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ADOPTION OF AGRO - HORTI SYSTEM FOR THE SUSTAINABLE DEVELOPMENT OF DRYLAND AGRICULTURE - AN OVERVIEW

S.R. SINGH[1], AWNINDRA K. SINGH[2], RAJENDRA.P. SINGH[1], AND J.P. LAL[1]
[1]Instititute of Agricultural Sciences, Banaras Hindu University, Varanasi – 221005. (UP) India.
Email: srsingh.bhu@gmail.com
[2]Central Agricultural Research Institute, Port Blair – 744 101 (A & N Islands) India

Abstract

Rainfed agriculture is being adversely affected by four-fold problems of land degradation, slow climatic change, degeneration of bio-diversity due to open grazing and poverty driven over utilization of natural resources. All these problems together lead to increasing challenges for sustainability of dryland crop production. These problems can be reversed, stopped, or at least reduced if the farming community can be motivated to adopt appropriate technologies developed by the National Agricultural Research System (NARS). This is possible only if an economy driven enterprise is the template of the farming system in vogue in these areas. This means that a farmer should receive higher and staggered income from the holding. The redefined agro-horti system is unique as it focuses on assisting farmers in creating a situation where they are managing their own natural resources including livestock in a sustainable productive way, and making them less dependent on outside labour and forest areas. In order to meet the challenges and the vagaries of monsoon, to evolve suitable technology to minimize such risk and to achieve stability in the dryland areas and consistent with the policy of conservation and desirability of preserving the integrity of the ecosystem, the alternate land use systems in the form of agro-horti system could be suggested. Agro-horti system is one of the most important cropping systems from the time of immemorial in which collective term for a land use system through crop diversification approach including agricultural crops/ pasture species with fruits species are used. The success of crop production in these areas depends on the amount and distribution of rainfall, as these influences the stored soil moisture and moisture used by crops. The present irrigation potential of the country is 33 per cent. Even if ultimate potential is utilized in next decade, about 50 per cent of the area will still remain rainfed. Hence keeping in view of the above fact an alternate land use system are suggested for the economic sustainability and profitability of the dryland farming community. This system envisages a coupling of multipurpose trees, horticultural plants with cereals, pulses and oilseeds, etc.

Keywords: Agro-horti system, dryland agriculture, rainfed, mulching and selection of varieties

INTRODUCTION

Indian agriculture is predominantly a rainfed agriculture under which both dry farming and Dryland agriculture included. Dryfarming was the earlier concept for which amount of rainfall (less than 500 mm annually) remained the deciding factor for more than 50 years. In modern concept, Dryland areas are those where the balance of moisture is always on the deficit side. In other words, annual evapotranspiration exceeds precipitation. In Dryland agriculture, there is no consideration of amount of rainfall. It may appear quite strange to a layman that even those areas, which receive 1100 mm or more rainfall annually, fall in the category of Dryland agriculture under this concept. To be more specific, the average annual rainfall of Varanasi is around 1100mm and the annual potential evaporation is 1500mm. Thus the average moisture deficit so created is bound to affect crop production under Dryland situation ultimately leading to total or partial crop failure. Accordingly the crop production is either low or extremely uncertain and instable which are the real problems of dryland.

The success of crop production in these areas depends on the amount and distribution of rainfall, as these influences the stored soil moisture and moisture used by crops. The amount of water used by the crop and stored in soil is governed by the water balance equation: ET = P

– (R + S). When the balance of the equation shifted towards right, precipitation (P) is higher than ET, there may be water logging or it may even lead to runoff (R) and flooding. On the other hand, if the balance shifts towards left, ET becomes higher than P, resulting in drought of various severities. In fact the balance of the equation is controlled by the weather, season, crops and cropping pattern.

About 95 m ha (67 per cent) cropped area is rainfed, which account for 44 per cent of food grain basket of the country. Water is one of the most important natural resources vital for economic development of a nation. The per capita per annum water availability presently at the level of 2001 m^3 will reduce to the stress level of 1700 m^3 in the next 2 –3 decades. Source of all water is precipitation. The average annual rainfall over the Indian sub-continent has been estimated at 1200 mm. On this basis annual precipitation including snowfall in estimated at 400 m.ha.m (4000 km^3). However, the distribution across the country varies from less than 100 mm in extreme arid are as of western Rajasthan to greater than 3600 mm in the NE states and 1000 mm from east coast to 2500- 3000mm in the west coast. Table 1 shows the details information on rainfall and monsoon pattern in India. About 300m ha m of this resource is generated during June to September and another 100m ha m is during rest of the year.

The present irrigation potential of the country is 33 per cent. Even if ultimate potential is utilized in next decade, about 50 per cent of thearea will still remain rainfed.

Table 1: Rainwater availability

Season / Period	M.ha.m	Percent
Winter (January - February)	12	03
Pre-monsoon (March - May)	52	13
South-West monsoon (June - September)	296	74
North-East monsoon (October - December)	40	10
Total	**400**	**100**

The current food production of the country is about 200 million tons, which has to be increased to 300 m tons by 2020 to feed growing population. There is no scope to expand the cultivated area due to various human activities. Future requirement has to be met through vertical growth by intensification as well as diversification of agriculture. Sustainable cropping pattern including legumes, trees, high value crops like vegetable as well as fruits, and animal as a component are being developed for different parts of the county.

It has now been recognized that handy horticultural crops must be incorporated into cropping system in dryland. Vegetable farming in our country has been an age-old enterprise of small and resource poor farmers who represent the major share in dry land areas. Because of quick growing and short duration characters, vegetable crops easily fit in the system well. Owing to perennial nature and deep root system of fruit trees, these are able to utilize the moisture commonly stored in deeper soil profile, they easily adapt to the marginal agro-ecological conditions such as undulating uplands, gullied and ravined lands, mining and industrial waste lands and poor sandy plains and can thus ameliorate the degraded ecology. On proper establishment fruit trees sustain the income of growers by providing permanent and assured income from fruits, fuel wood, and fodder. The trees also provide nutritive product to alleviate the problem of malnutrition and improve health standard of the people.

Nearly two third of a total of 169.65 million ha land under arable area and permanent crops in India is rainfed. The productivity of horticultural crops in dryland is, however, very low, extremely irregular, and variable depending upon the extent and pattern of rainfall. Besides water scarcity the other production constraints in drylands are;

1. Abiotic stresses due to extremes temperature and atmospheric humidity,
2. Biotic stress due to damage caused by wild animals, rodents birds, insect, and diseases,

3. Poor, degraded and marginal soil condition,
4. Difficult condition to execute agrotechniques, and
5. Difficulty in post harvest handling and marketing owing to limited and inefficient transport and market infrastructure.

Scientific management for efficient utilization of the resources, particularly water, can significantly improve and stabilize the productivity of horticultural crops in drylands.

Selection of crops

In dryland areas, crops should be able to complete maximal vegetative growth and reproductive phase during the period of maximum water availability. During the monsoon up to September starting from May in south India and from July in North India, soil and atmospheric moisture stress is low. The fruits such as ber, guava, pomegranate, custard apple, Indian gooseberry and sour lime, depending upon the aridity of location, conform to this prerequisite. The crops must have xeric characters, eg. deep root system (as in mango, ber, walnut), summer dormancy (as in ber), high bound water in the tissues (as in cactus, pear, fig), reduced leaf area (as in Indian gooseberry), leaf surface having shrunken stomata, thick cuticle wax coating and pubescence (as in fig, ber, phalsa, tamarind), and ability to adapt shallow soils, rocky, gravelly, and undulating wastelands (eg. pomegranate, anola, cashew, *Buchanaria lanzan*). In high rainfall areas, crop selection is based on the resistance to disease and pests owing to high humid conditions and adaptability to water stagnation (Table. 2).

Table 2: Fruit crops for drylands in different rainfall zones.

Rainfall (mm)	Plains	Plateaus and sub montain regions
> 500	Khejri (*Prosopis cineraria*) Ber (*Ziziphus mauritiana*) Phalsa (*Crewia subinaequalis*) Indian Fig (*Oputia fieusindica*) Karonda (*Carissa carrandas)* Ker (*Capparis decidua*) Gonda or lasora (*Cordia myxa*) Jharber (*Ziziphus nummularia*)	Custard apple (*Annona squamosa*) Bael (*Aegle marmelos*) Karonda, Ber, Ker, Jharber, Jamun (*Siziquam cumini*) Pilu (*Salvadora oleoides*)
500 - 1000	Ber (*Ziziphus mauritiana*) Anola (*Emblica officinalis*) Jamun (*Siziquam cumini*) Wood apples (*Feronia limonia*) Custard apple (*Annona squamosa*) Mahua (*Madhuca indica*) Wild date palm (*Phoenix sylvestris*) Indian almond (*Terminalia catappa*) Guava, Sour lime, Lemon, Mango (*Mangifera indica*), Tamarind	Doula, Bach, Ber, Custard apple, Chirounji (*Bachauria sauzau*), Wood apple, Karonda, Indian almond, Mango, Cashew, Tamarind, Sour lime, Lemon, Grape fruit, Pomegranate
> 1000	Mango, Litchi, Jackfruit, Mandrain, Avocado, Tamarind, Jamun, Mahua, Kokun (*Garcinia indica*)	Mango, Jackfruit, Guava, Tamarind, Mahua, Cashew nut, Cherry, Pomegranate.

Vegetable crops for dryland

Among the vegetable crops, bottle gourds (*Lagenaria siceraria*), ridge gourd (*Luffa acutangula*), sponge gourd (*Luffa cylindrica*), water melon (*Citrllus lanatus*), round melon (*Citrulus lantus* var. fistulosus), long melon (*Cucumis melo* var. utillisimus), bitter gourd (*Momordica charantia*), snap melon (*Cucumis melo* var. momordica),

kachari (*Cucumis callosus*), Arya (*Cucumis sp.*), drumstick (*Morinqua deifera*), cluster bean (*Cyamopsis tetragonoloba*), cowpea (*Vigna unguiculata*), okra (*Abelmoscous esculentus*), amaranth (*Amaranthus sp.*), brinjal, chilli and tomato are common.

Selection of varieties

Cultivars differ in their adaptability to different climatic condition. Varietal variation in endurance to drought has also been observed in horticultural crops. Early ripening cultivars seem to escape stress conditions caused by receding soil moisture stored in the soil during monsoon. Suitable cultivars of some fruits and vegetable crops have been identified (Table 3).

Ber cultivars such as Gola, Seb and Mundia for extremely dry area, Banarasi Karaka, Kaithli, Umeran and Maharawali for dry regions and Sanaur - 2, Umran and Mehrum for comparatively humid regions have been recommended (Anonymous, 1985). In northern India Gola ripens earliest; Kaithli and Mundia are mid season cultivars, and Umran is a late cultivar (Anonymous, 1983). Anola varieties selected for drylands are Kanchan, Krishna, NA-6 and NA-7. Selected cultivars of bael such as Narendra Bael-5 and Narendra Bael-9 have medium sized fruit with smooth surface, yellow skin, moderate fiber and soft flesh.

From the vast area under wild plantation of custard apple, good plant types such as Balanagar, Maumoth and Red Sitaphal have been selected. Some interspecific (Red Sitaphal x Maumoth) and interspecific (Pinks Maumoth x Balanagar and Bullock's Heart x Red Sitaphal or Balanagar) hybrids are considered promising because of high yield of fruits, low seed content and long shelf life eg., Arka Sachan (Anonymous, 1991). Cultivars of some fruits have been identified as drought resistant, eg. Balanagar – Mango; Kohir Safed and Safed Jam – Guava; Gola, Seb, and Mundia – Ber; Chakaiya – Anola; Muskat, Ganesh, Baseein seedless and Jalor seedless – Pomegranate and Balanagar – Custard apple.

Planting

The planting system to be adopted in dryland depends largely upon the topography of the land, fruitt species and soil type. In the plains, planting is generally done is square or rectangular system. On sloppy lands, fruit trees are planted on contour terraces, trenches and bunds, and micro-catchments. The trenches and bunds made across the slope are staggered. In micro-catchments, which may be triangular or rectangular, trees are planted at the lowest point where runoff accumulates. The spacing between rows and trees in such a runoff harvesting system has to be suitably varied and adjusted. The plant density will obviously vary depending largely upon the extent of rainfall, which influences runoff quantity.

Water management

Orchard soil moisture status, particularly during fruit development period, greatly affects productivity of the trees. Under dryland conditions, such measures as water harvesting, mulching and weed control are adopted to maintain optimum moisture availability in the root zone of the trees.

Water harvesting

Water supply to the plant can be improved by water harvesting using *in-situ* or *ex-situ* system. It has been observed that microcatchment slope greater than 5per cent did not significantly affect runoff at Jodhpur and that the highest ber yields were obtained when 0.5 per cent and 5 per cent slopes had 8.5 m and 7m length of run, and 72m^2 and 54 m^2 catchments area per trees, respectively (Sharma *et al.* 1982, 1986). A good number of fruits such as fig, almond, plum, olive, pomegranate, pistachio, peach, apricot, grape wine, sour and sweet cherries and apple have been cultivated in micro-catchments in Avdat and Shivta highlands under rainfall pattern of Israel (Evenari *et al.* 1971). Work done at Aruppukottai (Tamilnadu) and Anantpur (Andhra Pradesh) has indicated usefulness of *in-situ* water harvesting technique for fruit production (Anonymous, 1989).

At Hyderabad, micro-reliefs of 3 m width and 25cm height, spaced 9m from ridge to ridge, have been used to store extra rainwater for fruit trees such as kagzi lime, coorg mandarin, and sweet orange with tomato and okra as intercrops (Singh and Vishnumorthy, 1988).

The hilly, rocky and aggraded lands can generate runoff for cultivation of fruits and vegetables. In near by

watersheds, the runoff can also be collected in small or large ponds and recycled for irrigation at critical stages of plant growth and development.

Mulching

Intense aridity in dry regions causes considerable evaporative losses. Mulching with organic materials (eg. hay, straw, dry leaves and local weeds) has been found highly beneficial in reducing these losses. The practice also suppresses weed growth, prevents erosion and adds organic matter to the soil (Gupta, 1995).

Black polythene mulch is very effective in western India (Anonymous, 1989). Although, local organic mulch materials are cheaper than polythene mulches, these require proper care to maintain effective cover thickness. Leaf mulch has been used to conserve soil moisture in Sapota orchards in Karnataka, Tamilnadu and Andhra Pradesh. Sugarcane trash mulch is pomegranate fig and custard apple was found effective in Maharastra (Anonymous 1989). At the Indian Institute of Horticultural Research (IIHR) Banglore, mulching the tree basins could considerably reduce fruit cracking in litchi.

Table 3: Popular cultivars of fruit and vegetable crops in drylands of India

Crop	Cultivars
Fruit	
Ber	Gola, Mundia, Kaithli, Banarasi karaka, Early Umran
Anola	Kanchan, Krishna, Balawant, NA-6, NA-7
Pomegranate	P-23, P-26, IIHR Selection, Mridula
Custard apple	Balanagar, Maumoth, Red Sitaphal, Arka Sachan
Guava	Allahabad Safeda, Sardar, Kohir Safed, Safed Jam
Papaya	Pusa Delicious, Honey Dew, Pusa Majesty, Pusa Dwarf, Pusa Giant
Bael	NB-5, NB-9
Sapota	Kali Patti, Cricket Ball
Fig	Poona, Blackqschiq
Mango	Banglora, Neelam, Keshar, Bombay Green
Vegetable	
Tomato	Pusa Ruby, Pusa Early Dwarf, Pusa -120, Sweet-72, S-12, Mangla, Punjab Chhuhara
Chilli	Pusa Jwala, Mathania, Sindhur, Pant c -1, Arka Mohani, Arka Gaurav, Arka Basant, Bharat, Indira
Cowpea	Pusa Dofasali, Pusa Phalguni, Pusa Barsati, Pusa Rituraj
Cluster bean	Pusa Sadabahar, Pusa Mausami, Pusa Navbahar, Durga Bahar
Brinjal	Pusa Purple Long, Pusa Purple Round, Pusa Kranti, Pusa Anmol, Arka Sheel, Arka Kusumakar, Arka Navneet
Okra	Pusa Makhamali, Punjab Padmini, Parbhani Kranti, Arka Anamika
Pumpkin	Arka Chandan, CO-1, CO-2
Amaranth	Chhoti Chaulai, Badi Chaulai, CO-1, CO-2
Muskmelon	Pusa Sharabati, Pusa Madhuras, Hara Madhu, Punjab Sunehari, Durgapur Madhi
Water melon	Sugar Baby, Arka Manik, Arka Jyoti, Durgapur Meetha, Kesar
Bottle gourd	Pusa Summer Prolific Round, Pusa Summer Prolific Long, Pusa Meghadoot, Pusa Manjari, Pusa Naveen
Bitter gourd	Pusa Do Mausami, Arka Harit, Pride of Gujarat
Ridge gourd	Pusa Rasdar
Sponge gourd	Pusa Chikani
Round melon	Arka Tinda

Antitranspirahts

Transpiration losses can be reduced by the use of:

- Radiation reflectants: Spraying - 4 – 6 per cent Kaolin or 0.5 – 1.0per cent liquid Paraffin or 1.5per cent Power oil - reduced plant water losses. (Pareek and Sharma, 1991).
- Stomata closing chemicals:
- Phenyl mercuric acetate (PMA)
- Decinyl succinic acid (DSA)
- Abscisic acid (ABA)
- Acetyl alcohol,

Cause stomata closer and reduced transpiration (Jones and Mansfield, 1971;Chundawat, 1990). Plastic films Shelter belt and wind breaks can reduce evapotranspiration by reducing wind speed and stabilizing microclimate (Muthana *et al*., 1984)

Weed control

- Special significance in rainfed orchards in reducing soil moisture losses. Harrowing between tree rows after first rain is most beneficial. Timely weeding is essential to improve fruit quality even in high rainfall region. Application of pre-emergence weedicides – Diuron, Bromacil and Atrazine @ 2 - 3 kg ha^{-1} (Pareek and Vishal Nath 1996).

Nutrient Management

Application of organic manure at pit filling. In low rainfall areas-application should coincide with rains. N application in 2 – 3 splits doses at critical stages.

In Ber Orchards

- 10-15 Kg organic manure + annual application of 100 g N, 50 g P_2O_5 and 50 g K_2O per tree.
- Fertilizer doses should be raised with the age of plants and soil fertility of region.
- 15-20 Kg FYM per tree – found beneficial in Anola, Custard apple and tamarind.
- At MPKV, Rahuri – In addition to 50 Kg FYM, 625 g N, 225 g P_2O_5 and 225 g K_2O to 5 year old Pomegranate tree (Anonymous, 1983).
- In 6-7 years old Fig trees planted at 5 m x 5 m fertilization of 900 g N + 250 g K improved fruit production (Anonymous, 1985).
- At Banglore – 500 g N + 250 g P + 125 g K produced 6 times higher yield than control (Anonymous, 1989).
- Micronutrients – Often deficient in semi-arid and arid soil. Foliar feeding of nitrogen (0.5 – 2.0 per cent urea), Zinc (0.05 to 1.0 per cent Zn So_4), and boron (0.05 to 1.0 per cent borax) has given beneficial results in these areas (Pareek and Sharma, 1991).
- Salinity and alkalinity – Pose problems in some dryland areas. Runoff during rainy season may be used to leach out these salts. In medium rainfall regions of eastern Uttar Pradesh FYM, pond soil, gypsum and pyrite in sodic soils resulted in better – Anola and bael plants (Pareek and Vishal Nath, 1996).

Cropping System

- Under drylands monoculturing is risk prone due to crop failures.
- Suitable tree-crop combination, besides alleviating the risk, also generates extra income, improves productivity per unit area / volume as a result of efficient use of natural resources and inputs, and ameliorates and improve adverse agroclimate.
- Agri-horti combination with legume intercrops such as mungbean, moth bean, cluster bean and cowpea are beneficial.
- In rainfed orchards of guava and ber cluster bean, okra and cowpea in rainy season proved promising in medium rainfall region of Gujarat (Raturi and Hiwale, 1988)
- At Godhara - Cluster bean with ber gave a net return of Rs. 14,630 ha^{-1}. Brinjal and Chillies also good.

At Hyderabad – Cowpea, mungbean and Horse gram in ber orchards and Bitter gourd, tomato and Okra in acid lime orchards.

At Varanasi – intercropping high value crops (Okra) one row in 2 rows of Pigeonpea (60 cm) resulted in monetary advantage of Rs.17, 976 ha^{-1}.

In areas with large live stock population – Horti-postural system is beneficial.

In arid areas – Khejri (*Prosopis cineraria*) + ber + Dhaman (*Cenchrus ciliaris, C. setigerus*) or sewan (*Lasiurus sindicus*).

In semi arid areas – Perennial trees (mango, mahua, tamarind, sapota, jackfruit and palmyra palm) could be grown with fodder crops.

Horti-silviculture – wood for packaging and fuel.

In low rainfall (300 500 mm) zone – Khejri or ber or drum stick + vegetables.

In 500 – 700 mm rainfall – mango or ber or anola or guava + pomegranate or sourlime or lemon or drumstick + solanaceous or leguminous or cucurbitaceous vegetables.

In 700 – 1000 mm rainfall – mango or jackfruit or Mahua or Palmyra palm or tamarind or guava + sour lime or lemon or pomegranate or anola + vegetables.

Pest and disease management

Wild animals, rodents, birds and insects (termites) create serious problem to green belts in drylands.

Heptachlor dust (5 per cent) in pits (50 g pit^{-1}).

Fruit fly (*Carpomyia vesuviana*) serious damage to ber.First spray - at pea stage - 0.03 per cent Monocrotophos. 2nd spray - 15 DAF - 0.05 per cent Fenathion. 3rd spray - 15 DAS 0.1 per cent Carbaryl XLR. If necessary during fruit maturity weekly spray with 0.5 per cent Malathion mixed with 0.5 per cent gur or sugar. This schedule is also effective against fruit borer (*Meridarchis scyrodes*) in south & west. Collection and distribution of fallen fruits and digging soil under tree canopy decreases infestation. Pomegranate butter fly (*Virachola isocrates*) damages fruits. Bagging fruits with butter paper give good protection. For control - 0.002 per cent Deltamethrin and 0.2 per cent Carbaryl 50WP spray in rotation at 21 day intervals from fruit set. Ber Powdery mildew -- 0.1 per cent Dinocap or Carbendazim or Triadeomorph or Thiophenate methyl and 0.2per cent Wettable sulphur - 2 - 4 times at 15 - 20 day interval. Black leaf spot (*Isariopsis indica*) found under more humid condition - 2 - 3 spray of 0.2 per cent Captafol or Copper Oxyl-Chloride or Mancozeb and 0.1 per cent Carbendazim at 15 day intervals. For control of leaf and fruit spot in pomegranate - Foliar spray with 0.25 per cent Ziram and 1 per cent Bordeaux mixture at 15 day intervals. For control of ring rust of Anola - 4 spray of 0.2 per cent Chlorothalonil at 15 day intervals just after initiation of the symptoms.

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