Overview of Dryland Agriculture Research and Achievements in Scarce Rainfall Zone of Andhra Pradesh

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Brief history of the centre

Ananthapuramu, is a southern district in Rayalaseema region of Andhra Pradesh. Although, the district is located in the rain shadow region and chronically drought prone, agriculture is the major economic activity. The annual average precipitation is 550 mm which is unevenly distributed. Low rainfall and high intensity rainfall events lead to greater erosion losses of soil and low crop yields. Agricultural Research Station, Ananthapuramu under Acharya N.G. Ranga Agricultural University, Andhra Pradesh was originally established as "Soil Conservation Research Centre" during 1964 at Rekulakunta village, Bukkarayasamudram mandal, Ananthapuramu district. All India Coordinated Research Project for Dryland Agriculture at Agricultural Research Station, Ananthapuramu has been in operation since 29th September, 1971 and Operational Research Project (ORP) from 1986-1987 with an objective to conduct multi-disciplinary research on all aspects of dryland farming *viz*., rain water management, cropping systems, farming systems, nutrient management, alternate land use, crop improvement, designing and testing of farm implements, etc. The domain area of AICRP for dryland agriculture comes under Scarce Rainfall Zone (SRZ) of Andhra Pradesh and zone covers two districts *viz*. Ananthapuramu and Kurnool. Presently, the above two districts were divided into four, namely; Anantapuramu, Sri Sathyasai, Kurnool and Nandyal districts, respectively.

Agro-climatic zone characteristics

The domain districts of the AICRPDA centre, Ananthapuramu are located in the Scarcity zone (NARP) of Andhra Pradesh; and in the agroecological subregion (ICAR) 3.0 and in the agroclimatic region (Planning Commission) – Southern Plateau and Hills Region.

Climate

The climate in this zone is semi-arid. Anantapuramu is arid district with hot and dry conditions prevail for most of the year. The annual average rainfall of the district is 572 mm. The normal rainfall for the southwest monsoon period is 338 mm, which forms about 61.2% of the total rainfall for the year. The rainfall for northeast monsoon period is 156 mm, which forms 28.3 % of annual rainfall. The normal daily maximum temperature ranges between 29 °C and 42 °C. November, December and January are cooler months with minimum temperature around 17.2 °C. The aridity index is 73.8, with an average 5 run-off events per annum and PET is 2140 mm. The normal onset of monsoon during south-west monsoon is during first week of June while, withdrawal is during first to second week of October. The normal onset of monsoon during north-east monsoon is during first to second week of October while, withdrawal is during first to second week of December. The dry spells during crop season in August and October coincide with peg penetration, pod filling, pod development and harvesting stages of groundnut and flowering to reproductive stages in other crops. In Kurnool district, annual rainfall ranges from 500 mm to 750 mm. The normal average annual rainfall of Kurnool district is 670 mm. Nearly 68% of rainfall is received from south-west monsoon and 22% during north-east monsoon period.

Mean season-wise and annual rainfall and rainy days at AICRPDA Centre, Ananthapuramu

Rainfall	Normal rainfall (mm)	Normal rainy days (No.)
South-west monsoon (June - September)	379.0	20
Northeast Monsoon (October - December)	135.1	10
Winter (January - February)	2.2	-
Summer (March - May)	74.2	5
Annual	590.5	35

Major soil types

Shallow to medium deep red soils are predominant in the zone followed by medium deep black soils.

Major rainfed crops

The major rainfed crops cultivated in the zone during *kharif* are groundnut, pigeonpea, cotton, castor, sunflower and during *rabi,* chickpea.

Dryland agriculture problems

- Low water retention capacity of soils
- Uneven distribution and erratic rainfall
- Prolonged dry spells and chronic drought
- Inadequate *in-situ* moisture
- Use of traditional varieties / mono cropping system
- Poor soil fertility and imbalanced use of fertilizers, weed infestation and higher incidence of diseases and pests
- Fragmented holdings
- Lack of access to credit facilities, input supply, marketing facilities
- Poor storage facilities, low adoption of improved crop production technology

Research initiatives since inception of the centre

AICRPDA centre, Ananthapuramu collaborated with many institutes / projects / programmes to develop dryland technologies over five decades of dryland research at Anantapuramu. The following is the brief list of collaborations made over the years (Table. 1).

Significant achievements

Rainwater management

Rainfall is the critical input for crop production as much of the area is devoid of irrigation facilities. Proper management of time and space variations in rainfall is the key to better crop production. Under frequent dry spell situations, standard crop cultivation practices are not possible. Besides, research over the years revealed that the region experiences on average five runoff events per year which lead to 4-5 tons of soil loss per hectare. Conserving the rainwater reduces runoff and soil loss, consequently enhancing crop yields. The following are the significant findings over the years found efficient for effective rain water management.

In-situ soil and water conservation practices increase soil water storage which helps crops to withstand moisture stress. These are simple and practiced by even individual small farmers. Suitability of the practice depends on the topography of the field. Based on extensive research, soil and water losses are reduced by adopting *in-situ* conservation practices like conservation furrows at 3.6 m intervals across the slope (25-30 days after

Table 1: Research issues focussed in collaboration with other institutes / projects / programmes in the domain area of AICRPDA - Anantapuramu centre

Year	Major research issues focused	Collaborating Institutes / Projects / Programmes	Testing of dryland technologies under ORP on watershed basis
1972 to 1980	Soil and water conservation measures in rainfed crops	ANGRAU	----
1981 to 1990	Agro-techniques to enhance rainfed groundnut and pigeonpea productivity	ANGRAU AICRP - Pearl millet,	Kandukuru, Krishnamreddipalli villages under Yerra cheruvu watershed
1991 to 2000	Inter disciplinary approach for nutrient, pest and diseases management and contingent crop planning	ANGRAU, AICRPAM AICRP - Pearl millet	Nusikottala, Thanda villages under Pennar manirevu watershed
2001 to 2010	Soil test based fertilizer, micro nutrients, *in-situ* soil moisture conservation, cost reduction technology, rain water recycling (farm pond technology) and farm mechanization.	DFID, ICRISAT NATP, NAIP, RKVY, ACIAR UNDP, ANGRAU AICRPAM and AICRP – Pearl millet	Nagalaguddam Thanda Singanamala under Narasapuram Watershed & Eguvapalli Garladinne under K. Agraharam watershed
2010 to 2015	Integrated farming system, catchment – command-storage relationship, farm implements and machinery, agro-forestry systems and crop diversification, dryland technology park and custom hiring services, crop wise contingency plans to cope with weather aberrations	ICRISAT, NICRA, ANGRAU, AICRPAM and RKVY	Thuggali (M), Kurnool (D) under Girigetla watershed
2016 to 2021	Rain water management, real time contingency planning, rainfed integrated farming systems, suitable varieties for wet and dry spells, Bio-fertilizers, microbial consortia for drought tolerance and climate resilient technologies	ICAR - NICRA ANGRAU, AICRPAM AICRP – Castor and RKVY	Yerraguntapalli (V), Peapully (M), Kurnool (D) under Vajralavanka watershed

Source: AICRPDA Annual Reports, Agricultural Research Station, Anantapuramu (1970 - 2021)

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sowing) with the receipt of rains. Among various types of bunds tested, contour bunds proved most effective in conserving soil and water. In an experiment on the effect of dikes in Alfisols for increasing rain water productivity in groundnut, it was found that higher mean pod yield (1003 kg/ha) was recorded with one dike after every 4 rows by conserving *in-situ* rain water effectively. To overcome the adverse effect of sub-soil compaction in red soils and to break the hard layer facilitating more intake of rainwater, deep ploughing with a chisel plough up to 40-60 cm depth at one metre interval once in 2 years was found useful in groundnut, castor and pigeonpea.

Farm pond of 250 m^3 capacity (size of 10 x 10 m with 2.5 m depth) with side slopes of 1.5:1 is sufficient for catchment area of 2 ha. Soil + cement lining with 6:1 ratio was found very effective in reducing seepage losses. One supplemental irrigation of 20 mm to groundnut by sprinkler during dryspells at pod development stage enhanced the pod yield by 25-30%. Besides, to minimize the evaporation losses from farm pond, the bamboo mat material was found effective.

Crops and cropping systems

The cropping system based strategies for drought mitigation in the domain area of AICRPDA-Anantapuramu centre include growing crops and varieties that fit into changed rainfall and seasons. The groundnut varities; K-6, Dharani, Narayani, Kadiri Harithandhra, Visista and Kadiri Lepakshi are suitable for rainfed conditions due to their tolerance to drought, early duration and higher pod yield. Improved varieties recorded 10 to 12% higher yield than the local varieties.

Best yields of pigeonpea and castor were achieved when sown with groundnut as intercrop during June. Intercropping of groundnut + pigeonpea in 7:1or 11:1 or 15:1 row ratio instead of sole groundnut was found better. Optimum time for sowing of sole groundnut is June to July. If rainfall is delayed beyond July month, sowing of contingent crops such as sorghum, greengram, cowpea, pearl millet, horsegram and fodder sorghum is found profitable in the domain districts. Among different rainfed crops, pigeonpea, castor, clusterbean and sorghum can be grown as better alternate crops to groundnut in rainfed Alfisols as these crops gave maximum groundnut equivalent yield over years. Higher groundnut equivalent yield was recorded with groundnut + pigeonpea (8:1) which was on par with groundnut + pigeonpea (14:2) intercropping system. Higher net returns were recorded with groundnut + pigeonpea (8:1) followed by groundnut + pigeonpea (14:2), *korra* + pigeonpea (8:1) and *korra* + pigeonpea (14:2).

The fodder crops sown under delayed onset of monsoon, fodder maize and fodder sorghum were found efficient in fodder production. Fodder foxtail millet produced highest green fodder yield followed by fodder bajra and fodder maize. Fodder bajra, fodder sorghum and fodder maize are potential forage cereals because they can produce more quantity and quality fodder while also ensuring net monetary returns. Fodder cowpea and sunhemp are the next best suitable forage legumes under late-sown conditions in the semi-arid Alfisols of the domain districts.

Nutrient management

Poor soil fertility due to erosion, low soil organic carbon (SOC), emerging multi-nutrient deficiencies, poor soil physical and biological environment for crop growth are limiting factors for productivity enhancement in this region. Hence, improving the soil fertility, carbon storage and soil health in the domain area of rainfed Alfisols is most needed to sustain the crop production. In this context, some recommended practices for improving infiltration and water retention in soils include diverse crop rotations with legumes and addition of farmyard manure (FYM), use of groundnut shells and other crop residues, green leaf manuring, etc.

Integrated nutrient management

Thirty seven years long-term integrated nutrient management experiment conducted at Agriculture Research Station, Anantapuramu revealed that 100% NPK and 100% NPK + $ZnSO_4$ @ 50 kg ha^{-1} maintained higher mean pod yield (30.1 and 27.5% respectively) than control over 37 years but INM practice of 50% NPK + groundnut shells @ 4 t ha^{-1} sustained higher pod yield and additionally sequestered 30.2% of SOC, which is a strong determinant of soil quality and agronomic productivity, especially under semi-arid environments. INM practices maintained positive balance of available N, P, K, S, Ca, Mg, Cu, Mn, Fe, Zn and B compared to sole application of chemical fertilizers over 37 years. Addition of carbon inputs through groundnut shells @ 4 t ha^{-1} is proved as a critical practice to maintain optimum SOC level in soil. Thus, the integration of groundnut shells along with chemical fertilizers emerged as the practice in the domain district to sustain groundnut pod yields and soil fertility for long-term under rainfed Alfisols in semi-arid agro-ecosystem.

Besides, on-farm generation of organic matter with appropriate policy support needs to be promoted to maintain soil health and crop productivity. In an attempt to solubilize native soil phosphorus in rainfed groundnut, soil test based fertilizer (STBF) + phosphatic bio-fertilizer consortium (PSB @ 5 kg ha^{-1} + PSF @ 5 $kgha^{-1}$ + VAM @ 12.5 kg ha^{-1}) were applied as basal dose at the time of sowing of rainfed groundnut. The results over 4 years revealed that STBF + P bio-fertilizer consortium increased groundnut yield by 17.5% over control.

Foliar sprays for drought mitigation

The approach of foliar spray of nutrients not only facilitates better plant growth and development, but also helps to alleviate

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different kinds of abiotic stresses like drought. This form of foliar spray does not address any specific nutrient deficiency but supplies a small amount of all nutrients to keep leaf growth lush. In an experiment conducted under AICRPDA at ARS Anathapuramu to mitigate mid-season drought in rainfed groundnut, 0.5% KNO_3 as foliar spray at pod initiation and at pod development stage increased the pod yield and mitigated the dry spell effect on pod yield.

Improving soil fertility in rainfed Alfisols

The rainfed Alfisols are not only thirsty but also hungry. They are poor in soil nutrients as soil is subjected to fertility loss over years due to soil erosion. In this context, the local ITK - sheep penning is commonly used by local farmers to improve soil fertility. Sheep penning with one sheep per square meter significantly increased the pod yield of groundnut by 15% and haulm yield by 32% compared to control. Sheep penning significantly increased the available K_2O also in the soil and enhanced the soil fertility.

Energy management

In the backdrop of low and erratic rainfall, the sowing window is very narrow in the scarce rain fall zone. Hence, all the operations need to be done very quickly. Therefore, to cover the large area in less time and to save the cost of cultivation through labour wages, mechanization is essential. In this direction, the centre developed location-specific mechanization in the district for the benefit of farmers. Mechanical groundnut planters were recommended in the region to minimize delay in sowing, to optimise seed rate and ensure optimum plant population in groundnut. Among the different seed drills/planters tested for groundnut sowing, tractor drawn 8 row Ananta planter resulted optimum seed rate (100 kg/ha) and as well as plant population (33 plants per m^2). The mechanical seed drill developed by the centre is popular in the district. Department of Agriculture included the equipment in its subsidy scheme and that reflected the impact of technology in the region.

An interculture implement (tractor drawn) was fabricated for intercultivation in groundnut and tested in the fields where Ananta planter was used for sowing. The implement was developed to bring complete mechanization in groundnut cultivation. Suitable interculture implement for castor crop was fabricated and tested in the field conditions. Aqua planter to supplement water in conjunction with groundnut sowing simultaneously when moisture is insufficient was developed. Groundnut + pigeonpea planter was designed and developed for sowing groundnut and pigeonpea in 8:1 ratio. A tractor drawn blade *guntaka* was designed to harvest groundnut in four rows simultaneously with minimum field losses. Groundnut fresh pod thresher that can thresh groundnut immediately after the harvest, and dry pod thresher were introduced in Ananthapuramu region to make the stripping operation easy and economical.

Alternate land use systems

The soils of the domain area are red sandy loam and shallow in depth, with undulating topography and poor soil fertility. In class IV lands with limitations with respect to depth, wetness, slope, runoff and soil texture, soapnut is the only tree that withstands harsh climatic (low rainfall) and slopy (8-15%) topographic soil conditions. Since, tamarind comes to fruiting only in well distributed rainfall years, to make the unproductive class IV lands productive with tamarind species, it should be integrated with pastoral system of *Stylosanthes* as horti-pastoral and sheep rearing component.

Integrated farming systems

Integrated farming system sustains the system productivity and farmer economic stability. The research revealed that, for a farm of 1 ha of land, groundnut as a *kharif* rainfed crop with sheep rearing (10 rams) for 4 months (November to February) improved the total net returns by 100 percent compared to crop alone. Besides, it provides 65 man days of employment after harvest of groundnut to the farmer. Similarly, under agri-horti system groundnut + amla integrated with ram lamb rearing is appropriate system in class IV land for semi-arid region of Ananthapuramu for the best use of available natural resources.

Technologies developed

Rainwater management

- Standardization of farm pond size, and rainwater harvesting in farm pond and supplemental irrigation to rainfed groundnut
- *In-situ* moisture conservation measures for higher groundnut productivity

Cropping systems

- Use of small and medium seeds for groundnut cultivation
- Management techniques for late sown groundnut

Intercropping systems

- Groundnut + pigeonpea (8:1)
- Groundnut + castor (15:1)
- Pearlmillet + pigeonpea (5:1)

Double cropping systems

- Groundnut (30 x 10 cm) - horsegram
- Groundnut (45 cm x 6.7 cm) - horsegram
- Groundnut (30 x 10 cm) - fodder sorghum
- Groundnut (45 cm x 6.7 cm) - fodder sorghum

Nutrient management

- Phosphatic biofertilizer consortia for groundnut
- Micronutrient management in groundnut
- Drought mitigation through foliar application of KNO_3
- Soil test based P fertilizer application for groundnut in shallow arid Alfisols

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Crop	Nutrients (kg/ha)					Mode of application
	K	Zn	B	Mg	Fe	
Groundnut	-	1.0	-	-	2.5 + citric acid	Add 2 g of $ZnSO_4$ for each litre of water. Add 5 g of $FeSO_4$ for each litre of water
Chickpea	-	1.0	-	-	2.5	-
Desi cotton	-	1.0	0.75	5.0	2.5 + citric acid	$MgSO_4$ @ 1% twice at 45 and 75 DAS, Boron @ 0.15% twice at 60 and 90 DAS, and $ZnSO_4$ @ 0.2% twice at 4-5 days interval
Bt cotton						1% $MgSO_4$ (10 g/l) 2% urea/2% DAP/1% KNO_3 at flowering and boll development stage

Crop	INM practice
Groundnut	50% recommended dose of NPK + FYM @ 4t/ha
Chickpea	FYM @ 10 t/ha besides the recommended fertilizers
Desi cotton	FYM @ 10 t/ha besides the recommended fertilizers
Bt cotton	FYM @ 10 t/ha besides the recommended fertilizers
Castor	50% RDF (recommended dose of fertilizer) + seed treatment with *Azospirillum* + 25% N through FYM
Pigeonpea	FYM @ 10 t/ha besides the recommended fertilizers
Sunflower	FYM 7.5 t/ha 2-3 weeks prior to sowing besides the recommended fertilizers

Energy management

- Tractor drawn Ananta groundnut planter (8 rows)
- Tractor drawn Ananta interculture implement
- Tractor drawn ANGRAU Blade *Guntaka*
- Groundnut fresh pod thresher
- Groundnut dry pod thresher
- Sub soil chiseling (deep ploughing)
- Ananta Aqua planter for sowing rainfed crops
- Tractor drawn Ananta planter for sowing castor
- Ananta bullock drawn planter for sowing rainfed crops
- Mini tractor drawn Ananta planter and intercultivator
- Groundnut grader for kernel separation
- Groundnut + pigeonpea (8:1) intercropping planter

Alternate land use

- Alternate crops to groundnut for rainfed Alfisols
- Groundnut based farming system
- Soapnut trees for Class-VI lands

Integrated farming system

- Sheep penning to increase nutrient status in rainfed soils (revalidation of ITK)

Contingency crop planning

For *kharif* planning

a. **Crop/cropping system for normal onset of monsoon (15th June to July)**

- Sorghum - CSH-9, 13, CSV-12, 13, NTJ-1, NTJ-2, NTJ-3
- Pearlmillet - ABV-04, Dhanshakti, ICTP 8203, ICMV-221, ICMH-356
- Cowpea- TPTC-29
- Castor -ICH-66, GCH-4, DCH-519, DCH-177, PCH-111, PCH-222
- Greengram – LGG 407, LGG 460, WGG 42 and IPM 2-14
- Sunflower – KBSH 44, Prabhat, DRSH-1, NDSH-1012
- Setaria - Lepakshi, Surynandi, Garuda
- **Intercropping systems**: Groundnut + pigeonpea (LRG 52/ PRG-176) (8:1), groundnut + pigeonpea (15:1)

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

Delay by 2 weeks (3rd week of July)

- Pigeonpea- LRG-52, PRG-176, ICPL 85063
- Groundnut + pigeonpea (8:1)
- Castor -ICH-66, GCH-4, DCH-519, DCH-177, PCH-111, PCH-222

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Delay by 4 weeks (1st week of August)

- Pearl millet – ABV-04, Dhanshakti, ICTP 8203, ICMV-221, ICMH-356
- Sorghum - CSH-10, 13, CSV-11, 13, NTJ-1, NTJ-2, NTJ-3
- Cowpea – TPTC-29
- Greengram – LGG407, LGG460, WGG 42 and IPM 2-14

Delay by 6 weeks (3rd week of August)

- Sorghum - CSH-9, 13, CSV-12, 13, NTJ-1, NTJ-2, NTJ-3
- Pearl millet - ICTP 8203, ICMV-221, ICMH-451
- Cowpea - TPTC-29
- Greengram - LGG407, LGG460, WGG 42 and IPM 2-14
- Sunflower - KBSH1, Prabhat
- Setaria - Lepakshi, Surynandi, Garuda
- Fodder pearl millet – TSFB 15-4, TSFB 15-8
- Sorghum – CSH-10, 13, CSV-11, 13, NTJ-1, NTJ-2, NTJ-3
- Cowpea - TPTC-29
- Greengram – LGG 407, LGG 460, WGG 42 and IPM 2-14
- Horsegram : APTHG 11, CRHG-18R, PHG-2

Delay by 8 weeks (1st week of September)

- Pure crop of sorghum (fodder) (COFS-29)/pearl millet (ABV-04, ICMV-221,
- ICMH-451)/cowpea (TPTC-29)/greengram (LGG 407, LGG 460, WGG 42 and IPM 2-14)

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

Early season drought in groundnut

- Mulching with groundnut shells @ 5 t/ha within 10 days after sowing of the crop
- Supplemental irrigation of 20 mm with harvested rainwater in ponds, if available
- Opening of conservation furrow for every row or every two rows
- Avoid top dressing of fertilizer until receipt of sufficient rains
- Foliar spray of 2% urea

Mid-season drought in groundnut

- Mulching with groundnut shells @ 5 t/ha within 10 days after sowing of the crop.
- Supplemental irrigation of 20 mm with harvested rainwater in ponds, if available
- Opening of conservation furrow for every row or every two rows
- Avoid top dressing of fertilizer until receipt of sufficient rains
- Foliar spray of 2% urea

Terminal drought

- Provide supplemental irrigation (20 mm), with micro-irrigation if available for groundnut or pigeonpea
- Foliar spray of urea, not exceeding to 2% concentration for groundnut
- Sorghum/pearl millet to be harvested for fodder at 45 DAS and 65 DAS and left for grains if rains are continued

Agroforestry system

Tamarind (Anantha Rudhira/ Thettu Amalika varieties) 10 x 10 m or Soapnut trees + *Stylosanthus hamata* system in class IV to Class VI lands.

Amla based agri-horti system: Amla (10 x 10 m) + fodder sorghum, custard apple (5 x 5 m) + fodder sorghum, Jamun (10 x 10 m) + fodder sorghum

Technologies upscaled in convergence with various programmes

Scarce rainfall zone in Andhra Pradesh faces frequent droughts. Risk involved in successful cultivation of rainfed crops depends on the frequency of drought occurrence within the season in the zone. Hence, technologies developed from AICRPDA centre Anantapuramu were successful at research station and the same were tested and demonstrated at farmer's field and popularised. Such successful technologies were upscaled in convergence with Government programmes, NGOs and KVKs. The Centre's technologies were adopted by the Department of Agriculture, Government of A.P., NGOs, KVKs and included in ANGRAU package of practices. Farm pond technology for rainwater harvesting and supplemental irrigation to rainfed groundnut found place in *"Panta Sanjeevini"* programme of Government of A.P. and was adopted by MGNREGA scheme. Mini tractor drawn Ananta planter and intercultivator were included by NABARD in subsidy scheme for farm machinery.

Impact of technologies

Farm pond technology is popular, climate resilient and successful in rainwater harvesting and mitigating the frequent dry spells in the zone. Filled farm pond water from runoff is used for mitigating dry spells by giving supplemental irrigation. This technology increased groundnut pod yield by 25% - 30% during drought years and reduced farmers distress. Subsoiling increased the yields in rainfed crops such as groundnut, pigeonpea and castor by 20-25% as compared to normal tillage. Resilient technology to mitigate dry spells enhanced the castor yield by 14 to 23% and rainwater use efficiency by 1.3 to 1.7% as compared to farmer's practice. The technology was adopted by Department of Agriculture, Government of A.P. which is paying subsidy to farmers adopting this technology since 2014-15 onwards. Timely sowing can be done with aqua planter

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developed by ARS, Ananthapuramu by using 10000 to 20000 litre of water per acre depending upon the soil moisture content. Groundnut pod yield increased by 20-30%. By providing supplemental irrigation, Rs. 2030/ ha additional income was realized.

Groundnut + pigeonpea inter cropping system is adopted in 70% in domain area. Farmers realized approximately Rs. 3000 – 3500 per ha as additional income by adopting intercropping system. The adoption of drought management practices as a package in castor gave 35-50% higher yields over farmers practice with B:C ratio of 1.8. K-6, Dharani, Kadiri Harithandhra and Kadiri Lepakshi varieties are now recommended for rainfed conditions as they are tolerance to drought, early in duration and give higher yields. The improved varieties produce pod yield in a range of 540-699 kg/ha as compared to 421 kg/ha.

Soil test based fertilizer (STBF) technology saves cost of nutrients and also ensures balanced nutrition besides increasing pod yield of groundnut by 5% to 25%. Technology spread to 70 - 80% in domain area. Foliar application mitigates the mid-season drought and enhances the yield. The technology spread to 25-30 % in the domain area.

Tractor drawn Ananta planter ensured timely sowing in large areas under optimum soil moisture conditions as the sowing window is narrow. This technology increased the cultivable dryland area for groundnut by 25 - 30% in domain area. An amount of Rs.1000/ha can be saved with tractor drawn Ananta intercultural implement compared to farmers practice. Tractor drawn groundnut + pigeonpea intercropping (8:1) planter for intercropping of groundnut + pigeonpea was adopted in 70% of the total groundnut area (7.0 lakh ha) and found useful for sowing of large area in short sowing window.

Groundnut based IFS adopted in 20% of domain area has resulted in approximately Rs. 5000/ha increase in income among farmers. Practice of intercropping of groundnut with mixed pulses has been well adopted in slopy fields. This practice has been adopted in an area of 1.0 lakh ha.

Way forward

Frequent drought and extreme events continue to adversely impact production and productivity of rainfed crops in scarce rainfall zone of Andhra Pradesh. Further, these impacts are more pronounced due to climate change/ variability. In this context, future long-term and short-term research and management strategies suggested are: In the zone, water is the critical natural resource and managing rainwater *in-situ* or harvesting runoff water and recycling it is key to mitigate the chronic drought. Location-specific needs of soil & water conservation measures *vis-a-vis* changing rainfall scenario will address water issues much better. Adoption of improved varieties with real time crop planning (alternate crops in place of groundnut, contingent crops if monsoon is delayed) are important under changing climatic scenario.

There is an increased need for weather based agro-advisory services (AAS) in farming activities for timely agricultural operations, improved crop yields, reduced cost of cultivation, need based changes in cropping patterns and for improved livelihoods. Micro-level climate risk-assessment in various crop production systems and specific management strategies to manage abiotic stresses in crop production systems are very much needed. Developing weather indices through agronomic research for real–time monitoring, assessment and contingency measures implementation is also envisaged.

The main emphasis in scarce rainfall zone soils is to build the soil organic matter (SOM) for soil health restoration. Location - specific and need based crop residue management plan should be developed. The opportunity to promote adoption of various location specific integrated nutrient management (INM) practices is to be explored.

There is a need for multipronged approach to maximize crop production for which site specific crop production techniques have to be adopted. Crop based approaches for drought mitigation include growing crops and varieties that fit into changed rainfall and seasons. In addition, adoption of intercropping systems, crop diversification, improved agronomic practices and agro-forestry systems helps to cope with any adverse event, and in particular, rainfall variability and drought. After recognizing the specific needs of rainfed dryland agriculture in the scarce rainfall zone of Andhra Pradesh, considerable efforts are necessary at all levels to sustain the momentum.

The existing fragile rainfed agroecosystem in the scarce rainfall zone of Andhra Pradesh needs to be made more drought proof, more economical and sustainable under increasing frequency of droughts. The efficient use of rain water, soil and farm management practices in an integrated approach is both essential and a prerequisite. All India Coordinated Research Project for Dryland Agriculture (AICRPDA) Centre at Anantapuramu has developed several location specific technologies to cope with different situations including delayed onset of monsoon and mid-season drought. Key technologies among them are *in-situ* moisture conservation, rainwater harvesting in farm ponds and efficient utilization, INM, foliar sprays for drought mitigation, resilient crops and cropping systems, and contingency crop plans for the agro climatic zone. To achieve productivity enhancement in this fragile rainfed system, there is an urgent need to upscale these technologies through KVKs, NGOs, ATMA and other programmes of the governments which are aiming at farmers welfare.

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