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Overview of Dryland Agriculture Research and Achievements in Southern Zone of Tamil Nadu

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Brief history of the centre

The All India Coordinated Research Project for Dryland Agriculture Centre at Kovilpatti was started as a main Centre at Agricultural Research Station, Kovilpatti in 1971. This Centre is intended to cater the needs of the rainfed black soil areas which occupy a major portion of the southern districts of Tamil Nadu *viz*., Tuticorin, Tirunelveli, Virudhunagar, Madurai and Ramanathapuram districts.

Agro-climatic zone characteristics

AICRPDA, Kovilpatti centre is located in the Southern agro-climatic zone of Tamil Nadu with domain districts of Madurai, Sivagangai, Ramanathapuram, Virudhunagar, Tirunelveli, Thoothukudi and Tenkasi districts. The climate of this zone is semi-arid and the main cropping season is during north-east monsoon under rainfed conditions. Out of the total annual average rainfall of 699.1 mm in 42 rainy days, the south - west monsoon contributes 20.8% (145.2 mm) while north-east monsoon contributes 55.9% (390.6 mm) and 19.3% (134.7 mm) during summer. The onset of south west monsoon is during first week of June and north east monsoon is during third week of October. Occasionally the onset of south west monsoon may delay one or two weeks. Dry spells occur during the early season and during the middle of the cropping season. Highest maximum monthly temperature was recorded during May (38 °C) and lowest maximum monthly temperature was recorded during December (30.8 °C). Highest minimum monthly temperature was recorded during June (25.1 °C) and lowest minimum monthly temperature was recorded during the month of January (19 °C).

Mean season-wise and annual rainfall and rainy days (at AICRPDA centre, Kovilpatti)

Rainfall	Normal rainfall (mm)	Normal rainy days (No.)
South west monsoon (June-September)	145.2	9
North east Monsoon (October-December)	390.6	21
Winter (January-February)	28.6	2
Summer (March-May)	134.7	10
Annual	699.1	42

Major soil types

The major soil types in the zone are clayey, clay loam and sandy clay loam, red loam to deep red and black soils is observed in Tirunelveli, Thoothukudi , Viruthunagar and Tenkasi, Madurai districts. 51% the soil is Alfisols and Entisols, 31% Vertisols, 18% alluvial and sandy soils.

Major rainfed crops

The major rainfed crops cultivated in the zone during post-monsoon are cotton, sorghum, maize, pearlmillet, greengram, black gram, sunflower, sesame, chillies, coriander and senna.

Dryland agriculture problems

Soil and land management

- In this region black cotton soil occurs in nearly two-thirds and red soils occur in about one-third of the area. Soils possess high volume expansion followed by contraction, resulting in formation of cracks and loss of soil moisture. Soil cracks are formed generally during January and develop due to dry weather till receipt of summer showers in May.
- Soils are poor in available N and medium in P and high in K.

Crop production

- Crops are mainly grown depending on rainfall received during North-east monsoon season.
- Delayed onset of monsoon, prolonged dry spells during crop growth and early cessation of rains affect the crops at different stages.
- Poor farm mechanization
- Lack of Poor crop diversification

Socio-economic issues

- Small land holdings and fragmented lands
- Poor investment capacity of farmers
- Market risks
- Inadequate availability of agriculture inputs during the season

Significant achievements/findings

Rainwater management

To understand the runoff water generation for storing in a water harvesting structure and for effective reuse, rainfall-runoff relationship was developed by measuring the runoff water, and it was found that nearly 35% of the rainfall is available as runoff and runoff causing rainfall events were 3-4. Runoff causing rainfall (mm) was 170 mm. The probability of getting 30% of rainfall as runoff is 75%. This runoff water can be harvested through *in-situ* and *ex-situ* moisture conservation practices to increase the yield of dryland crops.

Adoption of tied inter-rows recorded higher average yield of 623 kg/ha of seed cotton which was 10.9% higher than that of farmers' practice. However, higher consumptive use efficiency was recorded with formation of small watersheds. Studies on suitable land treatment for soil and water conservation practices in vertisol revealed that compartmental bunding was found better for *in-situ* moisture conservation and achieving higher yields of cotton, sunflower, sorghum and blackgram. Compartmental bunding was superior as only 11.8% of the seasonal rainfall was lost as runoff as compared to the farmers' practice (30%). Similarly, the reduction in runoff due to the land treatments was 60, 48.3 and 27.0% due to compartmental bunding, vettiver and broad bed and furrows, respectively. For example, in semiarid vertisols, having a land slope of 1% and an annual rainfall of 600-700 mm, compartmental bunding (8 m x 5m) formed across the slope helps in reducing runoff to the tune of 60% resulting in 25% yield increase in sorghum with a B:C ratio of 1.40. For yield maximization in rainfed maize, broad bed and furrows along with application of recommended dose of fertilizer + 25 kg $ZnSO_4$/ha recorded highest grain yield of 2923 kg/ha with a B:C ratio of 1.96 and RWUE of 6.29.

Cropping systems

Intercropping of cotton with pulses at row ratio of 3:1 was observed to be more profitable and the yield of cotton was not affected. The performance of paired row system of cotton sowing and uniform row sowing along with 12 intercrops *viz*., greengram, blackgram, cowpea (long duration - CO 1), cowpea (short duration - EC4216), lab lab, coriander, sesamum, sorghum, sunflower, safflower, bajra and foxtail millet did not affect yield and monetary return of main crop. Cotton (MCU 6) with black gram combination produced higher yield of kapas than pure crop of cotton. Intercropping of foxtail millet and coriander were also found to be ideal for cotton based intercropping system. There was extra monetary return by growing cowpea, coriander, green gram, black gram or foxtail millet as intercrop with the pure crop of the cotton. Between the two system of planting namely, wider planting (60 cm between rows) and narrow planting (45 cm between rows), the narrow planting was found to be better and gave significantly higher yield.

High density planting of cotton at 45 cm x 15 cm recorded significantly higher number of bolls and kapas yield (1242 kg/ha) than 45 cm x 10 cm. Among the moisture conservation practices, broad bed & furrow system was found better than compartmental bunding. *In-situ* green manuring in cotton with sunnhemp and daincha produced on an average of 5 - 6 t/ha of green manure biomass, whereas the fodder cowpea yielded up to 7 to 8 tonnes of green biomass. Higher yield was recorded under cotton + sunnhemp (924 kg/ha) followed by cotton + dhaincha (899 kg/ha) as compared to sole cotton (754 kg/ha).

K.Tall (Tall) sorghum hybrids intercropped with different legumes viz., blackgram, lablab, cowpea and redgram, blackgram produced higher sorghum equivalent yields and net return than sole sorghum. Considering the LER and net income under sorghum based intercropping system, main crop sorghum with 100% population and intercrop of cowpea with 50% population was optimum to get higher income and LER value under dryland condition. Similarly, intercropping of sorghum with pulses such as lablab and pigeonpea in both 2:1 and 4:2 row ratios was found optimum for achieving higher yields and economic returns. Intercropping of bajra with cluster bean, cowpea and pigeonpea was found better for higher yields and highest net return. Among different millet-based cropping systems, sorghum + sunflower (2:1) was found superior followed by sorghum + sunflower (4:1). Among different vegetable based intercropping systems, field lab-lab + sunflower (6:1) was found better than other intercropping systems.

Nutrient management

Application of 120 kg N/ha was found optimum for rainfed cotton. Among the fertilizer application methods, application of 50% fertilizers as basal and 50% as top dressing increased the seed cotton yield (7.06 q/ha) followed by precision placement 5 cm by side and 5 cm below seed (6.68 q/ha). Application of 20 N + 60 P_2O_5 kg/ha registered higher grain yield (21.01 q/ha) and followed by the treatment received 40 N + 60 P_2O_5 kg/ha (20.06 q/ha) and 40 N + 40 P_2O_5 kg/ha (19.98 q/ha). Application of 10 kg P_2O_5 as DAP + 8 kg N/ha registered higher yield (8.81 q/ha) of Black gram.

Hand dibbling at 45 x 15 cm weeding as and when required, spraying for complete control of pest and diseases along with the fertilizer dose of 40:20:0 NPK kg/ha for bajra (KM2) recorded higher grain and straw yield. Combined application of urea (20 kg N/ha) + FYM (20 kg N/ha) + 10 kg P/ha improved the sorghum and pearl millet grain yield by 35 and 66%, over control. The highest B:C ratio was obtained with application of 20 kg N/ha as farm residue + 20 kg N/ha as urea + 10 kg P/ha. Combined application of organics along with inorganics (NPK) + zinc sulphate of 25 kg/ha recorded 34 and 64% increase over control for sorghum and pearl millet crops, respectively over

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years in semi-arid vertisols. In addition, application of organics along with inorganic (NPK) fertilizers helped to save 50% of recommended P besides enhancing crop production under dryland condition.

In a long-term manurial experiment on cotton + blackgram and sorghum + cowpea rotation-based cropping systems, sustainability in yield over years was maintained by combined application of urea at 20 kg N/ha, FYM at 20 kg N/ha and SSP at 20 kg P/ha. Combination of 75% of the recommended N as urea along with enriched FYM at 750 kg/ha and soil application of *Azospirillum* (2 kg/ha), *Phosphobacteria* (2 kg/ha) is recommended for cotton and sorghum in dry land vertisols. Combined application of 50% of the recommended dose of N (20 kg N/ha) as organics (FYM / GLM) and the remaining dose N (20 kg N/ha) through urea had beneficial effect not only to improve yield of crops (cotton and sorghum) but also enhanced moisture use efficiency and maintained soil fertility in terms of organic carbon, compared to application of 100% of the recommended dose of inorganics alone. In cotton (KC 3), application of recommended NPK with foliar spray of 1% $MgSO_4$ + 0.5% $ZnSO_4$ + 0.5% Borax recorded highest seed cotton yield and B:C ratio. In the vertisol tract of southern Tamil Nadu, combined application of 15 kg N/ha as compost and 20 kg N/ha as inorganic fertilizer was found ideal combination for increased yield of sorghum + cowpea intercropping system.

Alternate land use system

A field study on agro forestry systems revealed that neem, silk cotton and tamarind are ideal tree components for agro-forestry system which permit sustainable growth of agricultural crops at lower input levels. The configuration of land created by the land use system has also contributed much in soil and moisture conservation and utilization, besides, maintaining sustainable yield and income level. The average yield and higher B:C ratio were higher with tamarind plus blackgram system than other agro-forestry systems. It was observed that whenever rainfall distribution was uniform, cotton + blackgram intercropping system gave higher yield and income, whereas the B:C ratio was low due to high cost of cultivation for cotton. Under normal rainfall situation, the yield of blackgram raised under agri-silviculture and agri-horticultural systems were more. The late sown sunflower crop depends purely on late showers and residual soil moisture. Among the tree species, *Ailanthus excelsa* exhibited poor performance in deep vertisol as compared to tamarind. In another alternate land use system, sapota + maize registered higher system productivity followed by sapota intercropped with sorghum. The mean B:C ratio was also higher under sapota plus maize system (1.90) followed by sapota plus sorghum (1.80).

Integrated farming systems

The percentage contribution of agricultural component to the total gross and net income of integrated farming system was 10 and 6.7% as compared to the percentage contribution of dairy component with 90 and 93.3% indicating that a dairy unit also could be included as one of a successful farming system enterprise under dryland conditions. Involving crops, goat (2 +1), sheep (5+1), dairy (1 milch cow), and poultry (20 broiler birds) enterprises for an area of 1.0 ac including 0.5 ac for crop activity, fodder production and cattle shed based IFS model revealed that total gross income was higher under the IFS model having crop + goat + poultry + sheep + dairy and B: C ratio of 1.75, which was closely followed by IFS model having crop + goat + poultry + dairy. Modified integrated farming system (crop, diary, goat) model recorded mean gross income of Rs. 60644 /ha whereas cropping alone recorded Rs.16308 /ha with an additional income of Rs. 44336/ha was generated by non-crop units of the integrated farming system. The employment opportunities were also increased from 191 to 405 man-days/ ha with an additional 214 man-days by the integration of crop, dairy and goat rearing in dryland vertisols of southern zone of Tamil Nadu.

Energy management

Performance evaluation of tractor operated air assisted seed drill for sowing minor millets indicated that, line sowing of minor millets with air assisted seed drill resulted in 30 to 40% saving in seed rate. The time taken for sowing one hectare was 1.24 hours with air assisted seed drill and was three times faster than broadcasting resulting in high area of coverage which is essential under dryland conditions to make use of the soil moisture effectively. Sowing of barnyard millet, foxtail millet and little millet with air assisted seed drill also recorded higher yield. Rotovator ploughing + chisel ploughing recorded higher water use efficiency of 2.29 kg/ha-mm, 10 – 23% higher yield than conventional tillage, higher B:C ratio of 1.54 in green gram. In cotton (KC3), the rotovator ploughing + chisel ploughing recorded higher water use efficiency of 2.46 kg/ha-mm, 12% higher yield than the conventional tillage, and higher B:C ratio of 1.32.

Technologies developed

Rainwater management

- Ridges and furrows for *in-situ* moisture conservation in sorghum
- Broad bed and furrow technique for *in-situ* moisture conservation in rainfed maize
- Rainwater harvesting and utilization for enhancing water productivity for Bt cotton

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- Response of cotton to crop geometry, fertility levels and moisture conservation practices under high density planting system in vertisols conditions

Cropping systems

Intercropping systems

- Cotton + green gram (1:2)
- Cotton + radish (1:2)
- Cotton + onion (1:2)
- Cotton + clusterbean (1:1)
- Maize + blackgram (2:1)
- Sorghum + cowpea (2:1)
- Sorghum + greengram/blackgram (2:1)
- Pearl millet + blackgram
- Cotton + blackgram

Nutrient management

Integrated nutrient management practices

Crop	INM practice
Cotton	12.5 t/ha FYM+40:20:40 kg NPK/ha + 7.5 kg MN mixture
Sorghum	12.5 t/ha FYM+40:20:0 kg NPK/ha + 7.5 kg MN mixture
Maize	12.5 t/ha FYM+40:20:0 kg NPK/ha + 7.5 kg MN mixture
pearl millet	12.5 t/ha FYM+40:20:0 kg NPK/ha + 7.5 kg MN mixture
Blackgram	12.5t FYM+12.5:25:12.5 kg NPK/ha +7.5 kg MN mixture
Greengram	12.5t FYM+12.5:25:12.5kgNPK/ha +7.5 kg MN mixture
Sunflower	12.5t FYM+40:50:40 kg NPK/ha +7.5 kg MN mixture

Alternate land use

- Custard apple based alternate land use systems
- Aonla based alternate land use systems

Integrated farming system

- Dryland integrated farming systems

Contingency crop planning

For *rabi* planning

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

Delay by 2 weeks (3rd week of October)

- Black gram, green gram (VBN4, Co 6), pearl millet (Co (Cu) 9), sorghum (K 12, Private hybrids)
- Intercropping system: Sorghum (K 12) + cowpea (CO 5) (2:1)

Delay by 4 weeks (1st week of November)

- Pearl millet (CO(Cu)9, hybrid CO 9, CO 10, ICMV and private hybrids), Sunflower (CO-5, Hybrids - COH2, COH3 private hybrids), minor millets (barnyard millet (CO 2), foxtail millet (CO 5), little millet (CO 5), coriander (CO 2), chickpea (CO 3)

Delay by 6 weeks (3rd week of November)

- Medicinal senna (KKM-1), fodder sorghum (Co(FS)27,K11), horsegram (Paiyur 1)
- Relay inter cropping system: Coriander (CO 2) + Chickpea (CO 3) (6:1)

Foliar nutrition

Crop	Nutrients (kg/ha)					Mode of application
	KCl	$ZnSO_4$	Borax	$MgSO_4$	Combination	
Cotton	10	5	2	1	1% $MgSO_4$ + 0.5% $ZnSO_4$ + 0.2% borax at squaring and flowering stages Cotton plus 6.25 kg/ha	Foliar spray in 500 litres of water/ha
Sorghum	10	5	-	-	Polyfeed 19:19:19 + 0.5 % $ZnSO_4$ during the dry spell under rainfed condition	
Maize	10	5	2	1	1% KCl + 0.5% ZnSO4 + maize maxim 7kg/ha	
Pearlmillet	10	5	2	1	1% KCl + 0.5 % ZnSO4	
Blackgram	10	5	2	1	2% DAP / pulse wonder 5 kg/ha	
Greengram	10	5	2	1		
Chillies	-	5	1.25	-	Micro nutrient mixture 5 kg/ha at the time of flowering and 15 thereafter	
Sunflower	-	-	1.25	-	Micro nutrient mixture 5 kg/ha at the time of flowering and 15 thereafter	

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Delay by 8 weeks (1st week of December)

- Horsegram (Paiyura), medicinal senna (KKM1), periwinkle (Local)
- Intercropping system: Coriander (CO 2) + chickpea (CO 3) (6:1)

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

Early season drought

- Formation of ridges and furrows, opening of broad bed furrows
- Resowing, gap filling
- Life-saving irrigation, if available
- Thinning to retain one seedlings at 30 cm

Mid-season drought

- Life-saving irrigation, if available
- Foliar spray of 1% KCl, 3% Kaolin
- 1% $MgSO_4$ + 0.5% $ZnSO_4$ + 0.2% borax at squaring and flowering stages

Terminal drought

- Harvest at physiological maturity stage.

Agro-horti system / dryland horticulture technology

- Aonla (NA-7) + greengram (CO 7), aonla spacing: 5 x 5 m, planting time - 3rd week of October ; greengram: spacing: 30 x 10 cm; seed rate: 20 kg/ha; time of sowing: 3rd week of October in between the perennial tree crops; pre-emergence application of pendimethalin at 3 DAS followed by hand weeding on 30 DAS for effective weed management; foliar application of 10% pulse wonder at the time of flowering for enhanced seeds; prophylactic application of pesticides for effective pest and disease management
- Custard apple (APK 1) + greengram (CO 7) custard apple spacing: 5 x 5 m; planting time - 3rd week of October; pruning at the time of September every year; foliar application of micro nutrient mixture at the time of flowering for enhanced fruit setting; greengram: spacing: 30 x 10 cm; seed rate: 20 kg/ha; time of sowing: 3rd week of October in between the perennial tree crops; pre-emergence application of pendimethalin at 3 DAS followed by hand weeding on 30 DAS for effective weed management; foliar application of 10% pulse wonder at the time of flowering for enhanced seeds; prophylactic application of pesticides for effective pest and disease management.

Technologies upscaled in convergence with various programmes

The listed technologies have been upscaled in convergence with department of agriculture, Thoothukudi and Virudhunagar, KVKs of Thoothukudi and Virudhunagar districts and field demonstration through progressive farmers.

Impact of dryland technologies

Broad bed and furrow technique for *in-situ* moisture conservation in rainfed maize in Tamil Nadu, using ferti seed drill helped in formation of broad bed furrows (BBF), fertilizer application and sowing simultaneously saving time, labour and energy. The added advantage of the implement was that it can also be used for interculture operation. This technology helped the farmers of Thoothukudi, Tirunelveli, Virudhunagar and Tenkasi districts to take up timely sowing of maize in an area of 1.2 lakh hectares which resulted in higher yield and income. Forming ridges and furrows by using tractor drawn ridger and dibbling of seeds at 1/3rd distance from the top of the ridge resulted in better conservation of moisture and crop growth with 10 to 15% improved yield. Adoption of ridges and furrows for sorghum resulted in 11.11% increased yield of sorghum. The cropping system coriander + chickpea + senna individually and collectively performed well. The net profit ranged from a maximum of Rs. 15,000-20,000/ha under limited moisture condition. This system helped in better farm income and improved the profit of the farmers in an area of 8000 hectares in the domain districts.

Farm ponds of 500 cubic metre capacity for one ha catchment area can harvest runoff water for giving supplemental irrigation to 0.4 ha. Providing one supplemental irrigation at 5 cm depth during moisture stress period resulted in an increased yield of 12 to 15% in cotton. Rainwater harvesting by digging 300 ponds in each district of Thoothukudi, Tirunelveli, Virudhunagar and Tenkasi districts resulted in yield benefit of 360 tonnes and income of Rs.1.8 crores**.** Early sowing (immediately after the onset of monsoon) with higher seed rate of 20 kg/ha treated with imidacloprid @ 5 g/kg followed by spraying of NSKE @ 5% 45 DAS and neem oil @ 3% 60DAS was recommended as IPM for sorghum through OFTs which was accepted and included in crop production guide prepared by Tamil Nadu Agricultural University, Coimbatore.

Integration of intercropping system of cotton + black gram, sorghum + cowpea with animal component (goat) recorded higher system productivity (sorghum equivalent yield) of 16978 kg/ha and total system income of Rs.1,16,098/ha under dryland condition. This practice has been adopted by small and marginal farmers and this technology has generated the employment opportunities for the family members which ultimately resulted in improved standard of living of dryland farmers. Foliar spray of 1.0 % magnesium sulphate + 0.5% zinc sulphate (5.0 kg of

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$MgSO_4$ + 2.5 kg of $ZnSO_4$ /ha in 500 litres of water) at square formation stage and boll formation stages in cotton enhanced the seed cotton yield by 3280 tonnes and income by Rs.16.5 crores in Thoothukudi, Tirunelveli, Virudhunagar and Tenkasi districts.

Rainwater management technologies such as ridges and furrows, compartmental bunding and tied ridging for improving crop yield are being practiced by most of the rainfed farmers. These technologies have improved yield up to 20% for rainfed crops. Farm ponds are also constructed in dryland farmers' fields by providing subsidies through Tamil Nadu Agricultural Engineering Department and World bank funded TN-Irrigated Agriculture Modernization project. Using tillage equipment like disc plough, MB plough and chisel plough ensures higher yield due to enhancement of *in-situ* conservation of moisture. Seed drill, one of the most popular implements for taking timely sowing is being used in dryland areas.

Improved drought tolerant varieties recommended by AICRPDA centre such as sorghum - K12, cotton - KC 3, and K12, blackgram - VBN 8, VBN 11, greengram – CO7 and CO 8, maize – COH(M)6, COH(M)8, chillies – K1, K2, bajra – CO(Cu) 9, CO 10 are very popular among the dryland farmers. Improved rainfed cropping systems developed at AICRPDA centre like sorghum + cowpea, bajra + blackgram, cotton + cluster bean, cotton + greengram, cotton + black gram and cotton + onion have been adopted by the farmers in the domain districts.

Way forward

- Optimization on the use of natural resources, rainfall, land, water and minimize soil and water loss and degradation of environment.
- Development of strategies to tackle drought, diversifying more crops for resilient farming systems.
- Developing suitable sustainable farming system models for drylands.
- Identification of fitting alternate land use system for rainfed areas.
- Cotton intercropped with pulses for nitrogen economy, studies on water and nutrient interaction in cropping systems
- Development of crop models for high N use efficiency and water use efficiency, quantification of carbon sequestration and monitoring changes in soil carbon of agroforestry systems under rainfed condition.
- Nutrient balance studies in different crop production ecosystems, recycling of biodegradable wastes, revamping of fertilizer doses.
- Assessment of micronutrient status of the soils and micronutrient management in different cropping systems, foliar nutrition of macro and micro nutrients, organic farming.

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