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Overview of Dryland Agriculture Research and Achievements in North Gujarat Zone

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Brief history of the Centre

The All India Coordinated Research Project for Dryland Agriculture (AICRPDA) Centre came into existence as a sub-centre at Anand in 1970-71 and it was then shifted to Sardarkrushinagar in 1979. The Centre was elevated to main centre in 1984.

Agro-climatic zone characteristics

It is located in the North Gujarat Agro-climatic Zone- IV. The domain districts of the AICRPDA centre, Sardar Krishinagar are located in Northern Gujarat Zone (NARP) in Gujarat and in the Agroecological subregion (ICAR) 2.3 and in the agroclimatic region-13 (Gujarat plains and hills as per Planning Commission). The represents North Gujarat zone with seven domain districts under its jurisdiction viz., Banaskantha, Aravali, Sabarkantha, Patan, Mehsana, Gandhinagar and Kachchh. The climate of the zone is arid to semi-arid. The mean annual rainfall of the zone is 749.5 mm and receive in 26 rainy days. About 75% of the rainfall is received during last week of June to end of September. The normal onset of the monsoon is during 26th to 27th SMW and withdrawal is during 38th SMW. In general, winter is very cold and dry whereas, summer is extremely hot. May is the hottest month while January is the coolest, the monsoon season varies from June to September present the rainy months. The mean monthly maximum temperature ranges between 26 °C and 42 °C. The mean monthly relative humidity varies from 60 to 80%. The PET varies from 1614 to 1998 mm.

Mean season-wise and annual rainfall and rainy days at AICRPDA centre, S.K. Nagar

Rainfall	Normal rainfall (mm)	Normal rainy days (no.)
SW monsoon (June-September)	749.5	26.0
Post-monsoon (October-December)	29.4	1.0
Winter (January-February)	3.5	-
Summer (March-May)	8.6	1.0
Total	787.8	28.0

Major soil types

The major soil types in the zone are deep black, medium black to loamy sand, sandy loam to sandy and sandy and saline soils.

Major rainfed crops cultivated in the domain districts

The major rainfed crops cultivated during *kharif* are pearl millet, castor, cluster bean, moth bean, greengram and during *rabi* are mustard and chickpea.

Dryland agriculture problems

The problems related to domain districts are:

Soil and land management

- Loamy sand soils with shallow depth and low moisture retention capacity. The maximum water holding capacity of these soils varies between 22 and 24%. Loamy sand soils are normally poor in N and P and very low in organic matter. Some locations are also deficient in S and micronutrients like Fe and Zn.
- The soils have low CEC which results in low retention of exchangeable nutrients. These soils are highly erodible.
- Crusting on drying is a serious problem in seedling emergence and establishment of a good crop stand.

Crop production

- Due to weather aberrations, the crops suffer due to long dryspells
- Lack of suitable implements for farm operations
- Unavailability of drought tolerant/ short duration varieties

Socio-economic

- Small land holdings and pose problems in implementing land development programmes
- Investment capacity and risk bearing status is of dryland farmers is less.
- Market risks
- Inadequate availability of agriculture inputs during the season and for contingent measures

Significant achievements

Rainwater management

- *In situ* moisture conservation with compartmental bunding of 3.0 m x 4.5 m in pearlmillet grown in moderate slopy soil for resulted in higher yield while in compartmental bunding of 3.6 m x 6.0 m in castor gave higher castor yield.

- Adopting castor and cotton crop rotation system on medium black soils under rainfed condition, and deep ploughing with disc plough before sowing resulted in maximum yield and monetary returns of cotton and castor
- Use of roto till drill for sowing of clusterbean (GG 2) under rainfed condition gave higher seed yield, monetary returns and rainwater use efficiency with better moisture conservation.
- Opening furrows at 3.6 m interval with application of castor shell mulch @ 10 t ha^{-1} after last interculture gave higher seed cotton yield

Cropping systems

- Intercropping of pearl millet + cluster bean in 2:2 or 2:1 row ratio and greengram in 1:3 row ratio gave 10.5 & 25.5% higher pearl millet equivalent yield, respectively over sole pearl millet.
- Pearlmillet + sunhemp (4:2) at 30 cm spacing (*in situ* green manuring of sun hemp around 30 DAS by the help of rotary weeder) resulted in 19.5% higher yield. Intercropping of castor + cowpea (1:1) gave 31.5% higher net returns over normal sowing of castor.
- Intercropping of castor (90 x 60 cm) + sesamum (1:1) gave higher yield and 31.6% higher net return over sole castor.
- In pearl millet-clusterbean crop rotation, cultivation of field with 50% of conventional tillage (one ploughing by tractor cultivation) + interculturing at 20 and 40 DAS + pre-emergence application of atrazine @ 0.5 kg ha^{-1} for pearl millet and pendimethalin @ 1.0 kg ha^{-1} for cluster bean was found optimum. In this crop rotation, application of 80 kg N ha^{-1} for pearl millet and 20 kg N ha^{-1} for cluster bean through urea or 50% N through chemical fertilizer and 50% N through FYM resulted in higher yield and net returns.
- Castor taken as a relay crop in greengram resulted in 45.6% higher greengram equivalent yield over greengram alone, in which greengram was sown at onset of monsoon and castor sown after first picking of greengram.
- In agri-horti system, intercropping of either greengram or sorghum in ber was found beneficial and gave higher monetary return of 27.3 and 15.5%, respectively, over sole ber.
- Karingado taken as a mixed crop along with pearl millet in every third row gave 9.5% more pearl millet equivalent yield. Similarly, Karingado grown as a mixed crop in sorghum at every 6^{th} line gave higher monetary return under drought condition over sole sorghum.
- Spraying of 5% Kaoline solution in pearl millet at 30 DAS gave 6.4% more yield as well as it mitigate stress condition under rainfed condition.
- Intercropping of black gram in cotton hybrid (120 x 30 cm) (1:1) on medium black soil gave higher cotton equivalent yield and net return over sole cotton.
- Intercropping of maize in castor (1:1) at 45 cm spacing resulted in higher yield and net return over sole cotton.
- Sowing of sole moth bean at 45 cm or intercropping of Bt. cotton + moth bean (1:2) gave higher cotton equivalent yield as well as monetary returns in medium black soil of Kutch region under rainfed condition.

Integrated nutrient management

- Application of half dose of recommended N (HRD-N) through fertilizer along with HRD-N through *Gliricidia* leaves green manuring in between the two row of pearl millet and clusterbean gave 42.6 and 17.4% higher yield, respectively over control as well as improved fertility status of soil.
- Castor fertilized with 60-40-40 kg NPK ha^{-1} was found optimum and resulted in 23.6% higher yield over control (NP).
- Application of 25% recommended dose of N as basal and 75% RDN at 20 to 25 DAS for rainfed pearl millet and sorghum was beneficial for increasing yield and monetary return.
- Application of 50% RDN as basal and 50% RDN in two equal splits at 20 to 25 DAS and 40 to 45 DAS is recommended for castor.
- In pearl millet, clusterbean and castor crop rotation, integration of half recommended dose of N (HRD-N) through fertilizer along with HRD-N through FYM improved the yield of pearl millet, clusterbean and castor to the extent of 99, 86 and 89%, respectively over control.
- Application of three sprays of $FeSO_4$ @ 0.5% along with $ZnSO_4$ @ 0.5% (with 0.05% citric acid and lime solution @ 0.25%) at 30, 40 and 50 DAS along with recommended dose of fertilizers (80+40 kg N, P_2O_5 ha^{-1}) on medium black soil deficient in Fe and Zn under rainfed condition gave higher grain and fodder yield of maize as well as monetary return.
- In green gram-sesame crop rotation on loamy sand soils in organic farming, application of recommended dose of nitrogen @ 20 kg ha^{-1} for green gram and 50 kg N ha^{-1} to sesame either through vermicompost or FYM gave the maximum yield and net returns.
- In castor-clusterbean crop rotation under rainfed conditions, it is recommended to apply *Azotobactor* (Azo 8) + PSB (5 ml/kg seed) as seed treatment and 40 kg P_2O_5 ha^{-1} as basal to both crops and 30 kg N ha^{-1} through vermicompost (2.5 t ha^{-1}) and 30 kg N ha^{-1} through chemical fertilizer to castor

crop while 10 kg N ha^{-1} through vermicompost (0.83 t ha^{-1}) and 10 kg N ha^{-1} through chemical fertilizer to clusterbean crop for obtaining higher yield and net returns.

Energy management

- Sowing of clusterbean (GG 2) with roto till drill gave higher seed yield, monetary returns and rain water use efficiency through better moisture conservation.

Technologies developed

Rainwater management

- Compartmental bunding for moisture conservation and higher productivity in pearl millet
- Sowing of castor with ridges and furrow system method
- Efficient and economic use of harvested rainwater for sustainable crop production
- Mulching of castor shell in rainfed castor

Cropping system

Intercropping systems

- Green gram + castor as a relay crop (2 :1
- Castor + greengram (1:1)
- Castor + greengram (1:2)
- Castor + cowpea (1:1)
- Castor + clusterbean (1:1)
- Castor + sesame (1:1)
- Pearmillet + sunnhemp (4:2)

Nutrient management

- Foliar sprays effect of $ZnSO_4$ @ 0.5 % + $FeSO_4$ spray @ 0.5% on yield of maize
- Spacing (120 cm x 60 cm) and nitrogen requirement (75 kg ha^{-1}) in castor under rainfed condition

Integrated nutrient management

Crop	INM Practice
Pearl millet	50 % RDN through FYM (40 kg N ha^{-1}) + 50 % RDN through fertilizer (40 kg ha^{-1}) + *Azotobacter* + PSB seed treatment. 40 kg P_2O_5 ha^{-1} to be applied as common dose
Castor	50 % RDN through FYM(37.5 kg N ha^{-1}) + 50 % RDN(37.5 kg N ha^{-1}) through fertilizer + 20 kg S ha^{-1}+ *Azotobacter* + PSB 40 kg P_2O_5 ha^{-1} to be applied as common dose
Cluster bean	50 % RDN through FYM + 50 % RDN through fertilizer + *Rhizobium* + PSB and 40 kg P_2O_5 ha^{-1} to be applied as common dose
Greengram	5 ton FYM + RDF (20,40 kg NP ha^{-1}) + *Rhizobium* + PSB

Contingency crop planning

For *kharif* planning

a. Suggested contingency crops/cropping systems and cultivars under delayed onset of monsoon

Delay by 2 weeks (1st week of July)

- Maize (GM-1, GM-3, GDYMH 1), sorghum (GJ 41, CISV 21,GFS 5), blackgram (GU-1), clusterbean (GG 1, GG2), castor, groundnut (GG-5,7&TG 37), sesame, cotton, maize (GM-3) + blackgram (GU-1); Maize (GM-4) + pigeonpea (GT-101&GT-103); Castor (GCH-4, 7 & 8), castor + cowpea (GC-4, 5 and 6), clusterbean (GG-1&2); Pearl millet (GHB-538, GHB 1129), sesame (GT-1, 2 and 3)
- Intercropping systems: Castor + greengram (GM-4), castor + cowpea; cotton + greengram (GM-4), cotton (GTHH 49 BG II, G. Cot. Hyb 8 (BG II) + cowpea (GC-5), mothbean (GMO-2), fennel (GF 12l).

Delay by 4 weeks (3rd week of July)

- Maize (GM-1, GM-3), GDYMH 1 blackgram (GU-1), groundnut (GG-5, 7 & TG 37)
- Intercropping systems: Maize (GM-3) + blackgram (GU-1); maize (GM-4) + pigeonpea (GT-101&GT-103); Fennel (GF-2); Pearl millet (GHB-538, 577 and 1129); sesame (GT-2&3); Clusterbean (GG 2), castor (GCH-4, 7 & 8), castor (GCH-4, 5 & 7) + greengram (GM-4, 6), castor (GCH-4, 7 & 8) + cowpea (GC-6), mothbean (GMO-2); cotton + greengram (GM-4), cotton (Bt) + cowpea (GC-6); Fodder sorghum (GFS 6

Delay by 6 weeks (1st week of August)

- Maize (GM-4) + pigeonpea (GT-101 & GT-103); blackgram (T-9), pigeonpea (BDN-2); clusterbean (GG 2) fodder sorghum (GJ 43, GJ-39); castor (GCH-4, 7 & 8), fennel (GF-2, castor (GCH-4, 5 & 7) + cowpea (GC-6).

Delay by 8 weeks (3rd week of August)

- Maize (GM-4) + pigeonpea (GT-100 & GT-101); Blackgram (T-9), pigeonpea (BDN-2); Fodder sorghum (GJ 43, GJ-39 GFS5, 6); Castor (GCH-4, 7 & 8), fennel (GF-2); castor (GCH-4, 5 & 7) + cowpea (GC-6).

b. Crop, soil, water and nutrient management strategies during seasonal drought

Early season drought

- Maintain plant population by gap filling, thinning and resowing
- Ridges and furrows
- *In-situ* moisture conservation by opening conservation furrow
- Soil mulch by shallow interculturing

Mid-season drought

- Reduce plant population by 15 to 20% and use as mulch or fodder
- Repeated interculture
- Mulching with crop residue or farm waste
- Provide supplemental irrigation, alternate furrow irrigation in castor and cotton if available
- Foliar spray of 2% DAP + 1% KCI (MoP) during critical stages of crop (flowering and grain formation)/Kaolin @ 5%
- Removal of lower matured leaves and use as mulch
- Application of three sprays of $FeSO_4$ @ 0.5 % along with $ZnSO_4$ @ 0.5 % (with 0.05 % citric acid and lime solution @ 0.25 %) at 30, 40 and 50 DAS in maize

Terminal drought

- Harvest one row of pearl millet/maize at an interval of 3 lines and use as fodder
- Harvest maize cobs, pods of cowpea, clusterbean, and pigeanpea for vegetable purpose.
- Reduce leaf canopy by 20%
- Provide life-saving irrigation, if available

For *rabi* planning

a. Crops and varieties for normal season

- Dilseed (GD2, GD 3), Chickpea (GC 3, Gujarat chickpea 5), Mustard (GM 2,GDM 5)

b. Suggested crops and varieties for delayed season

- Dilseed (GD2)

Agro-horti systems

- Ber + greengram or fodder sorghum. The trees of Ber are prunned every year in April, by the time it attains full regrowth at the end of August, suitable field crops can be taken viz., greengram or sorghum (fodder) (Spacing: 45 cm for greengram and 30 cm for fodder sorghum and 80 + 40 kg N:P_2O_5 ha^{-1} for fodder sorghum and 20 + 40 kg N:P_2O_5 ha^{-1} for greengram) between two rows of ber (10 m x 6 m).
- Green gram or sorghum (fodder) (Spacing: 45 cm for greengram and 30 cm for fodder sorghum and 80 + 40 kg N: P_2O_5 ha^{-1} for fodder sorghum and 20 + 40 kg N: P_2O_5 ha^{-1} for greengram) between two rows of ber (10 m x 6 m).

Technologies upscaled in convergence with various programmes

Dryland technologies were upscaled on farmers' fields in collaboration with KVKs, department of agriculture and department of watershed, Government of Gujarat. District agriculture contingency plans were upscaled with the help of ATMA. The farm pond technology and soil and water conservation measures such as deep ploughing and compartmental bunding were upscaled through watershed program. The centre in collaboration with other AICRP schemes such as AICRP on small millet (pearl millet: GHB-558, GHB-538, GHB 1129), and legume research station developed various improved varieties of crops *viz.*,greengram: GM 3, GM 4, GM 6, cowpea: Gujarat Cowpea-1, Gujarat Cowpea-2, Gujarat Cowpea-4, Gujarat Cowpea-6, clusterbean: GG- 1, GG 2 pigeon pea: BDN 2. Oilseed research station (castor, GAUCH-1, GCH-2, GCH-4, GCH-5, GCH-6, GCH-7 and GCH 8), mustard: GM 2, GDM 4& GDM 5 which helped to increase the productivity of these dryland crops. All these varieties were evaluated and upscaled through frontline demonstration in farmers' fields in the domain area through KVKs of SAUs, ATMA and other line departments operating in the zone. Alternate land use management practices, viz, intercropping of clusterbean and sorghum in Ber and amla, were upscaled through department of horticulture.

Impact of technologies

Sowing of castor crop with ridges and furrow method of sowing for maximum use of harvested rain water in the furrows for *in-situ* moisture conservation gave yield of 1398 kg ha^{-1} of castor crop. Upscaling of this technology in 10% castor area (44970 ha) in North Gujarat region, the expected additional yield of 5666.2 metric tonnes with Rs. 8.32 crores as additional gain to the farmers of this region. Adoption rate of compartmental bunding for moisture conservation in North Gujarat is 41746 ha (8.8%) and productivity of pearl millet is increased 8 to 10%. In North Gujarat, at present this technology which gives Rs.16.3 crores additional income. With adoption of mulching with castor shell in castor in North Gujarat the farmers can get 25% more yield and net return of (Rs. 34939 ha^{-1}) than farmers' practice. Intercropping of castor (GCH 7) + green gram (Gujarat Mung 4) (1:1) gave castor equivalent yield of 1671 kg ha^{-1} and net return of Rs. 64934 ha^{-1} with a B:C ratio of 4.96 as compared to sole castor. Adoption of this technology is between 12 to 15% in different districts. Adoption of integrated nutrient management (75% RDN-FYM + 25% RDN-urea + PSB + *Azotobacter*) in pearl millet helps in realizing an additional pearl millet yield of 1654 ton and Rs.2.15 crores in 5% rainfed area (5514 ha).

Way forward

The future research has to focus on sstrengthening of IFS in dryland agriculture, to enhance *in-situ* moisture conservation in soil, introduction of medicinal crops in dryland ecosystem, rainwater management on watershed basis for intensification of soil and water conservation, alternate land use system including agri-silvi, agri-horti and horti-pastoral system, and INM with focus to reduced dependence on external input. Technologies for sustainable soil health management include enhancing moisture holding capacity through use of alternate sources of organic manures and sub soil manuring to improve nutrient availability from deeper layers, Mechanization which include nano-coated machinery for energy efficient small scale operation and crop centric seed to seed mechanization.