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PRODUCTION AND PROSPECTS OF FRUITS IN POTHOWAR

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INTRODUCTION

Total cultivated Area of the Punjab is 11.8 million ha out of which rainfed area is 3.1 million ha (26.3%). Complete districts of Rawalpindi, Attock, Chakwal and Jhelum (making Pothowar region) constitute the main rainfed areas of the Punjab. Parts of Sialkot, Narowal, Gujrat, Khushab, Mianwali, Jhang, Bhakkar, Layyah, D.G.Khan, and Rajanpur Districts are also rain dependent for production of agricultural crops.

Mianwali, Jhang, Bhakkar, Layyah, Muzaffar Garh, Dera Ghazi Khan, receive less than 300 mm rain whereas Attock, Chakwal, Khushab receive 300 to 500 mm rain annually and considered as medium rainfall areas. Districts of Rawalpindi, Jhelum, Gujrat, Sialkot and Narowal receive 500 to 1000 mm rain fall annually. Distribution of rains is in patches and more than 70% rains are received during monsoon (June, July, August and September), rest are scattered throughout the year (Figure 1). Temperatures are relatively mild in this part of Punjab with relatively prolonged winter ensuring enough chilling hours to allow deciduous fruit along with evergreen fruit production in this area. Soan Valley in Khushab district is even cooler allowing production of deciduous fruits of higher chilling requirement *vis-à-vis* quality.

Barani Agricultural Research Institute, Chakwal was established in 1979 to tackle the Agricultural problems of rainfed areas of the Punjab. It has well developed fruit research component at the campus in addition to Horticultural Research Station at Nowshera, District Khushab, especially developed for the promotion of deciduous fruits in this variable climatic pocket of Punjab province.

EVERGREEN FRUITS

Citrus

A number of cultivars belonging to different citrus species were tested at BARI, Chakwal. Where in sweet orange, grapefruit and sweet lime group were found successful. cv. Succari, Musambi, Salustiana and Blood Red among sweet oranges, Marsh, Shamber, Red blush among grapefruits and Palestine among sweet lime performed quite good under rainfed conditions of Pothowar (Table 1).

Though in Barani areas fruit number and size is almost same as compared to irrigated areas yet quality of fruit (in terms of sweetness and sugar to acid ratio) is quite high as compared to fruits produced in irrigated areas.

In sweet orange group, TSS was higher in all cultivars under rainfed conditions as compared to irrigated areas. Jaffa produced maximum TSS followed by Hamlin and Succari (Table 1). Among grapefruits, Marsh seedless produced highest TSS (Table 2).

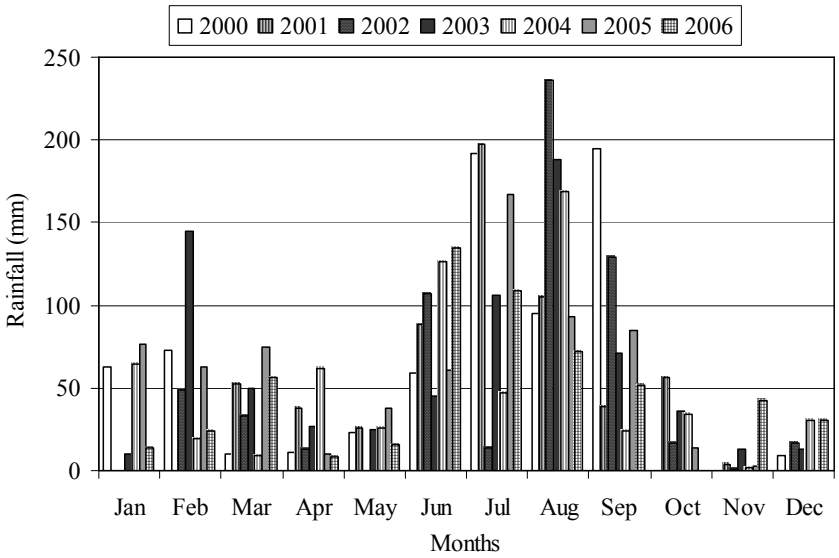

Figure 1: Month wise rainfall (mm) pattern during 2000-2006 recorded at Chakwal

Table 1: Varieties of different orange groups recommended for plantation in Pothowar area

Group	Cultivar recommended for Barani area
Sweet orange	Jaffa, Succari, Musambi, Salustiana, Blood Red
Mandarin/orange	Feutrell's Early
Grapefruit	Marsh, Shamber, Red Blush
Sweet lime	Palestine
Sour lime	Eustis Lime

Table 2: Quality parameters of sweet orange and grapefruit

Variety	TSS (%)		TSS/TA Ratio	
	Rainfed	Irrigated	Rainfed	Irrigated
a) Sweet orange				
Valencia Late	14.04	8.2	5.25	7.9
Salustiana	15.52	11.4	13.94	22.35
Blood Red	16.08	11.0	14.34	15.71
Pine apple	15.44	9.7	13.87	11.02
Jaffa	18.0	12.0	11.37	14.63
Musambi	15.52	11.0	30.13	24.44
Hamlin	17.52	11.2	11.99	20.8
Succari	16.8	---	26.2	---
b) Grapefruit				
Shamber	15.7	9.3	5.9	9.3
Marsh Seedless	16.0	7.5	6.0	5.0
Red Blush	15.0	9.6	4.7	7.1

Olive

The origin of the olive plant is Syria, Turkey and parts of Mediterranean Basin but it has spread over to America, Mexico, South America and Australia. At present about 2.3 million

tonnes of olive oil is produced in the world, mainly in the European countries, Tunisia, Syria and Turkey.

The presence of wild olive in various parts of Pothowar plateau and adjoining NWFP areas of Pakistan emphasized to initiate research activities for the improvement of olive at Barani Agricultural Research Institute, Chakwal. Climatic and topographical similarities between olive producing countries and Pothowar region also indicated possibility of successful olive cultivation, particularly in Pothowar and parts of Pakistan. The temperature of various olive producing areas in comparison with Chakwal is given in Figures 2 and 3.

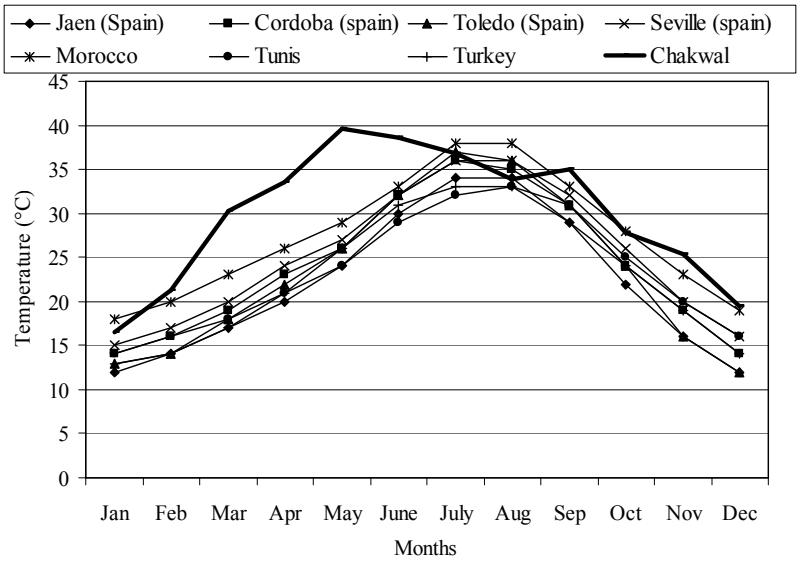

Figure 2: Maximum temperature regimes of major olive growing areas

To demonstrate varying degree of adaptation to local (Pothowar region) environment, 7 Italian varieties were grown successfully at Barani Agricultural Research Institute, Chakwal in 1991. The varieties were grown in a clay loam soil with planting distance of 6 × 6 m. After evaluation of these varieties for 8-10 years under local environmental conditions, four varieties viz., Ottobratica, Frantoio, Coratina and Leccino was found promising with a fruit yield of 15-35 kg per plant (Table 3) having oil contents from 18-22%. The rest of three varieties gave fruit only in those years with high chilling incidence. All the varieties exhibited alternate fruit bearing behaviour. Barani Agricultural Research Institute, Chakwal strengthened the germplasm resources and gathered about 30 varieties of olive (Table 4) from different sources and experimented different methods for the propagation of true to type plants for the farmers.

As olive is a new fruit tree in Pakistan, the process of true to type olive plant propagation is at the initial stage. Different methods applied to generate plants with varietal integrity were practiced to find out the most suitable method applicable in local environment. Now the plantlet production techniques have been standardized and true to type plants of often fruiting cultivars are being prepared and their growth is also being monitored (Table 5) at this institute.

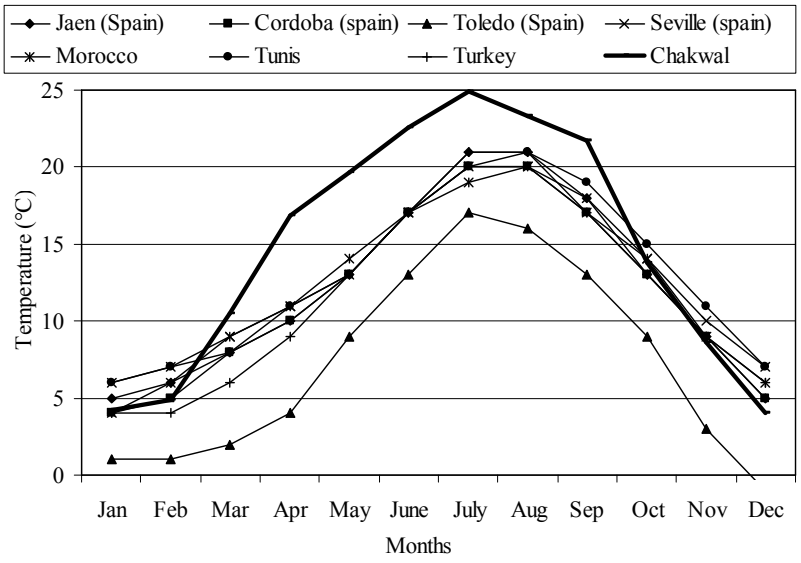

Figure 3: Minimum temperature regimes of major olive growing areas

To evaluate the adaptation of olive in various parts of Pothowar and in other parts of the Punjab Province, four to five varieties of olive are being planted in various ecological zones to test their yield and oil contents. This set of olive varieties have been planted in Pothowar region and in the other part of Punjab. It is worth mentioning that olive plants grown at Lahore, Okara and Faisalabad District have attained fruit bearing age and are giving normal fruit yields.

Table 3: Fruit yield of olive varieties at BARI, Chakwal (av. 2005 & 2006)

Variety	Fruit yield per plant (kg)
Ottobratica	19
Frontoio	16
Coratina	10
Moraiolo	17
Leccino	5
Pendolino	2

* 250 plants/ha.

Table 4: Olive gene pool available at BARI, Chakwal

Ottobratica	Nabali	Leccino	Pendolino	Biancolilla
Manzanilla	Sorani	Sevillano	Gemlik	Oslo
FS-17	Coratina	Kasur-1	Dremalali	Qaisi
Ofdibegon	Azerbaijan	Moraiolo	Corcea	Earlik
Frontoio	Haripur	Nocellara	Hamdi	Tabali
Souri	Tefahi	Dan	Khodeiri	Mawi

Table 5: Growth parameters of new olive varieties (age 3 years)

Variety	Plant Height (cm)	Stem Girth (cm)	Plant Canopy (m^3)
Earlik	255.8	35.0	5.3
Manzanilla	268.7	35.0	6.9
Azerbaijan	216.6	20.8	13.0
Sevillano	219.9	15.7	3.4
Souri*	202.5	16.7	1.4
Nocellara	183.0	30.4	1.8

* = 2 years

DECIDUOUS FRUIT FOR POTHOWAR

Selection of Suitable Variety

Selection of suitable variety is the number one requirement of successful orchard establishment programme. A number of deciduous fruit cultivars have been identified as successful for cultivation in Pothowar region (Table 6). The chilling requirement of Anna and Early Grand is 200 and 275 hours, respectively and are regarded as low chill varieties of apple and peach, respectively.

Table 6: Recommended varieties of different deciduous fruits for Pothowar areas

Fruit Crop	Varieties
Almond	Non-Parial, Jordonowla, Ne-Plus-Ultra, Vesta and Lajawab
Peach	Florida King, Early Grand
Nectarine	Gul Rukh, M-97, M-98
Plum	Fazal-e-Manani, Methley, Redbuit
Grapes	Anab-e- Shahi, Pearlet, Priest, white seedless
Fig	Shabhu, Tarnab, Black Ball, Gem Green,
Pomegranate	Sufaid Kandhari, Sadabahar, Jhlari
Apple	Anna
Apricot	Trevette, New cabe
Pear	Bagogosha, Leconte, Santa Maria

Soil

To obtain maximum growth and yield a tree must be planted in good soil. The suitable soil is one of the main requirements. The main factor in selecting a soil is its ability to drain water throughout the root system area. This is known as the internal drainage factor. To determine the internal drainage factor of a soil, dig an 8-inch diameter hole 32 inches deep and fill it with 5 gallons of water. Let the soil absorb the water for an hour then fill again. If the hole is empty in 24 hours, the soil has good internal drainage. If it requires 48 hours to drain, the internal drainage is poor but adequate. If any water remains after 48 hours do not plant trees. In Pothowar it is not uncommon to confront a soil condition known as caliche. Caliche is a chalky type soil, white in colour and chemically composed of calcium carbonate. It can be found in many forms as solid layers or crumbled pieces. The solid layers will restrict drainage and need to be cracked or drilled to allow water drainage. Another problem with caliche is its high pH, which restricts the uptake of micronutrients such as iron and zinc. It is recommended that before deciding to establish an orchard soil test should be carried out and fruit plants should not be planted in the soils where hard pan or excessive calcium is found.

Chilling requirements

Most deciduous fruit trees, including stone fruits, require accumulated exposure to cool temperatures during winter dormancy for the resumption of normal growth the following spring (Table 7). The chilling requirement for a variety is defined as the accumulation of hours below 7°C (45°F) and above 0°C (32°F). Satisfying the chilling requirement will result in normal growth and bloom following a dormant or winter period. During extremely mild winters the chilling requirement may not be satisfied and will result in uneven bloom. The tree will remain dormant until early summer when a small shoot or several fruit will form on the end of a long naked branch. Varieties with a chilling requirement of 600 hours or below are termed "low chill" varieties.

Table 7: General chilling requirements of various fruits

Fruit	Chilling Requirement (hours)	Fruit	Chilling Requirement (hours)
Almond	200 - 700	Grapes	100 - 500
Peach	150-1200	Pomegranate	100 - 200
Plum	400 - 1000	Fig	100 - 500
Apricot	400 - 1000	Apple	300 - 1200
Nectarine		Pear	400 - 1500

Fertilizer Requirement

Soil tests, especially for determinations of soil pH, phosphorus, potassium, calcium and magnesium may be helpful in determining fertilizer requirements. However, it should be understood that responses to fertilizer are slower for tree crops than for annual crops. The recommendation of fertilizer to various fruits plants in Pothowar is given below in Table 8 and 9.

Table 8: The fertilizer requirements of citrus plants of various ages

Age of Plant	Farm yard manure (kg plant^{-1} year^{-1})	Nitrogen (g plant^{-1} year^{-1})	Phosphorus (g plant^{-1} year^{-1})	Potash (g plant^{-1} year^{-1})	Zinc (g plant^{-1} year^{-1})
At the time of pit filling	-	100	50	50	10
First year	-	-	-	-	-
Second year	10	125	-	-	-
Third year	15	250	125	-	-
Forth year	20	500	250	-	-
5-9 year	40-60	750	500	500	50
10 year and after	60	1000	750	500	50

Farm Yard Manure should be well rotten other-wise white ant attack may damage the plants. For the fruit plants, Farm Yard Manure, Phosphatic and Potash fertilizers should be applied in the month of December. Half Nitrogen at the end of January and remaining half Nitrogen at the time of fruit formation (April) should be applied to deciduous fruits. For evergreen plants, Nitrogen fertilizer should be split into 3 parts (1/3 during end of February, 1/3 at fruit formation and remaining 1/3 after the start of monsoon rains). Fertilizer should not be applied around the trunk of the plant rather it should be applied under the periphery of the tree and 6-9" out side of the periphery of tree as in this area feeding roots of the plants exists.

Table 9: The fertilizer requirements of various deciduous (Apple, Peach, Almond, Pear, Plum) fruits

Age of Plant	Farmyard Manure	Nitrogen	Phosphorus	Potash	Zinc	Iron
	(kg plant^{-1} year^{-1})	(g plant^{-1} year^{-1})				
At the time of pit filling	20	-	180	-	20	25
First year	-	150	-	-	-	-
Second year	-	150	-	-	-	-
Third year	-	200	-	-	-	-
Forth year	25	250	225	225	20	25
Fifth year	30	250	225	225	-	-
6 year and after	40	300	225	225	20	25

Pruning and Training

Proper pruning and training of fruit trees is necessary to obtain maximum yields of high quality fruit throughout the life of the orchard. For fruit trees, pruning usually refers to the removal of limbs, twigs, or shoots to increase production of high quality fruit and maintain tree vigor. It should be done annually as needed to regulate tree shape, size, vigor, and crop load. On the other hand, training should begin at planting and may consist of light pruning along with other practices such as spreading, bracing, bending and trellising limbs, shoots or canes.

Different training systems are used for different types of fruit plants. Pear and apple trees usually are trained to a modified central leader system, which results in an upright tree with spreading lateral branches. Mature apple and pear trees should not be pruned severely. Moderate annual pruning is preferred to heavy pruning every 3 or 4 years. Heavy pruning causes less flowering and excessive vegetative growth, which can promote diseases.

Peach, nectarine and plum trees are best trained to an open-center system, which results in a low, wide-spreading tree. Peaches, nectarines and plums should be pruned annually. Remove crossing branches and those that are growing into the center of the trees. Cut back vigorous shoots to outward growing branches or buds to check upward development. Remove root suckers and exceptionally vigorous upright shoots, known as water sprouts, which often develop in the center of the trees. Thin out some of the smaller branches to reduce crowding. It is best to prune peaches after the coldest part of the winter passes, but before flowering. During the growing season, rub off shoots which develop on the trunk and on scaffold limbs within 2 feet of the trunk.

Grape vines are trained to a systematic distribution of growth on trellis. Cut back nursery grape plants to two buds on the most vigorous cane, and remove all other canes. Proper pruning of bunch grapes provides an adequate amount of 1-year-old wood each year, and prevents accumulation of unproductive wood. Vary the amount of cane pruning according to the vigor of the vine and its capacity to bear. The more buds left on a vine, the higher will be the yield in that year. The size of bunch, quality of fruit, and vigor of vine will definitely decrease if more than the optimum number of buds is left.

Fig trees grow vigorously. Pruning may be required to maintain a balance between new and old wood, as well as to remove suckers and to keep the tree's canopy at a reasonable size for easy harvesting (Tous and Ferguson, 1996). Pruning of the fig depends on the cultivar and condition of the plants. Generally, it is only necessary to head back the branches to keep the plant within bounds, thin out weak growth and remove dead wood. The young fig plant should be headed back to about half its height.

Pomegranate requires a long hot summer for its fruits to mature, yet can withstand low temperatures (of -9 to -12°C) in the winter. The tree requires minimal pruning, except for the removal of suckers at the base of the plant and some shaping of the canopy. It is propagated mainly by hardwood or softwood cuttings

FRUIT MATURITY AND HARVESTING

Most tree, bush, and vine fruits are soft when mature and require careful harvesting and handling. The fruits ripen over a period of time (Table 10) and require periodic harvesting to obtain full quality, avoid fruit drop, prevent the build-up of insects and diseases, and reduce bird damage.

Almond: When upper green bark is split it is evident that almond are ready to be harvested. After harvesting remove the upper easily removable flesh leaving hard almonds. Dry them under shade for 10 days.

Peach, Apricot and nectarine: These plants are harvested commercially just prior to softening on the tree. Fruit color is not a good indicator of peach maturity since some cultivars are highly colored well before they are mature. For home use, much higher quality is obtained when fruit are harvested tree ripe (when the fruit begins to soften slightly).

Plum: Most cultivars of plums can be harvested well before tree ripening or fruit softening and still ripen with full color and quality. Plums also may be harvested when fully ripe. Plums picked well before tree ripening may be kept under refrigeration for several weeks where they ripen slowly.

Apple: Apples should be picked when they have reached optimum size and color but before they soften. Immature fruit will not ripen with satisfactory quality in a refrigerator. Fruit will store in refrigeration satisfactorily for 6 to 8 weeks.

Pear: The hard pears are harvested when they reach full size and ground color begins to yellow. Whereas, soft pear varieties are harvested when, they are still firm. At room temperature storage, the fruit ripens more quickly and evenly. When left on the tree to full maturity, soft-flesh pears break down internally and are of poor quality.

Fig: Fruit bearing begins after three years. The crop matures in end May and June. Fresh figs are picked when they begin to soften and a color change indicates maturity. Since fresh figs ripen irregularly, picking should be undertaken daily or weekly during the long harvest period (4-6 weeks). After harvest, the dried figs are washed and can be stored for a few days at 0.1°C. The fruit is dried in the sun or by using an electric dryer at 60-70^{o}C before it is processed into dried figs (Tous and Ferguson, 1996). For preserving, pick before they have fully ripened. This reduces loss from fruit splitting and souring, and the fruit holds together better when cooked.

Grape: Bunch grapes are normally green, white red, or reddish black when ripe, depending on the cultivars. They are harvested in end June and early July. Harvested fruit lose moisture, aroma, and general quality rapidly, and thus should be refrigerated and used as soon as possible.

Pomegranate: The tree comes into bearing three to four years after planting. The fruit is harvested by hand from mid-September to early November. The most important problem is the cracking of berries, which affects pomegranate quality in storage and reduces its marketing value. The practice of picking early in the season, to avoid fruit cracking, is known to affect the fruit taste (Kumar, 1990).

INTERCROPPING IN ORCHARDS

At early stage of orchard development (normally up to 5 years) crops can easily be grown in the planted orchards. Care should be taken that crops should not be deep rooted and height should not be more than the orchard plants. The crops with frequent irrigation requirements (like rice and sugarcane) are not advised to grow in the orchard. Best crops recommended for intercropping in orchards includes pulses, (chickpea, mung, mash lentil etc.) and vegetable.

Fig: The fig tree can grow well under a wide range of environmental conditions, including drought, although it grows most vigorously when abundant water is available. The typical fig-producing regions (mainly Mediterranean countries) have mild winters and hot, dry summers. However, very hot, dry spells will cause fruit-drop even if the trees are irrigated (Morton, 1987). The tree has a low chilling requirement and can withstand some frost. However, a frost of -5 to -10^{o}C may kill the plant down to ground level (Tous and Ferguson, 1996). Figs can be grown on a

wide range of soils, including heavy clays, loams and light sands; but, ideally the soil should be well drained. The plant is moderately tolerant to high salinity (IBPGR, 1986).

Almond: The almond is a Mediterranean fruit crop, requiring mild winters and long, rainless, hot summers with a low humidity. Almond does well in the hot, dry interior valleys of the Mediterranean countries, where the nuts mature satisfactorily. It survives single digit temperatures and has a low winter-chilling requirement (200-700 chill units for proper bud break). Because of this low chilling requirement (or short rest period), and the relatively low amounts of heat required to bring the trees into bloom, the almond is generally the earliest deciduous fruit or nut tree to flower; it is, therefore, extremely susceptible to frost injury when late spring frosts prevail (Saure, 1985). Almond trees have been planted in certain areas with water supplies which are inadequate for other fruit or nut crops. Almond is reported to tolerate annual precipitation levels as low as 200 mm, although the yield of nuts will be low (Duke, 1983). Almonds need ample rainfall or irrigation water to produce the maximum number of well-filled almond nuts as is the case in California. In general, conditions favoring peach production will also favor almond production. The almond tree has been successfully grown on a wide range of soils, with pH ranging from 5.3 to 8.3. It is successfully grown in hilly and rocky areas although it is deep-rooted and draws heavily on the soil. For best results, soil should be deep, fertile, and well drained. Sandy loams are best, but they are often deficient in minerals. Almond trees have high N and P requirements although stone fruit trees are rarely fertilized in the Mediterranean countries. Sandy soils are easy to cultivate and it is comparatively easy to grow cover crops on them, provided they are properly fertilized (Duke, 1983). Fruit-bearing trees may be pruned of surplus branches to about 20% of the old-bearing wood. Trees exhibiting a decline in production may be severely cut back at the top. Seedlings are planted, and trees producing bitter kernels are grafted to superior individuals. Such trees are said to be more tolerant of drought and high soil pH than those obtained by vegetative propagation. For special types, scions are budded or grafted on to bitter or sweet almond, apricot, myrobalan, peach, or plum seedlings, Such trees are planted 6-8 m apart and can be irrigated, in spite of their drought tolerance for maximum yields.

Pomegranate: The plant favors a semi-arid climate and is extremely drought-tolerant. However, for good fruit production, the plant must be irrigated when grown in the dry areas. Pomegranate grow naturally as a bushy shrub or a small tree with spiny branches. The pomegranate bears heavily and regularly every year, and requires very little care. It thrives on calcareous, alkaline soil and on deep, acidic loam, as well as upon a wide range of soils in between these extremes.

Grape: Grape production is mainly limited to the Northern Hemisphere; it requires long, warm to hot, dry summers and mild winters. Plant damage occurs at -18°C; frost kills young shoots. The daily mean temperature should be at least 18°C.This species will not endure the high temperatures coupled with high humidity, which promote disease. Grapes do well in poor soils; they can grow in soils having pHs which range from 4.5 to 8.7. They prefer sandy or gravelly clay loams, which provide good drainage. Occurring in life zones that range from cool-temperature (from moist to wet) to tropical (from very dry to moist), *Vitis vinifera* L. is reported to tolerate annual precipitation rates and temperatures that are extremely variable (Duke, 1979). Grape culture is best in areas where there is no rain between blooming and harvesting. Irrigation is desirable, and often essential, in the dry areas. Several irrigations may be necessary, beginning in spring when available soil water is being depleted, and continuing until harvest, or even later in very hot regions (Duke, 1979).

REFERENCES

Duke, J.A. 1979. Ecosystematic data on economic plants. Quart. J. Crude Drug Res. 17(3-4):91-110.

Duke, J.A. 1983. Medicinal plants of the Bible. Trado-Medic Books, Owerri, NY.

IBPGR. 1986. Genetic resources of tropical and sub-tropical fruits and nuts. Int. Board Plant Genetic Resources (IBPGR). Rome.

Kumar, G.N. Mohan. 1990. Pomegranate. In: S. Nagy, P.E. Shaw, and W.F. Wardowski (eds.), Fruits of tropical and subtropical origin. Florida Science Source, pp.328-347.
Morton, J.F. 1987. Fruits of warm climates. Julia F. Morton, Miami, FL.
Saure, M.C. (1985). Dormancy release in deciduous fruit trees. *Horticultural Reviews*, 7, 239-299.
Tous, J. and L. Ferguson. 1996. Mediterranean fruits. In: J. Janick (ed.), Progress in new crops. ASHS Press, Arlington, VA. pp.416-430.

Table 10: Fruit size and ripening time of various fruit varieties in Pothowar

Fruit	Cultivar	Fruit Weight (g)	Ripening Time
Peach	Early Grand	120-160	May
	Florida King	50-120	May
	Haidry	30-80	May
	Michalie	120-170	May
	Coronet	50-70	Early July
	Sun crest	80-100	Mid June
	Swanee	80-100	Early July
Grapes	Anab-i-Shahi	150-450*	Early July
	White Seedless	150-400*	End June
	Priest	80-120*	Early July
	Pearlette	70-130*	End June
Fig	Black Ball	20-30	End May-June
Nectarines	Gul Rukh	35-50	Mid May
	M-97	50-80	Early July

* bunch weight

Annexure 1: Maximum temperature (°C) Barani Agricultural Research Institute, Chakwal

Year	January				February				March				April				May				June			
Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
2001	22.0	21.0	21.5	23.0	25.0	25.0	25.0	26.0	29.0	31.0	30.0	32.0	33.0	35.0	31.0	39.0	39.0	45.0	37.0	42.0	43.0	38.0	38.0	39.0
2002	22.0	22.0	19.0	22.0	21.0	24.0	26.0	29.0	27.0	28.0	36.0	33.0	31.0	39.5	40.0	37.0	40.5	44.0	43.0	45.5	42.0	43.0	43.0	43.0
2003	20.0	29.0	29.0	30.0	21.0	30.0	21.0	22.3	20.0	26.0	35.0	30.0	30.0	35.5	32.0	40.0	35.5	37.0	39.5	42.0	45.5	45.0	43.0	39.0
2004	17.5	22.6	21.0	17.4	21.0	23.0	24.0	28.5	30.5	31.0	34.5	35.0	36.0	36.0	38.5	35.8	37.0	42.5	43.0	43.0	42.5	39.0	38.0	39.0
2005	17.2	18.0	17.0	16.5	17.2	17.0	15.0	21.0	24.0	27.0	27.0	27.5	32.0	31.0	35.5	35.8	32.8	35.8	37.0	35.6	42.5	38.5	44.0	46.0
2006	17.6	20.0	16.7	24.0	25.8	28.5	26.6	26.8	28.0	28.0	26.0	32.5	35.0	33.0	34.0	41.0	42.5	45.0	40.0	42.8	41.4	41.5	38.5	42.2
2007	15.9	16.9	17.2	22.8																				

Year	July				August				September				October				November				December			
Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
2001	38.0	37.0	37.0	34.0	35.0	36.0	36.0	36.0	35.0	35.0	34.0	37.0	34.0	34.0	33.0	32.0	30.0	29.0	30.0	27.0	24.0	24.0	22.0	22.0
2002	45.5	42.5	43.0	42.5	39.5	39.0	37.0	35.0	34.0	33.5	33.5	34.5	34.5	32.5	31.5	30.5	28.5	25.5	27.0	25.5	23.0	23.0	25.0	19.0
2003	39.5	37.5	37.0	37.0	35.0	35.0	36.0	36.0	36.0	34.0	36.0	34.5	34.0	31.0	31.5	31.2	30.0	28.0	24.0	24.0	25.0	23.0	19.5	18.5
2004	39.0	39.0	37.2	39.5	36.2	36.0	36.0	36.0	39.5	39.5	35.0	36.0	35.0	34.5	30.0	29.5	27.5	27.3	27.0	26.0	22.0	23.2	25.0	18.0
2005	34.5	37.5	35.8	37.5	37.5	37.4	36.0	36.0	37.0	34.1	35.4	35.5	35.8	33.5	30.5	31.5	28.0	28.2	27.5	26.0	24.0	23.9	21.8	21.8
2006	41.5	41.0	37.4	37.5	36.5	36.8	37.0	37.0	35.6	35.8	35.7	36.0	37.1	35.0	32.9	30.0	30.0	29.5	23.5	21.5	17.0	17.4	19.8	17.6

Annexure 2: Minimum temperature (°C) Barani Agricultural Research Institute, Chakwal

Year	January				February				March				April				May				June			
Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
2001	0.1	-2.0	-1.0	-1.0	-2.0	0.0	3.3	3.0	4.0	6.0	7.0	9.0	10.0	14.0	11.0	13.0	18.0	20.5	19.0	22.0	20.0	21.5	20.0	21.0
2002	0.0	0.0	0.0	-1.0	-1.0	0.0	6.0	4.0	5.0	8.0	9.0	8.0	9.0	13.0	15.0	14.0	16.5	19.0	16.0	15.0	20.0	20.5	19.0	23.0
2003	-1.2	-1.5	0.0	3.0	-0.5	1.25	8.0	5.5	1.5	4.0	8.0	11.0	10.0	13.0	12.0	17.5	11.0	17.0	16.0	17.0	20.5	21.5	21.0	22.5
2004	-0.4	2.0	2.4	2.0	0.2	2.0	5.0	5.0	4.6	9.5	10.5	8.0	13.5	15.3	13.6	13.0	10.0	16.0	19.4	19.5	20.5	18.8	21.2	17.5
2005	1.5	0.5	-0.5	-0.5	0.0	6.5	-0.5	1.5	8.0	8.0	12.5	7.9	8.4	6.0	10.0	10.5	10.8	13.0	16.0	16.0	18.5	17.8	22.0	23.5
2006	-4.5	-4.4	-0.8	-1.5	2.8	4.3	6.5	5.7	6.0	9.5	6.5	9.5	12.5	6.2	10.5	16.5	13.0	20.2	20.0	21.2	20.0	20.0	17.7	20.2
2007	-1.5	-1.4	-2.5	3.8																				

Year	July				August				September				October				November				December			
Weeks	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
2001	21.0	21.5	21.5	22.0	22.0	23.0	22.0	22.0	20.0	18.0	18.0	17.0	16.0	12.5	12.0	13.0	8.0	7.0	6.0	4.0	4.0	3.0	2.0	1.0
2002	20.0	20.0	21.0	22.0	23.0	23.0	20.0	21.0	17.5	18.0	16.5	16.0	16.5	14.5	14.5	12.0	12.0	8.0	5.0	3.0	1.5	0.0	5.0	1.5
2003	22.0	20.0	22.5	22.0	20.0	21.5	20.0	21.0	20.0	21.4	23.0	14.5	15.4	12.0	13.0	11.5	9.5	7.4	4.0	2.0	2.0	3.0	1.0	-0.7
2004	24.0	21.3	21.5	23.5	21.7	21.5	21.5	20.5	19.0	23.5	19.6	17.2	16.5	10.5	11.0	8.0	8.0	7.5	7.5	8.0	2.5	1.5	3.0	0.3
2005	21.0	23.5	21.8	21.0	21.3	21.5	21.3	20.0	25.0	21.5	19.0	19.4	18.5	16.6	10.5	9.4	8.0	6.0	1.5	0.5	-1.0	-3.5	-2.4	-2.0
2006	22.5	21.2	20.5	22.7	22.2	21.5	22.0	20.5	19.0	19.5	20.0	15.2	16.0	14.3	14.5	12.0	11.6	10.2	10.0	4.9	4.6	4.4	2.9	3.6

Annexure 3: Rainfall pattern at Chakwal over years

Year	January	February	March	April	May	June	July	August	September	October	November	December
2000	62	73	10	11	23	59	192	95	195	0	0	9
2001	0	0	53	38	26	99	197	106	39	46	4	0
2002	0	49	33	13	0	107	14	236	129	17	1	17
2003	10	145	50	27	25	45	106	188	71	36	13	13
2004	65	19	9	62	26	126	47	169	24	34	2	30
2005	77	63	75	10	38	61	167	93	85	14	3	0
2006	14	24	56	8	16	135	109	72	52	0	42	30
2007	0	166										