marginal farmers can obtain higher profit by applying 40 to 60 N kg/ha to the intercropping system. Phosphorus should be applied uniformly.
**Sorghum**

In sorghum CSH 6 apply 90 N and 30 P$_2$O$_5$ kg/ha to in medium black soils.
In dual purpose sorghum CSH 5 apply 60 N and 30 P$_2$O$_5$ kg/ha,
In rainfed sorghum apply recommended dose of nitrogenous fertilizer in three splits i.e.
25% as basal + 50% at tillering + 25% at flag leaf stage instead of the two splits of
50% as basal and 50% at tillering stage. (Rajk 46, 50)
The farmers of North Saurashtra Agroclimatic Zone (AES-1) in fodder sorghum apply
50 N kg/ha in two equal splits, basal and top dress at 30 days after sowing with 30
P$_2$O$_5$ kg/ha to get more fodder yield and net return.

**Cotton**

In North Saurashtra Agroclimatic Zone apply 40 N kg/ha (equally as basal and top
dressing after 45-50 days after sowing when sufficient moisture is in the soil) to cotton
variety G.cot – 10 on medium black soils. For cotton variety G.cot – 10, phosphorus
application is not recommended. (Rajk 5, 36)
In Dhari region, in cotton variety G.cot-10 in medium black soils (medium in P) apply
60 N and 10 P$_2$O$_5$ kg/ha. Half of nitrogen and full dose of phosphorus should be applied
as basal dose and the remaining nitrogen at 45-50 days after sowing when sufficient
moisture is available.

**Castor**

In North Saurashtra Agroclimatic Zone to fertilize castor with 30 N and 30 P$_2$O$_5$ kg/ha.
(Rajk 3,9, 78,86)
The farmers of AES-IV of North Saurashtra Agroclimatic Zone are advised to apply 30
N kg/ha to castor.

**Alternate Land Use System**

**Grasses**

On sloppy fallow lands, grow *Dicanthium annulatum*

**Alley cropping**

In shallow soils and medium fertility to sow 16 rows of either groundnut (GG-2) or sorghum
(CSH-5) in alley of perennial pigeonpea (ICPL-185) keeping distance 8.1 m between
two rows for higher equivalent yield of green fodder
In shallow soils and medium fertility are recommended to sow 16 rows of either groundnut
(GG-2) or sorghum (CSH-5) crops in alley of subabul (Hawai Gaint ), keeping distance
of 8.1 m between two rows

**Implements**

For multipurpose tool bar, seed-cum-fertilizer drilling attachment (manually metered) is
recommended to carry out three operations i.e. fertilizer drilling, seed drilling and covering
at a time for the farmers of North Saurashtra Agroclimatic Zone.

**Soybean based Production System (Indore)**

- **Rainwater Management**: Broad bed furrow (BBF) for soybean in kharif
- **Crops and Cropping Systems**: Soybean-safflower sequence has been found to be more stable and remunerative in normal climatic conditions with 30 and 45 cm row spacing for the crops, respectively. (Indo 52)
- **Soil and Nutrient Management**: Planting at a high density of 0.6 plants/ha with soybean ideotypes

Soil and Nutrient Management

60 N - 35 P$_2$O$_5$ kg/ha is recommended. Over three years there was gradual increase
in the yield of soybean due to build up with 60 P$_2$O$_5$ kg/ha. Soybean is a heavy feeder
of N, P, K, Ca and S. (Indo 24,93,94,112,114)

**Fingermillet based Production System (Bangalore)**

- **Rainwater Management**: Watershed development

Providing a farm pond for individual holdings and making use of the excavated soil for
construction of bunds and filling up the depressions reduce the overall cost of land
development. This saved on the cost of construction and is presently being adopted in all the State Watershed Development Programmes.

The existing bund itself could be modified to act as graded bund by internal land smoothening. Open end contour bunds (0.8 m$^2$) or graded bunds (0.36 m$^2$) on a slope of 0.2 to 0.4%. Waterways are a viable with outlets. For every hectare of catchment the required capacity of the pond is 250 m$^3$. For controlling seepage and percolation losses plastering both the sides and the bottom with cement + sandy clay soil (1:8) is very effective.

**Vegetal treatments**

Establishing vegetative barriers either of khus or some local grass like *Nase Hullu* on the contour ensures subsequent cultivation on the contours. Earthen embankments with vegetated spillways in stabilized gullies are sustainable as cheap water harvesting structure. For stabilization of drop structure, spill ways and stabilization of embankments, *Pennisetum clandestinum*, and *Pennisetum ohsinikere* are suitable. Vetiver live barrier at 1 m vertical interval is an effective barrier as bunds under situations of lower slope (2%) and medium (>750 mm) rainfall, while combination of vegetative barrier and bund placed at 0.5 m vertical interval is most suitable under high slope (>3%). For stabilization of water ways (0.03 m$^2$) and bunds, *Lottononis bainesii* is preferred. In the gullies, bamboo, silver oak, *Acacia auriculiformis*, subabul, pongamia spp. have established well.

**Cultivation**

Finger millet + pigeonpea sown (10:1) with dead furrow between pigeonpea rows (Bang 38, 42)

Maize on ridges and furrows across the slope is effective in reducing runoff and soil loss. In close spaced crops like finger millet and groundnut, furrows may be opened on 0.2 to 0.4 percent slope to dispose the surplus water.

Summer tillage is essential to conservation water and reduce runoff.

Deep tillage is beneficial in crops like pigeonpea and maize.

Soil profile inversion up to 15 cm depth is suitable for higher productivity.

In widely spaced crops like maize ridging up individual crop rows for reducing run off. Fall ploughing and furrows at 3.3 m interval as inter terrace management practices are helpful.

Developing deeper soils (>45 cm) in to graded border strips of 10-12 m width on a gradient of 0.2 to 0.4 percent along the length.

Alleviation of crust is possible with the addition of 10t FYM/ha, 5 tonne maize residue/ha and 25 sand t/ha.

**Supplemental irrigation**

Surplus rainwater collected in dugout ponds and used for irrigation during critical periods. May sown crops need one or two irrigations in June and the crops sown in August September need protective irrigation in November-December. The crop yield doubles by two protective irrigations of 5 cm each.

<table>
<thead>
<tr>
<th>Crops and Cropping Systems</th>
<th>Cultivars</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize, groundnut, pigeonpea, sunflower and cowpea can replace part of the finger millet area under suitable conditions. Cowpea is a suitable crop for sowing both in the early season as well as late season. TVX-944-02E may be used for replacing the presently recommended variety C-152 that has become susceptible to bacterial blight and rust. (Bang 1,43). Another variety C-1 derived by a cross between C152 X FS-68 is also a high yielder with white grains. Cowpea TTB-7 released in 1987. Maize Deccan-101, DH-3-30 and groundnut RS-114, pigeonpea HY-3c, and sunflower BSH-1 are high yielders. (Bang 5, 35) Chilli-27 from the center (<em>Capsicum annum X C. fruticenses</em>) was found to performs better. Castor SA-2 suitable for the region. In horsegram, IC-11095 and BGM-1-1-8-3 are released.</td>
<td></td>
</tr>
</tbody>
</table>

Cropping system
With bimodal pattern of rainfall a system of growing cowpea either for grain or fodder in May followed by transplanted finger millet in August is an ideal double cropping system.(Bang 30, 38, 45)
Traditional intercrops like fodder sorghum, field bean and niger in finger millet can be adopted only when the fertility level is low. With improved fertility levels, an entire crop of finger millet is to be preferred.
Intercropping of finger millet and soybean in alternate rows was found profitable. (Bang 38)
Various intercrops like pigeonpea, french bean, cowpea and soybean were tried in maize but none of the combinations were remunerative.
Intercropping of paired rows of pigeonpea followed by 8 rows of finger millet (Bang 38) with a furrow between pigeonpea is recommended and widely adopted by the farmers. The system is found to be more profitable when pigeonpea is planted in May and finger millet in July. This gives opportunity and competition free time for pigeonpea to come up. Similar system is found profitable in groundnut both the crops are to be sown simultaneously.

Contingency Plans
About 40 cm of water was consumptively used by most of the dryland crops to produce reasonably high yield.
Selection of crop ad varieties for sowing should be made on the time of sowing. The following preference was found ideal.
May Cowpea, Redgram (Bang 48, 49)
June Groundnut, redgram
July Maize, long duration finger millet, Sunflower
August Short duration finger millet, transplanted finger millet, Cowpea
September Horsegram

Finger millet is the most stable and drought resistant crop of the region. (Bang 3,41)
For early sowing in July Indaf-8 is suitable, in the later part of July and early part of August PR-202 should be selected for late sowing Indaf-5 or 9 are to be preferred.
Planting maize and pigeonpea in alternate rows of 37.5 cm provides insurance against failure of maize. In adverse years, maize is harvested as fodder allowing pigeonpea crop to mature as full season crop. (Bang 56)
For late sown conditions, intercropping of horsegram and fodder maize is more profitable than entire crop of horsegram.

Management
Cultivation up to 10-12 cm depth is sufficient for finger millet whereas deep ploughing up to 30cm was beneficial in groundnut, pigeonpea and maize.
The recommended row spacing in finger millet was 22.5 cm and in maize 60 cm. It was observed that widening the row spacing up to 45 cm in finger millet and 75 cm in maize was advantageous.
For establishing finger millet crop in July, drilling the seeds is convenient but for late establishment transplanting the seedlings becomes essential to maintain the yield levels (Bang 46)

Plant protection
Weed control in maize and groundnut through use of simazine and alchlor respectively was found effective and economical. (Bang 26)

Soil and Nutrient Management

Residue incorporation
Incorporation of maize stover residue into the soil in maize - groundnut rotation is better than in maize-finger millet rotation. Cropping and ploughing in the residues was better than discing in, the whole plant.(Bang 44)
**Fertilizers**

A fertilizer dosage of 50:50:25 for finger millet, 75:50:25 for maize and 25:50:25 for groundnut N: P\(_{50}\): K\(_{25}\) kg/ha are recommended. P and K applied as basal and N at least in two equal splits for non-legume crops Band placement is better achieved through seed-cum-fertilizer drill. (Bang 9, 22, 29, 34, 35, 47)

Most of the oil seed crops (groundnut and sunflower) and pulses (cowpea) respond to lime application. Gypsum is useful in groundnut. (Bang 11, 18, 19, 52, 53, 67, 68, 1)

The red soils of the region normally have medium to high level of non-exchangeable K (510ppm). Response to the application of K is limited. However, after 8-10 years continuous cropping without K application depletes the soil reserve and crops start responding to external source of K.

Application of S 10 kg/ha for pulses and 20 kg/ha for sunflower increase the yield of crops. Zinc sulphate at 10 kg/ha improves the yield of maize.

**Integration**

Continues application of NPK fertilizers without addition of organic manures gradually reduced the yield levels. Organic manure either in the form of FYM (10 t/ha) or maize residue (5 t/ha) was helpful in maintaining the yield levels and substituted for 25:25:12.5 N - P\(_{50}\) - K\(_{25}\) kg /ha.

Application of 50% recommended N through green leaf manure was good substitute for FYM to reduce cost of input.

**Alternate Land Use System**

**Agro-forestry**

Casuarinas and silver Oak are better suited than other three species like eucalyptus, neem, Leucaena, Acacia etc.

The agroforestry system adapted on bunds with silver oak, glyricidia, caliandra, casuarina and drumstick have least effect on crops and to meet various needs like fruits, fodder, fibre, fuel and timber apart from substantial income during contingent needs. *Faidherbia albida* is more suitable for planting on bunds (E-W direction) in micro-watersheds.

**Wastelands**

*Stylosanthes hamata* is most suitable. *Stylasanthes scabra* should be adopted for gravelly shallow soils with low rainfall.

*Acacia auriculiformis, Cassia siamea, Dalbergia sissoo,* subabul and amla are more suitable and promising than other deep rooted high water intensive tree species under high gradient non-arable lands with shallow soils and rock out crops. For better establishment, trench method of planting is better than pit method.

Bamboo, Jambulina, pongamia, neem, *Albizia lebbeck*, peepal, and ficus species can be planted in the catch pits and pockets of deep soil.

**Forages**

Grasses like *Pennisetum pedicellatum* or *Cenchrus ciliaris* and legumes like *Microtelium axillaris* are suitable forage species.

**Horticulture**

In situ grafting/ budding of fruit trees like mango and ber found to be more economical than using grafted plants. Custard apple, Jack and tamarind were other species suitable to wastelands.

Mango, phylanthus, and jambulina performed better in the non-arable land.

**Implements**

**Seed-ferti drills**

For opening furrows at 3.3 m interval simultaneously with sowing the seeds of finger millet, the newly designed seed drill with furrow opener is a convenient implement. Four coulttered (shoe type) seed-cum-fertilizer drill for groundnut has been released in 1987 and is being fabricated by the Agro Industries Corporation apart from several local artisans.

Five coulttered, 30 cm row spaced finger millet seed-cum-fertilizer drills should be used for sowing finger millet. Multi furrow opener is very useful tool in opening furrows for hand dropping of seeds, transplanting seedlings and also for intercultivation. The multi furrow opener has become
more popular with the farmers, because of its multi-purpose use of the several implements designed at the centre. Groundnut seed-cum-fertilizer drill (four coulters) was found to be efficient and economically feasible for sowing soybean. Tractor drawn international seed drill with disc type furrow openers was found suitable for finger millet.

**Interculture**
Intercultivation in close sown crops like finger millet and groundnut can be made very effective by changing over to bent type hoe for duck foot hoe. Staggered bent tyne and duck foot hoe are designed during the period are becoming popular with farmers.

**Pearl millet based Production System (Hisar)**

**Rainwater Management**

<table>
<thead>
<tr>
<th>Off season</th>
</tr>
</thead>
<tbody>
<tr>
<td>Land shaping</td>
</tr>
<tr>
<td>Pre monsoon/ summer tillage and ridge furrow configurations across the land slope to improve moisture storage</td>
</tr>
</tbody>
</table>

**Kharif crops**
Two cross ploughing/ discing operation for sowing
Compartmental bund
Inter-row rainwater harvesting

**Rabi crops**
Shallow tillage after effective rainfall events in summer fallows for rabi crops sowing

**Crops and Cropping Systems**

**Kharif crops**
Pearl millet: HHB-50, HHB-60, HHB-67, HHB-68 (Hiss 20)
Mungbean: S-9, Asha
Clusterbean: RGC-936, HGS-365, HG-75, HG-182
Clusterbeans/ Mothbean: Jwala, Jadia, Marumoth-1, RMO-40
Cowpea: HFC-42-1, Charodi

**Rabi crops**
Mustard: RH-819, RH-30, RH-781, Lakshimi (Hiss26)
Chickpea: C-235, H-208, Gaurav, HC-1
Barley: BH-87, K-226, BG-138, BG-75 9Hiss35)
Taramira: T-27

**Cropping System**
Monocropping is normal and below normal rainfall years
Kharif crops – Fallow
Fallow-rabi crops (in conserved moisture)
Sequence cropping in above normal rainfall years
Pearl millet – Chickpea
Mungbean- mustard
Cowpea – Mustard
Pearl millet + Cowpea- Mustard/ Chickpea (Fodder crop)

Intercropping (2:1 in 30/60 cm paired rows)
Pearl millet + mungbean
Pearl millet + clusterbean

**Management**
Sowing time
Kharif crops in 1-15 July (optimum time) 16-30 July (late sown conditions) and rabi Crops 1-20 October (mustard and chickpea) and 25 October-15 November (taramira) (Hiss 50)
Plant spacing
- 45 cm between rows for all crops except barley (30 cm)
- 10 cm within rows after thinning in case of kharif crops and mustard

**Soil and Nutrient Management**

**Kharif crops**
Pearlmillet 40N + 20P₂O₅ kg / ha and pulses 20N + 40P₂O₅ kg/ha (Hiss20)
Integrated use of inorganic, organic and biofertilizers for pearlmillet

**Rabi crops**
Mustard 40N + 20P₂O₅ kg / ha and pulses 20N + 40P₂O₅ kg/ ha (Hiss 25)
Advance application of fertilizer by the end of monsoon for mustard (Hiss25)
Deep basal placement of fertilizer to chickpea
Integrated use of inorganic, organic and biofertilizers for mustard (Hiss 46)

**Micronutrients**
Basal application of ZnSO₄ 12.5 kg /ha along with recommended dose of NP fertilizer to mustard and chickpea in deficient soils (Hiss46)

**Alternate Land Use System**
Agri-Horti system of ber intercropped with cowpea, greengram, clusterbean and anjan grass.

**Implements**
Ferti-seed drills
Use of ridge-seeder for pearlmillet to avoid soil crusting
Furrow seeding of mustard under receding moisture conditions
Use of barani hal for mustard seeding.

**Interculture**
Use of blade type wheel hand hoe to save time and energy for Interculture operations

**Pearlmillet based Production System (Agra)**

**Rainwater Management**
Land treatment
Deep tillage during summer and making compartmental bunding after seedlings emergence. (Agra 3, 14, 16)
Criss-cross ploughing by country plough after each effective rainfall.
To mitigate early season drought, one extra inter cultivation along with straw mulch @ 5 t/ha is effective. One protective irrigation is only solution to control the adverse effect of late season drought.

**Supplemental irrigation**
Sufficient runoff water may be harvested during rainy season in the farm pond or in village pond and this harvested water can be used in dry period during kharif and at critical stage during rabi season crops.
Transplanting of pearl millet in late seeding condition along with one protective irrigation

**Crops and Cropping Systems**
Management
For growing kharif season crops the sowing period of first fortnight of July and for rabi crops, first fortnight of October are most suitable.
Broadcasting of seeds should be always avoided specially in rabi season.
The spacing between rows should be 45 cm for pearlmillet and mustard crops.

**Intercropping**
One row of pigeonpea or greengram in paired row planting (30/60 cm) of pearlmillet and two rows of greengram in paired row planting (30/90 cm) of pigeonpea are the best intercropping system. (Agra 5,10)
In rabi season, chickpea + mustard (4:1 row ratio) and barley + chickpea (3:2 row ratio). (Agra 2, 4, 8,18,25,26)

**Sequence cropping**
The greengram mustard crop sequence is more profitable, in which greengram is grown for green manuring after picking up the pods. The highest net profit from this crop sequence is received when mustard crop is fertilized with 45 kg N ha. (Agra 13, 19, 20)
Research Publications and Recommendations in Dryland Agriculture

Soil and Nutrient Management

Inorganics
Recommended dose of fertilizers are 60 kg N + 30 kg P₂O₅ ha for Pearlmillet, mustard and barley and 20 kg N + 40 kg P₂O₅/ha for greengram, blackgram, pigeonpea, clusterbeans and chickpea (Agra 11, 15, 17, 21))
High and stable yield of pearlmillet is achieved through the split application of recommended N, because applied N can be saved in case of any aberration in the weather. Full N + o dose of N at sowing and rest N at tiller initiation stage is more advantageous. (Agra 1)

Method
Broadcasting application of fertilizer is inefficient Placement leads to higher yield as well as healthy and vigorous seedlings. In rabi season, placement of fertilizers at 8-10 cm depth must be placed in moist zone.

Integration
In continuous cropping of pearlmillet, integrated use of organic and inorganic fertiliser is more beneficial. Half of the recommended N (60 kg) to met through FYM is a substitute of inorganic source and sound nutrient management strategy for higher and stable yield of pearlmillet.

Alternate Land Use System

Implements
Dryland weeder is quite effective and economic in controlling the weeds in both the seasons.

Pearlmillet based Production System (Dantiwada)

Rainwater Management

Crops and Cropping Systems

Intercropping
Greengram + pearlmillet (3:1)
Two lines of cowpea (GC-2) between castor (GAUCH-1) with the spacing of 120X30 cm for castor 30X7.5 cm or 30X10 cm for cowpea
Pearlmillet + clusterbeans (2:1) intercropping during kharif season
Pearlmillet + clusterbeans Malosan or HG-75 (2:2) (Danti 1)

Management
For hybrid castor GAUCH-1, inter-row spacing of 60 to 90 or 120 cm and intra-row spacing of 30 or 45 or 60 cm. (Danti 1)

Mixed cropping
In the light texture soils of North Gujarat agroclimatic Zone (AES-1) farmers are advised to follow mixed cropping of sorghum and karingado. Sowing of karingado in every sixth line of sorghum at 45 cm is more remunerative.

Plant protection
Castor GAUCH-1 in light soils should be kept weed free during 30-45 days after sowing preferably by two interculture operations and simultaneous hand weeding around the crop in 3rd and 5th weeks after sowing. (Danti 2)

Soil and Nutrient Management

Inorganics
Green chickpea application of 20 kg P₂O₅/ha
Pearlmillet CJ-104, application of 75 kg N/ha and 25 kg P₂O₅/ha. (Danti1,3)
There is no need to apply zinc under rainfed condition of North if soil contains medium to high available zinc
For the cultivation of castor GAUCH-1 in the light soil areas, application of 30 kg N/ha is recommended. If the soil is highly deficient in available nitrogen, application of 60 to 90 kg N/ha may be adopted.
For the cultivation of rainfed cowpea Gujarat Cowpea-2 (Chharodi -1) in light soils deficient in available nitrogen and medium to marginally high in available nitrogen and
medium to marginally high in available phosphorus, application of 15 kg N/ha and 20
kg P₂O₅/ha is recommended
The farmers growing sorghum malvan on S deficiete light textured soils are advocated
to apply 20 kg S/ha through gypsum (125 kg gypsum/ha)

Alternate Land Use System Horticulture
The farmers growing Ber (10X6 m) on light textured soils are advised to take inter crop of either greengram or sorghum (fodder)

Implement

Maize based Production System (Arjia)

Rainwater Management Water use efficiency
Chickpea is most suitable crop for growing in tank beds on conserved soil moisture. Wheat (LOK-1) is good for sowing under tank bed conditions with 125 kg/ha seed rate. (Bhil13)

Crops and Cropping Systems Kharif crops
D-765, Surya and Navjot of maize
CSH-5, CSH-6, CSH-9, and CSH-14 of sorghum
Pusa baisakhi and K-851 of greengram
T-9 of blackgram
Gwalior-3, T-21, Prabhat, ICPL-87 and ICPL-151 of pigeonpea
JL-24 and AK-12-24 of groundnut (Bhil10)
RT-125 and RT-46 of sesamum
Aruna, Gauch-1 and Gauch-4 of castor
Macs-13 and Js-71-05 of soybean

Rabi crops
Narmada-4 of chickpea (Bhil7)
Durgamani and Varuna of mustard
Bhima and JSF-1 of safflower
Chambal-1 of linseed.

Intercropping in kharif
Maize + blackgram (2:2)
Maize + pigeonpea (1:1) (Bhil20)
Sorghum + greengram (2:1) (Bhil 24,29,30,32)
Groundnut + sesame (6:2)
Castor + greengram (1:2) (Bhil21)

Intercropping in rabi
Chickpea + mustard (4:1)
Chickpea + safflower (2:1) (Bhil19)

Plant protection
Apply fluchloralin or pendmethalin at 0.5 kg/ha as pre-mergence applications followed by one hoeing at 30 days after sowing to control weeds in groundnut + sesame intercropping system

Soil and Nutrient Management Kharif crops
In maize + pigeonpea intercropping system it is recommended to apply 50% nitrogen through inorganic and 50% through organic sources.

Rabi crops
Application of 45 N - 22.5 P₂O₅ kg/ha is optimum for wheat under tank bed conditions (Bhil13, 16)

Maize based Production System (Hoshiarpur)

Rainwater Management Kharif crops
Plough open the fields to open the soil and to enhance its water intake.
Level the land and raise bunds all around the fields and provide outlets for safe disposal of excess rainwater before the onset of monsoon.
Spread locally available mulch material, such as basooti in the standing maize crop in the last week of August in light soils.

Sow the crops across slope on sloping lands

**Rabi crops**
Mulching the kharif crops helps in conservation of moisture in the surface layers and helps secure optimum stands of *rabi* crops. It also helps maize in case of drought. Start preparatory tillage soon after the harvest of Kharif crops.

**Supplemental irrigation**
Collect runoff water during monsoon in individual or community tanks. Give one irrigation to *rabi* crops at pre-sowing or 30-40 days after sowing. In case of drought during Kharif, a life saving irrigation can be given to the Kharif crops.

**Crops and Cropping Systems**

**Green manure**
Grow a green manure crop of sunhemp in the light textured soils which are generally kept fallow during the Kharif. Incorporate this crop in the middle of August to raise wheat in *rabi*.

**Cropping system**
Two crops a year viz. maize-wheat/ wheat+chickpea/ wheat+raya perform better on medium and high moisture storage soils (Hosh 18,34)
- Sow maize with first monsoon showers in rows 35-40X30 cm apart.
- Sow *rabi* crops from last week of October to last week of November
- Use higher seed rate of wheat (100 kg/ha) to cover the risk or poor germination and attack of white ants and termites.
- Sow wheat seed relatively deeper (8-10 cm) and in wider row spacing (30 cm).

**Plant protection**
Plough the fallow fields occasionally during kharif to keep them weed free or grow a green manure crop of sunhemp in kharif. Apply Atrazine @ 1 kg/ha on medium to heavy textured soils as pre-mergence spray in maize. The dose of herbicide can be reduced by 40% in light soils. Give one manual hoeing 15-20 days after sowing of maize, followed by haloding with desi plough at 30 days after sowing. (Hosh 2)
Give two hoeings to wheat to check weed growth and reduce evaporation from soil. For termite control, treat wheat seed with Aldrin 30 EC or chloropyriphos 20 EC @ 4 ml/kg seed.

**Soil and Nutrient Management**

**Organics**
Apply 8-10 t FYM/ha before sowing maize to get maximum benefit from fertilizer use

**Inorganics**
In maize apply half of N and whole of P and K by drilling at sowing and broadcast remaining N one month later depending on rain. (Hosh 10,17,30)

In *rabi* crops, fertilizer must be drilled at or before sowing so as to place it in the moist zone.

**Maize based Production System (Rakh Dhiansar)**

**Rainwater Management**
Water harvesting tanks are recommended.

**Crops and Cropping Systems**
Green fodder or after taking one picking of short duration greengram in kharif followed by *rabi* oilseed. 15% area of the dryland kandi belt of Jammu Kathua district have adopted this technology.

**Soil and Nutrient Management**
Recommended fertilizer doses on N and P for
Alternate Land Use System
Implements

**Rabi Sorghum based Production System (Solapur)**

**Rainwater Management**

- **Land treatment**
  - Ridges and furrows prior to sowing of crops.
  - Compartmental bunds

- **Interculture**
  - Minimum 3 hoeing in 3rd, 5th and 8th week from sowing for *rabi* sorghum to avoid cracking in Vertisols

- **Supplemental irrigation**
  - One to two protective irrigations at critical growth stages for dryland crops. (Based on this recommendations state Govt. has changed their policy of 12 months canal irrigation for comparatively small area to 8 months (*kharif* and *rabi*) canal irrigation for wider area in Scarcity Zone of Maharashtra)

- **Vegetal covers**
  - Spreading type of Kharif crops for land coverage to avoid soil and water erosion for sole cropping
  - Strip cropping (3:1)

**Crops and Cropping Systems**

- **Crop varieties**
  - *Rabi* sorghum
  - Shallow soils – Selection –3.
  - Medium deep soils – M.35-1
  - Deep soils – Swati, CSH-13R
  - Kidney bean - MBS-27
  - Horsegram – Man and Sina (Sola 46)
  - Sunflower - SS-56
  - Safflower – Bhima

- Improved varities of groundnut, castor, greengram, blackgram, cowpea, *rabi* sorghum, safflower, sunflower, chickpea were also recommended

- **Intercropping**
  - Pearlmillet+kidney bean/ Horse gram (2:1) for shallow soils.
  - Pearlmillet+ pigeonpea (2:1) for medium deep soils. (Sola 52)
  - Sunflower+pigeonpea (2:1) for soils having more than 45 cm depth.
  - Sorghum+pigeonpea (1:1) for kharif oriented scarcity zone of Maharashtra,

- **Sequence cropping**
  - Blackgram/ greengram – *rabi* sorghum (Sola 72,54,42)
  - Greengram/ sunflower – Bengal Gram

- **Rabi to Rabi crop rotation**
  - *Rabi* sorghum – chickpea
  - *Rabi* sorghum – Safflower
  - Safflower – chickpea

- **Crop management**
  - Introduced sunflower and developed package of practices
  - Crop planning according to land use capability. (Sola 21)
  - Improved technology for Kharif and *rabi* dryland crops (package of practices)
  - Varities developed at the station.

- **Plant protection**
  - Weed free plots in kharif crops for 1st 30 days.
  - Minimum 2 to 3 hoeings for other *rabi* crops
Contingency plans
Recommendation of mid season corrections for crop planning.
Aberrant weather planning with sunflower crop. In aberrant weather, plant population of 74000/ha should be reduced to 38000/ha by removing alternate plant in the row or skipping of alternate row.

Soil and Nutrient Management

Inorganics
Cereals and oil seeds -50 N + 25 P₂O₅ kg /ha
Pulses – 12.5 N + 25 P₂O₅ kg /ha

Organics
Leucaena loppings mulching in kharif season (10 t/ha) for enrichment of soil fertility and to reduce soil and water erosion. (Sola 15,30,66)
Recycling of farm waste materials

Alternative Land Use System

Agro-horticulture
Ber, custard apple, pomegranate, amla with intercropping of kharif (spreading) crops

Silvi-pastures
Stylo in initial 1-2 years of main crop
Cultivation of Marvel-8 grass on bunds for protection of bunds and for fodder.
Contour live bunds of Marvel-8 of Leucaena.

Implements
Bullock drawn two bowl ferti-seed-drill

Rabi Sorghum based Production System (Bijapur)

Rainwater Management
Land treatment
Rubbles at 0.3 m vertical interval on contour key lines for between soils water conservation.
In-situ moisture conservation practices like compartmental bunding, ridges and furrows, contour cultivation and fall ploughing helped to conserve more moisture in deep black soils. (Bija 19, 37, 38)

Vegetal covers
Barriers are recommended for inter-terrace land management practice, planting of khus grass and subabul in paired rows at vertical interval of 0.3 m is advocated.
Stabilization of bunds through stylosanthes species.
Bund painting with neem, sissoo and tamarind.

Microcatchments
For ber in marginal lands, rectangular basins with 5% inward slope for lands upto 2% slope, crescent bunding for lands having 2 to 4% land slope and staggered trenching/pitting for lands having more than 4% land slope.

Supplemental irrigation
A farm pond of 150 m³ capacity for every one hectare catchment was recommended for harvesting excess runoff in medium to deep black soils. Dryland horticultural crops with supplemental irrigation facility.

Crops and Cropping Systems
Management
Adoption of early sowing of rabi crops is essential - rabi sorghum, safflower 2nd fortnight of September and 2nd week of August is suitable for sunflower.
Wider row spacing for both Kharif and rabi crops - Sorghum, Sunflower, Safflower and Pearl millet 60 cm; Groundnut (bunch) 45 cm; Chickpea 30 cm; Pigeonpea 90 cm

Cultivars
Sunflower population (NSP-92-1-0E) which is superior to Morden is released for general cultivation.
A bunch groundnut variety (R-8808) and horsegram (PL-40) were released and included in the package of practices.
**Intercropping**
- Pigeonpea + pearl millet (1:3) (Bija 35)
- Chickpea + safflower (3:1 or 4:2)
- Chickpea + sorghum (1:2)
- Pigeonpea + groundnut (1:3)
- Pearl millet + groundnut (1:2)

**Soil and Nutrient Management**

**Inorganics**
For Kharif crops (pearl millet and sunflower) in shallow black soils, application of 50% dose at sowing and remaining 50% 30-35 days after sowing is advocated. (Bija 16,42,46)

**Incorporation**
Subabul loppings at 5 t/ha one month prior to sowing of rabi sorghum to reduce the fertilizer requirement of sorghum by 50%
Sunhemp in Kharif in medium and deep black soils after 35-40 days after sowing for rabi crops to save 50% nitrogen.
Crop residues at 5t/ha in vertisol. To reduce the C:N ratio of residues the conjunctive use of subabul or 20kg N/ha urea or cellulolytic organism is recommended. (Bija 34)

**Cropping systems**
- Adopt rotation of sorghum after chickpea, which accounts for 50 per cent saving of N for rabi sorghum. (Bija 42)
- Use of 50 percent nitrogen through organic source and remaining 50 per cent through inorganic source for sorghum and safflower. (Bija 16, 51, 53, 54)

**Alternate Land Use System**

**Horticulture**
Cultivation of mango, ber, sapota and curry leaf in the zing conservation bench terraces, waterways and on the embankment of farm ponds.

**Wastelands**
In shallow and marginal eroded soils, growing of agave and subabul is advocated.

**Implements**

**Cotton based Production System (Kovilpatti)**

**Rainwater Management**

**Crops and Cropping Systems**
For the vertisol belt of this region, cotton+blackgram (Kovi 29)
- Sorghum+Blackgram/ Cowpea (Kovi 12,18,21,27,47,61,63)
- Pre-monsoon sowing of Cotton MCU.10 + black gram CO.5 intercropping system receiving 750 kg/ha FYM
- Fertilizer DAP as seed treatment material for rainfed cotton. Both linted and lelinted cotton seeds soaked with 2% DAP increased seed cotton yield.

**Soil and Nutrient Management**
The basal application of 40N and 20 P kg/ha was recommended for cotton crop under rainfed vertisol situations. (Kovi 5)

**Alternate Land Use System**

**Implements**

**Cotton based Production System (Akola)**

**Rainwater Management**
On slopy land contour cultivation along vegetative hedge of Vetiver or Leucaena at 0.5 m V.I. in sorghum and cotton crops.
- BBF and opening of furrow after two crop rows in pigeonpea.
Slope length
From the toposequence study of micro-watershed, on a slopy field instead of growing cotton crop on entire field, it is profitable to take cotton on upper toposequence (80 % area) and soybean- chickpea crop sequence on lower topo sequence (20 % area).

Supplemental irrigation
Sorghum can be grown without irrigation
Cotton crop needs life saving irrigation during deficit period

Crops and Cropping Systems
Crops
Cotton, sorghum and pigeonpea recorded highest yield on class II soils, followed by class III and lowest yield was found on class IV soils. Sorghum crop recorded response to fertilizers on all three classes of soil, whereas cotton and pigeonpea registered response on class II and class III soils.

Sorghum (CS -3541) and sesamum crops grown on shallow soils without much reduction in yield as compared to the yields on medium deep soils. Cotton (AKH 081), a early variety of *hirsutum* cotton is suitable on shallow soils. Cotton, pigeonpea and hybrid sorghum are not suitable on shallow soils.

Intercropping
Sorghum + greengram (2:1 or 1:1) and cotton + greengram (1:1) i
Greengram-safflower crop sequence
Sorghum - chickpea If rains occur in October and November

Plant protection
Critical crop-weed competition period in hybrid sorghum and cotton was from sowing to 40 days and 55 days, respectively.

Contingency plans
Under situation of resowing or delayed sowing in kharif season, sunflower, pearl millet, pigeonpea, maize and castor crops recorded satisfactory yields.

Soil and Nutrient Management
Inorganics
Application of 20 kg P/ha was found optimum for pigeonpea and cotton, while 10 kg P/ha was optimum for sorghum crop.
Application of 80 kg P/ha to pigeonpea for continuous three years recorded residual effect on sorghum.
Zinc application @ 5 kg Zn / ha (25 kg Zn SO 4/ ha) to sorghum.

Integration
In cotton + greengram, half dose of nitrogen through FYM and half through inorganic fertilizers
In alley cropping (9 m width), incorporation of Leucaena loppings in cotton or sorghum crops, recorded 25 to 50 % economy in fermer use
Continuos use of Leucaena lopping was found to replace full recommended dose of nitrogen.

Alternate Land Use System
Horticulture
*Ber* agro-horticulture system (*Ber* + short duration legume crop) was found more remunerative than anola and custard apple horticulture system.

Pastures
Stylo sole and stylo-marvel pastural system recorded higher green fodder yield than sole or combination of grasses.

Implements
Out of eight ferti-seed drills tested, Shivaji, Solapur, CIAE and Malviya ferti-seed drills proved better on the basis of Overall Performance Index (OPI), but seeding with CIAE ferti-seed drill recorded higher yield of greengram and safflower recorded higher yield of greengram and safflower.
4. Subject Index

Alternate Land Use
  - Water management
  - In Situ conservation
    - Phulbani 40
Crops and cropping system
  - Agronomic practices
    - Bijapur 32, 45
    - Hyderabad 15
    - Jhansi 2
    - Phulbani 40, 42
  - Inter/mixed/relay/sequence cropping systems
    - Kovilpatti 13, 14
Weeds/pests/disease management
  - Dantiwada 14
Soil fertility and nutrient management
  - Major nutrients
    - Bijapur 45
    - Dantiwada 12
    - Ranchi 24
  - Organics, bio-fertilizers etc.,
    - Dantiwada 12
Socio economics
  - Hyderabad 15
Barley
  - Rainwater management
  - Insitu conservation
    - Indore 19
    - Indore 26, 27
    - Varanasi 9, 20, 54, 58
  - Supplemental irrigation
    - Varanasi 59
Crops and cropping system
  - Crop improvement and evaluation
    - Hoshiarpur 9
    - Rewa 26, 27, 32
    - Varanasi 3
  - Agronomic practices
    - Faizabad 19
    - Indore 27
    - Varanasi 9, 20, 36, 39, 50, 59
  - Inter/mixed/relay/sequence cropping systems
    - Varanasi 39, 59
Soil fertility and nutrient management
  - Major nutrients
    - Bhilwara 18
    - Varanasi 9, 20, 50, 54
  - Secondary and micro nutrients
    - Bhilwara 18
Socio economics
  - Faizabad 19
Black gram
  - Resource Characterization
Climate
  - Kovilpatti 38, 39
Rainwater management
  - Insitu conservation
    - Hoshiarpur 19
  - Supplemental irrigation
    - Varanasi 37
Crops and cropping system
  - Crop improvement and evaluation
    - Ranchi 66
    - Hoshiarpur 19
    - Bangalore 22
    - Kovilpatti 38
  - Agronomic practices
    - Ranchi 32
    - Kovilpatti 2, 47
  - Inter/mixed/relay/sequence cropping systems
    - Ranchi 32, 66
    - Kovilpatti 27, 29
Weeds/pest/disease management
  - Varanasi 35
    - Kovilpatti 29
Soil fertility and nutrient management
  - Major nutrients
    - Varanasi 38
    - Kovilpatti 27, 47
    - Bangalore 19
  - Secondary and micro nutrients
    - Agra 17
    - Organics, bio-fertilizers etc
    - Varanasi 38
Castor
  - Crops and cropping system
    - Crop improvement and evaluation
      - Dantiwada 2
      - Hisar 3
      - Hyderabad 12
      - Solapur 6
    - Agronomic practices
      - Hyderabad 5, 9, 12
      - Rajkot 3
    - Inter/mixed/relay/sequence cropping systems
      - Bangalore 53
      - Bhilwara 21
    - Weeds/pest/disease management
      - Rajkot 55, 62
Soil fertility and nutrient management
  - Major nutrients
    - Rajkot 3, 9, 77, 85
    - Kovilpatti 26
Chick pea
  - Rainwater management
Insitu conservation
Bhilwara 19
Hisar 9, 10, 14
Indore 1, 16
Solapur 67
Varanasi 9

Crops and cropping system
Crop improvement and evaluation
Agra 15
Hisar 35
Hoshiarpur 9
Indore 103
Rewa 2, 7, 23
Varanasi 13, 30, 32

Agronomic practices
Bangalore 21
Hisar 9, 10, 14, 22
Indore 16, 53, 103
Ranchi 65, 67
Varanasi 9

Inter/mixed/relay/sequence cropping systems
Agra 13, 15, 25, 26
Bhilwara 19
Indore 94
Ranchi 65, 67
Rewa 16
Solapur 47, 48

Weeds/pest/disease management
Agra 25

Soil fertility and nutrient management
Major nutrients
Agra 13, 15, 17, 26
Indore 94
Ranchi 65, 67
Varanasi 9
Bhilwara 7

Organics, bio-fertilizers etc.,
Indore 94

Chicory
Soil fertility and nutrient management
Major nutrients
Rajkot 41
Organics, bio-fertilizers etc
Rajkot 41

Cluster bean
Crops and cropping system
Crop improvement and evaluation
Hisar 8
Agra 12
Dantiwada 1, 5
Indore 5, 13

Agronomic practices
Hoshiarpur 15
Hisar 8
Agra 10

Weeds/pest/disease management
Jodhpur 5
Agra 10, 12

Cotton
Resource characterization
Soil
Indore 113

Rainwater management
Insitu conservation
Kovilpatti 19

Crops and cropping system
Crop improvement and evaluation
Bellar 4
Bijapur 44
Dantiwada 2
Indore 79
Kovilpatti 5, 48
Phulbani 27

Agronomic practices
Bijapur 44
Dantiwada 4
Bellar 4, 6
Indore 79
Kovilpatti 20, 28, 33, 34, 44
Rajkot 54, 61
Phulbani 2

Inter/mixed/relay/sequence cropping systems
Rajkot 64
Kovilpatti 28, 29

Weeds/pest/disease management
Rajkot 14, 37, 38, 39, 42, 43, 44, 52, 53, 56, 57, 58, 59, 60, 61
Kovilpatti 29

Soil fertility and nutrient management
Major nutrients
Rajkot 36
Indore 79
Kovilpatti 5
Dantiwada 4

Post harvest technology
Crop
Kovilpatti 40

Cowpea
Rainwater management
Insitu conservation
Bangalore 28

Crops and cropping systems
Crop improvement and evaluation
Bangalore 10, 25, 41, 50, 84

Agronomic practices
Phulbani 47
Kovilpatti 21, 22, 63

Inter/mixed/relay/sequence cropping systems
Phulbani 47, 70
Bangalore 28, 43
All India Coordinated Research Project for Dryland Agriculture (AICRPDA)

Kovilpatti 21, 63
Soil fertility and nutrient management
Major nutrients
Bangalore 11, 20, 28
Rajkot 83
Secondary and micro nutrients
Bangalore 11
Organics biofertilizers
Kovilpatti 63
Socio economics
Phulbani 70

Finger millet
Rainwater management
Insitu conservation
Bangalore 28
Crops and cropping system
Crop improvement and evaluation
Bangalore 2, 9, 23
Phulbani 12
Agronomic practices
Bangalore 1, 39, 40, 44
Phulbani 20
Ranchi 33, 34, 42, 43, 52, 69
Inter/mixed/relay/sequence cropping systems
Bangalore 28, 36, 43
Soil fertility and nutrient management
Major nutrients
Bangalore 5, 16, 18, 20, 27, 28, 33, 45
Indore 28, 30
Ranchi 45
Socio economics
Hyderabad 16

Energy management
Animals
Phulbani 20

Forages
Resource characterization
Vegetation
Indore 86
Crops and cropping system
Agronomic practices
Indore 75
Jhansi 4
Inter/mixed/relay/sequence cropping systems
Bijapur 39
Jhansi 5
Solapur 48
Soil fertility and nutrient management
Major nutrients
Jhansi 5
Alternate land use
Agro-forestry/ pastures
Hoshiarpur 24
Jhansi 6

Foxtail millet
Crops and cropping system
Crop improvement and evaluation
Bijapur 17
Agronomic practice
Kovilpatti 36

General
Resource characterization
Soil
Anantapur 1, 14, 18
Bangalore 26, 15
Bellary 12, 8
Hisar 19, 32
Hoshiarpur 13
Indore 6, 10, 11, 12, 13, 14, 34, 35, 37, 51, 63, 65, 66, 67, 68, 82, 85, 91, 96, 115
Rajkot 67, 71, 86,
Ranchi 14, 8, 9
Solapur 36, 40, 67
Climate
Bangalore 34
Bellary 2, 20
Bijapur 75
Dantiwada 6, 7, 13
Hisar 24, 31, 33
Indore 26, 87, 88, 98, 105, 109, 111, 121, 122, 123, 124, 125, 126, 127, 131
Phiulbani 21, 24, 30, 33, 36, 37, 44, 52, 60, 61, 63, 66, 67, 68
Rajkot 30, 86
Ranchi 13
Rewa 9
Solapur 17, 21, 52, 57, 58

Vegetation
Anantapur 1

General
Bangalore 73
Bellary 25, 27
Bhilwara 25
Bijapur 50
Indore 7

Rainwater management
Insitu conservation
Agra 3
Akola 1
Anantapur 8, 9
Bangalore 17, 29, 67
Bellary 3, 14, 15, 21, 22, 28, 32
Bhilwara 17
Bijapur 8, 22, 40, 47
Hisar 2, 17, 21, 23, 24, 30, 37, 40
Hoshiarpur 12, 13, 22
Hyderabad 8, 13
Indore 2, 3, 8, 10, 12, 15, 23, 34, 40, 63, 69, 77, 82, 85, 90, 101, 108, 117, 119, 120, 130
Research Publications and Recommendations in Dryland Agriculture

Kovilpatti 7
Phulbani 26, 31
Rajkot 15, 75
Ranchi 1, 6, 14
Solapur 14, 15
Varanasi 17, 33

Supplemental irrigation
Bangalore 63
Bellary 15, 16, 19, 34
Bhilwara 27, 28
Hisar 23
Hoshiarpur 22
Indore 20, 23, 40
Ranchi 12
Varanasi 5, 8
Hyderabad 3, 18

Crops and cropping system
Crop improvement and evaluation
Bellary 8, 11
Bijapur 19, 48
Faizabad 10
Hisar 4, 16
Kovilpatti 35
Phulbani 8
Rajkot 66
Rewa 11
Varanasi 11

Agronomic practices
Akola 3
Anantapur 16
Bangalore 17, 36, 55, 56, 58, 63, 72
Bellary 5, 24
Bhilwara 22, 23
Bijapur 9, 14, 18, 20, 23, 37, 46, 48, 52, 54
Dantiwada 11
Hisar 7, 28
Hoshiarpur 6, 7, 11
Hyderabad 4, 5, 9
Indore 4, 8, 14, 15, 22, 61, 62, 68, 69,
76, 101, 117, 118, 130
Kovilpatti 3, 32, 45
Phulbani 5, 19, 23, 31, 34, 45, 56, 69
Rajkot 34, 35
Ranchi 6
Rewa 10
Solapur 16, 19, 21, 31, 32, 50, 59, 60, 61,
66, 68, 72
Varanasi 24, 33, 44, 46

Inter / mixed / relay / sequence cropping systems
Bijapur 29, 33, 41
Faizabad 4, 7
Hoshiarpur 12
Indore 22, 100

Weeds/pest/disease management
Rajkot 63
Ranchi 17, 59
Varanasi 10

Soil fertility and nutrient management
Major nutrients
Bangalore 49, 61, 66
Bhilwara 11, 22
Bijapur 53, 54
Dantiwada 9
Hisar 28
Hoshiarpur 3, 26
Indore 45, 51, 66
Kovilpatti 3, 6, 7
Rajkot 15
Solapur 28, 39, 40, 66
Varanasi 53

Secondary and micro nutrients
Bangalore 74
Dantiwada 13

Organics, bio-fertilizers etc.,
Bijapur 34, 53, 54
Dantiwada 9, 11
Hisar 7, 28
Kovilpatti 3
Phulbani 39
Ranchi 14
Solapur 2, 15, 42, 65

Alternate land use
Agro-forestry/ pastures
Bangalore 64
Bellary 23
Bijapur 52
Kovilpatti 13, 14

Dryland horticulture
Live stock
Hisar 54

Energy management
Animals
Phulbani 9, 35
Ranchi 2

Tractors, other machinery etc
Varanasi 21
Bijapur 18

Hand tools
Bijapur 5, 36
Hisar 15

Socio economics
Bangalore 38
All India Coordinated Research Project for Dryland Agriculture (AICRPDA)

On-farm work
Front line demonstration
Ranchi 35

Watersheds
Agra 9
Bangalore 60, 62
Bellary 25, 26
Indore 102
Solapur 38, 45

Green gram
Rainwater Management
In situ conservation
Rajkot 25

Supplemental irrigation
Varanasi 37

Crops(s) and Cropping System
Crop improvement and evaluation
Anantapur 5
Kovilpatti 1
Phulbani 49, 50

Agronomic practices
Bhilwara 29, 30, 31
Rajkot 72
Ranchi 32

Inter/mixed/relay/sequence cropping systems
Agra 8, 11
Bhilwara 29, 31
Bijapur 1
Jodhpur 3
Ranchi 32

Weeds/pest/disease management
Jodhpur 5

Soil fertility and nutrient management
Major nutrients
Agra 11
Bhilwara 30, 32
Jodhpur 3
Rajkot 25, 32

Organics, bio-fertilizers etc
Bhilwara 30, 31
Rajkot 32

Ground nut
Rainwater management

In situ conservation
Anantapur 11
Bangalore 30
Hoshiarpur 19
Rajkot 68
Ranchi 30
Varanasi 47

Supplemental irrigation
Rajkot 26, 27, 33

Crop improvement and evaluation
Agra 6, 7
Bangalore 3, 37
Bhilwara 10
Hoshiarpur 19
Jhansi 3
Rajkot 6
Ranchi 63

Agronomic practices
Anantapur 2, 4, 7, 13, 15, 19
Agra 6, 7
Bangalore 31
Bellary 18
Bhilwara 10
Phulbani 10, 14
Rajkot 4, 6, 20, 26, 28, 31, 33, 40, 42, 46, 69, 73, 76
Solapur 41

Inter/mixed/relay/sequence cropping systems
Bhilwara 24
Phulbani 6, 10, 12, 14
Rajkot 74, 81
Ranchi 39, 63

Weeds/pest/disease management
Anantapur 12, 17
Bangalore 24
Bhilwara 24
Rajkot 48, 51
Ranchi 61

Soil fertility and nutrient management
Major nutrients
Agra 6, 7
Bangalore 16, 18, 20, 52
Bhilwara 10
Jhansi 3
Rajkot 6, 20, 26, 27, 76, 81

Organics, bio-fertilizers etc
Anantapur 20

Post harvest technologies
Anantapur 19

Horse gram
Crops and cropping system
Crop improvement and evaluation
Bangalore 50, 73, 82
Phulbani 22

Agronomic practices
Bangalore 57
Ranchi 37, 40
Solapur 46

Inter/mixed/relay/sequence cropping systems
Bijapur 31
Phulbani 71
Ranchi 60
Research Publications and Recommendations in Dryland Agriculture

Soil fertility and nutrient management
Major nutrients
Bijapur 31
Ranchi 40, 60
Organics, bio-fertilizers etc.,
Phulbani 72

HORT
Others
Indore 83
Rainwater management
Insitu conservation
Hisar 42
Crops and cropping system
Crop improvement and evaluation
Dantiwada 10
Hisar 43
Agronomic practices
Bangalore 70
Indore 106

Kodo millet
Crops and cropping systems
Crop improvement and evaluation
Kovilpatti 51

Legumes
Rainwater management
Insitu conservation
Hisar 34
Crops and cropping system
Crop improvement and evaluation
Agra 4
Ranchi 36, 46
Agronomic practices
Faizabad 18
Indore 104
Kovilpatti 17, 18
Ranchi 46
Inter/mixed/relay/sequence cropping systems
Bijapur 39
Faizabad 18
Kovilpatti 17, 18, 30
Rajkot 70
Ranchi 36, 48
Solapur 43, 54

Soil fertility and nutrient management
Major nutrients
Faizabad 18
Ranchi 50
Solapur 43

Lentil
Rainwater management
Insitu conservation
Varanasi 44
Crops and cropping system
Crop improvement and evaluation
Agra 22

Maize
Rainwater management
Insitu conservation
Hoshiarpur 5
Crops and cropping system
Crop improvement and evaluation
Bhilwara 20, 21
Ranchi 50
Agronomic practices
Bangalore 42
Bijapur 7
Dehradun 1
Hoshiarpur 30
Indore 5
Phulbani 47
Ranchi 70
Inter/mixed/relay/sequence cropping
Bangalore 54

Linseed
Rainwater management
Insitu conservation
Indore 1
Varanasi 19
Crops and cropping system
Crop improvement and evaluation
Faizabad 1
Agronomic practices
Indore 53
Inter/mixed/relay/sequence cropping systems
Solapur 47

Socio economics
Agra 22
Resource characterization
- Soil
  - Bellary 9
- Climate
  - Solapur 23

Rainwater management
- Insitu conservation
  - Agra 14
  - Anantapur 6
  - Hisar 6, 34
  - Hoshiarpur 19

Crops and cropping system
- Crop improvement and evaluation
  - Bijapur 35
  - Dantiwada 1, 5
  - Hoshiarpur 19
  - Rajkot 18, 65
  - Solapur 20

Agronomic practices
- Agra 14
- Dantiwada 3
- Hisar 53, 6
- Hoshiarpur 1, 8
- Kovilpatti 17, 25, 28, 52
- Rajkot 1, 2, 17
- Solapur 26, 51

Inter/mixed/relay/sequence cropping systems
- Agra 8
- Bijapur 35
- Jodhpur 3
- Kovilpatti 15, 17, 25, 28, 52
- Rajkot 29, 70, 81

Weeds/pest/disease management
- Hisar 12
- Rajkot 23

Soil fertility and nutrient management
- Major nutrients
  - Agra 1
  - Dantiwada 3
  - Hisar 20
  - Hoshiarpur 1
  - Jodhpur 2, 3
  - Rajkot 18, 81
  - Solapur 20, 23, 26
  - Varanasi 29

Organics, bio-fertilizers etc
- Jodhpur 2

Pigeonpea

Crops and cropping system
- Crop improvement and evaluation
  - Agra 4, 5
  - Bangalore 4, 48
  - Bhilwara 20
  - Bijapur 35
  - Indore 47, 48, 49, 58, 60, 74
Research Publications and Recommendations in Dryland Agriculture

Phulbani 11
Rajkot 10
Ranchi 36, 50, 63
Solapur, 8, 9, 10, 12, 13

Agronomic practices
Agra 18, 5
Anantapur 10
Bangalore 46
Bijapur 35
Faizabad 11
Indore 38, 47, 56, 72, 74, 99
Phulbani 10, 13, 14, 43
Ranchi 32, 39
Varanasi 48, 57

Inter/mixed/relay/sequence cropping systems
Agra 2, 18
Bangalore 54
Bhilwara 20, 26
Bijapur 35
Faizabad 6, 8, 11
Indore 28, 38, 44, 49, 56, 58, 60, 99
Phulbani 4, 6, 7, 10, 12, 13, 14, 15, 16, 18, 28, 43, 55,
Rajkot 21, 29, 30, 35, 39, 42, 53, 65, 66, 71
Rewa 12, 13
Varanasi 48, 56, 57

Weeds/pest/disease management
Anantapur 12
Phulbani 16
Ranchi 62

Soil fertility and nutrient management
Major nutrients
Bangalore 54
Bhilwara 26
Faizabad 8
Indore 44
Phulbani 4, 7, 15, 18
Ranchi 19
Rewa 12, 13, 15
Varanasi 48

Socio economics
Bhilwara 26
Ranchi 68

Poppy
Crops and cropping system
Crop improvement and evaluation
Bhilwara 6
Agronomic practices
Bhilwara 15
Soil fertility and nutrient management
Major nutrients
Bhilwara 4, 5, 6

Proso millet
Crops and cropping system
Agronomic practice
Kovilpatti 37

Rajmash
Rainwater management
Supplemental irrigation
Varanasi 59

Crops and cropping system
Agronomic practices
Varanasi 59

Inter/mixed/relay/sequence cropping systems
Varanasi 59

Rapeseed Mustard
Rainwater management
Insitu conservation
Hisar 18
Supplemental irrigation
Bhilwara 14
Hisar 48

Crops and cropping system
Crop improvement and evaluation
Agra 15
Faizabad 3, 20
Hisar 36, 41, 50
Hoshiarpur 9
Varanasi 45, 52
Agronomic practices
Bhilwara 3, 9
Hisar 22, 26, 50
Rajkot 7, 8
Varanasi 39, 40

Inter/mixed/relay/sequence cropping systems
Agra 11, 13, 15, 19, 25, 26
Hisar 51, 52
Hoshiarpur 35
Phulbani 70
Ranchi 64
Rewa 17
Varanasi 39

Weeds/pest/disease management
Agra 25
Hisar 25, 26
Phulbani 58
Ranchi 64

Soil fertility and nutrient management
Major nutrients
Agra 11, 13, 15, 26
Bhilwara 14
Faizabad 3
Hisar 25, 46, 48
Rajkot 8
Varanasi 52
Bhilwara 1

Secondary and micro nutrients
Faizabad 3, 20
Indore 42

Socio-economic
Phulbani 70
### Rice

**Resource characterization**

- Climate
  - Phulbani 17
  - Ranchi 3
  - Rewa 3, 5

**Rainwater management**

- In-situ conservation
  - Phulbani 32
  - Rewa 8
  - Varanasi 22, 46

**Crops and cropping system**

- Crop improvement and evaluation
  - Ranchi 18, 26, 29, 36
  - Rewa 21, 25, 28, 29, 31

**Agronomic practices**

- Dantiwada 8
- Indore 80
- Kovilpatti 60, 64
- Phulbani 17, 32, 43, 51, 62, 64, 65
- Ranchi 5, 15, 22, 3, 41, 47, 51, 65, 67
- Varanasi 1, 14, 18, 22, 26

**Inter/mixed/relay/sequence cropping systems**

- Phulbani 4, 7, 15, 18, 43, 71
- Ranchi 36, 62, 65, 67
- Rewa 4, 24
- Varanasi 60

**Weeds/pest/disease management**

- Phulbani 53
- Ranchi 53, 56
- Rewa 4, 14
- Varanasi 1, 14, 15, 25, 34, 41

**Soil fertility and nutrient management**

- Major nutrients
  - Dantiwada 8, 12
  - Phulbani 4, 7, 15, 18, 65
  - Ranchi 18, 22, 23, 26, 28, 41, 47, 56, 65, 67
  - Varanasi 4, 18, 26, 27, 43

- Secondary and micro nutrients
  - Ranchi 51
  - Varanasi 49

- Organics, bio-fertilizers etc.,
  - Dantiwada 8, 12
  - Hoshiarpur 32
  - Kovilpatti 46
  - Phulbani 65, 71
  - Varanasi 60

### Crops and cropping system

- Crop improvement and evaluation
  - Bellary 13
  - Bijapur 13, 21
  - Rajkot 11, 12
  - Rewa 19
  - Solapur 4, 7
  - Varanasi 12

- Agronomic practices
  - Bijapur 3
  - Hisar 1
  - Indore 16, 17, 53, 107
  - Phulbani 1
  - Ranchi 46
  - Solapur 11, 25, 29, 34

- Inter/mixed/relay/sequence cropping systems
  - Agra 19
  - Bhilwara 19
  - Indore 52, 92
  - Ranchi 46
  - Solapur 48

- Soil fertility and nutrient management
  - Major nutrients
    - Indore 50, 52, 92
    - Solapur 11, 22, 34
  - Secondary and micro nutrients
    - Indore 52

- Alternate land use
  - Agro-forestry/ pastures
    - Hisar 1

### Sericulture

- Crops and cropping system
  - Agronomic practices
    - Bangalore 78
  - Weeds/pest/disease management
    - Bijapur 6, 57

- Soil fertility and nutrient management
  - Major nutrients
    - Bangalore 76, 79, 81

- Alternate land use
  - Medicinal/Aromatic/spices etc
    - Bangalore 79, 81

### Sesame

- Crops and cropping system
  - Crop improvement and evaluation
    - Bhilwara 8
    - Bijapur 43
    - Solapur 1, 3
    - Varanasi 42

- Agronomic practices
  - Jodhpur 4
  - Kovilpatti 64
  - Phulbani 13
Research Publications and Recommendations in Dryland Agriculture

Inter/mixed/relay/sequence cropping systems
- Bellary 31
- Bhilwara 29, 30
- Bijapur 1, 12, 51
- Faizabad 18
- Indore 38, 56, 58
- Kovilpatti 12, 18, 21, 27, 52, 62, 63
- Ranchi 68
- Rewa 12, 13, 15
- Solapur 43, 54

Weeds/pest/disease management
- Bellary 1
- Bijapur 16
- Hoshiarpur 11, 12
- Kovilpatti 53, 61, 62

Soil fertility and nutrient management

Major nutrients
- Bellary 30, 33, 37, 38, 39, 40
- Bhilwara 30, 32
- Bijapur 15, 28
- Faizabad 18, 9
- Indore 21, 31, 78, 95, 128, 129
- Jhansi 1
- Kovilpatti 27, 47
- Rajkot 46, 50, 73, 78, 80, 82, 87
- Rewa 12, 13, 15
- Solapur 27, 43, 63, 69, 71, 73

Organics, bio-fertilizers etc.,
- Bellary 27, 47
- Bijapur 30, 43, 54
- Kovilpatti 52, 63
- Solapur 30, 64, 71

Energy management

Animals
- Bijapur 24

Hand tools
- Bijapur 25

Socio economics
- Bijapur 49
- Indore 128

Soybean

Resource characterization
- Soil
- Indore 73, 89

Rainwater management
- Indore 29, 39, 81

Crops and cropping system

Crop improvement and evaluation
- Indore 36, 39, 46, 49, 60, 70
- Phulbani 59
- Rewa 21, 31

Agronomic practices
- Indore 29, 41, 46, 57, 59, 73, 93, 97, 99, 107, 110, 112, 116
All India Coordinated Research Project for Dryland Agriculture (AICRPDA)

Ranchi 70
Inter/mixed/relay/sequence cropping systems
Bhilwara 26
Indore 28, 44, 49, 52, 57, 60, 92, 94, 99, 110, 114
Ranchi 58
Weeds/pest/disease management
Ranchi 58
Soil fertility and nutrient management
Major nutrients
Bhilwara 26
Indore 24, 44, 50, 52, 54, 64, 92, 93, 94, 97
Rajkot 84
Secondary and micro nutrients
Indore, 52, 112, 114, 116
Organics, bio-fertilizers etc
Indore 50, 54, 84, 92, 93, 94, 97, 107
Socio economics
Bhilwara 26

Sugarcane
Rainwater management
Insitu conservation
Hoshiarpur 23
Crops and cropping system
Crop improvement and evaluation
Solapur 70
Agronomic practices
Hoshiarpur 23
Indore 43
Solapur 70

Sunflower
Resource characterization
Climate
Bijapur 56
Solapur 49
Rainwater management
Insitu conservation
Agra 16
Rajkot 21, 22
Varanasi 16
Supplemental irrigation
Rajkot 21, 22
Crops and cropping system
Crop improvement and evaluation
Bangalore 69
Kovilpatti 41
Agronomic practices
Akola 2
Bangalore 69
Bellary 29
Hisar 39, 47
Kovilpatti 8, 10
Rajkot 21, 22
Solapur 49

Soil fertility and nutrient management
Major nutrients
Agra 16
Bangalore 51, 65
Kovilpatti 8, 11, 24
Rajkot 21
Solapur 35
Varanasi 16
Secondary and micro nutrients
Bijapur 4
Kovilpatti 9, 10, 24

Tobacco
Resource characterization
Soil
Bangalore 59

Turmeric
Crops and cropping system
Weeds/pest/disease management
Phulbani 41

Vegetables
Rainwater management
Insitu conservation
Jodhpur 1
Crops and cropping system
Crop improvement and evaluation
Bangalore 68, 80, 83
Hisar 11, 27
Hoshiarpur 28
Phulbani 58
Solapur 5, 24
Agronomic practices
Hoshiarpur 28
Jodhpur 1
Rajkot 45
Inter/mixed/relay/sequence cropping systems
Phulbani 28, 46, 55
Varanasi 51
Weeds/pest/disease management
Hisar 27, 38
Phulbani 38, 46, 54
Rajkot 13, 49, 58
Solapur 24
Soil fertility and nutrient management
Major nutrients
Jhansi 1
Ranchi 55
Energy management
Animals
Ranchi 20

Wheat
Resource characterization
Soil
Hoshiarpur 8, 25
Climate
Hoshiarpur 25
Ranchi 7
Rainwater management
Insitu conservation
Bhilwara 31
Hoshiarpur 4, 7, 14, 29, 34
Indore 1, 9, 16, 25, 32, 33
Ranchi 11, 16
Varanasi 6
Supplemental irrigation
Hoshiarpur 27, 31
Phulbani 2
Rajkot 19, 47
Varanasi 23
Crops and cropping system
Crop improvement and evaluation
Bangalore 13, 14
Bhilwara 2, 31
Hisar 29
Hoshiarpur 16, 25, 33, 35
Ranchi 7
Rewa 1, 6
Varanasi 30
Agronomic practices
Bhilwara 2, 12, 13, 16, 31
Hisar 45
Hoshiarpur 20, 21, 31, 34
Indore 16, 33, 53
Phulbani 2
Ranchi 10, 16, 25, 54
Solapur 29
Varanasi 7, 55
Inter/mixed/relay/sequence cropping systems
Indore 114
Ranchi 64
Rewa 4, 17
Weeds/pest/disease management
Ranchi 54, 57, 64
Rewa 4
Varanasi 2, 7
Soil fertility and nutrient management
Major nutrients
Bhilwara 12, 13
Hisar 45
Hoshiarpur 2, 6, 7, 8, 14, 16, 21, 27, 31, 34
Rajkot 19, 47
Ranchi 57
Rewa 16
Varanasi 6, 7
Secondary and micro nutrients
Hisar 44
Indore 114
Rajkot 79
Organics, bio-fertilizers etc.,
Hoshiarpur 18, 32
Socio economics
Hoshiarpur 34