Indian J. Dryland Agric. Res. & Dev. 2022 37(2): 139-148 10.5958/2231-6701.2022.00030.6

Overview of Dryland Agriculture Research and Achievements in Western Vidarbha Zone of Maharashtra

A.B. Chorey, V.V. Gabhane, R.S. Patode, M.M. Ganvir, A.R. Tupe and R.S. Mali

All India Coordinated Research Project for Dryland Agriculture Centre

Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra - 444104

E-mail: chiefscientist1057@gmail.com

Brief history of the centre

Indian Council of Agricultural Research (ICAR) started All India Coordinated Research Project for Dryland Agriculture (AICRPDA) in 1970 under the control of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola to solve location specific complexities through a cohesive, multi-pronged approach, emphasizing farmer's point of view.

Agro-climatic zone characteristics

AICRPDA Centre, Akola is located in the campus of Dr. Panjabrao Deshmukh Krishi Vidyapeeth, the jurisdiction of which covers 11 districts of entire Vidarbha region. There are two revenue administrative divisions *viz.,* Amravati and Nagpur. Akola is situated in the latitude 20°42' N and longitude 77°02' E with the altitude of 305 m above mean sea level. Domain area of the project includes Akola, Buldana, Washim, Amravati and part of Yavatmal districts. It is classified under moist semi-arid Agro-ecological sub-region with medium deep clayey black soils (shallow loamy to clayey black soils), medium to high available water holding capacity (AWC) and LGP of 120-150 days (K5Dm4). As per the planning commission, the domain districts of the centre *viz.,* Akola, Washim, Buldana, Amravati and Yavatmal fall under agroclimatic zone *i.e.* western plateau and hills region. As per the NARP agroclimatic zone classification, the region is classified under Central Vidarbha (AZ- 97).

Climate

Vidarbha region of Maharashtra state is mostly characterized by dryland farming. The climatic conditions of this region can be broadly described as semi-arid. The jurisdiction of Dr. Panjabrao Deshmukh Krishi Vidyapeeth is entire Vidarbha region. It is richly endowed with natural resources of varied types. Akola centre strives to solve location specific complexities through a cohesive, multi-pronged approach, emphasizing farmers' point of view all the time. The region comprises eleven districts *viz.* Buldana, Akola, Washim, Amravati, Yavatmal, Wardha, Nagpur, Bhandara, Gondia, Chandrapur and Gadchiroli. It lies in between 17° 57' - 21° 46' N latitude and 75° 57' - 80° 59' E longitude and covers an area of 97762.9 km^2, which is 31.92 per cent area of Maharashtra. The mean annual rainfall ranges from 700 mm at the west to 1700 mm at the east. The day length and temperature vary, giving a rise from north to south and rainfall from west to east. Thus, it gives rise to various agro climatic situations. This region mostly receives adequate rainfall in aggregate in monsoon period but suffers from vagaries of distribution and consequently the scarcity and semi-scarcity conditions. Some pockets in Khamgaon tahsil of Buldana district are drought prone. Monsoon sets in from 8th June regularly and rains commence in between 18th to 25th June with highest rainfall during July and August and withdraw on 8th October. However, rains are meagre after first fortnight of September. Total number of rainy days ranges in between 47 to 65.

The coefficient of variation of monthly rainfall is 40 to 50% even for the wet month *i.e.* July indicating the uncertainty of rains during the season. The climatic conditions of the region can be broadly described as semi-arid type on annual basis. The region experiences sub-humid to humid conditions in monsoon season, semi-arid in winter season and arid in summer season. Vidarbha region has been divided into three agro-climatic zones based on rainfall, soil types and vegetation viz., Western Vidarbha Zone (Rainfall 700 to 950 mm), Central Vidarbha Zone (Rainfall 950 to 1250 mm) and Eastern Vidarbha Zone (Rainfall <1250 mm).

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

Rainfall	Normal rainfall (mm)	Normal rainy days (Nos.)
South west monsoon (June-September)	656.2	34
North east Monsoon (October-December)	84.2	6
Winter (January-February)	18.1	2
Summer (March-May)	30.2	3
Annual	788.7	44

Major soil types

The soils of the region are shallow (Entisols) to deep black (Vertisols), neutral to alkaline in reaction, low in available nitrogen and phosphorus and high to very high in available potassium. In few pockets of eastern Vidarbha, Alfisols are also observed. The salt affected soils are observed in Purna valley covering the part of Amravati, Akola and Buldana districts.

Western Vidarbha soils are derived from trap rock and have varying depth depending upon their physiography. Most of the

soils are calcareous, highly base saturated, fairly well drained, well supplied with potash, moderate to low in phosphate, but low in organic matter content and slightly alkaline.

Soils of the Central Vidarbha are derived from basalt rock, black in colour and having varying depth depending upon their physiography. Inceptisols and Entisols are developed from basalt and they are very shallow to shallow.

Percentage area under different soil types in domain districts

District	Coarse shallow	Medium deep black	Deep black	Salt affected soil
Akola and Washim	6.03	42.80	24.87	61.31
Amravati	15.62	32.03	20.90	22.26
Buldhana	29.71	18.81	19.52	16.42
Yavatmal	48.64	6.36	34.72	0.00

Major rainfed crops

The major rainfed crops cultivated in the zone during *kharif* are cotton, soybean, pigeonpea, greengram, blackgram, sorghum and during *rabi* are chickpea and *rabi* sorghum. In western and central Vidarbha zone, predominant crops are cotton, sorghum, pigeonpea, greengram, blackgram, soybean, sunflower and maize. The rainfed cropping systems consist of sole cotton, sole soybean, Soybean + pigeonpea intercropping, Soybean-chickpea, Soybean-safflower, Greengram-safflower, Soybean-sorghum which are dependent upon the residual soil moisture status of delayed SW monsoon winter rains. Agri-horticulture and silvi pasture systems are cultivated in pockets and especially in degraded land. Only cotton was found suitable for dry seeding as compared to other *kharif* crops viz. sorghum, greengram, blackgram and pigeonpea. Cotton should be sown before the onset of monsoon to get higher yield.

Major shifts in cropping pattern /cropping systems for the last ten years

- Cultivated area under soybean has considerably increased replacing area under cotton and sorghum.
- Soybean-chickpea evolved as a prominent and major sequence cropping system in Vidarbha region
- Soybean + pigeonpea (4:2)/(5:1)/(6:1) evolved as a prominent intercropping in soybean based system followed by the farmers of Vidarbha region.
- Cotton + pigeonpea (7:1)/(9:1) intercropping is evolved as a prominent intercropping in cotton based system followed by the farmers of Vidarbha region.
- Pigeonpea is most prominent intercrop in both cotton and soybean crop.
- Paddy is the major crop grown in eastern Vidarbha region which includes districts viz: Gondia, Gadchiroli, Chandrapur, Bhandara and some parts of Nagpur region

Dryland agriculture problems

- Climate vulnerability associated with biotic and abiotic stresses such as: early-mid-terminal droughts, prolonged dry spells, high rainfall events, heavy infestation of diseases and pests etc.
- High cost of inputs such as seeds, fertilizers, insecticides and weedicides.
- Scarcity of labour and high wages.
- Attack by wild animals and their management.
- Lack of resources for irrigation.
- Lack of awareness towards the adoption of new technologies/ varieties among the farmers.
- Lack of farm mechanization.
- Issues pertaining to the availability of electricity.

Research initiatives since inception of the centre

- Climate resilient intercropping systems, double cropping systems, diversified cropping systems have been developed by the research centre to cope up with the issues of climate vulnerability
- Research centre has developed the low cost technologies for *in-situ* and *ex-situ* moisture conservation and rainwater management practices for increasing the productivity of rainfed crops.
- Dryland research centre has also developed technologies for nutrient management involving the integrated nutrient management strategies for sustainable soil health for maximizing the crop yields**.**
- National Innovations on Climate Resilient Agriculture (AICRPDA-NICRA) and AICRPAM-NICRA these two projects are implemented by the centre in various villages of the Akola District to disseminate and demonstrate the technologies of dryland agriculture for the farmers. Weather forecasting with agromet advisories are disseminated among the farmers of these villages to cope up with the climate vulnerabilities.

Significant achievements

Rainwater management

- In graded bunded field, for sustainable soil and water conservation and obtaining higher monetary returns it is recommended to plant and develop one vetiver line at the centre of adjacent graded bunds.
- Effect of land treatments for improving moisture regime in pulse based cropping system was studied at Akola, Achalpur, Washim, Yavatmal and Buldhana during 1991-92 to 1993-94. Opening of furrows (after two rows) at seeding or at 30 DAS is essential for improving moisture

status of the soil and in boosting crop yield in both contour sowing and sowing across the main slope in pulse based cropping system.

- Effect of land treatments on the yield of early cotton grown in shallow soils were studied at Akola and it is recommended to open furrow after every two rows at 30 DAS with a hoe for getting higher seed cotton yield in shallow soils.
- For obtaining higher cotton yield, monetary returns and improvement in soil fertility status, integrated application of 50% RDF (25:12.5:12.5 kg ha^{-1} N:P:K)+ FYM @ 5t ha^{-1} + PSB + *Azotobactor* and opening of furrow in each row at 30-40 DAS is recommended under dryland condition.

Cropping systems

- In western vidarbha region, sorghum + pigeonpea (3:3), pigeonpea + soybean (1:2) and cotton + greengram (1:1) intercropping should be adopted in place of respective sole crops.
- Intercropping of sorghum and pigeonpea in cotton was studied at Dryland Research Unit, Akola and recommended that, for getting higher monetary returns and to meet the requirement of food, fodder and fuel of the famers. Cotton + sorghum + pigeonpea + sorghum (6:1:2:1) four tier intercropping system is recommended under rainfed situation.
- For obtaining higher productivity and monetary returns, intercropping of Pearl millet + pigeonpea (1:1) at 30 cm row spacing in *Inceptisols* is recommended under dryland condition.
- For minimizing the risk in rainfed agriculture and obtaining higher yield and monetary returns, intercropping of cotton: soybean: pigeonpea: soybean (3:2:2:2) at 45 cm spacing is recommended.
- For ease in sowing cotton + sorghum + pigeonpea + sorghum (3:1:1:1) recorded statistically at par net monetary return of Rs. 20032/- with Cotton + sorghum + pigeonpea + sorghum (6:1:2:1) and it also recorded B:C ratio of 2.28 with seed cotton equivalent yield of 871 kg ha^{-1}.
- For obtaining higher production, economic returns, convenience in sowing and interculture operations, intercropping of soybean + pigeonpea (4:2) with 45 cm spacing between the rows is recommended under dryland condition.
- Under dryland condition, for higher productivity and monetary returns, intercropping of vegetables cotton (cotton + cowpea or clusterbean) sown at 45 cm in 1:1 row proportion and application of 125% RDF (75:37.5:37.5 NPK kg ha^{-1}) in two split doses i.e. half dose of N , Full dose of P and K applied at the time of sowing to cotton + vegetable intercrops (37.5 : 37.5 : 37.5 NPK kg ha^{-1}) and remaining half dose of nitrogen (37.5 kg ha^{-1}) applied at 30 DAS to cotton crop is recommended.
- For obtaining high monetary returns, soil moisture conservation on slopy field (up to 3% slope), it is recommended to take soybean-chickpea double cropping on 30% area of lower toposequence in place of sole cotton under cotton based cropping system in dryland condition.
- For obtaining higher system productivity and profitability, sowing of non *Bt* cotton + soybean (4:10)-safflower cropping system with tractor drawn seed drill and application of 45:55:30 kg ha^{-1} NPK to the Cotton + soybean (4:10) intercropping and 13.75:13.75:13.75 kg ha^{-1}NPK to safflower is recommended for dryland condition of Vidarbha region.

Nutrient management

- Application of 5 t FYM + 25 kg P_2O_5 ha^{-1} as a basal dose and 25 kg N ha^{-1} as top dressing after 30 days is recommended to Cotton + greengram (1:1) intercropping system as an Integrated Plant Nutrient Supply (IPNS) system for sustainable fertility and productivity of soil in drylands.
- Trial on green leaf manuring in sorghum, sunflower and pigeonpea (Alley cropping) was carried out at Akola and it was observed that *Leucaena* loppings @ 3.5 t ha^{-1} each year, if added for two years, curtail the fertilizer requirement and improve the soil health. After two years, there is no need of fertilizer for sunflower and pigeonpea crops. However, 70 per cent yield over recommended dose of fertilizer is noticed in case of sorghum when *Leucaena* loppings @ 3.5 t ha^{-1} was added.
- Studies on the effect of *Leucaena loppings* alone and in combination with fertilizers on soil properties and yield of seed cotton (AHH-468) were conducted at Akola and results revealed that combined use of organics and chemical fertilizers is more effective in increasing yield. Use of *Leucaena loppings* (4.5 t ha^{-1}) reduced recommended dose of fertilizers by 50%. Alley width of 15 m with 4 rows of *Leucaena* each at 45 x 45 cm is proposed in alley cropping. *Leucaena* hedge rows act as vegetative barriers for soil and water conservation.
- Experiments on the effect of *Leucaena* loppings alone and in combination with fertilizer on growth and yield of sorghum were conducted and it is recommended that, *Leucaena* loppings @ 4.5 t ha^{-1} and $3/4^{th}$ recommended fertilizer dose be applied to *kharif* hybrid sorghum for obtaining similar net monetary returns as that obtained with the recommended doses of fertilizer.
- In medium deep soils where available zinc status is low to medium, hybrid sorghum crop should be fertilized with 5

kg zinc ha^{-1} (25 kg $ZnSO_4$ ha^{-1}) along with recommended dose of fertilizer.

- Pigeonpea crop be fertilized with 20 kg P (46 kg P_2O_5 ha^{-1}) along with 5 t FYM and 1.5 kg phosphorus solubilizing bacteria (PSB) per hectare for economy in chemical fertilizer.
- Application of 4 t FYM and 100:50:50 kg N, P_2O_5 and K_2O ha^{-1} is recommended to variety Amber popcorn maize, for obtaining higher grain and fodder as well as monetary returns under dryland conditions.
- For obtaining higher yield and economic returns in zinc and boron deficient vertisols, it is recommended to apply 25 kg Zinc sulphate and 5 kg Borax ha^{-1} along with 50:25:00 NPK kg ha^{-1} to rainfed American cotton. The seed cotton yield (1062 kg ha^{-1}) obtained with improved practice is 23 per cent higher under 125% RDF + 25 kg/ha $ZnSO_4$ + 5 kg / ha Borax as compared to 100% NPK (50:25:00 NPK kg/ha) only (861 kg/ha) The net returns with improved practice is 19 per cent higher than the recommended dose. This also helps in quality of the cotton in general and improves the soil fertility status in vertisols.
- The improved practice gives higher seed cotton yield (887 kg/ha) with INM practice (50% recommended N (25 kg/ha) through green leaves of gliricidia + 50% N through urea (25 kg/ha) + 25 kg P_2O_5/ha +25 kg K_2O/ha) along with seed treatment, which is 15% higher as compared to recommended dose *i.e.,* 50:25:0 NPK kg/ha (750 kg/ha) with 28% higher net returns. The INM practice helps in improvement of fertility status of soil, especially nitrogen and potassium status of soil since 1 ton of gliricidia adds 21 kg N and 18 kg K annually. The loppings of gliricidia serve as mulch, thus conserve soil moisture, further helps in improving soil physical and biological properties on a long term.
- The yield of soybean (1760 kg/ha) with INM practice is 8 per cent higher as compared to recommended dose *i.e.* 30:75:00 NPK kg/ha (1618 kg/ha) with 13 % higher net returns. The INM practice helps in improvement of fertility status of soil, especially nitrogen and potassium status of soil since 1 ton of gliricidia adds 21 kg N and 18 kg K annually besides improving soil physical and biological properties.

Tillage and nutrient management

- In rainfed condition for sorghum crop, minimum tillage (one hoeing followed by one hand weeding) with 20 kg nitrogen through inorganic fertilizer+ 20 kg N through FYM (3.80 t ha^{-1}), 40 kg P_2O_5 and 40 kg K_2O as basal dose and remaining 20 kg nitrogen through inorganic fertilizer + 20 kg through gliricidia (3 t ha^{-1}, at 30 DAS) is recommended for higher rainwater use efficiency, higher grain yield and enhanced soil fertility

Agronomic technologies

- The efficiency of Planofix hormone (NAA) on the seed cotton yield conducted for three years revealed that two sprays of Planofix at the commencement of flowering and at 50% flowering should be given in order to get higher seed cotton yield of variety L-147.
- While studying optimum plant population of pigeonpea Hy-2 for three years, it was observed that spacing of 60 x 30 cm (55555 plants ha^{-1}) recorded the highest yield.
- Pigeonpea should be sown in 2nd fortnight of September with a spacing of 45 to 60 cm x 30 cm. Wider row spacing (60 cm) may be adopted for deeper soils
- Sorghum could be grown in all types of soil with recommended dose of fertilizers. Cotton could be grown on class II soils (60 cm) with recommended fertilizers. However, long duration varieties of pigeonpea should not be grown on shallow soils (20 cm). Pigeonpea should be fertilized with recommended dose of fertilizer on class II and class III soils.
- Sowing of castor on the onset of monsoon is recommended for Akola district. However, sowing could be extended up to middle of August under contingency. Sowing of castor in second week of August is recommended for Buldhana district and it could be delayed up to September when contingency arises. Spacing of 90 x 40 cm is recommended for castor at both the places
- Requirement of P for hybrid sorghum (CSH-9) on Vertisols were studied at Akola, Achalpur, Washim and Buldhana and results showed that, dose of 25 kg P_2O_5 ha^{-1} in deep heavy soils and 40 kg P_2O_5 in medium deep soils is recommended to hybrid sorghum (CSH-9).
- Cotton variety AKH-081 performed better in shallow soils (< 30 cm) under rainfed condition.

Technologies developed

Rainwater management

- ***In-situ* moisture conservation through topo sequence based cropping:** In cotton (Rajat) on fields (up to 3% slope), in the lower toposequence covering about 30% area is replaced by soybean (PKV-1), which is followed by chickpea (ICCV-2) in *rabi*. This enables double cropping in lower toposequence. For demarcation of such area, Vetiver key line is established in the beginning of the system, which also helps in moisture conservation.
- **Continuous Contour Trenches for moisture conservation and establishment of agri-horti systems:** The technology of continuous contour trenches (CCT)

comprise of demarcation of contour lines with dumpy level or contour marker on the selected land. Once the contour lines are drawn, parallel to these contour lines, continuous contour trenches of 60 x 30 cm are excavated such that the upper fertile soil is collected on upstream side and below murrum is spread at downstream side in the form of bund with suitable berm (space between trench and bund). Then the fertile soil is used to fill mound in the trench on desired spacing for example, in this technology, 5 to 6 m between the plants. The mound is used for planting of custard apple and hanuman phal at 5 m interval and remaining trench is left for *in-situ* rainwater conservation. For the first 5 years of establishment of the fruit trees, the interspaces between adjacent trenches are used for cultivation of greengram and blackgram for efficient utilization of land and resources. There is also scope for cultivation of soybean, horsegram, cowpea and other short duration crops.

- **Conservation furrow and integrated nutrient management for increasing cotton productivity:** The technology comprises of American cotton sown at 60 x 30 cm with bullock drawn 3 type seed drill. The seed rate of cotton is 15 kg ha^{-1}. The improved practice includes application of 50% recommended N (30 kg ha^{-1}) through FYM + 50% N through urea (12.5 kg ha^{-1}) + 30 kg P_2O_5 ha^{-1} + 30 kg K_2O ha^{-1} in rainfed cotton. Earlier, the seeds of cotton are treated with bio-fertilizers (*Azatobacter* and PSB @ 25 g/kg seed). The half dose of N (12.5 kg ha^{-1}), entire dose of P and K are applied as basal. The remaining half dose of N (12.5 kg ha^{-1}) is supplied through chemical fertilizer urea applied 30 DAS manually near the plant by ring method.)
- **Rainwater harvesting through farm pond:** Based on the runoff from two catchments, the capacity of the farm ponds have been decided. Accordingly, the location for construction of the farm ponds had been chosen and the dimensions were decided and construction of two farm ponds for two different catchments was done. Farm pond 1, capacity-2750 cum (size, 45 x 27 x 3 m) is having embankments on all sides however farm pond 2, capacity-370 cum (size, 18 x 11 x 3 m) have embankments on two sides only and other two sides are without embankments which will acts as inlets for sheet flow in the pond. The sheet flow is to be passed from the vegetative key lines surrounding the sides of the farm pond. These farm ponds are having pipe outlets located at suitable places for safe disposal of the excess water when the farm ponds are filled to its fullest capacity. The farm ponds are not lined. The berms are provided on all sides of the farm ponds for easy access and for stability of the embankments.

Cropping systems

- **Pearlmillet + pigeonpea (1:1) intercropping system in black soils of Western and Central Vidarbha region:** (The improved technology comprises of Pearl millet + pigeonpea intercropping system in 1:1 row proportion. Pearl millet (ICTP 8203) and pigeonpea (C 11) are sown in alternate rows at distance of 30 cm. The seed rate of pearl millet is 4 kg ha^{-1} and pigeonpea is 15 kg ha^{-1} and are sown with 3 type bullock drawn seed drill (Tifan /Sartah) with a basal fertilizer dose of 60:30 kg ha^{-1} of NP. Half of dose of N (30 kg ha^{-1}) and entire dose of P is applied as basal with ferti cum seed drill. Remaining half dose of N (30 kg ha^{-1}) is applied through urea at 30 DAS. One weeding and one hoeing with bullock drawn hoe is done at 30 DAS.)
- **Performance of cotton genotypes under HDPS with Soybean (6:6)-mustard strip intercropping system:** (The improved practice includes sowing of high density (45 x 15 cm) planting of desi Cotton (AKA-7) + soybean (6:6) with 40:50:25 NPK kg ha^{-1} or American cotton (AKH-081) + soybean (6:6) with 50:55:30 NPK kg ha^{-1} to both the crops and soybean strip sequenced with mustard at 45 x 15 cm spacing with recommended dose of fertilizer (40:20:20 NPK kg ha^{-1}) is recommended for dryland condition of Vidarbha region. The spacing for cotton crop is 45 x 15 cm whereas soybean is sown at 45 x 5 cm and mustard 45 x 15 cm with seed rate of cotton (12.5 kg ha^{-1}), soybean (37.5 kg ha^{-1}) and mustard (3 kg ha^{-1}).
- **Intercropping of pigeonpea and soybean in cotton with varying planting geometry:** For minimizing the risk in rainfed agriculture and obtaining higher yield and monetary returns, intercropping system of Cotton: soybean: pigeonpea: soybean (3:2:2:2) at 45 cm spacing is recommended.
- **Up scaling of Cotton + sorghum + pigeonpea + sorghum (6:1:2:1) intercropping system:** For ease in sowing and getting monetary returns comparable to risk minimizing intercropping system 6:1:2:1 (cotton : sorghum : pigeonpea: sorghum) and to meet the requirements of food, fodder and fuel of the farmers, 3:1:1:1 (cotton: sorghum: pigeonpea: sorghum) is recommended under dryland condition).

Nutrient management

- **Nutrient management through greengram incorporation in cotton:** Cotton (Rajat) is sown with 60 cm row spacing. Without hampering the plant population of cotton, one row of greengram (Kopergaon) is sown between two rows of cotton. At the same time 50% N (FYM) +50 percent N (urea) is applied to cotton. After picking of greengram pods, the biomass of greengram is incorporated into the soil by hoeing through interculture operations.)

- **Nutrient management in rainfed cotton on Vertisols:** The technology includes basal soil application of Zn @ 25 kg Zinc Sulphate and B @ 5 kg Borax/ha along with 30 (50 per cent dose of N): 30:00 NPK kg ha^{-1} with ferti cum seed drill. In this case, 60 kg $ha^{-1}$of N and 25 kg of P are recommended which is 10 kg ha^{-1} and 5 kg ha^{-1}, more than the recommended dose of N (50 kg ha^{-1}) and P (25 kg ha^{-1}) respectively. Remaining dose of N *i.e.,* 30 kg ha^{-1} is applied at 30 DAS.)
- **Integrated nutrient management in soybean in black soils:** The technology comprises of basal application of 50% recommended N (15 kg ha^{-1}) through green leaves of glyricidia + 50% N through urea (15 kg ha^{-1}) + 75 kg P_2O_5 + 25 kg K_2O ha^{-1} along with seed treatment of bio-fertilizers (*Rhizobium* and PSB @ 25 g/kg seed). The fresh toppings of glyricidia are applied manually in between the rows of soybean. The seed rate of soybean is 75 kg ha^{-1} and spacing is 45 cm in between rows and 10 cm intra rows.)
- **Integrated nutrient management in cotton in black soils:** The improved practice includes application of 50 per cent recommended N (25 kg ha^{-1}) through green leaves of glyricidia + 50% N through urea (25 kg ha^{-1}) + 25 kg P_20_5 /ha + 25 kg K_2O ha^{-1} in rainfed cotton (American cotton). Earlier, the seeds of cotton are treated with bio-fertilizers (*Azotobacter* and PSB @ 25 g/kg seed). The half dose of N (25 kg ha^{-1}) entire dose of P and K are applied as basal. The remaining half dose of N is supplied through fresh toppings of glyricidia, which are applied manually in between the rows of cotton at 30 DAS. The seed rate of cotton is 10 kg ha^{-1} and spacing is 60 cm in between rows and 30 cm intra rows.)
- **Performance of intercrops and levels of fertilizers in *G. hirsutum* cotton (AKH- 9916) under rainfed condition:** The improved practice gives higher seed cotton equivalent yield of 2464 kg ha^{-1} for cotton + cowpea (1:1) whereas 2442 kg ha^{-1} for cotton + clusterbean (1:1) cropping system with 50% N + 100% P and K applied through inorganic fertilizer at the time of sowing to intercrops and 50% nitrogen after one month to cotton crop only. This intercropping systems of cotton + cowpea (1:1) and cotton + clusterbean (1:1) provide higher crop profitability (Rs. 363.35/- and Rs. 366.47/- ha^{-1} day^{-1} respectively) and system profitability (180.18 and 181.73 Rs. ha^{-1} day^{-1} respectively) with higher values of crop productivity (13.61 and 13.49 kg ha^{-1} day^{-1} respectively).

Tillage and nutrient management

- **Tillage and nutrient management for resource conservation and improving soil quality:** The improved practice includes sowing of sorghum crop with low tillage *i.e* one hoeing followed by one hand weeding with 20 kg nitrogen through inorganic fertilizer + 20 kg through FYM (3.8 t ha^{-1}), 40 kg P_2O_5 and 40 kg K_2O as basal dose and 20 kg nitrogen through inorganic fertilizer + 20 kg through glyricidia (3 t ha^{-1}) is recommended for overall resource conservation *i.e*, higher water use efficiency, enhanced soil fertility and higher grain and fodder yield.)

Integrated nutrient management practices

Crop	INM practice
Cotton	FYM @ 5to10 t/ha or glyricidia 2.5 to 5.0 t/ha + 50%N + 100% P & K through inorganics + bio-fertilizer (*Azotobactor*) 25 g/kg seed
Soybean	FYM 5t/ha + bio-fertilizer (*Rhizobium* + PSB) @25 g/ kg seed + RDF
Pigeonpea	FYM 5t/ha + bio-fertilizer (*Rhizobium* + PSB) @ 25 g/ kg seed + RDF
Greengram	Biofertilizer (*Rhizobium* + PSB) @ 25 g/kg seed + RDF
Sorghum	FYM 3.0 to 5.0 t/ha + RDF + biofertilizer (*Azotobactor* + PSB) @ 20-25g/ kg seed
Chickpea	Biofertilizer (*Azotobactor* + PSB) @ 20-25 g/kg seed + RDF

Foliar nutrition

- In cotton, foliar application of 2% urea at the time of flowering1% urea + 1% magnesium sulphate at the time of boll setting, 1% KNO_3 at the time of boll development stage.
- In soybean foliar application of 19:19:19 water soluble mix fertilizer at pod initiation stage.
- In soybean during prolonged dry spells mulching of straw 5tonnes ha^{-1} with foliar spray of potassium nitrate 1% or magnesium carbonate 5% or glycerol 5% at 15 days after flowering.

Cropping systems

a. Intercropping systems

- Cotton + greengram (1:1)
- Cotton + Cowpea (1:1)
- Cotton + Clusterbean (1:1)
- Soybean + Pigeonpea (4:2)
- Cotton + Soybean (4:10) >Safflower
- Cotton + Soybean (6:6) > Mustard
- Pearl millet + pigeonpea (1:1)
- Cotton:soybean:pigeonpea:soybean (3:1:1:1)
- Cotton:soybean:pigeonpea:soybean (3:2:2:2)
- Soybean + pigeonpea (4:2)

b. Double/triple cropping systems

- Soybean-chickpea

Contingency crop planning

For *kharif* Planning

Crop/cropping system for normal onset of monsoon (second week of June)

- Cotton (AKH-09-5, AKH-9916), Soybean (AMS-1001, AMS-MB-5-18, JS-335 & JS-93-05), Pigeonpea (AKT-8811, Vipula, PKV- Tara & BSMR-736), Sorghum (CSH-9, PDKV Kalyani) Greengram (PDKV Greengold, PKV AKM-4), Blackgram (PDKV Black gold, PKV Udid-15)
- Intercropping systems: Cotton+pigeonpea (8:1/9:1), cotton+greengram/blackgram (1:1), soybean+pigeonpea (4:2/6:1), cotton+cowpea (1:1), cotton+clusterbean (1:1), cotton+soybean (4:10).

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

Delay by 2 weeks (4th week of June)

- Cotton (AKH-081 (B*t*), AKH-09-5, AKH-9916), soybean (JS-9560 & JS-93-05), pigeonpea (PKV- Tara & BSMR-736), sorghum (CSH-14, CSH-17, CSH-30), greengram (Pusa vaishakhi, Kopergaon) and blackgram (TAU-2).
- Intercropping systems: Cotton+pigeonpea (8:1/9:1), cotton+greengram/blackgram (1:1), soybean+pigeonpea (4:2/6:1), cotton+cowpea (1:1), cotton+clusterbean (1:1), cotton+soybean (4:10).
- Area under cotton be reduced and replaced by sorghum and area under groundnut be reduced and replaced by sunflower.
- Prefer greengram, blackgram, soybean, pigeonpea as intercrops.

Delay by 4 weeks (2nd week of July)

- Cotton (AKH-081, AKH-09-5, AKH-9916), soybean (JS-9560 & JS-93-05), pigeonpea (PKV- Tara & BSMR-736), sorghum (CSH-14, CSH-17, CSH-30), greengram (Pusa vaishakhi, Kopergaon) and blackgram (TAU-2)
- Intercropping systems: Cotton+pigeonpea (8:1/9:1), cotton +greengram/ blackgram
- (1:1), and soybean+pigeonpea (4:2/6:1).
- Prefer early varieties of American/ *Arboreum* cotton
- Replace sorghum, greengram and blackgram by soybean (JS-9560 & JS-93 -05) or pigeonpea (AKT8811, Vipula, PKV-Tara, BSMR-736)
- Adopt 20-25% more seed rate than recommended seed rate and reduce fertilizer dose by 25% for cotton
- Prefer three tier intercropping of cotton:soybean: pigeonpea: soybean (3:2:2:2) or cotton:sorghum:pigeonpea:sorghum (3:1:1:1).
- Replace the hybrids with improved varieties in cotton (American cotton: AKH-8828, PKV Rajat (Bt) & AKH-081(Bt); *Desi* cotton: AKA-5, AKA-7 & AKA-8).

Delay by 6 weeks (4th week of July)

- Sole pigeonpea (AKT-8811, Vipula, PKV Tara, BSMR-736); sunflower (hybrids) or sesame (AKT64) or castor (AKC-1, GCH-4,5,6 & DCH-117, 32) or pearl millet (PKV Raj, Shradha, Saburi)
- Intercropping systems: Pearlmillet + pigeonpea (2:1, 4:2).
- Avoid sowing of cotton otherwise use only short duration *desi* varieties with 25 to 30% more seed rate and reduced intra-row spacing; replace the hybrids with improved varieties in cotton (American cotton: AKH-8828, PKV Rajat (Bt), AKH-081(Bt); Desi: AKA-5, AKA-7, AKA-8).
- Avoid sowing of sorghum, greengram and blackgram.
- Alternative crops include sunflower, pearlmillet, sesame, castor and pearlmillet + pigeonpea (2:1or 4:2).

Delay by 8 weeks (2nd week of August)

- Pigeonpea (AKT-8811, Vipula); sunflower(hybrids)/ sesame (AKT64)/castor (AKC-1, GCH-4,5,6 & DCH-117,32/pearlmillet (PKV Raj, Shradha, Saburi); pigeonpea (PKV Tara, BSMR-736); pigeonpea (AKT-8811, Vipula); sunflower (hybrids)/sesame AKT64/ castor (AKC-1, GCH-4,5,6 & DCH-117, 32)/pearl millet (PKV Raj, Shradha, Saburi); greengram, blackgram.

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

Early season drought:

- Adoption of risk resilient cotton and soybean based intercropping systems such as cotton+greengram (1:1), cotton + cowpea (1:1), cotton+clusterbean (1:1), soybean + pigeonpea (4:2), soybean + pigeonpea (6:1) as preparedness to cope up with drought situations instead of sole cropping of cotton and soybean for assured and sustainable crop production.
- Sowing of cotton and soybean on broad bed furrow through BBF planter for *in-situ* moisture conservation and to cope up with moisture stress during early season drought.
- Raising of cotton seedlings in polythene bags for transplanting when sufficient moisture is available after receipt of rains can be practiced to compensate loss in plant stand with seedlings of similar age.
- If moisture stress occurs at very early stage i.e. within a week to10 days after sowing, it is recommended to resow with subsequent rains for better plant stand.
- In case of failure of *kharif* crops, prefer sowing of photo

insensitive crops such as pearlmillet, sunflower, sesame and pigeonpea once adequate rains are received.

- Gap filling to be done by watering 7 to10 days after sowing when crop stand is less than 75%.
- Interculture for removal of weeds and creating soil mulch.
- Open conservation furrows in each row in cotton and soybean by tying a rope to hoe and furrow across the slope for in-situ moisture conservation.
- In Pigeonpea, gap filling either with sesame or maize.
- In Sorghum, adopt thinning to maintain optimum plant population.
- Avoid applying fertilizer till sufficient moisture is available in soil.

Mid season drought

- Take up repeated interculture to remove weeds and create soil mulch to conserve soil moisture.
- If severe moisture stress, ratooning or thinning may be done in *kharif* sorghum and pearlmillet.
- Open conservation furrows in each row in soybean and cotton for *in-situ* moisture conservation by tying a rope to hoe during hoeing.
- Open alternate furrows in row crops such as soybean or furrows for every 6-8 rows of pigeonpea with Balaram plough in medium to deep soils.
- Foliar spray of 2% urea solution at flowering stage in cotton to supplement nutrition during mid season drought.
- Foliar spray of 19:19:19 mix water soluble fertilizer at pod initiation stage in soybean to supplement nutrition during mid season drought.
- Avoid top dressing of fertilizers until receipt of rains.
- Adopt surface mulching with crop residue or tree loppings of *Glyricidia* wherever possible.

Terminal drought

- Provide life saving or supplemental irrigation, if available preferably through sprinkler or drip irrigation at pod development stage in soybean and at boll development stage of cotton during prolonged dry spells of terminal drought.
- Harvest at physiological maturity with some reliable yield or harvest for fodder and prepare for rabi sowing in double cropped areas.
- Foliar spray of 1% KCl at boll development stage in cotton to supplement nutrition during prolonged dry spell.
- Advantage of this situation is exploited for double cropping with safflower and chickpea.
- Safflower may be sown after sorghum till 15th October. Beyond 15th October, chickpea may be sown.

For *rabi* planning

Crops and varieties for normal season

Crop	Varieties/hybrids
Chickpea	JAKI-9218
	PDKV Kanchan
	PKV Kabuli-4
Sorghum	CSH-15 R
	CSH-19 R
	PKV Kranti
	SPV-504
	CSV 14 R
	Phule Yashoda
	CSV 18 R
Safflower	AKS-207
	Bhima
	Nari-6 (thornless)
	PKV Pink

Suggested crops and varieties for delayed season

Crop	Varieties/ hybrids
Chickpea	JAKI-9218
	PDKV Kanchan
Sorghum	CSH-19 R
	PKV Kranti
Safflower	AKS-207

Alternate land use

- **Ber based agro-horticulture system for higher productivity:** The improved practice includes the plantation of Ber (*Ziziphus mauritiana*) at spacing of 6 x 6 m with pruning every year and the space between two rows of ber was intercropped with the cotton + soybean in 1:1 row proportion.)
- Diversification in cotton based cropping system (cotton + soybean (4:10)-safflower) under mechanization in dryland condition

Agro-horti systems

Custard apple with high density planting at 5 m x 2.5 m with greengram as a intercrop on with continuous contour trenches for *in-situ* moisture conservation.

- Ber at 5 m x 5 m spacing and intercropped with cotton + soybean (1:1/3:3) with continuous contour trenches for in-situ moisture conservation.
- Cultivation of anjan grass on bunds and field boundaries.

- Cultivation of glyricidia along the bunds used for integrated nutrient management with the incorporation of green leaf manuring, mulching with glyricidia leaf and serve as a amendment with NPK content.

Impact of technologies

If the harvested farm pond water is used for protective irrigation to soybean crop during *kharif,* then 38.56% yield increase was observed as compared to without irrigation treatment. Similarly for chickpea the yield increase was 31.84 % in protective irrigation treatment as compared to non-irrigated treatment. Vegetative barriers as interbund enables to achieve 11.23% increase in yield of soybean in interbund treatment followed by vetiver key line 10.39% and graded bund (4.20%) over control *i.e.,* no barrier treatment. Cotton + sorghum + pigeonpea + sorghum (3:1:1:1) gives net income of Rs. 20000/ha with seed cotton equivalent yield of 871 kg /ha. Cotton + soybean + pigeonpea+ soybean (3:2:2:2) intercropping gives 36% higher cotton seed equivalent yield (1537 kg/ha) with net returns Rs. 30,000 /ha compared to sole cotton (976 kg/ha), net monetary returns (Rs. 14956 /ha). Adoption is 10% area in the domain districts Pearl millet + pigeonpea intercropping system (1:1) gives 56% higher pearl millet equivalent grain yield (4018 kg/ha) with net returns of Rs. 30,000/ha and B:C ratio of 3.29 as compared to sole pearl millet yield (958 kg/ha). This system also enhances resource use efficiency and improves soil fertility due to pigeonpea as intercrop. Adoption is 5-10% area in Buldhana district. Soybean + pigeonpea (4:2) intercropping system gives 36 % increase in soybean equivalent yield (3277 kg/ha) with net returns of Rs.72,792/-ha, B:C ratio 4.31 and LER 1.47 as compared to sole soybean yield of 2058 kg/ha, net monetory returns of Rs. 36,413 and BC ratio of 2.65. This system also helps in covering the land during early stages, conserves moisture and also improves the soil fertility status. Adopted in more than 50% area of the domain districts (Akola, Buldhana, Washim, Yavatmal, Wardha. Cotton+ soybean (4:10)-safflower sequence cropping system with application of 45:55:30 kg ha^{-1} NPK to Cotton+ soybean (4:10) and 22:13.75:00 kg ha^{-1} NPK to safflower recorded high cotton equivalent yield, net monetary Return, B: C ratio sustainable value & yield index and system productivity and profitability. Opening of furrow in each row at 30-40 DAS has given 21.27 % increase in seed cotton yield with improved soil moisture availability and sustainable productivity. Adoption in 60-70% area in domain districts in predominantly grown crops.

Conservation furrow and integrated nutrient management gives higher seed cotton yield (969 kg/ha), net monetary returns (Rs. 30,00/ha). The INM practice also helps in improvement of fertility status of soil. Loppings of gliricidia also serve as mulch, thus conserves soil moisture. Integrated nutrient management in cotton in deep black soils gives higher seed cotton yield (887 kg/ha) with INM practice (50% recommended N (25 kg/ha) through green leaves of gliricidia + 50% N through (urea 25 kg/ha + 25 kg P_2O_5/ha + 25 kg K_2O/ha) along with seed treatment, which is 15 per cent higher as compared to recommended dose *i.e* 50:25:0 NPK kg/ha (750 kg/ha) with 28% higher net returns. Adoption in 10% area of domain districts. Integrated nutrient management in soybean in black soils gives higher soybean yield (1760 kg/ha) with INM practice (50% recommended N (15 kg/ha) through green leaves of gliricidia + 50% N through urea (15 kg/ha) +75 kg P_2O_5/ha + 25 kg K_2O/ha) along with seed treatment, which is 8 per cent higher as compared to recommended dose *i.e.,* 30:75:0 NPK kg/ha (1618 kg/ha) with 13% higher net returns. Adopted in 10% area of domain districts.

Balanced nutrition in cotton in deep black soils (60 kg N + 30 kg P + 25 kg Zinc sulphate + 5 kg Borax) gives 23% higher seed cotton yield (1062 kg/ha) as compared to recommended dose of NPK (50:25:00 kg/ha). Incorporation of greengram in cotton, over period of time improves soil physical condition and fertility status resulting in higher productivity and profitability (net returns of Rs. 12,000/ha) and adopted in more than 50% of cotton cultivated area in the domain districts. Micro site improvement with Continuous Contour Trenches (CCTs) helps in efficient *in-situ* moisture conservation, which further help in better establishment, survival and performance of the custard apple and hanuman phal. In the initial 5 years of establishment of the fruit trees, the inter space was used for cultivation of short duration pulse crops. *Viz.,* greengram and blackgram, resulting in efficient utilization of resources. The CCTs also helped in increasing ground water recharge as compared to square pit plantation.

Way forward

In the era of climate change, multiple abiotic stresses are the key challenges for future dryland crops. In the same season, crops experience drought in the early part and water logging in the later growing period due to erratic rainfall distribution. The centre aims to integrate other components like natural resources, and livestock and also to identify models for sustainable integrated farming systems to cope with drought situations. The research center works on research areas to increase agricultural productivity, especially in rainfed areas focusing on integrated farming and improved water use efficiency which is the current need for the development of such technologies for marginal and small farmers of rainfed regions. Therefore, a paradigm shift in future research is necessary.

The research focus needs to be on the following aspects:

1. Diversified farming systems to cope with the uncertainty of weather conditions imposing multiple risks during the crop season.

2. Development of rainfall-runoff relationship in a changing climate scenario for the planning of rainwater management structures and thereby the crop planning based on the availability of harvested rainwater.
3. Soil health management through conjunctive use of organic and inorganic sources of nutrients and synergizing resource conservation and carbon sequestration.
4. Integrated approach in resource allocation to field crops, horticulture, and livestock depending upon the resource endowments and proportional contribution.
5. Intensification of high-yielding varieties of different crops with special emphasis on minor millets.
6. Exploring the potential of marginal lands with highly productive alternate land use system modules.
7. Evolving good agronomic practices for inclusion in the package of practices of respective field crops.