Overview of Dryland Agriculture Research and Achievements in Low Altitude Sub-Tropical Zone of Jammu and Kashmir

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Brief history of the Centre

The All India Coordinated Research Project for Dryland Agriculture centre was initiated at Samba in 1970-71. In 1977 it was shifted to its present location at Rakh Dhiansar. The AICRPDA sub-centre came under the control of SKUAST-J&K in 1982 and after establishing a separate Agricultural University for the Jammu region, centre has since operated under the reigns of Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu (SKUAST-Jammu) in 1999. The AICRPDA, Rakh Dhiansar sub-centre is situated at a latitude of 32° 39' North and longitude of 74° 53' East at an elevation of 332 m above mean sea level. The location of the center represents the true *Kandi* (sub-montane) belt and comprising parts of Samba, Jammu, Kathua and Udhampur districts of Jammu province.

Agro-climatic zone characteristics

The plains and outer hills of lower Himalayas in Jammu province (Jammu, Samba, parts of Kathua, Reasi and Udhampur districts) are grouped in sub tropical zone. The altitude ranges from 215 to 360 m above MSL. The area under this region represents fringes of level lands, in continuation with the Punjab state plains and touches the Jammu hills. The climate of the zone is humid sub tropical. The mean annual rainfall of the zone is 1156.5 mm out of which 75 to 80% rainfall is received during South-West monsoon. The normal onset of monsoon is 27th June + 7 days and the normal withdrawal is experienced during third week of September. The mean annual rainfall of the zone (1156.5 mm) is received in 53 rainy days. The average seasonal rainfall during *kharif* (June-September) is 866.0 mm and the average seasonal rainfall during *rabi* (October-April) is 290.5 mm. In the recent past, the domain area has experienced dryspells during the month of September (36 SMW to 48 SMW) due to early cessation of monsoon which coincided with the grain filling/maturity stage of *kharif* crops (terminal drought). This dryspell usually extends upto November (36 SMW to 48 SMW) due to the late receipt of winter rains which result in delayed sowing of *rabi* crops. The average maximum and minimum temperatures during *kharif* crop season is 34.8 ^{0}C (22 SMW to 26 SMW) and 23.7 ^{0}C while during *rabi* season is 24.4 ^{0}C and 10.5 ^{0}C (01 SMW to 05 SMW), respectively. June is the hottest and January remains the coldest month. With respect to shifts in climate within the agro-climatic zone, it is being observed that there is a small shift in the onset of monsoon beyond normal (27th June + 7 days) and similarly, a shift is also being observed in winter rains received through Western Disturbances (WD) from October/November to December/ January.

Mean seasonal and annual rainfall and rainy days (at AICRPDA centre, Rakh Dhiansar)

Rainfall	Normal rainfall (cm)	Rainy days (No.)
South west monsoon (June-September)	866.0	34
North east monsoon (October- December)	62.9	3
Winter (January- February)	97.3	7
Summer (March-May)	130.3	9
Annual	1156.5	53

Major soil types

The major soil types in the agro climatic zone is categorized into 6 major groups:

1). Brown forest soils are in parts of Kathua, Udhampur, Doda, Poonch, Rajouri, Districts; 2). Degraded or grey brown podzolic soils occur in parts of Baderwah, Ramnagar and Poonch districts ; 3). Red and yellow podzolic soils occur in parts of Udhampur, Kathua, Rajouri and Poonch; 4). Hill or mountain forest soils are sandy loam to loamy in texture. They occur at lower elevations and have 32-41% water holding capacity. 5). Lithosols occur on steep slopes in the forest hills of 400 to 600 meters above sea level in Jammu, Udhampur, Kathua, Rajouri, and Poonch districts. They belong to great group Ustorthents and 6). Alluvial soils cover plains of Kathua, Jammu Rajouri, Poonch, Udhampur districts. They are situated in the flood plains of Ravi and Chenab rivers and their tributaries.

Major crops

The major rainfed crops cultivated in the zone during *kharif* are maize, blackgram, greengram, cowpea, pearl millet and sesame, during *rabi* are wheat, mustard, gobhi sarson, chickpea, lentil and barley.

Dryland agriculture problems

Soil and land related

- Moderate to severe erosion
- Undulating topography with number of ravines and gullies
- Soils are low to medium in organic matter
- Problems of water logging , salinity and alkalinity

Cropping systems related

- Predominantly mono cropping
- Lack of knowledge on intercropping systems

Socio-economic factors

- Small and marginal land holdings and continued fragmentation
- Changes in land use to other non-agricultural purposes
- Poor resource availability
- Poor farm mechanization

Significant achievements

Rainwater management

- Sowing across the slope
- Compartmental bunding
- Repeated interculture to remove weeds and create soil mulch to conserve soil moisture.
- Remove lower leaves and use them as mulch during the terminal drought.
- Opening of conservation furrows at 30-35 DAS for moisture conservation.
- Continuous trenching for retaining the soil moisture for longer period of time, thereby enhanced the yield compared to farmers practices.
- Highest grain yield of maize (1978 kg/ha) was obtained with two life-saving irrigations at critical stage as compared to farmers' practice of without irrigation (1533 kg/ha). Highest B: C ratio (2.03), highest RWUE (3.11 kg/ha/mm), highest net returns Rs. 20110/ha was observed.

Cropping systems

- Maize + cowpea: Planting of two rows of cowpea as an intercrop in paired rows of maize in additive series wherein maize is sown at 60 cm row spacing and cowpea at 20 cm row distance without compromising the maize plant population for higher productivity in maize based intercropping system while coping with aberrant weather conditions.
- Maize + cowpea: Significantly highest maize grain yield was obtained in treatment with broad bed furrow (BBF) + mulching with *Dhaincha* to the tune of 3281 kg/ha with net returns, B:C and RWUE of Rs.38905, 2.61 and 5.19 kg ha^{-1} mm^{-1}, respectively.
- Maize + blackgram: Significantly highest maize equivalent yield was obtained when blackgram was intercropped with maize 1:1 ratio (additive series) with maize grown at row spacing of 75 cm.

Nutrient management practices

- Application of integrated use of inorganic and organic fertilizers, *i.e.*, FYM 10 t/ha + 40 N kg/ha and *Leucaena leucocephala* (*Subabul)* leaves 5 t/ha + 40 kg N/ha proved to be the best if the organics are applied in the soil about 2 weeks before sowing of maize crop in maize-wheat cropping sequence.
- Application of integrated use of inorganic and organic fertilizers, *i.e.*, 50% Recommended NPK + 50% N (FYM) and 50% Rec. NPK + 50% N (crop residues) and the organics are to be applied in the soil about 2 weeks before sowing of maize crop under cereal-oilseed system. There is a pronounced residual effect of the organics in the succeeding gobhi sarson crop.
- Application of 75% N (inorganic) +25% N vermicompost recorded highest pearl millet mean grain yield of 2637 kg/ha with 70% increase over control.
- Combined foliar spray of 0.5% N (through urea) and 0.5% K (through KCl) with RDF (N: P_2O_5: K_2O (60:30:20)) is recommended for obtaining highest grain and straw yield in wheat.

Tillage and nutrient management practices

- Treatment with 50% conventional tillage + herbicide (atrazine @ 1.5 kg/ha) + interculture operations along with 100% inorganic fertilizer (N: P_2O_5:K_2O (60:40:20)) results in increasing the grain yield in maize as compared to farmers' practice (conventional tillage + two hand weeding with *khurpi* + no herbicide + use of N and P only).

Agroforestry systems

- Growing mixed fodder (maize + cowpea + pearl millet) in the alleys of *Leucaena leucocephala* is found to be remunerative as this land use system recorded higher maize equivalent yield (MEY), sustainable yield index (SYI) and rain water use efficiency (RWUE) as compared to other land use systems in the rainfed sub-tropics of lower *Shiwalik* foothills of Jammu and Kashmir.
- The maize crop recorded grain yield of 2595 kg/ha in treatment Agri-horti-silvi-pastoral System (Guava + *Melia* + *Setaria* Spp.+ Maize- Gobhi sarson) wherein the maize crop was sown in the alleys formed by Horti-Silvi-Pastoral component. However in *rabi*, the wheat crop recorded grain yield of 4226 kg/ha in treatment Agri-Horti-Silvi-Pastoral system (Guava + *Melia* + *Setaria* Spp.+ Black gram - wheat) wherein the wheat crop was sown in the alleys formed by Horti-Silvi-Pastoral component.

Technologies developed

Rainwater management

- Induction of drought tolerance in chickpea (*Cicer arietinum*) under receding moisture conditions
- *In-situ* moisture conservation in maize under rainfed conditions
- Surface mulch using cowpea straw for higher moisture conservation and yield in wheat
- Mulching with *Adhatoda vasica* along with FYM for moisture conservation and higher grain yield in wheat
- Mulching with *Adhatoda vasica* for moisture conservation and higher grain yield in maize
- Mulching with *sarson* trash for moisture conservation and higher grain yield in wheat
- Application of NPK (60:40:20) along with one life saving irrigation to relieve moisture stress at critical stages for higher yield in maize
- *In-situ* moisture conservation through continuous trenching method for higher yield in Maize-wheat cropping system under rainfed conditions

Cropping system

Inter-cropping systems

- Maize + blackgram (1:1)
- Maize + greengram (1:1)
- Maize + cowpea (1:1)

b. Double/triple cropping systems

- Maize-wheat
- Maize-gobhi sarson
- Black gram-wheat
- Sesame-chickpea

Nutrient management

Integrated nutrient management practices

Crop	INM Practice
Maize	50 % NPK (30:20:10) through inorganic sources through urea, DAP and MOP + 50 % N through organic source i.e. FYM @ 10 t/ha which should be applied one month before sowing. FYM @ 10 t/ha + 40 kg N/ha through urea + recommended P and K (40 kg/ha and 20 kg/ha, respectively) should be applied in maize. Well decomposed FYM @ 10 t/ha should be incorporated into the soil thoroughly at the time of first ploughing. The entire quantity of inorganic fertilizers i.e. recommended DAP and MOP for supplying P (40 kg/ha) and K (20 kg/ha), respectively and 2/3rd of N (40 kg/ha) through urea should be drilled at the time of sowing as basal dose. Remaining quantity of nitrogen should be top dressed in two equal splits i.e. 1st at knee high stage of maize crop (30 days after sowing) and 2nd at just before tassel formation (about 60 days after sowing).
Pearl millet	Application of 75% N through inorganic fertilizers + 25% N through vermicompost (37.5 kg N through Urea + 12.5 kg N through vermicompost/ha) along with P and K as per recommended dose (30 kg/ha and 15 kg/ha) through DAP and MOP. Half dose of nitrogen and full dose of phosphorus and potash should be applied as basal dose at the time of sowing and remaining half dose of nitrogen is to be top dressed at 40 DAS. Vermicompost should be incorporated on equivalent dose of nitrogen one week before sowing of pearl millet.

Foliar nutrition

- In maize, water soluble complex fertilizer (19:19:19) @ 0.5 %+ recommended dose of Zinc should be applied to relieve moisture stress caused by dry spells during mid crop season.
- In wheat, combined foliar spray of 0.5% K solution in water through KCl + foliar spray of 0.5% N solution in water through urea during dry spell at critical crop growth stage. The entire quantity of inorganic fertilizers i.e. recommended DAP and MOP for supplying P (30 kg/ha) and K (20 kg/ha), respectively and 2/3rd of N @ 40 kg/ha though urea should be drilled at the time of sowing as basal dose. Remaining quantity of N should be top dressed in two equal splits i.e. 1st at active tillering stage of wheat (30-35 DAS) and 2nd at 10 days before ear head emergence (65-70 DAS).

Energy management

- Two ploughings along with interculture operations for higher grain production in wheat
- Double end hoe for interculture in maize under dryland condition.
- Tractor operated seed cum fertilizer drill for higher grain yield in wheat
- Application of 50% N through FYM and 50% N through inorganic fertilizers along with 50% C.T.+ herbicide + interculture for obtaining higher yield in maize-wheat cropping system
- Line seeding of wheat using seed-cum fertilizer drill in rainfed conditions
- Line sowing of maize using maize planter in rainfed conditions
- Wheel hand hoe for interculture operations in maize-wheat cropping system

Alternate land use/Agroforestry

- Maize (grown in alleys) with *Leucaena* under alternate land use system for higher production of maize and tree fodder in rainfed conditions of Jammu

- Wheat (grown in alleys) with guava under alternate land use system for higher production of wheat
- Agri-silvi-pastoral system (*Leucaena leucocephala* + mixed fodder (*local maize* + *sorghum* + *bajra* + *cowpea*)) in *kharif* and wheat in *rabi* for higher green fodder, fuel wood and wheat grain yield in *kandi* region of Jammu
- Aonla + maize fodder (*Kharif*) and gobhi sarson (*rabi*) based Agri-Horti system under rainfed conditions of Jammu

Contingency crop planning

For *kharif* planning

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

Delay by 2 weeks (21st July onwards)

- Maize - Kanchan-517 (Hy), Kanchan-612 (Hy), Kanchan-517 Gold (Hy), Double dekalb (Hy), JMC 3 (C), Mansar (C)
- Pearl millet: Composite: Pusa composite 383, Pusa composite 701; Hybrids: GHB-744, GHB-732, HHB-223, Nandi 65
- Greengram: PDM-54, ML- 818, SML 668, PDM 139, IPM-2-3
- Blackgram: Pant U-31, Uttara, Mash-338
- Cowpea: PL 1, PL 2
- Sesame (Til) Punjab Til No 2, RT 351, RT 346
- Intercropping of maize + blackgram/greengram/cowpea (1:1)
- Maize (Double dekalb/ Kanchan-517) + blackgram (Pant U-31/ Uttara),
- Maize (Double dekalb/ Kanchan-517) + greengram (PDM-54/ IPM-2-3/ ML-818)
- Intercropping of Pearl millet + cowpea/ blackgram/ greengram (1:1)
- Pearl millet (Pusa composite 383/ Pusa composite 701/ GHB-744/ HHB-223/ Nandi 65) + cowpea (Dhiansar local/ lobia super 60),
- Pearl millet (Pusa composite 383/ Pusa composite 701/ GHB-744/ GHB-732/ HHB-223/ Nandi 65) + blackgram (Pant U-31/ Uttara),
- Pearl millet (Pusa composite 383/ Pusa composite 701/ GHB-732/ HHB-223/ Nandi 65) + greengram (PDM-54/ IPM-2-3/ ML-818)

Delay by 4 weeks (04th August onwards)

- Maize (fodder) - African tall
- Pearl millet - Composite: Pusa composite 383, Pusa composite 701; Hybrids: GHB-744, GHB-732, HHB-223, Nandi 65
- Sesame (Til) - Punjab Til No 2, RT 351, RT 346
- Intercropping of maize (fodder) + cowpea (1:1) for fodder purpose
- Maize fodder (African tall, Vijay composite/Jawahar) + Cowpea (Dhiansar local/lobia super 60)
- Intercropping of sorghum (fodder) + cowpea (1:1) for fodder purpose
- Sorghum fodder (PC 6/PC 9/UP Chari 1/Raj. Chari 1) + cowpea (Dhiansar local/lobia super 60)
- Intercropping of Pearl millet + cowpea/ blackgram/ greengram (1:1)
- Pearl millet (Pusa composite 383/ Pusa composite 701/ GHB-744/ HHB-223/ Nandi 65) + cowpea (Dhiansar local/ lobia super 60)
- Intercropping of Sesame + blackgram (1:1)
- Sesame (Punjab Til No 2/ RT 351/ RT 346) + blackgram (Pant U-31/Uttara)

Delay by 6 weeks (18th August onwards)

- Maize (fodder)
- African tall, Vijay composite/Jawahar
- Intercropping of maize (fodder) + cowpea (1:1) for fodder purpose
- Maize fodder (African tall/ Vijay composite/Jawahar) + Cowpea (UPC 287/Bundel lobia 1)
- Intercropping of sorghum (fodder) + cowpea (1:1) for fodder purpose
- Sorghum fodder (PC 6/PC 9/UP Chari 1/Raj. Chari 1) + Cowpea (UPC 287/Bundel lobia 1)
- Intercropping of Pearl millet + cowpea (1:1)
- Pearl millet (Pusa composite 383/ Pusa composite 701/ GHB-744/ HHB-223/ Nandi 65) + cowpea (UPC 287/ Bundel lobia 1)

Delay by 8 weeks (04th September onwards)

- *Toria* -RSPT-2, RSPT-6
- Intercropping of maize/ sorghum/pearlmillet + cowpea (for fodder)
- Maize (African tall/ Vijay composite) + cowpea (UPC 287/ Bundel lobia 1)
- Sorghum (PC 6/PC 9/UP Chari 1) + cowpea (UPC 287/ Bundel lobia 1)
- Pearlmillet (Pusa composite 383/ Pusa composite 701/ GHB-744) + cowpea (UPC 287/Bundel lobia 1)

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

Early season drought

- Reduction of plant population (thinning)

- For achieving the optimum plant population in crust prone areas, amendments like *Adhatoda vasica* leaves, FYM, cowpea straw (1 cm thick layer) may be used on the sown rows.
- Compartmental bunding is done to conserve the water.
- Gap filling when 15-20% of the total plant stands is poorly established.
- Resowing on receipt of subsequent rains if germination is less than 30% from the optimal plant stand.
- Interculture (dust mulch) to break soil crust and to remove weeds to conserve soil moisture.

Mid season drought

- Reduce plant population (thinning) by 25% by uprooting weak plants to overcome moisture stress and use them as mulch/fodder.
- Weeds after removal should be used as mulch.
- Apply life saving irrigation (if available).
- Conserve soil moisture by using locally available mulch materials.
- Foliar spray of 0.5% N through Urea + 0.5% K through KCl after dry spells to relieve stress.
- Opening of conservation furrows at 30-35 DAS for moisture conservation.
- Repeated interculture to remove weeds and create soil mulch to conserve soil moisture.
- Supplemental/protective irrigation from harvested water wherever possible.
- Foliar spray of 2% urea solution or 1% water soluble fertilizers like 19-19-19 to supplement nutrition and to relieve stress during dry spells.
- Surface mulching with locally available organic mulch materials.
- Dust mulch to break soil crust and to remove weeds to conserve soil moisture.

Terminal drought

- Provide life saving irrigation, if available.
- Harvest the crop on physiological maturity.
- Maize to be harvested green for fodder purpose.
- Residual moisture of receding monsoon rains should be conserved *in-situ* through tillage practices.
- Life-saving or supplemental irrigation wherever available from harvested water.
- Harvest maize crop at physiological maturity as green cobs and use the maize stocks as green stover for fodder purpose.
- Sowing of contingent crop (Toria) on receipt of rains and/or under receding soil moisture conditions.

For *rabi* planning

Suggested crops and varieties for delayed season (3rd week of November and onwards)

- Wheat -WH-1080, JAUW-598
- Gobhi sarson - DGS 1, RSPL 25
- Chickpea - GNG 1581, RSG 963
- Barley- Kailash, PL 56
- Lentil - VL 125, PL 639, PL 406

Agri-horti system/Dryland horticulture technology

Alternate land use systems	Crops/horticultural plants/ agroforestry trees/grasses
Agri-Horti-Silvi-Pastoral System	Guava + *Melia* + *Setaria* Spp.+ Maize-Wheat
Agri-Horti-Silvi-Pastoral System	Guava + *Melia* + *Setaria* Spp.+ Maize-Gobhi Sarson
Agri-Horti-Silvi-Pastoral System	Guava + *Melia* + *Setaria* Spp.+Black gram-Wheat
Agri-Horti-Silvi-Pastoral System	Guava + *Melia* + *Setaria* Spp.+ Blackgram-Gobhi Sarson

Horticultural plants/agroforestry trees: 6 m × 6 m (square planting) spacing for Guava and *Melia* and should be planted alternatively within each row.

Management practices

- During *kharif*, under horti-silvi-pastoral system components viz., Guava Var. *L-49* -*Melia* Spp - *Setaria* Spp. may be taken to rainfed conditions of Jammu. However, maize and blackgram should be sown in the alleys formed by horti-silvi-pastoral components. The maize and blackgram sown in the alleys should be given 60:40:20 and 16:40:0 kg N, P and K/ha, respectively.
- During *rabi*, wheat and gobhi sarson may be taken as alley crops under horti-silvi-pastoral system with 100:50:25 and 50:30:15 kg N, P and K/ha, respectively.
- Conservation furrows should be created along side of the tree rows to drain the field runoff and store it in the furrows for long retention of soil moisture and its utilization by the Guava, *Melia* and *Setaria* grass.

Technologies upscaled in convergence with various programmes

The research technologies recommended for inclusion in the package of practices of SKUAST-Jammu were discussed during the Zonal Research and Extension Advisory Committee meeting (ZREAC) from time to time with the officers such as Director of Agriculture and allied departments for their further dissemination amongst the farmers of domain area by way of integrating the same into State/District Action Plans.

Impact of technologies

The higher maize yield was obtained in continuous trenching method of *in-situ* moisture conservation followed by strip trenching method. The maximum B:C ratio of 2.42 was obtained in continuous trenching method in maize while maximum B:C ratio of 3.08 in wheat. Higher maize equivalent yield (MEY) was obtained in paired rows of maize with 2 rows of cowpea (2610 kg/ha) with mean LER values of 1.23 and highest RWUE as well as B:C ratio values of 3.40 kg/ha-mm and 1.83, respectively. Planting two rows of cowpea as intercrop in paired rows of maize in additive series. Intercropping of cowpea with maize is gaining popularity among the rainfed farmers of the *kandi* region of Jammu. This technology has been adopted by more than 70 farmers with a horizontal spread over an area of about 4.5 ha area. Sowing of maize using maize planter resulted in maximum benefit cost ratio of 2.59 followed by line sowing with liner and broadcasting with B:C ratio of 2.10 and 2.01, respectively. The technology has been extensively demonstrated in the farmer's fields. Sowing of wheat by Seed cum fertilizer drill (improved practice) resulted in maximum benefit cost ratio of 3.19 followed by line sowing with liner and sowing by broadcasting (farmers' practice) with B:C ratio of 2.57 and 2.34, respectively. The technology has been extensively demonstrated in the farmer's fields. Among the alternate land use system, mixed fodder-gobhi sarson grown in the alleys of aonla trees under agri-horti-pastoral system followed by mixed fodder-wheat grown in the alleys of *Leucaena* trees under agri- silvi-pastoral system were found to be most remunerative systems as compared to all other systems. The technology has been demonstrated at farmer's field and appreciated by the farmers.

Way forward

The AICRPDA, Rakh Dhiansar Center will focus on mitigating land degradation by adopting practices that improve soil health, sustainable water management and promoting diversified sustainable production systems that are suited for the agro-ecosystems and promoting a holistic approach to risk reduction and climate resilience of farms and landscape. Evaluation of suitable varieties of millets, legumes, oilseeds, dryland medicinal and horticultural crops will contribute to efficient and successful crop production. More focus would be on development of integrated farming systems (IFS), which synergistically integrate two or more enterprises (crops, horticultural crops, livestock, poultry, apiculture, and mushroom cultivation) that can offer improved income, resilience, and soil carbon sequestration potential.