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Overview of Dryland Agriculture Research and Achievements in South West Semi-Arid Zone of Uttar Pradesh

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Brief history of the Centre

Agra Centre of All India Co-ordinated Research Project for Dryland Agriculture, located at Agra under the jurisdiction of Raja Balwant Singh College, Bichpuri Agra, formerly known as B.R College and was initiated in 1970 as a sub-centre at same location. The Agra centre of AICRPDA represents South-western semi-arid region of Uttar Pradesh covering 8 districts, i.e., Agra, Firozabad, Mainpuri, Hathras, Aligarh, Mathura, Etah and Kansi Ram Nagar with geographical area of 22424 Km^2, accounting for 7.62% area of the state.

Agro-climatic zone characteristics

The climate is semi-arid sub-tropical characterized with dry hot summer months and severe cold in winter months. Out of the total annual average rainfall of 664.5 mm, south-west monsoon contributes 88% while 9.0% from north-east monsoon and 2.5% during summer. The normal onset of south-west monsoon is during first week of July and withdrawal is during third week of September. The dry spells during crop season had been experienced in July, August and September coinciding with germination, vegetative and grain formation stags of the major rainfed crops. In summer, temperature raises upto 48^0C with desiccating winds. The potential-evapo-transpiration (PET) is about 1850 mm with an average of 5.05 mm/day, a maximum of 10.7 mm/day in June and a minimum of 2.13 mm/day in January. Winter is short (end of November to February). The temperature is as low as 0.5^0C or occasionally 0^0C at the peak of winter in the month of January. The normal onset of monsoon during south-west monsoon is during third week of June while withdrawal is during first to second week of October.

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

Rainfall	Normal rainfall (mm)	Normal rainy days (No.)
South west monsoon (June-September)	589.1	35
North east monsoon (October-December)	28.5	2
Winter (January-February)	23.5	5
Summer (March-May)	23.4	-
Annual	664.5	42

Major soil types

The soils in the zone are alluvial in origin and vary from sandy loam to loamy sand.

Major rainfed crops

The major rainfed crops cultivated in the zone during *kharif* are pearl millet, sesame, green gram, black gram, cluster bean and pigeon pea and during *rabi* are chickpea, mustard, lentil and barley.

Dryland agriculture problems

The problems related to domain districts are as enlisted below

Rainfall, soil and land management

- Rainfall pattern of area is highly erratic, crops may suffer from moisture stress at any stage of growth in each and every year, resulting in poor yields.
- Soils of the region are inceptisols, which are sandy loam to loamy sand with pH of 7.9 to 8.6, low in organic matter, low in fertility status and deficient in micronutrients,
- Ground water table is depleting at an alarming rate, mainly due to over exploitation of ground water, which is saline to alkaline in nature commonly applied in cereals crops during *rabi* season. Ground water of the area is saline in nature and about 70% ground water is not suitable for growing pulses and oilseeds.
- Numbers and area of natural reservoirs /community tanks decreasing day by day, which are the major contributors of ground water recharge.
- Small land holding size and scattered ownership, farmers cannot individually adopt rain water management techniques with special reference to farm pond technology.
- Lack of accurate forecasting of rains.

Crop production

- Mostly varieties developed for irrigated conditions are also recommended for dryland conditions.
- Most of the varieties performed better in normal season, but they are not suitable for aberrant weather conditions especially during late *kharif* season.

Socio-economic

- Unavailability of agricultural inputs at proper time.

- Unavailability of equipment suitable for different agricultural operations for fragmented holdings
- Farmers are well aware of the importance of line sowing, yet they do not follow this practice on their fields, especially in *kharif* season. They are dependent on hired machinery covering more area in less time. It was felt that the machinery of agricultural operations should be available at least at the block or *panchayat* level.
- Bluebull is severe problem for pulses cultivation in the region, which is also responsible for preference to cereal crops.

Research initiatives since inception of the centre

The focus of research since the beginning was on identification of suitable crops and their varieties and development of improved agronomic practices for increasing crop yield. The centre involved in development of suitable cropping systems and alternate land use systems. The centre developed feasible and economically viable, soil, crop & water management techniques for south western zone of Uttar Pradesh. The major emphasis was on rain water management, integrated nutrient management, energy management, crops and cropping systems, contingency planning, tillage and farm machinery, drought mitigation strategies and alternate land use system. The centre has developed many dryland technologies for the region which led to increased and sustainable production of rainfed crops. The contingency plan under aberrant weather conditions has been developed.

Significant achievements

Rainwater management

Rainwater harvesting in farm pond and their availability indicated that there is good scope of rain water harvesting. About 1200 m^3 can be harvested each year, which can be utilized to avoid moisture stress during *kharif* season or as pre-sowing irrigation in *rabi* season. Off season tillage by MB plough /disc plough helped in increasing moisture conservation (15-20%), efficient weed control (25-30%) timely land preparation and sowing resulted in up to 20-30% increase in yield. In various moisture conservation techniques, planting of pearl millet on shoulder of ridge in ridge and furrow system of sowing with 40-45 cm row spacing found to be effective technique towards building *in-situ* moisture resource, safe disposal of extra rain water, enhanced biomass, economic yield and reduction in cost of operation. Under delayed monsoon or late sowing up to 10th August, pearl millet sowing by ridge & furrow system gave appreciable yield without any reduction as compared to yield recorded in timely sown crop. *Kharif* crops grown on ridge by raised bed planter gave higher yield from 13.1 to 27.2 per cent over yield recorded in respective crops grown on conventional system. Overall 17.8% more yield harvested with sowing on ridge. Maximum pearl millet yield (PEY) (4992 kg/ha) and B:C ratio (2.78) were recorded in cluster bean grown on ridge. The next best PEY and B:C ratio were obtained with sesame. In delayed monsoon or late sowing up to 1st week of August, *kharif* crops grown on ridge gave appreciable higher mean yield from 25.7% in pearl millet to 28.8% with cluster bean over yield obtained in flat system. The highest PEY of 4151 kg/ha was obtained in cluster bean, followed by sesame. However, sesame grown on ridge under delayed conditions produced appreciably higher mean BC ratio of 2.80 followed by cluster bean (2.51). In tillage and nutrient management system, conventional tillage comprising of one harrowing in summer + one harrowing after onset of monsoon rains and two ploughings by cultivator and one intercultural operation were found to be effective and productive tillage practice. The grain yield of pearl millet increased significantly with respect to different tillage practices. The maximum yield (2720 kg/ha) was obtained with summer tillage by MB plough/disc plough, which was 22.8% more over yield obtained in tillage by cultivator alone. To evolve a suitable device for sowing of *kharif* crops, ridger seeder appeared to be more effective seeding device in rainfed areas, gave maximum mean yield (2752 kg/ha.) and BC ratio (2.42).

Cropping systems

The pearl millet grown on ridge in ridge and furrow system was found more effective and gave overall 25.5% more yield over flat system of sowing. Among different varieties of mustard, Bio-902 followed by NRCHB-101 & DRMRIJ-31 (GIRIRAJ) are identified as higher yielders. In various cluster bean based inter cropping system tested, cluster bean + pearl millet/sesame grown in 6:1 row ratio produced higher CBEY. In sub-normal monsoon year cluster bean + pearl millet/sesame was more beneficial system. Experience from the field study indicated that soil surface temperature always is higher by 12-15°C over atmospheric temperature during late September or early October, leading to low mustard yields, therefore sowing in 2nd week of October (11-20 Oct) was found to more appropriate sowing time of mustard. Among high value crops (vegetables), bottle gourd performed better when grown on ridge and proved to be more profitable. Aonla/Ber based agri-horti system was found profitable and drought proof. For better resources utilization and highest net return, inter space between ber plants, green gram, sesame should be grown. Inter spaces in Aonla orchard, can be utilized for growing *kharif* pulses and oilseed, i.e., sesame.

Crops grown on ridge recorded appreciably higher mean yield of 13.1 to 27.3% in normal sowing conditions and 20.8 to 27.7% more in delayed sowing conditions (up to 30th July) over to yield obtained under flat system of sowing under both conditions respectively. The mean of PEY of 13.1 to 27.0% higher recorded with ridge planting over to flat system of sowing and highest PEY recorded with cluster bean. In delayed conditions

higher PEY (4151 kg/ha) was recorded with cluster bean. The maximum mean B:C ratio of 2.78 with cluster bean in normal and 2.80 with sesame under ridge plant of both crops in delayed sowing conditions respectively. Over all 17.8 and 25.6% more PEY registered with ridge sowing in normal and delayed sowing conditions.

Integrated nutrient management

Application of N (75 kg/ha) equally split in three parts (1/3 at sowing +1/3 at tillering and 1/3 at flag leaf stage, found to be more advantageous for boosting yield of pearl millet, produced 37.8 and 17.3 per cent more yield over full N applied at sowing and split in two parts. Impact of potassium application on mustard reveals that recommended dose of fertilizer (60 + 40 kg N/ha) in conjunction with 50 kg K/ha as basal produced significantly higher mean yield (2507 kg/ha) which was 73.0 and 17.5 per cent superior over yield obtained without K (1449 kg/ha) and 25 kg K/ha (2133 kg/ha) addition. Benefit cost (B:C) ratio of 5.08 also higher registered in same practices. Application of 40 kg sulphur by gypsum in association with RDF (20 + 40 kg NP/ha) proved to effective for achieving economically higher yield of cluster bean . For realizing more benefit application of crop residue @ 5.0 tons/ha as mulch for moisture conservation and RDF (40 + 20 kg NP/ha) along with sulphur @ 20 kg /ha prove to be ideal practice. Site specific nutrient management on pearl millet under rain fed areas revealed that application of 25% more RDF (75+50+50 kg NPK/ha) along with all limiting nutrient (Zn, B and Mn) on soil test basis gave mean highest yield (3523 kg/ha). However, 25% more RDF with zinc @ 25 kg/ha proved to be more effective, produced economically higher yield (3166 kg/ha) and BC ratio (3.57). Efficient management of deficient nutrient indicate that application of Zinc, Boron and sulphur (on soil test basis) in association with RDF (on soil test basis) in mustard realized maximum mean yield of (1644 kg/ha) by applying 25% more RDF and all limiting nutrients. However, 25% more RDF in association with sulphur @ 25 kg/ha gave economically higher yield (1616 kg/ha) and BC ratio (3.29). Application of FYM to be equivalent of 50% nitrogen of RDF (30 kg N/ha) in conjunction with rest 50% N of RDF to meet through inorganic fertilizer proved to be effective combinations of fertilizer schedule, could sustained productivity of pearl millet.

Technologies developed

Rainwater management

- Deep tillage and compartmental bunding for enhanced pearlmillet productivity
- Tillage with disc harrow after each effective rainfall for enhancing mustard productivity under conserved soil moisture
- Summer tillage for *in-situ* moisture conservation and enhancing productivity
- Efficient utilization of harvested water from farm pond for growing high value crops (vegetables) during *kharif* season.
- Early season drought management practices for stability in production of pearl millet
- Late season drought management practices for stability in production of pearl millet.
- Field bunding and land shaping to enhance productivity of *kharif* crops in semi arid inceptisols of Agra region
- Contingency crop planning South-Western Zone of Uttar Pradesh

Cropping system

- Ridge planting of pearl millet for higher productivity
- Strip cropping of pearl millet + cluster bean (4:4) as an insurance against aberrant weather situation
- Strip cropping of pearl millet + sesame (4:4) as an insurance against aberrant weather situation
- Inter cropping of pearl millet + pigeon pea (2:1) for insurance against risk
- Weed management in pearl millet in South-Western Zone of Uttar Pradesh

Nutrient management

- Sesbania green manuring for higher mustard productivity in semi- arid Inceptisols
- Sulphur application for higher productivity
- Split application of nitrogen for higher productivity of pearl millet
- Potassium application for higher yield of mustard
- Foliar spray to cope with dry spells and higher productivity of rainfed crops
- Rainfed area network programme on balanced nutrients on mustard
- Response of fertilizer application on yield of pearl millet

Integrated nutrient management practices

Crop	INM practice
Pearl millet	50% of recommended dose of N (30 kg/ha) through organic + 50% of recommended dose of N (30 kg/ha) through inorganic + 40 kg P_2O_5
Mustard	60 + 40 + 50 kg/ha NPK+ 25kg S/ha

Foliar spray

Foliar spray of 0.5% NPK (19:19:19 kg/ha) in pearl millet; and 2.0% NPK (19:19:19 kg/ha) and 2% KCl in mustard.

Cropping systems

Inter-cropping systems

- Pearl millet + pigeonpea (2:1)
- Pearl millet + greengram (2:1)
- Pearl millet + blackgram (2:1)
- Clusterbean + pearlmillet (6:1)
- Clusterbean + sesame (6:1)
- Pigeonpea+ greengram (2:2)
- Barley + chickpea (3:2)
- Chickpea + mustard (4 -5:1)

Double cropping systems

- Greengram/blackgram (green manuring after first picking) - mustard
- Pearl millet + cowpea (fodder) - mustard
- Green manuring in *kharif* (Sesbania) - mustard

Alternate land use

Agro-horti systems

- Aonla based agri-horti system: Amal (8m x 8m)+ pearl millet/cluster bean/green gram (spacing – 45 cm x15 cm for pearlmillet/cluster bean; 30 cm x15 cm for greengram. Pearl millet + cow pea for fodder spacing – 30 cm x10 cm.
- Ber based agri-horti system : Ber (10 m x 10 m)+ pearl millet/cluster bean/green gram (45 cm x15 cm for pearli millet/cluster bean; 30 cm x15 cm for green gram. Pearl millet + cowpea for fodder spacing – 30 cm x10 cm.

Contingency crop planning

For *kharif* planning

a. Crop/cropping systems for normal onset of monsoon

- Pigeonpea (UPAS-120, Narendra 1 & 2), pearl millet (Proagro 9001 and Pioneer 86 M 88), greengram (Pant-Mung-1 & Pant Mung-2), blackgram (Ajad & Type-9), sorghum for fodder (Varsha, CHS 13, 23 & Bundela), clusterbean (RGC-1025 & RGC-1017), sesame (Shekhar & HT-1); pigeonpea + pearl millet + blackgram (1:2:1); pigeonpea + sorghum; fallow- lentil/ mustard/pea/chickpea.

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

Delay by 2 weeks (1st week of July)

- Pigeonpea (UPAS-120, Narendra 1 & 2), pearlmillet (NDFB 3), greengram (Pant Mung-1 & Pant Mung-2), blackgram (Ajad & Type-9), sorghum for fodder (Varsha, CHS 13, 23 & Bundela), clusterbean (RGC-1025 & RGC-1017), sesame (Shekhar & HT-1); pigeonpea + pearl millet + blackgram (1:2:1); pigeonpea + sorghum; fallow-lentil/ mustard/pea/chickpea.

Delay by 4 weeks (3rd week of July)

- Clusterbean (RGC-1025 & RGC-1017); greengram (Pant Mung-1, 2, Samrat, Asha and K-851); blackgram (Type-9, Pant U-19 & 30)
- Intercropping system: Pigeonpea + pearlmillet + blackgram (1:2:1)
- Short duration varieties of pearlmillet (WCC 75, Pusa 322 & 323)

Delay by 6 weeks (1st week of August)

- Short duration variety of pearl millet for fodder (NDFB 3); greengram (Pant Mung-1, 2, Samrat, Asha and K-851), blackgram (Type-9, Pant U-19 & 30)
- Prefer sole blackgram on raised bed using raised bed planter

Delay by 8 weeks (3rd week of August)

- Planning for early *rabi* crops in September e.g. toria (Type 36, Type 9 & Bhavani), mustard (Varuna & Pusa bold)

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

Early season drought

- Gap filling and thinning to maintain optimum plant population
- Resowing, if the plant population is < 30%
- Extra intercultivation
- Mulching with mustard straw @ 5 t/ha for conserving moisture
- Adopt interculture to break soil crust, remove weeds and create soil mulch
- Open conservation furrows

Mid season drought

- Repeated interculture to remove weeds and create soil mulch
- Opening conservation furrow at 30-35 DAS to conserve soil moisture
- In pearl millet, foliar spray of urea (2%) at 30-35 days after sowing
- Under severe moisture stress, ratooning or thinning may be done in *kharif* sorghum and pearl millet
- Avoid top dressing of fertilizers until receipts of rains
- Foliar spray of 0.5% NPK (19:19:19)/ha

Terminal drought

- In case of severity, harvest pearl millet and sorghum for fodder
- Provide life-saving or supplemental irrigation, if available.

For *rabi* planning

Crops and varieties for normal season

- Mustard - DRMRIJ-31, RH-406, RH-749, NRCDR-2 and NRCHB-101
- Chick pea - Avrodhi and Udai
- Barley - Narendra-2 and T-36
- Lentil-Pant-206, Pant-209, DPL-62, L-4594 and Pant Lentil-5

Technologies upscaled in convergence with various programmes

The centre is working in close collaboration and consultation with ICAR-CRIDA, AICRP on Use of saline water in agriculture, cropping system, IISWC centre, Chhalesar, State Line department, KVKs, and NGOs along with farmers of the district for developing and refining technology for improving profitability in rainfed farming and passing on the technologies to development agencies and extension functionaries for faster adoption by the farmers. Centre has also developed linkage with CAZRI, Jodhpur and Coordinating cell of AICRP on sesame & niger, JNKVV, Jabalpur. Centre also takes technical inputs from IISWC, Chhalesar and National Research Centre on Rapeseed-mustard, Bharatpur to generate valuable output for the benefit of the rainfed farmers.

Impact of technologies

Ridge planting of pearl millet resulted in higher productivity. Pearl millet performed better on ridges with a grain yield of 2288 kg/ha compared to farmers practice (1586 kg/ha). The increase in the yield is 44.3% and net return is Rs. 13761/- with a BC ratio of 2.23 over farmers' practice of broadcasting of seed. Ridge planting provides enough aeration and porosity to soil for enhanced root growth apart from safe disposal of excess rainwater and reduction in soil loss. Pearl millet is grown on 1.07 lakh ha in the region with an average of 1407 kg/ha. There is a scope to enhance yield level up to 2288 kg/ha. Deep tillage in summer and compartmental bunds after germination can support up to 1.5 to 2.0 tones/ha of pearl millet yield under rain fed conditions. Deep tillage + compartmental bunds conserve moisture effectively and gave a pearl millet (WCC-75) yield of 1875 kg/ha which is 31% higher than yield attained with farmers practice (1230 kg/ha). This technology gave a net return of Rs. 10,045/ha with B:C ratio of 3.23 as compared to farmers practice, even during sub-normal rainfall situations. Supplemental irrigation at flowering and silique formation stages of mustard give a yield of 2076 kg/ha compared to1459 kg/ha under farmers practice. The yield advantage is about 42.3% with a net income of Rs. 10,000/ha and B:C ratio of 3.80. Mustard is grown in about 79,000 ha in Agra district.

With the adoption of supplemental irrigation to rainfed mustard, additional production valued at 79 crores could be realized by the farmers in the district. Sesbania green manuring resulted in higher mustard productivity in semi-arid Inceptisols of Agra region of Uttar Pradesh. The improved technology involves raising a green manure crop during *kharif* season and incorporation into the soil, The field is prepared in advance before onset of monsoon. Seeds of *Sesbania aculeata* are broadcast in dry soil. Planking and bund making is done across the slope to check runoff from the field, Sesbania crop is ploughed back into soil after 40-45 days after sowing. Mustard (Varuna, Rohini) is sown during *rabi* with a nutrient application of 45 kg N + 40 kg P_2O_5/ha. In Agra district, mustard is grown on about 79,000 ha in fallow-mustard sequence. If *Sesbania* is included in this system, considerable saving of N fertilizer can be made. At present about 15-20% area is under the improved technology. Application of K along with recommended dose of N and P gave mustard yield of 2039 kg/ha compared to farmers practices (1603 kg/ha) which was higher by 27.2 percent. The net income of Rs 56736/ha with BC ratio of 5.09 was registered with improved practice as compared to farmers practice which gave net income of Rs 42305/ha and BC ratio of 4.07. Further, it was observed that additional investment on MOP fertilizer to mustard gave ten times more return. Mustard is grown on 1.15 lakh ha in the region with an average yield of 1700 kg/ha. There is scope to enhance yield level up to 2100 kg/ha. Strip cropping of pearl millet + cluster bean (4:4) gave pearl millet equivalent yield of 2587 kg/ha (1040 kg pearl millet + 555 kg cluster bean) with an advantage of 29.4% yield over farmers practices (2000 kg/ha) and additional yield of 600 kg/ha with extra net income of Rs. 4000/ha, with BC ratio of 2.54.