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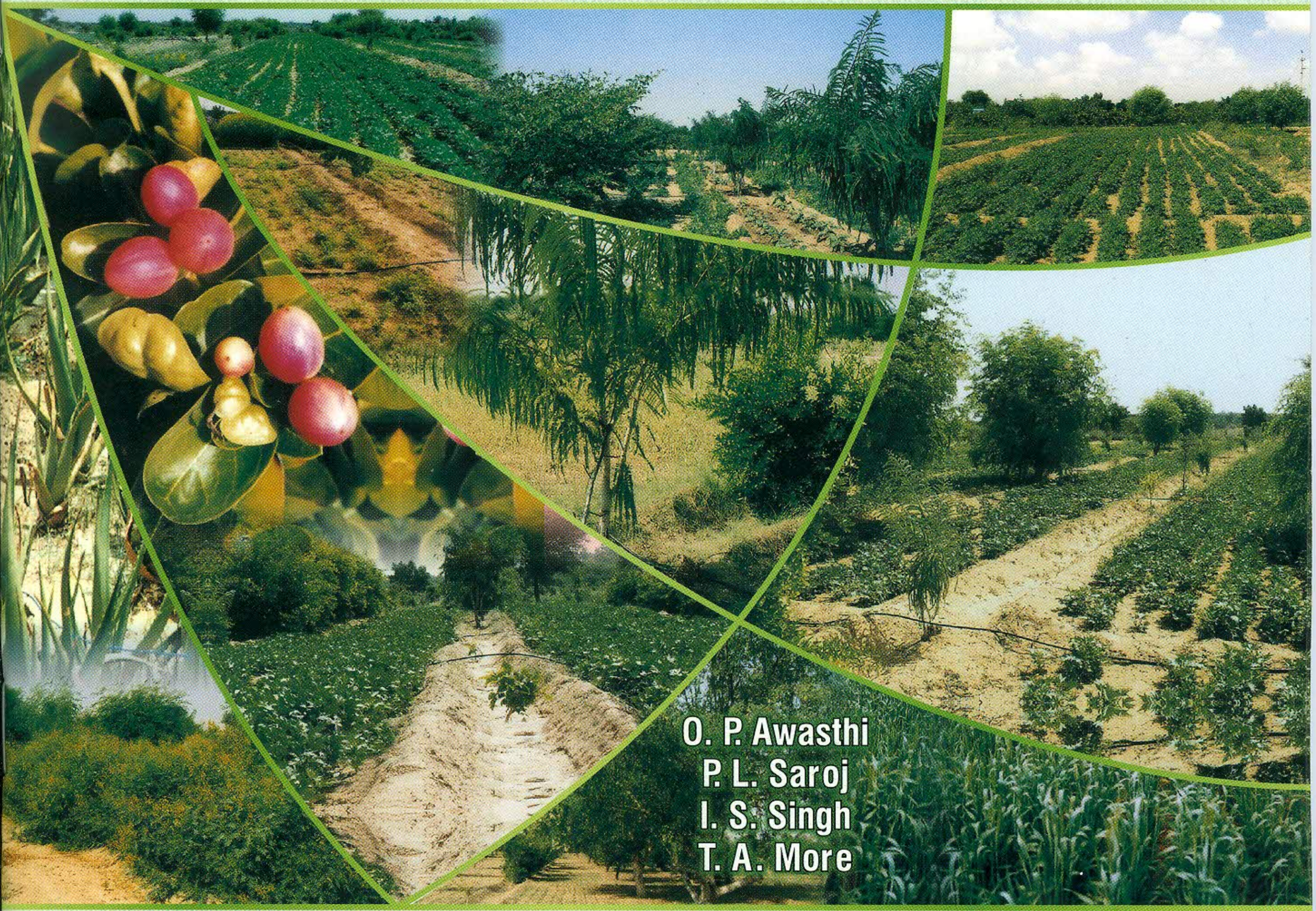

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Foreword

TO achieve sufficient and regular supply of food for subsistence is the primary goal of most human population living in the arid and semi-arid regions. Many studies have shown that the intensification and simplification of food producing systems renders them liable to instability and collapse. Arable land contracting in the face of land degradation and urban expansion, a movement towards intensification of existing farming system, shortening of food chains and reduction of cash cropping in its many forms, seems to be the only way by which the growing population of arid and semi-arid regions can be fed. This gave rise to the concept of crop diversification through "cropping system" approach for increasing production and productivity without detrimental effect to the ecology.

The present Technical Bulletin would be very useful to the teaching staff, researchers and extension agency who are involved in the horticultural development. I congratulate the authors for their endeavor in publishing this important Technical Bulletin.

(T. A. More)
Director

Bikaner
18th December, 2007

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Introduction

In arid region low and erratic rainfall, extreme temperature conditions, high evapo-transpiration, scarce water resources, infertile and saline soils with ill-defined profile development threaten sustainable agriculture. Thus drought and poverty, the double plague presents a scenario of misery and insecurity across the arid region where agriculture is the chief means of subsistence for the rural people. Subsistence farmers who face famine would consider a technology to be one that produces at least some yield in the worst year. Sustainable productivity is difficult to achieve by growing only seasonal or forage crops. Under such situation adoption of fruit based cropping system seems an apt option to achieve the objectives.

Benefits of Crop Diversification

Fruit based cropping approach seeks to increase production and income in a sustainable manner by efficient utilization of both natural resources (land, solar radiation, water) and inputs (labour, credit, power, market infrastructure), meeting the diverse need of the farmers (4Fs, i.e. food, fruit, fuel and fodder), economizing productivity, generating employment opportunities, improving economic conditions of the farmers and entrepreneurs, increasing export and nutritional security to the people. Additional advantages of diversified fruit based cropping systems are diversified rotations can reduce pests, labour may be spread more thoroughly, different planting and harvesting times can reduce risks from weather, new crops can be source of renewable resources or have nutracentical traits, and when a pure stand of a crop suffers damage from say wind, hail or frost, there are always options that plants of other species are less damaged and compensate the losses incurred.

2

Diversification Shifts

In the past there had been a shift in cultivation of crops from traditional areas to non-traditional areas. In arid region particularly in western Rajasthan (Bikaner, Jaisalmer, Barmer, Churu) where life saving irrigations facilities are available, there had been a rapid expansion in area under fruit crops like ber, aonla, bael, citrus, karonda, medicinal plants such as senna, isabgol, gugal, etc. and multipurpose trees like drum stick. Some times introduction of new crops or development of new crop cultivars/varieties through technological innovations triggers the change and paves the way for new cropping systems which are more productive/profitable than the existing ones. These changes are occurring due to the following reasons.

- Incidence of certain insect, pests and diseases in epidemic form in component crop.
- Creation of demand for certain commercial crop(s) on account of socio-economic or potential decision or international trade for some crops on account of socio-economic or political decision, which favour development of processing industry or international trade for some crops.
- Technological break through, such as development of new genotypes in preferential crops making their cultivation feasible in non-traditional areas.

As a consequence of any one or more reasons mentioned above farmer's decision swing in favour of better alternative crops, and new systems emerge at macro-level. Before discussing the promising traditional and research based diversified cropping system, potentially important horticultural, agricultural and fodder crops are discussed herewith.

3

Potential Horticultural, Agricultural and Fodder Crops for Arid Regions

3.1 Fruits

The nutritive horticultural crops, particularly the perennial fruit trees form an important component of the flora of arid regions. Several drought hardy fruit yielding tree species like ker (*Capparis decidua*), pilu (*Salvadora oleoides*), lasora or goonda (*Cordia dichotoma*), goondi (*Cordia gharaf*), wild jujube or jharberi (*Ziziphus nummularia*), bordi (*Ziziphus mauritiana* var. rotundifolia) and jujube or ber (*Ziziphus mauritiana* Lam.) not only provide life support to the people living in a fragile ecosystem of arid region receiving an average annual rainfall of <300 mm but also provide their nutritive moisture laden leaves to the animals. The leaves of khejri [*Prosopis cineraria* (L.) Druce] and jharberi contain about 75 per cent moisture even during the hot summer.

Several other fruit crops such as aonla (*Emblica officinalis* Gaertn.), pomegranate (*Punica granatum*), bael (*Aegle marmelos*), date palm (*Phoenix dactylifera* L.), kinnow, mulberry (*Morus alba*), karonda (*Carissa congesta*) and phalsa (*Grewia subinaequlais* DC.) can be grown successfully where life saving irrigation facilities are available.

3.2 Vegetables

Among the vegetable crops, brinjal (*Solanum melongena*), bottle gourd (*Lagenaria siceraria*), ridge gourd (*Luffa acutangula*), sponge gourd (*Luffa cylindrica*), mateera (*Citrullus lanatus*), round melon (*Parecitrullus fistulosus*), long melon (*Cucumis melo* var. *utilissimus*), snap melon (*Cucumis melo* var. momordica), kachri (*Cucumis* spp.), drumstick (*Moringa oleifera*), cluster bean (*Cyamopsis tetragonoloba*) and cowpea (*Vigna unguiculata*) are common.

3.3 Cereals and Pulses

Cereals and pulses (seasonal crops) constitute major component of the diet and calorie intake of the people. Bajra (*Pennisetum typhoides*) is the most important staple food in the Thar Desert. Its stalks are fed to cattle or used for thatching. Wheat and groundnut are grown in areas having irrigation facilities of which groundnut does not seem to have much potential in the long run because of its high irrigation requirement. *Kharif* pulses such as moth bean (*Phaseolus aconitifolius*), cluster bean (*Cyamopsis tetragonoloba*), urd (*Phaseolus aureus*) and chick pea (*Cicer arietinum*) withstand extreme aridity. Rapeseed (*Brassica campestristoria*) and mustard (*Brassica campestris*) are important oil seed crops.

3.4 Pastoral Crops

Sewan (*Lasiurus sindicus*), anjan (*Cenchrus ciliaris*), dhaman (*Cenchrus setigerus*) and *karad* (*Dichantnium annulatum*) are found in naturally pasture lands, *gochar*, *oran* and rangelands. Halophytes like *Haloxylon salichornicum and Salsola baryosma* are preferred feed for camels and are well adapted to saline soils (>20 dsm^{-1}).

3.5 Medicinal Crops

Several medicinal plants grow in arid region, e.g. senna (*Cassia angustifolia* Vahl.), ashwagandha [*Withania somnifera* (L) Dunal], gugal (*Commifera wightii*), castor (*Ricinus communis*), shankhpushpi (*Evolvulous alsinoides*), guarpatha (*Aloe barbadensis* Mill.), tumba [*Citrullus colocynthis* (L.) Schrad], dhatura (*Datura stramonium* L.), mehandi (*Lawsonia inermis*), etc.

3.6 Spices

The main spice crops are fenugreek (*Trigonellafoenum graecum*), cumin (*Cuminum cyminum*), chilli (*Capsicum frutiscens*), coriander (*Coriandrum sativum*), fennel (*Foeniculum vulgare*), etc.

Based on the diversity of fruit, vegetable, agricultural and other crops grown in the region, traditional and research based cropping system in the form of Horti-Agri system is discussed herewith.

4

Horti-Agri Systems for Arid Regions

4.1 Traditional Practice

This system provides sound farm economy, improved nutrition and health standards of the family and stability of income. Growing of vegetable crops, pearl millet, moth bean, cluster bean, and gram between khejri [*Prosopis cineraria* (L.) Druce] and certain fruit trees such as bordi (*Z. rotundifolia*), lasoda (*Cordia myxa*), pilu (*Salvadora oleoides*) and ker (*Capparis decidua*) is an old traditional agri-horti system prevalent in arid region. Table 1.

Table 1. Traditional Horti-Agri system in western Rajasthan

Districts	Main tree/shrub species	Main crops	
		Rainfed	Irrigated
Ganganagar, Hanumangarh	*P. cineraria*	Pearl millet, mung bean, cluster bean	Wheat, cotton, rice and mung bean
Bikaner	*Z. nummularia, P. cineraria, Calligonum polygonides*	Mung bean, moth bean, cluster bean and pearl millet	–
Jaisalmer	*Z. nummularia, P. cineraria, C. decidua*	Mung bean, pearl millet, cluster bean	–
Barmer	*P. cineraria, Z. nummularia, C. decidua*	Pearl millet, mung bean and cluster bean	–
Jodhpur	*P. cineraria, Z. nummularia, C. decidua*	Pearl millet, mung bean and cluster bean	Wheat, chilli, mustard and mung bean
Churu, Jhunjhunu, Sikar	*P. cineraria, Z. nummularia*	Pearl millet, mung bean and cluster bean	–
Nagaur	*P. cineraria*	Pearl millet and mung bean	Wheat, mung bean and mustard
Jalore	*P. cineraria, S. oleoides, S. persica, P. granatum*	Pearl millet, mung bean, isabgol, sorghum	cumin
Pali	*Salvadora* spp.	Sorghum, pearl millet, mung bean and cluster bean	–

Source: (Harsh *et al.*, 1992)

Fruit trees make proper use of the soil moisture and nutrients as an overstorey component in association with groundstorey crops. In arid western Rajasthan, 25-40 per cent of irrigation or rainwater that penetrates the murram sub-stratum is of little use for the groundstorey crops and grasses, but can be effectively used through the deep roots of the fruit trees.

A number of other alternate systems based on fruit trees such as ber, aonla, khejri and lasora have been investigated and tested in different pockets of arid region for their potentiality.

4.2 Ber based system

Mung bean, moth bean and cluster bean between bordi trees and mung bean, cluster bean and gram between ber trees are the popular traditional cropping systems adopted by the farmers in rainfed areas even during the drought years. The inter space is also utilized for production of drought hardy cucurbits (*mateera, kachri*, etc.). Crops like pearl millet grow in association with jharber even on soil sediments in rocky plateaus near Jaisalmer and Jodhpur. Cluster bean has been found to be a potential and remunerative intercrop at all the locations. The other crops found profitable are mung bean and green gram at Jodhpur. Three years old plantation of ber (*Z. mauritiana*) at a density of 400 plants/ha in association with green gram at Jodhpur performed very well with a seasonal rainfall of 210 mm. Intercropped green gram yielded only 160 kg ha^{-1} as against 620 kg ha^{-1} from pure crop. The fruit yield from the intercropped system increased the net profit to Rs 2, 886. This shows that this Horti-agri system minimizes the risk in arid regions and helps in imparting economic stability (Gupta *et al.*, 2000).

Ber based cropping system at CIAH, Bikaner

Research on ber based cropping system was initiated under irrigated conditions of hot arid ecosystem of western Rajasthan to quantify the potential of the system (Saroj *et al*, 2000). *In situ* budded ber cultivar Gola with three spacings as overstorey component and groundnut (*Arachis hypogia*) – wheat (*Triticum aestivam*), cluster bean (*Cyamopsis tetragonoloba*)- mustard (*Brsassica compestris*) and Indian aloe (*Aloe barbedensis* Mill) as groundstorey component were integrated into the system. Results revealed that in the initial stage of its establishment, there was no competition between groundstorey and overstorey components for resources. Instead the inputs applied for the groundstorey crops enhanced the vegetative vigour of the ber plants compared to the sole plantation. The ber plants grown with Indian aloe were more vigorous due to the higher level of inputs, particularly irrigation water that Indian aloe received as compared to the other combinations.

Integration of different components into the system, led to multiple benefits. From groundnut dry pods; from cluster bean-green pods (for vegetable purpose);

Plate 1 (Ber - Indian Aloe)

from wheat and mustard-grain yield; from Indian aloe-green leaf pad (for vegetable purpose) and from ber-fruits, besides considerable amount of biomass from all the components except Indian aloe.

Yield of overstorey crops

In situ budded ber cv. Gola started bearing in third year of its plantation. Better establishment of overstorey component at the initial stages and subsequent quicker growth resulted into profused bearing of quality fruits. An average fruit yield of 14.44, 8.13 and 8.23 q ha^{-1} fruits were recorded under 6 m × 6 m, 8 × 8 m and 16 m × 4 m respectively. The yield recorded from individual plant clearly indicated that spacing had non significant effect on the fruit yield of ber. However,

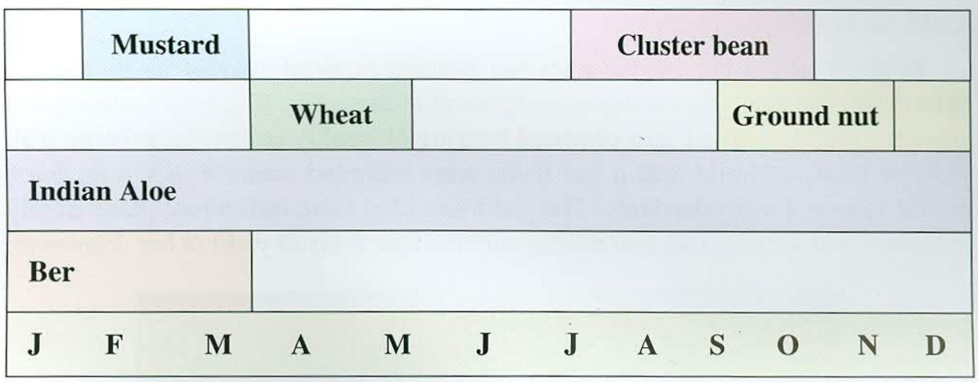
Plate 2 (Ber - Mustard)

different crop rotation adopted into the system have significant influence on the fruit yield. Among different crop combinations, the highest fruit yield of ber was recorded with Indian aloe (13.55 q ha^{-1}) while with ground-wheat and cluster bean-mustard, the yield level was almost at par (9.62 and 9.80 q ha^{-1}, respectively) and minimum yield was recorded under sole plantation (8.09 q ha^{-1}).

Groundstorey crops

The average yield of groundstorey crops over two years was recorded as 3.48, 50.97, 10.05, and 11.49 in groundnut (dry pods), wheat and mustard (grain). Average leaf pad yield of Indian aloe was 53.32 kg ha^{-1}. Highest average yield (55.62 kg ha^{-1}) of Indian aloe (green leaf pads) was recorded under sole cropping whereas, it was 51.98, 52.60 and 53.06 kg ha^{-1} under 6 m × 6, 8 m × 8 m and 16 m × 4 m spacing respectively. Plant spacing have marginal effect on the yield of groundstorey crops during the initial stages. The biomass production under different groundstorey components was also recorded and recycled in the same proportion after decomposition from where they were harvested.

Cash-flow from Ber based cropping system



Economics

Among the three groundstorey combinations, Indian aloe gave the highest economic returns of Rs 65802 ha^{-1}, followed by cluster bean-mustard, Rs 26144 ha^{-1} and minimum return was obtained from groundnut-wheat combination i.e. Rs 1203 ha^{-1}.

Keeping in view the land use efficiency and monetary returns, potential crop combinations in ber plantations have been identified in trials conducted in arid regions of India (Table 2).

Table 2. Promising cropping systems identified for higher monetary returns in arid regions

Location	Av. Rainfall (mm)	Crops
Bikaner	240	Cluster bean, moth bean, mustard, Indian aloe
Jodhpur	290	Cluster bean, mung bean, green gram
Pali	490	Mung bean, sesame, cluster bean

4.3 Aonla-based system

During the past few years there had been a rapid extension in area under aonla in arid region particularly western Rajasthan due to development of suitable cultivars coupled with development of required production technologies. The tree canopy of aonla allows filtered light and permit intercropping even after it has made full growth.

Aonla Based Cropping System at CIAH, Bikaner

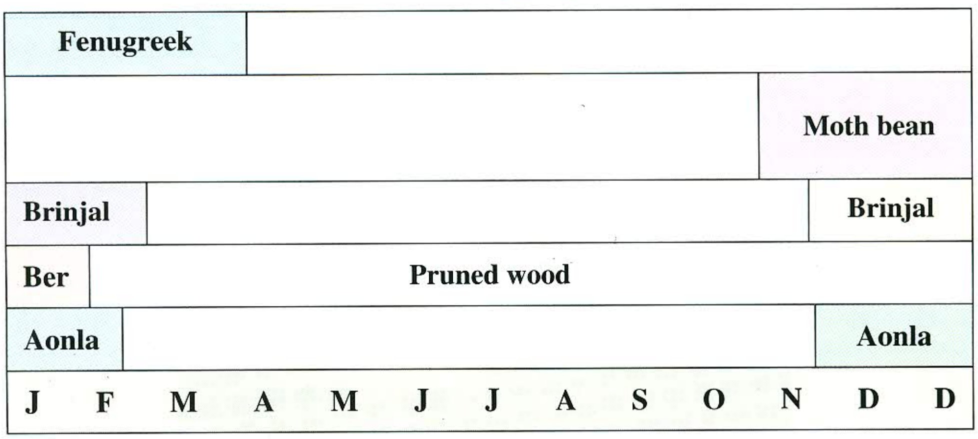
For sustainable production and ecological restoration, aonla based multi species cropping system/models integrating perennial fruit trees, annual/ seasonal crops (vegetables, cereals, legumes and medicinal plants), was initiated at Central Institute for Arid Horticulture, Bikaner in the year 2002. Among the various multi species cropping models, two eco-feasible cropping models have been found promising (Awasthi *et al.*, 2005). The models are Aonla-Ber-Brinjal-Moth bean-Fenugreek (M_1) and Aonla-*prosopis-suaeda*-moth bean-mustard (M_2). The net return obtained from these cropping models through groundstorey crops

Plate 3 (Aonla-Ber-Brinjal-Moth bean-Fenugreek)

Table 3. Gross Return (Rs ha^{-1}) under different Cropping model during first year

Cropping Models	Ber	Drum-stick	Moth bean	Brnjal	Fenu-greek	Gram	Senna	Suaeda	Mustard	Total
Aonla-ber-brinjal-moth bean-fenugreek (M_1)	2,328	–	6,286	5,000	10,000	–	–	–	–	23,614
Aonla-bael-karonda-moth bean-gram (M_2)	–	–	6,426	–	–	7,890	–	–	–	14,316
Aonla-khejri-saji-moth bean-mustard (M_3)	–	–	5,712	–	–	–	–	700	19,250	25,662
Aonla-drumstick-senna-moth bean-cumin (M_4)	–	590	6,000	–	–	–	6,000	–	–	12,590
Control	600	100	4,480	2,320	6,250	5,730	4,800	560	14,000	–

Cash Flow from Aonla Based Cropping System



during the first year when other perennial components were in their establishment phase was to the tune of Rs 23, 614 and Rs 25, 662 respectively while during the second year it increased by 20 per cent in Model 1 (M_1) and by 15per cent in Model 2 (M_2). It is obvious that during juvenile phase of aonla there are ample opportunities for raising annual, biennial and perennial crops which in turn can meet the diversified need of the farmers.

4.4 Khejri [*Prosopis cineraria* (L.) Druce] based system

Prosopis cineraria (L.) Druce, commonly known as khejri, is considered the "*kalpvriksha*" of the Indian desert. The tree has monolayered canopy and root system that does not interfere with the annual crops as most of it lies below 50-60 cm depth. Existence of fruit trees such as bordi (*Z. rotundifolia*), lasora (*Cordia myxa*), pilu (*Salvadora oleoides*), and ker (*Capparis deciduas*) can commonly be seen between khejri plantations. In the alluvial plains of Jodhpur, Barmer, Nagaur and parts of Pali, crops like jowar, pearl millet, moth bean, cluster bean and sesame are grown during *kharif* season between the scattered khejri trees. The khejri based cropping systems that emerged promising in the arid and semi arid regions are given in Table 4.

Table 4. Promising Prosopis based cropping systems

Location	Av. Rainfall (mm)	Crops
Bikaner	240	Jowar, pearl millet, moth bean, cluster bean and sesame
Jodhpur	290	
Barmer	350	
Nagaur	362	
Pali	490	

4.5 Cordia based system

Lasora (*Cordia* myxa.) also known as cherry of the desert, owing to its higher productivity, suitability to adverse soil and climate conditions and high processing value is now becoming popular as monoculture and Horti-Agri System. *Cordia myxa* has been observed to be a suitable tree in association with which several crops can be grown (Table 5).

Table 5. Cordia in agro-forestry system in arid zone

Location	Av.Rainfall (mm)	Crops	
		Rainfed	Irrigated
Jodhpur (Pipad)	290	Pearl millet, cluster bean	Rapeseed, mustard, wheat, green gram
Pali and adjoining areas	490	Vegetables, pearl millet, cluster bean, taramira	Raya, wheat, green gram
Jalore, Sirohi	434-544	Vegetables/spices, cluster bean, pearl millet	Rap seed, mustard
Bikaner, Barmer	243-350	Pearl millet	Rape seed, mustard

5

Criteria for Selection of Over and Understorey Crops

While growing agricultural crops in association with fruit trees due consideration should be given on tree morphology and other characteristic so that there is a symbiotic association between overstorey and groundstorey components.

5.1 Overstorey crops

The fruit trees selected should posses following characters:

- Xeric characters such as deep tap root system; high bound water in tissues, sunken stomata, waxy coating, thick cuticle and pubescence.
- Ability to complete maximum vegetative and reproductive phase during the period of moisture availability
- Root system and root growth should be able to exploit deeper soil layers than those tapped by the under and groundstorey crops.
- Branching habit that allows light penetration to the understorey crops.
- Species should be strong coppicer and possess self-pruning properties or should respond to pruning.
- Leaf fall during the growth period of the ground crops.
- The rate of litter fall and litter decomposition should have positive effect on soil fertility.
- Resistance to pests and diseases.

5.2 Groundstorey crops

The selected crops should have following characteristics:-

- Should have shade tolerance suiting the amount of available solar radiation.
- Should not compete with the perennial companion crop.
- Should not be more susceptible than the main crop to the diseases they have in common.
- Should not require harvesting or other operations that would damage the main crop or induce soil erosion or damage soil structure.
- Should not have economic life longer than that of main crop.
- Should suit the local agro-climate, labour, irrigation and market/ processing facilities.
- Leguminous groundstorey crops that have nitrogen fixing capacity should be preferred.

6

Agro-techniques

6.1 Establishment of new plantation

The planting system depends upon the topography of land, soil type and crop species. In the plains, planting is generally done in square or rectangular system. Placement of under and groundstorey crops is accordingly decided. On slopy lands, fruit trees are planted on contour terraces or near the trenches and bunds. The trenches and bunds are made across the slope and are staggered. Trees are planted at the lowest point in a triangular or rectangular microcatchment where the runoff accumulates. Following guidelines have been suggested (Pareek, 1987) to ensure establishment success of the trees.

- Pits should be dug and filled at least a month in advance for planting at the onset of monsoon.
- Planting system should favour better soil moisture conditions near the newly planted tree.
- A barrier of clay of 2-3 cm thickness may be placed at the bottom and sides of the pit before filling to reduce percolation loss of water in light textured soils.
- Polythene mulch or 8-10 cm thick cover of the available organic material should be used to reduce evaporative moisture loss.
- Plant should be covered to protect moisture loss through radiation and wind action.
- Pitcher irrigation can be done to each plant. A pitcher of 3 litre capacity, having a snugly fitting cotton wick in the hole at its bottom, is buried alongside each tree and is periodically filled with water.

6.2 Protection against adverse weather conditions by wind breaks and shelterbelts

The high wind velocity occurring in arid region causes mechanical damage to the fruits and branches and their desiccation due to excessive transpiration loss of water. Windbreaks of fast growing and deep rooted trees are planted around farms and orchard to provide a protective barrier against hot and cold winds. *Lasora* (*Cordia myxa*), neem and shisham trees form suitable windbreaks in arid region. Around large holdings shelterbelts are planted providing wide and long belts of several rows of trees and shrubs across the prevailing wind direction. The suitable shrubs for this purpose may be phalsa or karonda as per suitability of the region.

6.3 Propagation and Planting

Since nursery propagated plants invariably lose their tap roots as a result of repeated transplanting or develop coiled roots when raised in pots or polybags, *in situ* budding is preferred. In ber (Pareek, 1978b), seeds of desired species are sown during August-September at proper spacing in the field and when the rootstocks are 9-10 months old, budding/grafting with desired scion is carried out during favourable period depending upon the region.

6.4 Training and Pruning of Trees

Fruit trees require training during the first few years after plantation to give them proper shape and strong frame. The bushy pomegranate should be trained keeping 3-5 stems from the ground level (Anon., 1983). In other fruits, single stem training is done keeping properly spaced 3-4 main branches. Branching at desired heights can be induced by pruning. Annual pruning may be required in some species to obtain quality fruit production, e.g. in ber, phalsa and pomegranate, pruning time varies in different fruits. Annual pruning is done during summer in ber, in February in phalsa, and in early summer in mulberry. Defoliation is done in *goonda* during the winter to induce early flowering and fruiting. Lopping of *Prosopis* trees is done to obtain leaf fodder and fuel wood. Complete lopping gives higher yield of leaf fodder (58.7 kg/tree) than by lopping two-third (28.5 kg/tree) or one-third (19.7 kg/tree) crown (Beniwal *et al.*, 2003). For the production of edible pods the trees are kept unlopped.

6.5 Water Management

Water is the foremost constraint in arid land horticulture. Therefore, conservation and judicious use of water assumes importance. In the vast rainfall areas, major portion of rainwater is lost through evaporation and seepage. The concept of *in situ* water harvesting is of vital importance under these situations. Sharma *et al.* (1982, 1986) have reported that micro-catchment's slopes greater than 5 per cent did not significantly effect run off 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 7 m length of run, and 72 m^2 and 54 m^2 catchments area per tree, respectively. Recycling of rainwater stored in ponds helps to guard against water deficits at critical stages in certain locations.

In irrigated systems, optimum irrigation programme based on optimally sequenced evapo-transpiration deficits provides water at critical stages avoiding losses. Sub-surface irrigation by drip system avoids losses of moisture through both evaporation and gravitation. In the deep-rooted perennial fruit trees, the concept of irrigation scheduling based on plant water contents rather than the ET alone would perhaps be ideal.

6.6 Mulching and anti-transpirants

Conservation of soil moisture by mulching enhances water use efficiency by: (i) reducing evaporation from soil surface, (ii) cutting supply of heat energy to the evaporating site and (iii) decreasing thermal conductivity of the soil. The conservation of soil moisture by using various mulches like wheat and rice straw, sugarcane trash, sawdust, black and colourless polyethylene have been reported (Adams, 1966). At NDUAT, Faizabad, locally available organic mulches viz., paddy straw, sugarcane trashes and grasses in aonla orchard have been reported to improve the hydraulic conductivity and field capacity. The organic mulches were also effective in reducing the ECe, ESP and cations content around the tree basin (Rao and Pathak, 1996). At Central Institute for arid Horticulture (CIAH), Bikaner, in an experiment on aonla based cropping system, organic mulches have been reported to curtail soil temperature by 1.1-5.6°C during warmer months while an increase in temperature by 0.6-3.2°C have been reported during the winter months. (Awasthi *et al.*, 2006).

Water loss due to transpiration can be reduced by use of radiation reflectants, stomata closing chemicals and plastic films. Spraying of 4-6% Kaoiln, 0.5-1.0% liquid paraffin and 1.5% power oil, after occasional rains in low rainfall areas and after the post monsoon in high rainfall areas, considerably reduced plant water losses (Pareek and Sharma, 1991). Chemicals such as phenyl mercuric acetate (PMA), decinyl succinic acid (DSA), abscissic acid (ABA) and Cetyl alchol cause stomata closure and thereby reduce transpiration (Chundawat, 1990).

6.7 Nutrition Management

Fertility management in cropping system is important. Fruit trees should normally derive their nutritional supplements from the residues of the intercrop. However, annual application of manures and fertilizers near the zones of maximum root activity coinciding with rainfall incidence gives good results. In arid soils micronutrients particularly Zn and Fe (Sharma *et al.*, 2003) are often deficient. Foliar feeding of nutrients such as nitrogen (0.5 - 2.0% urea) and Zinc (0.05-1.0%) has given goods results (Pareek and Sharma, 1991).

6.8 Management of intercrops

In cropping system, the intercrops selected should be able to complete maximal vegetative and reproductive phase during the period of maximum water availability. Varieties should be selected as per the suitability of the region. Early ripening cultivar seems to escape stress conditions caused by the receding soil moisture stored in soil during the monsoon. Planting should be done in a proper geometry. While selection of crops allelopathic effect of main crop on subsidiary crops and vice-versa and its susceptibility to insect pest and diseases must be considered. The intercrops selected should leave sufficient biomass such as *C. tetragonoloba*.

7

Future Thrust

1. Screening of crop and their varieties best suited for getting higher income needs to be worked out.
2. In the development of a fertilizer programme for diversified cropping system, a rational will be to develop a single fertilizer schedule for the whole system considering the nutrient input and exhaust ratios. Besides the enormous addition of organic matter (Carbon dynamics) and indirect addition of nutrient to the system also needs to be worked out.
3. Complementary, competitive and supplementary effect of different crops over a period of time for different cropping system should be worked out.
4. Involvement of many crops in the system will result in continuous addition of biomass. Allelopathic effects with regards to changes in soil physico-chemical and biological properties of soil and productivity of groundstorey crops should be studied for the different systems.
5. Adoption of cropping system will cause marked changes in microclimate. Their effect on the soil moisture relationship, nutrient availability and uptake and disease incidence needs to analysed critically.

8

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