

Efficient intercropping

systems for diverse rainfed agro-ecologies

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Rainfed agriculture is challenged by many abiotic and biotic stresses besides socio-economic factors. Farmers in rainfed areas traditionally cultivate mixed crops. Crop diversification with intercropping in rainfed crop-based production systems is one strategy to increase system productivity and profitability per unit area. Further, intercropping in rainfed production systems reduce the risk of crop failures due to agricultural drought. The network centres of All India Coordinated Research project for Dryland Agriculture developed agro-ecology specific risk resilient and efficient intercropping systems which can be scaled out in convergence with central and state government, and district level programmes.

Keywords: Intercropping systems, Productivity, Rainfed Agriculture, Risk resilience

CROP diversification is practiced in dryland areas to reduce the risk factor of crop failures due to recurring droughts. Crop substitution and crop shift are also taking place in areas with specific soil related problems. It also provides better conditions for food security and enable farmers to grow surplus products for sale at market and thus, help them obtain increased income to meet other needs related to household well-being. Diversifying from the monoculture of traditional staples can have important nutritional benefits for farmers in developing countries and can support a country for becoming more self-reliant in terms of food production. It can also manage price risk on the assumption that all products may not suffer from low market prices at the same time and increase the profitability of the farming community.

Intercropping, where alternative crops or non-crop plants are incorporated alongside major rainfed crops, is one of the simplest ways to diversify rainfed agriculture. It can be employed in varying spatial configurations. Various types of complementary intercrops can efficiently utilize space, water and nutrients, smother weeds, improve natural suppression of pests, and enhance overall crop productivity relative to conventional crop monocultures, which often require more chemical inputs and fossil fuel consumption than diversified fields. The performance of the intercropping systems is strongly correlated with the amount of seasonal rainfall, when it is above normal, optimum

productivity can be achieved; under normal rainfall conditions, fairly high values of land equivalent ratios can be achieved; and under low rainfall conditions, one of the two crops reasonably yielded provides an insurance against the risk due to weather aberrations. Further, the intercropping systems over the years and across locations in India proved that rainy (*kharif*) season is more favourable to intercropping than winter (*rabi*), probably due to replenishment of soil moisture. Ecological intensification with tools like intercrops is necessary to boost food production for growing global populations while simultaneously enhancing crop protection, improving resilience to climate change and reducing the carbon footprint of agriculture.

The network centres of All India Coordinated Research Project for Dryland Agriculture (AICRPDA) have been developing agro-ecology specific, efficient and risk resilient intercropping systems keeping in view of the changing cropping patterns, natural resources, climate variability and socioeconomic factors in the centres' domain agro-climatic zones (Table 1).

Rainfed cereal crops based intercropping systems

Cereal-legume intercropping promotes ecological intensification while ensuring quantitative dry matter yield equivalent to that produced by the same two pure crops and increases protein yield and reduces nitrogen requirement. The symbiotic relationship between the legume and the bacteria housed in the nodes of its root

Table 1. State-wise and AICRPDA centre wise recommendation domain for scaling out of agro-ecology specific intercropping systems

State	AICRPDA centre	Recommendation domain: Agroclimatic zone/Climate/Soil type/Districts
Assam	Biswanath Chariali	North bank plains zone/humid (Hot)/Alfisols; Dhemaji, Lakhimpur, Biswanath, Sonitpur, Darrang and Udalguri districts
Andhra Pradesh	Anantapuramu	Scarcity zone/Semi-arid/Arid (Hot)/Alfisols; Ananthapuramu, Kurnool, YSR Kadapa and Chittoor districts
	Darsi	Krishna zone/Semi-arid/Alfisols; Prakasham district
Bihar	Munger	South Bihar alluvial plain zone/sub-humid/Inceptisols
Chhattisgarh	Jagdalpur	Bastar plateau zone/sub-humid (hot moist)/Inceptisols; Bastar, Narayanpur, Kondagaon, Bijapur, Sukma, Dantewada and Kanker districts
Gujarat	Rajkot	North Saurashtra zone/semi-arid (hot dry)/Vertisols; Jamnagar, Devbhoomi Dwarka Morbi, Surendranagar, Amreli, Bhavnagar, and Rajkot districts
	S K Nagar	Northern Gujarat/semi-arid/arid (hot dry)/Entisols; Banaskantha, Aravali, Sabarkantha, Patan, Mehsana, Gandhinagar and Kachchh districts
Haryana	Hisar	South western dry zone/arid (Hyper)/Inceptisols; Sirsa, Fatehabad, Hisar, Bhiwani, Mahendergarh, Rewari, Jhajjar, Nuh, Palwal, Jind, Gurugram and Panchkula districts
Jammu	Rakh Dhiansar	Low altitude sub-tropical zone/semi-arid (Moist dry)/Inceptisols; Jammu, Samba, Kathua, Udhampur and Rajouri districts
Jharkhand	Chianki	Western plateau zone/sub-humid (hot moist)/Inceptisols; Palamu, Garhwa, Latehar, Chatra, Lohardaga, Gumla and Simdega districts
Karnataka	Bengaluru	Eastern, southern and central dry zones/semi-arid (hot moist)/Alfisols; Mysore, Tumkur, Kolar, Ramanagara, Bengaluru (Rural and Urban), Chamarajanagar, Hassan, Chikkaballapur and Mandya districts
	Vijayapura	Northern dry zone/semi-arid (hot dry)/Vertisols; Vijayapura, Bagalkote, Gadag, Bellary, Koppal, parts of dharwad, Belagavi and Raichur districts
Maharashtra	Akola	Central Maharashtra plateau zone/semi-arid (hot moist)/Vertisols; Akola, Washim, Buldana, Yavatmal, Amravati, Wardha and of Nagpur districts
	Parbhani	Central Maharashtra plateau zone/semi-arid (hot moist)/Vertisols; Parbhani, Hingoli, Nanded, Beed, Latur Osmanabad, Aurangabad and Jalna districts
	Solapur	Scarcity zone/semi-arid (hot dry)/Vertisols; Solapur, Ahmednager, Sangli, Pune, Dhule, Jalgoan, Nandurbar, Satara districts
Madhya Pradesh	Indore	Malwa zone/semi-arid (hot moist) Vertisols; Mandsaur, Ratlam, Ujjain, Rajgarh, Shajapur, Indore, Dewas, Dhar, Jhabua and Sehore districts
	Rewa	Keymore plateau and satpura hill zone/sub-humid (hot dry)/Vertisols; Rewa, Sidhi, Singroli, Satna, Panna, Katni, Jabalpur and Seoni districts
Odisha	Phulbani	Northeastern ghat zone/sub-humid (hot moist)/Inceptisols; Kandhamal, Gajapati, Rayagada, Ganjam, and parts of Koraput districts
Punjab	Ballawal Saunkhri	Kandi region/sub-humid (hot dry)/Inceptisols; Roopnagar, Hoshiarpur, Shaheed Bhagat Singh Nagar, Pathankot, Sahibzada Ajit Singh Nagar districts
Rajasthan	Arjia	Southern zone/semi-arid (hot dry)/Vertisols; Bhilwara, Chittaurgarh, Rajsamand, Udaipur and part of Sirohi districts
Tamil Nadu	Kovilpatti	Southern zone/semi-arid (hot dry); Thoothukudi, Tirunelveli, Madurai, Tenkasi and Virudhnagar districts
Telangana	Adilabad	Northern Telangana zone/sub-humid (hot moist)/Vertisols; Adilabad, Nizamabad, Asifabad, Mancherla, Nirmal, Kamareddy, Jagtial districts
Uttar Pradesh	Agra	South-western semi-arid zone/semi-arid (hot dry)/Inceptisols; Agra, Mathura, Mainpuri, Aligarh, Hathras, Firozabad, Etah and Kanshiram Nagar districts
	Faizabad	North eastern plain zone/sub-humid (hot dry)/ Inceptisols; Faizabad, Sultanpur, Basti, Gonda, Ambedkar nagar districts
	Varanasi	Eastern plain and Vindhayan zone/sub-humid (hot dry)/ Inceptisols; Varanasi, Chandauli, Sant Ravidas Nagar, Jaunpur, Ghazipur, Mirzapur and Sonbhadra districts

system enables the plant to fix atmospheric nitrogen, thereby allowing it to meet its nitrogen nutrient requirements. Thus, the intercropping meets the need to reduce chemical inputs (fertilizers and phyto sanitary products).

Intercropping system with legume such as black gram, green gram, chickpea and even ridge gourd

in maize could simultaneously reduce N fertilizer. Intercropping of rice and other compatible crops is also widely practised in rainfed areas of India. Rainfed rice-based intercropping cropping system includes pulses, oilseeds, green manures, vegetable, etc. Rice based cropping systems may include lowland and upland crops. So far, most people have been focussing on

individual crops disregarding the fact that each crop is only a component of a cropping system. In rice growing areas, several crop combinations (cropping systems) are in practice based on agro-ecological conditions, market and domestic needs and facilities available with farmers.

Millet is an important staple food crop to the millions of people in the arid and semi-arid regions of the world due to their greater resistance to pests and diseases, good adaption to a wide range of environment and good yielding capacity. They can withstand significant levels of salinity, short-growing season, resistant to water logging, drought tolerant, require little inputs during growth. Among the millets, finger millet known as 'ragi' or 'chodi' is an important crop in India and is a dryland crop cultivated in both tropical and subtropical regions (Karnataka, Andhra Pradesh, Tamil Nadu and Kerala). Finger millet can survive with 28% of paddy's water needs. They are better adapted for current and

future droughts and provides food security to poor people. Growing only millets is not much remunerative in the present scenario of agriculture to fulfil the diverse demand of consumers and rapidly growing population. Hence, there is an urgent need of inclusion of the legumes and vegetables in millet based cropping systems. Initial slow growth of finger millet will facilitate the better establishment of intercrops. Moreover growing of intercrops will suppress the unwanted weed growth and produce greater output from unit area than sole crop. The better quality of cereal produced in intercropping with legume can also have economic benefits for farmers by increasing the protein rate (Table 2).

Rainfed pulse crops based intercropping systems

More than 70% area of pulses in India is covered under intercropping systems. Pulses are intercropped with oil seeds, cereals, coarse grains and commercial crops. Pigeonpea is also inter/mixed cropped with short growing grain legumes. Having deeper and more

Table 2. Some best rainfed cereal crops based intercropping systems

State	AICRPDA centre/Major Rainfed Crop based Production system	Efficient Intercropping systems
Assam	Biswanath Chariali/ rainfed Rice	Oat + pea; Oat + khesari; Maize + pea/khesari/cowpea/rice bean; Teosinte + cowpea/rice bean
Chhattisgarh	Jagdalpur/rainfed Rice	Upland rice + pigeonpea (8:1); Finger millet + pigeonpea (6:1); Maize + pigeonpea (4:1); Maize + cowpea (4:1); Maize + okra (4:1)
Gujarat	S.K.Nagar	Pearlmillet + sunnhemp (4:2)
Haryana	Hisar/Pearlmillet	Pearlmillet + greengram/clusterbean/cowpea (8:4)
Jammu	Rakh Dhiansar/Maize	Maize + blackgram/greengram/cowpea (1:1)
Karnataka	Bengaluru/Finger millet	Finger millet + pigeonpea (8:2); Maize + pigeonpea (4:1)
	Raichur/Rabi sorghum	Rabi sorghum + chickpea (2:1)
	Vijayapura/Rabi sorghum	Pearlmillet + pigeonpea/castor (2:1); Pearlmillet + bunch groundnut (4:2); Sorghum + chickpea (2:1); Foxtail millet + niger (2:4)
Maharashtra	Akola/Cotton	Pearlmillet + pigeonpea (1:1)
	Parbhani/Cotton	Sorghum + pigeonpea (4:2); Maize + soybean (2:2); Maize + greengram (1:1)
	Solapur/Rabi sorghum	Sorghum + cowpea (4:4 and 6:6); Pearlmillet + sunflower (2:1 or 2:2)
Madhya Pradesh	Indore/Soybean	Maize + soybean (2:4)
	Rewa/Soybean	Wheat + chickpea (2:1)
Odisha	Phulbani/rainfed Rice	Maize + cowpea/pigeonpea/runner bean (2:2); Maize + bitter gourd/cucumber/ridge gourd (2:1)
Punjab	Ballawal Saunkhri/Maize	Maize and cowpea strip-intercropping with maize strip 4.8 m and cowpea strip width 1.2 m; Maize and mash strip-intercropping with maize strip 6.0 m and mash strip width 2.4 m wheat + mustard/chickpea (6:1)
Rajasthan	Arjia/Maize	Maize + blackgram (2 :2); Maize + pigeonpea/castor (1:1); Sorghum + greengram (2:1)
Tamil Nadu	Kovilpatti/Cotton	Maize + blackgram (2:1); Sorghum + cowpea/greengram/blackgram (2:1); Pearlmillet + blackgram
Uttar Pradesh	Agra/Pearlmillet	Pearlmillet + pigeonpea/greengram/blackgram (2:1)
	Varanasi/Rice	Maize+blackgram (1:2); Maize + okra (1:1)

Note: Recommendation of the above intercropping systems is given in Table 1.



Maize + blackgram (2:2) - Arjia

abundant roots, pulse crops can utilize greater amounts of water, stored deep within the soil and can withstand drought better than shallow-rooted crops (Table 3).

Rainfed oilseed crops based intercropping systems

Oilseeds are typically intercropped with legumes such as pigeonpea, cowpea and lentils. It is thought that the legumes furnish nitrogen to the oilseed crops while the oilseed crops compete with weeds and use moisture not readily accessible to legumes. Additionally, there appear to be beneficial shifts in insect ecology and soil microbial populations. Some of the best intercropping systems worked well and proved better are given in Table 4.

Table 3. Some best rainfed pulse crops based intercropping systems

State	AICRPDA centre/Major rainfed crop based production system	Efficient intercropping systems
Assam	Biswanath Chariali/ rainfed Rice	Pigeonpea + ginger/turmeric; Cowpea/maize (fodder) + soybean/toria; Pigeonpea + Sesamum/blackgram/greengram; Pea (grain) + oat (fodder); Lentil + oat (fodder)
Gujarat	S K Nagar/ Pearlmillet	Greengram + castor as a relay crop (2:1)
Haryana	Hisar/Pearlmillet	Moth bean paired row 30:60 cm + 1 row of cluster bean
Jharkhand	Chianki/rainfed Rice	Pigeonpea + okra/maize/sorghum (1:1); Pigeonpea + groundnut (1:2); Chickpea + linseed (4:2); Chickpea + safflower (2:1)
Karnataka	Bengaluru/Finger millet Vijayapura/Rabi sorghum	Pigeonpea + field bean/cowpea (1:1) Pigeonpea + bunch groundnut (4:2)
Maharashtra	Parbhani/Cotton Solapur/Rabi sorghum	Pigeonpea + Sesamum (2:4) Pigeonpea + sunflower/pearl millet (1:2); Pigeonpea + soybean (2:4 or 1:6); Pigeonpea + blackgram/greengram/bajara fodder (1:3); Sorghum + cowpea (4:4 and 6:6); Chickpea + Safflower (2:4)
Madhya Pradesh	Rewa/Soybean	Chickpea + linseed (4:2)
Odisha	Phulbani/ Rainfed rice	Pigeonpea + radish (2:2)
Rajasthan	Arjia/Maize	Pigeonpea + groundnut (1:1); Chickpea + mustard (Intra cropping) across the sowing of chickpea at 2.7 m interval
Uttar Pradesh	Agra/Pearlmillet Faizabad/ rainfed rice Varanasi/ rainfed rice	Clusterbean + pearlmillet/sesame (6:1); Pigeonpea + greengram (2:2); Chickpea + mustard (4-5:1) Pigeonpea + maize/greengram/blackgram (1:1); Chickpea + mustard (4:2) Pigeonpea + rice/sesame/okra (1:1); Pigeonpea + blackgram (1:2); Chickpea + mustard (4:1); Chickpea + linseed (2:1)

Note: Recommendation of the above intercropping systems is given in Table 1.



Pigeonpea + cowpea (1:1)



Pigeonpea + field bean (1:1)

Table 4. Some major rainfed oilseed crops based intercropping systems

State	Agroclimatic zone/AICRPDA centre/ Major rainfed crop based production system	Efficient intercropping systems
Assam	Biswanath Chariali/rainfed Rice	Sesamum + blackgram (1:1)
Andhra Pradesh	Ananthapuramu/Groundnut	Groundnut + pigeonpea (8:1); Groundnut + castor (15:1)
Gujarat	Rajkot/Groundnut	Groundnut + castor (3:1); Groundnut + cotton (2:1); Castor + cowpea/greengram (1:1); Castor + greengram (2:1)
	S K Nagar/Pearlmillet	Castor + greengram/cowpea/clusterbean/sesame (1:1)
Haryana	Hisar/Pearlmillet	Castor paired 60:120 cm × 60 cm + 2 rows of blackgram; Castor paired 60:90 cm × 60 cm + 1 row of blackgram
Karnataka	Bengaluru/Finger millet	Groundnut + pigeonpea (8:2)
	Vijayapura/Rabi sorghum	Safflower + chickpea (2:4 or 1:3)
Maharashtra	Akola/Cotton	Soybean + pigeonpea (4:2)
	Parbhani/Cotton	Soybean + pigeon pea (4:2)
Madhya Pradesh	Indore/Soybean	Maize + soybean (2:4)
	Rewa/Soybean	Soybean + pigeonpea (4:2)
Punjab	Ballowal Saunkhri/Maize	Toria + <i>gobhi sarson</i> (1:1)
Rajasthan	Arjia/Maize	Castor + greengram (1:2)
Uttar Pradesh	Faizabad/rainfed Rice	Linseed + chickpea/lentil (2:4)
	Varanasi/rainfed Rice	Linseed + mustard (4/6:2)



Groundnut + castor (3:1)



Safflower + chickpea (2:4)



Soybean + pigeonpea (4:2)

Table 5. Rainfed cotton based intercropping systems

State	AICRPDA centre/Major rainfed crop based production system	Efficient intercropping systems
Gujarat	Rajkot/Groundnut	Cotton + sesame/cowpea/greengram/groundnut/cowpea
Maharashtra	Akola/Cotton	Cotton + greengram/cowpea/clusterbean (1:1); Cotton:soybean:pigeonpea:soybean (3:1:1:1)/(3:2:2:2)
	Parbhani/Cotton	Cotton + pigeonpea (6:1); Cotton + greengram (1:1)
Tamil Nadu	Kovilpatti/Cotton	Cotton + greengram/blackgram/radish/onion (1:2); Cotton + clusterbean (1:1)

Note: Recommendation of the above intercropping systems is given in Table 1.



Cotton + greengram (1:1)



Cotton:soybean:pigeonpea:soybean (3:2:2:2)

Strip cropping

Strip cropping is a method of farming which involves cultivating a field partitioned into long, narrow strips which are alternated in a crop rotation system. It is used when a slope is too steep or when there is no alternative method of preventing soil erosion. Strip cropping can improve crop yields by encouraging infiltration and thereby increasing soil moisture. It is one of the least costly measures available for farmers to reduce sheet and rill erosion. Intercropping is the cultivation of two or more crops simultaneously on the same field with a row arrangement whereas strip cropping is the cultivation of different crops in alternate strips of uniform width on the same field (Table 6).

Table 6. Some efficient strip cropping systems

State	AICRPDA centre/ Major Rainfed Crop based Production system	Efficient strip cropping system
Punjab	Ballawal Saunkhri/ Maize	Maize and cowpea strip- intercropping with maize strip 4.8 m and cowpea strip width 1.2 m; Maize and mash strip-intercropping with maize strip 6.0 m and mash strip width 2.4 m
Rajasthan	Arjia/Maize	Maize (2/3 area) – blackgram (1/3 area) (8:4)
Maharashtra	Parbhani/Cotton	Soyabean + pigeonpea (5.4 m) (6 & 3 rows/strip)
	Solapur/Rabi Sorghum	Sorghum + cowpea (4:4 and 6:6); Pearlmillet + sunflower (2:1 or 2:2)
Karnataka	Bengaluru/Finger millet	Finger millet – cowpea (21:21)



Maize 6 m strip + blackgram 2.4 m



Finger millet + cowpea (21:21)

SUMMARY

Rainfed agriculture is challenged by many abiotic and biotic constraints, particularly weather aberrations in cropping season. Intercropping systems in rainfed agriculture play a vital role in climatic adaptations and risk resilience. Crop diversification with intercropping systems enhances resource use efficiency, overall system productivity and income per unit area to the small holders. Further, crop diversification with intercropping systems provides better conditions for food and nutritional security and enables farmers to grow surplus products or sale at market and thus, helps to obtain increased income to meet other needs related to household well-being. Diversifying from the monoculture of traditional staples can have important nutritional benefits for farmers. Diversification can also manage price risk, on the assumption that all products may not suffer from low market prices at the same time and can increase the profitability of the farming community. Thus, crop diversification with intercropping systems contributes in achieving food and nutritional security, income growth, employment generation and sustainable rainfed agriculture.

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